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Designing Regulation of Network System

Final Draft

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Electric Power Development Co., Ltd.
Shikoku Electric Power Co., Inc.
West Japan Engineering Consultants, Inc.

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PART 1 DEFINITIONS

Chapter 1-1 General Issues

Article 1. General

1) Terms
2) Scope of Technical Regulations
3) Rated Value
4) Noise Level
5) Insulation Level
6) External Insulation
7) Internal Insulation
8) Self-restoring Insulation
9) Non-self-restoring Insulation
10) Insulation Co-ordination
11) Imbalance Factor
12) Minimum Working Clearance
13) Minimum Clearance
14) Transmission of Electricity
15) Distribution of Electricity
16) Connection Point
17) Stand Alone Power Supply Resource
18) High Voltage Providing Electricity
19) Synchronous Operation of Power Systems
20) Interconnection of Power Systems
21) National Grid

As stipulated in Technical Regulation.

22) Area Classification

Polluted environmental area is shown by Site pollution severity (SPS) classes. Definition of SPS is based on the IEC 60815-1.

For the purposes of standardization, five classes of pollution characterizing the site severity are qualitatively defined, from very light pollution to very heavy pollution as follows:

a -Very light
b - Light
c - Medium
d - Heavy
e -Very heavy.

The following table gives, for each level of pollution, an example and approximate description of some typical corresponding environments.

For standardization purposes, Relation between surface pollution of insulators and creepage distance for insulators based on the SPS class are specified in the Article 334.

Table 1 Environmental classification

Description of typical environments	SPS Class
> 50 km [I] from any sea, desert, or barren hills > 10 km from man-made pollution sources [II] Within a shorter distance than mentioned above of pollution sources, but: - prevailing wind not directly from these pollution sources - and/or with regular monthly rain washing	a Very light
10-50 km [I] from the sea, a desert, or barren hills 5-10 km from man-made pollution sources [II] Within a shorter distance than mentioned above of pollution sources, but: - prevailing wind not directly from these pollution sources - and/or with regular monthly rain washing	b Light
3-10 km [III] from the sea, a desert, or barren hills 1-5 km from man-made pollution sources [II] Within a shorter distance than mentioned above of pollution sources, but: - prevailing wind not directly from these pollution sources - and/or with regular monthly rain washing	c Medium
Further away from pollution sources than mentioned above (distance in the range specified for “Light” areas) but: - dense fog (or drizzle) often occurs after a long (several weeks or months) dry pollution accumulation season - and/or the present heavy rain with high conductivity - and/or there is a high NSDD level, between 5 and 10 times the ESDD	c Medium
Within 3 km [III] of the sea, a desert, or open dry land Within 1 km of man-made pollution sources [II]	d Heavy
With a longer distance from pollution sources than mentioned above (distance in the range specified for “Medium” areas) but: - dense fog (or drizzle) often occurs after a long (several weeks or months) dry pollution accumulation season - and/or there is a high NSDD level, between 5 and 10 times the ESDD	d Heavy
Within the same distance of pollution sources as specified for “Heavy” areas and: - directly subjected to sea-spray or dense saline fog - or directly subjected to contaminants with high conductivity, or cement type dust with high density, and with frequent wetting by fog or drizzle - Desert areas with fast accumulation of sand and salt, and regular condensation	e Very heavy
I. During a storm, the ESDD level at such a distance from the sea may reach a much higher level. II. The presence of a major city will have an influence over a longer distance, i.e. the distance specified for sea, desert or barren hills. III. Depending on the topography of the coastal area and the wind intensity.	

23) System Diagram

24) System Operational Diagram

25) **Power System Planning**
26) **Power System Stability**
27) **Load Stability**
28) **Steady State Stability of a Power System**
29) **Transient Stability of a Power System**
30) **Conditional Stability of a Power System**
31) **Operation Regulation**
32) **System Demand Control**
33) **Management Forecast of a System**
34) **Reinforcement of a System**
35) **Cold start-up of a Thermal Generating Set**
36) **Hot start-up of a Thermal Generating Set**
37) **Overload Capacity**
38) **Load Shedding**
39) **Available Capacity of a Unit (or of a power station)**
40) **Reserve Power of a Power System**
41) **Hot Stand-by**
42) **Cold Reserve**
43) **Outage Reserve**
44) **Load Forecast**
45) **Generation Mix Forecast**
46) **Steady State of a Power System**
47) **Transient State of a Power System**
48) **Balanced State of a Polyphase Network**
49) **Unbalanced State of a Polyphase Network**
50) **Service Reliability**
51) **Service Security**
52) **Economic Loading Schedule**
53) **Balancing of a Distribution Network**
54) **Load Recovery**
55) **Basic Impulse Insulation Level (BIL)**

As stipulated in Technical Regulation.

Article 2. Electrical Equipment

1) **Electrical Equipment**
2) **Location and installation**
3) **Conductor, Wire, Line and Cable**
4) **Distribution Line and Transmission Line**
5) **Busbar**
6) **Oil-Immersed Electrical Equipment**
7) **Explosive Resistant Electrical Equipment**
8) **Electrical Materials**

As stipulated in Technical Regulation.

Article 3. Electrical Facilities

1) Electrical Hall

2) National Load Dispatch Center

3) Gas Insulated Switchgear (GIS)

As stipulated in Technical Regulation.

Article 4. Electrical Systems

1) Energy System

2) Power System

3) Supervisory Control Data Acquisition System (SCADA system)

4) Reactive Power Compensation System

As stipulated in Technical Regulation.

Article 5. Voltage

1) Voltage Level

2) Nominal Voltage of a Power System

3) Operating Voltage in a Power System

4) Highest (or Lowest) Voltage of a Power System

5) Highest Voltage for Equipment

6) Voltage Deviation

7) Voltage Fluctuation

8) Overvoltage

9) LineVoltage Drop

10) Temporary Overvoltage

11) Transient Overvoltage

12) Voltage Surge

13) Voltage Recovery

14) Voltage Unbalance

15) Switching Overvoltage

16) Lightning Overvoltage

17) Resonant Overvoltage

18) Transient Recovery Voltage (TRV)

As stipulated in Technical Regulation.

Chapter 1-2 Definitions of Transmission and Distribution Lines

Article 6. House and Outside Wirings with voltage up to 35kV

1) Applicable Scope for House and Outside Wirings with voltage up to 35kV

Technical words corresponding to house and outside wirings are followings.

(1) Inlet branch

An inlet branch from overhead power lines to house is a power line connected from overhead power lines to insulators which are installed on outer walls or roofs of buildings or construction structures.
If branches from the overhead power lines into the house are cables, the cables must comply with the requirements for house and outside wirings, branches using the insulated wire or bare conductor must comply with the requirements for overhead power lines.

The requirements of house and outside wirings do not apply to the special line power supply for the electrical equipment.

(2) Support wire

Support wires are support elements such as steel wires for House and outside wirings, and are closely running on walls or ceilings etc., and are used to fix conductors and cables.

(3) Support bar

Support bars are support elements such as metal bars for House and outside wirings, and are closely installed on walls or ceilings etc. to fix conductors and cables.

(4) Box

A box is closed empty structure with rectangular cross-section or other shapes, and is used for installing conductors, cables and electrical instrument in it at indoor or outdoor. A box has function to protect conductors, cables and electrical instrument from mechanical damage.

A box is one block or with cover for being opened. Walls and covers of a box can be closed or have holes. For once-piece box, its walls shall be closed at all sides and shall not have covers.

(5) Trough

A trough is opened structure, and is used for installing conductors or cables in it at indoor and outdoor. A trough does not have function to protect conductors and cables from mechanical damage. A trough must be made of non-flammable materials. There are kinds of troughs which are closed at all sides or have holes.

(6) The Attic compartment

A roofed compartment is a non-productive compartment at the highest floor of buildings, and the top is a building roof. An Attic compartment is composed of support structures (roof, rafters, bars, beams etc.) made of flammable materials.

Similar compartments which are between walls in buildings or made of non-flammable materials, or technical floor which are under the roof of building, are not considered as an attic compartments.

2) Construction and Category of House and Outside Wirings

Live parts of house and outside wirings are composed by conductors and busbars made of copper, aluminum and aluminum or aluminum alloy with steel reinforced core.

3) Opened and Closed House and Outside Wirings

4) Outdoor and Indoor

5) Extension House and Outside Wirings

As stipulated in Technical Regulation.

Article 7. Power Cable Lines with Voltage up to 220kV

1) Applicable Scope for Power Cable Lines with Voltage up to 220kV

2) Power Cable Lines

3) Cable Structures

Cable structures are structures designed for installment of cables, cable connection boxes, oil suppliers and other equipments in order to ensure normal operation of power cable lines.

Cable tunnel (Culvert) 	Cable room  
Cable cellar  	Cable well  
Cable canal (Pit)  	Cable corridor 
Cable storey 	Cable trough (Duct) 
Double floor 	Cable rack 
Cable block (Conduit)  	

Figure 7-1 (Reference) Cable structures

4) Cable Channel and Cable Bracket

1. The distance between the power cable with voltage exceeding 1kV and the control cable should be secured at least 100mm or more.
2. The distance between cables should be secured the exceeding distance shown in Table 7.

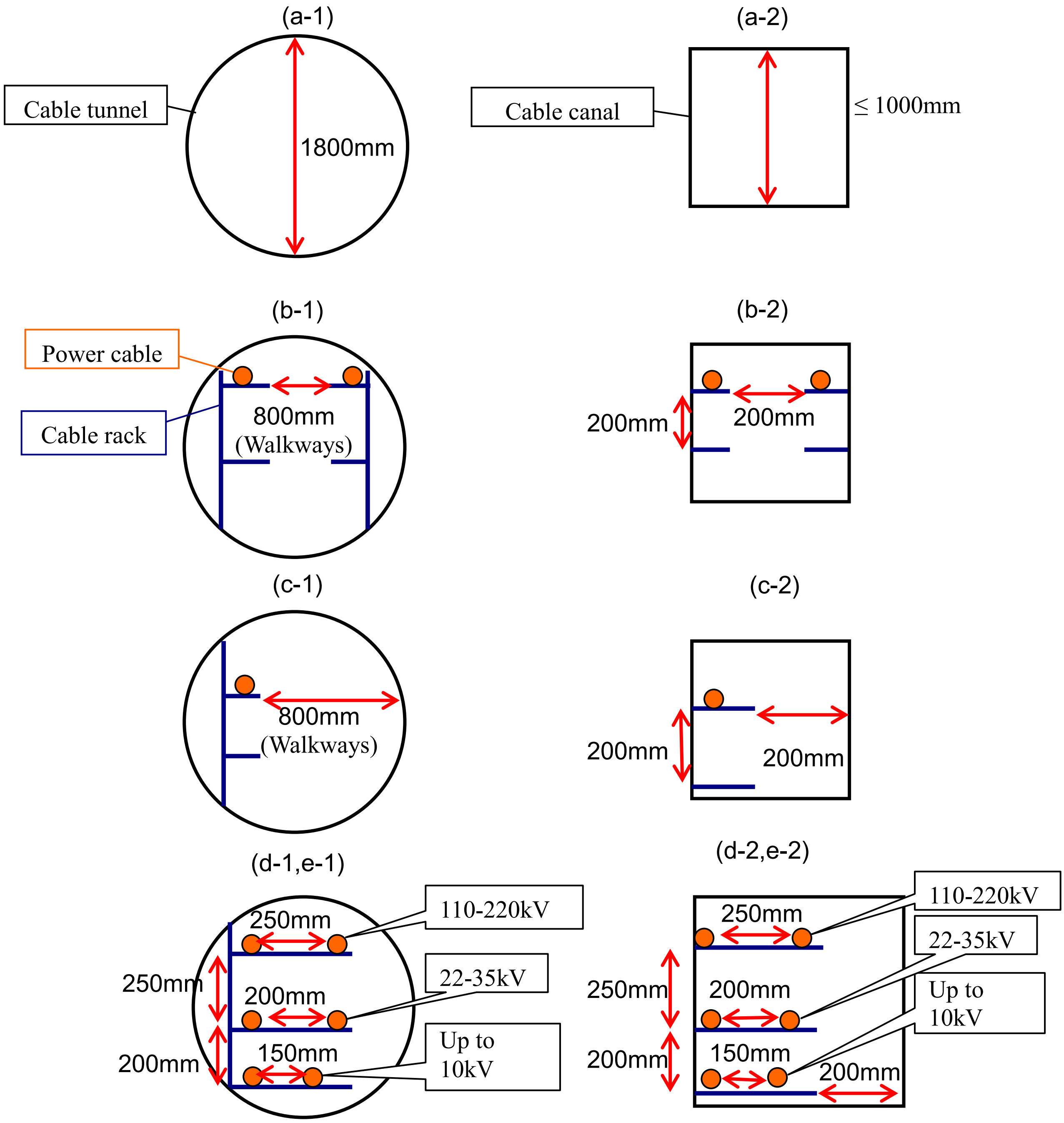


Figure 7-2 The sample of cable arrangement

Table 7 Minimum permissible distance between power cables

Classification		The minimum permissible distance (mm): 1. cable tunnel (The arrangement of the same type of cable)	The minimum permissible distance (mm): 2. cable canal
a. The height of cable structure		1,800	-
b. Horizontal distance between two cable racks when the racks are arranged in two rows		800 (There is a passage between the racks.)	200
c. Horizontal distance between a cable rack and a wall when the rack is arranged in one row		800 (There is a passage by the racks.)	200
Horizontal distance between cables when the number of cables on the rack is from two to four	d.Up to 10kV	150	150
	e.20 to 35kV	200	200
	f.35kV or more	Offset distance provided in the design material or the specification	

5) Safety Corridor for Power Cable Line

Safety corridor of power cable lines is shown in Figure 7-3..

Horizontal distance and vertical distance shall comply with the values in Table 7 in Technical RegulationVol.1.

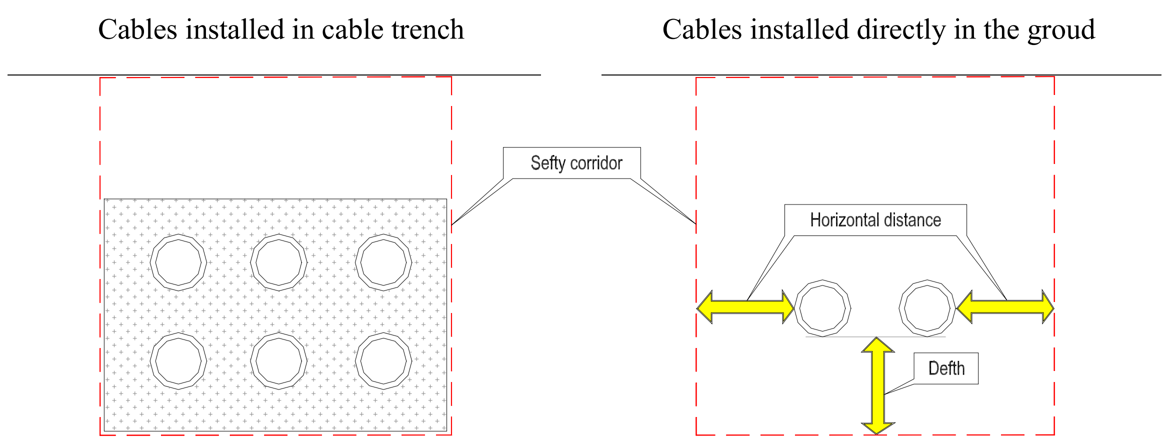


Figure 7-3 Safety corridor of power cable line

Article 8. Overhead Power Lines with voltage up to 500kV

1) Applicable Scope for Overhead Power Lines with Voltage up to 500kV

2) Limitation of Overhead Power Lines

3) Mechanical Design Condition

4) Densely and Thinly Populated Areas

5) Large Overcrossing Span

6) Safety Corridor of Overhead Power Lines

Safety corridor of overhead power lines is shown in Figure 8-1, 2.

Horizontal distance and vertical distance shall comply with the values in Table 8 in Technical RegulationVol.1.

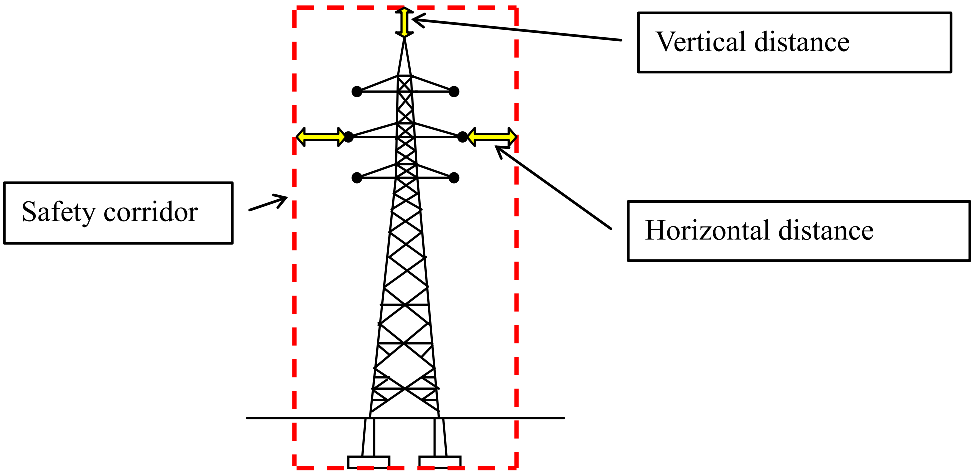
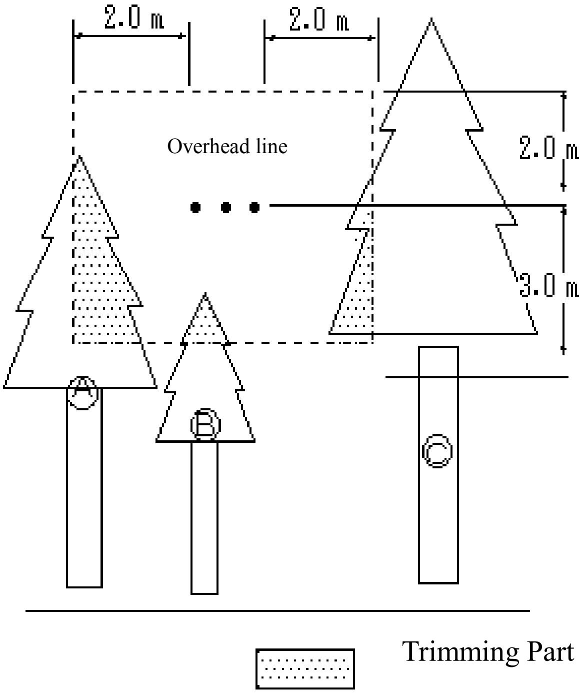


Figure 8-1 Safety corridor of overhead power line



For example:
Range trimming trees for OPL-35kV

Figure 8-2 Safety corridor of tree

Effective preventive measures against the adverse effects of animals and plants shall be used for ensuring a safe distance between trees and overhead power lines.

The tree pruning shall be done periodically to consider the possibility of development of the tree.
The works in the farms and national parks shall be applied for approval and follow the instructions of the competent authority.

Chapter 1-3 Definitions of Distribution Equipment and Substations

Article 9. Distribution Equipment

As stipulated in Technical Regulation.

Article 10. Substation

1) Outdoor Substation
2) Indoor Substation
3) Adjoining Substation
4) Workshop Substation
5) fully-equipped substation
6) On-pole Substation
7) Transmission Substation
8) Distribution Substation

As stipulated in Technical Regulation.

Article 11. Switching Station

As stipulated in Technical Regulation.

Article 12. Installation Compartments

As stipulated in Technical Regulation.

Article 13. Safety corridor, operation corridor and explosion- exit corridor in the substation

1) Safety corridor
2) Operation corridor
3) Explosion-exit corridor

As for the operation control corridor, detailed provision shall refer to Article 349.

As for the explosion-exit corridor, detailed provision shall refer to Article 349, 350 and 356.

Chapter 1-4 Definitions of Protective Relays and Control Systems

Article 14. Protective Devices

As stipulated in Technical Regulation.

Article 15. Types of Protection

As stipulated in Technical Regulation.

Article 16. Remote Control Systems

As stipulated in Technical Regulation.

Article 17. Secondary Circuits

As stipulated in Technical Regulation.

Chapter 1-5 Definitions of Metering

Article 18. Electricity Meter

As stipulated in Technical Regulation.

Article 19. Multi Tariff Meter

As stipulated in Technical Regulation.

Article 20. Checking Meter

As stipulated in Technical Regulation.

Chapter 1-6 Definitions of Earthing

Article 21. Earth Fault

As stipulated in Technical Regulation.

Article 22. Earthing System

1) Earthing Electrode

2) Earthing Conductors

As stipulated in Technical Regulation.

Article 23. Zero Area of Voltage

As stipulated in Technical Regulation.

Article 24. Resistance of Earthing

As stipulated in Technical Regulation.

Article 25. Earth Fault Current

1) Large Earth Fault Current

2) Small Earth Fault Current

As stipulated in Technical Regulation.

Article 26. Neutral of Power System

For 500kV, 220kV, 110kV, 22kV and 15kV power system, direct grounding is applied to its neutral. Grid 6kV, 10kV, 35kV is isolated neutral with arc-suppression coil, in special cases can be grounded directly.

Table 26 Neutral point grounding method

Voltage level	Neutral point grounding method
110,220,500kV	Direct grounding
35kV	Isolated neutral or Resistance grounding
15, 22kV	Direct grounding (3-phase 3-wire) or grounding repeatedly (3-phase 4-wire)
6, 10kV	Isolated neutral
less than 1kV	Direct grounding (grounding neutral, grounding repeatedly, neutral earthing combined)

1) Direct earthed neutral

2) Isolated Neutral

3) Effective Earthed Neutral

4) Neutral Conductor

As stipulated in Technical Regulation.

Article 27. Protective Breaking

As stipulated in Technical Regulation.

Article 28. Main Insulation

As stipulated in Technical Regulation.

Article 29. Auxiliary Insulation

As stipulated in Technical Regulation.

Article 30. Double Insulation

As stipulated in Technical Regulation.

PART 2 GENERAL REQUIREMENTS

Chapter 2-1 General Issues

Article 31. Electrical design and conditions

As stipulated in Technical Regulation.

Article 32. Specifications of Electrical Equipment

The electrical equipment and related structures shall ensure the following condition.

1) Its elevation less than 1,000m above sea level
2) Atmospheric temperatures is from - 5°C to +45°C
3) Other conditions such as abnormal level of salinity, humidity and gas

Otherwise out of above conditions, special specifications are needed to satisfy the conditions.

Article 33. Electric Mode

As stipulated in Technical Regulation.

Article 34. Civil Part

For the power projects which don’t need duty staffs, it is not necessary to build control room, auxiliary room for workers as well as repairing workshop and laboratory. Designing and selecting options for the electrical project shall be based on comparison of technical-economic criteria, application of simple and reliable diagrams, skills and experience, new technological application, optimal selection of materials.

Article 35. Security in Power Projects

Safety for power project shall be complied with the obligations of the Electricity Law, in particular Decree and National Technical Safety Standard;

For the power projects there must be have appropriate measures to ensure safety as follows:

- The appropriate electrical insulators shall be used and in the exceptional case the reinforced insulators are used.
- The appropriate distances to live parts must be arranged or live parts must be enclosed. Detail descriptions are mentioned in Article 331 and 334 of Technical Regulation.
- The barriers shall be made. Detail descriptions are mentioned in Technical Regulation of Vol.1.
- The interlocks are installed for electrical instruments and barriers in order to prevent operational errors. Detail descriptions are mentioned in Article 145 of Vol.1.
- Automatic reliable and quick tripping circuits in order to isolate faulted parts of equipment and damaged parts of power grid. Detail descriptions are mentioned in Article 417 - 435 of Vol.1
- Grounding electrical equipment enclosures and all components of power project which may be earth faulted. Detail descriptions are mentioned in Article 549 - 558 of Vol.1

- Using isolated transformers or voltages up to 42V for leveling voltages.
- Using warning signal system, announcement signs and boards.
- Using protection tools.

Article 36. Prevention of Personal Accidents

As stipulated in Technical Regulation.

Article 37. Enclosures or Covers of Electrical Live Parts

As stipulated in Technical Regulation.

Article 38. Requirements of Barriers and Covers

The barriers and covers shall have enough mechanical strength. For equipment with voltage over 1000V, thickness of metal cover shall not be less than 1mm. The cover of conductors shall be put deeply in the electrical machines, equipment and instruments.

Detail descriptions are mentioned in Article 333 of Technical Regulation.

Article 39. Firefighting

The fire fighting equipment must be arranged in compliance with fire protection and fighting regulation. Detail descriptions are mentioned in Article 56, 315, 340, 350, 351, 360, 361 of Vol.1 and TCVN 2622.

Article 40. Compliance for Electricity Supply

As stipulated in Technical Regulation.

Article 41. Electricity Supply Plan

As stipulated in Technical Regulation.

Article 42. Electricity Supply Alternatives

As stipulated in Technical Regulation.

Article 43. General Electricity Development Plan

As stipulated in Technical Regulation.

Article 44. Power Transmission Capacity in Industrial Enterprises

It needs to ensure,

1) Transmission surplus capacity of exclusive power plant of industry to the power grid in all operation conditions.

2) Receiving capacity, from the power grid, when the biggest power generator of exclusive power plant operation stops due to fault or for planned repairs and inspection.

Article 45. Agreement of Managing Agency of National Power Grid

As stipulated in Technical Regulation.

Article 46. Coordinate power supply for industrial enterprises and residents

As stipulated in Technical Regulation

Article 47. Categorization of Electricity Users

The power users are divided into 3 categories:

- Category I includes electricity users whose electricity supply interruption will affect national security, important organizations' activities, endangering people life, serious national economic damage, complicated technology process disorder and especially important areas of cities.
- Category II includes electricity users whose electricity supply interruption will cause damage of series of products, economic loss, machine operation stop and industrial transport stop, disorder of normal operation of large part of city.
- Category III includes electricity users who are not belonged to the above two categories.

The electricity users of the category I shall be supplied with electricity from at least two independent power resources and one local stand-by resource. The electricity supply is allowed to be interrupted during the time when stand-by power resource is being automatically closed. The anti-asynchronous closing system must be installed.

For electricity users with small capacity, the back-up power supply resource can be fixed substation and mobile substation with generator and uninterruptible power supply (UPS) etc. mobile, battery, compression ignition engine - generator etc. or power line connected to the lower voltage substation with independent power supply resource by automatically connecting to stand-by resource.

For electricity users of the category II, the electricity supply is allowed to be interrupted in the necessary time in order duty person or repairing group to close standby resource. The anti-asynchronous closing system must be installed.

The electricity users of the category II shall be supplied with electricity from at least one independent power resource and one local stand-by resource. The electricity supply is allowed to be interrupted in the necessary time in order to close stand-by resource are allowed to be supplied with electricity from one overhead power line with medium or higher voltage. If users are supplied with electricity by cable, one cable line is allowed but at least two cable sections connected in parallel through separate disconnectors.

Where there is central power supply resource available, the electricity users of the category II are allowed to be supplied with electricity from one transformer.

The electricity users of the category III is allowed to be interrupted in the necessary time in order duty person or repairing group to close stand-by resource. For the electricity users of the category III, electricity supply interruption is depending on technical, economic, social conditions there and agreement between electricity supplier and users.

Article 48. Electrical Diagram

The power supply resources must be arranged near to the electricity load centers of industrial enterprises and cities by power lines at voltages of 100-220kV as near as possible, construction of substation near the load center or within the enterprise, division of substations. The ring circuit should be used for supplying electricity to substation.

For supplying electricity to separate substations, direct branching from one or two power lines in parallel should be used. At branching point, disconnector should be installed.

The substation electrical simple diagram without circuit breaker at inlet and without busbar at the high voltage side or with only single busbar system is recommended to be used. The double busbar system can be used only when there is proven justification.

The electrical distribution diagram in the enterprise shall ensure the supply of electricity to production lines.

The installation of circuit breakers at the inlet shall be considered in the following cases:

1. At inlet of substation with voltage 110kV and above.
2. At inlet of up to 35kV substation with power 1600kVA and above nodal and system connection substations.

Installation of circuit breakers at inlet of users' substation which receives electricity from the national power grid must be agreed by electricity management agency.

It is recommended to use fuse disconnector combined with load disconnector and/or short circuit protection disconnector for transformers with voltage up to 35kV. And capacitors if fuses have parameters appropriate to power system (in terms of voltage, current, short circuit current) and selective, reliable actuation.

The sectionalizing circuit breakers are installed in busbar only standby power supply resource requires automatic closing or at big nodal substations.

In other cases, in order to sectionalize busbar, the switch can be used instead of disconnector.

In the electrical diagram of the power supply center there must be measure to limit short circuit capacity in the power system to the maximal permissible breaking capacity of circuit breakers installed in the system.

When short circuit capacity is limited by current limiting reactor installed on the outgoing power line, the reactor is allowed to be used for many power lines provided that each power line shall be connected through separate switch. In this case, the divided reactor should be used.

Article 49. Design for Power Networks

As stipulated in Technical Regulation.

In some cases, when substation is designed, shedding of some less important loads shall be taken into account in the fault conditions.

Article 50. Future Electricity Supply in the event of Extension of the City

As stipulated in Technical Regulation.

Article 51. Electricity Quality in the Power Network

1. Voltage

- In the normal working conditions of the electricity supply center, during the time when total load is reduced to 30% of the maximal load, the voltage at the busbar must be kept at the nominal voltage level of the power network, but during the time of maximal load, voltage must be increased by 5%.
- For voltage regulation in power system with voltage of 110kV and above, the transformers with on load tap changer with voltage regulation range (10 - 15%) should be used.

Besides, use of local voltage regulation devices should be considered as follows:

+Voltage compensator

+ Synchronous motor

+ Synchronous compensator

+ Capacity compensating capacitors

+ Connection power lines with voltage up to 1,000V between substations in order to disconnect some transformers in the minimum load conditions.

+ Selection of voltage and power systems supplying electricity to motive loads and lighting in workshops using electricity at voltage up to 660kV shall be comprehensively solved.

If transformers are used to supply electricity for motors and lighting for users, the electrical diagram shall allow partially disconnecting some transformers during off working time, days-off or holidays and electricity for lighting will be supplied by small capacity transformers or power line connected to working transformers.

2. Power Factor

In case cos φ < 0.85 by download of households using electricity, using electricity must take measures to ensure that the power factor cos ≥ φ 0.85 can apply the following measures:

- Installation of reactive power compensation equipment to increase cos φ ≥ 0.85.
- Purchase of reactive power on the power system from the power supply.

3. Frequency

As stipulated in Technical Regulation.

4. Harmonics

As stipulated in Technical Regulation.

5. Voltage Flicker

As stipulated in Technical Regulation.

Article 52. Inspection of Voltage Fluctuation

If voltage deviation exceeds the permissible limitation, measure for voltage regulation shall be applied.

Article 53. Increased Surface Temperature caused by Solar Radiation

As stipulated in Technical Regulation.

Article 54. SF_6 Gas Leakage

In rooms with SF_6 installations, which are above ground, natural cross-venting is sufficient. In this case, approximately half of the cross-section of the ventilation openings required shall be close to the ground. This measure depends on the size of the room and the gas quantity. In cases of malfunction, mechanical ventilation may be required.

NOTE 1: Permanent ventilation may be omitted for chambers in installations which are not accessible. For small installations (total quantity of $SF_6 \leq$ 1,000liter under atmospheric pressure), ventilation on one side of the room is sufficient.

In rooms with SF_6 installations, which are below ground on all sides, mechanical ventilation shall be provided if gas quantities which pose an intolerable risk to the health and safety of personnel (see note 2 below) are capable of collecting due to the gas quantity and the size of the room.

Chambers, ducts, pits, shafts, etc., situated below SF_6 installation rooms and connected to them, shall be able to be ventilated.

Mechanical ventilation may be omitted provided the gas volume of the largest gas compartment at atmospheric pressure does not exceed 10% of the volume of the room. In this case the total volume (calculated at the normal temperature and pressure) of SF_6 gas in the cylinders connected to the SF_6 installations shall be taken into account for the purposes of calculation.

No part of equipment in contact with air may exceed a temperature of 200°C.

NOTE 2: For maximum SF_6 concentration, national regulations should be considered.
(Reference: Japanese maximum SF_6 concentration is 1,000vol PPM.)

Article 55. Oil Leakage

The transformers and shunt reactors shall have oil-collecting system (refer to Article 337 of Vol.1 in Technical regulation).

For indoor electrical equipment, the impermeable floor with edge high enough can be used as an oil collecting sump if the number of transformers is not exceeding 3 and oil volume in each transformer is less than 1,000liter.

For outdoor equipments, oil collecting sump might not be required if the transformer contains less than 1,000liter of oil. Such regulation shall not be applied for water collecting areas and/or the areas where the water resources are protected.

For the outdoor switchyards with the transformers are suspended on the poles, oil tanks are not necessary.

Installation of oil-collecting system shall meet stipulations provided in the article 157 and 354 of Vol.1.

Article 56. Materials for Electrical Equipment

According to the physical properties, electric engineering materials are classified into:

1. Refractory materials mean non-flammable materials or not becoming ash, and in case of being burnt, they are not able to continue burning themselves or slow burning.
2. Arc-resistant materials mean the materials whose properties are unchanged under arc action in normal operating condition.
3. Moisture-resistant materials mean the materials whose properties are unchanged under the action of moisture.
4. Heat-resistant materials mean the materials whose properties are unchanged under action of high or low temperatures.
5. Chemical-resistant materials mean the materials whose properties are unchanged under action of chemicals.

At the fire-resistance level (FRL), materials and building structures are classified into three groups which are specified in the following table.

Table 56 Flame resistant for construction materials and structures

Group	Flammability of materials	Flammability of structures
Nonflammable group	Under the action of flame or high temperature, materials are not ignited, not continuously burning, not becoming ash.	Structures are made of non-flammable materials or having flammability of non-flammable materials.
Difficult flammable group	Under the action of flame or high temperature, materials difficult ignited, difficult continuously burning, difficult becoming ash. When separated from flame resources they stop burning	Structures are made of difficult ignited materials or flammable materials protected with non-flammable materials and having flammability of difficult flammable materials.
Flammable group	Under the action of flame or high temperature, materials are ignited, or continuously burning. When separated from flame resources they continue burning or low burning	Structures are made of flammable materials not protected with non-flammable materials and having flammability level of easy-flammable materials.

Article 57. Protection against corrosion

It is important to consider the following matters at the time of construction and maintenance of paint equipment. Because it is concerned that the strength reduction and the increase of contact resistance of metal parts occur due to the corrosion of metal parts.

(1) Construction: In order to prevent the galvanic corrosion at the contact portion between dissimilar metals, appropriate material shall be used for the bolt and the terminal, so that the difference of ionization potential between the bolt and the terminal shall become small. In addition, the connection

portion shall be caulked, not to enter the moisture between the terminal and the bolt. As for appropriate combination of dissimilar metals, refer to the article 92 of Vol.3.

(2) Maintenance: It is desirable that zinc-rich paint (Cold Galvanizing Paint) containing more than 94% of metallic zinc powder in dry paint film is used for the refinish paint, in order to prolong the life of anticorrosive effect. In addition, the coating film of the above mentioned paint should be ensured about 80μm.

It is desirable to do anti-rust treatment on the metal surface of equipment by the one of the following methods for a fine view and rustproof purpose.

(1) Painting
A painting has the advantage of a fine view, because paint colors can be selected freely.
But if the coating film is damaged for some reason, the relevant part will get rusted in a short time without refinish paint. Because a painting does not have the function of sacrificial protection which a hot-dip galvanizing has.

(2) Hot-dip galvanizing
A hot-dip galvanizing is not suitable for the equipment which is installed in the place where requires a fine view, because paint colors can not be selected. But it is strong against the damage on the surface of plating and it is the most economical method for rust-proofing because it has long durable years, due to the function of protective coating and sacrificial protection.
As the following table, the thickness of plating is different based on the way of zinc galvanizing. Therefore, it should select a proper way of zinc galvanizing according to the use application.

Table 57-1 Thickness of plating and way of zinc plating

Way of zinc plating	Material	Thickness (μm)
Hot-dip galvanizing	Structure	75 - 125
	Bolt and nut	45 - 70
	Attachment lug	35 - 75
	Pipe	75 - 100
	Wire	12 - 35
	Galvanized sheet	8 - 20
Electrogalvanizing	General product	5 - 25
	Iron plate	2 - 8
Zinc spraying	General product	75 - 125
Zinc-rich paint (1 coated)	General product	10 - 35

Table 57-2 (Reference) Durable year of hot-dip galvanizing in the atmosphere

Exposure location	Corrosion rate ($g/m^2/year$)	Duration(year)
Urban and industrial area	8.0	62
Rural area	4.4	113
Coast	19.6	25

As for the durable year in the atmosphere, it can be calculated from the corrosion rate, the amount of deposition of zinc and the following formula:

Durable year = Amount of zinc / Corrosion rate * 0.9

Note: The durable year in the above table is calculated from the following assumptions:

- Amount of zinc : 550g/m^2
- Remaining amount of plating : 10%

Metal parts of poles shall be galvanized with zinc or painted by anti-corrosion paint for protecting corrosion. (Zinc galvanization is the most effective protection method against corrosion.)

Adhesion ratio of zinc galvanization is shown in the following table as reference.
Painting shall be carefully conducted by referring the contents in article 530 in GuidelineVol.3.

Table 57-3 (Reference) Plating attachment quantity of zinc galvanization

Item	Plating attachment quantity of zinc galvanization (g/m^2)	
	Average	Minimum
Metal parts or members of poles	600	550
bolts or nut	400	350

Article 58. Distinction of Elements

In an electrical power project, measures are required to distinguish elements in a single part such as diagrams, equipment layout schemes, lettering, numbering, different color paints etc.

Busbar conductors, conductors must be painted as follows: according to the provisions of Section 5 of Article 2 in theVol.1 of Technical Regulation.

Article 59. Avoidance of Interference for Telecommunication Projects

In order for power projects not to interfere with and endanger telecommunication projects, existing related standards and norms as below must be complied with and comply with the provisions of Article 281, 282, 284, 286, 287 and 288of Vol.1 in Technical Regulation.

Article 60. Automated Equipment for unmanned substation

Substations designed with automated equipment and unstaffed. In case that a fault happens, remote control equipment and warning signals shall be used for switching to eliminate the fault from a load dispatch center remotely.

Remote control equipment and information such as state of equipment, warning signals, telemeter, etc. is used for remote control from load dispatch center. The example of equipment and information is shown in the following table.

Table 60 (Example) Equipment and Information used for remote control

Items		Sort	Objects
Remote control equipment		ON / OFF	Circuit breaker, Disconnetor
		Tap change	Transformer
		Use / Non use	Relay, Automatic recloser
Information	State of equipment	ON / OFF	Circuit breaker, Disconnetor,
		Tap No.	Transformer
		Use / Non use	Relay, Automatic recloser
	Warning signals	Fault	Relay operation, Fault situation
		Abnormal condition	Equipment trouble, Over voltage, Under voltage , Fire, Oil leakage
	Telemeter	Voltage	Transmission line, distribution line, busbar
		Ampere	Ditto
		W,Var	Transmission line, Transformer

Article 61. Short Circuit Currents for All Equipment with Shunt Reactors

As stipulated in Technical Regulation.

Article 62. Utilization of Overhead Lines and Underground Cables

In places where the approved planning is not available, the overhead transmission line is recommended to be used, and in urban areas and industrial zones where the planning is approved, underground cables are recommended to be used.

For building in places where power development plan is approved, underground cable lines shall be used. For buildings in the places without approved power development plan, the overhead power lines are used. In cities, twisted cable and / or underground cables are used.

For low voltage power lines, the sheathed conductors are strongly recommended to be used. For power lines with voltage up to 22kV in the places with narrow corridor or many trees, the sheathed conductors are recommended to be used too.

Article 63. Overload Capacity

The overload capacity of electrical equipment and standby power resources must be considered when solving reserve issues. The overload capacity of electrical equipment shall be considered with manufactures' specifications individually.

Depending on the power demand, power network with voltage of 1kV and higher should be constructed at the diagram with self-closing device for standby power supply source.

Article 64. Conditions of Fault Calculation

As stipulated in Technical Regulation.

Article 65. Selecting of Conductor Size

The cross section of power cables to be constructed in the initial stage must be selected in consideration of following items.

1. Loads of electricity users

Loads of electricity users which are connected to the power system with voltage up to 380V shall be calculated in compliance with the following:

For the initial development stage, calculated load is equal to existing load plus 10% - 20% /year. If voltage is lower than normal, the calculation results must be adjusted.

2. Coincidence coefficient for calculation (Normal users)

Coincidence coefficient for calculation of maximal load of normal users is taken as follows:

For public lighting: $k = 1$

Residential load: $k = 0.9$

Commercial, services, office loads: $k = 0.85$

Small industry, handicraft: $k = 0.4 - 0.5$

3. Formula for calculation

If there is no base for calculation of coincidence coefficient due to combined loads, the following formula can be used:

$$M_{max} = K_{dt} (P_{assh} + P_{cn,tcn} + P_{nn}) = K_{dt} \Sigma P$$

Where:

Passh : Total capacity for residential lighting

Pcn,tcn : Total capacity of industry, handicraft

Pnn : Total capacity for agriculture

Kdt is Coincidence coefficient of loads which can be selected as follows:

When $P_{assh} \le 0.5\ \Sigma P$, $K_{dt} = 0.6$

When $P_{assh} = 0.7\ \Sigma P$, $K_{dt} = 0.7$

When $P_{assh} = \Sigma P$, $K_{dt} = 0.9$

For other cases, Kdt is extrapolated.

4. Coincidence coefficient for calculation (Power lines)

Coincidence coefficient for calculating loads of power lines with voltage from 6kV to 35kV:

For power line with 3-5 substations, $K_{dt} = 0.9$

For power line with 6-10 substations, $K_{dt} = 0.8$

For power line with 11-20 substations, $K_{dt} = 0.75$

For power line with above 20 substations, $K_{dt} = 0.7$

Article 66. Transmitting Signal of Fault Circuit Breakers

Transmitting signal of the fault circuit breaker shall be met as specified in Article 60.

Chapter 2-2 Electrical Equipment

Chapter 2-2-1 The Selection of the Conductor Cross-Section Area

Article 67. General Provisions

As stipulated in Technical Regulation.

Article 68. Selection by Permissible Heating

Considered maximal load is the average maximal load in half hour which is considered for development in 10 future years for overhead power line and after 20 years for underground cable line.

For short time load or short time repeatable load (total time for one cycle is up to 20 minutes and working time in the cycle is less than 4 minutes), in order to check cross section area of the conductor according to permissible heating, the calculated load is converted to the continuous working condition:

For copper conductor with cross section area up to 6mm2 and aluminum with cross sectional area up to 10mm2, the calculated load is taken equal to short time load and considered as continuous load.

For cooper conductor with cross sectional area over 6mm2 and aluminum with cross sectional area over 10mm2, calculated load is the short time load multiplied with the following coefficient:

$$\frac{0.875}{\sqrt{t_{lv}}}$$

Where, tlv is ratio between working time in the cycle and total continuous cycle time.

For short time working condition with closing time not excessive 4 minutes and off-time between two closings enough to cool conductor down to atmospheric temperature, the maximal permissible load is determined based on economic current density or voltage drop as well as other criteria.

For short time working condition with closing time excessive 4 minutes and off-time between two closings not enough to cool conductor down to atmospheric temperature, the maximal load is considered as maximal continuous working load.

For two or more cables work permanent in parallel, when considering the development level of a heating for problems in the faults, a faults that is in the aerial cable lines in operation temporarily.

The neutral wire in the 3-phase, 4-conductor power system must have electricity conductivity lot smaller than 50% of conductivity of the 3-phase conductor.

When calculating permissible continuous current for bare conductors, bare busbars, rigid and soft wires in atmospheric temperature conditions or other conditions, the adjusted coefficients in Table 72-4 to Table 72-8 are used.

Permissible continuous current for conductors with rubber or PVC sheath, or soft conductors insulated with rubber, cable insulted with rubber or plastic covered lead, as mentioned in Table 68-1 to Table 68-8, is calculated according to core heating temperature of + 65°C when atmospheric temperature is +25°C or when earth temperature is +15°C or when calculating number of conductors placed in one pipe (or cores of multi-fiber conductor) without taking neutral wire into account for 3 phase, 4-conductor power system (or core grounded).

Table 68-1 Permissible current for copper core conductor covered with rubber or PVC

Core cross sectional area, mm^2	Permissible electricity current (A)					
	Open placed conductor	Conductors placed in one pipe				
		2 conductors 1 core	3 conductors 1 core	4 conductors 1 core	1 conductor 2 cores	1 conductor 3 cores
0.5	11	-	-	-	-	-
0.75	15	-	-	-	-	-
1.0	17	16	15	14	15	14
1.5	23	19	17	16	18	15
2.5	30	27	25	25	25	21
4	41	38	35	30	32	27
6	50	46	42	40	40	34
10	80	70	60	50	55	50
16	100	85	80	75	80	70
25	140	115	100	90	100	85
35	170	135	125	115	125	100
50	215	185	170	150	160	135
70	270	225	210	185	195	175
95	330	275	255	225	245	215
120	385	315	290	260	295	250
150	440	360	330	-	-	-
185	510	-	-	-	-	-
240	605	-	-	-	-	-
300	695	-	-	-	-	-
400	830	-	-	-	-	-

Table 68-2 Conductor with cooper core, rubber insulation in metal sheath and cable with copper core, rubber insulation in lead cover, PVC or rubber sheath, with or without steel bands

Cross sectional area of core mm^2	Permissible electricity current (A)				
	Conductor and cable				
	One core	Two cores		Three cores	
	When placed in				
	Air	Air	Earth	Air	Earth
1.5	23	19	33	19	27
2.5	30	27	44	25	38
4	41	38	55	35	49
6	50	50	70	42	60
10	80	70	105	55	90
16	100	90	135	75	115
25	140	115	175	95	150
35	170	140	210	120	180

Cross sectional area of core mm^2	Permissible electricity current (A)				
	Conductor and cable				
	One core	Two cores		Three cores	
	When placed in				
	Air	Air	Earth	Air	Earth
50	215	175	265	145	225
70	270	215	320	180	275
95	325	260	485	220	330
120	385	300	445	260	385
150	440	350	505	305	435
185	510	405	570	350	500
240	605	-	-	-	-

Table 68-3 Conductor with aluminum core, rubber or PVC insulation

Core cross sectional area, mm^2	Permissible electricity current (A)					
	Open placed conductor	Conductors placed in one pipe				
		2 conductors 1 core	3 conductors 1 core	4 conductors 1 core	1 conductor 2 cores	1 conducto r 3 cores
2.5	24	20	19	19	19	16
4	32	28	28	23	25	21
6	39	36	32	30	31	26
10	60	50	47	39	42	38
16	75	60	60	55	60	55
25	105	85	80	70	75	65
35	130	100	95	85	95	75
50	165	140	130	120	125	105
70	210	175	165	140	150	135
95	255	215	200	175	190	165
120	295	245	220	200	230	190
150	340	275	255	-	-	-
185	390	-	-	-	-	-
240	465	-	-	-	-	-
300	535	-	-	-	-	-
400	645	-	-	-	-	-

Table 68-4 Cable with aluminum core, rubber or plastic insulation, lead, PVC or rubber cover, with or without steel band

Cross sectional area of core mm^2	Permissible electricity current (A) (1)				
	One core	Two cores		Three cores	
	Air	Air	Earth	Air	Earth
2.5	23	21	34	19	29
4	31	29	42	27	38
6	38	38	55	32	46
10	60	55	80	42	70
16	75	70	105	60	90
25	105	90	135	75	115

Cross sectional area of core mm^2	Permissible electricity current (A) (1)				
	One core	Two cores		Three cores	
	Air	Air	Earth	Air	Earth
35	130	105	160	90	140
50	165	135	205	110	175
70	210	165	245	140	210
95	250	200	295	170	255
120	295	230	340	200	295
150	340	270	390	235	335
185	390	310	440	270	385
240	465	-	-	-	-

Table 68-5 Soft cable with cooper core, rubber insulation, movable used in underground mines

Cross sectional area of core,mm^2	Permissible electricity current (A) (1)		
	One core	Two cores	Three cores
0.5	-	12	-
0.75	-	16	14
1.0	-	18	16
1.5	-	23	20
2.5	40	33	28
4	50	43	36
6	65	55	45
10	90	75	60
16	120	95	80
25	160	125	105
35	190	150	130
50	235	185	160
70	290	235	200

Notes: (1) For cables with or without core

Table 68-6 Soft cable with cooper core, rubber insulation, movable use in brown coal enterprises

Cross sectional area of core,mm^2	Permissible electricity current (A) (1)		
	0.5kV	3kV	6kV
6	44	45	47
10	60	60	65
16	80	80	85
25	100	105	105
35	125	125	130
50	155	155	160
70	190	195	-

Notes: (1) For cables with or without core grounded.

Table 68-7 Soft cable with cooper core, rubber insulation, used for mobile electrical machines

Cross sectional area of core,mm^2	Permissible electricity current (A) (1)	
	3kV	6kV
16	85	90
25	115	120
35	140	145
50	175	180
70	215	220
95	260	265
120	305	310
150	345	350

Notes: (1) For cables with or without core grounded.

Table 68-8 Conductors with cooper core, rubber insulation, voltage of 1,3, 4kV, used in transport sector

Core cross sectional area(mm^2)	Permissible current (A)	Core cross sectional area(mm2)	Permissible current (A)
1.0	20	50	230
1.5	25	70	285
2.5	40	95	340
4	50	120	390
6	65	150	445
10	90	185	505
16	115	240	590
25	150	300	670
35	185	350	745

Permissible continuous current of underground cables

The permissible continuous current of underground cables with voltage up to 35kV, oiled paper insulation, aluminum, lead or PVC cover, is selected according to the permissible heating temperature of the conductor core heating: +80°C for voltage up to 3kV, +60°C for voltage up to 6kV, +60°C for voltage up to 10kV, +50°C for voltage up to 35kV. Permissible continuous current of underground cable will be selected according to manufacturer's permissible parameters or concrete levels if such documents are provided by the manufacturer.

For underground cables, permissible continuous currents given in Table 68-10, 12 to 14, 17 are calculated for cables placed in canals at the depth of 0.7 - 1 m, earth temperature of +15°C and earth thermal resistivity of 120 cm. °F /W.

If earth resistivity is other than the above value, the permissible continuous current of underground cable will be multiplied with the coefficients given in the following Table:

Table 68-9 The adjustment coefficient

Earth features	Thermal resistivity, (cm. °F /W)	Adjustable coefficient
Sands with moisture content over 9%, sand-clay with moisture over 1%	80	1.05
Soil and sands with moisture content 7-9%, sand-clay with moisture over 12-14%	120	1.00
Sands with moisture content over 4% and less than 7%, sand-clay with moisture over 8-12%	200	0.87
Sands with moisture content up to 4%, soil and stones.	300	0.75

For cable placed in water, permissible continuous currents given in Table 68-11, 14, 15 are calculated with water temperature of +15°C.

For cables placed in the air, permissible continuous currents given in Table 68-11 to 17 are calculated with distance between cables placed indoor, outdoor and in tunnel not less than 35mm and in canals not less than 50mm, for any number of cables and air temperature of +2°C.

The permissible continuous current of the cable placed in pipe buried under the ground without forced ventilation will be taken equal to the values of cables when placed in the air.

When cable line going through different environments, permissible current of the cable will be calculated for section with worst conditions if this cable section has length longer than 10m. In this case, cable of this section should be replaced with bigger cable.
When some cables are placed in the earth or pipe, the permissible continuous current will be reduced by multiplication with values in Table 68-18 to 21, not including standby cables. When cables are placed in earth, distance between cables will be not less than 100mm.

Permissible currents of oil, gas, XLPE and EPR cables, one core-steel banded cables will be selected according to the manufacturer's documents (see Annex II.2.1 (I.3A)).

Table 68-10 Aluminum core cable with pine resin impregnated insulating paper, lead or aluminum cover, placed in earth

Cross sectional area of core mm^2	Permissible electricity current (A) (1)					
	One core cable up to 1kV	Two core cable up to 1kV	Three core cable			Four core cable 1kV
			Up to 3kV	6kV	10kV	
6	80	60	55	-	-	46
10	110	80	75	60	-	65
16	135	110	90	80	75	90
25	180	140	125	105	90	115
35	220	175	145	125	115	135

Cross sectional area of core mm^2	Permissible electricity current (A) (1)					
	One core cable up to 1kV	Two core cable up to 1kV	Three core cable			Four core cable 1kV
			Up to 3kV	6kV	10kV	
50	275	210	180	155	140	165
70	340	250	220	190	165	200
95	400	290	260	225	205	240
120	460	335	300	260	240	270
150	520	385	335	300	275	305
185	580	-	380	340	310	345
240	675	-	440	390	355	-
300	770	-	-	-	-	-
400	940	-	-	-	-	-
500	1080	-	-	-	-	-
625	1170	-	-	-	-	-
800	1310	-	-	-	-	-

Notes: (1) Permissible current of one core cable is DC current.

Table 68-11 Aluminum core cable with pine resin impregnated insulating paper, lead cover, placed in water

Cross sectional area of core mm^2	Permissible electricity current (A) (1)			
	Three core cable			Four core cable 1kV
	Up to 3kV	6kV	10kV	
16	-	105	90	
25	160	130	115	150
35	190	160	140	175
50	235	195	170	220
70	290	240	210	270
95	340	290	260	315
120	390	330	305	360
150	435	385	345	-
185	475	420	390	-
240	550	480	450	-

Table 68-12 Aluminum core cable with pine resin impregnated insulating paper, lead or aluminum cover, placed in air

Cross sectional area of core mm^2	Permissible electricity current (A) (1)					
	One core cable up to 1kV	Two core cable up to 1kV	Three core cable			Four core cable 1kV
			Up to 3kV	6kV	10kV	
6	55	42	35	-	-	35
10	75	55	46	42	-	45
16	90	75	60	50	46	60
25	125	100	80	70	65	75
35	155	115	95	85	80	95
50	190	140	120	110	105	110
70	235	175	155	135	130	140
95	275	210	190	165	155	165
120	320	245	220	190	185	200
150	360	290	255	225	210	230
185	405	-	290	250	235	260
240	470	-	330	290	270	-
300	555	-	-	-	-	-
400	675	-	-	-	-	-
500	785	-	-	-	-	-
625	910	-	-	-	-	-
800	1080	-	-	-	-	-

Notes: (1) Permissible current of one core cable is DC current.

Table 68-13 6kV copper 3-core cable with common lead sheath, oil impregnated insulation, placed in earth and air

Cross sectional area of core mm^2	Permissible electricity current (A)		Cross sectional area of coremm2	Permissible electricity current (A)	
	Placed in earth	Placed in air		Placed in earth	Placed in air
16	90	65	70	220	170
25	120	90	95	265	210
35	45	110	120	310	245
50	180	140	150	355	290

Table 68-14 6kV aluminum 3-core cable with common lead sheath, oil impregnated insulation, placed in earth and air

Cross sectional area of core mm^2	Permissible electricity current (A)		Cross sectional area of coremm^2	Permissible electricity current (A)	
	Placed in earth	Placed in air		Placed in earth	Placed in air
16	70	50	70	170	130
25	90	70	95	205	160
35	110	85	120	240	190
50	140	110	150	275	225

Table 68-15 Copper 3-core cable with separate lead sheath, oil and fire-resistant oil impregnated insulation paper, placed in earth, water and air

Cross sectional area of coremm^2	Permissible current of three core cable, A					
	22kV			35kV		
	Placed in					
	Earth	Water	Air	Earth	Water	Air
25	110	120	85	-	-	-
35	135	145	100	-	-	-
50	165	180	120	-	-	-
70	200	225	150	-	-	-
95	240	275	180	-	-	-
120	275	315	205	270	290	205
150	315	350	230	310	-	230
185	355	390	265	-	-	-

Table 68-16 Aluminum 3-core cable with separate lead sheath, oil and fire-resistant oil impregnated insulation paper, placed in earth, water and air

Cross sectional area of core mm^2	Permissible current of three core cable, A					
	22kV			35kV		
	Placed in					
	Earth	Water	Air	Earth	Water	Air
25	85	90	65	-	-	-
35	105	110	75	-	-	-
50	125	140	90	-	-	-
70	155	175	115	-	-	-
95	185	210	140	-	-	-
120	210	245	160	210	225	160
150	240	270	175	240	-	175
185	275	300	205	-	-	-

Table 68-17 Copper one-core cable with oil impregnated insulation paper, lead sheath, without steel band, placed in air

Cross sectional area of core,mm2	Permissible electricity current (*) A		
	Up to 3kV cable	22kV cable	35kV cable
10	85/-	-	-
16	120/-	-	-
25	145/-	105/110	-
35	170/-	125/135	-
50	215/-	155/165	-
70	260/-	185/205	-
95	305/-	220/255	-
120	330/-	245/290	240/265
150	360/-	270/330	265/300
185	385/-	290/360	285/335
240	435/-	320/395	315/380
300	460/-	350/425	340/420
400	485/-	370/450	-
500	505/-	-	-
625	525/-	-	-
800	550/-	-	-

Notes: (*) Numerator is for cables placed on the same plane in distance of 35-125mm. Denominator for cables placed in grazing points of equilateral triangle

Table 68-18 Aluminum one-core cable with oil impregnated insulation paper, lead sheath, without steel band, placed in air

Cross sectional area of core mm^2	Permissible electricity current (*) A		
	Up to 3kV cable	22kV cable	35kV cable
10	65/-	-	-
16	90/-	-	-
25	110/-	80/85	-
35	130/-	95/105	-
50	165/-	120/130	-
70	200/-	140/160	-
95	235/-	170/195	-
120	255/-	190/225	185/205
150	275/-	210/255	205/230
185	295/-	225/275	220/255
240	335/-	245/305	245/290
300	355/-	270/330	260/330
400	375/-	285/350	-
500	390/-	-	-
625	405/-	-	-
800	425/-	-	-

Notes: (*) Numerator is for cables placed on the same plane in distance of 35-125mm. Denominator for cables placed in grazing points of equilateral triangle

Table 68-19 Coefficients for case in which many cables working in parallel and placed in earth with or without pipe (Coefficient k)

Number of cable / Spaces between cables, mm	1	2	3	4	5	6
100	1.0	0.00	0.85	0.80	0.78	0.75
200	1.0	0.92	0.87	0.84	0.82	0.81
300	1.0	0.93	0.90	0.87	0.86	0.85

The values of permissible currents of oiled cables as given in the above tables, are calculated with air temperature of +25°C and water temperature of + 15°C.

When cables are placed in pipe buried in the earth the cables are considered as placed in the air with temperature of the earth.

When cables are placed in block, the permissible continuous current is determined by the following formula:

$$I = k * a * b * c * d * I_o$$

Where:

Io : the long-term current given in Table 68-1 to 18.

k: the coefficient of multiple parallel cable, for Table 68-19.

a: adjustment coefficient given in Table 68-20 depending on cross sectional area and arrangement of cable in the block.

b: adjustment coefficient according to nominal voltage of cable, given in Table 68-21

c: adjustment coefficient according to average daily load of the whole cable block, given in Table 68-22.

d: the distance coefficient between the cable block, for Table68-23

Table 68-20 Coefficient a:

Core cross sectional area mm^2	Number of cables in the block			
	1	2	3	4
25	0.44	0.46	0.47	0.51
35	0.54	0.57	0.57	0.60
50	0.67	0.69	0.69	0.71
70	0.81	0.84	0.84	0.85
95	1.00	1.00	1.00	1.00
120	1.14	1.13	1.13	1.12
150	1.33	1.30	1.29	1.26
185	1.50	1.46	1.45	1.38
240	1.78	1.70	1.68	1.55

Table 68-21 Coefficient b:

Nominal voltage of cable, kV	10	6	Up to 3
Coefficient b	1	1.05	1.16

Table 68-22 Coefficient c

Stbn Sdd	1.0	0.85	0.7
Coefficient c	1.0	1.07	1.16

Where: Stbn is the average daily load of cable block; Sdd is the nominal load of the block.

Permissible current of cables in two identical blocks arranged in parallel will be reduced by coefficient dependent on distance between two blocks as given in the following Table:

Table 68-23 Distance between blocks

Distance between blocks	500	1.000	1.500	2.000	2.500	3.000
Reduction coefficient	0.85	0.89	0.91	0.93	0.95	0.96

Article 69. Selection by Permissible Voltage Drop

All conductors (bare conductors, sheathed conductors, cables and busbars) shall meet permissible voltage drop conditions.

The longer length of a conductor becomes and the larger load current becomes, the higher voltage drop at the end of a conductor becomes. So the cross-sectional area of a conductor shall be selected in consideration of the length of a conductor and the load current.

Because the effect of voltage drop caused by load current is significantly high in low-voltage circuit, it shall be paid particular attention to the voltage drop in low-voltage circuit.

The permissible voltage drop for each case depends on requirement of load type, including starting of electrical motors and taking into account increase of load in future, especially with underground cable.

For some loads which require highly stable voltage, if conductor cross sectional area is selected according to permissible voltage drop, the conductor is too big and too expensive. In this case, it needs to make comparison with alternative to increase voltage of the power line together with installation of low voltage transformers at the end of the line or alternative ensuring normal voltage drop together with installation of automatic voltage stabilizers at the end of the line.

The formula for calculation of the voltage drop is as below.

$Vd=Ku*I*L*Z*10^{-3}$

Vd :Voltage drop [V]

Ku : Coefficient according to the power distribution scheme

Ku=2 ; between conductors for single-phase two-wire system and single-phase three-wire system

Ku=1 ; between a conductor and a neutral line for single-phase three-wire system and three-phase four-wire system

Ku=√3 ; between conductors for three-phase three-wire system and three-phase four-wire system

I : Load current [A]

L : Length of conductor [m]

Z : Impedance [Ohm/km]

Permissible voltage drop for indoor wiring .

Table 69 Permissible voltage drop for indoor wiring

Scheme of power supply	Length of conductor [m]	Permissible voltage drop [%]	
		Main line	Branch line
Without transformers	60 or less	2 or less	2 or less
	120 or less	4 or less	4 or less
	200 or less	5 or less	5 or less
	More than 200	6 or less	6 or less
With transformers	60 or less	3 or less	2 or less
	120 or less	5 or less	5 or less
	200 or less	6 or less	6 or less
	More than 200	7 or less	7 or less

Article 70. The Selection Conductors of up to 1kV

As stipulated in Technical Regulation.

Article 71. Selection Conductors of exceeding 1kV

The cross-sectional area of conductors over 1kV is selected with respect to economical current density by adding to article 68 and 69 of Vol.1.

In some cases, when upgrading or rehabilitating, in order to avoid increasing number of power lines or number of circuits of the power line, the economic current density is allowed to be higher than and to level double of the limitation values given in the following table.

In technical economic calculation, total increased investment cost of lines and equipment in bays at both ends of the lines shall be included.

The alternative of upgrading power lines is also considered.

The above indications are also applied for the case when upgrading with increasing conductor cross section area due to overload. The rehabilitation cost shall include costs of new equipment and materials deducted by recovery value.

Table 71 Economic current density

Electricity conducting material	Economic current density (A/mm^2)		
	Hours of maximal load using in year (h)		
	From 1000 to 3000	From over 3000 to 5000	Over 5000
Bars and bare conductors:			
- Copper	2.5	2.1	1.8
- Aluminum (steel core aluminum wire)	1.3	1.1	1.0

Article 72. The Selection of Bare Conductors with large cross-section

The continuous permissible current of bare conductors and busbars are taken from the manufacturer's documents or according to the values given in Tables 72-1, 72-2, 72-3, 72-4, 72-5, 72-6 and 72-7.

These values have been calculated with permissible heating temperature of +70°C when air temperature is +25°C. In selecting conductors and busbars, it needs to check continuous permissible current at the working conditions of the conductors and busbars. The check calculation of continuous permissible current is performed according to guidelines given in the Annex II.2.2.

When arranging rectangular busbars in horizontally, the currents given in Table 72-2 and 72-6 must be reduced by 5% for busbar with width up to 60mm and 8% for busbar with width more than 60mm.

Table 72-1 The continuous permissible currents by heating of copper, aluminum or steel-core-aluminum bare conductors (Permissible heating 70°C at Air 25°C)

Aluminum/ steel cross sectional area [mm2]	Permissible current according to conductor symbol [A]					
	AC, ACK, ACKП, ACSR		M	A, AKП	M	A, AKП
	Indoor	Outdoor	Indoor		Outdoor	
10/1.8*	84	53	95	-	60	-
16/2.7*	111	79	133	105	102	75
25/4.2*	142	109	183	136	137	106
35/6.2	175	135	223	170	173	130
50/8	210	165	275	215	219	165
70/11	265	210	337	265	268	210
95/16	330	260	422	320	341	255
120/19	390	313	485	375	395	300
120/27	375	-				
150/19	450	365	570	440	465	355
150/24	450	365				
150/34	450	-				
185/24	520	430	650	500	540	410
185/29	510	425				
185/43	515	-				
240/32	605	505	760	590	685	490
240/39	610	505				
240/56	610	-				
300/39	710	713	1050	815	895	690
300/48	690	705				
300/66	680	-				
330/27	730	-	-	-	-	-
400/22	830	713	1050	815	895	690
400/51	825	705				
400/64	860	-				
500/27	960	830	-	980	-	820

Aluminum/ steel cross sectional area [mm2]	Permissible current according to conductor symbol [A]					
	AC, ACK, ACKП, ACSR		M	A, AKП	M	A, AKП
	Indoor	Outdoor	Indoor		Outdoor	
500/64	945	815				
600/72	1050	920	-	1100	-	955
700/86	1180	1040	-	-	-	-

Notes: (*): Conductors ACSR don't have these sizes.

Table 72-2 Continuous permissible currents of copper or aluminum round busbars or pipes

Diameter [mm]	Round busbar		Copper pipe		Aluminum pipe	
	Current (*) [A]		Ext./inter. diameter	Current, [A]	Ext./inter. diameter	Current, [A]
	Copper	Aluminum				
6	155	120	12/15	340	13/16	295
7	195	150	14/18	460	17/20	345
8	235	180	16/20	505	18/22	425
10	320	245	18/22	555	27/30	500
12	415	320	20/24	600	26/30	575
14	505	390	22/26	650	25/30	640
15	565	435	25/30	830	36/40	765
16	610/615	475	29/34	925	35/40	850
18	720/725	560	35/40	1100	40/45	935
19	780/785	605/610	40/45	1200	45/50	1040
20	835/840	650/655	45/50	1330	50/55	1150
21	900/905	695/700	49/55	1580	54/60.	1340
22	955/965	740/745	53/60	1860	64/70	1545
25	1140/1165	885/900	62/70	2295	74/80	1770
27	1270/1290	980/1000	72/80	2610	72/80	2035
28	1325/1360	1025/1050	75/85	3070	75/85	2400
30	1450/1490	1120/1155	90/95	2460	90/95	1925
35	1770/1865	1370/1450	95/100	3060	90/100	2840
38	1960/2100	1510/1620	-	-	-	-
40	2080/2260	1610/1750	-	-	-	-
42	2200/2430	1700/1870	-	-	-	-
45	2380/2670	1850/2060	-	-	-	-

Notes: (*) Numerator is the permissible AC current, denominator is permissible DC current

Table 72-3 Continuous permissible current of copper rectangular busbar

Dimensions [mm]	Permissible current by number of busbars in one phase [A]			
	1	2	3	4
15x3	210	-	-	-
20x3	275	-	-	-
25x3	340	-	-	-
30x4	475	-	-	-
40x4	625	-/1090	-	-
40x5	700/705	-/1250	-	-
50x5	860/870	-/1525	-/1895	-
50*x6	955/960	-/1700	-/2145	-
60x6	1125/1145	1470/1990	2240/2495	-
80x6	1480/1510	2110/2360	2720/3220	-
100x6	1810/1875	2470/3245	3770/3940	-
60x8	1320/1345	2160/2485	2790/3020	-
80x8	1690/1755	2620/3095	3370/3850	-
100x8	2080/2180	3630/3180	3930/4690	-
120x8	2400/2600	3400/4400	4340/5600	-
60x10	1475/1525	2560/2725	3300/3530	-
80x10	1900/1990	3100/3510	3990/4450	-
100x10	2310/2470	3610/4395	4650/5385	5300/6060
120x10	2650/2950	4100/5000	5200/6250	5900/6800

Notes: (*) Numerator is the permissible AC current, denominator is permissible DC current

Table 72-4 Continuous permissible current of aluminum rectangular busbar

Dimensions [mm]	Permissible current by number of busbars in one phase [A]			
	1	2	3	4
15x3	165	-	-	-
20x3	215	-	-	-
25x3	265	-	-	-
30x4	365 / 370	-	-	-
40x4	480	- / 885	-	-
40x5	540 / 545	- / 965	-	-
50x5	665 / 670	- / 1180	- / 1470	-
50*x6	740 / 745	- / 1335	- / 1655	-
60x6	870 / 880	1350 / 1555	1720 / 1940	-
80x6	1150 / 1170	1360 / 2055	2100 / 2460	-
100x6	1425 / 1455	1935 / 2515	2500 / 3040	-
60x8	1025 / 1040	1680 / 1810	2810 / 2330	-
80x8	1320 / 1355	2040 / 2100	2625 / 2975	-
100x8	1625 / 1690	2390 / 2945	3050 / 3620	-
120x8	1900 / 2040	2650 / 3350	3380 / 4250	-
60x10	1155 / 1180	2010 / 2110	2650 / 2720	-
80x10	1480 / 1540	2410 / 2735	3100 / 3440	-
100x10	1820 / 1910	2860 / 3350	3640 / 4160	4150 / 4400
120x10	2070 / 2300	3200 / 3900	4100 / 4800	4650 / 5200

Notes: (*) Numerator is the permissible AC current, denominator is permissible DC current

Table 72-5 Continuous permissible current of bronze or steel-core bronze conductor

Bronze conductor		Steel-core bronze conductor	
Conductor mark	Permissible current	Conductor mark	Permissible current
-50	215	C-185	515
-70	265	C-240	640
-95	330	C-300	750
-120	380	C-400	890
-150	430	C-500	980
-185	500		
-240	600		
-300	700		

Notes: (*) permissible current for bronze with resistivity of $\rho_{20} = 0.003\ \Omega.mm^2/m$

Table 72-6 Continuous permissible current of copper or aluminum square busbar

(see figure I.2.43-1)

Dimensions [mm]				Cross sectional area of four busbars [mm²]	Permissible current for whole set	
h	b	h1	H		Copper	Aluminum
80	8	140	157	2560	5750	4550
80	10	144	160	3200	6400	5100
100	8	160	185	3200	7000	5550
100	10	164	188	4000	7700	6200
120	10	184	216	4800	9050	7300

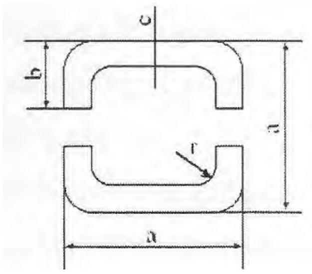


Figure 72-1 Cross section of square busbar

Table 72-7 Continuous permissible current of copper or aluminum box busbar

(see figure 72-2)

Dimensions [mm]				Total cross sectional area [mm²]	Permissible current for whole set	
a	b	c	r		Copper	Aluminum
75	35	4	6	1040	2730	-
75	35	5.5	6	1390	3250	2670
100	45	4.5	8	1550	3620	2820
100	45	6	8	2020	4300	3500
125	55	6.5	10	2740	5500	4640
150	65	7	10	3570	7000	5650
175	80	8	12	4880	8550	6430
200	90	10	14	6870	9900	7550
200	90	12	16	8080	10500	8830
225	105	12.5	16	9760	12500	10300
250	115	12.5	16	10900	-	10800

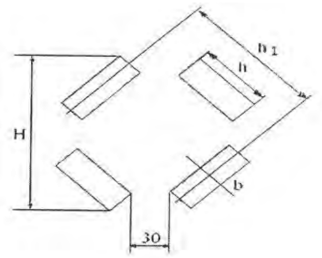


Figure 72-2 Cross section of box busbar

Table 72-8 Adjustment coefficients for permissible currents of bare conductors and insulated conductors, underground cables, busbars, according to air and earth temperatures:

Calculated temperature of environment [°C]	Standard temperature of core [°C]	Adjustment coefficient of permissible current according to temperature of environment [°C]							
		15	20	25	30	35	40	45	50
15	80	1.00	0.96	0.92	0.88	0.83	0.78	0.73	
25	80	1.09	1.04	1.00	0.90	0.80	0.80	0.80	
25	70	1.11	1.05	1.00	0.94	0.88	0.81	0.74	
15	65	1.00	0.95	0.89	0.84	0.77	0.71	0.63	
25	65	1.12	1.06	1.00	0.94	0.87	0.79	0.71	
15	60	1.00	0.94	0.88	0.82	0.75	0.67	0.57	
25	60	1.13	1.07	1.00	0.93	0.85	0.76	0.66	
15	55	1.00	0.93	0.86	0.79	0.71	0.61	0.50	
25	55	1.15	1.08	1.00	0.91	0.82	0.71	0.58	
15	50	1.00	0.93	0.84	0.76	0.66	0.54	0.37	
25	50	1.18	1.09	1.00	0.89	0.78	0.63	0.45	

Article 73. Inspection by Corona Conditions

For voltage of 110kV and above, conductors must be checked by corona conditions, air average temperature and air density dependent on elevation above sea water. Maximum electric-field intensity (E) on the external surface of the conductors must not exceed $0.9E_0$ (E_0 means electric-field intensity at which corona starts on conductor).

$$E_0 = 17 \text{ to } 21\text{kV/cm}.$$

Actual electric-field intensity is calculated at below formula:

$$E = \frac{0{,}354.U}{n.r.\lg\frac{D_{tb}}{r_{td}}}\left[1 + 2\frac{r.\sin\frac{180^o}{n}}{a}(n-1)\right] , \quad \left[\frac{kV_{\max}}{cm}\right]$$

Where,

- U: nominal voltage,kV
- n: number of split-phase conductor, in case of no phase split n =1
- a: distance between split-phase conductor, cm

- r: radius of each conductor, cm
- D_{tb}: mean geometric distance between phases
- r_{td}: equivalent radius, at below formula:

$$r_{td} = R\sqrt[n]{\frac{n.r}{R}} \text{ [cm] , where } R = \frac{a}{2\sin\frac{180}{n}} \text{ [cm]}$$

For the voltage of 110kV, minimum cross section to limit corona generation is 70mm^2, and for the voltage of 220kV, the said cross section is 240mm^2.

For the voltage of 220kV and above, split in 2 or 4 smaller conductors can be applied to limit corona.

Wireless communication interference by corona must be checked too.

Article 74. The Selection of Lightning Conductor

As stipulated in Technical Regulation.

In selection of lightning conductor, thermal stability conditions when short circuit of one phase occurs must be checked according to guidelines given in Annex II.2.3 (I.3C).

Chapter 2-2-2 The Selection of Electrical Equipment by Short Circuit Conditions

Article 75. General provisions

As stipulated in Technical Regulation.

Article 76. Short Circuit Currents calculation scheme

It must calculate short circuit currents for power generation and transmission development diagram at least for the period 10 years after putting equipment into operation (approximate calculation).

The following short circuit cases shall be considered:

1. Three phase short circuit for checking electrodynamic stability of equipment, busbars, conductors and support structures.
2. Three phase short circuit for checking thermal stability of equipment, busbars and conductors. At generator voltage, selecting whichever causing higher heating from 3 phase or 2 phase short circuit currents for checking.
3. Three phase or one phase earth fault short circuit current, whichever bigger will be chosen for checking short circuit current breaking capacity of equipment. If circuit breaker has both 3-phase and one -phase current breaking values, both short circuit currents must be chosen.

Article 77. Calculate the Time for Thermal Stability

When checking thermal stability, the calculation time is assumed to be equal to the total time required for the trip of the main protective relay and circuit breaker nearest to short circuit point and breaking time of circuit breaker itself including arcing time.

If the main protector has dead zone (by current, voltage, resistance etc.) the thermal stability shall be checked according to protector's trip time when short circuit happens in the dead zone plus total trip time of the circuit breaker.

Article 78. Increasing Temperature in Fast Self-Reclosing Devices

When checking the thermal stability of equipment and power line conductors with fast self-reclosing devices, the increase in temperature due to the increase in total short circuit time must be taken into account. When checking heating according to short circuit conditions, the conductors of one phase will be considered as one conductor with cross sectional area equal to total cross sectional area of all conductors in this phase.

Article 79. Short Circuit Currents

Equipment and conductor of circuit shall be selected according to maximum short-circuit current passing through.

They shall withstand the maximum short-circuit current for 2 seconds.

The short-circuit current is maximized when the maximum number of generators are connected with the power network and three-phase short-circuit fault happens

Article 80. Checking Items for Short Circuits

As stipulated in Technical Regulation.

Article 81. Electromotive Forces

Busbar, conductor, insulator and rigid support structure must withstand the electromotive force which generates in the maximum short-circuit current.

Electromotive force acting on soft conductors, insulators, terminals and conductor harness is calculated according to average square value of short circuit currents of two adjacent phases. For conductors in one phase and soft conductor harness, the acting force of short-circuit current in conductors in one phase is determined with respect to effective value of three-phase short-circuit current.

Mechanical force of short-circuit current acts on busbar to support insulator and wall trance insulator must not exceed 60% of minimum destructive force of insulator if insulator is single, and not exceed 100% of destructive force if insulator is double.

If conductors consist of several flat or U-shaped bars, the mechanical stress is equal to total stress generated by reciprocal forces between phases and elements of each bar.

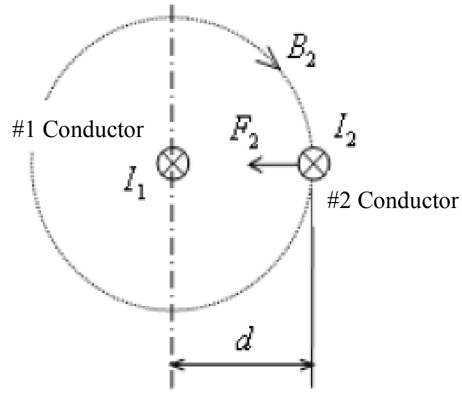
The maximum mechanical stress of materials of rigid conducting bars must not exceed 70% of instantaneous destructive force.

The detail of calculation example is as follows.

The supporting insulators which support busbars and connected conductors, and these conductors shall bear the short-circuit electromagnetic force.

The strength calculation sample of aluminum pipe bus in consideration of the short-circuit electromagnetic force is shown below.

(1) The short-circuit electromagnetic force between two conductors



The calculation formula of magnetic flux density (B_2) of the #2 conductor that arise from the current (I_1) of the #1 conductor is shown below.

$$B_2 = \frac{\mu_0 I_1}{2\pi \cdot d} \quad (Wb/m^2 \equiv T)$$

The calculation formula of the electromagnetic force of the #2 conductor is shown below.

$$F_2 = I_2 B_2 = \frac{\mu_0 I_1 I_2}{2\pi \cdot d} \quad \text{(N/m)}$$

$$\left[F = 2.04 \times \frac{I_1 I_2}{d} \times 10^{-8} (kg/m) \right]$$

Where

- μ_0: Magnetic permeability ($4\pi * 10^{-7}$ H/m)
- I_1, I_2: Current (A)
- d: Clearance between two conductors (m)

Figure 81-1 Electromagnetic force between conductors

(2) The strength calculation sample of aluminum pipe bus

[Calculation condition]

- Short-circuit current: 20kA
- Clearance between poles: 1.6m
- Clearance between supported point: 4m
- Bus length: 8m

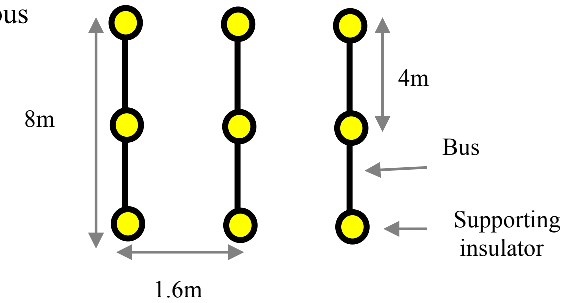


Figure 81-2 Bus arrangement

- Calculation formula of electromagnetic force

$$F = \frac{\sqrt{3}}{2} * \frac{2.04 * Is^2 * K}{d * 10^8}$$

Where

- $\sqrt{3}/2$: Coefficient of horizontal bus arrangement
- I_s : Short-circuit current (A)
- K : Stress factor (3 to 4)
- d : Clearance between two conductors (m)

The strength calculation under the above condition is shown below.

- The short-circuit electromagnetic force of bus $F_1 = \dfrac{0.866 * 2.04 * 20000^2 * 4}{1.6 * 10^8}$

$= 17.6kg/m$

- The short-circuit electromagnetic force of a supporting insulator $F_2 = \dfrac{17.6kg/m * 8m}{3}$

$= 46.9kg$

Article 82. Permissible Values for Heated Conductors

The temperature of a heated conductor when a short circuit occurs must not exceed permissible values given in the following table.

Table 82 Highest permissible temperature

Electricity conductor types and materials	Highest permissible temperature [°C]
Conducting bars: - Copper - Aluminum	 300 200
Copper or aluminum core cables, oil impregnated paper insulation, voltage up to 10kV	200
Copper or aluminum core cables, oil impregnated paper insulation, voltage up to 22-220kV	125
Cable with PVC sheath: - Cross sectional area up to 300mm^2 - Cross sectional area > 300mm^2	 160 140
Copper or aluminum core cables with rubber insulation	150
Copper or aluminum core cables with XLPE or EPR insulation	250
Bare copper conductor with pulling force up to 20 N/mm^2	250
Bare copper conductor with pulling force of 20 N/mm^2 and above	200
Bare aluminum conductor with pulling force up to 10 N/mm^2	200
Bare aluminum conductor with pulling force of 10 N/mm^2 and above	160
Aluminum part of steel cored aluminum conductor	200

Article 83. The Selection of Circuit Breakers

To select circuit breaker, it is necessary following requirements:

1. By breaking capacity: calculated breaking current is overall active short-circuit current (including acyclic elements) which is determined with tripping contact time of circuit breaker equals to total individual breaking time of the circuit breaker (from sending command on breaking to releasing the contact for arc elimination) plus the time for extinguishment of the arc.
2. By closing capacity: at that time, the circuit breaker of the transformer installing at the side of transformer voltage needs to be checked in case of asynchronous energization in phase opposition state.

Apart from being selected according to breaking capacity, circuit breaker shall also be selected based on transient recovery voltage (TRV) after short circuiting. The TRV capacity of a circuit breaker must exceed the calculated capacity in each location of circuit breaker in the network. This criterion needs to be specially paid attention for 500kV and 220kV circuit breakers at the terminals of long power lines, generator circuit breakers and circuit breakers placed near to reactor coils.

Article 84. The Selection of Fuses

In selection of fuses, thermal stability for the maximum short-circuit current passing through shall be considered.

In a large current range, current limiting fuses can break immediately and prevent to flow large short-circuit current. In selection of fuses, the characteristics in the following table shall be considered. Not to break with inrush current of transformer or condenser and starting current of motor, appropriate fuse shall be chosen.

NOTE: With regard to fuses, there are some types such as for transformer, for condenser, for motor, etc.

Table 84 Breaking characteristics of fuses

Types of fuse	Over-current characteristic in repeated condition
For transformer	Not to break by flowing 10 times of rated current for 0.1 second repeated 10 times
For condenser	Not to break by flowing 70 times of rated current for 0.002 second repeated 100 times
For motor	Not to break by flowing 5 times of rated current for 10 seconds repeated 10,000 times

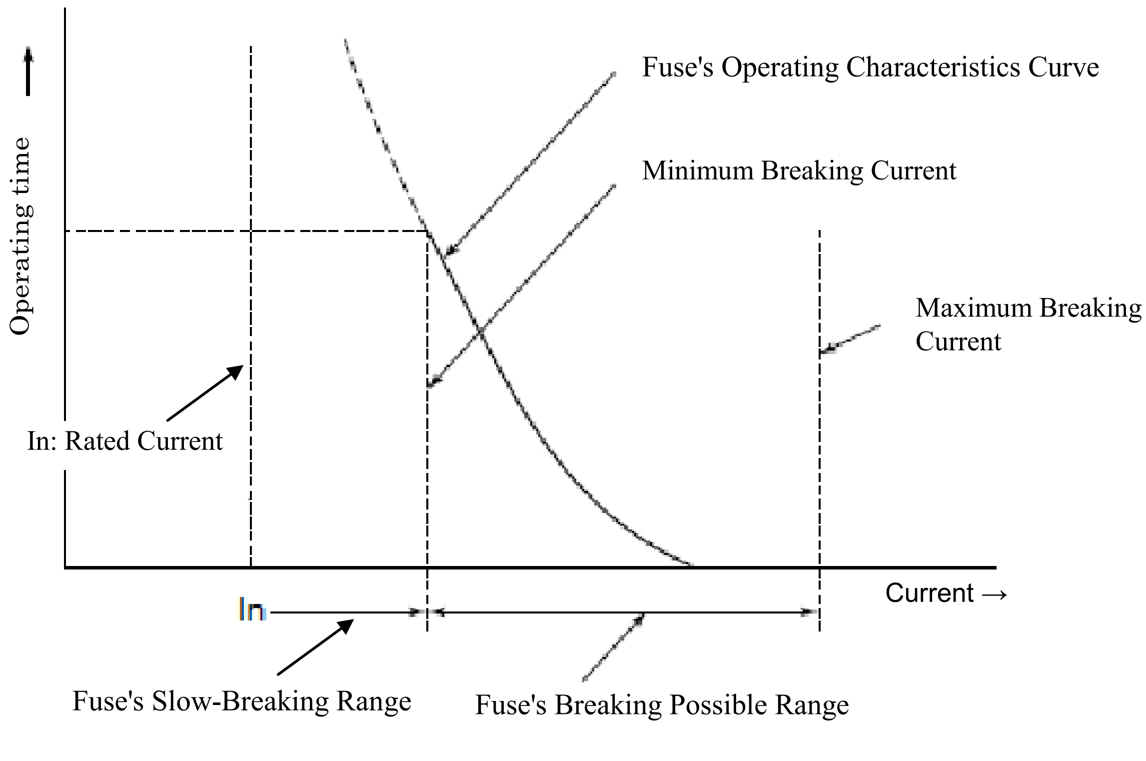


Figure 84 Breaking performance of fuses

Chapter 2-3 Transmission and Distribution Lines

Chapter 2-3-1 House and Outside Wiring Systems with Voltage up to 35kV

Article 85. Cross-Sectional Areas

- Cross-sectional areas of earthing conductors and neutral earthing conductors shall comply with requirements in Part6 in Technical RegulationVol.1 and this Guideline.
- Cross section of wires and cables gut of the electrical path indoors and outdoors in the following table.

Table 85 Minimum cross-sectional area for house and outside wirings

Type of conductor or cable	Minimum cross-sectional area (mm^2)	
	Copper	Aluminum
Soft conductor for connecting electrical household appliance	0.35	-
Cable for connecting electrical mobile and movable equipment used in industries	0.75	-
Twisted-pair conductor, multi-stranded core fixed on pulleys	1.00	-
Insulated conductor without sheath used for fixed house wiring inside building:		
• Directly placed on the floor, pulleys, wire clamps and suspending wire	1.00	2.50
• Placed in trough, box (except solid box)		
+ For core with threaded connection	1.00	2.00
+ For core with welded connection:		
- One core conductor	0.50	-
- Multi-stranded conductor (soft)	0.35	-
• Placed on insulator	1.50	4.00
Non-sheathed insulated conductors of outside wirings:		
• Placed on the wall, insulated structures or insulators on electric poles and entering from overhead power line	2.50	4.00
• Placed on pulleys under roof overhang	1.50	2.50

Article 86. Installation of Conductors and Cables

Conditions for insulated conductors and cables in pipes etc. that belong to constructions is shown as below.

1. Permissible conditions of shared installation for insulated conductors and cables in steel and other material pipes, hoses, boxes, trough and closed canals which belong to construction structures of the building (exceptional cases when they are standby for each other).
   (1) All circuits of one unit.
   (2) The motive and control circuits of some machines, cubicles, boards, control panels, etc. are related to each other in terms of technology process.

(3) Complicated lighting circuits.

(4) Operative lighting or emergency lighting circuits of the same type of some groups and total number of conductors in one pipe not more than 8.

(5) Lighting circuits with voltage up to 42V, and lighting circuit with voltage exceeding 42V to 1,000V that the conductors of the circuits up to 42V are separately installed in insulated conduits.

2. Conditions for replacement

Insulated conductors and cables which are installed in pipes, boxes, metal hoses and closed canals must be replaceable.

3. Conditions for lighting circuits etc. and spare circuits

(1) Operative lighting and emergency lighting circuits, circuit with voltage up to 42V and circuits with voltage exceeding 42V to 1000V (except the cases mentioned above 1-(5)) are prohibited to be installed together with spare circuits in the same pipe, hose, box, closed canal of construction structure or trough. These circuits are permissible to be installed in different compartments of a box or trough with closed walls which are separated along the whole length of box, etc. and are made of non-flammable materials or materials has flame withstanding ability not less than 0.25 hours.

(2) It is permitted to install operative lighting and emergency lighting circuits on different external sides of metal bars (U shaped channel bar), angle bar, etc. respectively.

4. Conditions in productive and electrical halls

(1) Insulated conductors or cables in productive and electrical halls shall have sheaths which are made of non-flammable or flame resistance materials.

(2) Insulated conductors and cables without sheaths in productive and electrical halls shall be installed on insulators which are made of non-flammable or flame-resistant materials.

5. Conditions for power and neutral conductors with AC or rectified current

(1) Power and neutral conductors with AC or rectified current shall be installed together either in a steel pipe or an insulated pipe with steel sheath.

(2) Power and neutral conductors with rated current up to 25Aare permitted to be installed in separated steel pipe or insulated pipe with steel sheath respectively.

6. Conditions for structural elements

The structural elements for installing conductors and cables in building, works, closed canals and closed space shall be made of non-flammable materials.

7. Conditions for distance from conductors to pipe or technical equipment

The distance from conductors without protective covers (IP00) to pipes shall be not less than 1m and the distance from the conductors to technical equipment shall not be less than 1.5m. The distance from busbars with protective covers (IP21, 31, 65) to pipes or technical equipment is not specified.

Article 87. Provisional Length of Conductors and Cables

The provisional length of insulated conductors and cables shall be long enough for connection works and their arrangement.

Article 88. Installation of Connections and Branches

Connections and branches of insulated conductors and cables of house and outside wirings shall be installed as below.

1. Connections and branches shall be pressured, welded and clamped in compliance with existing instructions.
2. Connection and branch points shall not be stressed by tension of insulated conductors and cables.
3. Connection and branch points shall have the equivalent insulation to the other parts of the insulated conductors or cables.
4. Connections and branches should be arranged in connection boxes, branch boxes, insulated enclosures of clamps, special compartments of construction structures and enclosures of electrical equipment.

Article 89. Construction and Material of Connections, Branch Boxes and Clamp Connectors

Connection and branch boxes, clamps shall be used in compliance with the instructions.

Article 90. Protection against Corrosion of House and Outside Wirings

Metal parts of house and outside wirings shall be painted or galvanized so that corrosion by chemical materials (salt, etc.) from surrounding decelerates.

Corrosion protection shall comply with Article 57 of Vol.1 in Guideline.

Article 91. Crossing with Thermal Expansion Slots and Fracture Slots

Insulated conductors and cables shall be arranged to avoid the shift of the tension and the position by their heat extension.

Article 92. Protection against Chemical Substances

1. Places with air containing active chemical substances means places with air containing powder dust (magnesium, aluminum, iron, flour, man-made fabric, etc.) or flammable gas (propane, acetylene, ethanol, methanol, etc.), etc.
2. Measures to protect from active chemical substances

(1) Insulated conductors shall be installed in steel pipes or cables with metal sheath shall be installed.

(2) Anti-friction, anti-corrosion and anti-pressure packing shall be used at connection point of pipes or boxes so that active chemical substances can not intrude in pipes, etc..

(3) Pipes or boxes shall be connected without a gap by parallel screws with screw head of 5 and more or lock nuts.

Article 93. Calculation and Selection Condition of Conductors

Conductors, insulation, accessories, structures and instruments of house and outside wirings shall have mechanical strength, dielectric strength, dimensions (cross-sectional area, size of accessories, etc.) and materials which can withstand voltage, current, mechanical force, weight, and temperature calculated in the normal working conditions and in short circuit conditions.

Article 94. Symbols and Paint

Painted colors to distinguish phases of house and outside wirings shall comply with the requirements in article 25 of Vol.1 in Technical Regulation.

Article 95. Method for Preventing Conductor Proximity at Short Circuits

Conductors and insulators at bearing point shall have mechanical strength which can withstand electromagnetic force by short circuit current.
Short circuit current shall be calculated in accordance with requirements in Chapter 2-2-2.

Article 96. Earthing Live Parts

1. Requirement for earthing measure
   Fixed or movable blades of disconnectors and grounding rods shall be installed in accordance with requirements of article 146 in Technical RegulationVol.1 and this Guideline.

   They shall be arranged at both terminals of house and outside wirings as well as intermediate points.
2. Requirements for induced voltage
   The number of mobile ground placement shall be determined so that induced voltage does not exceed 250V when short circuit happens at adjacent wirings

Article 97. Mechanical Load and Temperature Requirements

Mechanical safety factors for conductors, insulators and accessories shall be complied with article 324 to 328 in Technical RegulationVol.1.
Mechanical safety factors are shown in the following table as reference.

Table 97 (Reference) Mechanical safety factor

Items	Mechanical safety factor
Flexible conductor	3
Rigid conductor	Calculated according to article 81 in Technical RegulationVol.1 and this Guideline
Suspension insulator	4
Accessories for bridging flexible conductor	3

Article 98. Combination and Configuration for Installation and Maintenance

Combinations and configurations of house and outside wirings shall be designed in accordance with the following items.

- Locations of the wirings shall be arranged with numbering, hanging labels or paint not to be misunderstood by workers for installation and maintenance. If a large number of wirings are installed and the worker might misunderstand the location, signs for helping workers' recognition shall be added.

- Wirings shall be arranged properly so that the installation and maintenance works can be conducted smoothly and safely.
- If a number of wirings are in a location, conditions for current capacity of the wirings shall be confirmed not to exceed allowable conditions.

Article 99. Protection against Lightning

1. Lightning conductor

Requirements for lightning conductors are in Chapter 3-3-1 of Vol.1 in Technical Regulation and this Guideline.

2. Arrester

Arresters shall be installed at the following locations.

- The connection of cables to overhead power lines
- The connector at the position to receive the power
- Inlet branches for power user with receiving capacity of 500kW

Arresters shall be attached to earthing system satisfies the stipulations in Part 6 of Vol.1 in Technical Regulation and this Guideline.

Article 100. Reduction of Electricity Loss

For house and outside wirings with symmetrical load current of 2.5kA and more, they shall satisfy the requirements in this article in Technical Regulation Vol.1 and take measures (e.g. multiple conductor in a phase or phase transposition, etc.) to reduce the impedance of the wirings.

Phase transposition is recommended to be applied to extended soft house and outside wirings. The number of phase transposition shall be determined by the calculation depending on the length of the wirings.

For house and outside wirings with unsymmetrical load current, measures calculated by particular case for reducing electricity loss shall apply.

Article 101. Eliminating Dangerous Stress

1. Countermeasure against temperature change
   - Conductors shall be limited to be risen the temperature of them by ventilation or thermal insulation.
   - Current in the electric conductors must be limited not to exceed the permissible temperature of them in consideration of the expected temperature increase.
   - Rigid conductors shall be equipped with compensators at the places of thermal expansion and settling joints of buildings or structures.
2. Countermeasure against explosion
   - Conductors shall be installed in pipes which can withstand the explosion.

- All the facilities of house and outside wirings shall be closely installed not to ignite in explosive room

3. Countermeasure against vibration from transformer
   - House and outside wirings shall be installed on the material to weaken the vibration or suspended in the air.
4. Measures against subsidence of the foundation
   - Conductors shall have surplus length for absorbing their movement due to building sinking

Article 102. Connection of House and Outside Wirings

Connection of conductors shall comply with the following requirements.

- Tensile strength of conductors at connection point shall be secured not to be less than tensile strength at line parts of conductors. (except parts at where large tension is not applied such as jumper parts.)
- Pressured connection sleeves shall be used at the connection point, or connection of conductor shall be welded.
- Additionally, insulation of insulated conductors or cables at connection point shall be ensured not to be less than insulation at line parts by using connection boxes or winding insulation tapes.

Article 103. Cross-Sectional Area for Permanent Permissible Current

Cross-sectional area of conductors of house and outside wirings shall be determined based on the requirements in Chapter 2-2-1 of Vol.1 in Technical Regulation and this Guideline.

Chapter 2-3-2 Power Cable Line Systems with voltage up to 220kV

Article 104. Design and Construction Requirements

All the requirements for power cable lines in this Guideline shall be complied in consideration of policy in this article in Technical Regulation.

Article 105. Cable Route Selection

The route of power cable lines shall be selected in consideration of limitation for roads and fire-fighting as well as social environment of the route and be avoided the following places as much as possible.

- Narrow roads where the traffic of cars and people is expected to be blocked during the construction works.
- Places near hospitals or schools, where serious problems are easily caused by noise and vibration of the cable works.
- Places near gas stations or storage of explosive materials.
- Places with corrosive gas or waste drainage
- Approaches of shrines or temples
- Shopping streets where a large number of people pass by.

In the area with harmful substances (e.g. soil with salt, mud, ash) to steel, the construction machines or electro-chemical corrosion, cables shall be used which are with aluminum sheath and plastic protective covers.

Article 106. Requirements in the Installation and Operation Process

Refer to the requirements in Chapter 7 in Part 6 in Technical Regulation and GuidelineVol.3 for specific procedures and methods of installation of power cable lines.

Article 107. Protective Cables

1. Requirements against corrosion

The vinyl and the polyethylene with the following characteristics are generally preferable as the material of the protective covering outer sheath to protect the cable from corrosion.

(1) High insulation and high dielectric strength are possessed and does not decrease over a long period of time.

(2) Waterproof, oil-proof, chemical resistance and flame resistance are possessed, and a chemical characteristic is stable over a long period of time.

(3) Excellent weather resistance and resistance to aging are possessed.

(4) Abnormality does not appear in temperature of the outer sheath of the cable operated generally (About -10°C to 70°C).

(5) Mechanically strong, excellent flexuous and abrasion resistance are possessed, and friction coefficient is not large.

(6) Manufacturers can process easily.

Table 107 Characteristic of protective covering outer sheath

Item	Material of protective covering outer sheath	
	Vinyl	Polyethylene
Anti-damage	G	G
Anti-friction	G	G
Heat resistance	G	G
Cold resistance	G	VG
Anti-weatherability	G	G
Anti-ozone	VG	G
Anti-aging	G	G
Flame resistance	VG	P
Anti-chemical	G	VG
Waterproof	G	VG
Anti-fungus	VG	G
Anti-radial ray	G	G

Note:VG:Very good, G:Good, P:Poor

2. Requirements against sunlight

   As for the parts of power cable lines exposed directly to sunshine, the cables are preferable to be installed in pipes or trough for avoiding aging of protective covering outer sheath and rising temperature of the parts.

3. Requirements against heat source

   When power cable lines go nearby the heat resources and they are heated by the heat resources, the permissible current of power cable liens is limited. Therefore, power cable lines are preferable to be installed far away from the heat resources.

   If power cable lines cross or go nearby heat pipelines, requirements in article 214 of Vol.1 in Technical Regulation and this Guideline shall be complied.

4. Requirements against explosion
   - Cables shall be installed in pipes which can withstand the explosion.
   - All facilities of power cable lines shall be closed not to ignite in an explosive room

5. Requirements against flame

   Power cable lines installed in cable tunnels shall have the measures for protecting the flame.

   - To Use cables with protective covering outer sheath made of non-flammable or flame resistance materials.
   - To cover cables by tapes or paint made of non-flammable or flame resistance materials.
   - To install cables in pipes or trough made of non-flammable or flame resistance materials.

Article 108. Factors in Calculations for Underground Cables

Buried pipes which power cable lines are installed shall be 3 times stronger than the withstand loads shown in the following formula.

$W=W_1+W_2+W_3+W_4$

W : Distributed load applied to buried pipes (kN/m^2)

W_1: Pressure of the earth (kN/m^2)

W_2:Vehicle load passes on ground surface (kN/m^2)

W_3: Enhanced pressure of earth after earth retaining walls for the excavation work are removed (kN/m^2)

W_4: Distributed weight of buried pipes and cables (kN/m^2)

Article 109. Cable Placement Requirements

Cable structures as well as cables shall be made of non-flammable materials. (Refer to article 107 in this Guideline)

Even if temporary cable structures are used only in a short period of time, they shall satisfy all the requirements in Technical Regulation and Guideline.

Article 110. Bended Cable

Bending radius of cables shall be more than permissible bending radius shown in the following table.

Table 110　　Permissible bending radius

Kind of cable			Permissible bending radius (m)
Oil-filled cable	Aluminum sheath	Single core	15×(Cable radius)
		Triple cores	12×(Average twisted radius)
XLPE cable	No metallic sheath	Single core	10×(Cable radius)
		Triple cores	8×(Average twisted radius)
	Aluminum sheath	Single core	15×(Cable radius)
	Stainless sheath	Single core	17.5×(Cable radius)

Remark: Permissible bending radius specified by the manufacture can apply.

Article 111.　Cable Tension

Cable tension shall not be exceeded permissible tension as below.

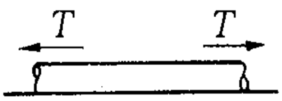
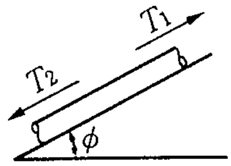
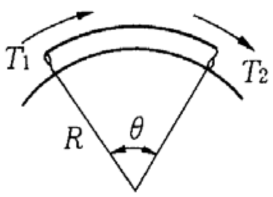
- Cables with copper core: 68.6*N*A (N)
- Cables with aluminum core: 39.2*N*A (N)

N : Number of cores of cable

A : Cross sectional area of cable (mm^2)

As reference, calculation formulae of cable tension are shown in the following table.

Table 111　　(Reference) Calculation formulae of cable tension

Installation	Figure of installation	Calculation formula
Straight and flat section		$T = \mu WL$ T : Cable tension μ : Friction coefficient W : Weight of cable a meter L : Length of cable
Straight and incline or decline section		(1) In case of incline $T_1 = WL(\mu\cos\phi + \sin\phi)$ ϕ : Angle of inclination Other symbols means the same as above (2) In case of decline $T_2 = WL(\mu\cos\phi - \sin\phi)$ ϕ : Angle of declination Other symbols means the same as above
Curve and flat section		Bigger tension in two formulae is adopted $T_2 = WR\sinh\left(\mu\theta + \sinh^{-1}\frac{T_1}{WR}\right)$ $T_2 = T_1\cosh(\mu\theta) + \sqrt{T_1^2 + (WR)^2}\sinh(\mu\theta)$ R : Curvature radius θ : Horizontal angle Other symbols means the same as above

Article 112. Nameplate

Nameplate (sign) shall comply with the requirements in article 479 to 482 in GuidelineVol.4.

Article 113. Routes of Cable Underground or Underwater

Measurement for mapping the route of power cable lines shall be conducted as below.

- Measurement is conducted along the center axis of the route
- The scope of measurement includes buildings and structures, etc. within 10m from both side edges of the road.
- 1 Altitudes of main measurement points such as inflection point of the road are measured from existing benchmarks or special landmarks precisely.
- Auxiliary measurement points are set at the interval of 20m.

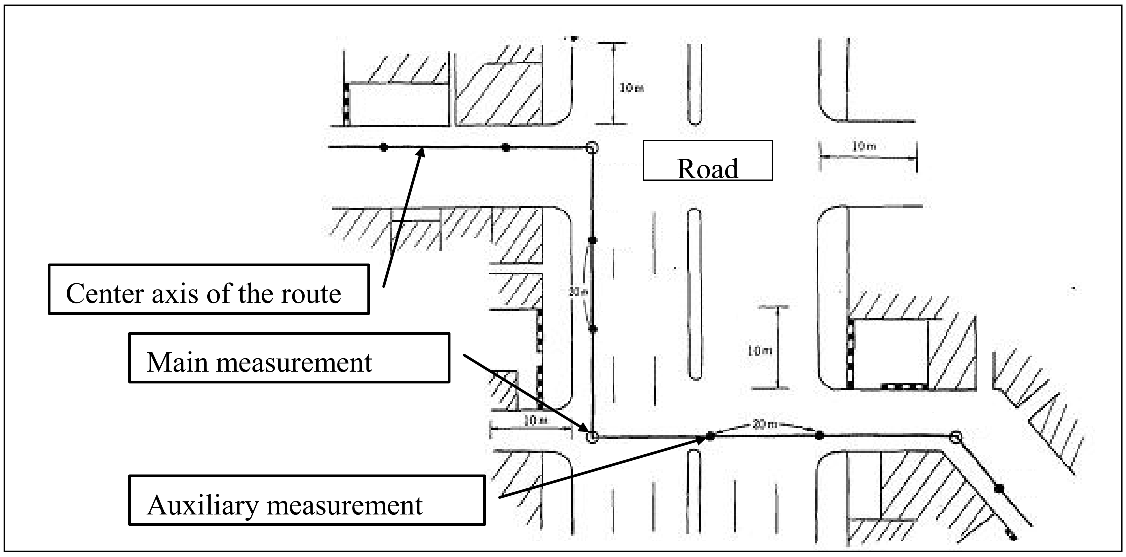


Figure 113 (Sample) Map of the route

Article 114. Arrangement Pattern

1. Arrangement for power cable lines with voltage up to 35kV
- The number of cables in cable canal shall be up to 6.
- In case that the number of cables is more than 6, power cable lines shall be arranged in cable tunnels, cable bridge, cable trench, corridors or separated cable canals spaced not less than 0.5m.
- In case that many cables are gathered at intersection with railways or roads, the power cable lines shall be arranged in cable blocks in order to avoid breaking sheathes each other.

2. Arrangement in power station
- Power cable lines shall be arranged in cable tunnels, blocks, trough, bridges or corridors.
- Six or less power cable lines for auxiliary structures which are far from power plant (e.g. fuel depot, workshop) are permitted to be arranged in cable canals.

- Power cable lines in the area of power station with capacity up to 25MW are permitted to be arranged in cable canals.

3. Arrangement in industrial enterprise
   Power cable lines in the area of industrial enterprise shall be installed in underground cable canals, tunnels, blocks, troughs, bridges, corridors or on walls of buildings.
4. Arrangement in substation or distribution station
   Power cable lines in the area of substation or distribution station shall be arranged in cable tunnels, canals, bridges, corridors, troughs or tubes.
5. Arrangement in urban or rural area
   Power cable lines using single-strand cables in urban or rural areas shall be arranged in underground cable canals under pavements, near right-of-ways or parks expect roads with vehicle traffic.
6. Arrangement under street or square
   Power cable lines with 10 and more cables under streets or squares with utilizable underground structures shall be arranged in cable tunnels or blocks. Power cable lines at intersection with heavy traffic on the streets or squares shall be arranged in cable blocks or tubes, and surface of the intersection shall be completely paved.
7. Arrangement in building
   Power cable lines in buildings shall be permitted to arrange directly and openly or in boxes or tubes in accordance with the structures, as well as in cable tunnels, troughs, pipes, under compartments and cable storey, and under floor and foundation of equipment.
8. Arrangement for oil-filled cable
   Oil-filled cables shall be arranged in cable tunnels, corridors and underground cable canals and the arrangement method shall be specified by the design.

Chapter 2-3-3 Overhead Power Line Systems with voltage up to 500kV

Article 115. Consideration Requirements and Conditions

To take into consideration the most stringent requirements means to select the largest cross-sectional area or the highest height of conductors, etc.

To take into consideration the least favorable condition means to select the largest load or the nearest situation, etc.

Article 116. Calculation Method

Calculation method shall comply with the contents in this article in Technical RegulationVol.1.

Article 117. Installation Condition for Poles

The location of poles shall be selected to where poles do not obstruct pedestrian, traffic, and where poles do not collided by vehicles.

Article 118. Protection and Signal against Vehicles

Concrete walls or crash barriers shall be installed around poles which might be collided by vehicles.

Additionally, signs or fences shall be installed by such poles, for drivers of vehicles can recognize the poles easily.

Article 119. Transposition

The transposition shall be implemented so that the length of one phase in each step of transposition cycle is identical as much as possible.

Overhead power lines with voltage from 110kV to 500kV and with the length of 100km and more shall have transposition.

Overhead power lines with voltage from 110kV to 500kV and with many sections less than 100km long are permitted to have transposition at substations (at busbars in a substation, in the span between the edge of the lines and the gantry in a substation).

Overhead power lines with two circuits with the same voltage on the same pole shall have transposition equally.

Article 120. Access for management and maintenance

1. Road to access overhead power lines for management and maintenance:
   For overhead power lines with voltage of 500kV, the width of access roads shall not be less than 2.5m, and the location shall be within 1 km from the route of the lines.

   Overhead power lines voltage from 110 to 220kV must have a way to be as close a route of the power lines and pole.
2. Operation management station
   Operation management station is constructed as below.
   - The location is in the area where many overhead power lines are converged and the transportation is convenient.
   - The architecture is simple and compact. (It is preferable to utilize existing architecture.)
   - Communication lines are connected to regional power network and repairing units of the lines.

   The station should be designed based on the requirements of power management agencies, the scale of overhead power lines and existing regulations.

Article 121. Installation of Poles near Areas with Water

Possibility of erosion shall be carefully investigated in riparian land, lake side, hill, basalt areas, and especially primary forest.

Possibility of erosion shall be less than the values shown in the following table.

If above-mentioned data are not available, the highest level of historical flood shall be applied. In this case, poles shall have measures for protecting from flood. (special foundation, dyke, embankment, drainage trench, additional pole, etc.)

Furthermore, poles arranged at the following areas shall have above-mentioned measures for preventing the flood.

- The area where often struck by flood.

- The slopes of hills or mountains where possibly eroded by flood

Table 121 Erosion possibility

Voltage (kV)	Erosion possibility
Exceeding 1 to 35	5% and less (Once in 20 years)
110 and 220	2% and less (Once in 50 years)
500	1% and less (Once in 100 years)

Article 122. Pole Signs

Pole signs shall be installed before the operation of overhead power lines start

Arrangement of pole signs shall be at the approximate height from 2.0 to 2.5m and at the position to be seen easily.

For the pole of overhead power lines with many circuits, they must have clear signs with stating pole number and the name of each circuit.

Figure 122 Pole sign

Article 123. Protection against Corrosion of Poles

Metal parts of poles shall be galvanized with zinc or painted by anti-corrosion paint for protecting corrosion. (Zinc galvanization is the most effective protection method against corrosion.)

Corrosion protection shall comply with Article 57.

Article 124. Warning Signs and Signal Lamps

Warning signs (Painted sign) and signal lamps are shown in the following figure as reference.

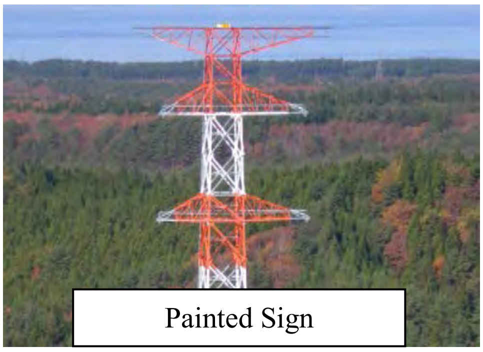


Figure 124 Painted signs and signal lamps

Article 125. Fault Locating Equipment

It should install fault locating equipment for overhead power lines with voltage 110kV and more according to importance and traversing route of the lines, if necessary.

Summary of fault locating equipment is shown in the following table.

Table 125 Fault locating equipment

Type	Principle
Pulse radar (Type-C)	High-frequency impulse is sent to overhead power lines after seizing signal from relay. Fault location is rated by measured period of time from the start of impulse to the return to fault point.
Impedance calculation (Type-Z)	Fault location is rated by measured voltage and current values at an edge of overhead power line and calculated impedance of the section from the edge to fault point.

Article 126. The Selection of Alternative Routes

The areas with disadvantageous surrounding conditions means the areas with strong wind, land collapse, swamps, stone rolling, etc., and the areas where need to be considered in the design particularly.

When overhead power lines traverse the above areas, the route of them must be considered to avoid going through in the areas, to calculate and to compare economic efficiency and technical assurance to determine choosing the route

Article 127. Determination of Climate Conditions

Combinations of temperature and wind pressure in calculations of overhead power lines with voltage up to 1kV shall be taken into account the combinations in the following table.

Besides, the natural conditions mean the conditions of bumpy topography, altitude, large lake side, wind directions, etc.

Table 127 Combination of temperature and wind pressure

Number	Temperature	Wind pressure
1	Maximum T_{max}	q=0 (No wind)
2	Minimum T_{min}	q=0 (No wind)
3	Average of annual T_{tb}	q=0 (No wind)
4	25°C	Maximum q_{max}

Article 128. Calculation and Consideration of Wind

1. Wind pressure

Standard wind pressure, wind pressures by region and factors increasing or reducing wind pressure for overhead power lines with voltage exceeding 1kV shall be adopted the values in TCVN-2735-1995. However, standard wind pressure of the lines with voltage of 110kV and more shall not be less than $600N/m^2$.

Assumed time of use shall be adopted the values in the following table.

Table 128-1 Assumption time of use

Voltage (kV)	Assumed time of use (year)
Exceeding 1 to 35	15
110	20
220	30
500	40

2. Standard wind pressure

Standard wind pressure applied to conductors and lightning conductors of overhead power lines with voltage exceeding 1kV shall be calculated by the following formula.

$$P = a \times C_x \times K_1 \times q \times F \times \sin^2 \varphi$$

P : Standard wind pressure (N)

a : Coefficient for unequal wind pressure in the span (Refer to Table 128-2)

Table 128-2 Coefficient for unequal wind pressure

Wind Pressure (N/m^2)	Coefficient for unequal wind pressure*
270	1.00
400	0.85
550	0.75
760 and more	0.70

*Note: Intermediary values are interpolated.

C_x : Aerodynamic coefficient

- 1.1: The diameter of conductors or lightning conductors is 20mm and more.

- 1.2: The diameter of conductors or lightning conductors is less than 20mm.

K_1 : Conversion factor in consideration of impact of span on wind pressure (Refer to Table 128-3)

Table 128-3 Conversion factor in consideration of impact of span on wind pressure

Span-length (m)	Conversion factor*
Up to 50	1.20
100	1.10
150	1.05
200 and more	1.00

*Note: Intermediary values are interpolated.

q: Standard wind pressure by regions specified in TCVN-2737-1995 (This coefficient is calculated to the provisions of above-mentioned standard wind pressure of item 1 in this article.)

F: Area of conductor or lightning conductor interrupting wind (m^2)

φ: Angle between wind direction and the axis of the route of the lines

3. Special requirements of standard wind pressure

Standard wind pressure of overhead power lines with voltage exceeding 1kV to 22kV on conductors lower than 12m high is permitted to be reduced 15%, except the case that factors reduce wind pressure in the area where the wind are interrupted have already be applied.

Maximum standard wind pressure of overhead power lines which traverse at the following places with strong wind in the mountains shall follow the current standards, if observed data are not available.

- The places higher than the surrounding area (peaks, passes, etc.)

-Valleys and canyons

4. Wind pressure at the converted height of conductors and lightning conductors

(1) Conductors at normal span

Wind pressure acting on conductors shall be determined at the height converted to gravity point of all conductors. The converted height is calculated by the following formula.

$$h_{qd} = h_{tb} - \frac{2}{3} f$$

h_{qd} : The height converted to gravity point of all conductors (m)

h_{tb} : The average height of conductors installed on insulators (m)

f : The maximum sag of conductors (the maximum temperature) (m)

(2) Lightning conductors at normal span

Wind pressure acting on lightning conductors shall be determined by the height of lightning conductors at the centre.

(3) Conductors and lighting conductors at large overcrossing span

Wind pressure acting on conductors and lightning conductors shall be determined by requirements of item 1 in this article and comply with the additional requirements as below in this article.

1) In the case of only one large overcrossing span, the height converted to gravity point of conductors and lightning conductors shall be calculated by the following formula.

$$h_{qd} = \frac{h_1 + h_2}{2} - \frac{2}{3} f$$

h_{qd} : The height converted to gravity point of conductors and lightning conductors at large overcrossing span (m)

h_1, h_2 : The height from ordinary water level of river, bays, etc. or ground surface to the installation point of conductors or lightning conductors (m)

f : The maximum sag of conductors (the maximum temperature) (m)

2) In the case of many large overcrossing spans, the height converted to gravity point of conductors and lightning conductors at whole large overcrossing span (between 2 anchor poles) shall be calculated by the following formula.

$$h_{qd} = \frac{h_{qd1} l_1 + h_{qd2} l_2 + \cdots + h_{qdn} l_n}{l_1 + l_2 + \cdots + l_n}$$

$h_{qd1}, h_{qd2}, \cdots h_{qdn}$: The height converted to gravity point of conductors and lightning conductors at each large overcrossing span (m)

$l_1, l_2, \cdots l_n$: Each span-length (m)

5. Wind pressure of poles

Wind pressure acting on poles shall be determined according to the height from the ground surface to poles.

Wind pressure of poles shall be which at average height of poles in each range whose length is not more than 15 m, and wind pressure in each range shall be adopted the same values.

6. Climate condition

(1) Design

Climate condition on designing overhead power lines with voltage exceeding 1kV shall be complied with the contents in Table128-4.

Table 128-4 Air temperature and wind pressure on design

Condition	Air temperature	Wind pressure
Normal condition	Maximum T_{max}	q=0 (No wind)
	Minimum T_{min}	q=0 (No wind)
	Average of annual T_{tb}	q=0 (No wind)
	25°C	Maximum q_{max}

Condition	Air temperature	Wind pressure
Fault condition	Minimum T_{min}	q=0 (No wind)
	Average of annual T_{tb}	q=0 (No wind)
	25°C	Maximum q_{max}*

*Note: Maximum wind pressure in fault condition is allowed to be adopted the values in TCVN-2737-1995.

(2) Poles

Poles shall be checked by the calculation according to the installation condition at air temperature 15°C and wind pressure q=62.5 N/m2.

(3) Distance from live parts to structures

The distance from live parts of overhead power lines with voltage exceeding 1kV to non-live parts of structures of the lines or other structures shall be checked by the calculation under climate conditions in the following table and as below.

Table 128-5 Air temperature and wind pressure on checking the distance

Voltage	Air temperature	Wind pressure
Operating Voltage	25°C	Maximum q_{max}
Atmospheric over-voltage	20°C	$q=0.1q_{max}$ (not less than 62.5N/m^2)
Internal over-voltage	20°C	$q=0.1q_{max}$ (not less than 62.5N/m^2)

The angle to vertical direction of deflecting suspension insulator strings by wind shall be calculated by the following formula.

$$\tan\gamma = \frac{KP_2}{G_d + 0.5G_c}$$

γ : Angle to vertical direction of deflecting suspension insulator strings by wind action

K : Coefficient of oscillation of conductors. The value depending on wind pressure in the following table shall be adopted.

P_2 : Wind pressure acting on conductors in consideration of horizontal force by tension in case of supporting angle (N/m^2)

G_d : Load of conductors acting on insulator strings (N)

G_c : Weight of insulator strings (N)

Table 128-6 Coefficient of oscillation of conductors K

Wind pressure (N/m^2)	Coefficient of oscillation of conductor K
400	1.00
450	0.95
550	0.90
650	0.85
800	0.80
100 and more	0.75

Chapter 2-4 Distribution Equipment up to 1kV

Article 129. The Selection of Appropriate Devices in Distribution Equipment and Substations

As stipulated in Technical Regulation.

Article 130. Instructions Provided at Each Facility

As stipulated in Technical Regulation.

Article 131. Identification of the Circuit

There are a lot of circuits which have a different use, such as a control circuit, a power circuit, AC and DC circuits, etc. in a switching board and a cubicle. And a lot of insulated cables are used in those circuits. Therefore, it is desirable to use color-coding of insulated cables (conductors) for identification of circuits according to the following table, to avoid the accident derived from the false recognition of workers.

Table 131 The color identification of conductor in circuit (IEC60204)

Use application	Color identification
Protective conductor	Green and yellow
Neutral conductor	Light Blue
AC or DC power circuit	Black
AC control circuit	Red
DC control circuit	Blue
Control circuit for interlocking	Orange

Article 132. Arrangement of Phases and Electrodes

The arrangement of phase shall comply with the Article 104 of Volume 3.

Article 133. Coating with an Anti-corrosive Layer

Corrosion protection shall comply with the Article 57.

Article 134. Grounding

The grounding shall be carried out in accordance with the regulations and guideline stated in Part 6.

Chapter 2-5 Substations above 1kV

Article 135. Electric Equipment Installation Condition

As for the minimum clearance between live parts or between live parts and earth, this clearance is shown in the Article 331 in Technical Regulation.

As for the safe clearance about arc, the following items should be taken into consideration.

- The clearance between equipment that generates arc during a breaking operation, such as disconnector, and combustibles, should retain the clearance shown in the Article 136.
- The safety clearance during a breaking operation, for circuit-breakers with an external exhaust for ionized gas of flame (for MCCB), should consider the contents of the Article 305.

Article 136. No-load disconnector switching

The minimum clearance of disconnectors between live parts or between live parts and earth is shown in the Article 331 in Technical Regulation. In addition, it should be checked that the disconnector is isolated from combustibles at a safe enough clearance, because the disconnector generates arc during operation. The minimum clearance is shown in the following table.

Table 136 Minimum clearance between the equipment which generates arc and combustibles

Nominal voltage	Minimum clearance *
7kV and less	1m and more
More than 7kV	2m and more
In case that the direction and length of arc are restricted so that there is no fear of fire and the nominal voltage is 35kV and less.	1m and more

* Note: The above clearance shall not be applied, when fireproof materials are installed between the equipment which generates arc and combustibles.

Article 137. Conditions of Kinetic Stability and Heat Stability

As for breaking capacity of circuit breakers, the rated short-circuit breaking current shows the actual performance of breaking capacity. The rated short-circuit breaking current is the highest short circuit current which the circuit breaker shall be capable of breaking under the conditions of use.

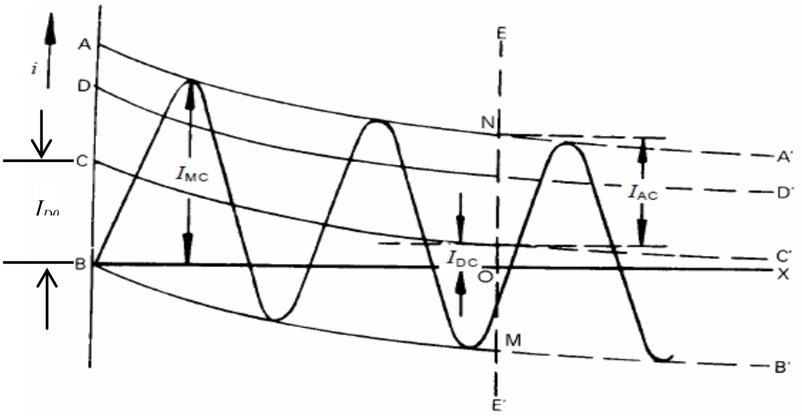
The following are the outline of the determination of the rated short circuit breaking current.

The rated short-circuit breaking current is characterized by two values: (see the figure 137-1)

- The value of its AC component (RMS)
- The DC time constant of the rated short-circuit breaking current which results in a percentage of DC component at contact separation. The percentage DC component varies with time from the

incidence of the short circuit and with the corresponding DC time constant of the rated short circuit breaking current.

Note: If the percentage of DC component at contact separation doesn't exceed 20%, the rated short-circuit breaking current is characterized only by the AC component.



AA' : Envelope of current-wave
BB' : ditto
BX : Normal zero line
CC' : Displacement of current-wave zero-line at any instant
DD' :The value (RMS; root-mean-square) of the AC component of current at any instant, measured from CC'
EE' :Instant of contact separation (initiation of the arc)
I_{MC} : Making current
I_{AC} : Peak value of AC component of current at instant EE'
I_{DC} : DC component of current at instant EE'

$\frac{I_{DC}}{I_{AC}} \times 100 = \frac{\overline{ON} - \overline{OM}}{\overline{MN}} \times 100 = \left(\frac{2 \times \overline{ON}}{\overline{MN}} - 1 \right) \times 100$: Percentage value of the DC component

$I_{DC} = I_{D0} \times \varepsilon^{\frac{-R}{L}t}$ (L/R is the time constant of the circuit)
I_{D0} : The initial value of the DC component
cos φ : Short circuit power factor (Phase Angle φ = arctan (ω L / R))

Figure 137-1 Determination of short-circuit breaking currents and of percentage D.C. component

The standard DC time constant is 45ms. The following are special case DC time constants, related to the rated voltage of the circuit breaker:

-120ms for nominal voltage of system up to and including 35kV

- 60ms for nominal voltage of system 110kV and 220kV

- 75ms for nominal voltage of system 500kV

These special case time constants recognize that the standard value may be inadequate in some systems. They are provided as unified values for such special system needs, taking into account the characteristics of the different ranges of rated voltage, for example their particular system structures, design of lines, etc.

The curves in the following table are based on a constant AC component and on the short circuit power factor (see the Figure 137-1) stated in the following table, corresponding to a standard time constant (45ms) and the special case time constant (60ms, 75ms and 120ms), respectively.

Table 137 Relationship between short circuit power factor and time constant

Time constant (ms)	Short circuit power factor cos φ
45	0.071
60	0.053
75	0.042
120	0.026

When the location of the installation is sufficiently remote electrically from rotating machines, the decrement of the AC component is negligible and it is only necessary to verify that the short circuit power factor is not less than 0.071 in case of the standard time constant.

As stated above, the rated short circuit current shall correspond to the rated voltage and is related to the DC time constant of the system. For DC time constant τ = 45ms, it shall be 2.5 times (i.e. approximately 1.8 * √2 times) the AC component of the rated short circuit breaking current of the circuit breaker. If one of the special case DC time constant (60ms, 75ms or 120ms), the rated short circuit current shall be 2.7 times the AC component of the rated short circuit breaking current of the circuit breaker.

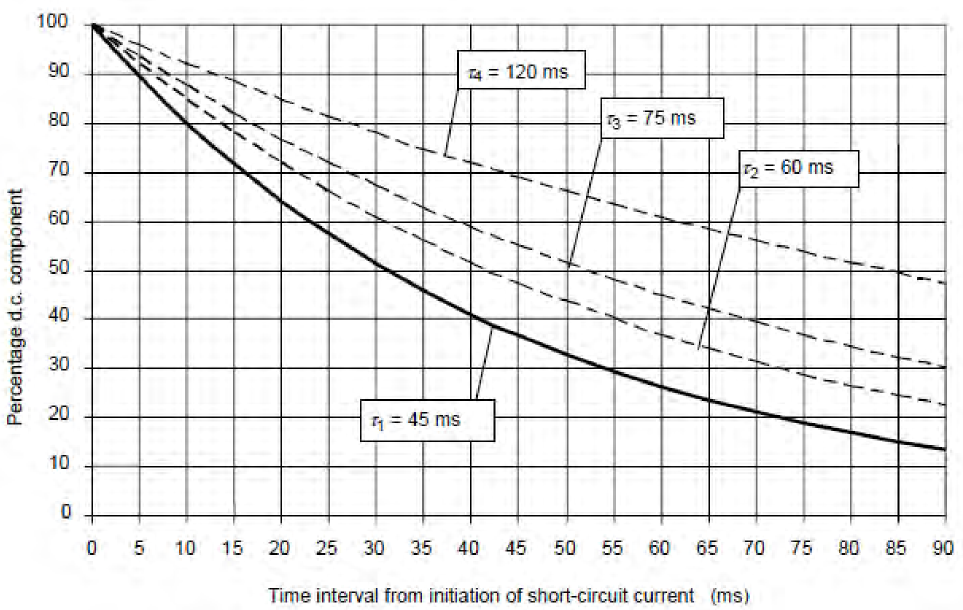


Figure 137-2 Percentage DC component in relation to the time interval from the initiation of the short circuit for the standard time constant and for the special case time constants

Article 138. Ability to Withstand Gravity Force

The short circuit electromagnetic force which acts on structure shall be calculated based on the requirements regulated in article 81.

The increased temperature which is accessible part of the structure located in close to a live part shall be within 50°C, and in case of inaccessible position, increased temperature shall be within 70°C. It is not necessary to test the increased temperature of the structure which is close to a live part of nominal AC current at 1,000A or lower.

Article 139. Installation of Disconnect Switches

In the circuits of distribution equipment, disconnecting devices shall be installed in the place where their disconnecting position of each circuit can be checked by visual.

This requirement is not applicable to fully equipped distribution system such as (including GIS), high-frequency reactor and communication capacitors arranged at busbars and terminals of outgoing power lines, lightning arrester installed at the outlet of transformer and at the transformer connected by cable.

In particular case, depending on design of structure or diagram, it is permissible to install voltage transformer before disconnectors in order to disconnect the remained equipment of this circuit from power supply source.

Article 140. Close or Open Indicators for Circuit Breakers

The provisions of this article shall refer to the Article 294 of Volume 4.

Article 141. Insulation in Dirty Air Condition (Prevention of Dust, Harmful Gases, and Steam)

In case distribution system and substation are located in the polluted environmental area, appropriate measures shall be applied in order to ensure reliable and safe operation of equipment, such as:

- Use of reinforced insulators.

- Use of conducting bars made of materials that are resistant to environmental impacts or covered with protection paint.

- Avoiding wind direction that may cause damage.

- Use of simple electrical diagrams.

- Use of distribution equipment and substations of close type or GIS.

- Preventing dust, harmful gases and steam from invading the distribution equipment compartment.

In case outdoor distribution equipment and substation are located at the place less than 5 km away from the seacoast or a chemical plant, it shall use the anticorrosive aluminum conductor or the copper conductor. Because experience shows that polluted air make aluminum conductor corrosive at such a place.

Article 142. Installation at Higher Elevation at a height of 1000m

For equipment mounted at a height of 1000m above sea level:

Minimum clearance for the maximum working voltage must be increased as compared with the largest number of Table 254 of Technical Regulation every about 100m up 1.4% from a height of 1,000m above sea level.

For installation at an altitude higher than 1,000m, the insulation level of external insulation shall be determined by multiplying the insulation withstand voltages (see the article 331 of the technical regulation) required at the service location by a factor Ka in accordance with the following figure.

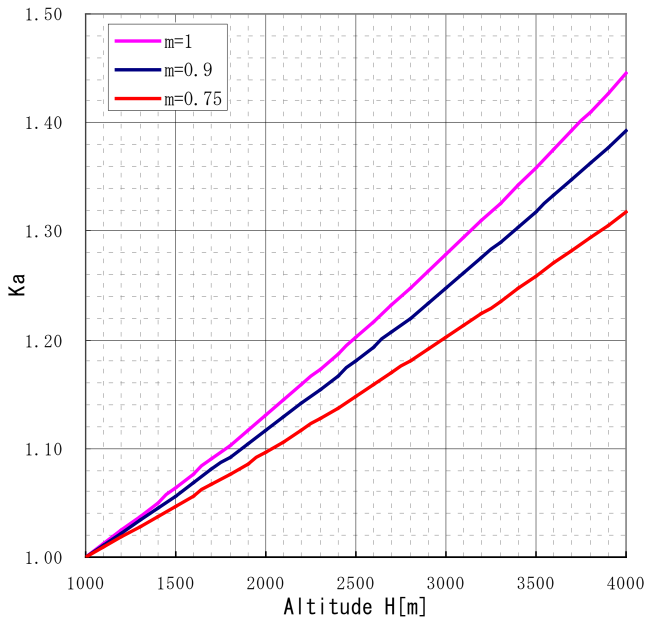


Figure 142 Altitude correction factor

These factors can be calculated from the following equation:

$$Ka = e^{m\,(H-1\,000)/8150}$$

where

H is the altitude in meter

m is taken as fixed value in each case for simplification as follows:

- m = 1 for power-frequency, lightning impulse and phase-to-phase switching impulse voltages
- m = 0.9 for longitudinal switching impulse voltage
- m = 0.75 for phase-to-earth switching impulse voltage.

Article 143. Materials of Distribution System Conductors

As stipulated in Technical Regulation.

Article 144. Phase Symbols/Signs

The provisions of this article shall refer to the Article 104 of Volume 3.

Article 145. Switches with Interlocks

Circuit breakers, disconnectors and earthing switches of the power lines and bus ties shall have the interlock provided in the Article 100 of Volume 3.

Regarding the earthing switch of line disconnectors for power lines, the mechanical interlock which connected to the drive mechanism of line disconnectors shall be installed to avoid closing the earthing switch while the line disconnector is closed. (refer to the figure 145-1)

In case of using the electrical interlock for the earthing switch, an under-voltage relay shall be installed to ensure that the power line is dead before the earthing switch is closed. (refer to the figure 145-2)

For the distribution equipment with simple electrical diagram, a mechanical interlock is recommended. For other cases, an electrical interlock should be used.

Drive mechanism of the disconnector shall have space for locking when it is in the closing/opening position if it is located in area approachable by unauthorized persons.

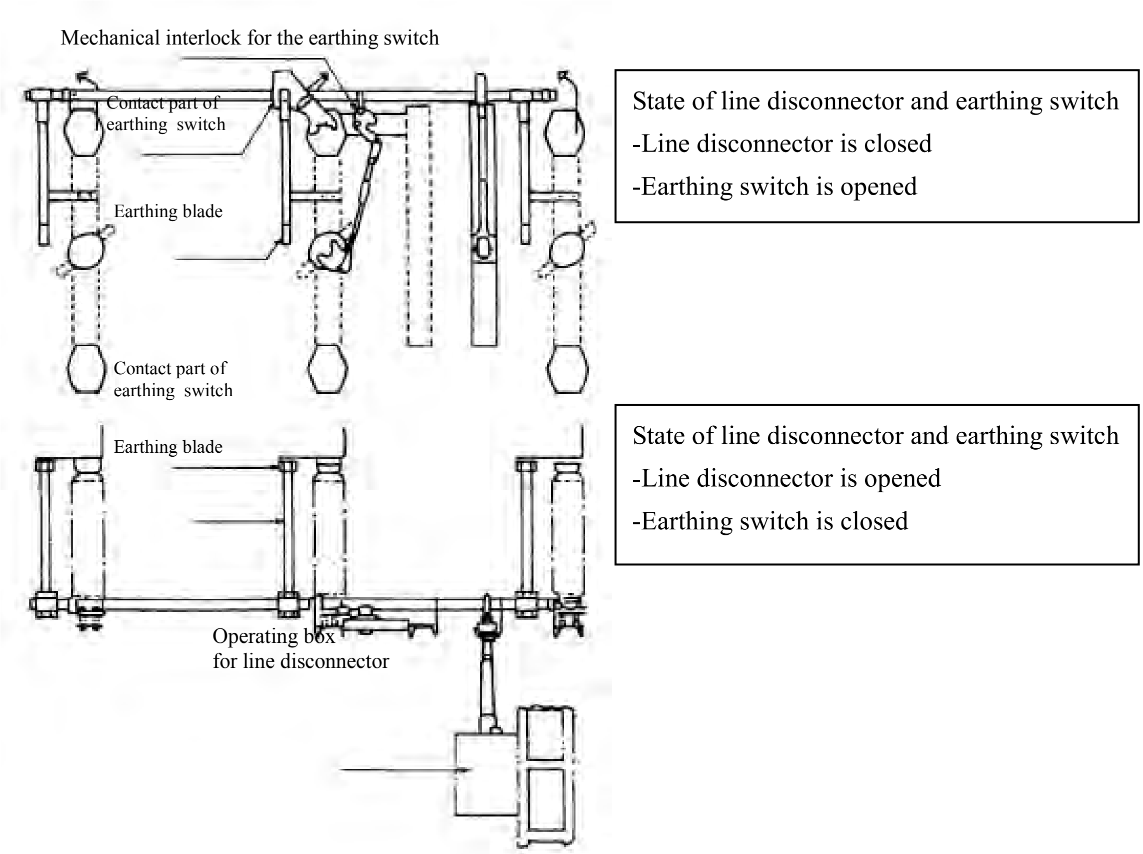


Figure 145-1 Mechanical interlock between line disconnector and earthing switch

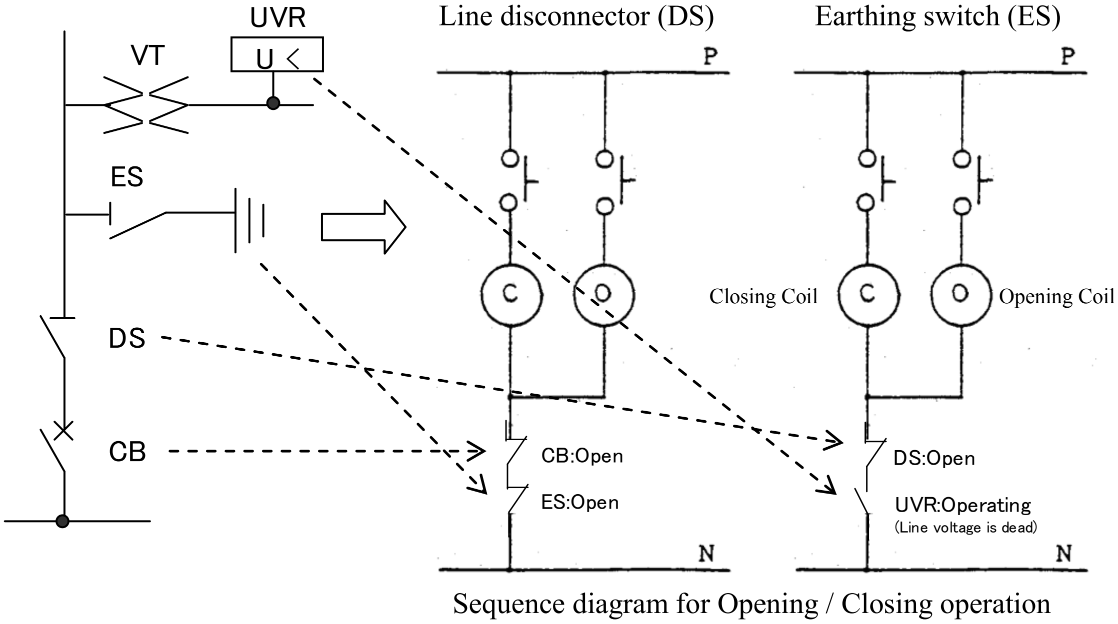


Figure 145-2 Electrical interlock for line disconnector and earthing switch

Article 146. Grounding Switches

For distribution system and substation with voltage above 1kV, fixed grounding switch should be applied to ensure safe grounding. Normally, portable grounding equipment should not be applied.

However, in the location where fixed grounding switch cannot be used, conductors and bars shall have space or terminal for connecting the portable grounding equipment. (refer to the following figure)

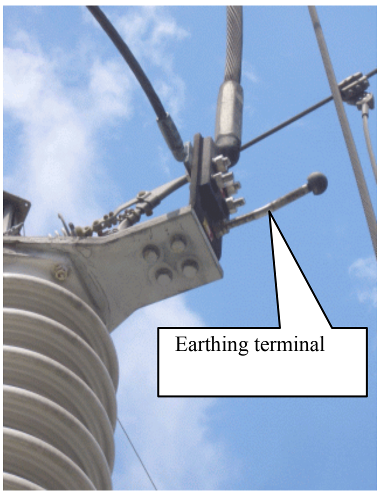


Figure 146 (Reference) Earthing Terminal

Article 147. Height of the Fence

The site of outdoor distribution equipment and substations shall be enclosed by external fences/wall (except the indoor substation, prefabricated substation and on-pole substation), and external fences/walls shall have locks and be made of incombustible materials.

Regarding the external fences/walls and protective barriers, minimum clearance and etc. shall meet the criteria provided in the Article 333 and 334 in Technical Regulation.

The mesh size of protective barrier and external fence is provided in the Article 333 in Technical Regulation f(The mesh size shall meet IP1XB or IP2X.) However, the smallest mesh size shall be 10 x 10mm (corresponding to IP2X) and maximum size shall be 25 x 25mm (corresponding to IP1XB).

It is allowed to install barrier-rods at entries of the compartments of circuit breaker, transformer or other electrical equipment so that the operator can stand outside of the barrier-rods to observe live parts.

Barrier-rods shall be removable and be arranged at a minimum height of 1.2m and a maximum height of 1.4m. In case that the floor of the compartment is 0.3m higher above the ground, the distance between the door and barrier-rod shall be not less than 0.5m or the space in front of the door shall be secured for operators to observe the equipment.

Article 148. Prevention of Damage from Temperature or Vibration

When an earthquake occurs, a tensile force of lead wires connecting equipment may occur. Because the lead wire is pulled by the vibration of equipment due to the earthquake. At this time, if an extra length of the lead wire is too short, the tensile force will get large. And so the insulator of pulled equipment by the tensile force may break.

Therefore lead wires should have a minimum extra length regulated below. In addition, if lead wires can't have a sufficient extra length, flexible wires should be used instead of rigid wires to absorb the tensile force (vibration).

[Policy of an extra length of lead wires (Example of Japanese design)]

- Earthquake-resistant design condition: Keeping a sufficient extra length of the lead wire at the time of vibrating the connected equipment at the 0.3G resonant three cycle sine wave (G is gravitational acceleration).

Keeping the extra length which is more than the maximum value of the following three items, in order to meet the above design condition.

(1) Keeping the extra length which is more than the top displacement at the time of vibrating the equipment at the 0.3G resonant three cycle sine wave

(2) Keeping the extra length which is more than 5% of the span length

(3) Minimum value: 70mm

Required extra length (Le) =

$$\text{maximum value of the above items} + 10 / 3\ \tan^{-1}(H/S) * \sqrt{(S^2 + H^2)} / S$$

where S: Span length

H: Difference in level

The calculation example according to the above formula under the below condition is given as follows.

1. Calculation condition
   - Span length: 1,000mm
   - Difference in level: 20mm

2. Displacement at the time of vibrating the equipment

(1) Top displacement

- Circuit breaker: 5mm --> 5* 1.5 = 7.5mm
- Disconnecting switch: 15mm --> 15 * 1.5 = 22.5mm

From the above, top displacement is 22.5mm.

(2) 5% of the span length: 1,000 * 0.05 = 50mm

(3) Minimum value: 70mm

From the above, maximum value is 70mm.

Therefore, Required Extra Length is;

$$Le = 70 + 10 / 3 \tan^{-1} (20 / 1,000) * \sqrt{(1,000^2 + 20^2)} \; / \; 1,000$$

$$= 74mm$$

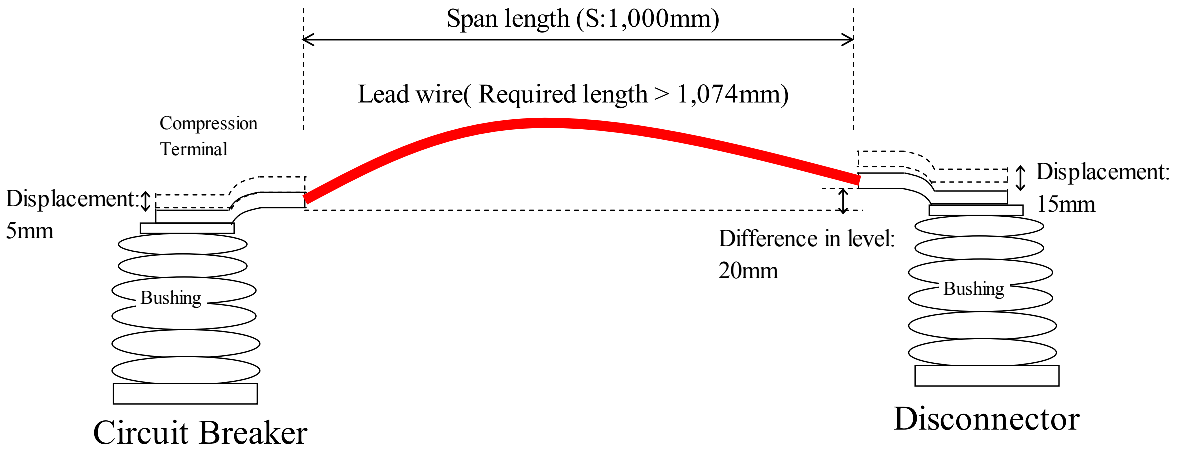


Figure 148 Necessary length of lead wire which connects between two equipment

Article 149. Oil Indicator and Temperature Gauge

It is necessary to find an oil leakage of oil immersed equipment early in terms of prevention of insulation performance degradation and environmental pollution. Because of this, oil level gauges should have a upper limit and lower limit level, and in case of the large transformer, because the oil level widely changes according to the oil temperature, the characteristic curve which shows the relation between oil temperature and oil level should be provided on site in order to easily confirm the adequate oil level according to the oil temperature under operation.

Article 150. Oil-resistant Material for the Facilities

When the electric cable is connected to the oil-immersed equipment, the metallic conduit which is not affected by insulation oil or the machine oil, etc. shall be used for an electric conduit work.

In addition, an oil proof electric cable shall be used. However, since the oil resistance of an electric cable changes with types of oil to be used, the appropriate electric cable shall be adopted with the type of oil which is used.

Article 151. Color of Transformers, Reactors, Capacitors

For the paint for outdoor equipment, a bright color and a gloss paint have an advantage in the heat barrier, because reflectance of solar radiation is high. In addition a gloss paint have an advantage in cleaning the paintwork easily and improving the weatherproof performance. But in case of high gloss paint, neighborhood inhabitant may make a complaint against the reflected light from the gloss painted equipment, because the high gloss paint has a high reflection effect of solar radiation. Therefore, local environment as same as the paint performance should be taken into consideration at the time of deciding the paint for outdoor equipment.

Article 152. Lighting System in Substation

A lighting facility for supervising, operating and maintaining for equipment shall be installed in a distribution system and a substation, etc.. In practical installation, it is desirable to set the illumination range of installation site according to the following table.

In addition, an emergency light shall be installed there for a safe evacuation, in consideration of the loss of AC power supply due to the power outage or the fire disaster of substations, etc.. Regarding the specification of this light, it is turned on by DC power supply, and the illumination intensity shall be maintain 1lux and more on the floor surface after lighting during 30 minutes.

Table 152 Illumination range of installation site

Illumination range (lx)	Place (Application)
1,500 - 700	Control center
700 - 300	Distribution board room
300 - 150	Protective relay room, Telecommunication equipment room
150 - 70	Workshop, Assembly shop
70 - 30	Transformer room, Cubicle, Switchgear room, Battery room, Compressor room, Cable room
30 - 15	Passageway, Stairs, Storehouse
15 - 7	Outdoor main equipment
7 - 3	Outdoor main passageway
3 - 1.5	Outdoor patrol route
1.5 - 0.7	General indoor

Article 153. Communication System in Substation

As stipulated in Technical Regulation.

Article 154. Transportation Accessibility

Within closed electrical operating areas, transport routes should be constructed for assembling, repairing and testing equipment using heavy machines, etc. Minimum protective clearance between vehicles and live parts shall be ensured at the time of designing the transport routes. As for concrete clearance, refer to the article 320.

Article 155. Noise Regulations

As stipulated in the item 4 of article 1 of Vol.1 in Technical Regulation.
Noise abatement measures:

- Technical measures: industrial design, separation, isolation of noise resources, using technologies with low noise level, electrical equipment with low sound power.
- Acoustic measures in construction: sound-damping materials or sound deadening materials will be used.
- Application of remote control and automation.

Article 156. Corrosion Regulation

Corrosion protection shall comply with Article 57.

Article 157. Oil Collecting Systems

The quantity of insulating oil in equipment, the volume of water from rain and fire protection systems, the proximity to water courses and soil conditions shall be considered in the selection of a containment system.

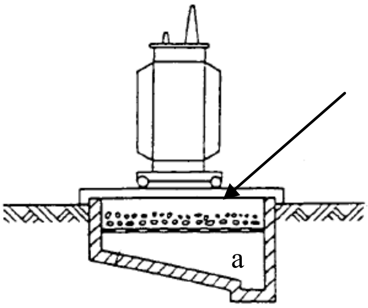
Containments and holding-tanks, where provided, may be designed and arranged as follows:

- tanks;
- sump with integrated catchment tank for the entire quantity of insulating oil (figure 157-1);
- sump with separate catchment tank. Where there are several sumps, the drain pipes may lead to a common catchment tank; this common catchment tank should then be capable of holding the insulating oil of the largest transformer (figure 157-2）;
- sump with integrated common catchment tank for several transformers, capable of holding the insulating oil of the largest transformer (figure 157-3).

The walls and the associated pipings of sumps and catchment tanks shall be impermeable to liquid.

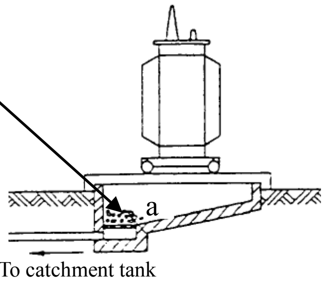
The capacity of the sumps/catchment tanks for insulating and cooling oil shall not be unduly reduced by water flowing in. It shall be possible to drain or to draw off the water.

The entire layout example of including the oil sumps, catchment tank, weir of oil outflow prevention and etc. is shown in the Article 162 of Vol. 3.



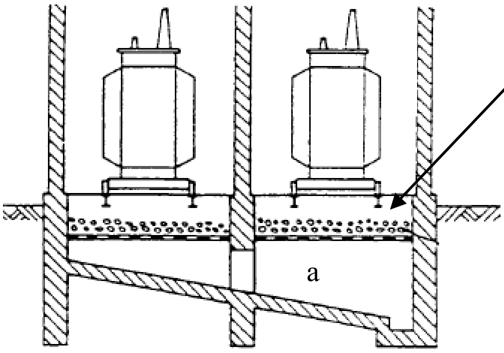
[a] In addition, the water from the fire extinguishing installation (if any) should be considered.
Containment: the entire quantity of insulating oil of the transformer plus rain water.

Figure 157-1 Sump with integrated catchment tank



[a] Containment: minimum 20% of the insulating oil from the transformer.

Figure 157-2 Sump with separated catchment tank



[a] In addition, the water from the fire extinguishing installation (if any) should be considered.
Containment outdoor: the entire quantity of insulating oil of the largest transformer plus rain.
Containment indoor: the entire quantity of insulating oil of the largest transformer.

Figure 157-3 Sump with integrated common catchment tank

Article 158. AC Power Source

As stipulated in Technical Regulation.

Article 159. Utilization of Isolating Power Transformers

[Reference] Isolating transformers are used for the power supply of medical equipment, etc. which need the surge protection and the prevention of power interruption by earth leakage breakers.

But the ground fault in the secondary side of the transformer can't be detected by the introduction of isolating transformer, so insulation level monitoring devices shall be installed to supervise the insulation level anytime. In addition, name plates which show the circuit's name should be attached on the outlet to distinguish whether the circuit is through the isolation transformers (see the following figure)

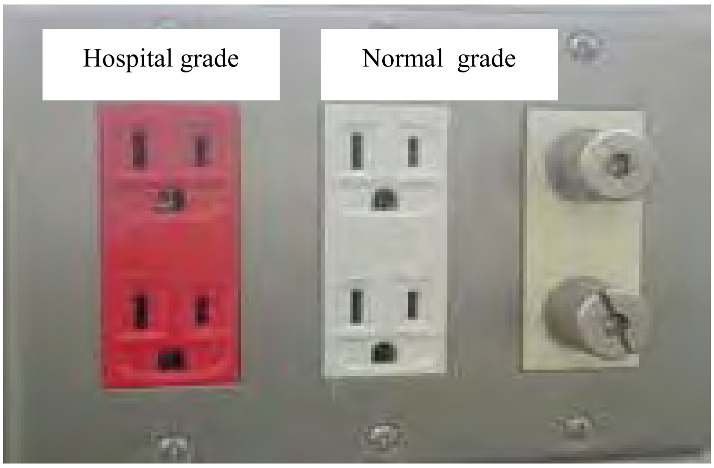


Figure 159 The outlet layout example of hospital grade (Connected to isolating TR) and normal grade

Chapter 2-6 Measure the electrical energy (Metering)

Chapter 2-6-1 Metering System

Article 160. General Requirements

(1) The requirement of power metering system

1. Measurement system for power grid voltage of 110kV or more:
   - Position the main meter is defined identical or adjacent to the connection point.
   - In case of failure to qualify for the main meter layout prescribed or position does not ensure accurate measurement of power delivery, power distribution units and customers to agree the location and installation of replacement meter, and define the power conversion method from the measured position instead of the connection points.
2. Installation of meters for power grid voltage 1000V to 35kV
3. Installation of meters for low voltage grid
4. When the power purchase boundary is not determined, there shall be agreement between electricity buyer and seller and approved by authorized agency.
5. When electricity can be exchanged two directions at the boundary, the two directive meters or one multi directive meter must be installed.
6. Selection of mechanical meters or electronic meters and requirement to transmit data from meters must be performed in compliance with existing regulation of the power sector.

Counting active electricity must ensure determination of active electricity amount:

1. Generated by each electrical generator.
2. Own used in the power plant, substations including compensating station and diesel power generation station.
3. Supplied to or received from other power system.
4. Provided by power plant to transmission and distribution network.
5. Supplied to electricity consumers.

Apart from ensuring counting electricity for billing, counting electricity must also ensures inspecting electricity used by consumers, checking electricity exchanged at boundary, electricity balancing, development of technical-economic indicators and electricity load forecast.

Counting reactive electricity must ensure determination of reactive electricity amount:

1. Generated by each electrical generator.
2. Provided by power plants to transmission and distribution power networks.
3. Generated by rotary compensators or static compensating stations.
4. Supplied to or received from other power systems.
5. Of electricity consumers, production-business, services facilities which have transformers with capacity of 100kVA and above or used capacity of 80kW and above.

   Apart from counting reactive electricity for billing, counting also plays function of checking, monitoring, used by consumers, checking electricity exchanged at boundary, electricity balancing, development of technical-economic indicators and electricity load forecast.

(2) Location for electricity meter installation

Purchase electricity meter installed identical or adjacent to the connection point or at a convenient location agreed upon by the buyer and the seller.

Metering System should be carried as follows:

- In power plants and power systems, active electricity meters must be installed at:

1. Each electricity generator.
2. Each step up transformer, at secondary side high and medium voltage sides, except balancing winding.

   Side of transformer, at which electricity is exchanged in two directions, two one-directive electricity meters or one two-directive meter must be installed. When low voltage of step up transformer doesn't have own current transformer for meter, the meter must be installed at voltage of generator.
3. Each out going line feeder from substation, except low voltage feeder to public consumers or exclusive low voltage out going feeders which have meters at terminals of power lines. The power lines on which electricity is exchanged in two directions, two one-directive electricity meters must be installed.
4. Two directive meters must be installed at both ends of power line which is connecting power systems.

   If power line has branch connected to the other electricity network, two directive meters must be installed at the end of branch.
5. Auxiliary transformer:

   The meters are installed at high voltage side of the auxiliary transformer. If installation at high voltage side is difficult, installation at low voltage side is also allowed.
6. Each auxiliary generator: If auxiliary generator has it own power supply, at this part meter must be installed.

- In substation, active electricity meters must be installed at:

1. Both inlet of power line, two director meters or one two director meter must be installed.
2. Low voltage side of two-winding transformer.
3. Low and medium voltage sides of three winding transformer, except balancing winding

4. Each outgoing line feeder, except low voltage feeder to public consumers or exclusive low voltage out going feeders which have meters at terminals of power lines.
5. Each auxiliary transformer.

- Active electricity billing meters for consumers must be installed at:

1. Each outgoing line feeder, except low voltage feeder to public consumers or exclusive low voltage out going feeders which have meters at terminals of power lines.
2. At inlet of consumer's substation if it doesn't connect with other substations or other consumers at its supply voltage.
3. At inlet of consumer's substation if it supplies electricity to or connecting to substations of other consumers at supply voltage. When having not current transformer with accuracy class required by measuring circuit at 35kV and above, meter is allowed to be installed at low voltage side of the transformer.
4. Low voltage side of transformer if at high voltage side there is load switch, automatic disconnector or fuse bridge switch.
5. Out going line feeder to many consumers. Even each consumer has its separate meter, it needs a general meter for monitoring and checking.

- Reactive electricity meters must be installed at:

1. Electricity generator with capacity of 1,000kVA or more.
2. Medium voltage and low voltage windings of transformers and important places where active electricity meters are installed. If there is no current transformer with accuracy class as required, reactive electricity meter is allowed to be not installed at low voltage side of the transformer.
3. On 35kV power line, if billing electricity to consumers is based on active meters of that power line.
4. At outlet of compensating machine or at main line of capacitor with capacity of 100kVA or more.
5. Near to active electricity billing meters of motive electricity consumers.
6. At elements of electricity system, boundary requiring billing or monitoring reactive electricity.
7. At consumers with generated reactive electricity, two directive reactive electricity meters must be installed.
8. At boundary with power exchange, two directive reactive electricity meters must be installed.

- Meters must be installed on rigid board, cubicles or boxes. Meters are allowed to be installed on metal, stone or plastic boards but not on wooden boards.
- In places where are easy to be hit, dusty and many people passing or external interference, meters must be placed in cubicles or boxes with lock, sealing and hole for peering through.

  Many meters can be placed in one box or cubicle or in the same place with low voltage current transformers.
- Connecting wires to meters must be copper conductors used for connection with cross sectional area not less than 1.5mm2 in compliance with requirements.
- Wire connecting with the meter circuit must not be connected and not welded.
- Wiring section close to meter must have 120mm surplus at least. Cover of “zero” wire before meter must have easy recognized color at least 100mm of terminal.
- Distance between electricity conducting parts on electric board with meter and current transformer must comply requirements specified in Article 413.

- In low voltage electricity network, when being installed in dangerous and very dangerous halls, the covers of meters and current transformers must be grounded through separated copper conductors (“zero” wire).
- When two or more meters are installed close to each other, there must be name plates for each meter

  In power plants or substations with two or more meters installed, there must be name plats for each meter.

(3) Backup Metering

A Metering System shall be considered faulty and not in compliance with this Distribution Code if it is determined that any part of that Metering System does not comply with this Distribution Code.

If a Metering System fault occurs, the Distributor shall provide Urgent Metering Services to repair or replace the Metering System as soon as is reasonably practicable and in any event within two working days of the Distributor discovering that the fault exists.

The User shall use Metering Equipment in a safe and prudent manner and shall take due care to avoid damage. The User shall notify the Distributor of any damage to the Metering Equipment, however caused.

The Distributor shall ensure that suitable data is obtained or estimated for the period of time commencing when a Meter or Metering Equipment becomes faulty until the completion of the repair or replacement.

The Distributor shall record all relevant Meter parameters for a replacement Meter in that Metering System.

(4) Payment meters

As specified in the Technical Regulation.

Article 161. Power metering system configuration

1. Fully configurable for power metering system include:

   a) current transformer;

   b) voltage transformers;

   c) the power meter;

   d) the secondary circuit and cable

   e) equipment for metering data collection and transmission of data;

   f) equipment safety, position for sealed, pair of lead;

   g) equipment for auxiliary equipment, to transfer connection, equipment to isolate the measurement circuit, when need to test

   And logic devices for transfer connection voltage circuit to anotherVT, equipment to check the voltage and current

2. Specific configuration of a metering system is determined by the voltage level and the characteristics of the location of measurement..

Article 162. Requirements for equipment of power system measurements

(1). Electric power metering system 110kV and above

1. Requirements for the power meter:
   a) Type 3-phase 4-wire;
   b) Type of integrated electronic and programmable function;
   c) There are many tariffs;
   d) Measurement of active and reactive power in two separate receiver and transmitter by 4-quadrant
   e) The maximum power measurement function, recorded total load chart;
   f) The appropriate protocol to collect, read the data in local and remote;
   g) Supplied from the secondary voltage measurement system and to maintain the operation to in the event of loss of any one or two phase voltage;
   h) There are multiple levels of password;
   i) The sealing position, leaded ensure inaccessible to the wiring terminals and change the settings in the meter if not sealed lead break;
   j) Information storage function measurement, load charts least 60 days with cycle recording measured values do not exceed 30 minutes;
   k) For metering system to at the main meter placement, the measured active power meter must have accuracy class 0.2 according to IEC 62053-22 and accuracy class 2.0 according to IEC 62053-23 if reactive power measurement or other equivalent standards;
   l) For backup metering systems, meters measure the active power to achieve the accuracy class of 0.5 according to IEC 62053-22 and accuracy class 2.0 according to IEC 62053-23, if measured reactive power or other equivalent standards.
2. Requirements for measuring current transformer for measure of power:
   a) With separate secondary windings used to measure the electrical energy
   b) The nominal value of the secondary current is 1A or 5A;
   c) The location for the lead seal in the lid of the box to the joints of the secondary coil wiring to measure the for power meter to ensure that no impacts on circuit connection without breaking the seal;
   d) Current transformer for main meter must achieve accuracy class of 0.2 according to IEC 60044-1 or equivalent standards
   e) Current transformer for backup meter must achieve accuracy class of 0.5 according to IEC 60044-1 or equivalent standards
3. Requirements for voltage transformers used to measure the electrical energy:
   a) With separate secondary windings used to measure the electrical energy;
   b) The nominal value of the secondary voltage is 100V or 110V;
   c) The location for the lead seal in the lid of the box to the joints of the secondary coil wiring to measure the power meter to ensure that no impacts on circuit connection without breaking the seal;
   d) Voltage transformers for main meter must achieve accuracy class of 0.2 according to IEC 60044-2 for type electromagnetic-induction-transformer and standard IEC 60044-5 for type capacitor-transformer or the other equivalent standard;

e) Voltage transformer for backup meter must achieve the accuracy class of 0.5 according to IEC 60044-2 for type electromagnetic-induction-transformer and, standard IEC 60044-5 for type capacitor-transformer or other equivalent standards.

(2). Power measuring system from 1000V to 35kV

1. Requirements for the power meter:

a) To meet the requirements specified in points a, b, c, d, e, f, g, h, i, j, of this article;

b) For the main metering system, power meter measured the active power to achieve the accuracy class of 0.5 according to standard IEC 62053-22 and accuracy class 2.0 according to IEC 62053-23 if measured reactive power or other equivalent standards;

c) Accuracy class of backup measurement system (if any) shall be determined by agreement between unit sales and customers using electricity.

2. Requirements for current transformer for metering power:

a) With the secondary coil of separate measurement used for measuring equipment and power meter;

b) The nominal value of the secondary current is 1A or 5A;

c) lead-sealed position in the wiring box cover secondary measurement coil for measuring equipment and power meter ensure no impact on circuit connection without breaking the seal;

d) Current transformer for main measurement to achieve the accuracy class 0.5 according to IEC 60044-1 or equivalent standards

e) Accuracy of current transformer metering service backup (if any) shall be determined by agreement between the Power Distribution Unit and Client using the distribution grid.

3. Requirements for voltage transformers used for electricity metering

a) With the secondary coil separate of measurement used for measuring equipment and power meter;

b) The nominal value of the secondary system voltage is 100V or 110V;

c) sealing position in the wiring box cover secondary measurement coil for measuring equipment and power meter ensure no impact on the circuit connection;

d)Voltage transformers for metering must achieve accuracy class 0.5 according to standard IEC 60044-2 for type electromagnetic-induction-transformer and standard IEC 60044-5 for type capacitor-transformer or the target other equivalent standard;

e) Accuracy of metering voltage transformers in service backup (if any) shall be determined by agreement between the Power Distribution Unit and Client using the distribution grid.

(3). Low-voltage measurement system

1. Requirements for the power meter:

a) A type 3-phase 4-wire or 3-phase 3-wire measurement using 3-phase-meter, and 1-phase 2-wire type using one-phase-meter;

b) The position sealing, leaded ensure no access to the wiring terminals and change the settings in the meter without breaking the seal;

c) For 3-phase meter, active power meter measurement, must achieve the accuracy class 1.0 according to IEC 62053-21 standard for electronic type meter, standard IEC 62053-11 for induction type meter or other equivalent standards. For 1-phase meter, active power meter measurement, must achieve accuracy class 2.0, according to IEC 62053-21 for electronic meter type, IEC 62053-11 standard for induction type meter or other equivalent standards.

2. Requirements for current transformer when using for low voltage power measurement
   a) The secondary coils are separated for the measurement equipment and power meter;
   b) The nominal value of the secondary current is 1A or 5A;
   c) Lead-sealed position in the wiring box cover secondary measurement coil for measuring equipment and power meter ensure no impact on circuit connection without breaking the seal;
   d) To achieve the accuracy class 0.5 according to IEC 60044-1 or other equivalent standards.

Article 163. Requirements for the connection of energy measuring system

1. Cable of secondary measuring circuit must be accompanied by the shortest route, the number of connections over the clamp is at least qualified and have implemented measures seal lead the circuit to be measured at the connector.
2. For metering system 110kV and above, the secondary coil of CT, VT and secondary cable connected to the power meter of the main metering system is not used for any other purpose and must be completed independent measuring system backup. The second main metering system to separate and directly from the wiring box of CT, VT meter cabinets without intermediate in the cabinet clamps.
3. Where is a voltage meter from one of busbarsVT through the switching voltage device, the connected terminals of voltage circuit switches to ensure lead-sealed conditions and power meter must be programmed to record the time and duration of the switching voltage.
4. Secondary circuit load CT, VT, including power meter load should not exceed the normal capacity of CT, VT.
5. In the Case circuit current of the backup measurement system used in conjunction with other measurement devices, must not affect the accuracy of the measurement system and eligible to perform lead-sealed for all of current circuit, measuring devices and power meter.
6. The test boxes must be installed to test for the verification of measuring equipment eligible to seal lead.
7. The technical requirements and the accuracy of the meter:
   Distributors must ensure that the accuracy of each meter in each measurement system certified by laboratory testing meter was officially recognized and approved by the Ministry of Science and Technology and that the meter meets the provisions current limit accuracy.
   In the case of not meet required standards, the distributor must restore the accuracy of the meter in the measurement system to achieve standards of accuracy in the shortest time reasonably practical. Distributors shall maintain Profile certification qualified related to the specific type and model of the meter in the metering system.
   The distributor shall maintain records of the information refer to in this section for each measurement system for at least six years and will provide the data upon request of the competent authorities, inspection and testing of installation .
8. Periodical inspection
   The Distributor shall be based on the minimum requirement from the Directorate for Standards and Quality (STAMEQ), ensure that each Metering System is inspected according to these minimum frequencies:
   a) 1-phase meter: 5 years
   b) 3-phase meter: 2 years

c) CT, VT: 5 years

- Requirements on data for loss calculation and adjustment as well as requirements on data validation and loss adjustment factor are not clear and need to be specified / clarified.

The Distributor may, and on the direction of the Authority shall, carry out periodic, random and unannounced inspection and or testing of any Metering System and associated data for the purpose of ascertaining whether the Metering System complies with the requirements of this Distribution Code. The User may request the Distributor to carry out such inspection and or testing, provided that the User pays the cost, unless an error or malfunction not caused by the User is discovered. In addition, the Authority may carry out its own unannounced inspection and or test, in which case the User shall grant access to the Authority.

The Distributor shall, as soon as practicable, make the results of any inspection and or tests conducted pursuant to this Section available to the requesting party and to the User associated with the Metering System.

Article 164. Technical requirements for sealed, pair of lead and security

1. Complete energy metering system including wiring box CT,VT, power meter, clamps, connectors, circuit current, voltage, auxiliary equipment, logic switch cabinets meters, communication networks must be lead-sealed to prevent unauthorized intervention.
2. For electronic power meter, meter software must be password protected with different access rights.
3. The event of a power distribution unit installation and exploitation of the data collection system to measure automatically, they must meet the following requirements:
   a) Measured power data after it is read and transmitted to the server located at the measurement location must be encrypted to prevent unauthorized changes;
   b) Reading system management software, communications and integrated power metering data must be secured with the multi-level password to ensure that the security, accuracy and reliability of the measurement data.

Chapter 2-6-2 Electrical Measurements

Article 165. Electrical Measurements

As stipulated in Technical Regulation.

Article 166. Requirements for Electrical Measuring Instruments

All electrical measuring instruments must meet following basic requirements:

1. Indicating or recording tools must have accuracy class of 1.0-2.5. Ammeter without number zero (0) at the scale, installed in low voltage distribution substation, supplying electricity to residential use and electrical motors, can have accuracy class of 4.
2. Accuracy class of shunt, auxiliary resistors, measuring transducers must not be smaller than the values given in the following table:

Table 166 Accuracy class of electrical measuring instruments

Accuracy class of measuring device	Accuracy class of shunt, auxiliary resistors	Accuracy class of measuring transducers
1	0.5	0.5
1.5	0.5	0.5
2.5	0.5	1
4	-	3

3. Limit of division on scale or limit of indicating numbers must ensure measurement the whole range of values to be measured.

- Connecting current winding of measuring tool and protection device with secondary winding of current transformer supplying electricity to billing meter must comply with specifications in Article 162.
- At low voltage distribution substation without duty man, it does not allows to install electricity measuring indicating tools but a space must be arranged for connecting testing instruments or clamp-on tester.
- Electricity measuring tools with indicator, there must be red division presenting rated value on the measurement scale.
- Electrical measuring tool with decision “zero” in the middle of the measurement scale must have written directions in two sides of division “zero”.
- Electrical measuring tool must have name plate for identifying measurement points, except it is put close to the measurement on the connection diagram.
- Apart from indicating measured values on the spot, in necessary case, the measured values need to be recorded or put into memory space or transmitted to remote measurement location, on requirement of operation.

Article 167. Measuring Voltage in 3-Phase

- Metering voltage in 3-phase electric power networks should be carried out as using one phase-phase voltmeters follows:

  At electric power network with voltage over 1000V, large earth fault current, phase voltage must be measured by one voltmeter which has switching lock.

  At electric power network with voltage over 1000V, small earth fault current, voltages of 3-phase conductors must be measured.

  At low voltage electric power network, only conductor voltage must be measured if there is no special requirement.
- The insulation tester must be installed in over-1000V power network with small earth fault current, up to 100V power network with isolated neutral conductor and DC electric power network with isolated middle point. Insulation tester may be indicating meter, relay-based device (sound, light signal system) or combination of the above types.

Insulation tester must meet the following requirements:

Identifying earth fault when electric power network operates separately or through star - triangle connected transformer.

Easy identifying earth faults in case the substation without duty-man.

When necessary, the sound, light signalizing system for local warning or transmission to central control is arranged.

- The insulation tester in up to over-1000V power network and in DC electric power network must be able to detect resistance value of insulation, when necessary, the sound, light signalizing system is attached and acting when insulation level is reduced to set value.
- It is not necessary to install insulation tester in simple and not important DC circuit, DC circuits with voltage up to 48V. Periodical testing insulation of these circuits by using voltmeter must be performed.
- It is allowed to use voltmeter to periodically test insulation of each pole to earth of excitation circuit of rotating electric machines.

Voltmeter with circuit switching lock may be used for testing insulation in some points of excitation circuit.

- The single phase voltage transformer of 3-phase 5-coil voltage transformer must be used for testing insulation. The high voltage winding must be connected in star with earthed neutral.

In order to supply electricity to both insulation testing circuit and measuring circuit from one voltage transformer, there must be two secondary windings of which one connected in star, with phase voltage of 100/√3V, used for measuring circuit and one winding connected in open triangle, with phase voltage of 100/√3V, used for insulation testing circuit.

Article 168. Measuring Points for AC & DC Currents

1. AC & DC currents for measuring electricity current must be measured at appropriate places.

   Circuits which need systematic testing during operation process.

   Generators, high and medium voltage power line feeders and loads, important low voltage power line feeders and loads.

   Primary and secondary circuits of voltage transformers with capacity of 1000kVA or more. In the circuit of arc extinguishing coil there must be space for connecting recording or potable ammeters.
2. If technology process requires, recording ampere meters must be installed.
3. DC current must be measured at:

   Circuits of DC power generators and rectifiers.

   Battery circuits, solar PV circuits.

   Excitation circuits of generators, compensators and synchronous motors.

   4. Three ampere meters must be installed for: 3-phase AC electric power generators with nominal capacity of 200 kW or more, synchronized to the electric power network;

Stand alone 3-phase generators;

1) Power lines with controlled each phase
2) Power line supply electricity to electric furnace.
3) Power lines with series compensation
4) Power lines can be operated continuously in phase-lost-condition
5) 500kV power lines

6) It is permissible to install an Ammeter with switch over selector to measure 3-phase current of up to 200kW power generator.

5. When selecting ampere meters and current transformers, the temporary overload of motor circuit during starting must be taken into account. Current must not be saturated and ampere meters must be capable to stand indicate starting currents.
6. DC ampere meters must have measurement scale at both sides or pole reversing switches if measured current may change direction.
7. AC ampere meter can be directly connected or connected through current transformer. Ampere meter can be directly connected to busbar or conductor. Ampere meter is connected through current transformer if cannot be directly connected.
8. Direct connecting ampere meter to over-1,000V AC circuit and over-500V DC circuit must ensure the following conditions:

   Safety for operation, management, testing and repairing staff convenience for reading indication, compliance to existing electricity safety regulation.

   Insulation of electricity carrying parts of ampere meter from the earth by insulation which withstands the corresponding voltage or voltage directly exposed on busbar section between two adjacent insulators, ensuring distance of ampere meter between phase and phase, phase and earth.

   Base of ampere meter must paint red and on measurement scale there must be red mark indicating high voltage.

   9. In order to easily read indication, the ampere meter is allowed to be connected to current difference between two phases or to two paralleled secondary windings of two current transformers of the same type, same ratio or to two secondary windings, of one current transformer, which have the same characteristics and ratio. In both cases, the measurement scales must be ruled to match phase current of the primary side.

   Ampere meter installed at DC equipment are allowed to be directly connected or through shunt.

Article 169. Measuring Points for Voltage

Voltage must be measured at appropriate points:

1) Each section of AC or DC busbars at all voltage levels if this section can work separately. It is allowed to install one voltmeter with circuit switching lock in order to measure many phase positions.

2) At low voltage distribution substation, only low voltage is measured if there is no voltage transformer at medium voltage side.

3) AC and DC circuits of generator, compensator, standby exciter and over-100kVar and compensation capacitor.

4) 1000kVar

5) Outlet of battery rank or industrial solar PVs.

6) Two sides of synchronizing Arc quenching circuit.

At test nodes of power system, voltmeter must have accuracy class of 1.0.

Article 170. Measuring Points for Power

1. Each Metering Point shall be situated as close as is reasonably practicable to the relevant Connection Point. If the Metering System cannot be installed at the Connection Point, the Metering System shall be installed as close as possible to the Connection Point. In this case, a procedure shall be established to account for the Energy loss between the Connection Point and point of metering.
2. Power must be measured in compliance with the following the requirements:

1) Measurement of active and reactive power for each generator. For generators with capacity of 100MW or more, meters with accuracy class of 1.0 must be used.

2) Measurement of active power for each voltage transformer and power lines with voltage of 6-35kV, which supply auxiliary electricity to power plant.

Measurement of reactive power for compensating machine and compensating capacitor of 25MVar or more.

Measurement of active and reactive power for 2 coil step up transformer of power plants measurement of active and reactive power at low voltage and medium voltage for each step up transformer and power plant except transformers connected with generator in block diagram.

Step up 3 coil transformer and autotransformer at substations, measurement of active and reactive power for each transformer capacity of 35/22-15-10-6kV or more. For other transformers, only measurement of active power is necessary.

3. It must use wattmeter and Var meter with two side measurement scales for those circuits whose power flow is various.

Article 171. Measuring Points for Frequency

1. Frequency shall be measured at:

1) Each section of busbar at generator voltage.

2) Outlet of generator of block

3) Each high-voltage busbar system of power plant.

4) Nodes which can separate the power system to the asynchronous operating parts.

2. Self-record frequency meter shall be installed.

1) At power plant with capacity of 200MW or more in power system.

2) At power plant with capacity of 6MW or more and operates independently.

3. Absolute errors of Self-record frequency meter at power plants involving in frequency modulation shall not exceed from -0.1Hz to +0.1Hz.

PART 3 TRANSMISSION AND DISTRIBUTION LINES

Chapter 3-1 House and Outside Wiring Systems with Voltage up to 35kV

Chapter 3-1-1 The Selection of Types of House and Outside Wirings with voltage up to 1kV and Installation Methods

Article 172. Appropriation for Power Projects

1. Environment condition
   House and outside wirings shall not affect surrounding people and natural environment by noise or other influence.
2. Purpose and value of project
   House and outside wirings shall supply electricity according to the demand of consumer
3. Construction and architectural feature.
   House and outside wirings shall have sufficient mechanical and electrical strength which can withstand the assumed load and stress.

Article 173. Selecting Lines and Conductors, Cable Installation Methods

1. Installation method and selection of conductor and cable
   Installation methods for house and outside wirings and selection of conductors and cables shall be complied with the requirements in the following table.

   Insulations and protective covers of conductors and cables shall meet the installation method and environment conditions. Also, the insulations shall meet the nominal voltage of house and outside wirings.

Table 173 Installation method and selection of conductor and cable

Installation condition	environment condition	Installation method	Conductor and cable
Opened installation	Dry and humid halls	On pulleys and clamps	Single core conductor without sheath
	Dry hall	Ditto	Double cores twisted conductor
	Other halls except above-mentioned and outdoor	On insulators and pulleys in very humid hall On large size pulleys outdoor or the place where rain or snow directly fall on the wirings (under eaves, etc.)	Single core conductor without sheath
	Outdoor	On walls and ceilings directly Supporting wires and supporting bars and other structures	Cable with metal or non-metal sheath
	All halls	Ditto	Single and multiple cores conductor with or without sheath Cable with metal or non-metal sheath
	All halls and outdoor	In troughs and boxes with openable covers	Ditto
	All halls and	Suspending wires	Special conductor with

Installation condition	environment condition	Installation method	Conductor and cable
	outdoor		suspending wire Single and multiple cores conductor with or without sheath Cable with metal or non-metal sheath
Closed installation	All halls and outdoor	In non-metallic pipes made of flammable materials (e.g. polyethylene) In closed canal in construction structures Under plastered layers However, the followings are prohibited. - To use insulated pipes with metallic covers in very humid hall and outdoor - To use steel pipes and boxes with thickness not more than 2mm in very humid hall and outdoor	Single and multiple cores conductor with or without sheath Cable with non-metallic sheath
	Dry, humid and very humid halls	In block in construction structures	Conductor with protective cover
Opened and closed installation	All halls and outdoor	In metal hoses, steel pipes (conventional and thin wall) and steel boxes In non-metallic hoses, boxes made of flame-resistant materials In insulated pipes with metallic cover However, the followings are prohibited. - To use insulated pipes with metallic covers in very humid hall and outdoor - To use steel pipes and boxes with thickness not more than 2mm in very humid hall and outdoor	Single and multiple cores conductor with or without sheath Cable with non-metallic sheath

2. Particular requirements

(1) When there are special requirements specified by the characteristics of equipment, the insulation and protective covers of conductors or cables shall be selected in consideration of such requirements.

(2) In places where ambient temperature is high, conductors and cables with insulation sheath made of high temperature resistance materials shall be used. Conductors and cables with insulation sheath made of normal heat-protective materials are prohibited to be used.

(3) In the case of installation in very humid hall or outdoor, the insulation of conductors, support and suspension structures, pipes, boxes and troughs shall be humidity resistant.

(4) In dusty halls, the installation methods which it is difficult to clean dusts accumulated on parts of house and outside wirings shall not be applied.

(5) In the case of installation in all halls or outdoor with highly active chemicals, all parts of house and outside wirings shall withstand the impacts of such chemicals or be protected from the impacts.

(6) Conductors and cables with insulations or covers which are unstable to the sun light shall be protected from direct sun light.

(7) In places where house and outside wirings might be suffered from mechanical damage, opened conductors and cables shall be protected by protective covers. If the conductors and cables have such protective covers or the strength enough to withstand the mechanical impacts, they shall be inserted in pipes, boxes or barriers, or installed closely.

(8) In case of supplying electricity to power mobile or portable devices, flexible copper conductors or cables shall be used in consideration of mechanical actions. Flexible copper conductors or cables, including earthing conductors, shall be placed in the shared enclosures, protective nets and insulations. Machines (cranes, portable sawing machines, electric gate, etc.) which the movable scope is limited shall have measures to protect the conductors and cables for supplying electricity to them and being broken, such as. hanger rings of flexible conductors and rolling rack of flexible cables.

(9) As for the places where oil or chemicals are put in, oil resistant conductors shall be used or conductors shall be protected from effects of such substances.

(10) The distance between different phases of conductors of house and outside wirings with voltage exceeding 1kV, the distance from conductors without sheath (IP00) to poles, and the distance from the conductors to the wall of the buildings or earthing systems shall not be less than 50mm. And, the distance from the conductors to flammable components of the building shall not be less than 200mm.

(11) The insulators of house and outside wirings shall be made of non-flammable materials.

The following additional requirements apply to the electricity system in the span of the crane:

(12) House and outside wirings shall comply with the following requirements, which cranes are in the span.

- House and outside wirings with non-insulated conductors or conductors without protective covers, and installed on rafters shall not be less than the height of 2.5m above floors of the bridge or vehicle of cranes. In the cases that the height of the wirings is less than 2.5m but not less than the beams of roof, the wirings shall be shielded for the whole length to prevent inadvertent contact from the floor or vehicle. The above-mentioned shields are permitted to be suspended on the bridge or installed under the wirings.
- The section of the wirings without protective covers on the repairing compartments of crane shall be protected so that the live parts of the wirings would not to be touched by persons. If the wirings are at the height more than 2.5m from the floor of crane or insulated conductors are used at the section, it is not necessary to protect the wirings. In case of using insulated conductors, the height of the wirings shall be determined by the repairing conditions.

- The wirings without protections against mechanical damage are permitted to be installed under crane in dead zone of crane. Busbars with protective covers and current up to 630A are not required to be applied protections against chemical impacts, which are placed near to technical equipment out dead zone of crane.

(13) House and outside wirings near buildings or halls of the project and outdoor explosive equipment shall comply with requirements stipulated in current standards on fire and explosion protection.

Article 174. Fire Safety Protection Conditions

1. Installation methods and selection of conductors and cables with respect to fire safety protection conditions

   Installation methods and selection of conductors and cables with respect to fire safety protection conditions shall comply with the requirements in the following table.

Table 174 Installation methods and selection of conductors and cables with respect to fire safety protection conditions

Installation condition	Installation method on ground floor and structures		Conductor and cable
	Flammable material	Non-flammable or flame-resistant materials	
Opened installation	On pulleys, insulators, object lined with non-flammable layers	Directly	Conductors without protective covers Conductors and cables with non-flammable protective covers
	Directly	Ditto	Conductors and cables with non-flammable or flame-resistant protective covers
	In non-flammable pipes and boxes	In non-flammable or flame-resistant pipes and boxes	Conductors with or without protective covers Cables with flammable or flame-resistant protective covers

Installation condition	Installation method on ground floor and structures		Conductor and cable
	Flammable material	Non-flammable or flame-resistant materials	
Closed installation	Non-flammable layers covered or protected with other non-flammable layers at all sides*	Directly	Conductors without protective covers Conductors and cables with flammable protective covers
	Non-flammable layers*	Ditto	Conductors and cables with flame-resistant protective covers
	Directly	Ditto	Conductors and cables with non-flammable protective covers
	In pipes and boxes made of flame-resistant materials lined with non-flammable layers and plastered*[2]	In pipes and boxes made of flammable materials in blocks , canals or non-flammable solid layers*[3]	Conductors without protective covers cables with non-flammable, flame-resistant or flammable protective covers
	In pipes and boxes made of non-flammable materials placed directly	In pipes and boxes made of non-flammable or flame-resistant materials placed directly	

*Note: Non-flammable protective covers shall cover all sides of conductors, cables, pipes and boxes not less than 10mm.

*[2]Note: Mortar, gypsum etc. with thickness not less than 10mm shall be plastered.

*[3]Note: Non-flammable solid layers such as cement mortar, gypsum or concrete shall have the thickness not less than 10mm.

2. Other requirements for installation method

(1) In the case that conductors or cables with flammable covers or conductors without protective covers are openly installed, the distance from the conductors or the cables to the floor surface, structures and parts made of flammable materials shall be more than 10mm. If the distance is not ensured, conductors and cables shall be isolated from floor surface by non-flammable layers covering each side of the conductors or the cables with surplus not less than 10mm.

(2) In the cases that cables with flammable covers or conductors without protective covers are closely installed in closed compartments or spaces of construction structures (e.g. the space between wall and plastered layer) or in slots etc. which are made of flammable materials, the conductors and cables shall be protected by non-flammable solid materials at all sides of them.

(3) When flame-resistant pipes and boxes for conductors or cables are openly installed along the non-flammable and flame-resistant floors and structures, the distance from pipes and boxes to the surface of floors and structures or flammable parts shall be more than 100mm. If the distance is not ensured, non-flammable materials (mortar, gypsum, cement mortar, concrete, etc.) with the thickness of 10mm and more shall be placed between all sides of pipes or boxes as well as between the above-mentioned surfaces.

(4) When flame-resistant pipes and boxes are closely installed in closed compartments empty space in construction structures (e.g. the space between wall and covering layer) or in closed canals etc., non-flammable solid layers with thickness of 10mm and more shall be placed between all sides of the pipes or the cables and surface of structures or flammable parts.

(5) House and outside wirings crossing in the short section at flammable parts of the construction structures shall comply with the requirements specified item (1) and (2) 4) in this article.

Article 175. Arrangement of Switching Devices and Protective Devices

Switching and protective devices shall comply with the requirement of Part 5 in Technical RegulationVol.1 and this Guideline.

Article 176. Safety Warning Plates

Safety warning plates shall be installed as below.

- Installed location: at the intersection of car roads in urban areas.

- Installed places: hanging on the conductor at intersection.

Chapter 3-1-2 House Wirings with Voltage up to 1kV

Article 177. Prevention against Contact

1. Height of conductor without protective cover

- The minimum height of conductor without protective cover in less dangerous and dangerous halls stipulated in Table 177 in Technical RegulationVol.1 shall be applied to opened insulated conductors without protective covers installed on floors, pulleys, insulators, suspension wires and in troughs, but to conductors in the section connected to switches, sockets, starting devices, electrical boards and wall lamps.
- The minimum height of conductor without protective cover in production halls stipulated in Table 177 in Technical RegulationVol.1 shall be applied to conductors in the sections connected to switches, sockets, electrical equipment, electrical boards, etc.
- In utility halls of industrial enterprises and domestic houses, the conductors without protection against mechanical impacts are permitted to be used in the above-mentioned sections.
- In halls which only trained staff can access, the height for installation of opened insulated conductors without protective covets is not stipulated.
- The minimum height of conductor without protective cover at platform of crane car stipulated in Table 177 in Technical RegulationVol.1 shall be applied to conductors without protective covers. If the floor of crane is higher than the platform, the height from the floor to conductors shall comply with the value in Table 177 in Technical RegulationVol.1
- If the height in platform of crane car is not secured, protective means to avoid inadvertent contact shall be applied for the conductors. Protective means shall be installed on the entire length of conductors or crane in the section installed the conductors.

2. Height of conductor with protective cover

The height of the following conductors is not stipulated.

- Conductors and cables with protective covers.
- Conductors and cables inserted in pipes and boxes not less than IP20 or in flexible metallic hoses.

3. Particular requirement

(1) In industrial halls, the height of house wirings with protection class of IP00 shall not be less than 3.5m and the height of house wirings with protection class not less than IP31 shall not be less than 2.5m.

(2) The height of house wirings with insulated conductor with protection class not less than IP20 and house wirings with protection class not less than IP40 are not stipulated. The height of house wirings with AC voltage up to 42V and DC voltage up to 110V are not stipulated.

(3) In private halls (e.g. technical infrastructures of buildings) where only specialized staffs can access, the height of house wirings with protection class not less than IP20.

(4) In electrical halls of industrial enterprises, the height of house wirings with protection class not less than IP00 are not stipulated. In the places where house wirings with protection class of IP00 might be contacted by persons, barriers for protecting inadvertent contact shall be arranged.

(5) In the places where house wirings might be affected by mechanical damage, the protection shall be enhanced for the wirings.

(6) House wirings and barriers above the paths shall be installed at the height not less than 1.9m from the floors or working platforms.

(7) Auxiliary requirements are shown as below.

- The barrier nets of house wirings shall have the mesh not larger than 25mm square.
- The structures above house wirings shall be made of flame-resistant materials with flame withstand time not less than 0.25 hours.
- In the section where house wirings go through the roofs, wattles and walls, measures shall be provided for the wirings to avoid the fire and smoke from going from a hall to another hall.

Article 178. Conductors without Protective Covers

The distance from opened conductors without protective covers to crossing other conductors shall not be less than 10mm at intersection. In the cases that such distance is not secured, insulation layers shall be added on all conductors without protective covers

Article 179. Crossing with and Installation in Parallel Pipes

When house wirings cross or go nearby pipes, the wirings shall comply with the requirement in this article in Technical RegulationVol.1.

Article 180. Condition for Traversing Walls and Floors

1. Requirement for opened house wiring

(1) The section where opened house wirings go through walls or floors shall be in the form of pipes, boxes or holes etc.

(2) The slots between opened conductors or cables and pipes, boxes or holes (including reserve ones) shall be tightly sealed with non-flammable materials for preventing water penetration, accumulating and flowing into or going out through holes of walls or floors. The tight sealing means that the replacement or addition of conductors, and cables can be implemented. Heat withstand limitation of through-hole shall not be lower than that of walls or floors.

(3) Metal pipes, boxes and hoses inserted in opened house wirings shall be installed not to accumulate moisture.

2. Requirement for closed house wiring

Metal pipes, boxes and hoses inserted in closed house wirings shall comply with the requirements in item 1 (3) of this article as well as in article 183 in Technical RegulationVol.1 and this Guideline. Besides, metal pipes, etc. shall be tightly sealed (Refer to item 1 (2) in this article) and be used with boxes of one-piece from.

Article 181. Installation in Dry and Humid Halls

Opened house wirings shall be installed in consideration of situation of halls and comply with the requirements in this article in Technical RegulationVol.1.

Also, cable pipes shall comply with requirements in article 179 to 183 in Technical RegulationVol.1 and this Guideline.

Article 182. Limitation for Conductors and Cables Installed in Bundles

In the troughs, surface of supports, suspension wires, supporting bars or other supporting structures, conductors and cables with different forms (e.g. round or rectangular multiple layers) are permitted to be installed in the bundles (groups).

Conductors and cables in each bundle shall be tightened together.

Conductors and cables in form of multiple layers are permitted to be installed in a box regardless of the position.

Cross-sectional area of all conductors and cables counted by external diameters including the insulations and the sheaths shall not be more than 35% of internal cross-sectional area of a box without protective covers and 40% of internal cross-sectional area of a box with removable protective covers.

Article 183. Connection of Pipes, Boxes and Hoses

In clean and dry halls without vapor and gas negatively affecting the insulation and protective covers of conductors and cables, connection parts of metal pipes, boxes and flexible metallic hoses are permitted not to be sealed.

The connection parts of pipes, boxes and flexible metallic hoses as well as enclosures of electrical equipment, etc. shall satisfy the following requirements.

- In halls with vapor and gas which negatively affect the insulation and protective covers of conductors, outdoor and in places where grease, lubricant oil, water or emulsion can penetrate to the pipes, boxes and flexible metallic hoses, the connection parts shall be sealed. In these cases, the boxes shall have closed walls and covers. If the boxes are not solid type, they must be sealed.

The boxes which can be dismantled shall be sealed in the place where they are dismantled. Connections of metal hoses shall be conducted in the form shuts the gas off.

- In dusty halls, connections of conductors and cables shall be in form of sealed pipes, branch pipes, boxes and metal hoses to prevent them from the dusts.

Article 184. Prohibition of Installation inVentilation

Installation of closed house wirings at tunnels and channels shall comply with the requirements in this article in Technical RegulationVol.1.

Article 185. Installation in Roofed Halls

Installation of house wirings in roofed halls shall comply with the requirements in this article in Technical RegulationVol.1.

Article 186. Conductors in Roofed Halls

Conductors and cables of house wirings in roofed halls shall comply with the requirements in this article in Technical RegulationVol.1.

Article 187. Connections and Branches in Roofed Halls

Connections and branches of house wirings in roofed halls shall comply with the requirements in this article in Technical RegulationVol.1.

Article 188. Switching Devices in Roofed Halls

Switching devices in roofed halls shall comply with the requirements in this article in Technical RegulationVol.1.

Chapter 3-1-3 Outside Wirings with Voltage up to 1kV

Article 189. Requirements for Outside Wirings

1. Distance from conductor to support structure
   The distance from conductors of outside wirings with voltage up to 1kV to support structures shall not be less than 50mm.

2. Supplement requirements for installation near building

- Inlet terminal through walls of the buildings shall be installed in insulated pipes which can protect the water from flowing into and pooling in the buildings.
- The distance from conductors near the buildings to other subjects shall be ensured the values shown in the following table.

Table 189 Distance from conductors near the buildings to other subjects

Description of distance	Minimum distance (m)
- Distance from conductors to the ground in front of entrance o the buildings - Distance from conductors at inlet terminal to the buildings	2.75
- Distance between conductors on insulators at inlet terminals to the buildings - Distance from conductors to the protruding parts (veranda, etc.)of the buildings	0.2
-Vertical distance from conductors of the branches to inlet terminals -Vertical distance from conductors at the branches to the roof of the buildings	2.5*[1]
- Distance from conductors of branches to inlet terminals of the house - Distance from conductors of inlet terminals to the roofs	0.5*[2]

*[1]Note: Inlet terminals through the roofs of buildings are permitted to be made of steel pipes.

*[2]Note: In case of conductors on roofs of low buildings and without people, and the distance from the conductors to ground surface shall not be less than 2.75m.

Article 190. Distance to Firefighting Roads

The distance shown in this article in Technical RegulationVol.1 shall be ensured for outside wirings not to obstruct the firefighting activities or the traffic of the firefighting cars.

Article 191. Installation in Pipes and Boxes

Metal pipes, boxes or hoses inserted in outside wirings shall comply with the requirements in article 180 and 183 in Technical RegulationVol.1 and this Guideline.

Chapter 3-1-4 House and Outside Wirings with Voltages above 1kV up to 35kV

Article 192. Installation Height

The height shown in this article in Technical RegulationVol.1 shall be secured for house and outside wirings installed in production halls and electrical halls.

Article 193. Lightning Protection for Outside Wirings

Outside wirings shall comply with the requirements for protections against lightning in article 99 in Technical RegulationVol.1.

Article 194. Installation in Tunnels and Corridors

House and outside wirings installed in tunnels and corridors shall be installed in consideration of the following requirements.

1. Requirement for minimum gap
   Article 345 in Technical RegulationVol.1 and this Guideline shall be referred for the requirement for minimum gap.

2. Requirement for working corridor

   The width of working corridors of house and wirings shall be ensured the values shown in the following table.

Table 194 Minimum width of working corridor

Length of the wiring (m)	Arrangement of the wiring in working corridor	Minimum width (m)
150 and less	The wirings arrange at one side of working corridor	1.0
	The wirings arrange at both sides of working corridor	1.2
Exceeding 150	The wirings arrange at one side of working corridor	1.2
	The wirings arrange at both sides of working corridor	1.4

3. Requirement for barricade

   The height of the barricades shall comply with the requirements in this article in Technical RegulationVol.1.

4. Requirement for Earthing

   Fixed earthing system or structures for portable earthing system shall be arranged at the both edges and intermediate points of house and outside wirings. The number of intermediate points shall be selected so that the induced voltage between two adjacent points for earthing does not exceed 250V in the event of short circuit.

5. Requirement for lighting system

   Lighting systems in tunnels and corridors shall be supplied with electricity from two sources. Lamps from each source shall be arranged alternately.

   In tunnels and corridors where house and outside wirings without sheathes are installed, lighting system shall have protective covers (e.g. corridors in steel pipes) to ensure the safety for maintenance.

6. Requirement for ventilation

   Ventilations shall be performed so that the difference of ambient temperature between inside tunnels or corridors and outside does not exceeds 15°C.Vents of the ventilations shall be equipped with shutter, guard nets or protective shields.

7. Requirement for other structures

   Structures for arrangement of the wirings shall be made of flame-resistant materials. Reinforced concrete construction structures shall have flame-resistant rate not less than 0.75 hours, and steel pipes shall have flame withstand time not less than 0.25 hours.

   Any pipes are prohibited to cross each other.

   Communication equipment shall be installed in tunnels and corridors. Means and places for communication shall be determined by the special design.

Article 195. Installation of Soft Outside Wirings

Soft outside wirings shall be installed to comply with requirements in this article in Technical RegulationVol.1.

Article 196. Distance from Live Parts

The distance between conductors of soft outside wirings shall not be less than 6 times of the diameter of conductors.

Also, reference for the distance from live parts of soft outside wirings with voltage exceeding 1kV to 35kV are followings.

- Distance between live parts: 245 and 266
- Distance from live part to earthing: 275
- Distance from live part to buildings and other structures: 246 and 270
- Distance from live part to car roads: 293
- Distance from live part to railways: 291

Article 197. Condition for the Checking Distance

In consideration of the distance between phase conductors or conductors in multiple conductors, the maximum temperature shall be selected by the specification of the conductors.
The maximum temperature after the fault shall been taken by specification of the manufacturer, if that not, that shall been taken by 70°C.

Article 198. Expected Location of Earthing Connection for Extension of Soft Outside Wirings

The number of earthing connection points shall be determined by earthing means and the induced voltage which comply with the requirements in article 194 in this Guideline.

Article 199. Calculating Conditions for Soft Outside Wirings

In the calculation of soft outside wirings, normally the tension force in a phase shall not exceed 9.8kN.

Chapter 3-2 Power Cable Line Systems with Voltage up to 220kV

Chapter 3-2-1 The Selection of Cables

Article 200. Requirement for Different Environmental Conditions

For power cable lines with the length less than the length of a roll of cable traverse the area with different condition of installation environment, Cross-sectional area and structures of the cables shall be selected according to the harshest conditions

For power cable in long lines which installed under the water, the lines with maximum three different types of cross-sectional areas are permitted to be used in one cable route

Article 201. The Selection of Cables and Protection

1. Selection of sheath

(1) Cables of power cable lines laid underground or in the water shall have sheathes which can withstand mechanical load (the pressure of the water or the earth). Wherever the lines are installed, sheathes of the cables shall withstand mechanical load, frictional force for pulling the cables in cable blocks, etc. as well as the impacts of heat or chemical substances during operation or maintenance.

(2) Single-phase cable alternating current (AC) must not be used with protective shell made of magnetic materials.

2. Selection of protective measures

(1) Cable trough

Cable troughs of oil-filled cables with high pressure shall have protective measures against corrosion.

(2) Production hall, etc.

In the production workshops without the risk of mechanical damage, power cable lines are permitted to be used unarmored cables, but in the production workshops with high risk, the lines shall have protective armors or protective measures.

Unarmored cables are permitted to be installed at the height not less than 2m outside the cable structures. Unarmored cables installed at the height less than 2m shall have protective measures such as cable pipes, etc.

Cables with metallic sheaths installed in the cable structures or production halls shall not have external protective covers. Also, cables without metallic sheaths shall not be made of flammable materials.

Cables installed openly are prohibited to have flammable polyethylene insulations.

Metallic sheaths or parts of cables shall be covered by anti-corrosion coating made of non-flammable materials. If power cable lines are installed in corrosive environment, the cables which can withstand the corrosion from the environment shall be used for the lines.

3. Selection of cable

(1) Power station, etc.

In power stations, substations or important points of the power network, power the cables with metallic sheaths and covers made of non-flammable materials shall be use for cable lines. In power stations, cables with the sheaths made of flammable materials shall not be used for the lines.

(2) Cable block, etc.

For power cable lines installed in cable blocks and pipes, it is permitted to use unarmored cables with reinforced lead sheaths.

In the section of cable blocks or branches, it is permitted to use armored cables with lead or aluminum sheaths without external protective covers made of fibers for power cable lines.

For power cable liens installed in cable blocks, it is permitted to use cables with sheaths made of rubbers or polyvinylchloride.

(3) Unstable area

Power cable lines installed in unstable area shall be wire-armored cables or have protective measures against the movement of soil (e.g. surplus length of cables, compacting soil, driving stakes).

(4) Stream, etc.

Cables used for underground or underwater shall be selected as power cable lines traverse the stream, alluvial flat or canal in consideration of ducking them in the water or burying them in the ground. (Refer to 210 and 229)

(5) Bridge

Cables with aluminum sheathes shall be used for power cable lines installing along the bridge.

(6) Mobile equipment

The flexible cables which can withstand movement or bending many times shall be used for power cable lines supplying electricity to mobile equipment.

(7) Underwater

Power cable lines installed underwater shall be armored cables with steel strands. The connections of cables underwater are prohibited. Thus, it is prone to be used single core cables which are manufactured easily in long length.

Cables with double metallic covers or sheaths shall be used for the power cable lines in places such as the seas with big waves, fast-flowing rivers, banks tend to be eroded, and underwater with the depth from 40m to 60m.

Cables with rubber insulations in polyvinylchloride sheaths and cables with aluminum sheaths without sealing coats are prohibited to be used underwater.

Armored cables are permitted to be used in alluvial flats not larger than 100m with steady water flow of small rivers without any traffic.

(8) Laying

Cables, cable terminals and cable connection boxes shall be used not to exceed the permissible values stipulated in the specifications at vertical sections or slopes of power cable lines.

Power cable lines shall be arranged as below to absorb the shrinkage of the cables due to the heat generated by operation current of power cable lines.

- Cable: wavy laying and arrangement (arrangement like snake shape)
- Connection box: lay on the sliding rack

(9) Cable core

In power cable lines with voltage up to 35kV with 3 phase network, the three-cores cables shall be used preferentially for the lines or single-core cables shall be selected after calculating, comparing technical and economical benefits

The temperature increase of the sheaths due to induced current of neighboring cables shall be taken into account for cross-sectional area of single-core cables..

In above-mentioned cases, measures to identify each operation current of cables going in parallel, to ensure safety for person touching protective covering outer sheaths and to minimize the heat transferred to adjacent metallic sheaths shall be applied, and the cables shall be fixed by insulated clamps.

Article 202. Design for Oil-Filled Cables

The design for oil-filled cables shall comply with this article in Technical RegulationVol.1.

Article 203. Installation of Neutral Conductor

Neutral conductors shall be installed in compliance with requirements in this article in Technical RegulationVol.1.

Article 204. Oil Cable Systems

Oil cable systems shall comply with this article in Technical RegulationVol.1.

Chapter 3-2-2 Installation of Cable Connection Boxes and Cable Terminals

Article 205. Installation of Cable Connection Boxes and Terminals

1. Rubber cable

As for cables with flexible rubber insulations and rubber coats, the connection shall be performed by hot curing (autoclave curing) the rubber; and the connection points shall be covered by waterproof layers.

2. Number of connection boxes

Maximum number of cable connection boxes in one kilometer of power cable lines is shown in the following table.

Table 205 Maximum number of connection boxes per 1 km

Cable core	Voltage (kV)	Cross-sectional area (mm^2)	Referential maximum number of cable connection boxes
Single-core	Not stipulated	Not stipulated	2
Triple-cores	Exceeding 1 to 10	Up to 95	4
Triple-cores	Exceeding 1 to 10	From 120 to 240	5
Triple-cores	15, 22, 35	Not stipulated	6
Single and triple-cores	Not stipulated	Not stipulated	determined by design

Article 206. Requirements for Cable Connection Boxes

The lenqgth of section between connection boxes and installation positions of ones shall be determined in consideration of the following requirements.

1. Cable pulling tension should not exceed the permitted tension of cable.
2. Cable pulling tension should not exceed the permitted tension of the hook for pulling the cable in the cable room.
3. Cable pulling lateral pressure should not exceed permitted lateral pressure.
4. Length of a cable for one connected section should not exceed maximum winding length of a cable drum (Maximum winding length of a drum is limited by transportable weight considering the weight of a cable winded to a drum and tension capacity of cable pulling machine).

5. Sheath voltage to the ground should not exceed 50V.

Chapter 3-2-3 Special Requirements for Power Cable Lines

Article 207. Provisions against Fire

The requirements in this article in Technical RegulationVol.1 and this Guideline is applicable to the combination of cables connected to a power plant with capacity not less than 25MW, and switch equipment and transformer with voltage from 220kV to 500kV as well as special switch equipment and transformer.

Power cable lines shall comply with the following requirements for fire protection.

- In places where power cable lines are linked to switch equipment in closed room, opened switch equipment and cubicles, the lines shall be separately installed by the wall with flame withstand time not less than 0.75 hours.
- In places where power cable lines are linked to control panel of power plant, the lines shall be protected by the wall with flame withstand time not less than 0.75 hours.
- Cable cellars shall be separated from cable tunnels, cable storey and other cable structures with the wall made of non-flammable materials with flame withstand time not less than 0.75 hours.
- Cable wells shall be equipped with the entry and ladders or hooks for people going up and down.

Article 208. Cable Structures in Power Plants

Power cable lines installed in power plants shall comply with the following requirements.

- Cable structures for cable groups in power plants shall be separately arranged from technical equipment.
- Non-responsible people are prohibited to access to them.
- Cables with flame withstand time not less than 0.25 are permitted to be installed in the area of power generators. However, cable structures (oil tank, etc) which might be the source of fire shall be separately arranged by walls with flame withstand time not less than 0.75 hours.
- It is permitted to be installed outside exclusive cable structures only if power cable lines in the area of power generators are ensured not to be damaged due to mechanical actions, dust or sparks during repair for technical equipment, and ensured to be operated conveniently,.
- A path with flats shall be installed to access power cable lines at the height not less than 5m. The flats of path do not need to be installed for single-core cables or small cable groups up to 20, except the case that they need to be installed for quick replacement of the lines or the repair during the operation.
- If power cable lines are arranged outside except cable structures in the area of power generators, the route of the lines shall be selected by ensuring the performance of the cables.
- Cable tunnels and storeys for different cables linked to various power generators shall be divided to units or rooms for cable structures (cable tunnels, storeys, canals, troughs etc.), and sections which cables go through shall be separated by the wall with flame withstand time of 0.75 hours.

In places where power cable lines traverse compartments or roofs, the location shall be considered the convenience for replacement and installation of additional cables as well as the separating walls made of non-flammable and drillable materials with flame withstand time not less than 0.75 hours.

- In the case that power cable lines in power plants are long, the exits shall be arranged in every 50 m or less.
- Cable group in power plants shall be separately installed by the wall with flame withstand time not less than 0.75 hours from cable tunnels for power cable lines going out the power plants.

Article 209. Spare Cables

Combination of cables (power, control, signal cables, etc.) shall be divided into sub-groups depending on the site conditions and separately arranged each other.

Chapter 3-2-4 Cables Installed Underground

Article 210. Installation Underground

Power cable lines shall be protected from mechanical actions for whole length by the followings.

- The surface of cable canals of power cable lines with voltage less than 35kV shall be covered with concrete slabs with the thickness not less than 50mm.
- The surface of cable canals of power cable lines with voltage less than 35kV shall be protected with concrete slabs, brick layers lined horizontally along the lines or other hard materials. (Silica bricks, perforated or hollow bricks are prohibited to use.)
- Underground cables of power cable lines with voltage up to 22kV (except urban area, railways, car roads, tramways) buried in larger than 1m below the ground level are not required to be protected from mechanical impacts.

Article 211. Depth of Buried Cables

1) The distance from power cable lines with all voltages buried underground to foundations of buildings and construction structures shall not be less than 0.6m.
2) Power cable lines are prohibited to be arranged under foundations of buildings or construction structures. When power cable lines go through underground foundations, the specification of foundations shall comply with promulgated State regulations.

Article 212. Installation Nearby and Crossing Other Cable Lines

When power cable lines with voltage from 110kV to 220kV are arranged with communication lines in parallel, the impact of electro-magnetic fields to the communication lines shall be considered, in addition to the distance shown in Table 212 in Technical Regulation.

When power cable lines cross other cable lines, the distance of soil layers between the lines at intersection shall be not less than 0.5m. The distance between power cable lines with voltage up to 35kV and other cable lines are permitted to reduce the distance to 0.15m, if the power cable lines are protected by pipes or concrete slabs which are as long as whole intersected section and 1m longer than the section at both sides. Power cables shall be arranged under secondary or communication cables.

As for cable pipes inserted power cable lines and buried underground, the distance between the cable pipes and the distance from the cable pipes to other power cable lines or other structures, the same values specified for power cable lines without cable pipes. (Refer to Table 212 in Technical Regulation) shall be applied.

When power cable lines are arranged under the floors of workshops, the same values specified for underground power cable lines shall be applied to the distance between the line and the floor.

Article 213. Installation in Parallel to Other Objects

Power cable lines installed in parallel with other objects shall comply with the following requirements and the distance shown in this article in Technical RegulationVol.1.

1. Forest, garden, etc.

In power cable lines traversing the forest or tree planted area, the distance from the lines to the foot of trees shall be not less than 2 m. If local concerned parties agree and the lines insert in cable pipes, above-mentioned distance are permitted to be reduced. Also, in the gardens with small trees, the distance is permitted to be reduced to 0.75 m.

2. Pipelines

Power cable lines are prohibited to be arranged in parallel with the pipelines (water or gas pipeline, etc.) in superposition.

When power cable lines are installed in parallel with heat pipelines, the temperature of ground surrounding the lines shall not be increased exceeding the values in the following table.

Table 213 Temperature increase of ground surrounding cable

Voltage (kV)	Limitation of temperature increase
Up to 10	10°C
From 22 to 220	5°C

Article 214. Crossing Other Objects

Power cable lines cross other objects (railways or car roads, etc.) comply with the following requirements and the distance shown in this article in Technical RegulationVol.1.

- The angle between power cable lines and electrified railway shall be form 75 degrees to 90 degrees.
- Power cable lines installed under the dead-end roads, internal roads of enterprises and exclusive roads with little vehicle traffic are permissible to be installed underground directly.
- Cable blocks and pipes of power cable lines at intersection shall have reserve ones for maintenance. They are sealed at both edges.
- Power cable lines crossed tramways shall be installed in cable blocks or insulated pipes.

- Power cable lines crossed garages or parking lot shall be installed in cable pipes.
- Power cable lines traversed streams, water canals or alluvial flats shall be installed in cable pipes.

Article 215. Installation of Cable Connection Boxes

Connection boxes of power cable lines shall be installed in compliance with requirements in this article in Technical RegulationVol.1.

Article 216. Protection against Stray Electricity Currents

Power cable lines exposed to stay electricity current at dangerous level shall have the following countermeasures.

- The route of the lines shall be changed to the area with stay electricity current at non-dangerous level.
- In case that the route change is impossible, the lines shall use high anti-corrosion cables or have electrolytic protections shown in the following table.

Table 216 Electrolytic protection

Electrolytic protection	Applicable general cases
Anodic protection	Urban area (This system is adopted which causes little impact to other lines since urban area has low thermal resistance of soil, and there are many other lines adjacently)
Impressed current system	Mountain area (This system is effective in case of high thermal resistance of soil, and there are a little other lines)
Anodic protection and impressed current system	Long distance lines
Selective drainage corrosion	The place where cable lines can be easily connected to rails of electrical railway. (This system shall be considered the interference to other lines)

Article 217. Cable Pipes and Cable Blocks

Cable blocks and pipes of power cable lines shall comply with the following requirements.

- Materials of cable blocks and pipes shall be steels, cast irons, concretes, ceramics, plastic, etc., and be selected in consideration of underground water level, erosion and stray electricity current.
- Each phase of single-core cables shall be separately arranged in different pipes made of non-magnetic materials (concrete, etc.).
- The number and dimension of compartment of power cable lines and the distance between compartments shall be selected based on heat condition generated by the current applied to the cable, the ground temperature surrounding the lines, etc. The number of reserved compartment shall be not less than 15% of all operating ones. (however, the number shall be not less than one.)
- The slope of cable blocks and pipes shall not be less than 0.2%.
- Internal surface of cable blocks, pipes and troughs shall be flat and smooth to avoid the damage of protective covering outer sheaths while pulling cables.

Article 218. Structures for Cable Arrangement

Cable structures (Cable cellars, blocks and pipes and troughs) for laying and arrangement of power cable lines shall comply with the following requirements.

1. Cable cellars shall be installed to facilitate the laying and connection work of the cables at the following places.

- The points where cables placed in cable blocks change the direction of the route
- The points where cables placed in cable blocks need to connect them including the straight section. (For the positions of cable cellars, refer to item 2 in this article.)
- The points where cables go into the ground from cable blocks.

2. The distance between cable cellars shall be selected based on the permissible cable length for pulling the cable. The permissible cable length shall be considered together with the distance between connection boxes and the position of the boxes. (Refer to article 206 in this Guideline)
3. When the number of power cable lines with voltage up to 35kV is 10 or less, it is permissible to penetrate them into the ground from cable blocks directly. In this case, waterproof protection shall be applied to cable blocks.
4. Power cable lines going from cable blocks or pipes to the buildings or tunnels, etc. shall be arranged by the following measures.

- Direct arrangement into the building
- Arrangement in cable cellars or rooms in buildings or near the wall of buildings

5. The measures to prevent the water or small creatures (mouse, snake, etc.) from entering into the buildings or tunnels, etc.
6. In the place with high water level, power cable lines shall be arranged for outdoor distribution substations in troughs or cable boxes shown as below.

- Troughs (including the coves) shall be made of reinforced concrete.
- Troughs shall be arranged on support concrete pillars, and the tilt of troughs shall not be less than 0.2%.
- Troughs shall be arranged at the position not to obstruct the transportation or affect maintenance and operation of other equipment.

7. Cable racks are permitted to be arranged in cable canals in compartment of outdoor distribution substations. In this case, cables and cubicles do not need to be arranged in cable pipes but protective measures against mechanical action shall be applied to them.

Chapter 3-2-5 Installation of Power Cable Lines in Cable Structures

Article 219. Reserve Cable Structures

Cable structures shall have the reserve of approximately 15% of designed amount.

Article 220. Requirements for Cable Structures

1. Flame withstand time of cable structure

Cable structures shall be equipped with support structures with flame withstand time not less than the value shown in Table 220-1.

Table 220-1 Flame withstand time

Cable support structures	Flame withstand time (Hour)
Flame-resistant wall separate the compartment and other cable structures in cable tunnel, cellar, corridor, storey and bridge	0.75
Door and separating floor for electrical equipment specified in article 207 in this Guideline	0.75
Door and separating floor except the one mentioned above	0.60
Reinforced concrete structure (pole, console) supporting cable storey or outdoor cable corridor	0.75
Steel plate supporting cable storey or outdoor cable corridor	0.25
Cable bridge, cable corridor and support structure	0.75
Flame-resistant wall to divide into compartment in cable corridor	0.75

2. Dimension of cable structure

Cable structures shall be ensured the dimensions shown in the following table.

Table 220-2 Dimension of cable structure

Description of cable structures	Dimension
The distance between separating walls which divide long cable tunnel for oil-filled cable into sections with a door.	100m and less
The distance between separating walls which divide long cable tunnel for cables except oil-filled cable into sections with a door.	150m and less
The area of cable tunnel with double floor	600m2 and less
The distance between entrances of cable bridge or cable rack	150m and less
The distance from the foot of ladder or cable rack to entrance	25m and less
The distance between entrances of cable corridors which oil-filled cables are installed	120m and less
The distance between entrances of cable corridor which cables except oil-filled cable are installed	150m and less
The distance of each section of cable corridors which oil-filled cables are installed	120m and less*
The distance of each section of cable corridors which cables except oil-filled cable are installed	150m and less*

*Note: Outdoor corridors with closed sections do not need to follow those regulations.

3. Other requirement

1) Entrance and exit

The exits from cable structures shall be installed outward or toward rooms or workshops with fire fighting conditions at high level. The number and position of the exits shall be determined according to site conditions. However, the number shall be not less than two. Only one exit is permitted, if the length of cable structures is not more than 25m.

The entrance of cable structures shall be self-closing type and equipped with the packing. The exits shall be opened outward and be lockable. The exits shall be able to unlock from inside without the key. The doors between compartments of cable tunnel shall be opened toward the nearest exit.

The doors of entrance shall be installed so that strange people can not enter freely.

2) Ladder

Cable bridge and cable rack with technical platform shall equip the ladder for access.

3) Covering slabs

Cable canals and double floors in switch distribution substations or rooms shall be closely covered by removable covering slabs made of non-flammable materials. The covering slabs shall be arranged so that the equipment can be transported. In the hall placed electrical rotating machines, waved steel plates shall be used as the covering slabs.

Article 221. Requirements for Cable Tunnels, Canals and Other Cable Structures

1. Drainage

The slope of the bottoms of cable tunnels and canals toward water pits or water discharge canals shall not be less than 0.5%.

Automatic drainage pumps, which are operated depending on the water level, shall be installed in cable tunnels. Electrical motors and control devices to start equipment shall be able to be operated under wet conditions.

In outside cable canals at higher than underground water level, the bottoms of them are permitted to be constructed by pebble layer with the thickness from 10 to 15 cm paved on the compacted soil.

2. Slope roads

The tilt angle shall not more than 15 degree, whose slope roads are from a compartment to another compartment at different height. The stairs in a compartment of cable tunnels are prohibited to be installed.

The tilt angle of the slope roads between cable bridges and cable canals shall not be more than 15 degrees. In special cases, Stairs with tilt angle not more than 45 degree are permitted to be installed.

3. Covering slab

The weight of removal covering slabs shall not be more than 50kg. Removal covering slabs shall have hooks to lift them up.

4. Underground cable tunnel

Underground cable tunnels outside of buildings shall be covered by soil layers with the thickness of 0.5m.

5. Arrangement of other cable

Secondary cables, cables with steel belt of which cross-sectional area is not less than 25mm^2, as well as lead sheath cables without steel belt shall be arranged on cable racks in cable structures. Secondary cables without steel belt, lead sheath cables without steel belt and other cables without sheath and of which cross-sectional area is less than $16mm^2$, shall be arranged in troughs or on cable racks separated by plates.

Cable canals installed in the depth not more than 0.9m are permitted to arrange cables at the bottom directly, if one of the following means is applied to them.

- The distance between the group of cables with voltage exceeding 1kV and secondary cable group shall not be less than 100mm.
- Above-mentioned cable group shall be separated by the wall with flame withstand time not less than 0.25 hours.

6. Minimum distance between cables in cable structures

Minimum distance between cables in cable structures shall comply with the values shown in the following table.

Table 221-1 Minimum distance between cables in cable structures

<table>
<tr><th colspan="2" rowspan="2">Description of distance</th><th colspan="2">Minimum dimensions</th></tr>
<tr><th>In cable tunnels, corridors, bridges</th><th>In cable canals and double floors</th></tr>
<tr><td colspan="2">Height</td><td>1,800mm
(1,500mm*)</td><td>1,200mm and less</td></tr>
<tr><td colspan="2">Horizontal distance between cable racks arranged when cables are arranged at both sides</td><td>1,000mm</td><td>300mm for depth of 0.6m
450mm for depth exceeding 0.6m to 0.9m
600mm for depth more than 0.9 m</td></tr>
<tr><td colspan="2">Horizontal distance from cable rack to wall when cables are arranged at one side</td><td>900mm</td><td>Ditto</td></tr>
<tr><td rowspan="4">Vertical distance between horizontal cable racks*[2]</td><td>Up to 10kV</td><td>200mm</td><td>150mm</td></tr>
<tr><td>From 20 to 35kV</td><td>250mm</td><td>200mm</td></tr>
<tr><td>110kV and more</td><td>300mm
(250mm*[3])</td><td>250mm</td></tr>
<tr><td>- secondary cables
- communication cables
- power cables with cross-sectional area of $3x25mm^2$ and voltage less than 1kV</td><td colspan="2">100mm</td></tr>
<tr><td colspan="2">Distance between racks (consoles) along cable structure</td><td colspan="2">From 800mm to 1,000mm</td></tr>
<tr><td colspan="2">Vertical and horizontal distance between cables with voltage up to 35kV*[4]</td><td colspan="2">Not less than the diameter of cable</td></tr>
<tr><td colspan="2">Horizontal distance between control cable and communication cable*[4]</td><td colspan="2">Not specified</td></tr>
<tr><td colspan="2">Horizontal distance between cables with voltage of 110kV and more</td><td>100mm</td><td>Not less than the diameter of cable</td></tr>
</table>

*Note: Above figure applies to underground tunnel with the length not less than 100m in narrow place and with exit at the end and arranged cables with voltage up to 10kV and comply with the distance shown in the following table.

*[2]Note: Above distance applies to cable racks with effective length less than 500mm of support arms at straight routes.

*[3]Note: Above figure applies to cables with triangle arrangement.

*4Note: Above distance includes cables arranged in cable wells.

7. Minimum distance from cable rack, cable corridors to building and construction structures

The distance from cable rack, cable corridors to building and construction structures shall not less than the values shown in the following table.

Table 221-2 Minimum distances from cable rack, cable corridors to building and construction structures

Arrangement of Cable and structure	Structures	Description of distance	Minimum dimensions
Horizontal in parallel	Buildings and structures with closed walls	From cable bridge and corridor to building and structures walls	Nor specified
	Buildings and structures with holed walls	As above	2.0m
	Non-electrified railway in the plant area	From cable bridge and corridor to the nearest external point of the structure	- Cable bridge and corridor with human traffic: 1.0m - Cable bridge and corridor without human traffic: 3.0m
	Car roads in plant area and fire fighting roads	From cable bridge and corridor to external edge of drainage trench of road	2.0m
	Cable railway	From cable bridge and corridor to external edge of movable part	1.0m
	Pipeline placed on the ground	From cable bridge and corridor to the nearest part of pipeline	0.5m
	Overhead power line	From cable bridge and corridor to conductors	Refer to article 278
Vertical crossing	Non-electrified railway within the plant area	From the lowest point of cable bridge and corridor to surface of rail	5.6m
	Electrified railway within the plant area	From the lowest point of cable bridge and corridor to surface of rail	7.1m
		From the lowest point of cable bridge and corridor to the highest cable line or steel cable of touch net	3.0m
	Car roads in plant area and fire fighting roads	From the lowest point of cable bridge and corridor to surface of car road or fire fighting road	4.5m
	Pipelines placed on the ground	From cable bridge and corridor to the nearest part of pipeline	0.5m
	Overhead power line	From cable bridge and corridor to conductors	Refer to article 283
	Telephone line and radio line	As above	1.5m

Article 222.   Prohibition of Installation in Dangerous Places

In places where there is molten metal, liquid, or materials, power cable lines and cable structures shall be installed in compliance with the requirement in this article in Technical RegulationVol.1 for ensuring the safety of them and people.

Article 223.   Limitation of Heat Exposure from Heated Pipelines

1. Measures to prevent temperature increase due to heat pipeline
- Thermal insulation materials cover heat pipelines.
- Ventilation in cable structures

2. Limitation of maximum permissible current of cable

If air temperature in cable structures increases after above-mentioned measures are conducted, cable shall be limited the maximum permissible current not to exceed cable permissible temperature.

Article 224.   Fire Resistance and Firefighting in Cable Structures

1. Power cable lines installed in cable structures

1) Power cables shall be arranged under secondary cables and communication cables, and be separated by the partitions between power cables and the other ones. However, the partitions at intersected points and branch points are not required.

2) Power cables with voltage up to 1kV are permitted to be installed next to secondary cables.

3) Power cables with voltage up to 1kV shall be arranged over power cables with voltage exceeding 1kV, and be separated by the partitions between power cables with voltage up to 1kV and power cables with voltage exceeding 1kV.

4) Different power cables with voltage exceeding 1kV shall be arranged at different height and be separated by the partitions between them, which are connected to generators, transformers, etc. of the load of category I.

5) Above-mentioned partitions (Item 1), 3), 4)) shall be made of flame-resistant materials with flame withstand time not less than 0.25 hours. In cable canals with automatic fire extinguish systems or water spray systems, above-mentioned partitions (Item 1), 3), 4)) are not required.

6) Cable canals and cable corridors with partially covered do not require above-mentioned partitions (Item 1), 3), 4)). In this case, the distance between reserve cables (except power cables for the load of category I) shall be not less than 600mm. Cables in cable bridges shall be arranged at both sides of horizontal cable racks of main support structures (beam, hook, etc.), and cables in cable corridors shall be arranged at both sides of passage-way.

2. Requirement for oil-filled cable

Oil-filled cables shall be arranged in separate cable structures. If oil-filled cables are arranged under other cables and on horizontal cable racks with flame withstand time not less than 0.75 hours separately. Above-mentioned methods shall be also applied between oil-filled cables.

3. Countermeasures against fire

1) The level and quantity of automatic equipment of fire warning alarm and fire protection shall be specified based on approval instruction documents.

2) Fire cocks in cable bridges and corridors shall be arranged within 100m from all points in cable bridges and corridors.

Article 225. Requirement for Cable Wells

The drainage pits and pumps for pumping out rainfall and underground water shall be installed at bottom of cable wells, which comply with the requirements in article 221.

Cables and connection boxes in cable wells shall be arranged on cable racks, troughs or separate plates.

The covers of cable wells shall have the handle to be held.

Article 226. Installation of Oil-Filled Power Cable Lines

Oil-filled cable lines shall be installed in compliance with requirement by the manufacturer.

Article 227. Ventilation Equipment and Lighting Systems

Both natural and forced ventilations are permitted for the ventilations in cable structures (except cable storey, cellar), but they shall be independent for each compartment. In the calculation of ventilations in cable structures, the difference of air temperature between inside and outside shall not exceed 10°C. The flow of hot air in narrow and bending places is limited under this condition.

The ventilation equipment shall have the function (side board, chock valve) to block the air flow and to prevent the outside air flowing into cable structures in the event of the fire.

When cables are installed in cable rooms, the cables shall be taken attention to over-temperature of them due to the ambient air and impacts of technical equipment.

Chapter 3-2-6 Installation of Cable Lines in Production Halls, Water or Special Structures

Article 228. Installation of Cables in Production Halls

The distance between cables in production halls shall comply with the values shown in Table 221-1 in this Guideline.

When power cable lines go nearby pipelines in parallel in production halls, the distance between the line and the pipeline shall not be less than the values shown in the following cable.

Table 228 Minimum distance between cable and pipeline in production hall

Type of pipeline	Minimum distance (m)
Liquid fuel and gas pipelines	1.0 (0.5*)
Pipeline except above-mentioned pipeline	0.5

*Note: Above figure applies to the cables which is installed in narrow place and have protection against mechanical action with the length as long as approximate section and 0.5m longer than the section at both sides.

When power cable lines cross the passage, the lines shall be arranged at higher than 1.8m.
Power cable lines under the floor and double floor shall be installed in troughs or pipes without compact arrangement.
In places where power cable lines go through walls or floors, pipes and holes for supporting the lines can be installed and opened slots shall be sealed with flame-resistant materials.

Article 229. Installation of Cables in Water

1. Arrangement at bottom

   Power cable lines shall be arranged at the bottom of rivers, streams or canals where the cables do not inflected due to its weight and whose sharply acicular parts are smoothed.

   Power cable lines shall be avoided to be arranged at reefs, abyss and place with underwater obstacles as much as possible. If it can not be avoided, the lines shall be installed in cable canals or troughs.

   When oil-filled cables with voltage from 110kV to 220kV cross the rivers and streams as water transportation, the lines shall be installed in cable canals and be covered by sand on the top of the canals to protect against mechanical damage.

2. Depth at bottom

   The depth of power cable lines at the bottoms of rivers, streams or canals shall comply with the values shown in the following table.

Table 229-1 Depth at bottom

Description of place	Minimum depth (m)
Banks and shallow places where ships or boats pass when oil-filled cables traverse at rivers, streams and canals.	2.0
Banks and shallow places where ships or boats pass when cables except cables traverse at rivers, streams and canals.	1.0
Dams and reservoirs whose bottoms are dredged periodically.	Depth agreed by reservoir management agency

3. Distance between underwater cables

   The distance between cables of power cable lines underwater shall comply with the values shown in the following table.

Table 229-2 Distance between underwater cables

Description of distance	Minimum distance
Distance between cables installed at the bottoms of rivers, streams and canals.	0.25m
Distance between underwater cables.	Specified by the design
Distance between above-mentioned cable and cable of other lines installed in parallel.	5.0m
Distance between separated phases of cables installed underwater with the depth exceeding 15m or flow speed exceeding 1m/s.	Specified by the design
Horizontal distance between cables installed at the bottoms of rivers, canals, reservoirs and lakes and pipelines (oil, gas, etc.)	Specified by the design (50m* at least)

*Note: Above distance are permitted to be reduced with agreement between cables and pipelines of management units.

4. Requirement for brink

   Power cable lines going into the water at places without complete embankment shall have surplus length of 10m at rivers or streams and 30m at the sea.

   Cable cellars shall be constructed at the place where power cable lines go into the water.

   Power cable lines at the embankments and shores shall be installed in cable pipes. The cable pipes shall be tilted and reinforced firmly in a cable cellar above the bank as well as at 1m or deeper from the bottom of the water level.

   When power cable lines traverse the area where the boundary between water flow and bank, and the lines are affected by erosion, banks near them shall be consolidated to protect from erosion and flood (stake driving, dike construction, etc.).

Article 230. Installation of Cables under the Sea

For power cable lines are installed under the sea, cables shall be used armored cables covered by galvanized steel strands with the diameter not less than 6mm, or be installed in cable pipes.

Sediment at the bottom of the sea or the beach does not affect the cable due to tidal or wave.

Section of power cable lines at the shore shall be installed that human can not touch them easily and they can not be affected by the natural environment such as wind or rain.

Article 231. Prohibition of Crossing Other Cables in Water

If power cable lines are forced to cross with other power cable lines in the water, the solutions shall be agreed with by the manufacture and design agency mutually.

Article 232. Warning Plates on Banks

Warning signs for power cable lines on banks shall be installed in compliance with the requirements in this article in Technical RegulationVol.1.

Article 233. Installation of Cables in Special Structures

1. Bridge

When power cable lines go along the bridges made of stone, reinforced concrete or steel, the lines shall be arranged under the pedestrian ways of the bridges and be installed in troughs or cable pipes made of flame-resistant materials. These cable pipes shall have protections to minimize the direct rain on them. In addition, power cable lines installed along bridges made of reinforced concrete or steel shall be insulated from metallic parts on bridges.

When power cable lines traverse expansion of bridge and places between structures and abutment, the lines shall be protected from mechanical damage.

Oil filled cables are prohibited to be installed along bridges.

2. Wooden structure

Power cable lines along wooden structures (bridge, berths, jetties, etc) shall be installed in cable pipes made of steel or flame-resistant materials.

3. Dam, dyke, wharf

Power cable lines installed along dams, dykes, wharves, jetties or directly in soil channels shall be covered with soil layers with the thickness not less than 1m.

Chapter 3-3 Overhead Power Line Systems with Voltage up to 500kV

Chapter 3-3-1 Power Conductors and Lightning Conductors

Article 234. Requirements of Conductors with Voltage up to 1kV

The cross-sectional area of conductors of overhead power lines with voltage up to 1kV shall not be less than the values shown in Table 234 in this article in Technical RegulationVol.1.

Article 235. Conductor Connections

1. Strength of connection

The mechanical tensile strength of conductor connections shall not be less than 90% of traction breaking strength of conductors.

2. Connection to post-type insulator

Conductor shall be connected to post-type insulators by fasten wires or dedicated locks.

For the exceptional regulations of conductor connections, refer to article 271, 275, 278, 290, 292and 298 in Technical RegulationVol.1 and this Guideline.

Article 236. Condition of Sag

The sag of conductors of overhead power lines shall be determined according to the conditions shown in this article in Technical RegulationVol.1.

Article 237. Requirements for Conductors with Voltage exceeding 1kV

1. Multiple conductors

The phases of overhead power lines with voltage exceeding 1kV are permitted to be used with single or multiple conductors. The cross-sectional area, the number of multiple conductors and the distance between multiple conductors shall be determined by the followings condition.

- Cross-sectional area: Mechanical strength according to condition around the lines and transmission capacity
- Number of multiple conductors: Transmission capacity and corona noise.
- Distance between multiple conductors: Electromagnetic force in the event of short circuit and size of spacers

2. Additional requirement

(1) Corona loss

Corona loss is calculated by the following formula.

$$P = \frac{241}{\delta}(f + 25)\sqrt{\frac{d}{2D}}(E - E_0)^2 \times 10^{-5} \quad \text{(kW/km)}$$

P : Power loss of one conductor with the length of 1 km (kW)

E : Effective value of voltage to ground (kV)

d : Diameter of conductor (cm)

D : Distance between multiple conductors (cm)

f : Frequency (Hz)

$$\delta = \frac{0.2892p}{273 + t}$$

δ : Relative density of air

p : Barometric pressure (hPa)

t : Temperature of air (°C)

$$E_0 = \frac{30}{\sqrt{2}}\delta^{\frac{2}{3}}(1 + \frac{0.301}{\sqrt{r\delta}}) \quad \text{(kV/cm)}$$

E_0 : Corona critical voltage (kV)

r :Radius of conductor (cm)

(2) High frequency interference and wireless radiobroadcast

For high frequency interference and wireless radiobroadcast, refer to article 288 in Technical RegulationVol.1 and this Guideline.

(3) Impact of elector-magnetic field

For impact of electro-magnetic field, refers to article 287 in Technical RegulationVol.1 and this Guideline.

(4) Calculation for conductor and lightning conductor

Calculations for conductors and lightning conductors of overhead power lines shall be done based on the specification for them or existing standards.

Article 238. The Selection of Lightning Conductors

1. Check for thermal stability of lightning conductor
   For the check for thermal stability of lightning conductors, refers to Annex II.2.3
2. OPGW (Composite fiber-optic ground wire)
   OPGW shall be selected based on mechanical strength and thermal stability as it applied to normal lightning conductors.

Article 239. Calculation Condition for Conductors and Lightning Conductors

Permissible stress of conductors and lightning conductors shall not be more than the values shown in the following table.

However, the stress at the highest fixed point including large crossing spans shall not be more than 110% of the values shown in the following table for aluminum conductor steel reinforced and 105% of ones for other conductors.

Table 239 Ratio of tensile permissible stress to tensile breaking stress of conductor and lightning conductor

Conductor and lightning conductor	Cross-sectional area (mm^2)	Ratio of tensile permissible stress to tensile breaking stress	
		Maximum external load at minimum temperature	At annual mean temperature
Aluminum conductor	From 16 to 35	35 (40*1)	25
	From 50 to 70	40	
	95	40	
	120 and more	45	
Aluminum alloy conductor	From 16 to 95	40	30
	120 and more	45	
Steel lightning conductor	Not stipulated	50	30
Aluminum conductor steel reinforced and aluminum alloy conductor steel reinforced	From 16 to 25	35	25
	From 35 to 95	40	
	120 and more (A:C=6.11-6.25)	40 (50*2)	
	120 and more (A:C=4.29-4.39)	45 (50*2)	
	150 and more	45 (50*2)	
Copper conductor	Not stipulated	50 (40*)	30

Note : *1 The above values can be applied to overhead power lines which cross other structures in the populated areas.

*2 The above values can be applied to overhead power lines which are calculated by wind pressure that is not less than $1,000N/m^2$.

Article 240. Requirements against Rust

1. Places where may be exposed to rust
   The places where may be exposed to rust means coastal areas, salty rivers and lakes, chemical manufacturers, etc.
2. Anti-rust safety distance
   The distance from overhead power lines with voltage exceeding 1kV to the place where may be exposed to rust shall not be less than 5 km for coastal areas and 1.5km for chemical manufacturers.

Article 241. Protection against Vibration

Conductors and lightning conductors of overhead power lines with voltage exceeding 1kV whose stress at annual mean temperature are not less than the values shown in the following table shall be protected from vibration,. However, the sections of overhead power lines with voltage exceeding 1kV which are protected from horizontal action by wind are excepted (along the valleys or through the forests).

Overhead power lines with multiple conductors not less than three in one phase are not required to be protected from vibration in the cases that the stress at annual mean temperature is not more than 67.5N/mm^2 ,and the distance between spaces is not more than 60m, and the span-length is not more than than 500 m.

Table 241 Judgment of vibration protection

Span-length (m)	Type of conductor or lightning conductor	Cross-sectional area (mm^2)	Stress of conductor or lightning conductor (N/mm^2)
From 120 to 500	Aluminum conductor	Not stipulated	40 and more
	Aluminum conductor steel reinforced and Aluminum alloy conductor steel reinforced	Up to 95	60 and more
	Ditto	120 and more	50 and more
	Steel lightning conductor	Not stipulated	240 and more
Exceeding 500	All conductor and lightning conductor	Not stipulated	All

Article 242. Phase Divided Conductors (Multiple Phase)

Multiple conductors within the span or at jumper parts shall be appropriately secured the distance between the conductors by spacers which the distance between the spaces in the span does not exceed 75m.

Chapter 3-3-2 Arrangement of Power Conductors and Lightning Conductors

Article 243. Arrangement of Conductors, Neutral Conductors and Equipment

Conductors of overhead power lines on poles are permitted to be arranged at any configure.

Article 244. Distance between Conductors in the Same Line

1. Minimum distance between conductors with voltage up to 1kV

The distance between conductors of overhead power lines with voltage up to 1kV shall not be less than the values shown in the following table.

Table 246 Minimum distance between conductors with voltage up to 1kV

Span-length (m)	Conductor	Minimum distance (m)
Up to 30	Insulated conductor and cable	0.10
	bare conductor	0.20
Exceeding 30	Insulated conductor and cable	0.15
	bare conductor	0.30

2. Minimum distance between conductors with voltage exceeding 1kV

The distance between conductors of overhead power lines with voltage exceeding 1kV shall be determined in consideration of the operating conditions (refer to 128) in the span and permissible insulation distance (refer to 254) between the conductor and parts of the poles.

3. Distance between conductors with suspension-type insulators with voltage not less than 35kV

(1) Horizontal distance

The horizontal distance between conductors of overhead power lines with suspension-type insulators with voltage not less than 35kV shall not be less than the values calculated by the following formula according to operating conditions in the span.

$$D = \frac{U}{110} + 0.65\sqrt{f + \lambda} \quad \text{(m)}$$

D : Horizontal distance between conductors (m)

U : Nominal voltage (kV)

f : Calculated maximum sag (m)

λ : Length of insulator string (m)

(2)Vertical distance

The vertical distance between conductors shall not be less than the values calculated by the following formula.

$$D = \frac{U}{110} + 0.42\sqrt{f} \quad \text{(m)}$$

The symbols mean the same as above

(3) Not horizontal or vertical distance

If two conductors are installed neither horizontally nor vertically, the distance between them shall not be less than the values calculated by the following formulas.

$$D = \frac{U}{110} + 0.65\sqrt{f + \lambda} \quad \text{(m) When the difference of height of conductors } h < \frac{U}{110}$$

$$D = \frac{U}{110} + 0.43\sqrt{f} \quad \text{(m) When the difference of height of conductors } h \geq \frac{U}{110}$$

4. Distance between conductors with post-type insulator with voltage of 35kV and between conductors with voltage of 22kV

At overhead power lines with post-type insulators with voltage of 35kV and lines with voltage of 22kV, the distance between conductors shall not be less than the values calculated by the following formula.

$$D = \frac{U}{110} + 0.45\sqrt{f} \quad \text{(m)}$$

Symbols mean the same as above

Article 245. Distance between the Nearest Conductors of Multiple Circuits

The distance between the nearest conductors of double circuits on the pole shall comply with the requirements in this article in Technical RegulationVol.1.

Article 246. Distance from Live Parts on Poles

If independent power station is connected to overhead power lines with voltage not less than 110kV, the structures of poles shall comply with the requirements in this article in Technical RegulationVol.1 so that repairing works can be carried out without interrupting of the lines.

Article 247. Installation of Conductors with Different Voltages

1. Installation of overhead power lines with different voltages on the same pole
   Overhead power lines with voltage up to 35kV and those with voltage up to 1kV are permitted to be installed on the same pole in compliance with all of the following requirements.
   - Overhead power lines with voltage up to 1kV shall follow the conditions of mechanical calculations as applied to lines with higher voltage.
   - Overhead power lines with voltage up to 35kV shall be arranged at higher than lines with voltage up to 1kV. Also, the distance between two lines with different voltage shall be exceeding 2 m for bare conductors and exceeding 1 m for insulated conductors and cables.
   - Double post-type insulators shall be applied for overhead power lines with higher voltage at each fixed position.
2. Limitation of inducted voltage on the same pole
   The isolated or not directly grounded neutral voltage of overhead power lines with voltage up to 35kV due to electro-static and electro-magnetic induction under normal operation shall not be more than 15% of the voltage of the lines with lower voltage, within the section where overhead power lines with voltage up to 35kV are installed at the same pole with higher voltage lines. There is no requirement on overhead power lines directly grounded being inducted by lines with higher voltage.

Chapter 3-3-3 Insulators

Article 248. Suspended Insulators

1. Insulators used at special points

   Insulators (multi-stage insulators or special insulators) shall be used at branch points, etc. of overhead power lines with voltage up to 1kV. The neutral conductor shall be connected to insulators.

   Suitable post-type insulators are permitted to be used at transpositions or near arresters, circuit breakers or disconnectors of overhead power lines with not less than 110kV.

As for poles with appropriate insulated composite arms, it is not necessary to use insulators.

   As for overhead power lines with voltage up to 35kV, both post-type insulators and suspension-type insulators are permitted to be used.

2. Number of suspension insulator bowl

(1) Suspension-type insulator bowls of overhead power lines with voltage up to 35kV

The number of suspension-type insulator bowls at one insulator string of overhead power lines with voltage from 6kV to 35kV shall be selected as below (creepage distance of each bowl shall not be not less than 250mm.).

- Up to 10kV: 1 bowl
- From 15kV to 22kV: 2 bowls
- 35kV: 3 bowls

The number of suspension-type insulator bowls at one insulator string and post-type insulators are permitted to be selected independent of altitude of the lines.

The requirements for suspension-type insulator bowls of overhead power lines with voltage of 15kV and directly grounded neutral shall be selected as those for the lines with voltage 10kV and isolated neutral.

(2) Suspension-type insulator bowls of overhead power lines with voltage from 110kV to 500kV

The number of suspension-type insulator bowls at one insulator string of overhead power lines with voltage from 110kV to 500kV at altitude up to 1,000m shall be calculated by the following formula. Calculated number shall be rounded up to the nearest integer.

$$n = \frac{d \cdot U_{\max}}{D}$$

n : Number of suspension-type insulator bowls at one insulator string

d : Selective creepage distance (mm/kV)

- 12.7mm /kV: Very light polluted environment
- 16mm/kV: Light polluted environment
- 20mm/kV: Medium polluted environment
- 25mm/kV: Heavy polluted environment
- 31mm/kV:Very heavy polluted environment

$U_{\max}$: Maximum operating voltage (kV)

D : Creepage distance of one suspension-type insulator bowl of the specification (mm)

When a type of suspension insulators are selected for each insulator string with creepage distance longer than 2.3 times of designed creepage distance of insulator string in normal operating voltage condition, the bowls of insulators shall be added according to the calculated creepage distance. For polymers insulator, the creepage distance shall be selected to the same length of one of ceramic insulators or glass insulators. Requirement in details shall refer to IEC 60815-3-2008/3.

3. Additional requirements for the insulation hanging bowl

(1) The number of all types of suspension-type insulator bowls at each strain insulator string of overhead power lines with voltage up to 110kV and 500kV shall be one bowl more than these in support insulator string., The number of suspension-type insulator bowls in each strain insulator string of overhead power lines with voltage of 220kV and these in support insulator string are the same.

(2) For the pole with the height over 40m in the large cross span, they shall be installed with additional bowls of suspended insulators in each insulator string

- One insulator on overhead power lines equipped with lightning arresters at the crossing section.
- One insulator for every additional 10m to the height of 40m poles with lightning conductors.

e.g. A40m pole: X insulators
A50m pole: X + 1 insulator
A60m pole: X + 2 insulators

(3) For overhead power lines with voltage up to 110kV traversing areas at altitude exceeding 1000m to 2,500m and overhead power lines with voltage from 220kV to 500kV traversing areas at the altitude exceeding 1,000m to 2,000m, the number of suspension-type insulator bowls in insulator string shall be added to one more than the number shown in item 3-(1) and 3-(2) in this article.

For overhead power lines traversing the area (near industrial enterprises, coastal areas, etc) which is severely polluted, the number and type of insulators shall be selected base on the actual conditions.

Article 249. Mechanical Strength of Insulators

1. Safety coefficient of insulator with voltage up to 1kV

Mechanical safety coefficient (the ratio of breaking stress to maximum standard load acting on insulator) of insulators shall not be less than 2.5.

Mechanical safety coefficient of feet of insulators and hooks shall not be less than 2.0.

2. Safety coefficient of insulator with voltage exceeding 1kV

Safety coefficient of post-type insulators (the ratio of destructive stress to maximum standard load acting on insulator) and the one of suspension-type insulators (the ratio of electro-magnetic strength to maximum standard load acting on insulators) shall not be less than 2.7 in normal operating conditions and not less than 5.0 at annual mean temperature.

Safety coefficient of feet of insulators shall not be less than 2.0 in normal conditions, and not be less than 1.3 in fault conditions.

Safety coefficient of suspension-type insulators of overhead power lines with voltage of 220kV in fault conditions shall not be less than 1.8, and that of the one with voltage of 500kV in fault conditions shall not be less than 2.0.

The contents shown in article 258 in this Guideline shall be referred for the force acts on suspension-type insulators.

3. Special requirement for overhead power lines cross car roads etc.
   When overhead power lines cross car roads of class I and II, car roads in urban areas, railways and water ways with ship or boat traffic, insulators of the lines at intersection shall be double insulators.

Chapter 3-3-4 Power Line Accessories

Article 250. Accessories

Conductors of overhead power lines shall be fixed to suspension-type insulators by support or anchor locks, and to post-type insulators by dedicated straps or clamps.
It is permitted to use fixed-type and slide-type support locks. Conductors and lighting conductors in large overcrossing span are permitted to be suspended by special pulleys or locks.
Conductors of different phases on the same poles as well as conductors of one phase on different poles are permitted to be fixed by different support locks (fixed-type and slide-type).
Lightning conductors on support poles shall be fixed by fixed support locks. Conductors on anchor poles shall be fixed by support locks.
Conductors and lightning conductors of overhead power lines with voltage not less than 110kV shall be fixed by dedicated locks, and it is permitted to be fixed by bolt clamps.
Mechanical safety coefficient (the ratio of destructive mechanical stress to the maximum load acting on accessories) of accessories shall not be less than 2.5 in normal operating conditions and not less than 1.7 in fault operating conditions.
The force acting on accessories shall be determined by the contents shown in article 258 in this Guideline.

Chapter 3-3-5 Overvoltage Protection

Article 251. Atmospheric Overvoltage Protection

1. Protection for overhead power lines with voltage up to 35kV
   Overhead power lines with voltage up to 35kV are not required to be protected for the whole length of them from lightning by lightning conductors. Poles of the lines shall be earthed in compliance with the requirements in article 554 in Technical RegulationVol.1 and this Guideline.
2. Protection in the substation
   Overhead power lines with exceeding 1kV in the section where they traverse substations shall be protected against atmospheric overvoltage.
3. Shielding angle (Protection angle)
   Lightning conductors shall be installed in compliance with the following requirements.

   (1) The shielding angle of single metallic or reinforced concrete poles with one lightning conductor of overhead power lines with voltage exceeding 1kV shall be not more than 30 degrees.

(2) The shielding angle for the outer edge power conductor arranged horizontally on single metallic pole with two lightning conductors of overhead power lines with voltage exceeding 1kV shall not be more than 20 degrees.

(3) The shielding angle for the outer edge power conductor of overhead power lines with voltage exceeding 1kV on reinforced poles with gantry shape shall not be more than 30 degrees.

(4) The distance between two lightning conductors of overhead power lines with voltage exceeding 1kV at the top of a pole shall not be more than 5 times of vertical distance between the power conductor and the lightning conductor.

(5) The value of shielding angle to be designed is permitted to be reduced to not more than the above-mentioned values depending on the lightning days, topography of the area where the overhead power line with voltage exceeding 1kV traverse, the height of poles and importance of the line.

4. Vertical distance between power conductor and lightning conductor

The minimum vertical distance against atmospheric over-voltage protection between power conductor and lightning conductor of overhead power lines with voltage exceeding 1kV without consideration of the swing of both conductors due to wind shall not be less than the values shown in the following table.

Table 251 Minimum distance between power conductor and lightning conductor

Span-length* (m)	Minimum distance (m)	Span-length* (m)	Minimum distance (m)
100	2.0	700	11.5
150	3.2	800	13.0
200	4.0	900	14.5
300	5.5	1,000	16.0
400	7.0	1,200	18.0
500	8.5	1,500	21.0
600	10.0	-	-

*Note: If the span-length is in between the above values, interpolation method can be applied.

5. Earthing of lightning conductor

If the case that short circuit with the current more than 15kA might occurs on overhead power lines of overhead power lines with voltage exceeding 1kV, lightning conductors with cross-sectional area not more than 50mm^2 shall be earthed by a conductor connected in parallel with the locks.

Article 252. Additional Lightning Conductor Requirements

Lightning conductors of overhead power lines with voltage exceeding 1kV shall be earthed at all poles. However, lightning conductors are permitted to be fixed to insulators with the gap, if inducted electro-magnetic force and current are not more than the permissible values.

When OPGW are arranged in parallel with lightning conductors without optical fiber cables, all lightning conductors shall be earthed at all poles.

Article 253.   Lightning Protection

Metal parts of cables connected to overhead power lines shall be grounded.
Lightning protective equipment shall be installed at the location shown in the following table:

Table 253   Installed place of lightning protection

Lightning protection	Installed place
Lighting Arrester	Step voltage regulator Recloser Both Side of the underwater cable Tapping point of the Substation Power lines with high voltage at every 300m
Grounding conductor	Power lines with high voltage at every 300m
Insulation gap	Enhanced insulator (Ex. double insulation)
	ZnO cut out
Arcing horn	Along the main road

Article 254.   Insulation Distance

Correction of minimum insulation distance by altitude

On overhead power lines with voltage exceeding 1kV traverse at altitude area, the minimum insulation distance shown in Table 254 in Technical RegulationVol.1 shall be increased by 1.4% for every additional 100m once it exceeds 1,000 m.

Article 255.   Minimum Distance between Conductors at Branch or Phase Transposition Pole

The minimum distance between conductors at special poles (transposition or branch poles, etc.) of overhead power lines with voltage exceeding 1kV shall not be less than the values shown in Table 255 in Technical RegulationVol.1.

Chapter 3-3-6   Poles

Article 256.   Kinds of Poles

1. Kind of poles
  (1) Support poles shall be arranged between two straight anchor poles. These poles do not need to bear the force along the overhead power lines in normal conditions.
  (2) Anchor poles shall be arranged at anchor points in straight sections of the overhead power lines and at intersection with other structures. These poles shall bear the difference of forces between front and back spans in normal conditions, if any.
  (3) Corner poles shall be arranged at bending points of the route of overhead power lines. These poles are permitted to be utilized as support and anchor poles. These poles shall bear combined force in next spans by bisector of the route of the lines.
  (4) Dead end poles (breaking poles) shall be arranged at the beginning and end of overhead power lines. These poles shall bear the force which all conductors are pulled toward one side.

(5) Branch pole shall be arranged at points where overhead power lines branch two or more directions.
(6) Crossing poles (intersection poles) shall be arranged at points where two or more different overhead power lines cross each other.
(7) Transposition poles shall be arranged at transposition points of overhead power lines.
(8) Special poles shall be arranged at special points except the points of above-mentioned poles.

2. Other requirement for pole

- Guys are permitted to be used for all poles depending on site conditions except the place where they obstruct the traffic.
- Site locations for anchor poles shall be determined based on operation and installation conditions.
- The anchor section of overhead power lines with conductors with cross-sectional area not more than 185mm^2 installed by fixed or slide locks shall not be more than 5km, and the section with cross-sectional area more than185mm^2 shall not be more than 10km.
- The span-lengths of conductors connected to fixed locks or post-type insulators shall be determined by site conditions of overhead power lines.

Article 257. Anchor Wires

Anchor wires (guys) are permitted to be connected to underground anchor foundations, bricks, stones, reinforced concrete buildings and structures.

Anchor wires shall be selected by the calculations according to the load, and cross-sectional area of them shall not be less than 25mm^2.

Article 258. Calculation of Poles

1. Calculation on pole of overhead power line with voltage up to 1kV

(1) Support pole: The load to the route of the lines and poles in horizontal direction due to wind perpendicular.
(2) Anchor pole: The load to the route of the lines and poles in horizontal direction due to wind perpendicular, and the load along the route of overhead power lines in horizontal direction due to the difference of tension of conductors between front and back spans.
(3) Corner pole: The load in horizontal direction due to tension of conductors and the load in horizontal direction due to wind acting conductors and poles.
(4) Dead end pole (breaking pole): The load along the route of overhead power lines in horizontal direction due to tension of conductors to one side.

2. Calculation on pole of overhead power line with voltage exceeding 1kV

(1) Anchor pole: The load along the route of overhead power lines in horizontal direction due to the difference of tension of conductors and lightning conductor between front and back spans.
(2) Poles with double circuits: The load shall be checked, which only one circuit is installed in all conditions. It shall be checked the load in conditions for installation and erection of poles as well as condition for installation of conductors and lightning conductor.

3. Normal condition for pole of overhead power lines with voltage exceeding 1kV

Poles in normal conditions shall be calculated in the following conditions.

- Conductors and lightning conductors are not broken and the maximum wind pressure is taken into account (q_{max}).
- When representative span-length of corner poles is shorter than ultimate one, the minimum temperature (Tmin) shall be considered.
- Dead end poles (breaking pole) shall be calculated in the condition which tension of all conductors and lightning conductors is applied to one side of them, and the conditions as there is no conductors and lightning conductors in opposite side such as spans beside substations and adjacent to large overcrossing span.

4. Fault condition on pole of overhead power lines with voltage exceeding 1kV

(1) Support pole

The maximum bending torque and maximum twisting torque at support poles with conductors fixed by suspension-type insulators shall be calculated in the following fault conditions.

1) Breakage of conductor and lightning conductor
- One and more conductors of one phase (at any number of conductors on a pole) are broken. Lightning conductors are not broken.
- All conductors are not broken. One lightning conductor is broken.

2) The load which conductors and lightning conductors are not broken shall be considered.

3) Standard tension of single conductor by strain insulation set, in the case that one conductor is broken, is stipulated in the following talbe. However, for other poles (poles made of new materials, metal poles with flexible structures, etc.) than which shown in the following table, it shall be calculated with the coefficient depending on the bending level on poles within the range shown in the following table.

Table 258 Fault condition for single conductor

Pole	Cross-sectional area (mm^2)	Tension*
Rigid pole (free-standing metal pole, reinforced concrete poles with guy, other rigid pole)	Up to 185	0.50 T_{max}
	240 and more	0.40 T_{max}
Reinforced concrete pole	Up to 185	0.30 T_{max}
	240 and more	0.25 T_{max}

*Note: T_{max} means the maximum tension of single conductor in fault condition.

4) In fault condition that multiple conductors in one phase on support poles of overhead power lines with voltage up to 220kV are broken, standard tension of one conductor in multiple conductors shall be determined by applying the same condition as single conductor in one phase of overhead power lines. Standard tension in one phase shall be multiplied the number of conductors in one phase by the following coefficient.
- Two conductors in one phase: 0.8
- Three conductors in one phase: 0.7
- Four conductors in one phase: 0.6

5) Standard tension of lightning conductors shall be 0.5TLmax. TLmax means the maximum tension of lightning conductor in fault condition

Standard tension in the case that lightning conductors of overhead power lines with voltage exceeding 1kV on reinforced concrete poles without guys are broken, are permitted to be determined in consideration of the flexibility of the poles.

6) In the fault condition that multiple conductors in one phase on support poles of overhead power lines with voltage of 500kV are broken, the load of one phase at the point the conductors are fixed shall not be less than 0.15Tmax and 18kN.

(2) Anchor pole and dead end pole (breaking pole)

Anchor and Dead end poles in fault conditions shall be calculated in consideration of the maximum bending torque and the maximum twisting torque generated in the following cases.

- All conductors of one phase in one span at any circuits on the pole are broken. Lightning conductors are not broken.
- All conductors are not broken. One lightning conductor is broken.

(3) Crossing pole

Standard tension on crossing poles in fault conditions that conductors are not broken and lightning conductors are broken shall be equal to the total of the maximum tensions of each lightning conductor.

(4) Pole in large overcrossing span

1) In the fault condition that single conductor hung by suspension being set on support poles of overhead power lines at large overcrossing span are broken, tension shall be equal to the total of tension of conductors calculated in climate conditions stipulated in article 128 in Technical RegulationVol.1 and this Guideline.

2) The tension along the route of overhead power lines with conductors or lightning conductors hung by pulleys in fault conditions shall be as below.

- 20 kN: single conductor in one phase
- 35 kN: two conductors in one phase
- 50 kN: Three conductors in one phase

3) Poles with one circuit shall be calculated in the fault condition that conductors of one phase are broken. Poles with two circuits shall be calculated in the fault condition that conductors of two phases are broken and lightning conductors are not broken.

4) Standard tension acting on poles in the fault condition that conductors are not broken and lightning conductors fixed by strain set are broken shall be equal to total of the maximum tensions of each lightning conductor.

5) Anchor poles with one circuit and dead end poles in large overcrossing span shall be calculated in fault condition that conductors in one phase are broken. Anchor poles with multiple circuits shall be calculated in fault condition that conductors in two phases are broken and lightning conductors are not broken.

Article 259. Material of Poles

Poles of overhead power lines shall be the ones stipulated in this article in Technical RegulationVol.1.

Article 260. Buried Portion of Poles

The depth of poles buried in the ground must be calculated appropriately according to the topographical and geological conditions of the pole location as well as physical and mechanical characteristics of the pole.

Article 261. Confirmation for Anchor Poles

1. Requirement for anchor pole
  (1) Installation conditions of conductors and lightning conductors of overhead power lines with voltage exceeding 1kV for checking shall be as below.
    - Conductors of one circuit are only installed at one side of a span and lightning conductors are not installed.
    - Conductors are not installed and lightning conductors are only installed at one side of a span.
  (2) Climate conditions during the check for anchor poles shall follow the contents in article 128 in Technical Regulation and this Guideline.
  (3) For installation works such as pole erection or installation of conductors or lightning conductors of overhead power lines with voltage exceeding 1kV, if necessary, temporary enhancement of parts of pole and temporary guys are permitted to be used.
2. Special requirements for anchor pole of overhead power lines with voltage of 500kV.
  (1) Installation conditions of conductors and lightning conductors for checking shall be as below.
    1) All conductors and lightning conductors are installed at one side of spans, and none of them are installed at the opposite side of spans. The tension of conductors and lightning conductors which have already installed at one side of spans shall be equal to two-thirds of the maximum tension in the climate condition that air temperature is 15°C (T=15°C) and wind pressure is 70N/m2 (q=70N/m2). If poles and all parts are tightly fixed to foundations, their condition shall meet Technical Regulation on the condition that temporary guys are not used.
    2) All conductors on poles at one side of the span have already installed with any order, procedure and number of them when lightning conductors are not installed yet.
    3) All lightning conductors on poles at one side of the span have already installed with any order, procedure and number of them when conductors are not installed yet.
  (2) In installation works such as pole erection or installation of conductors or lightning conductors, if necessary, temporary enhancement of parts of pole and temporary guys are permitted to be used.

Article 262. Confirmation for Arms and Support Bars

1. Standard loads of accessories and workers with installing tools

Standard loads of accessories and workers with installing tools shall be the values in the following table, and other loads shall depend on the design values and the specification values of each structure.

Table 262 Standard loads of accessories and workers with installing tools

Voltage (kV)	Pole	Insulator	Standard load (kN)
Not stipulated	All poles	Post-type insulator	1.0
Up to 220	Support pole	Suspension-type insulator	1.5
Up to 220	Anchor pole	Suspension-type insulator	2.0
500	All poles	Not stipulated	2.5

2. Strength of guy

Strength of guys shall be determined so that the stress in guy in the event of breaking conductors and lightning conductors of overhead power lines with voltage exceeding 1kV is not more than 70% of the breaking strength of materials of guys.

Article 263. Safety for Workers Climbing on Poles

The tilt angle of tie-bars to horizontal plane on metal poles shall be less than 30 degrees. If the angle is bigger than 30 degrees, the stairs shall be installed. Reinforced concrete poles shall have the holes for putting tools to climb.

In calculation of brace parts of poles except horizontal braces connecting between two sections at the top of poles, the weight of person shall be considered as 70kg.

Poles which the height of the highest conductor is not less than 70m shall have ladders and rest platforms with surrounding protection by lattices.

Chapter 3-3-7 Particular Requirement

Article 264. Confirming Condition of Conductors near Houses

The distance from conductors of overhead power lines with voltage up to 1kV to houses, structures and architectural structures shall be determined by considering the movement of conductor due to air temperature (the sag of conductor) and wind pressure (the swing of conductor).

Article 265. Distance from the Outer Edge of Poles Foundation

The pole foundations of overhead power lines with up to 1kV shall be installed to secure the safety distance stipulated in this article in Technical RegulationVol.1.

Article 266. Crossing Overhead Power Lines with Voltage up to 1kV

In the places where overhead power lines with voltage up to 1kV cross other lines with voltage up to 1kV, anchor poles and support poles are permitted to be used.

When the lines cross over/under the span, the intersection shall be close to the pole with higher height and the distance between bare conductors shall not be less than 2m.

Article 267. Twisted Cable

1. Requirement for twisted cable

- Twisted cables are prohibited to be installed underground.
- Accessories for twisted cables shall accommodate to the conductors. Tools for installation of the cables and accessories shall be used in response to the instructions.
- Twisted cables of overhead power lines with voltage up to 1kV shall be used based on the specifications. If the specifications do not exist, the cables are permitted to be used based on the contents in Annex III.3.2 and III.3.3.

2. Distance for twisted conductor

The distance between twisted conductor and conductor of overhead power line with voltage up to 1kV shall comply with the requirements in article 279 in Technical RegulationVol.1 and this Guideline.

The distance from the twisted conductor of overhead power lines with voltage up to 1kV to the ground shall comply with the requirement in article 272 and 293 in Technical RegulationVol.1 and this Guideline.

The distance from the twisted conductor of overhead power lines with voltage up to 1kV to architectural structures shall not be less than the maximum deviation (refer to Annex III.3.1) plus 0.1m.

The maximum deviation means the swing of twisted conductor due to wind depending on cross-sectional area, span-length, tension, sag and temperature.

The distance from the twisted conductor of overhead power lines with voltage up to 1kV to architectural structures or the walls conductors are installed shall not be less than 5cm.

Chapter 3-3-8 Traversing Non-Populated Areas

Article 268. Requirement for Non-Populated Areas

Cross-sectional area of conductors of overhead power lines with voltage exceeding 1kV traversing non-populated areas shall satisfy the requirement in article 237 in Technical RegulationVol.1 and this Guideline.

Connections of conductors of the lines traversing the areas shall satisfy the requirement in article 237 in Technical RegulationVol.1 and this Guideline.

Overhead power lines with voltage exceeding 1kV traversing forests shall follow Decree “Protection of safety of high-voltage power grid works (106/2005/ND-CP&81/2009/ND-CP).

In safety corridor of overhead power lines with voltage of 500kV, irrigation works by water spray equipment in cultivated area are prohibited.

Article 269. Vertical Distance for Non-Populated Areas

Vertical distance from the lowest conductor to the ground surface in non-populated areas shall be calculated in the following conditions.

- Maximum air temperature
- No swing of conductors due to the wind
- No heat of conductor due to electrical current

Article 270. Distance from Nearest Conductors

The distance from the outer edge conductor of overhead power lines with voltage exceeding 1kV to houses or structures shall comply with the requirement in this article in Technical RegulationVol.1.

Chapter 3-3-9 Traversing Populated Areas

Article 271. Requirement in Populated Areas

1. Installation state
The angle between overhead power lines with voltage exceeding 1kV traversing populated areas and roads are not stipulated.

Poles with guys are prohibited to be installed on the streets.

2. Mechanical strength
(1) Conductor and lightning conductor

Conductors and lightning conductors of overhead power lines with voltage exceeding 1kV shall have cross-sectional area or mechanical strength not less than that of the following conductors and lightning conductors.

- Aluminum conductor with cross-sectional area of $50mm^2$.
- Aluminum conductor steel reinforced or aluminum alloy conductor steel reinforced with cross-sectional area of $35mm^2$.

(2) Insulator, lock and connection

- Post-type insulators and suspension-type insulators in suspension set shall be double.
- Conductors not less than $300mm^2$ are permitted to be used with the slide locks.
- Conductors with cross-sectional area less than $240mm^2$ are prohibited to be connected in the span but conductors with cross-sectional area not less than $240mm^2$ are permitted to be connected at only one point in the span.

Article 272. Distance Safe Distance to Populated Areas

1. Conductor conditions for calculating vertical distance
Vertical distance from the lowest conductor to the ground surface in populated areas shall be determined in the following conditions.

- Maximum air temperature
- No swing of conductors due to the wind
- No heat of conductor due to electrical current

2. Distance in fault condition

When overhead power lines with cross-sectional area less than $185mm^2$ cross streets, the distance from conductor excluding the heat due to electrical current at annual mean temperature in the fault condition which the conductor in adjacent span are broken to the ground surface shall not be less than the values in the following table.

Table 272 Minimum distance from conductor in fault condition to ground

Voltage (kV)	Minimum distance (m)
Up to 110	4.5
220	5.0

Article 273. Distance in Area Required High Safety Level

The distance in the area required high safety level should focus on safety shall comply with the requirements in this article in Technical RegulationVol.1.

Article 274. Traversing Houses and Structures in Safety Corridor

Houses and buildings in safety corridor of the overhead power lines with voltage from 1kV up to 220kV shall comply with the requirements stated in this article in Technical RegulationVol.1.

Chapter 3-3-10 Traversing Areas with Water

Article 275. Requirement in Areas with Water

1. Requirement for area with water

When overhead power lines with voltage exceeding 1kV traverse areas with water (river, channel, lake, bay, port, etc.), the cross angle between the lines and the river, etc. is not stipulated.

When support poles are used for overhead power lines cross the rivers, etc., conductors and lightning conductors of overhead power lines with voltage exceeding 1kV shall be fixed to fixed support locks or dedicated locks.

2. Requirement for area with ship and boat traffic

Anchor poles shall be used at rivers, channels or lakes where ships and boats sail.

Overhead power lines with voltage exceeding 1kV and with cross-sectional area not less than $120mm^2$ at such places shall comply with the following requirements.

- Fixed support locks or dedicated locks shall be used for fixing conductors.
- Support crossing poles are permitted to be used in the case that they are adjacent to anchor poles.

3. Requirement for large overcrossing span

Dead end poles shall be used in large overcrossing span.

Overhead power lines with voltage exceeding 1kV and with cross-sectional area not less than $120mm^2$ shall comply with the following requirements.

- Fixed support locks and dedicated locks shall be used for fixing conductors.
- Support crossing poles are permitted to be used in the case that they are adjacent to dead end poles.

4. Requirement for conductor and lightning conductor
When overhead power lines with voltage exceeding 1kV cross rivers, etc., conductors and lightning conductors shall have cross-sectional area or mechanical strength not less than that of the following conductors and lightning conductors.

- Aluminum conductor with cross-sectional area of $70mm^2$.
- Aluminum conductor steel reinforced or aluminum alloy conductor steel reinforced with cross-sectional area of $35mm^2$.

Conductors with cross-sectional area less than $240mm^2$ are prohibited to be connected within the span but conductors with cross-sectional area not less than $240mm^2$ are permitted to be connected at only one point in the span.

Article 276. Crossing Areas with Water

Safe distance from the overhead power lines to the means of waterway transport implementation shall be secured not less than the distance in this article in Technical RegulationVol.1.

Article 277. Arrangement of Signs and Signals for Areas with Water

The signs and signals, which are installed at banks at the both sides of rivers and channels where ships and boats sail, shall comply with related State regulations,

Chapter 3-3-11 Crossing or Going Nearby Overhead Power Lines

Article 278. Requirement when Crossing and Going Nearby Other lines

1. Pole location
When overhead power lines cross other overhead power lines, the cross angle between the lines is not stipulated.

Overhead power lines with higher voltage shall be arranged above overhead power lines with lower voltage. As an exceptional case, overhead power lines with voltage up to 110kV which have conductors with cross-sectional area exceeding $120mm^2$ and double insulators are permitted to be arranged above overhead power lines with voltage of 220kV.

2. Pole type
Anchor poles and support poles are permitted to be used at intersection where overhead power lines cross other overhead power lines.

3. Conductor and insulator
Cross-sectional area of conductors of overhead power lines with voltage exceeding 1kV at intersection shall not be less than the value shown in article 271 in Technical RegulationVol.1 and this Guideline.

Conductors of overhead power lines with cross-sectional area less than 240mm^2 at higher height are prohibited to be connected in intersected span but conductors with cross-sectional area not less than 240mm^2 are permitted to be connected at only one point in the span.

When overhead power lines at higher height shall use support poles, the conductors shall be fixed by fixed support locks. If cross-sectional areas of conductors are not less than 300mm^2, slide locks are permitted to be used.

When post-type insulators are used at overhead power lines with voltage exceeding 1kV at higher height, the insulators shall be double installed in intersected spans.

Article 279. Vertical Distance in Crossing Places

1. Vertical distance between conductors or between the nearest conductor and the lightning conductor

In the calculation for vertical distance between conductors or between the nearest conductor and the lightning conductor, air temperature shall be 20°C. (Refer to Table 279 of Technical Regulation)

Poles of overhead power lines with voltage up to 110kV at lower height are permitted to be installed under conductors of other overhead power lines, if vertical distance between the lowest conductor of the line at higher height and the top of poles of the lines at lower height is not less than the value shown in Table 279 in Technical RegulationVol.1 plus 2m..

2. Requirement for overhead power lines with voltage up to 1kV
When overhead power lines with voltage up to 1kV and with voltage exceeding 1kV are arranged on the same pole as well as they cross each other on the same pole, they shall comply with the requirements in article 247 in Technical RegulationVol.1 and this Guideline.

When two overhead power lines with voltage up to 1kV are arranged on the same pole, vertical distance and horizontal distance between two lines shall not be less than the values in Table 279 in this Guideline.

Article 280. Horizontal Distance between Outer Edge Conductors

The horizontal distance between the outer edge conductors of overhead power lines with voltage exceeding 1kV shall comply with the value of horizontal distance shown in Table 8-1 in article 8 in Technical RegulationVol.1.

Chapter 3-3-12 Crossing or go near Peripheral Telecommunication's Cable Network

Article 281. Crossing peripheral telecommunication's cable network

Peripheral telecommunication's cable network shall comply with requirement in this article in Technical RegulationVol.1.

Article 282. Requirement for Overhead Power Lines with Voltage of 500kV

The impact of overhead power lines with voltage of 500kV on communication and signal lines shall be considered with the contents in article 298 in Technical Regulation and this Guideline.

Article 283. Other Requirements for Poles

Protection against collision by vehicles shall be installed in compliance of the contents in article 118 in Technical RegulationVol.1 and this Guideline.

Article 284. Intersection with Underground Telecommunication's Cable

Overhead power lines crossing underground telecommunication's cables shall comply with requirement in this article in Technical RegulationsVol.1.

Article 285. Installation on Same Poles

When overhead power lines with voltage up to 110kV and peripheral telecommunication's cables are arranged on same poles, they shall comply with safety requirements and be agreed with management agency of overhead power lines.

Article 286. Going Nearby Communication and/or Signal Structures

Overhead power lines with voltage exceeding 1kV arranged nearby underground communication and signal lines shall comply with the requirements in article 281 in Technical RegulationVol.1 and this Guideline.

Article 287. Protection against Electromagnetic Induction

1. Limitation of induced voltage

The voltage of communication and signal lines induced from overhead power lines shall not exceed 650V, which is calculated by Carson pollaczek formula as below.

$$V = \varpi M \ell K I$$

V: Induction voltage

ϖ : $\varpi = 2\pi f$ (f: Frequency (Hz))

K: Shielding coefficient

I: Fault current (A)

M: Mutual inductance between overhead power line and communication and signal lines per a kilometer (H/km). The calculation of mutual inductance is as shown below.

(1) kd < 0.5

$$M = [2\ln\frac{2}{kd} - 0.1544 + \frac{2\sqrt{2}}{3}k(hp + hc) - j\{\frac{\pi}{2} - \frac{2\sqrt{2}}{3}k(hp + hc)\}] \times 10^{-4} \text{ (H/km)}$$

(2) 0.5 ≤ kd < 10

$$M = [4\frac{Kei'(kd)}{kd} - j4\{\frac{Ker'(kd)}{kd} + \frac{1}{(kd)^2}\}] \times 10^{-4} \text{ (H/km)}$$

(3) kd $\leq$ 10

$$M = -j\frac{4}{(\mathrm{kd})^2}\times 10^{-4}\ \text{(H/km)}$$

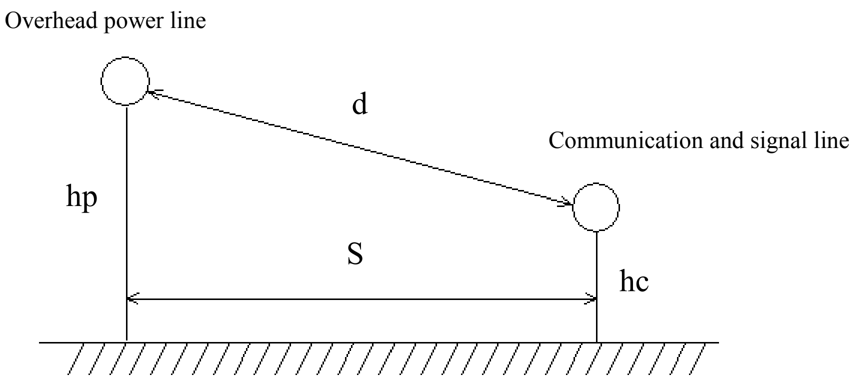


Figure 287 Distance for induction

d: Distance between overhead power line and communication and signal line (m)

d= $\sqrt{S^2 + (hp - hc)^2}$

S: Horizontal span between overhead power line and communication and signal line (m)

hp, hc: Height of overhead power line and communication and signal line (m)

k: $k = \sqrt{4\pi\varpi\times 10^{-7}}$

σ : Electric conductivity (1/$\Omega\cdot$m)

ker’(kd), kei’(kd): Modified Bessel function (refer to the following table)

Table 287 Modified Bessel function

kd	ker'(kd)	kei'(kd)	kd	ker'(kd)	kei'(kd)
0.0	0	0	5.0	0.0171900	-0.0008200
0.1	-9.9610000	0.1460000	5.1	0.0157500	-0.0018610
0.2	-4.9230000	0.2230000	5.2	0.0143700	-0.0027260
0.3	-3.2200000	0.2743000	5.3	0.0130400	-0.0034330
0.4	-2.3520000	0.3095000	5.4	0.0117700	-0.0040000
0.5	-1.8200000	0.3332000	5.5	0.0105800	-0.0044400
0.6	-1.4570000	0.3482000	5.6	0.0094470	-0.0047690
0.7	-1.1910000	0.3563000	5.7	0.0083880	-0.0050000
0.8	-0.9873000	0.3590000	5.8	0.0074000	-0.0051460
0.9	-0.8259000	0.3574000	5.9	0.0064810	-0.0052170
1.0	-0.6946000	0.3524000	6.0	0.0056320	-0.0052240
1.1	-0.5859000	0.3445000	6.1	0.0048500	-0.0051760
1.2	-0.4946000	0.3345000	6.2	0.0041330	-0.0050830
1.3	-0.4172000	0.3227000	6.3	0.0034790	-0.0049510
1.4	-0.3511000	0.3096000	6.4	0.0028850	-0.0047810
1.5	-0.2942000	0.2956000	6.5	0.0023490	-0.0046000
1.6	-0.2451000	0.2809000	6.6	0.0018670	-0.0043930
1.7	-0.2027000	0.2658000	6.7	0.0014370	-0.0041710
1.8	-0.1659000	0.2504000	6.8	0.0010540	-0.0039390
1.9	-0.1341000	0.2351000	6.9	0.0007164	-0.0037010
2.0	-0.1066000	0.2198000	7.0	0.0004205	-0.0034600
2.1	-0.0828200	0.2048000	7.1	0.0001633	-0.0032180
2.2	-0.0623400	0.1901000	7.2	-0.0000584	-0.0029790
2.3	-0.0447500	0.1759000	7.3	-0.0002474	-0.0027450
2.4	-0.0297100	0.1621000	7.4	-0.0004066	-0.0025170
2.5	-0.0169300	0.1489000	7.5	-0.0005388	-0.0022960
2.6	-0.0061360	0.1363000	7.6	-0.0006465	-0.0020840
2.7	0.0029040	0.1243000	7.7	-0.0007322	-0.0018810
2.8	0.0104000	0.1129000	7.8	-0.0007982	-0.0016890
2.9	0.0165300	0.1021000	7.9	-0.0008467	-0.0015070

2. Countermeasure against inducted voltage

If induced voltage exceeds above-mentioned limited value, the following countermeasures shall be conducted for limiting the voltage within the permissible value.

- Shorten the break time of circuit breakers
- Limit the ground fault current by increasing ground resistance of neutral point
- Expand the distance between overhead power line and communication and signal line
- Transposition overhead power liens
- Use lightning arresters and optical fiber cables or shielding cables for communication and signal lines

Article 288. Prevention of Corona Noise and Radio, Television Wave Reception Interference

1. Corona noise

(1) Permissible value of corona noise

Signal to noise ratio due to corona noise shall comply with the following levels.

- Fair or cloudy weather: 40dB and more
- Rainy weather: 20dB and more

SN=S-N

SN: Signal to noise ratio (dB)

S: The measured value of broadcast electric field intensity during fair weather (dB)

N: Corona noise level is calculated by the next item (2) (dB)

(2) Corona noise level

N=Ns+3.5(E-15)+Nd+(Kh+Nx)

N: Calculated corona noise level (dB)

Ns: Corona noise level on electrical gradient of surface of conductor with the diameter of 30mm. Normally, it is adopted to 43dB. (dB)

Nd: Correction to conductor diameter is calculated by the following formula.

$$Nd = 40\log_{10}\frac{2r}{3} \text{ (dB)}$$

r: Radius of conductor (cm)

Kh: Attenuation of corona noise against the height of conductor is calculated by the following formula.

$$Kh = 20\log_{10}\frac{10}{h} \text{ (dB)}$$

h:Vertical distance between the lowest conductor and measured point on ground surface (m)

Nx: Attenuation of corona noise against perpendicular direction to overhead power line

$$Nx = 20\log_{10}\left\{1+\left(\frac{x}{h}\right)^2\right\} \text{ (dB)}$$

x: Horizontal distance from conductor to measured point

E: The maximum electrical gradient of surface of conductor (kV/cm)

The maximum electrical gradient of surface of single conductor is calculated by the following calculation.

$$E = \frac{18CV}{r} \text{ (kV/cm)}$$

V:Voltage of overhead power line (kV)

C: Electrostatic capacity to ground

$$C = \frac{0.02413}{\log_{10}\frac{2h}{r}} \text{ (}\mu\text{F/km)}$$

Chapter 3-3-13 Crossing or Going Nearby Special Structures and/or Places

Article 289. Crossing or Going Nearby Electric Railways

1. Place of arrangement

Overhead power lines with voltage up to 1kV shall be arranged outside areas of touching power network including poles of the network.

2. Position

Overhead power lines with voltage up to 1kV shall be arranged above guys of touching power network.

3. Conductor

Conductors of overhead power lines with voltage up to 1kV shall have cross-sectional area not less than that of the following conductors.

- Aluminum conductor with cross-sectional area of 35mm2.

- Aluminum conductor steel reinforced or copper conductor with cross-sectional area of 16mm2.

Conductors and lightning conductors are prohibited to be connected at intersected span.

Conductors of overhead power lines with voltage up to 1kV shall be installed on double insulators.

4. Pole

Poles of overhead power lines with voltage up to 1kV shall be checked in fault condition which a conductor is broken.

5. Distance

In calculation of the distance between conductors and electric railways or electric tramcar ways, the sag of conductors shall be the maximum sag.

The distance between conductors of overhead power lines with voltage up to 1kV to guys and conductors of touching power network shall not be less than 1.5m.

6. Installation method

Overhead power lines with voltage up to 1kV are prohibited to be installed at the places where conductors of electric railways and electric tramways are hung by cross arms.

Article 290. Crossing or Going Nearby Railways

1. Crossing angles

Crossing angle between overhead power line with voltage exceeding 1kV and the railway shall not be less than 40 degrees, and is preferable to be close to 90 degrees.

2. Pole

Anchor poles with double insulators shall be used at the intersection where overhead power lines with voltage exceeding 1kV cross railways and electric railways.

Support poles are permitted to be added at intersected span between anchor poles where overhead power lines with voltage exceeding 1kV cross many railways where trains with passengers rarely pass through.

It is permitted to use support poles which conductors are fixed by fixed support locks for overhead power lines with voltage exceeding 1kV cross dedicated railways.

3. Foundation

Reinforced concrete poles and steel poles are prohibited to be used as grounding means.

4. Conductor

Conductors of overhead power lines with voltage exceeding 1kV shall have cross-sectional area not less than that of the following conductors.

- Aluminum conductor with cross-sectional area of 70mm2.

- Aluminum conductor steel reinforced and aluminum alloy conductor steel reinforced with cross-sectional area of 35mm2.

Conductors and lightning conductors of overhead power lines with voltage exceeding 1kV are prohibited to be connected in intersected span.

5. Distances to trees along railway

The distance between the conductor of overhead power lines with voltage exceeding 1kV and trees along railway shall comply with the requirements in article 268 in Technical RegulationVol.1 and this Guideline.

Article 291. Distances to Railways

1. Pole

Poles are permitted to be attached guys in narrow places.

2. Distance from the conductor of overhead power lines to the rail surface or the boundary of safety corridor of the railway and electric railway

In the calculation of the distance from the conductor of overhead power lines to the rail surface or the boundary of safety corridor of the railways and electric railways, the sag of the conductor in normal condition shall be determined at the maximum air temperature in consideration of the heat due to electricity current. If there is no data of the load of overhead power lines, the maximum temperature, 70°C, shall be applied.

The sag of the conductor in fault condition shall be determined at annual mean temperature and wind speed of 0 m/s.

When overhead power lines cross or go nearby communication and signal lines along the railways, they shall comply with the requirement not only this article but also article 280 in Technical RegulationVol.1 and this Guideline.

Article 292. Crossing or Going Nearby Car Roads

1. Pole
Overhead power lines with voltage exceeding 1kV shall be installed on anchor poles, when they cross car roads class I (refer to Table 293 in Technical Regulation Vol.1).

Overhead power lines with voltage exceeding 1kV are permitted to be installed on support poles, where they cross car roads at class from II to V (refer to Table 293 in Technical Regulation Vol.1).

2. Conductor and insulator
Insulators shall be double installed in intersected spans with car road class I.

At intersection with car road from II to V, conductors on support poles shall be fixed by fixed support locks, and post-type insulators shall be double installed, if they are used.

Conductors at intersection with car road of class I and II shall have cross-sectional area not less than that of the following conductors.

- Aluminum conductor with cross-sectional area of $70mm^2$.

- Aluminum conductor steel reinforced or aluminum alloy conductor steel reinforced with cross-sectional area of $35mm^2$.

Conductors with cross-sectional area less than $240mm^2$ and lightning conductors of overhead power lines are prohibited to be connected at intersected span with car roads of class I and II but conductors with cross-sectional area not less than $240mm^2$ are permitted to be connected at only one point in the span.

3. Cross angle
The cross angle between overhead power line with voltage exceeding 1kV and car road is not stipulated.

Table 292 Technical Class of car road

Main indicators	**Technical classes of car roads**						
	Topography	**I**	**II**	**III**	**IV**	**V**	**VI**
Calculated speed (km/h)	Plain	120	100	80	60	40	25
	Mountain	-	80	60	40	25	15
Number of lanes	Plain	2 - 4	2 - 4	2	2	1	1
	Mountain	-	2	2	2	1	1
Width of road surface (m)	Plain	15.0	7.5	7.0	6.0	3.5	3.5
	Mountain	-	7.0	6.0	5.5	3.5	3.5
Width of road bed (m)	Plain	26.0	13.5	12.0	9.0	6.5	6.0

Article 293. Distances to Car Roads

In the calculation of distance between overhead power lines with voltage exceeding 1kV to car roads, the maximum sag of the conductor in normal condition shall be determined at the maximum temperature without the heat due to electricity current. The sag of the conductor in fault condition shall be determined at annual mean temperature and wind speed of 0m/s.

Article 294. Going Through Bridges

1. Pole

Overhead power lines with voltage exceeding 1kV which cross bridges and bascule parts of bridges shall be installed on anchor poles or anchor structures,.

2. Insulator

Conductors of overhead power lines with voltage exceeding 1kV shall be fixed by double insulators and fixed support locks, and other support parts are permitted to be used with intermediate support structures.

3. Installation situation

As for metal bridge for railways with car roads below, conductors of overhead power lines with voltage exceeding 1kV are permitted to be installed directly on upper spans or outside of bridge frames, if the base is equipped for the whole length of the bridge on the top.

Overhead power lines with voltage exceeding 1kV on the bridge in cities or above roads are permitted to be installed outside bridge structures as well as within the width of pedestrian parts and road parts for vehicles.

Article 295. Distances to Bridges

In the calculation of the distance between overhead power lines with voltage exceeding 1kV and parts of the bridge, the sag of conductors shall be determined at the maximum temperature.

Article 296. Traversing Dams and/or Dikes

In the calculation of the distance between overhead power lines with voltage exceeding 1kV and parts of the dike or the dam, the sag of conductors shall be determined at the maximum temperature.

The minimum horizontal distance between the foundation of poles and the base of dikes shall comply with current legislations for protection of dikes

Article 297. Distances from Poles to Important Water Dams

Poles of overhead power lines with voltage exceeding 1kV are permitted to be installed within safety corridor of dikes or dams, if the management agency of the dikes or the dams agrees with the installation.

Article 298. Crossing or Going Nearby Aerial Transport Cable Lines and/or Pipelines

1. Overhead power line with voltage up to 1kV

(1) Position

Overhead power lines shall be arranged under aerial transport cable lines.

(2) Protective measure

The safe range of the cable-air transport or overhead cable transport shall be determined to ensure a safe distance prescribed in this article of Vol.1 in Technical Regulation.

Metal pipelines above the ground and metal structures of aerial transport cable lines shall be grounded with ground resistance in compliance with the requirement in article 555 of Vol.1 in Technical Regulation and this Guideline.

2. Overhead power lines with voltage exceeding 1kV

(1) Pole

Overhead power lines with voltage exceeding 1kV, which cross aerial transport cable lines and pipelines above the ground, shall be installed on anchor poles.

If cross-sectional area of conductors of overhead power lines with voltage exceeding 1kV is not less than 120mm^2, support poles are permitted to be used at intersection with aerial transport cable lines and pipelines above the ground.

Poles are prohibited to be equipped with protective nets.

(2) Conductor and insulator

Conductors at intersection with aerial transport cable lines and pipelines above the ground shall have cross-sectional area not less than that of the following conductors.

- Aluminum conductor with cross-sectional area of 70mm^2.

- Aluminum conductor steel reinforced or aluminum alloy conductor steel reinforced with cross-sectional area of 35mm^2.

Conductors with cross-sectional area less than 240mm^2 and lightning conductors of overhead power lines are prohibited to be connected at intersected span with aerial transport cable lines and pipelines above the ground but conductors with cross-sectional area not less than 240mm^2 are permitted to be connected at only one point in the span.

Conductors with suspension-type insulators on poles at intersection shall be fixed by fixed support locks.

Post-type insulators on poles at intersection shall be double installed.

(3) Protective measure

Protective fences shall be installed at the intersection where overhead power lines with voltage of 500kV cross aerial transport cable lines and pipelines above the ground. The fence shall be installed at the point where is the maximum swing of the outer edge conductors plus 6.5m away.

(4) Position

The cross angle between overhead power lines with voltage exceeding 1kV and aerial transport cable lines or pipelines above the ground are not stipulated.

Overhead power lines with voltage exceeding 1kV shall be arranged above aerial transport cable lines and pipelines above the ground.

If overhead power lines with voltage up to 110kV are equipped with protective bridges or nets, the lines are permitted to be arranged under aerial transport cable lines and pipelines above the ground.

(5) Distance from overhead power lines to aerial transport cable lines and pipelines above the ground

In the calculation of horizontal distance (refer to Table 298) from overhead power lines to aerial transport cable lines and pipelines above the ground, the maximum swing of conductors in normal condition shall be taken into account.

In the calculation of vertical distance (refer to Table 298 in technical regulation) from overhead power lines to aerial transport cable lines and pipelines above the ground, the maximum sag of conductors in normal condition shall be taken into account.

Article 299. Distances to Gas or Oil Pipeline and Petroleum Products

Overhead power lines with voltage more than 1kV which cross or go near the gas or oil pipelines and petroleum products shall ensure the safety distance according to the regulations for oil and gas project.

Article 300. Crossing or Going Nearby Underground Pipelines

1. Cross angle

The cross angle between overhead power lines with voltage up to 35kV and underground pipelines are not stipulated.

The cross angle between overhead power lines with voltage not less than 110kV and gas, oil, petroleum product pipelines shall not be less than 60 degrees.

2. Distance between overhead power lines with voltage of 500kV and gas flashing cocks

The distance between overhead power lines with voltage of 500kV and gas flashing cocks shall not be less than 60m.

3. Distance between overhead power lines with voltage of 500kV and water pipelines, etc.

When overhead power lines with voltage of 500kV cross or go nearby water pipelines, water discharge systems, or water drainage systems, the distance from the nearest ground systems and foundations of poles of the lines to water pipelines, etc. shall not be less than 3m.

Article 301. Crossing or Going Nearby Pressured Pipelines

1. Installation location

Main steam, petroleum product pipelines with the pressure more than 1.2MPa shall not be installed within safety corridor of overhead power lines with voltage exceeding 1kV.

2. Welded joint

Welded joints of main steam, oil, petroleum product pipelines with the pressure more than 1.2MPa shall be checked by physical method, which are installed within safety corridor of overhead power liens with voltage exceeding 1kV.

Article 302. Going Nearby Structures containing Explosives and/or Flammable Substance

Overhead power lines with voltage exceeding 1kV which go nearby structures containing explosive and flammable substances shall comply with standards and norms for safety protection against fires and/or explosions, and the distance between the lines and structures which are not stipulated by the standards, etc. shall not be less than 60m.

Article 303. Going Nearby Oil and/or Gas Flames

Overhead power lines with voltage exceeding 1kV going nearby oil and gas flames shall secure the distance from the flames stipulated in this article in Technical RegulationVol.1.

Article 304. Going Nearby Airports

Overhead power lines with voltage exceeding 1kV going nearby airports shall be approved as shown in this article in Technical RegulationVol.1.

PART 4 DISTRIBUTION EQUIPMENT AND SUBSTATIONS

Chapter 4-1 Distribution Equipment up to 1kV

Chapter 4-1-1 Electric Equipment Installation

Article 305. Safety Installation of Electrical Equipment

When MCCB (Molded-Case Circuit-Breaker) is installed, it shall maintain the arc space* (safety boundary) between the power supply terminal of MCCB and obstacle such as metal wall and busbar, according to manufacturer's instructions, in order to prevent the secondary fault as follows.

*Note : If the arc space is not enough, secondary fault may occur due to the conductive ionized gas which exhausted from the MCCB, during the breaking operation of the first fault at load side of MCCB.

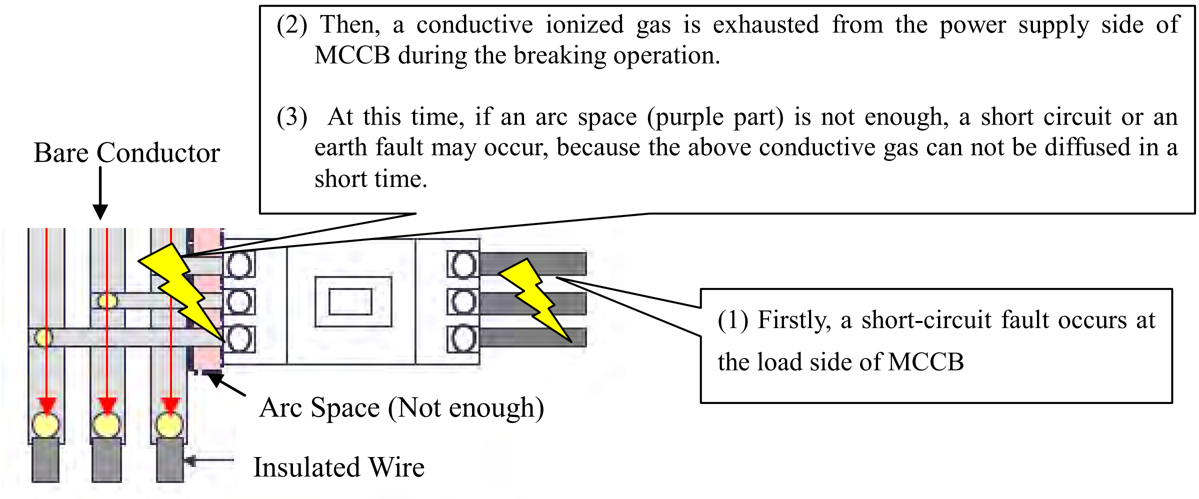
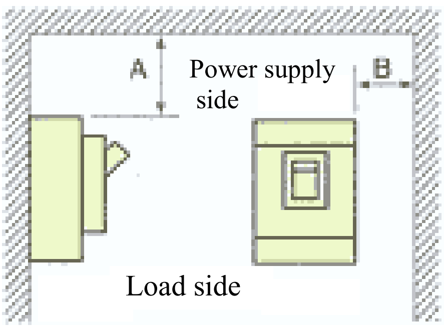


Figure 305 The example of secondary fault due to the shortage of arc space

Table 305 The example of Arc Space



Flame size [AF]	Minimum clearance [mm] A	Minimum clearance [mm] B
75 or less	30	25
100-250	50	40
400-800	80	50
1000 or over	150	100

Article 306. Connection Method of Switching Devices

Switching devices have a fixed terminal and a movable terminal. Especially, non-sealed switching devices such as a knife switch, have a movable terminal which can be touched easily. If the movable terminal is connected to the power supply side, in touching the exposed live part, an operator may get electric shock, although the switch is turned off. Therefore, the fixed terminal shall be connected to the power supply side, and the movable terminal shall be connected to the load side.

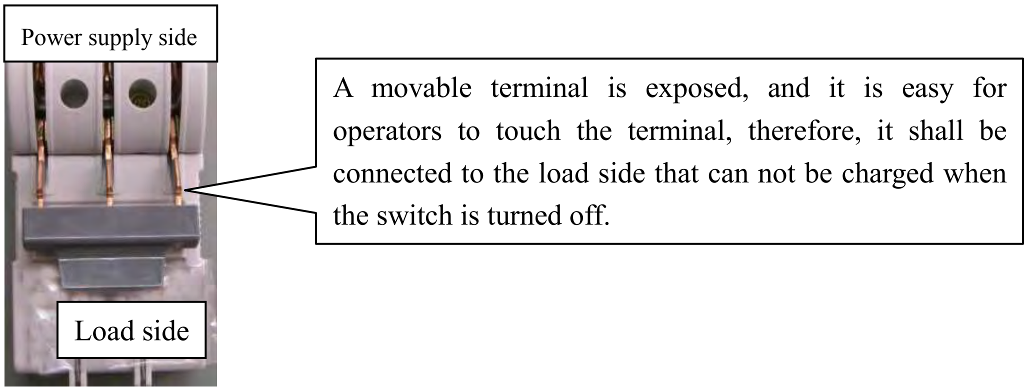


Figure 306　　Connection diagram of knife switch

Article 307. Manually Controlled Switchgears

For fireproof performance of the protective case, the specification of the distribution panel board shall comply with the Article 315.

Article 308. Identification of Switching Devices

As stipulated in Technical Regulation

Article 309. Power Sources of the Automatic Circuit Breaker (Auto-breaker)

When a repair work, a removal/installation work, etc. of a circuit breaker are carried out, it shall get other isolation by the disconnector for safety work. But in the following cases, it is permissible not to get other isolation.

- Pull-out type circuit breakers
- In case that it can stop a wide range of equipment including the work object by opening the circuit breaker on the upstream side.
- In case that it is ensured that the work of the auto-breaker can be carried out safely, although it is still energized at the both ends of it. (e.g. in case of the work which can keep the working clearance between live parts and the worker)

Article 310. Connecting Direction of Fuses

As for the installation of fuses, fuses shall be installed in such a way that their replacement can be carried out safely according to manufacturer's instructions.

In case of the following screw-in fuse, to prevent the electric shock in installing the fuse, the upper terminal of the fuse base shall be connected to the load side and the bottom terminal shall be connected to the power supply side.

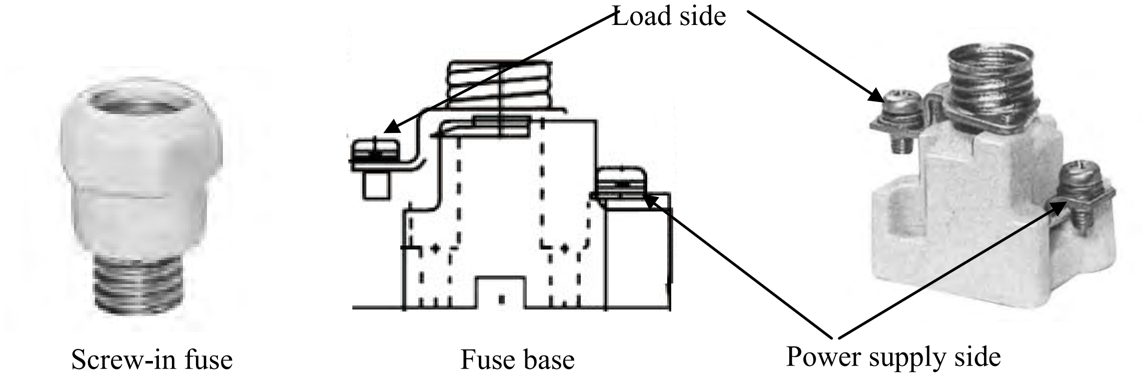


Figure 310 The Example of screw-in fuse and fuse base

Chapter 4-1-2 Distribution Panel Boards

Article 311. Minimum Clearance in Air of Bare Conductor

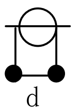
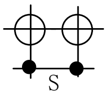
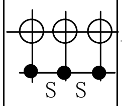
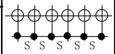
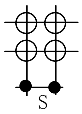
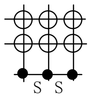
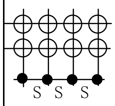
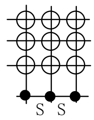
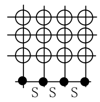
Air clearance between exposed live poles as well as between exposed live parts and non-live metal components shall be not less than 12mm. In the same case, creepage distance shall be not less than 20mm.

Air clearance between exposed conductors and protective barrier must be not less than: 100mm in case of wire mesh type and 40mm in case of insertable insulated walls.

Article 312. Site requirements for Electrical Cabinets

When the cable-laying of multilayer is performed, the permissible current of cable is reduced, due to the influence of mutual induction between cables. For this reason, the permissible current of the multilayer shall consider the following current reduction rate.

Table 312 Current reduction rate

	Current reduction rate								
Number of cable	**1**	**2**	**3**	**6**	**4**	**6**	**8**	**9**	**12**
Layout / Center span									
S=d	1.00	0.85	0.80	0.70	0.70	0.60	-	-	-
S=2d		0.95	0.95	0.90	0.90	0.90	0.85	0.80	0.80
S=3d		1.00	1.00	0.95	0.95	0.95	0.90	0.85	0.85

Article 313. Conductor Material for Grounding Wire

Bare conductors are used for earthing conductors. So, due to mechanical strength and stability against corrosion minimum cross-sections of conductors are:

- Copper : $16mm^2$
- Aluminium : $35mm^2$
- Steel : $50mm^2$

Article 314. Controlling and Measurement Devices

The provisions of this article shall refer to the chapter 2-6 and 5-3.

Article 315. Flame-resistant Materials for the Distribution Panel Boards

(Reference) Japanese specification of distribution boards with heat-resistant

The distribution board which supplies a power to the disaster prevention equipment, such as an indoor fire hydrant, a sprinkler, a smoke ventilation and an emergency outlet, etc. shall have the following heat-resistant specification.

- The distribution board which installed in the place with the potentiality of the fire spread, such as a living room, a roof terrace, general passage way, general staircase and outdoor, shall be the first-class heat-resistant.
- The distribution board which installs in the place without the potentiality of the fire spread, should be the second-class heat-resistant.

Table 315 Specification of the distribution board with heat-resistant (Japanese specification)

Class	Specification of heat-resistant
First-class heat-resistant	The distribution board shall be able to supply a power to the equipment after overheating it at the maximum temperature 840°C for 30 minutes. Internal devices shall withstand the heat at 280°C.
Second-class heat-resistant	The distribution board shall be able to supply a power to the equipment after overheating it at the maximum temperature 280°C for 30 minutes. Internal devices shall withstand the heat at 120°C.

Article 316. Prevention of Vibration for the Distribution Panel Boards

The provisions of this article shall refer to the Article 132 of section 4 in the volume 3.

Article 317. Safety Measures for Electrically Inexperienced Workers

In case of using distribution equipment with live non-insulated components, it shall be protected with protective barrier. Protective barrier shall be a wire mesh, solid wall or combined type with minimum height of 1.8m. Distance from wire mesh to live non-insulated parts shall be not less than 0.7m. As for the solid wall, it shall meet the guideline in the Article 311.

Article 318. Installation Outdoor

The outdoor installation of distribution equipment shall meet the following requirements.

- The equipment shall be placed on a flat plane at minimum elevation of 0.3m above ground surface. In case of cubicles, the elevation shall be at least 0.5m.
- In electrical cubicles, if needed, drying devices such as a space heater and a dehumidifier device shall be installed for ensuring normal operation of the components, relays, measuring instruments and electrical meters.

Chapter 4-2 Distribution Equipment and Substations above 1kV

Article 319. Scope of this Chapter

As stipulated in Technical Regulation..

Chapter 4-2-1 Outdoor Distribution Equipment and Outdoor Substations

Article 320. Transport routes

As stipulated in Technical Regulation.

Article 321. Prohibition the cut conductor among the pole span when connection branch

When connecting branch with wires, wire must not be cut between pole span.

After compression work for a compression terminal or sleeve, or attachment of various clamps on lead wires, in order to make sure that above installation works were carried out tightly, it shall be checked that the electrical resistance of the compression portion or the clamp gripped portion is 100% or less of the electrical resistance of the gripped portion of the lead wire. This inspection is carried out by the voltage-drop method (see the following figure)

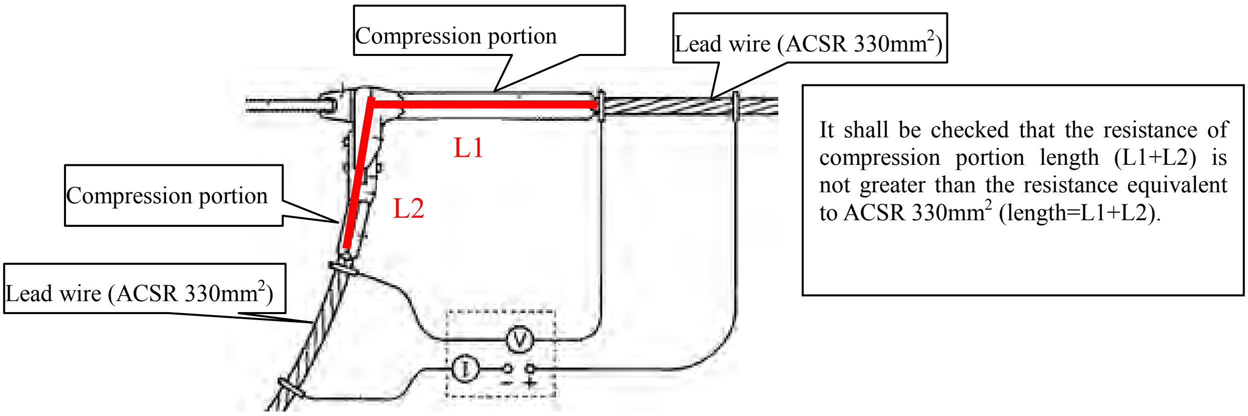


Figure 321 Measurement of resistance of compression part using the voltage-drop method

Article 322. Arrangement of Branch Wire

The clearance between a branch wire and a live part that intersects with the wire shall meet the minimum clearance provided in the article 331 in Technical Regulation.

Article 323. Calculation of Wind Load and Air Temperature

The wind load acting on conducting bars and structures shall be calculated based on the formula given in the Article 128.

In calculation of forces acting on flexible conducting bars and on ends of insulators of equipment or transformers, the weight of insulator strings and branching wires to equipments and transformers shall be calculated.

In calculation of forces acting on structures, the weight of workers with tools and means for installation shall be added as follows:

- 250kg : for 500kV electric tower.
- 200kg : in case of using suspension insulators for blocking anchor pole/tower with voltage up to 220kV.
- 150kg : in case of using suspension insulators for support poles with voltage up to 220kV.
- 100kg : in case of using post insulators.

Article 324. Mechanical Safety Factor Flexible Conductors

As stipulated in Technical Regulation.

Article 325. Mechanical Safety Factor Suspension Insulators

As stipulated in Technical Regulation.

Article 326. Mechanical Safety Factor Rigid Conductor

The short-circuit electromagnetic force which acts on busbar, post type insulator and rigid support structure shall be calculated based on the requirements regulated in article 81.

Article 327. Mechanical Safety Factor Bridging Flexible Conductors

As stipulated in Technical Regulation.

Article 328. Pole Material

The reinforced concrete pole and steel pole which are used as the supporting structure of distribution lines shall have the intensity which bears the load of the following table.

Table 328 The Load against supporting structure

The type of supporting structure	Application load
Reinforced concrete (- Length ≤ 20m, - Design load ≤ 614.7kN)	Wind load and the following vertical load - The weight load of strung wires, insulators and supporting structures, etc. - The vertical load caused by the tensile force of the guy wire in case of using guy wires to support the supporting structure

Article 329. Designing for Intermediary or Dead-end Anchor Poles

The provisions of this article shall refer to the previous article.

Article 330. Creepage Distance for Insulator

For standardization purposes, Relation between surface pollution of insulators and creepage distance for insulators are specified in the following table.

Regarding the measurement of NSDD and ESDD, refer to the ANNEX C of IEC 60815-1.

Table 330 Basic USCD and SPS

[IEC 60815-1]

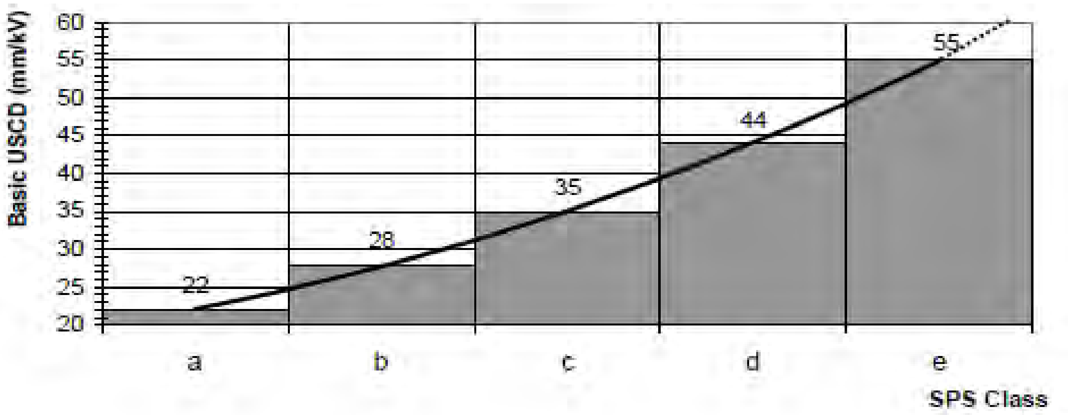
SPS *1	a (Very light)	b (Light)	c (Medium)	d (Heavy)	e (Very heavy)
ESDD *2 [mg/cm^2]	Not greater than 0.004	Not greater than 0.02	Not greater than 0.1	Not greater than 0.5	greater than 0.5
NSDD *3 [mg/cm^2]	0.1	0.1	0.1	0.1	0.1
USCD *4 [mm/kV]	22	28	35	44	55

***1 SPS (Site Pollution Severity):** Definition of SPS is based on the IEC 60815-1. Concrete descriptions refer to the '22) Area classification- Polluted environment area' of the Article 1.

***2 ESDD (Equivalent Salt Deposit Density):**The amount of sodium chloride that, when dissolved, gives the same conductance as that of the natural deposit removed from a given surface of the insulator divided by the area of this surface; generally expressed in mg/cm^2.

***3 NSDD (Non Soluble Deposit Density):** The amount of the non-soluble residue removed from a given surface of the insulator divided by the area of this surface; generally expressed in mg/cm^2.

***4 USCD (Unified Specific Creepage Distance):** The creepage distance of an insulator divided by the highest operating voltage across the insulator (forA.C. systems usually Um/√3 [phase to ground])



Quantity of suspension insulators is selected based on the formula given in the Article 248.

Article 331. Minimum Air Clearance of Outdoor Distribution and Substation Facilities

As stipulated in Technical Regulation.

Article 332. Withstand Voltage Test of Outdoor Distribution and Substation Equipment

As stipulated in Technical Regulation.

Article 333. Protective Barrier Clearances and Boundary Clearances

As stipulated in Technical Regulation.

Article 334. Minimum Height over Access Area

As stipulated in Technical Regulation.

Article 335. Minimum Working Clearance

As stipulated in Technical Regulation.

Article 336. Prohibited to Install Overhead Line above the outdoor distribution equipment

As stipulated in Technical Regulation.

Article 337. Fire Prevention Measures of Outdoor Substations

As stipulated in Technical Regulation.

Article 338. Railways in Substations

As stipulated in Technical Regulation.

Article 339. Clearances to Building

As stipulated in Technical Regulation.

Chapter 4-2-2 Indoor Distribution Equipment and Substations

Article 340. Flameproof level of Distribution Compartments

Distribution station/compartments and transformer's (reactor's) compartments shall be made of flame-resistant materials in accordance with TCVN 2622. For reference, minimum requirements for the indoor transformers (reactors) provided in the IEC are given in the following table.

Table 340 Minimum requirements for the installation of indoor transformers

[IEC 61936-1 Table 4]

Transformer type	Liquid volume	Safeguards
Oil insulated transformers	≤ 1,000	EI 60 respectively REI 60
	> 1,000	EI 90 respectively REI 90 or EI 60 respectively REI 60 and automatic sprinkler protection
Less flammable liquid insulated transformers without enhanced protection		EI 60 respectively REI 60 or automatic sprinkler protection
Less flammable liquid insulated transformers with enhanced protection	≤ 10MVA and Um ≤ 38kV Um: Highest voltage for equipment	EI 60 respectively REI 60 or separation distances 1.5 m horizontally and 3.0 m vertically
Dry-type transformer	Fire behavior class	
	F0	EI 60 respectively REI 60 or separation distances 0.9 m horizontally and 1.5 m vertically
	F1 / F2	Non combustible walls

Note 1: REI represents bearing system (wall) whereas EI represents non-load bearing system (wall) where R is the load bearing capacity, E is the fire integrity, I is the thermal insulation and 60/90 refers to time in minutes.

Note 2: Enhanced protection means

- Tank rupture strength;
- Tank pressure relief;
- Low current fault protection;
- High current fault protection.

Note 3 Fire behavior class

- F0: No special risk of fire to be considered
- F1: Risk of fire exists, limited flammability is acceptable. Self extinguishing of the fire must occur within 60 minutes.
- F2: Class F1 requirements must be fulfilled. In addition, the transformer must be capable of operating for a defined time* when subjected to an external fire.

(* To be agreed between the manufacturer and the buyer.)

Doors shall have a fire resistance of at least 60 min. Doors which open to the outside are adequate if they are of fire-retardant material and construction.Ventilation openings necessary for the operation of the transformers are permitted. When designing the openings, the possible escape of hot gases shall be considered.

Article 341. Distance from Independent Distribution Stations

The clearances from independent distribution station to manufacturing halls and other premises in an industrial enterprise, to residential housing and public structures shall meet the value for transportation and fire fighting stipulated in the TCVN 2622.

In case of narrow space, the above-mentioned fire fighting clearance can be reduced provided that the distribution building has solid wall, no doors directed towards neighboring houses or works, and upon agreement with local fire prevention and fire fighting authority.

There is no requirement on clearance between the adjacent substations and or inside house, or along industrial house area.

Special requirements for adjacent substations or inside public house or civil house are those specified in the existing construction standards, norms.

For substation adjacent to existing house, if wall of that house is used as wall of substation, there shall be agreement and special measure applied in order to avoid damage of common wall.

Article 342. Separated Distribution Compartments

As stipulated in Technical Regulation.

Article 343. Condition of Installation Place

As stipulated in Technical Regulation.

Article 344. Selection of Insulators

Insulators at the input point and insulators subject to outdoor open conductors of generators with pole voltages of 6 and 10kV shall be handled based on the specification of 20kV; pole voltages from 13.8 to 24kV shall be handled based on the specification of 35kV. When the above mentioned insulators are installed in the polluted area, the creepage distance for Insulator shall be decided in accordance with the pollution level. (see the article 330)

Article 345. Minimum Air Clearance of Indoor Substation Facilities

As stipulated in Technical Regulation.

Article 346. Withstand voltage test of indoor substation equipment

Withstand voltage test of indoor substation equipment shall satisfy the requirements stipulated in article 332.

Article 347. Offset distance from live components with barrier

As stipulated in Technical Regulation.

Article 348. Distance between live components without compartment

As stipulated in Technical Regulation.

Article 349. Operation control corridor

(1) Passageway width of operating area

As for easy maintenance of equipment and easy transportation of them, the passageway width for operating area between protective barriers shall be not less than:

- 1m: if equipment are installed on one side of passageway
- 2m: if equipment are installed on both sides of passageway

In case that the mechanical section of circuit breakers, disconnectors at opened position are installed in the passageway of operating area, the above mentioned value shall be increased to 1.5m and 2m respectively (to ensure the same width). If the relevant passageway is 7m long and equipment are installed along both sides, it is allowed to reduce the passage width to 1.8m.

The passageway width for fire-exit shall be not less than 1.2m.

In the passageway of operating area and fire-exit, the protruding part of equipment shall be within 0.2m.

(2) Exit of explosion-exit corridor

Distribution equipment compartment shall have exit of passage ways in compliance with the following requirements:

- If the length of passage ways for compartment is up to 7m, one exit should be placed.
- If a relevant length is from 7m to 60m, two exits should be placed at opposite ends of the compartment. It is allowed to place exit in distance up to 7m from the end of compartment.
- If a relevant length is over 60m, in addition to two main exits placed at opposite ends, side-doors should be arranged so that the distance from any point in operation control corridor ways or explosion-exit corridor for fire and explosion to the nearest exit shall not exceed 30m.

Doors of the exits can open to the outside; into the stairs led to other production rooms in which walls and ceiling are fireproof, and there are no inflammable or explosive equipment and materials; or into other distribution equipment compartments.

Doors shall be made of fireproof or non-flammable materials with fire resistance capacity not less than 0.6 hour.

In the multi-floor distribution equipment installation compartment, the one of two main exits and the side doors can open into the balconies where there is fire-fighting ladder available.

Article 350. Fire Prevention Measures for Indoor Substations

(1) Division of compartments

If the explosion-exit corridor is too long, it shall be divided into compartments with length shorter than 60m. Partitions between compartments shall be made of flameproof materials with fire resistance capacity not less than 1 hour. Compartments shall have doors which meet requirements in the article 349 and 351. The explosion-exit corridor shall have doors which open to the outside or to the stairs.

(2) Floor and wall of distribution equipment compartment

The floor level of the distribution equipment compartments should be same. The surface of floors shall be dust-resistant finish. It is not basically allowed to place sill at the doors between compartments and in the corridors.

In addition, plates covering ditches shall be tight, made of fireproof, anti-slipping, anti-stumbling materials, and placed at the same floor level. The weight of each plate shall be not less than 50kg.

Holes that are bored through floors, walls or partitions (including cable holes) shall be sealed with non-flammable materials with fire resistance capacity for duration not less than 0.75 hour.

To prevent the compartments against the entering of animals, all the holes led to the outside must be protected with meshwork sized 10x10mm.

Article 351. Doorway of Indoor Substation

Doors of the distribution equipment compartments shall be of the swing-out type, opening to the outside or into other compartments. Doors shall also be equipped with auto-locked latches so that they can be opened from the inside with no key required.

Doors (gates) of the compartments where oil-filled equipment with oil content more than 60kg are installed shall be made of non-flammable materials with fire resistance capacity which is not less than 0.75 hour, if doors which open to other compartments that are out of substations area, or their locations are in the midway between explosion-exit corridor and distribution equipment compartment. For other cases, doors can be made of materials with lower fire resistance capacity.

If the width of doors (gates) is larger than 1.5m, a side entry gate shall be built for people passing through.

Distribution equipment compartment should not have windows. In the area without guarding, window shall not be allowed. In case natural illumination is required, it is permissible to use glass bricks or steel-cored glass.

Window of distribution equipment compartment shall be non-open type.

If the window is protected with wire mesh/screen with size not larger than 25*25mm/mesh hole from the outside, it can be opened but swung into the inside.

Placing window on the roof for getting illumination is forbidden.

Article 352. Oil-immersed transformer installed indoor

In the compartment installed distribution equipment at voltage level of 1kV and above, it is allowed to place one oil-filled transformer with capacity up to 630kVA or two oil-filled transformer with capacity of each up to 400kVA, provided that they are separated with the remaining space of the compartment by flameproof partition with fire resistance capacity rated 1 hour.

Live parts without insulation with voltage level above 1kV shall be protected by protective barriers in accordance with requirements in the article 347.

The equipment related to starting electrical motors or synchronous compensators, etc. (such as: circuit breaker, start-up reactor, transformer, etc) are permitted to be installed in the same compartment without partitions.

In the distribution equipment compartment with doors that open to the explosion-exit corridor, it is allowed to place oil-filled transformer with oil content up to 600kg.

Regardless of the amount of oil, it is allowed to place instrument transformers in the open compartment. But the weir of oil outflow prevention or sloping the floor area of the equipment to keep the entire quantity of oil is necessary.

Oil circuit breaker with oil content more than 60kg shall be placed in separated explosion-prone compartments with doors that open to the outside or to the explosion-exit corridor.
Oil circuit breaker with oil content from 25kg to 60kg can be placed in open compartments or explosion-prone compartments. The circuit breaker that installed in open compartments or in compartments with doors that open to explosion-exit corridor shall reserve the 20% of the rated breaking capacity.
Oil circuit breaker with oil content up to 25kg, low oil content circuit breaker and oil less circuit breaker can be placed in open compartments.
As for the compartment where to put low oil content circuit breaker with oil content 60kg or more in a phase, the weir of oil outflow prevention shall be installed to keep entire oil volume.
Circuit breaker placed in open compartments shall be separated by fireproof partitions shall be also separated from drive device by partitions or protection boards made of fireproof materials. The top edge of partition or protection board shall be at less 1.9m high above the floor.
It is not required to use partition for air circuit breaker.
It is not allowed to install the equipment with live parts without insulations in the explosion-exit corridor.

Article 353. Oil collection sump

As for the oil-collecting system for indoor substations located in separated house, adjacent to or inside manufacture house, it is not required to construct catchment tank in compartments where there are installed transformers, oil circuit breakers and other oil-filled equipment with oil content in each tank up to 600kg, provided that these compartments are in the first floor and have doors open to the outside.
If the oil content of a tank is more than 600kg, catchment tank or weir of oil outflow prevention shall be built using fireproof materials, with capacity equivalent to 20% of the entire quantity of oil of the largest transformer. Besides, appropriate measures should be applied to prevent waste oil from flowing into cable ditches.
The example of oil-collecting sump and catchment tank, etc is shown in the article 157.

Article 354. Installation of oil collecting sump

As for the compartments placed on basement or on the 2nd floor and upper with doors that open to explosion-exit corridor, in such cases, catchment tank shall be built under transformers, oil circuit breakers and other oil-filled equipment in compliance with the following requirements:

1. If the oil amount in transformer or in each tank of oil-filled equipment is less than 60kg weir of oil outflow prevention or sloping the floor area of the equipment to keep the entire quantity of oil.
2. If the oil content in one tank is from 60 to 600kg:
   a. Build catchment tank to collect the entire quantity of oil.
   b. Build border or make the floor slope down inside in order to keep the entire quantity of oil.

3. If the oil content in a tank is more than 600kg:

a. Build catchment tank that is capable of containing at least 20% of the entire quantity of oil of the largest transformer or the oil-filled equipment with drain pipe led to the common catchment tank for several equipment.

Oil drain pipe from the oil collecting sump under transformer shall have diameter of at least 10cm.

Oil drain pipe shall be covered with meshwork at the end connected to the oil collecting sump.

b. In the case catchment tank is built without drain pipe to the common catchment tank, it shall be installed with a grating on which a layer of ballasting with thickness of 25cm is laid. The catchment tank shall be capable to contain the entire quantity of oil with the maximum oil level 5cm lower than the grating. Topmost surface of the layer of ballasting shall be 7.5cm lower than ventilation hole. Bottom of catchment tank shall have a slope of 2 degrees downwards to its sunken point. Catchment tank shall have surface area larger than groundwork of the transformer or the equipment.

Examples of oil-collecting sump and catchment tank, etc. are shown in the Article 157.

Article 355. Ventilation System in Transformer Compartment

(1) Amount of required ventilation from the amount of generated heat

In case that the heating elements such as transformers, etc. are installed in the room, the amount of required ventilation from the amount of generated heat can be calculated by the following formula.

It is preferable to use natural ventilation for transformer rooms to cool the room temperature within the permissible temperature. If room temperature is not able to be cooled within the permissible temperature by natural ventilation, it is necessary to introduce a forced ventilation or air conditioning.

Ventilation openings shall be designed so as to prevent any dangerous proximity to live parts and any dangerous ingress of foreign objects.

$$\text{Amount of ventilation [m3/h]} = \frac{H}{d * Cp * (t2 - t1)}$$

Where:

H: Amount of generated heat [J/h]

d: Specific gravity of air [1.2kg/m3]

Cp: Specific heat of air [1006J/(kg*k)]

t2: Permissible room temperature [°C]

t1: Intake air temperature [°C]

And furthermore, temperature in compartments where control panel-board and distribution equipment is placed shall be ensured in accordance with requirements set by the equipment manufacturers. And temperature in compartments where on-duty person is present for 6 hours and more must be kept at temperature not lower than 18°C and not higher than 28°C.

(2) Emergency ventilation system

Explosion-exit corridor and management corridor of open compartments or complete cubicles containing equipment which are filled with oil or other synthetic fluid shall be equipped with emergency ventilation system that is controlled from outside and not related to other air ventilation systems.

Emergency ventilation system shall ensure that its air exchanging capacity in 1 hour will be equal to 5 times of the total air volume of the compartment.

(3)Ventilation pipeline

In distribution equipment installation compartments, it is allowed to place continuous welded pipeline of ventilation system without any vent-hole, flange, valve or manhole. It is also permissible to place across these compartments the ventilation pipelines with tight waterproof casing.

Chapter 4-2-3 Workshop Substation

Article 356. Scope

As for the workshop substation installed with full-equipped distribution system, the following requirements shall be satisfied:

(1) Every full-equipped workshop substation should be installed with oil-filled transformers with total capacity not exceeding 3,200kVA.

The oil filled transformers in full equipped substation as well as the transformer in compartments protected by compartment wall shall keep the space, in order to install ventilation system and to facilitate operation.

There is no requirement on the distance between separated rooms of different full-equipped substations or between tight compartments where oil-filled transformer are installed.

(2) Only one full-equipped substation should be installed in the one compartment of workshop substation (it is not allowed to install more than 3 full-equipped stations). The permissible total capacity shall be within 6,500kVA.

Total oil volume of transformers installed in enclosed compartment shall be not over 6.5 tones.

(3) Protective barriers of compartments where full-equipped substations with oil-filled transformer or tight compartments of oil-filled transformers and oil containing equipment are installed with total oil volume of 60kg or above, shall be made of non-flammable materials with fire resistance capacity of at least 0.75 hour.

(4) Total capacity of oil-filled transformers installed on the second floor shall not exceed 1,000kVA. It is forbidden to install the oil-filled transformer and full-equipped substation with oil-filled transformer on the third and upper floors.

(5) As for workshop substations and full-equipped substations installed with dry transformer or fireproof insulators, there is no requirement on the limitation of capacity, number of units, distance between them and their locations (on which floor) as well.

Article 357. Workshop Sites

Workshop substation can be installed on the first or second floor of the main or auxiliary manufacture compartments graded level I or II according to fire regulations mentioned in theVietnam Standard TCVN 2622.

Requirements for installing the workshop substation in dusty or chemically noxious compartments are provided in the Article 360.

Article 358. Installation of Compartments

When equipment for workshop substation are openly installed in the manufacture compartment, regarding measures for protection against direct contact, protection by enclosure, protective barrier, or placing out of reach is allowed.
When protection by enclosure is used, the degree of protection shall meet the requirements of IP2X in minimum.(see the following figure)
When protection by protective barrier is used, see the protective barrier clearances of the Article 333 in Technical Regulation.
When protection by placing out of reach is used, see the Article 334 and 339 in Technical Regulation.

Figure 358 Example of protection by enclosure for the conductor of the transformer

Article 359. Oil-collecting Sump

An oil-collecting sump shall be built under transformers and other oil-filled equipment in accordance with the article 353.

Article 360. Ventilation and Fire Prevention Measures of the Transformers Compartment

When installing ventilation system for transformer compartment in workshop substation with normal surrounding environment, it is allowed to utilize air in the workshop for the ventilation.
In order to ventilate transformer compartment arranged in dusty room where air include conductive or corrosive substances, the ventilation system shall be supplied with outside air or cleanly filtered air.
If the ceiling is made of fireproof materials, it is allowed to directly exhaust air from transformer compartment to the workshop space.
If the ceiling is made of non-flammable materials, exhaust air from transformer compartment shall be flowed into chimney that is extended at least 1m higher against the roof and according to the following items.

-Ventilation pipe of the transformer compartment adjoined to other house where the walls are fireproof but the roof is made of inflammable materials shall be installed at least 1.5m far from house walls or separated by a barricade wall that is made of nonflammable materials and at least 0.6m higher than the roof of the house.

- It is forbidden to install the top opening of the ventilation pipe opposite to the window of the house.
- It is not allowed to install the top opening of the ventilation pipe on the wall right under the inflammable lean part of roof or near the air hole on the wall of the adjacent house.
- If there is a window above the door or above the top opening of the ventilation pipe, a protection board jutted out at least 0.7m shall be constructed under such window. The protection board shall be wider than the window by at least 0.8m at each side of the window.

Regarding full equipped substation installed in separated compartment, ventilation system for its transformers shall comply with requirements in the article 355.

Article 361. Fire Prevention Measures

Compartments where oil-filled transformers or oil circuit breakers are installed shall have doors made of non-flammable materials. And those fire-resistive performances shall be not less than 0.6 hours.

Article 362. Clearance from Passageway

When a substation is placed beside a passageway for transportation, it shall be protected against collision by vehicles with a sign or a barricade fence.

Full equipped distribution system and substation should be installed in the area away from moving traffic of transportation / lifting means. The passageway width along full equipped distribution equipment and substations as well as passageways along the wall of substations with doors or air holes shall be not less than 1m. Besides, passageways shall be suitable for transportation of transformers and other equipment.

In the workshop which has internal transportation used very often, or large concentration of equipment, materials, products on the ground, full equipped substation and distribution system should be protected by fence. In such case, protective fence shall be installed to leave a passageway which meets the following items.

The passageway width on which full equipped trolley distribution system and full equipped substation are moved, rotated and operated shall be properly sized.

In case full equipped distribution system and substation are installed in separated compartments, the passageway width is determined as followings:

- Equal to length of trolley of complete distribution equipment plus at least 0.6m if they are arranged in one bank.
- Plus at least 0.8m if they are arranged in two banks.

In any case, the passageway width shall be not less than values specified in the article 362 and in partially narrow places in the corridor, the width shall be not less than diagonal dimension of the trolley that may cause obstacle on the movement of trolley.

Passageway width on the back for observation of the full equipped distribution system cubicle and full equipped substation shall be not less than 0.8m. In the narrow point of passageways, the protruding part of equipment shall be within 0.2m.

In case of installing full equipped distribution system and full equipped substation in manufacture compartment, width of the share passageway is determined based on the arrangement of manufacturing equipment, but it shall ensure the transportation capacity of the most cumbersome compartments of the full equipped distribution system and full equipped substation and in any case, this width shall be not less than 1m.

Article 363. Height of Compartment

Height of the compartment shall be not less than the height of the highest components in full-equipped distribution system and full-equipped substation added with 0.8m up to the ceiling and 0.3m up to the beam. Such values can be shortened as long as it still ensures safe and easy implementation of activities such as replacing, repairing or adjusting the equipment of the distribution system and substation.

Surface of road and floor on which equipment of full-equipped distribution system and full-equipped substation are moved shall be selected based on the maximum loading capacity of the equipments. Doors shall be suitable with dimensions of the equipments.

Chapter 4-2-4 Distribution Equipment and On-Pole Substation

Article 364. Scope

As stipulated in Technical Regulation.

Article 365. As stipulated in Technical Regulation. Configuration of Distribution Equipment and substation on-pole

Distribution equipment configuration or substations are specified in the Technical Regulations.

Method of mounting circuit breaker on the pole is shown in the following figure.

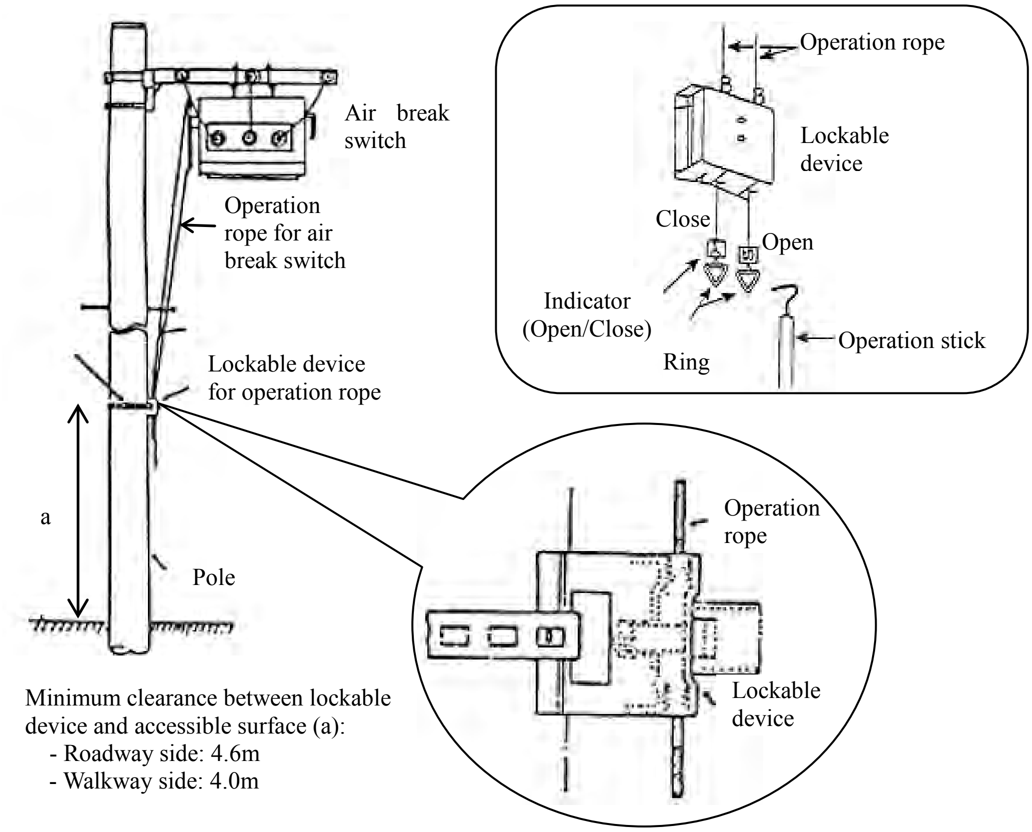


Figure 365 (Reference) Japanese installation example of drive engine with lock system of the disconnecting switch in one pole

Article 366. Safety of substation on - pole

As stipulated in Technical Regulation.

Article 367. Minimum clearance from operational floor

As stipulated in Technical Regulation.

Article 368. Placement in an Enclosed Cabinet

As stipulated in Technical Regulation.

Article 369. Connecting Wires

Regarding the protection of wires between the transformer and the panel board and between the panel board and low-voltage overhead lines against mechanical breakdowns, a insulated cable shall be used and this cable should be protected by conduit.

Regarding the material of the conduit, it is preferable to use PVC conduit that have a weather resistant and a self extinguishing performance.

Figure 369 PVC conduit (with a weather resistant and a self extinguishing performance)

Article 370. Minimum clearance for fire prevention

As stipulated in Technical Regulation.

Chapter 4-2-5 Lighting Protection

Article 371. Outdoor Switchyard with System against Direct Lightning Strikes

As stipulated in Technical Regulation.

Article 372. Protection against Direct Lightning Strikes for Indoor Substation

As stipulated in Technical Regulation.

Article 373. Lightning Rods

(1) It is permissible to set up lightning rods on construction structures of distribution equipment with voltage of 110kV and above if ground resistance standard is met.

It should be ensured that lightning current from lightning rods of outdoor distribution equipment at voltage level of 110kV and above flowing to common grounding system by at least 2 or 3 paths. Additionally, 1 or 2 grounding stakes with length of 3-5m shall be driven and distance from them to the pole where lightning rod is placed is not less than the length of the grounding stake.

It should be ensured that lightning current from lightning rods of outdoor distribution equipment at voltage level of 35kV following to common grounding system by at least 3 or 4 paths. Additionally, 2 or 3 grounding stakes with length of 3-5m shall be driven and distance from them to the pole where lightning rod is placed is not less than the length of the grounding stake.

Insulators string mounted on gantry of distribution equipment at voltage level of 35kV where lightning wire or lightning rod is installed and insulators string mounted on the dead-end pole of 35kV overhead lines shall be added with 2 pieces of insulator to that required by overhead line standards, if the lightning wire of overhead line is not extended into the substation.

In-air distance from the structures of outdoor distribution equipment installed with lightning rod to live components shall be not less than the length of the insulators string.

(2) In case the headlight-mounted pole is used to place lightning rod, the conductor supplying power to the headlight (the section protruded out from cable ditch to the pole and along the body of the pole)

shall be armored cable or passed through metal conduit if armored cable is not available. The part nearby lightning pole of this cable line shall be buried in the ground at least 10m of length.

At the place where cables go into the ditch, all the metal sheaths, steel belts of the cable and conduits shall be grounded to the common grounding system of the substation.

Article 374. Installing Lightning Rods on gantry of transformer

(1) It is allowed to install lightning rod on gantry of transformer, branching reactor and structures of outdoor distribution equipment if distance from gantry of transformer, gantry of reactor to transformer or reactor is less than 15m along the common grounding circuit provided that the earth equivalent resistivity in lightning season is less than 350Ωm and the following conditions are complied with:

1. Lightning arrester is placed on the outlets of windings of 6-35kV transformers or away from such outlets not more than 5m along the conductor's length.

2. It shall be ensured that the grounding current from lightning arrester to the common grounding system will follow through 3 or 4 paths.

3. On the common grounding system from 3 to 5 m far from lightning rod, there shall be driven 2 - 3 grounding stakes with length from 3m to 5m.

4. In the substation with voltage up to 35kV where lightning rods are installed on gantry of transformer, the resistance of grounding loop shall be not more than 4Ω (regardless grounding loop of outdoor distribution equipment); if without lightning rods on gantry of transformer, then stipulations in Article 579 -Volume I will be applied.

5. Grounding wire of lightning arrester and transformer connected to the grounding system shall be so arranged that the grounding point of lightning arrester is located between grounding point of grounding wire of gantry with lightning rod and grounding point of transformer.

(2) Regarding the protection against direct lightning strikes for outdoor distribution equipment, if for a certain reason that lightning rod can not be installed on construction structure, it is required to set up a separated independent lightning pole with grounding resistance not higher than 80Ω.

Underground distance between separated grounding system and the common grounding loop of the outdoor distribution equipment shall be equal to:

$S_d \geq 0.2 \times R_c$ (but not less than 3m)
Where: Sd - Underground distance (m).

Rc - Grounding impulse resistance of the separated independent lightning arrester pole (Ω) at lightning surge current of 60kA.

The in-air distance from the independent lightning pole with separated grounding system to live components of grounding structures and equipments of the outdoor distribution system (or outdoor transformer) shall be equal to:

$S_k \geq 0.12 R_c + 0.1H$ (but not less than 5m)
Where: Sk: in-air distance (m).

H: height level from top of the lightning rod to the ground (m).

The grounding wire of the separated lightning pole can be connected to the common grounding loop of transformer if the technical requirements on lighting rod placement on construction structure of the outdoor distribution equipment are satisfied. (see the Article 373 and item (1)).

Distance from the grounding point of separated lightning pole (or lightning wire) connected to common grounding loop system of transformer to grounding point of transformer (reactor) connected to that common grounding loop shall be not less than 15m counted along the common grounding circuit. The connection from separated independent lightning pole to common grounding loop of outdoor distribution equipment with voltage of 35-110kV shall be so implemented that the lightning stroke current will flow along 2 or 3 paths.

The grounding of the independent lightning arrester pole where headlight is installed shall be connected to the general grounding loop of the substation.

If the requirements set in item (1) are not satisfied, the following requirements shall be met:

- 3 or 4 stakes with length of 3-5m shall be additionally driven in distance of 5m from separated independent lightning pole.

- If distance along the common grounding loop from grounding point of lightning pole to grounding point of transformer (reactor) is longer than 15m but shorter than 40m, then lightning arrester shall be arranged near outlets of windings with voltage up to 35kV of transformer.

In-air distance from the independent lightning arrester pole grounded to the common grounding loop of substations to live components is determined as follows:

$$S_k \geq 0.1\ H + L$$

Where: H - height of live component to ground surface (m).

L - length of insulator string (m).

Lightning rods shall not be allowed to place on the structures of outdoor substation within a distance of 15m from:

- Transformer that is connected to the electrical rotation machine by flexible conductor or bare busbar.

- Bare busbar to support pole supporting flexible conductor connected to electrical rotation machine.

Gantry of the transformer that is connected to the rotation machine through bare busbar or flexible conductor shall be placed in the area shielded by independent lightning pole or lightning rod installed on construction structures.

(3) Lightning rods shall not be allowed to place on the structures of outdoor distribution system within a distance of 15m from:

- Transformer that is connected to the rotation machine by flexible conductor or bare bus bar.

- Exposed bar-conductor that is connected to the pole from which flexible conductor is connected to the rotation machine.

Gantry of the transformer that is connected to the rotation machine through bare bus bar or flexible conductor shall be placed in the area shielded by independent lightning arrester pole or lightning rod installed on construction structures.

Article 375. Ground wires of overhead lines

Grounding wire of 35kV overhead line shall not be connected to the grounding structures of the outdoor distribution system (or substation).

Ground wire of overhead lines at voltage level of 110kV shall be allowed to connect to the grounded structures of the outdoor distribution system if the equivalent resistivity of the earth in lightning season is up to 750Ωm without depending on master grounding area, from 750 to 1,000Ωm when the master grounding area of the station is more than 10,000m2.

The pole supporting to ground wire in the outdoor distribution system at voltage level of 35kV or above 110kV shall be connected to the main ground wire through 2 or 3 paths. Besides, 2 or 3 more of grounding piles with length of 3 - 5m shall be driven so that they are apart from each other as well as from the pole a distance that is equal to the length of one pile, as the least.

Grounding resistance of the dead-end pole of the overhead lines 35kV before entering substations shall be not higher than 10Ω.

If the ground wire of the overhead lines is not allowed to string into the substation, it will be stopped at the dead-end pole of the overhead lines. The overhead lines section inside the substation that are not protected by ground wire should be shielded by lightning rod placed right on or nearby the overhead lines poles inside the substation. The connected joint of the ground wire of the structures that are installed with lightning rods to the master grounding system of the substation shall be at least 15m away from that joint of transformer (or reactor), along the master grounding loop.

Article 376. Lightning Shields

(1) Lightning Protection of the overhead line sections connected to the outdoor distribution system and substations shall also be in accordance with the requirements in chapter 6-2.

(2) For overhead line in temporary operation mode at voltage level lower than its nominal voltage, at the first pole of its section connected to the substation, there shall be arranged lightning arrester at voltage equivalent to temporary working voltage of that overhead line. If lightning arrester of that voltage is not available or voltage is not appropriate in terms of short circuit current, protection slot or bypassing among some pieces in insulator banks on 1 or 2 consecutive poles can be arranged. The quantity of insulators that are not bypassed in the bank shall ensure insulation capacity corresponding to temporary working voltage of overhead line. For the overhead line section situated in the substation area where reinforced insulation is applied, lightning arrester shall be placed on the first pole of such line section, and this arrester shall be suitable to operating voltage of the line. If the lightning arrester is not corresponding to operating voltage level of the line, or has only limited capacity of interrupting power when short circuit occurs, in such cases, protection slot can be installed.

Article 377. Ground wires in Substations

(1) For the purpose of protecting against direct lightning strikes, the edge of the overhead lines shall connect to the ground wire of the 35kV substation with transformers of the capacity 1,600kVA and more. Length of the lightning-protected overhead line sections is from 1 to 2km

1. Angle of wire lightning protection ≤ 300

2. Earth resistance for most of the poles is 10Ω when resistivity is up to 100Ωm; is 15Ω when resistivity from 100 to 500Ωm; 20Ω when resistivity above 500Ωm

Ground wire shall be installed for every pole, except particular cases described in Chapter 3-3. In the region that lightning rarely occurs, it is allowed to raise grounding resistance of the dead-end pole of 110-220kV overhead lines system connected into substations by multiply the values regulated in item (3) with the followings:

- 1.5 times if the lightning hours are less than 20.

- 3 times if the lightning hours are less than 10.

In case it is impossible to implement the grounding complying with the requirements, ground wire shall be extended for counterpoise.

In the areas where resistivity is higher than 1,000Ωm, then it shall be allowed to protect the overhead lines sections strung inside the substation by independent lightning arrester pole. The lightning grounding resistance is calculated by the actual condition..

(2) In the areas where annual lightning hours is not more than 60, it shall be allowed not to install ground wire in the last sections of 35kV overhead line connected into the substation where placed 2 transformers rated up to 1,600kVA for each unit or 1 transformer rated up to 1,600kVA but equipped with standby feeding power source from low voltage side. In such cases, the poles of the overhead line sections with length not less than 0.5km shall be grounded with grounding resistance according to the values specified in item (3). Distance from lightning arrester shall not be more than 10m.

The 35kV overhead line sections strung inside and connected to the substation where installed 1 transformer rated up to 1,600kVA without standby feeding power source from low voltage side shall be shielded with ground wire with length of not less than 0.5km.

(3) It is not required to place lightning arrester CS1 on the gantry of the substation if this section of the line is protected by lightning wire connected to substation, counted from power line side.

For 35kV overhead line of which the first section entered the substation is protected by ground wire, and in lightning season, it is subject to long-term power cut from one side, it should be additionally equipped with the second lightning arrester (CS2) on the substation gantry or on the first pole at the side of power line that is subject to power cut.

Distance from lightning arrester CS2 to the power-interrupting device shall be not over 40m for 35kV overhead line.

On the dead-end pole of the 110kV and 220kV overhead line, the grounding should be arranged for the poles with grounding resistance not over 5 Ω, 10 Ω; 15Ω when the resistivity of the earth is 100Ωm, above 100Ωm to 500Ωm or above 500Ωm respectively.

In the areas with little lightning strikes, grounding resistance is allowed to be increased at terminal poles of 110kV - 220kV overhead lines entering to substations as follows:

- by 1.5 times in areas having less than 20 lightning hours.
- by 3 times in areas having less than 10 lightning hours.

For terminal poles located in the areas with earth resistivity higher than 1,000Ωm, grounding resistance is allowed to be 20Ω but not but not higher than 30Ω.

(4) At 6kV - 22kV substation, if transformers are connected to busbars by cable, the distances from lightning arrester to transformers and other equipment are not limited (exceptions are specified in Article 374). If transformers are connected to busbars of 6kV - 22kV substation by bare wires, the distances from lightning arrester to transformers and other equipment shall be not longer than 90m. Overhead line section of 6kV - 22kV entering to substation is not necessary rob e protected by lightning wires.

In case that the 6kV - 22kV overhead line section might be subject to long-lasting power cut during lighting season from one side, the lightning arrester shall be installed on a structure of the substation or on the dead-end pole of the overhead line at the side subject to long-lasting power cut. Distance from lightning arrester to switching equipment shall be not more longer 15m.

Grounding resistance of lightning arresters shall not be higher than 10Ω if earth resistivity is up to 1000Ωm and not higher than 15Ω if earth resistivity is higher than 1000Ωm. For 6kV - 22kV overhead line section entering to substation on steel poles and reinforced concrete poles in distance of 200m - 300m to substation, the grounding is necessary with grounding resistance not higher than 10Ω.

In order to protect 6kV - 22kV substations connected to 6kV - 22kV overhead lines, lightning arresters shall be installed at both high and low voltage sides.

If lightning arresters are placed in the same compartment of voltage transformer, the lightning arrester shall be located before fuse's location.

(5) If substation has transformer with capacity up to 40MVA branching to 35kV - 110kV overhead line without lightning conductor, and branch length is short, it can be protected by simple schematic diagram of lightning protection as follows (see Figure 377-1):

- Lightning arrester is placed as near as possible to transformer and distance shall be not more than 10m.
- The branch connected to the substation shall be entirely protected by lightning wire. If the branch is less than 150m long, lightning wire or lightning pole shall be arranged as one additional span of main overhead line at both branch sides.

If the branch is more than 500m long, lightning arrester is not required. If distance between lightning arrester and transformer exceeds 10m, the protection of substation shall comply with requirements specified in Article 364, 378.

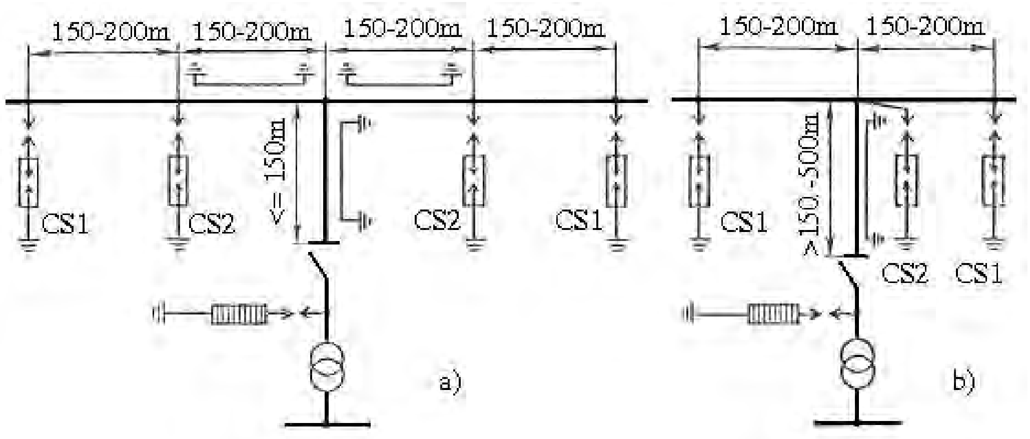


Figure 377-1 Schematic diagram of atmospheric over-voltage protection of substations connected to overhead line via branches with a) length up to 150m b) length over 150m to 500m

Simple protection in accordance with the above-mentioned requirements is allowed to be applied to the substations that are connected to existing overhead line via two short in and out branches (Figure 377-2). In such case, transformer shall be protected by lightning arrester.

It shall not be allowed to apply simple schematic diagram for protection of substation connected to the new overhead line.

(6) In the areas that earth resistivity is 1000Ωm or above, grounding resistance of lightning arresters of CS1 and CS2 at voltage level of 35 - 110kV for protecting substations connected to overhead line, by branch (Figure 377-1) or by going-in and going-out short sections (Figure 377-2), can be higher than 10Ω but not over 30Ω. In such case, grounding circuit of the second lightning arrester CS2 shall be connected to the common grounding system of the substation by using extended grounding electrodes.

(7) Disconnecting switch used for overhead line at voltage level of 35kV and 110kV at branch junctions shall be directly placed on pole where lightning arrester CS2 is installed. If the disconnect switch of the line is placed on pole without lightning arrester CS2, another lightning arrester shall be added right on the same pole. In any case, lightning arrester shall be placed on the same pole with the disconnect switch that is used for isolating the line from the power source.

(8) If the overhead line supported by poles made of steel or ferroconcrete is entirely shielded by ground wire on all over its length, then all its branches also shall be protected by ground wire if they transmit energy to the important loads.

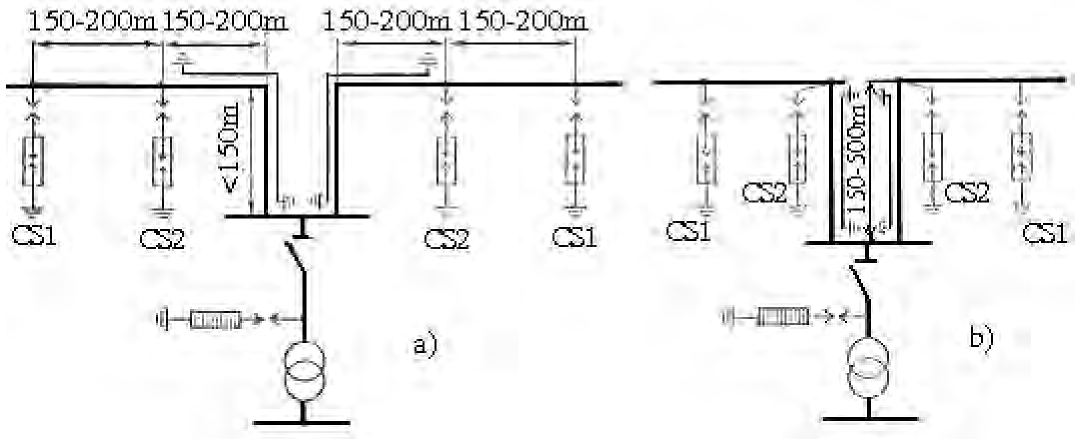


Figure 377-2 Schematic diagram of atmospheric over-voltage protection of substations connected to overhead line via branches with (a) length up to 150m and (b) over 150m.

Article 378. Lightning valves

(1) Lightning arrester should be installed in the 6kV or above substation connected to overhead line system.

Selecting lightning arrester shall be selected based on protection capacity, as well as the insulation of the equipment. Also, the discharge voltage of the lightning arrester shall match with the voltage level of the location of lightning arrester when single-phase earth fault occurs. It is possible to increase the distance between lightning arrester and the protected equipment in order to reduce the necessary quantity of lightning arresters; aiming to such purpose, lightning arrester with capacity higher than that required by the set forth requirements can be installed, but in any case, equipment insulation shall be taken into account.

Distance along conductor from lightning arrester to transformer and other equipment shall not exceed 10m and so short so good.

If this requirement cannot be met, the calculation of maximum allowable distance between lightning arrester and equipment to be protected shall be based on the number of lines and lightning arrester connected to the substation in normal working condition. In case of installing lightning arrester at location that the above-mentioned distance is more than the required value, additional lightning arrester shall be placed on the bus bar.

Quantity and installation location of lightning arrester shall be based on the designed electric diagram, the number of overhead lines and transformers in every operating technology of the substation. Faulty mode and repairing mode can be disregarded.

(2) Lightning arrester can be directly connected to transformer (including reactor) without using disconnector.

(3) When transformer is connected to busbar of distribution equipment by one or more cables with voltage of 110kV and above, the lightning arrester shall be installed at the connection point of cable to busbar, and the grounding terminal of lightning arrester shall be connected to the metal sheath of the cable.

(4) Low and medium voltage windings of power transformer (autotransformer) that are not in use shall be interconnected in wye-form or delta-form and lightning arrester shall be connected to each phase. Not-in-use low-voltage windings are protected by grounding one of the 3 delta-form points, one of the 3 phases of the wye-form or the neutral point; or by placing lightning arrester corresponding to voltage level of each phase.

The not-in-use windings that permanently connected to the grounded armored cable with length of 30m or more are not required to be installed with lightning arrester.

(5) Lightning arrester shall be placed to protect neutral points of the 110-220kV windings of the transformers which have insulation capacity lower than that of the outlets and operating at ungrounded neutral point mode. It is forbidden to install disconnector at the neutral point of the transformer that is not allowed to be isolated from ground.

(6) 500kV branching reactors shall be protected against atmospheric over-voltage and internal over-voltage by the installation of lightning arresters or over-voltage protectors installed at circuits of reactors.

Article 379. Insulation Co-ordination

(1) Summary of insulation coordination study

Insulation coordination is a process determining the level of insulation for system equipment in accordance with the corresponding over-voltage protection (e.g. surge arresters). There are three basic elements for insulation coordination as follows.

- Determining the overvoltage from the power system
- Determining the insulation strength of specific equipment in the substation
- Selecting the technical parameters of surge arrester and locations, or neutral grounding system, etc., to ensure the system-imposed overvoltage don't exceed the insulation strength of the equipment including an appropriate protective margin

The above mentioned overvoltage can be determined by simulation. In power systems, there are four general types of overvoltage that shall be considered in studying the insulation coordination. These are:

- Maximum continuous operating overvoltage
- Temporary overvoltage (PFWV); caused by single-line to ground fault, load rejection, etc.
- Switching overvoltage (SIWV)
- Lightning overvoltage (LIWV)

(2) Basic idea of selecting the basic impulse insulation level (BIL)

For example, the basic idea of selection of the basic impulse insulation level (BIL) for power equipment in the power system with the nominal voltage of 220kV shown in the Table 331-1 in Technical Regulation is as follows.

Firstly the BIL regulated in IEC are two types of 950kV and 1,050kV and the adopted BIL is normally selected from those values.

In practical selection of BIL, BIL shall be selected according to the maximum overvoltage applied to the target equipment based on the result of surge analysis (simulation in the above item (1)). Because the overvoltage applied to the actual target equipment vary according to various conditions (actual arrangement of equipment, equipment configuration, neutral grounding system, the specification and arrangement of surge arresters and etc.). Eventually, the optimal specification and arrangement of surge arresters, and adopted BIL are determined by repeating the simulation while changing above-mentioned conditions.

At this time, if applied overvoltage is low from the result of above analysis, adopted BIL can be chosen from low values. (e.g. from 950kV or 850kV) On the other hand, if applied overvoltage is high, it is necessary to select from 1050kV or BIL adopted with the rated voltage of the higher rank, such as 1,175kV.

Chapter 4-2-6 Lightning Protection for Rotation Machine

Article 380. Connection of Overhead Line

As stipulated in Technical Regulation.

Article 381. Protection of Rotation Machines Connected to Overhead Lines

For the protection of generator, synchronous compensator, electric motor with capacity more than 3MW (3MVA) connected to overhead line, appropriate lightning valve and capacitor with capacitance not less than 0.5µF shall be installed in every phase. Besides, the overhead line sections connected to the power plant (or substation) shall be protected against lightning strikes at impulse current of not less than 50kA.

Lightning valve should be placed on the bus bar (or part of the bus bar) of generator to protect the generator (or synchronous compensator) with capacity up to 15MW (15MVA), on the bus bar of distribution station to protect electric motor with capacity over 3MW, or on the outlets of generator (synchronous compensator) with capacity over 15MW (15MVA).

As for the protection of generator (synchronous compensator) with isolated neutral and without winding insulation (insulation bar windings type) rated from 20MW (20MVA) and up, instead of using 0.5µF capacitor at every phase, lightning valve can be installed at the neutral conductor, with nominal voltage of the generator (synchronous compensator).

It is not required to install protection capacitor if the total capacitance of the cable system connected to the generator (synchronous compensator) with length up to 100m can derive a capacitance of 0.5µF or above for every phase.

Article 382. Protection of Overhead Lines with Rotation Electric Machine

If electric rotation machine and overhead line are jointly connected to the busbar of a power plant or a substation, such overhead line should be protected against lightning in accordance with the following requirements:

1. The first section of overhead line shall have lightning wire with length of at least 300m. The lightning arrester shall be installed on this section of the line (Figure 382a). Conductors of overhead line shall be placed on insulators with insulation class for 35kV. Grounding resistance of lightning arrester shall not exceed 5Ω, grounding resistance of the pole where grounding wire is installed shall not exceed 10Ω.

At the beginning of the line, appropriate lightning arrester can be installed instead of line lightning arrester. In such case, grounding resistance of the lightning arrester shall not exceed 3Ω.

2. If the overhead line is connected to power plant or substation through cable section with length up to 0.5km, such section will be protected as an overhead line without connected cable (see point 1) and appropriate lightning arrester should be additionally installed at the junction between the cable and the overhead line. Lightning arrester shall be connected by the shortest path to metal sheath of cable or to the grounding system. Grounding resistance of the lightning arrester shall not exceed 5Ω.

3. If overhead line section with length of 300m or longer is already protected against direct lightning strike thanks to high buildings, trees or high structures, then it is not required to install lightning wire. In such case, at the terminal of overhead line section protected (at side of line), lightning arrester shall be installed. The grounding resistance of lightning arrester shall not exceed 3Ω.

4. If overhead line is connected through a line section of 100 - 150m to busbar of substation which has electric rotation machine, that line section shall be protected against direct lightning strike by lightning wire (Figure 382b). The line lightning arrester shall be installed at the end of line section

protected by lightning wire, and lightning arrester shall be installed at the reactor. The grounding resistance of line lightning arrester shall not exceed 5Ω.

5. If the overhead line is connected to the busbar of distribution station where rotation machine is placed through reactor and cable with length of more than 50m, it is not be required to install lightning protection device. At the connection point of connecting cable and the overhead line, it needs to install lightning arrester with grounding resistance not exceeding 5Ω, and lightning arrester shall be placed before reactor location. (Figure 382c).

6. If overhead line is connected through a line section with length not less than 0.5km to busbar of power plant (substation) which has electric rotation machine with capacity less than 3MW (3MVA) and pole grounding resistance not exceeding 5Ω, then lightning arrester shall be installed at distance of 150m to power plant (substation). The grounding resistance of this lightning arrester shall be not more than 3Ω. In such case, it is not necessary to install lightning wire for that overhead line section.

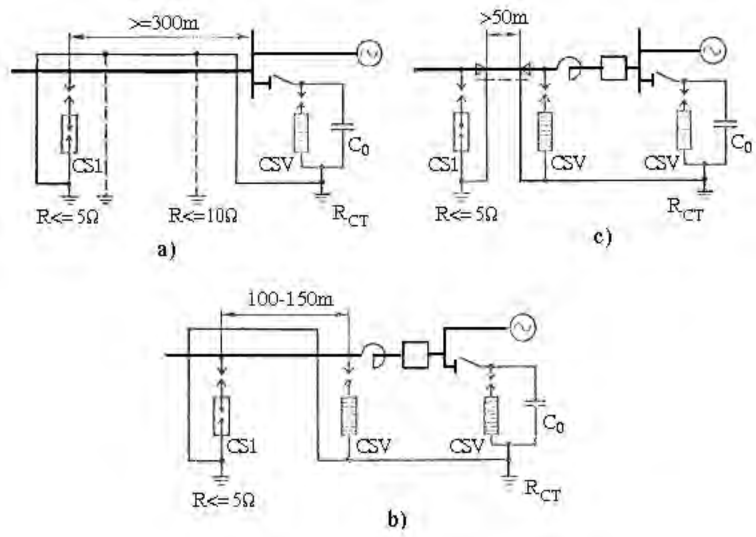


Figure 382 Atmospheric overvoltage protection diagram for electric rotation machine

If generator (synchronous compensator) is connected with transformer through bare conducting system, the live parts of this system shall be located in the protection area of lightning poles or structures of power plant (substation) against direct lightning strikes. Distance from grounding points of lightning poles to grounding points of power conducting system shall be not less than 20m (measured along the grounding wire).

In case that the power conducting system is not located in the area protected by the lightning arrester placed in the outdoor station, they shall be protected against direct lightning strikes by independent lightning arrester poles or lightning wire hung on a separated poles with protection angle not over 200 degree. Independent lightning arrester poles and lightning wire poles should be connected to a separated grounding system. If such pole is connected to the common grounding system of the station, the connection point shall be at least 20m far away from that of power conducting system.

In air distance between the independent lightning system or lightning wire poles and live parts or grounding parts of power conducting system shall be not less than 5m.

Underground distance between the separated grounding system or underground parts of independent lightning poles to grounding system or underground parts of power conducting system shall be not less than 5m.
If the substation of an industrial enterprise is connected through overhead line to the distribution station of power plant where installed generators with capacity of up to 120MW for each unit, the protection against direct lightning strikes on that overhead line shall be implemented as stipulated in the above items.
If the bare conductor is connected to distribution equipment at generator's voltage through reactor, appropriate lightning arrester shall be installed before the reactor.
In order to protect generator against lightning surge transmitted along conducting bars as well as against induced over-voltage, proper lightning arrester and capacitor shall be installed for protection of all 3 phases. Capacitance of capacitor shall be not les 0.8μF for voltage level of 6kV, not less than 0.5μF for voltage level of 10kV and not less and 0.4μF for voltage level from 13.8 to 20kV.
It is not required to install protection capacitor if the total capacitance of the generator and cable network connected to the generator's busbar is at required voltage value. For the calculation of capacitance value of the cable network in such case, only cables with length up to 750m are taken into account.
It is allowed not to install device for protection of overhead line section against direct lightning strike if that overhead line is connected to electric motor with capacity up to 3MW fed by stable standby power source.
If the overhead line section with length of over 250m is connected into the substation and grounding resistance of poles of this section is not over 10Ω, lightning arrester is not be required.
If the overhead line is connected to the substation through cables with any length, the lightning arrester shall be installed before this cable section. Grounding of lightning arrester shall be connected to the metal sheath of the cable.
For electric motors, appropriate lightning arrester and 0.5μF protection capacitor shall be installed in each phase.

Chapter 4-2-7 Internal Overvoltage Protection

Article 383. Internal Overvoltage Protection for 6-35kV

In the power grid at voltage level of 6 to 35kV where installed arc suppression coil, capacitance between phase to ground should be balanced for each phase by rational placement of phases and high-frequency communications capacitors.
The difference of capacitance for each phase shall be not over 0.75%.
The location of arc suppression coil shall be determined based on power grid structure, the possibility of dividing the power grid into separated areas, the probability of faulty modes, the effect on automatic circuits of railway and communications channel.
It is forbidden to place arc suppression coil into transformer in the following cases:

- Transformer is connected to the bus bar via fuse
- Transformer is connected to the power grid via only one transmission line.

Capacity of arc suppression coil shall be determined by the total capacity to ground in consideration of the extension of the power network system in the future.

Power grid at voltage level from 6 to 35kV where installed arc suppression coil or generator (synchronous compensator) with directly water-cooled stator winding, it is not required to install the neutral displacement protector.

The above power grid, that is without arc suppression coil or water-cooled generator (synchronous compensator), or in the power grid where the equipment such as arc suppression coil and water-cooled generator (synchronous compensator) are disconnected when the power is automatically interrupted, it is required to carry out the interconnection of some circuits in order to prevent the neutral displacement when implementing activities such as finding earth fault point, or periodical test and maintenance of equipment. That is: a 25Ω-impeder capable of permanent resistance to 4A current flow should be installed in the open delta windings on secondary side of transformers at voltage level from 6 to 35kV in order to test the insulation of the power grid; and of course necessary tools for removing that impeder shall be also equipped.

Moreover, in the diagram of generator-transformer and compensator-transformer, the second impeder as mentioned above should be connected parallelly to the permanent impeder if the ferromagnetic resonance occurs.

If the power grid is not required to measure phase-to-ground voltage (insulation testing) or “zero” sequence voltage, then transformer with ungrounded primary winding should be utilized.

Article 384. Internal Overvoltage Protection for 110-220kV

As for 220kV transformers and autotransformers which have normal insulation level, they shall be protected from internal over voltage by arrangement of surge arresters in accordance with requirement in the Article 378.

In addition, the arrangement of surge arresters should be determined according to the following policy.

Protection of the equipment against over voltages should normally be provided by the surge arresters installed on the feeders (distribution and transmission lines). In some cases, the protection given by surge arresters may be inadequate. This situation arises mainly in the following configurations.

- Large distance between the surge arrester and the equipment
- The equipment connected to the surge arrester by means of power cables
- Long bus bars open at their ends
- Connection to overhead lines by means of insulated cables;
- Locations with high probability of lightning strikes.

For these configurations, the installation of additional surge arresters may be required. Their location should be based on experience with similar situations or on calculations.

Article 385. Internal Overvoltage Protection for 500kV

In 500kV power grid, depending upon the total length and quantity of overhead lines, types of circuit breakers, capacities of transformers and other parameters, appropriate methods should be applied to prevent the substantial voltage rise in a long time and operating over voltage (temporary overvoltage, switching overvoltage and etc.) based on the calculation of over-voltage levels. Acceptable limit of insulation level of 500kV equipment should be determined depend on the duration of its effect.

In 500kV power grid, operating over-voltage levels shall be limited to the values in the table 332-2 of technical regulation.

In order to restrain dangerous over-voltage failures happened to the overhead line system, it shall be equipped with combination of varied lightning valves, electromagnetic potential transformer or other devices. Also, proper solutions to control substantial voltage increasing in a long time (such as the installation of a current-limiting reactor, or methods related to the schematic diagram or system automation) should be considered.

The installation of protection devices for over-voltage control in 500kV equipment shall be implemented based on the calculations of internal over-voltage in the power system.

For 220kV-500kV distribution equipments with air circuit breakers, the measures shall be applied for elimination of over-voltage due to ferromagnetic resonance derived from switching voltage transformers and capacitor voltage divider of circuit breakers which are connected in series

Chapter 4-2-8 Installation of Power Transformers

Article 386. Oil-Filled equipment

In order to install and maintain the oil-filled equipment of the substation, mobile oil system shall be set up, including all equipments to transport oil filter or oil treatment

The site and scale of the oil mobile system shall be subject to the approved alternative.

Article 387. Power transformer requirements

As stipulated in Technical Regulation.

Article 388. Overload Operation of Power transformers

Regarding the overload operation of transformer, the current and temperature limitations are stated in the following table.

Table 388 Maximum Current and temperature limits applicable to loaded transformer exceeding nameplate rating

Types of loading	**Distribution transformers** (*1)	**Medium power transformers** (*1)	**Large power transformers** (*1)
Normal life expectancy loading *2			
Current (p.u.)	1.5	1.5	1.3
Winding hot-spot temperature and metallic parts in contact with cellulosic insulation material (°C)	120	120	120
Other metallic hot-spot temperature (in contact with oil, aramid paper, glass fiber materials) (°C)	140	140	140
Top-oil temperature (°C)	105	105	105
Long-time emergency loading *3			
Current (p.u.)	1.8	1.5	1.3
Winding hot-spot temperature and metallic parts in contact with cellulosic insulation material (°C)	140	140	140
Other metallic hot-spot temperature (in contact with oil, aramid paper, glass fiber materials) (°C)	160	160	160
Top-oil temperature (°C)	115	115	115
Short-time emergency loading *4			
Current (p.u.)	2.0	1.8	1.5
Winding hot-spot temperature and metallic parts in contact with cellulosic insulation material (°C)	*5	160 *5	160 *5
Other metallic hot-spot temperature (in contact with oil, aramid paper, glass fiber materials) (°C)	*5	180 *5	180 *5
Top-oil temperature (°C)	*5	115	115

NOTE

*1 : The temperature and current limits are not intended to be valid simultaneously. The current may be limited to a lower value than that shown in order to meet the temperature limitation requirement. Conversely, the temperature may be limited to a lower value than that shown in order to meet the current limitation requirement.

*2 : Normal life expectancy loading

Higher ambient temperature or a higher-than-rated load current is applied during part of the cycle, but, from the point of view of relative thermal ageing rate (according to the mathematical model), this loading is equivalent to the rated load at normal ambient temperature. This is achieved by taking advantage of low ambient temperatures or low load currents during the rest of the load cycle. For planning purposes, this principle can be extended to provide for long periods of time whereby cycles with relative thermal ageing rates greater than unity are compensated for by cycles with thermal ageing

<table>
<tr><th>Types of loading</th><th>Distribution transformers
(*1)</th><th>Medium power transformers
(*1)</th><th>Large power transformers
(*1)</th></tr>
<tr><td>Normal life expectancy loading *2</td><td></td><td></td><td></td></tr>
<tr><td colspan="4">rates less than unity
*3 : Long-time emergency loading
Loading resulting from the prolonged outage of some system elements that will not be reconnected before the transformer reaches a new and higher steady-state temperature
*4 : Short-time emergency loading
Unusually heavy loading of a transient nature (less than 30 min) due to the occurrence of one or more unlikely events which seriously disturb normal system loading
*5 : The limits on load current, hot-spot temperature, top-oil temperature and temperature of metallic parts other than windings and leads stated in the above table should not be exceeded. No limit is set for the top-oil and hot-spot temperature under short-time emergency loading for distribution transformers because it is usually impracticable to control the duration of emergency loading in this case. <u>It should be noted that when the hot-spot temperature exceeds 140°C, gas bubbles may develop which could jeopardize the dielectric strength of the transformer</u></td></tr>
</table>

Article 389. Oil level monitoring

It is necessary to find an oil leakage of oil immersed equipment early in terms of prevention of insulation performance degradation and environmental pollution. Because of this, oil level gauges should have a upper limit and lower limit level, and in case of the large transformer, because the oil level widely changes according to the oil temperature, the characteristic curve which shows the relation between oil temperature and oil level should be provided on site in order to easily confirm the adequate oil level according to the oil temperature under operation.

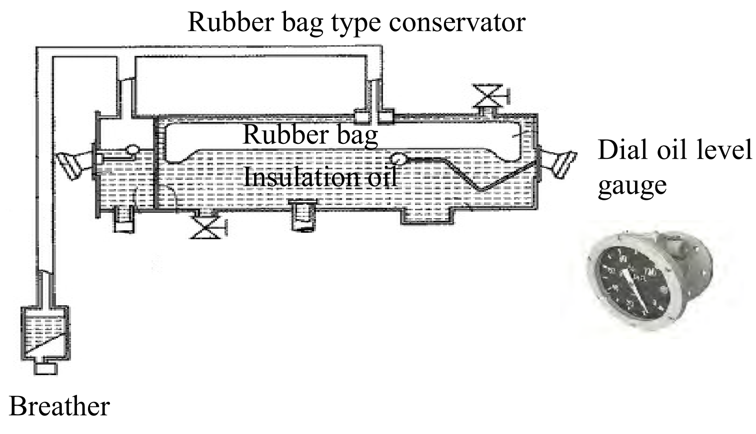


Figure 389 Installation example of oil level gauge

Article 390. Buchholz relays

Buchholz relay is used for the following detection.

- Decomposed gas caused by minor accidents, such as partial discharge and overheating of abnormalities in internal transformer.
- Rapid oil flow due to a major accident, such as transformer internal short-circuit detection.

For this reason, the relay is mounted in the middle of the connecting pipe between the conservator and main tank of the transformer. (see the figure 390-1)

Therefore, the ladder for approach to the upper part of transformer shall be installed so that maintenance personnel can safely check the relay operation state and amount of generated decomposed gas and collect the gas at the time of the relay operation.

However, the mounting position of the ladder shall be determined in consideration of the working clearance between workers and the live parts, such as bushings which are installed in the upper part.

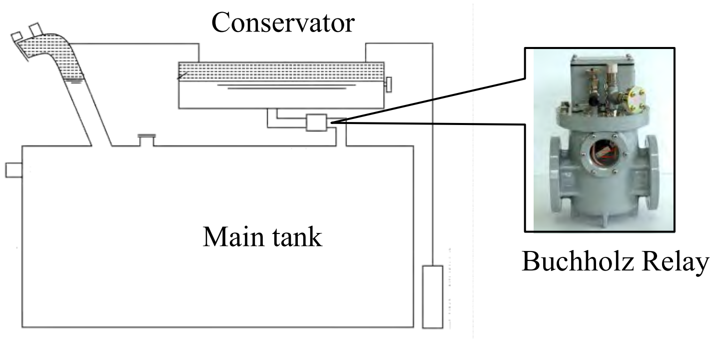


Figure 390-1 Installation example of Buchholz Relay (Japanese case)

Figure 390-2 Installation example of maintenance ladder (Japanese case)

Article 391. Lightning arrester for transformers

As stipulated in Technical Regulation.

Article 392. Wheels platform

As stipulated in Technical Regulation.

Article 393. Gradient for the site

As stipulated in Technical Regulation.

Article 394. Supplementary oil drums

As stipulated in Technical Regulation.

Article 395. Explosion-prevention tube

In case of installing a bursting tube in a transformer, that outlet shall curve downward and keep some distance from the control device so that the operator can safely operate the device.

When pressure relief devices operate at the time of internal faults of a transformer, the insulation oil will discharge from the outlet of the bursting tube. Therefore the outlet should connect the oil catchment tank in terms of the oil outflow prevention.(see the following figure)

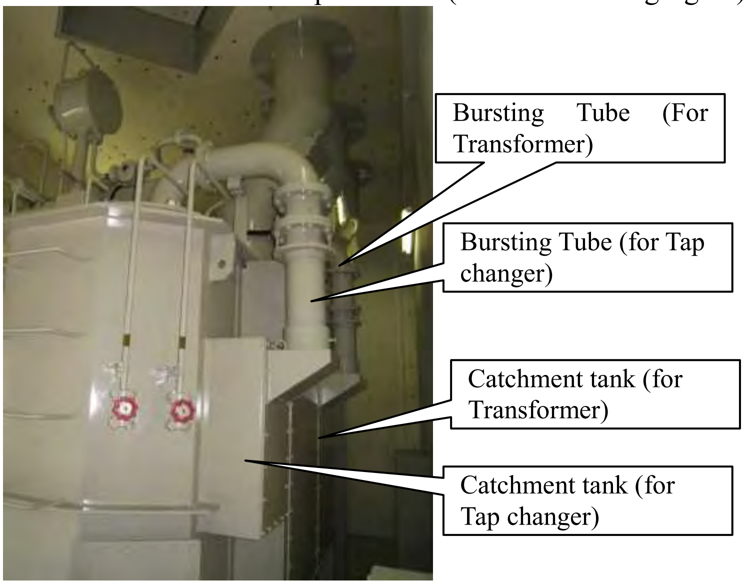


Figure 395 Installation example of bursting tube and catchment tank

Article 396. Series regulating transformer

As stipulated in Technical Regulation.

Article 397. Automatic fire extinguishers

For fire extinguishing equipment of outdoor equipment, using faucets or the fire extinguishing equipment of sprinkler type are adopted. For indoor equipment, the fire fighting is more difficult than outdoor one. Therefore, it is desirable to install the following automatic fire extinguishing equipment which has high performance in the transformer compartment

In addition, the specification of distribution boards and control boards for the fire extinguishing equipment shall have been manufactured according to requirement stipulated in the article 315.

Table 397 Automatic fire extinguishing equipment for indoor equipment

<table>
<tr><th></th><th colspan="2">(Inactive gas fire extinguishing systems)</th><th colspan="3">(Haloid fire extinguishing systems)</th></tr>
<tr><th>Kind of extinguishant</th><th>Carbon dioxide (CO2)</th><th>Nitrogen (N2)</th><th>Halon 1301 (CF3BR)</th><th>Trifluoromethane HFC-23 (CHF3)</th><th>HFC-227ea Heptafluoropropane (CF3CHFCF3)</th></tr>
<tr><td rowspan="2">Required quantities of extinguishant</td><td>Q≥tV+5K

where

-Q: Required quantity of extinguishant
-t: Required quantities of extinguishant per 1m3 of protective compartment
-V:Volume of protective compartment
-K: Aperture area of protective compartment</td><td>0.740≥Q≥0.516V

where

-Q: Required quantity of extinguishant
-V:Volume of protective compartment</td><td rowspan="2">Q≥0.32V+2.4K

where

-Q,V,K:refer to the items of Carbon dioxide type</td><td rowspan="2">0.80V≥Q≥0.52V

where

-Q,V:refer to the items of Carbon dioxide type</td><td rowspan="2">0.72V≥Q≥0.55V

where

-Q,V:refer to the items of Carbon dioxide type</td></tr>
<tr><td colspan="2">Minimum limit of parameter t, Q<table><tr><th>V[m3]</th><th>t[kg]</th><th>Minimum required quantity of extinguishant</th></tr><tr><td>V<50</td><td>1.00</td><td>-</td></tr><tr><td>50≤V<150</td><td>0.90</td><td>50</td></tr><tr><td>150≤V<1500</td><td>0.80</td><td>135</td></tr><tr><td>1550≤V</td><td>0.75</td><td>1,200</td></tr></table></td></tr>
<tr><td>Remarks</td><td colspan="5">The ventilation system for transformer compartment shall be stopped automatically in case of fire. In order to cut off the air supply in case of fire, fire dampers which can close themselves by the gas pressure of fire extinguishing shall be installed</td></tr>
</table>

Article 398. Indoor oil-Filled transformer

Regarding the installation of indoor oil-filled transformer, if transformer is installed on location higher than second floor or lower than first floor by more than 1m, it shall be dry transformer or transformer filled with fireproof insulating substances. Installation of transformer in the compartment also shall comply with stipulations in the article 343.

It is allowed to place 2 oil-filled transformers rated up to 1,000kVA each in the same compartment if 2 machines have the same functions, common control and protection system and they are considered as 1 unit.

6 units of dry transformer or transformer filled with fireproof insulating substance are allowed to be placed in one compartment if that placement doesn't affect over the operation and repairing conditions.

Article 399. Clearance from Indoor oil-Filled transformers

When transformer is installed indoors, the clearance between the most protruded part of transformer (at height of 1.9m to the floor) and :

a. walls and partitions - is not less than 0.3m for transformers with capacity up to 400kVA; 0.6m for transformers with higher capacity.

b. doors and protruded part of wall at entry - is not less than:
   - 0.6m for transformers with capacity up to 400kVA
   - 0.8m for transformers with capacity over 400 to 1,600kVA
   - 1.0m for transformers with capacity over 1,600kVA

Chapter 4-2-9 Battery Systems

Article 400. Scope of Battery Systems

As stipulated in Technical Regulation.

Article 401. Battery Systems Compartments

If using portable battery (for instance, auto battery) with total capacity not exceeding 72Ah to supply power to fixed electrical equipments, the battery can be placed together with the equipments in the same separated compartment with natural ventilation or in the general production compartment which is out of explosion-prone danger or in metal cubicle with ventilation system. If the above requirements are complied with, the category on dangerous explosion-prone area of the manufacture compartment is maintained unchanged.

The battery system where charging voltage of each unit is not over 2.3V can be placed in the general production compartment without explosion-prone danger, provided that ventilation sleeve shall be installed over each battery unit. In such case, the category of dangerous explosion-prone area of the manufacture compartment is maintained unchanged.

The battery system compartment shall be equipped with emergency lighting used when failure occurs.

Article 402. Capacity of the battery system

DC power supply for communication system in power station shall be provided from separated battery system.

In case that electrical equipment are protected by two main protective systems, the DC power supply for such equipment shall come from two separately operated busbars which are independently operating.

For important 220kV and 500kV substation, two battery supplies shall be arranged for regular operation.

Article 403. Charging Equipment

Regarding the charging equipment, it shall meet the following specification.

- In battery compartment shall be equipped with voltmeters with switching lock and ampere-meters in charging and sub-charging circuits of battery system.
- Sub-charging equipment shall ensure stable voltage of the busbar of the battery system within limitation from -2% to +2%.
- Battery charging equipment shall equip the voltage regulator in order to control charging voltage within the range specified by the manufacturer.
- Rectifier for charging and sub-charging batteries shall be connected to AC power supply via isolating transformer.
- DC busbar shall be equipped with specific device that regularly measures the insulating resistance of the poles and signalizes when insulating resistance of each pole is decreased to 20kΩ in 220V power system, 10kΩ in 110V power system, 5kΩ in 48V power system, 3kΩ in 24V power system.

Article 404. Auto-Circuit Breakers for Battery Systems

This provision of this article shall refer to the article 299 of Volume 4.

Article 405. Battery racks and cabinets

When a battery system is installed on rack or in reliable cabinets, it shall be ensured that all elements of battery system are reachable. And the clearance between racks, between rack and the wall, or between rack and the inner side of cabinet shall be appropriate for the operator and the maintainer to reach all cells of the battery system in consideration of the operation and the maintenance.

Battery racks shall be manufactured and tested in accordance with the requirements of the effective specification. The rack and cabinet shall be covered with sustainable layer to protect against the electrolyte and other corrosive chemical substances.

Battery cells shall be electrically insulated with supporting racks. The rack supporting to battery system with voltage level up to 48V can be installed without insulation material.

A space of at least 200mm height above the batteries shall be arranged for people to access. The clearance from the inner side of cubicle to the batteries (in case of placing battery in cubicle) shall be sufficient to avoid short circuit fault. Ventilation tube above the battery shall be able to turn around 180 degree so that the supplementary solutions can be done easily.

Article 406. Battery bus bar & cable

Bare busbars shall be painted with two layers of paint resistant to corrosive chemicals. After the painting layers are dried, positive pole (+) shall be painted with red color and negative pole (-) shall be painted with green color. The places which are impossible to be painted shall be covered with a vaseline layer to prevent a corrosion before electrolyte is poured into a battery vessel.

The clearance between adjacent bare conductive bars shall be determined based on calculated mechanical durability. The mentioned clearance and the clearance from the busbar to other parts in the station and grounded components shall be not less than 50mm.

Busbars shall be placed on and screwed tightly to insulator.

The clearance between the supporting points of busbar (in any shape) are determined based on the calculated mechanical strength, but shall be not more than 2m. Structure, insulation, auxiliary parts, parts for fixing busbars shall have sufficient mechanical and electrical strength, and resistant to long-term impact of the electrolyte mist. Grounding of support structures is not required.

The board supporting through-wall conductive bar which is protruded out of the battery compartment shall be resistant to long-term impact of the electrolyte mist. It is not allowed to use stone or layer-structured materials for the supporting board.

The connection from output panel-board of the battery compartment to switching devices and DC distribution panel shall be done through single core cable or bare conductive bar.

During the transporting process, batteries shall be fixed and their air vents shall be closed. In addition, the installation, operation, maintenance and safety issues shall comply with guidelines and recommendations of the manufacturers.

PART 5 PROTECTIVE RELAYS AND CONTROL SYSTEMS

Chapter 5-1 Protective Relays up to 1kV

Article 407. Scope of Application

As stipulated in Technical Regulation.

Article 408. The Selection of Breaking Capacity

As stipulated in Technical Regulation.

Article 409. The Selection of Rated Current

As stipulated in Technical Regulation.

Article 410. Application of Fuses and Auto-Breakers

Regarding the protection of a neutral line, the reason for prohibition against use of automatic circuit breakers is as follows.

- Solidly earthed neutral: The fault current can't flow after interruption of a neutral line
- Isolated neutral: if a neutral line is interrupted and the load between the supply lines and the neutral line is unbalanced in the single-phase three-wire distribution system, the load equipment may breakdown or ignite at worst due to the overvoltage which rises after interruption of the neutral line.

For electrical equipment with voltage up to 1kV in power system which has directly grounded neutral conductor, in order to ensure automatic disconnection of faulted line section, phase conductor and protective neutral conductor shall be so selected that in case if earth fault of cover or protective neutral conductor happens, short circuit current shall be not lower than:

- 3 times of nominal current of nearby fuse.
- 3 times of nominal current of non-adjustable breaker or calibrated current of adjustable switch of circuit breaker with reverse-current relay.

In case that protecting power network by automatic circuit breaker with only magnetic interrupter (high speed overflow), the above-mentioned conductor shall maintain the current not lower than starting calibrated current multiplied with dispersed/decay factor (according to data of manufacturer) and reserve factor is 1.1. In case that data of manufacturer are not available, as for automatic circuit-breaker with nominal current to 100A, multiple of short circuit current in comparison to calibrated current shall be not lower than 1.4; For automatic circuit-breaker with nominal current over 100A, the above-mentioned multiple shall be not lower than 1.25. In all cases, full conductance of productive neutral conductor shall not be lower than 50% of conductance of phase conductor

If the required multiple is not met in case earth fault of cover or protective neutral conductor, interruption of this short circuit fault shall be performed by special protective device.

Article 411. Display of Nominal Current

As stipulated in Technical Regulation.

Article 412. Short Circuit Fault Protection

Regarding the protection of short circuit, it shall be carried out with minimum breaking time and selective breaking.

It shall be always operated if the following faults occur at the end of the protected area:

- Single- and multi-phase for solidly earthed neutral grid
- Two- and 3-phase for isolating neutral grids.

If ratio between minimum calculated short circuit current and nominal current of fuse or automatic circuit-breaker is not lower than the value stipulated in Article 410, a breaking operation is ensured.

In the power grid, only short circuit protection is required. It is not necessary to calculate the multiple of short circuit current as required in Article 410, if the following conditions are satisfied: in case of comparison with allowable long-term currents, protective devices have multiple not higher than:

- 3 times of nominal current of fuse wire.
- 4.5 times of calibrated current of automatic circuit breaker which has quick-break, overflow interrupter.
- 1.0 time of nominal current of automatic circuit breaker with non-adjustable reverse-current relay (not dependent on whether quick interrupter is available or not).
- 1.25 times of starting current of built-in interrupter in automatic circuit breaker with adjustable reserve current. In case that high speed interrupter is available in automatic circuit breaker, the multiple of starting current of quick interrupter is not limited.

Article 413. Overload Protection

In circuits with overload protection, selection of conductors should be based on calculated current and ensuring conditions as specified for permissible current values in Chapter 2-2-Part II and the protection device shall have the multiple not higher than:

- 80% of nominal current of fuse wire or calibrated current of automatic circuit breaker, which only has high speed interrupter (for conductors covered with synthetic plastic, rubber or insulators with the similar thermal characteristic). This figure is allowed to reach 100% for conductors which are placed in inflammable and not-explosive spaces.
- 100% of nominal current of fuse wire or calibrated current of automatic circuit breaker which has only quick-interrupter (for power cables covered with insulating paper).
- 100% of nominal current of automatic circuit breaker with non-adjustable reserve current, not depending on whether quick interrupter is available or not (for all types of conductor).
- 100% of starting current of automatic circuit breaker with adjustable reserve current for conductors covered with synthetic plastic, rubber or insulators with the similar thermal characteristics.
- 125% of starting current of automatic circuit breaker with adjustable reserve current for power cables covered with insulating paper and vulcanized polyethylene insulator.

Permissible long-term load current of conductor to motors with squirrel cage rotor shall be not lower than:

- 100% of nominal current of rotors in areas without fire and explosion risks.

- 125% of nominal current of rotors in areas with fire and explosion risks.
Relationship between permissible long-term load current of conductor connected with squirrel cage rotor and calibrated current of protective devices, in any case, shall be not higher than values specified in Article 412.

If permissible long-term load currents of conductor determined according to the values specified in the above mentioned and Article 412 are not satisfying values mentioned in Tables of permissible currents presented in Chapter 2-2-Part II, it is allowed to select the conductors with smaller cross section area closed to values in the Tables but not higher than values determined according to calculated currents.

Article 414. Installation Location

It is necessary to install protective devices in places where their conductor's cross section area downsizes (towards load side) in electric circuit, or at points where it needs ensuring sensitivity and selectivity (refer to Article415, 416).

Article 415. Placement of Protective Devices

The protective device shall be placed right at the point of connecting protected component to feeding line. In case of necessity, it is allowed to use up to 6m length of branching section between protective device and feeding line. Cross section area of this line section can be less than that of feeding line but not less than cross section area of conductor after protective device.
For branches arranged at inconvenient places (e.g. at too high point), it is allowed to use up-to-30m-long section connected to protective devices for facilitating operation (e.g. input line of switchyard, starters of electrical equipment, etc.). In this case, cross section area of branch shall be not smaller than cross section area determined according to calculated current, and make sure not smaller than 10% loading capability of protected main line. The above-mentioned branching conductors (6m or 30m) shall have insulating sheath and be going inside refractory conduits. For other cases (except underground power cables), in inflammable and explosive areas, such conductors can be laid out open on structures which are prevented from mechanical damages.

In case that fuses are used for protecting power grid, they shall be installed on all poles or normal phase (ungrounded phase).
It is prohibited to install the fuses on neutral wires.

In case automatic circuit breaker is used for directly protecting grounded neutral power network, its interrupter shall be installed on each ungrounded conductor.
In case that automatic circuit breaker is used for protecting power network with 3-phase-3-lines, or 1-phase-2-lines neutral wire, or DC power grid, it is necessary to install interrupter of automatic circuit breaker on 2 phases (for 3-line power grid) and on 1 phase (pole) (for 2-line power grid). Note: in one power grid, protective devices should be installed on phases (poles) which have the same name.
It is only allowed to install interrupter of automatic circuit breaker on neutral conductor if when it actuates all live conductors shall be switched off at the same time.

Article 416. Exception of Protective Devices

It is not allowed to install the protective devices on joints between feeding line and controlling, measuring and signaling circuits in case that the outage of such circuits can cause serious consequences (switching firefighting pumps, fan for preventing creation of explosive mixture, equipments, machines of auxiliary power system in power plant, etc.). In every case, conductors of such circuits shall be placed in conduits or covered with fire-resistance coat. Cross section area of such circuits shall be not smaller than values stipulated in the article 536.

Chapter 5-2 Protective Relays above 1kV

Chapter 5-2-1 Common Protection Methods

Article 417. Applicable Scope

As stipulated in Technical Regulation.

Article 418. Purpose of Protective Relays

It is necessary to display the trip of relay protection by relay built-in indicator, by particular signaling relay or by the digital and study on operation of relay protection.

It is necessary to have signals on the interruption flow of relay protection so that signal of each relay protection is displayed. As for complicated protection - sending signals for each part of protection (different protection level, particular compound protection for various faults, etc.)

Regarding the tripping circuit and power supply, it would be better to use direct tripping relay (primary and secondary) and protective relay is fed by AC power supply source if such application can simplify and reduce cost but secure reliability and selectivity.

Generally, current transformer of protected components is used as AC power source for short circuit protecting system. It is also allowed to use transformer or auxiliary transformer as the above mentioned AC power source.

Depending on concrete conditions, one of the following diagrams shall be used: shunt circuit reducing diagram of tripping coil of circuit breakers, block diagram with feeding supply and diagram with charging device for capacitor.

Protective relays should be separated from operation at the requirements of power grid's operating mode, requirements on selectivity or on other reasons. It is necessary to have particular switching devices so that the operators can separate the relays from their operation.
For convenience in checking and testing, protecting diagram shall have testing boxes or testing clamps in necessary places.

Article 419. Main Role of Protective Relays

As stipulated in Technical Regulation.

Article 420. Protection Zones

All faults that occur on the power system should be removed but at the same time it shall be ensured that only the minimum section of the power system shall be isolated in order to clear the fault. Figure 420-1 shows typical different protection zones on the power system. In order to provide complete coverage by the protection, the neighboring protection zones are set to overlap. Figure 420-2 shows the relationship between the circuit breaker and current transformer's locations. In the figure 420-2 (a), the current transformers are installed on both sides of the circuit breaker, one for line protection and the other for busbar protection, enabling the protection coverage to overlap. Figure 420-2 (b) shows the case where the same current transformer (or other current transformer of the same side) is used for both the line protection and busbar protection. In this case, the line protection would operate for a fault which occurred midway between the current transformer and circuit breaker, but the busbar protection would not operate, thus failing to remove the fault. It is important to prevent blind spots in power system protection design.

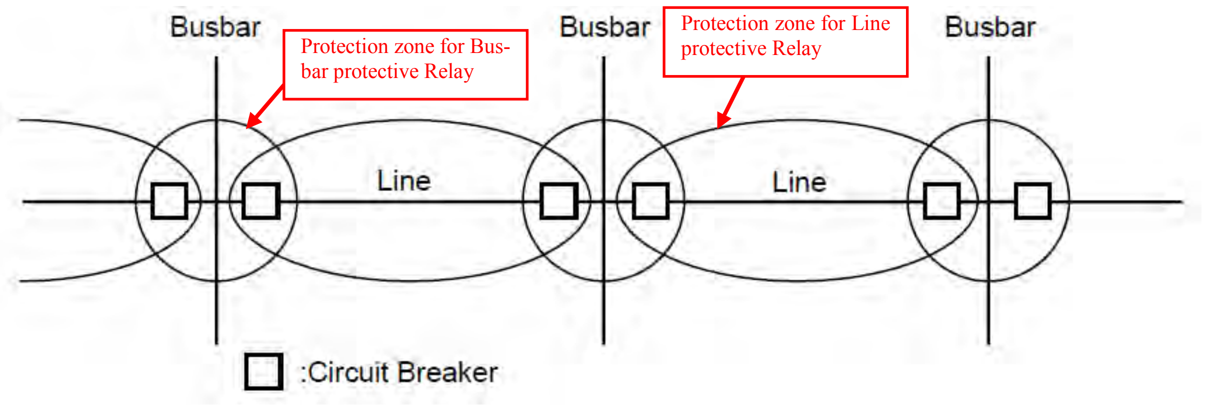


Figure 420-1 Protection Zones

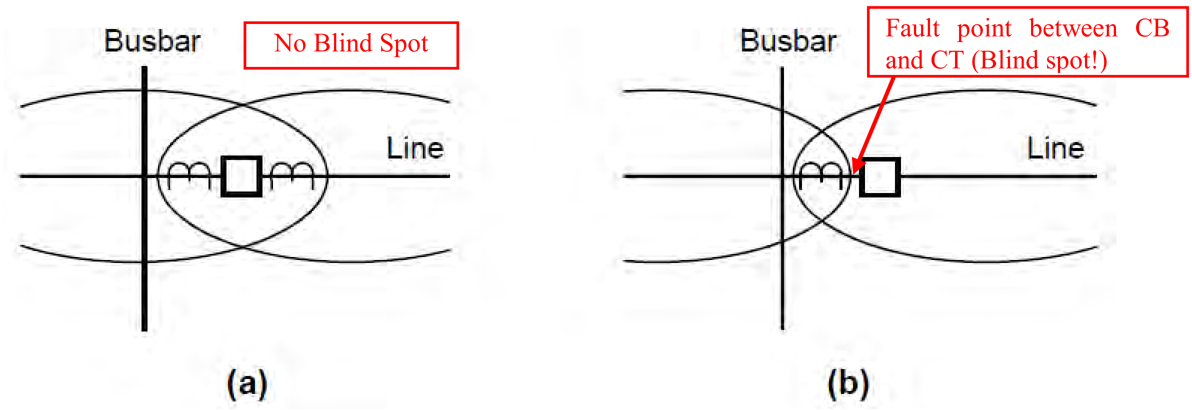


Figure 420-2 Protection Zone and the arrangement of circuit breaker and current transformer

Article 421. Selectivity of Protective Relays

This provision of this article shall refer to the previous article.

Article 422. Coordination of Operation Time

The power system protection system generally consists of a main protection and a backup protection to reliably remove all faults. In principle, system faults shall be removed in the shortest possible time and cause the minimum outage. This important function is served by the main protection. The backup protection provides power system protection with a set time delay, its timer value is set in a range that allows coordination with the main protection. To achieve time coordination with the main protection, the time delay of the backup protection is determined with a margin in consideration of the following factors:

- Operating time of main protection relay
- Operating time of circuit breaker
- Reset time of backup protection relay

Article 423. Time-Delay Relays

As for relay protection with time delay, depending on each case to consider whether relay protection should secure to trip at the setting value or not, in order to prevent the wrong trip or failure of operation of relay protection. (due to attenuation of short-circuit current by time, electrical oscillation or occurrence of arc at faulted points, etc.)

Article 424. Improvement of Reliability

Reliability of protective relay (tripping when condition which requires tripping occurs) shall be secured by using equipment with parameters and configurations in line with their tasks and the operation of such equipment.

In case of necessity, special measures to improve reliability should be applied, e.g. check of operating conditions in continuous or periodical manner, etc.

It is also necessary to consider the possibility of making a mistake by the operator during the operation of protective relays.

Article 425. Operation Lock

Regarding the sending signals for the prevention of the wrong relay trip in case of the failure of voltage transformer, voltage circuit shall have the flowing signals:

- When breaking automatic circuit breaker - it shall base on their auxiliary contacts.
- In case that repeat relay of busbar disconnector does not work - based on checking devices for controlling circuit breaking and circuit of repeat relay.
- In case that fuse at circuit of high-voltage winding of voltage transformer is broken - based on central devices.

Article 426. Relay Interlocks

Power swings occur when the output voltages of generators at different points in the power system slip relative to each other, as a result of system instabilities which may be caused by sudden changes in load magnitude or direction, or by power system faults and their subsequent clearance.

During the course of such a power swing, the impedance seen by a distance relay may move (relatively slowly) from the load area into the distance protection operating characteristic. In fact, this phenomenon appears to the distance protection measuring elements like a three phase fault condition and may result in tripping if no countermeasure is applied. Most power swings are transient conditions from which the power system can recover after a short period of time, and distance protection tripping is therefore highly undesirable in such cases. Therefore, the distance protection shall be blocked by a power swing blocking function to prevent unwanted tripping during a power swing. The following figure illustrates the typical impedance locus as seen by a distance relay during a transient power swing.

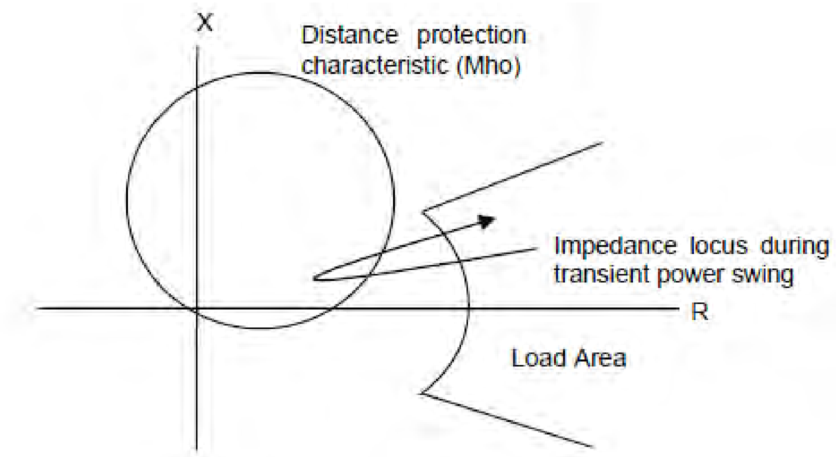


Figure 426 Impedance locus during transient power swing

Article 427. Double Protections

As stipulated in Technical Regulation.

Article 428. Back-up and Remote Back-up Relays

In order to ensure operation in case protection or circuit breakers of neighboring components fail to operate, it is necessary to equip remote backup protective relay.

If main protective relay of any component has absolute selectivity (e.g. power line carrier pilot protection, vertical or transversal differential protection), it is necessary to equip back-up protective relay on that component. This back-up protective relay shall not only provide remote backup protection for neighboring components but also protection for that component itself, i.e. this remote backup protective relay shall trip if main protective relay of that component failed to operate, or is disconnected from its operation. For example, if short-circuit main protective relay between phases is used for phase differential protection, then back-up protection can be used for distance protection.

If main relay protection with voltage of 110kV line and above has relative selectivity (time multi-protective relay levels), then:

- It is allowed not to equip individual back-up protective relay provided that remote back-up protective relays of neighboring components ensure tripping in case that line faces short-circuit.
- It is necessary to have measures to ensure operation of nearby backup protection in case short-circuit occurs and the remote backup protection fails.

It is necessary to arrange separate backup protection by complete protection equipment so that main or backup protection systems can be checked separately while the protected part is in operation. In

that case, separate main and backup protection systems shall be supplied with electricity from another current transformer. Tripping circuit of relay should be connected to separate breaking circuit (tripping coil) of circuit breaker.
In general, protective relays of equipment with voltage of 220kV and above are often supplied with electricity from two different DC supply system.

In case that the satisfaction of remote backup protection cannot be reached or technically too complicated, it is allowed:

- To shorten remote protected area (back-up protection may not break short circuit faults behind transformer, on lines with reactors, nearby lines with additional power supply source, local protection currents much lower than that in fault places).
- That remote backup protection is only applied for usual faults, without considering the rare operating mode but taking into account stage trip of protection.
- Unselective trip in case that short circuit fault occurs at a neighboring components (when protection has function of remote backup protection) can cause the outage of some substations but faults shall be overcome by using auto-closer and auto-recloser.

Article 429. Instantaneous Overcurrent Relays

As stipulated in Technical Regulation.

Article 430. Breaker Failure Protection

Standby protective device against fail-to-operate (FTO) of circuit breaker shall be installed at equipment with voltage of 110kV - 500kV. FTO standby protective device shall trip for breaking every circuit breaker which is connected to one busbar in case that one of protective relays of the above-mentioned component started but cannot break short circuit current in specified time. It is allowed not to install to FTO standby protective device for equipment of 110kV - 220kV if the following conditions are met:

- Ensuring the required sensitivity and definite time for tripping of remote backup protective device under stable conditions.
- In case that the standby protection trips and without any additional component is switched off due to the interruption of circuit breakers are not directly connected to the ones which failed to operate (e.g. no sectionalized circuit breaker and branch line).

In power plant which has directly cooled winding generator, in order to keep such generator from being broken when 110kV - 500kV circuit breaker failed to operate, FTO standby protective device shall be equipped without conditions.
In case that one of circuit breakers of the components is broken (line, transformer, busbar) or failed to operate, FTO standby protective device shall trip the neighboring circuit breakers.
If protective relay is connected with current transformer arranged outside the transformer, the FTO standby protective device shall trip in case short circuit fault occurs in between current transformer and circuit breaker.
It is allowed to use simple FTO standby projective device to trip in case that short circuit fault and failure for operation come from the circuit breaker which does not cover all components (e.g. when

short circuit fault happens on the line); apart from that, at the voltage of 35 - 220kV, FTO standby device is allowed to be used for tripping sectionalized circuit breaker only.

In case that remote backup protection cannot satisfy the required efficiency, it is necessary to improve the reliability of nearby backup protection by increasing the number of FTO standby protective devices.

Article 431. Setting of Sensitivity

1. Evaluation of sensitivity of main protective relays shall be based on the satisfaction of the following sensitivity factors:

(1) Over-current protection with or without directional or non-directional under-voltage starter, as well as 1-level directional protection or non-directional protection with selector of negative (phase) sequence and zero (phase) sequence:

- For current and voltage circuits: - about 1.5
- For negative (phase) sequence and zero (phase) sequence - directional circuits: about 2 by capacity and 1.5 by current and voltage.
- For directional circuit connected to full current and full voltage circuits: no limit for capacity but the sensitivity factor is 1.5 for current.

For over-current protection of transformer with low-voltage of 0.23kV - 0.4kV, the smallest sensitivity factor can be 1.5.

(2) Current protection for each level or protection of directional and non-directional current and voltage circuits connected to full current and voltage circuits or to zero (phase) sequence components: For current and voltage circuit of protection level which is tripped in case that short circuit occurs at the end of protected part, protection sensitivity factor without backup protection trip: 1.5. In case with backup protection level satisfying the selective trip, sensitivity factor is allowed to be reduced to 1.3; If individual protective relay for busbar is installed at the terminal of line, corresponding selectivity factor is about 1.5 and 1.3. For zero (phase) sequence protection, it is allowed to trip at stage mode with breaking by level.

- For directional zero (phase) sequence and negative (phase) sequence components, sensitivity factor is about 2 by power and 1.5 by current and voltage.
- For directional components connected to full current and full voltage circuits: no limit for power but for current the sensitivity factor is 1.5.

(3) Multi-phase short circuit distance protection:

- For start circuit of any protection type, and for the 3rd-level distance protection, the sensitivity factor shall be 1.5.
- For 2nd-level distance protection circuit which is tripped when short circuit fault happens at the end of protected line without backup protection trip, the sensitivity factor is about 1.5. For the 3rd-level distance protection, such the sensitivity factor is about 1.25. For the above-mentioned circuits, sensitivity factor by current is about 1.3 (according to ratio of working currents) if the short circuit occurs at this point.

(4) Longitudinal differential protection of generator, transformer, line and other components, as well as full differential protection of busbar, selectivity factor is about 2.0; For starting circuit by current of non-full differential protection, distance protection of busbar of generator, selectivity factor is

2.0. For 1st-level of non-full differential protection of busbar generator with quick-break mode, selectivity factor is 1.5 (in case that short circuit occurs at busbar).

For differential protection of generator and transformer, sensitivity factor shall be checked in case t hat short-circuit occurs at their outlets. However, for generators of hydraulic and steam turbines with directly cooled stator windings, not depending on selectivity factor, tripping current shall be lower than nominal current of power generators (refer to Article 437). For auto-transformer and step-up transformer with capacity of 63MVA and above, tripping current without consideration of braking should be lower than nominal current (for auto-transformer, it should be lower than the current corresponding to standard capacity). For remaining transformers with capacity of 25MVA and above, tripping current without braking should be not higher than 1.5 nominal current of transformer.

Sensitivity factor of transformer differential protection or transformer-generator block is allowed to be reduced to 1.5 in the following cases (for satisfying sensitivity factor of 2.0, protection shall be quite complicated or technically impossible):

- In case that short-circuit occurs at low-voltage outlet of step-up transformer with capacity less than 80MVA (with taking voltage regulation into account).
- In the mode of energizing transformer under-voltage as well as at short term operation regime (e.g. in case that switching off one of electricity supplying sources for 3-winding transformer).

In case that connecting one of power supply sources to faulted busbar, sensitivity factor for busbar differential protection is allowed to be reduced to 1.5.

For transformer differential protection in case of short circuit behind reactor at low-voltage side of transformer and in differential protection zone, sensitivity factor shall be 1.5. If other protection covers the reactor and satisfies the requirements on sensitivity of transformer differential protection in case of short circuit at the above-mentioned point, sensitivity is not be stipulated.

(5) Directional transversal differential protection for lines operating in parallel:

- For starter’s current relay and voltage relay of protection system against short-circuit between phases and ground fault, sensitivity factor is about 2.0 if circuit breakers at the two ends of faulted line are closed (short-circuited at point of same sensitivity factor), and sensitivity factor is about 1.5 in case that circuit breaker at the other end of faulted power line is opened.
- For zero (phase) directional power components, sensitivity factor is about 4.0 by power and 2.0 by current and voltage in case circuit breaker at the other end of faulted power line is opened.
- For directional circuit connected to the full current and full voltage circuit, the sensitivity factor by power is not stipulated but sensitivity factor will be 2.0 if circuit breaker at the other end of faulted line is opened.

(6) Directional protection with high-frequency interlock:

- For zero (phase) or negative (phase) directional power components for controlling breaking circuit, sensitivity factor is about 3.0 by power and 2.0 by current and voltage.
- For start circuit controlling breaking circuit, sensitivity factor is about 2.0 by current and voltage and 1.5 by resistance.

(7) High-frequency phase deferential protection:

- For start circuit controlling breaking circuit, sensitivity factor is about 2.0 by current and voltage and 1.5 by resistance (distance).

(8) Timeless quick-break protection arranged at generator with capacity up to 1MW and at transformer, in case that short-circuit occurs at the point of protective relay installation, sensitivity factor is about 2.0.
(9) Earth fault protection on underground cable lines in isolated neutral power grid (operating for sending signals or breaking): for protection tripping at basic frequency current, sensitivity factor is about 1.25; for protection tripping at high frequency current, sensitivity factor is about 1.5.
(10) Earth fault protection on overhead line in isolated neutral power grid with trip of sending signal or breaking, sensitivity factor is about 1.5.

2. In defining sensitivity factors mentioned in Item 1, points 1, 2, 5 and 7, it is necessary to take into account following factors:
(1) Sensitivity factor by power of directional power inductive relay shall be checked only when it is connected to negative (phase) and zero (phase) sequence current and voltage components.
(2) Sensitivity factor of directional power relay connected under comparing diagram (absolute value or phase) shall be checked by current when it is connected to full current and full voltage; and shall be checked by current and voltage when it is connected to negative (phase) and zero (phase) sequence current and voltage components.

3. For power generators directly connected to busbar, sensitivity factor of ground fault short circuit protection of tripping stator winding shall be defined by starting current not higher than 5A, in case of exception, such starting current is allowed to increase to 5.5A.
As for power generators which operate in generator-transformer block, sensitivity factor of ground fault short-circuit protection covering the whole stator winding shall be not lower than 2.0. For zero (phase) sequence voltage protection which does not cover the whole stator winding, starting voltage shall be not higher than 15V.

4. Sensitivity factor of protective relay, which uses AC current and is operated by shunt reducing diagram of electromagnetic breaking winding, shall be checked actual error of current transformer after reducing shunt. Sensitivity factor of protective relay, which uses AC current and is operated by shunt reducing diagram of electromagnetic breaking winding, shall be checked actual error of current transformer after reducing shunt. Thus, minimum sensitivity factor of electromagnetic breaking winding for reliable trip shall be higher than 20% of that of corresponding protective relays (refer to Item 1).

5. Minimum sensitivity factor for backup short-circuit protection at the end of neighboring components or the end of furthest components of series components in backup protected zone (refer to the article 428) shall be equal to:
- 1.2 for the parts of current, voltage and resistance.
- 1.4 by power and 1.2 by current and voltage for negative (phase) and zero (phase) sequence directional power component.
- 1.2 by current and not specified by power for directional full current and voltage circuits.

The evaluation of sensitivity factors of nearby backup protection (see the article 428) shall be based on sensitivities factors specified in Item 1 for protection respectively.

6. For timeless quick-break current protection on lines for sub-protection, sensitivity factor shall be about 1.2 in case that short circuit happens at the protected point in the most favorable conditions of sensitivity.

7. In case that protective relays of the back component trips but protective relays of the front component does not trip (maybe due to insufficient sensitivity factor), then sensitivity factor of such protective relays should be coordinated together.

It is allowed to not coordinate the sensitivity factors for remote backup protection if the failure of short-circuit trip caused by the insufficient sensitivity factor of the back component's protection (negative (phase) sequence protection of generator, auto-transformer) can cause the serious damage.

Article 432. Cooperation between Grounding Method and Protection Relays

In solidly earthed neutral power grids, due to the requirement of protective relays, it is necessary to choose the neutral mode of transformers (e.g. allocation of solidly earthed neutral transformers) so that when ground fault short-circuit occurs, values of current and voltage are sufficient for the trip of protective relays of component in all operating modes of power system.

For step-up transformers or transformers which are fed with electricity from two or three power sources, (or significantly fed from synchronous engines or synchronous compensators) and neutral output winding with step-down insulation, it is necessary to eliminate the possibility to occur prohibited operating mode of isolating grounded transformer at busbar, or at section of 110kV - 220kV power grid which is disconnected if single-pole ground fault occurs (refer to 455). Thus, in case some grounding neutral transformers are in operation at the same time, it is necessary to use isolating neutral transformer protective relay, or automatic grounding before switching off grounding neutral transformers which are working on the same busbar or at that section of power grid.

Article 433. Accuracy of Current Transformers for Current Relays

Current transformer which feeds the secondary current to the short-circuit protective relay shall satisfy the following requirements:

1. For the aim to prevent wrong trip in case that short-circuit occurred out of protected zone, the error of current transformer (global error or current error) shall not exceed 10%. These errors are allowed to be higher in case that the protective relay with bigger errors is used, the correct trip of protective relay is ensured by other special measures (e.g. differential relay with restraint for bus protection).

The above-mentioned requirements shall be applied for:

- Multi-level protection: once short-circuit happens at the end of tripping zone of protection level; directional and level-protection: as mentioned above and in case of external short circuit.
- Remaining protections: in case of external short circuit.

For current differential protection (busbar, transformer, generator, etc), it is necessary to consider the global error of current transformer. For remaining protections, it is necessary to consider current error, except the case of connecting according to overall current of two or more current transformers and the case of external short circuit, it is necessary to consider global errors.

2. In order to prevent the protection from failing to operate when short circuit happens in the beginning of protected zone, current error shall be not higher than:

- Permissible value according to increased vibration of directional power relay's contact or current relay - permissible values for selected relay.
- For directional power relay and directional resistance relay, phase displacement is 50%.

3. Output voltage of a secondary winding of current transformer in case short-circuit happens in protected zone shall be not higher than permissible value of relay protection and automation.

Article 434. Separation of Current Transformers for Measurement and Protection

Current Circuit for the power meter for electricity trading (within the rules) should be connected to the different current transformer.

Circuit current of the protection relay to be connected to the coil separately from the other uses

However, they are allowed to be connected to the same circuit, if the requirements mentioned in the Article 433 or the following item are satisfied.

- Meters should be installed at secondary winding of current transformer exclusively for measurement. In special case using secondary winding of current transformer is allowed to be used for electricity counting, measuring if relays ensure permissible errors and relays' characteristics are not changed.
- In principle, protecting circuit can incorrectly trip or non-operation, if current circuit is damaged, it is only allowed to connect measuring devices through suitable auxiliary current transformers, provided that main current transformer meets the requirements mentioned in Article 433 in case that secondary circuit of the auxiliary current transformer is open.

Article 435. Usage of Fuses

A fuse or a fuse wire can be used instead of circuit breakers, automatic circuit breaker and protective relays for reducing protection cost, if the following requirements are satisfied.

- The fuse which satisfy required parameters (voltage and nominal current, nominal breaking current, etc.) can be selected.
- Satisfying requirements of selectivity and sensitivity as same as protective relay.
- Not impeding operation of automatic equipment (auto-reclosing devise, automatic closing standby power source, etc.) under working conditions of electrical equipment.
- The fuse which satisfies the load characteristics stipulated in the article 84 can be selected.

Chapter 5-2-2 Protection of Generators

Article 436. Relay Components for Generators

As stipulated in Technical Regulation.

Article 437. Differential Relays

Regarding the basic operating point of differential relays, the vertical differential protection is operated with tripping current not higher than 0.6 I_{dd}. (I_{dd} is nominal current of power generator). For the indirectly cooled windings power generator with capacity up to 30MW, it is allowed to be protected with tripping current equal to 1.3 - 1.4 I_{dd}. Tripping test of protective relay should be carried out in case that the operating value is higher than I_{dd}.

In addition, it shall decide the setting value of vertical differential relay not to operate against unbalanced transient current. (e.g. transformer relay against inrush current of transformer)

A protective relay should basically be arranged in each 3-phase. For power generator with capacity up to 30MW, it is allowed to use 2-phase protective relay system in case that an earth fault protection is available in two points.

Article 438. Differential Relays and Instantaneous Current Relays

For power generator with higher capacity but without particular output of each phase at the medium voltage side of stator, it can use quick-break protection instead of vertical differential protection.

For independent power generator with voltage over 1kV and capacity up to 1MW, it is allowed to use external short circuit protection as short-circuit protection for phases in stator winding (refer to Article 443). Protective relay shall trip to break all circuit breakers of power generator and magnetic extinguishers.

Article 439. Grounding Protection stator of the generator

Regarding the protective relay for the one phase ground fault in stator winding of power generator with voltage over 1kV, if the fault current is 5A or over, current protective relay which operates the fault current or its high harmonic wave can be applied. If it is necessary, to use zero-sequence current transformer directly installed at terminals of generator.

To guard against the problem single-phase earth fault in the stator winding of the generator with voltage above 1kV, natural capacitive currents at earth fault exceeds the value large enough for overcurrent relays to operate at the time of earth fault (regardless of whether or not compensation), It must set operating value for the relay according to this current. Necessary to use a zero-sequence current transformer located directly at the output of the generator. Also can be used voltage protection to detect overvoltage order not in the case of capacitive currents is not big enough to start the over-current relays.

Protective relay should be also used in case ground fault capacitive current is lower than 5A. Protective relay shall be calibrated in accordance with transient operation and tripping process as mentioned in the article 437 or the article 438.

In case ground fault protection is not installed, if sensitivity is not sufficient (due to the ground fault capacitive current is lower than 5A) or the protective relay does not trip (e.g. in case with compensation on capacitive current in power network of power generator), insulating tester on busbar will be used to trip for sending signals.

In case that the zero-sequence current transformer is installed on power generator to protect against one phase ground fault, it is necessary to use two-pole ground fault relay and this relay is connected to the above mentioned current transformer.

In order to improve the reliability of protective relay when operating at high fault current, relay with saturated current transformer should be used. Protection shall be carried out instantly and trip as mentioned in the article 437 or the article 438.

Article 440. Protection of Short Circuits in Coils

As stipulated in Technical Regulation.

Article 441. Negative Sequence Current Relays

To protect power generator with capacity over 30MW from asymmetric external short circuit, and from overload of negative sequence current, it is necessary to install the negative sequence current relay which will trip at 2-level time (refer to the article 443).

For power generator with directly cooled winding, multi-level time protection or time dependent protection. At that time, 2-level time and time of dependent shall particularity be not higher than permissible overload negative sequence current particularity.

For power generator with indirectly cooled winding, it is necessary to use time dependent protective relay with tripping current not higher than permissible negative sequence current of this power generator within 2 minutes. Minimum time level of the protection shall be not higher than permissible time while short circuit touches two phases of power generator’s terminals.

Negative sequence current protective relay shall be equipped with more sensitive component to trip for sending signals with time independent protection particularity. Tripping current of this component shall be not higher than permissible long-term negative sequence current for this power generator type.

Article 442. Under Voltage Relays attached to Overcurrent Relays

Regarding the basic operating point of overcurrent relay with voltage restraint, for power generators with capacity exceeding 30MW, tripping current of this protection shall be equal to from 1.3 to 1.5 I_{dd} and starting voltage shall be equal to from 0.5 to 0.6V_{dd}. (I_{dd} andV_{dd} are nominal current and voltage of power generator). For power generator with capacity from over 1MW to 30MW, starting current of this protection and starting voltage of under voltage circuit will be taken according to the above mentioned values , starting voltage of relay for filtering sequence voltage is equal to from 0.1 to 0.2V_{dd}.

Article 443. Symmetric Overload Protection of Stators

For protecting power generator with voltage over 1kV and capacity to 1MW from external short circuit, it is necessary to use over-current protective relay connected to current transformer installed at neutral terminal side of power generator. Selection of calibrated values shall be based on load current at necessary reserve. The low-voltage protection is also allowable (without current relay).

For protecting generators with capacity over 1MW from external short circuit the following requirements shall be satisfied:

- Protective relay shall be connected to current transformer installed at neutral terminal side of power generator.
- If busbar with generator voltage is sectionalized, protection shall be at 2-level time: the first level - short duration - tripping sectionalizing circuit breaker; the second level- long duration - tripping circuit breaker of power generator and magnetic extinguisher.

Article 444. Overload Protection of Rotors

For directly cooled winding power generator, it is necessary to be equipped with rotor overload protection while it operates with main or auxiliary exciter. Protection will trip at time dependent or independent particularity and react to once voltage or current increases highly in rotor winding. Protector will trip to break power generator and magnetic extinguisher. At shorter time, it shall trip for reducing load of rotor.

Power generator's symmetrical overload protection shall use one-phase current of stator for time-over-current protection with tripping for sending signals.

In order to reduce the load or when directly cooled winding power generator is shut down automatically in case that symmetric overload occurred, it is allowed to use the above mentioned protection of rotor and trip at overload of rotor which caused overload of power generator.

Article 445. Protection of Grounding Faults at Exciters

Protective relay for one-pole ground fault shall be equipped to detect such ground fault. This protective relay is used to detect one-pole ground fault, not to interrupt exciter. It needs to equip one set of double-pole to ground fault (short circuit) protection in main exciting circuit of power generator. This protective relay shall be only put in operation in case that detection of one-pole to ground fault in exciting circuit during periodical check of insulation. It shall interrupt circuit breaker and magnetic extinguisher of directly cooled winding generator and send the signals or interrupt power generator (in case of indirectly cooled winding power generator).

Article 446. Protection of Asynchronous and Loss of Field of Exciters

For power generator, it is necessary to install protective relay for asynchronous mode and loss of excitation. It is allowed to be superseded by automatic detector of asynchronous mode only by state of magnetic extinguisher. When protective relay trips or when automatic magnetic extinguisher (TDT) is interrupted, for power generator which is allowed to operate in asynchronous mode, it is necessary to trip for sending signal of loss of excitation.

Refer to Article 468 for power generators which are not allowed to operate in asynchronous mode.

Article 447. Overvoltage Protection for Generators

As stipulated in Technical Regulation.

Article 448. Circuit Breakers with Overcurrent Protection

In order to protect power generators with voltage up to 1kV and capacity up to 1MW with ungrounded neutral pole from all types of faults and abnormal operating modes, it is allowed to install automatic circuit-breakers with over-current interrupter, or circuit breakers with over-current protective device on 2-phase. In case that power generator has terminal at the neutral side, if possible, such protective devices should be connected to current transformer installed at this terminal.

For the above-mentioned power generators but with solidly grounded system, the protective devices on 3-phase shall be arranged.

Chapter 5-2-3 Protection of Transformers and Shunt Reactors

Article 449. Relay Components of Transformers

The protection system of transformers should be equipped against the following items other than items stipulated in the technical regulations.

- Partial discharge at 500kV bushings.
- One-phase ground fault in isolating neutral power grid of 6 - 10kV behind transformer which is interrupted when facing one-pole ground fault for the safety (refer to the article 476).
- One-phase ground fault protection at 6 - 35kV side for autotransformer which has voltage equal to or higher than 220kV at high-voltage side.
- For 500kV transformer, mechanical relays which operate to trip a circuit breaker, have a possibility of incorrect operation, if an earthquake happens. So, an earthquake detector should be equipped in the tripping circuit of the above mentioned relay for the prevention of incorrect operation.

Article 450. Relay Components of 500kV Shunt Reactors

The protection system of 500kV shunt reactors should be equipped against the following items other than items stipulated in the technical regulations.

- Partial discharge at bushings.
- Mechanical relays which operate to trip a circuit breaker, have a possibility of incorrect operation, if an earthquake happens. So, an earthquake detector should be equipped in the tripping circuit of the above mentioned relay for the prevention of incorrect operation.

Article 451. Application of Buchholz Relays

Regarding the Buchholz relay, the relay shall send alarm signals when amount of generated decomposed gas is low and oil level is decreased. It also has to trip for interruption in case of amount of the gas is high and oil level continues being decreased.

It is possible to use pressure relay to protect against faults inside of transformer. Protection of oil level decrease can be performed by particular oil level checking relay which is built in oil conservator of transformer.

In order to protect contact on-load tap changer with arc extinguishment in oil, it is necessary to equip particular oil flow relay and pressure membrane.

It is necessary to separate the alarm signal from the tripping signal of the Buchholz relay at the time of the relay operation, and separate the alarm circuit from the tripping circuit of that.

Buchholz relay is only allowed to send the alarm signal (not send the tripping signal) in the following cases:

- For transformer installed in earthquake areas.(For 500kV transformer, see the article 450)
- For step-down transformer with capacity up to 2.5MVA without circuit breaker at high-voltage side.

Article 452. Short circuit protection incidents directly inside of Transformers and Shunt reactors

Regarding the installation of differential relay for transformers exceeding 6.3MVA and 500kV shunt reactors as well as transformers of 4MVA which operate in parallel, the relay can be installed in lower capacity transformer but not lower than 1MVA if:

- Quick-break protective relay's sensitivity is not sufficient, and time over-current protective relay's trip is longer than 0.5 second.
- Transformer is installed in the earthquake areas.

Vertical differential protection shall be carried out by using special current relays which are calibrated to avoid the inrush current, transient unbalanced current and to keep stability (e.g. using saturated current transformer, relays with current restrain).
For transformers with capacity up to 25MVA, it is allowed to use current relays which have starting current calibrated to avoid the inrush current, transient unbalanced current (quick-break differential protection) if such relays secure sufficient sensitivity.
Vertical differential protection shall operate so that connected parts of transformer are also located in the protected zone.
It is allowed to use built-in current transformer of transformer for differential protection in case that other relays secure to trip short circuit (at required time) of the connection part of transformer to bus-bar. In case that the reactor is installed at the low-voltage side of the transformer and protection of transformer is not sensitive enough for the short circuit protection behind reactor, it is allowed to install current transformer at the low-voltage side to protect reactor.

Differential protection relays and Buchholz relay of transformer, autotransformer and shunt reactor do not have to equip sensors with function to start up firefighting equipment. Startup of firefighting equipment shall be performed by specific fire detectors.

500kV-input insulation tester shall trip for sending signals in case that partial discharge at input occurs (without necessity to interrupt immediately) and the trip for interruption in case that the input insulators are damaged (before the insulators are punctured completely).
It is necessary to equip interlock to keep input insulation tester from wrong operation in case that the circuit connected input insulation tester to input is broken.

Article 453. Protection of Short Circuits in Turn

As stipulated in Technical Regulation.

Article 454. Countermeasures against Outside Faults

For transformer with capacity of 1.6MVA and above, in order to prevent incorrect operations from the over-current due to external short circuit, it is necessary to use protective relays with the trip as follows:

1. For step-up transformer which is fed by supplying from 2 sides: asymmetric negative sequence short circuit protection and under-voltage starting over-current protection for symmetric short circuit protection, or over-current protection in combination with voltage startup (refer to article 442).
2. For step-down transformer: over-current protection with or without combination of voltage decrease conditions. For large step-down transformer, if supplying source from 2 sides is available, it is allowed to use asymmetric negative sequence short circuit protection and under-voltage starting over-current protection for symmetric short circuit protection.

When selecting starting current over-voltage protection, it is necessary to pay attention to possible overload current in case that interrupting transformers are in parallel operation and self-starting current of motor which is supplied with electricity from the transformer.

For 500kV step-down autotransformers, distance protection should be installed for tripping external multi-phase short circuit in case of requiring to secure remote backup protection, or coordination with protective devices of neighboring power grids. It is also allowed to install the above mentioned protective devices for 220kV autotransformers.

For transformer with capacity lower than 1.6MVA, it is necessary to use over-current protection which trips for interruption in case that external multi-phase short circuit happens.

For transformer of 35kV downwards, and capacity of 1.6MVA downwards, it is possible to install fuse instead of quick-break and over-current protection.

Protection against external multi-phase short circuit shall be installed as follows:

1. For 2-winding transformer: installed at main feeding source side.
2. For multi-winding transformer with 3 or more circuit breakers: installed at every sides of transformer. However, it is allowed not to install protection in one among sides, but protection at main feeding source shall have 2-level time, and shorter level time is for interrupting breaker at the side without 2-level time protection.
3. For 2-winding step-down transformer which feeds separate operating sections: installed at the supplying side and at each section's sides.

Protection of external multi-phase short circuit shall follow the above point 2, moreover, it is necessary to consider the necessity to supplement quick-break current protective relay to break the short circuit on busbar at low-voltage and medium-voltage sides with shorter time (based on short circuit current level, availability of busbar individual protective relay, ability to coordinate with protective relay of outgoing feeder).

In case that external short circuit protective relay of step-up transformer is not sensitive and selective enough, it is allowed to use current relay of corresponding protection of power generator to protect transformer.

Article 455. Back-up Protection for Outside Short Circuits

For step-up transformer exceeding 1MVA and transformer with 2 and 3 supply sources, and auto transformers, as required, backup protection should be equipped for ground fault short circuit in neighboring components. For autotransformer, apart from the above-mentioned protection, it is necessary to secure the selectivity of ground fault protective relay of power grid at various voltages by installing zero sequence relay for external ground fault short circuit at winding side connected to power grid with high grounding current.

In case that power grid which has some transformers with insulated coils at step-down neutral terminal is in operation with neutral isolation, it is necessary to have measure to prevent the prohibited operating mode with neutral of this transformer mentioned in the article 432. Therefore, power plants or transmission substations which own earthed neutral and isolated neutral transformers, it is necessary to ground their neutral automatically, or install breaking protective relay for isolated neutral transformer before interrupting earthed neutral transformer which shares the same busbar or same section of power grid.

For autotransformers and multi-winding transformers which are fed by some sources, external short circuit protective relays shall trip directionally if the selectivity requires such trip.

For 220 - 500kV autotransformer in transmission substation, or for generator-transformer of 500kV and 220kV- 500kV connecting autotransformer of power plant, it is necessary to install external short circuit protective relay with fast trip acceleration, when busbar differential protection relay is not put in operation, to secure to break remaining faulted components without quick-break relay in 0.5 second.

Article 456. Protection against Earth Faults for Transformers

For step-down transformer and transformer-main line bock, which have voltage at high-voltage side lower than 35kV and winding at low-voltage side is connected in star to earthed neutral, it is necessary to equip single-phase earth fault protection shall be equipped at low-voltage network by using:

1. External short circuit over-current protection installed at high-voltage side of transformer, if necessary, sound sensitivity shall be secured for readiness of using 3-relay diagram.
2. An automatic circuit-breaker or fuse at the output of low-voltage side.
3. Aspecial zero sequence protective relay installed on neutral conductor of transformer (in case that the sensitivity of protective relay as mentioned in point 1 and 2 cannot be ensured).

It may be not necessary to install protective relay as mentioned in point 3 for industrial electric equipment in case that low-voltage cubicles are equipped with protective devices for outgoing feeders nearby transformer (distance up to 30 m from transformer), or if 3-phase cable is used to connect transformer to the above-mentioned cubicles.

In case that protective relay is installed according to point 3, it is allowed not to coordinate it with protective relay of outgoing feeder from low-voltage cubicle.

For line-transformer diagram, if protective relay is used as mentioned in point 3, it only needs to trip automatic circuit-breaker at low-voltage side without needing installation of secondary cable so that the mentioned protective relay trip circuit breaker at high-voltage side.

In case that high-voltage side of the above-mentioned transformer is equipped with fuse, the stipulations in the above-mentioned point can be applied for it.

For step-down transformer at high-voltage side of 6 - 10kV, low-voltage side will feed outgoing feeder’s cubicle with fuse protection, master fuse or automatic circuit-breaker should be installed.

If fuses at the low-voltage cubicle side and fuses (or protective relays) at the high-voltage side are watched over by one operator, master fuse or automatic circuit-breaker may not need being installed at the low-voltage side.

Article 457. Overvoltage Relay for Overload Protection

For transformers exceeding 0.4MVA, depending on rate and overload withstanding capability, over-current protective relay for overload protection by sending alarm signals should be equipped.

For transmission substation without on-duty staff, the above-mentioned protective relay is allowed to trip automatically to reduce load or interrupt (in case that overload cannot be fixed by other solutions).

Chapter 5-2-4 Protection of Transformer and Generator Blocks

Article 458. Relay Components for Transformer and Generator Blocks

For generator-transformer with power generator exceeding 10MW, it is necessary to equip protective relays for all kinds of faults and abnormal operating modes as follows:

1. Ground fault short circuit at the side of generator voltage.
2. Multi-phase short circuit in stator windings of generators and their terminals.
3. Short circuit in between winding turns of one phase in stator winding of generator (corresponding to the article 460).
4. Multi-phase short circuit in winding of transformer and its terminals.
5. Single-pole ground short circuit fault in winding of transformer and in terminal which is connected to power network with high ground fault current.
6. Short circuit in between turns of windings of transformer.
7. External short circuit.
8. Transformer overload due to the negative sequence current (for the block with generator over 30MW).
9. Symmetric overload of stator winding of generator and windings of transformer.
10. Overload of rotor of generator due to exciting current (for steam turbine generator which has directly cooled windings and for hydraulic turbine generator).
11. High voltage in stator winding of generator and transformer of the block (for steam turbine-generator exceeding 160MW and for all blocks which have hydraulic turbine-generator) (refer to the article 466).
12. Single-phase ground fault (refer to Article 445) and two phases ground fault (refer to the article 467) in exciting circuit.
13. Asynchronous mode with loss of excitation (refer to the article 468).
14. Oil level in transformer is reduced.
15. Partial discharge at 500kV inlet insulator of transformer.

Regulations on protection of generator and step-up transformer while they operated independently shall be the ones applied for block of generator-transformer (auto-connected transformer), except some changes mentioned in the chapter 5-2-2 and 5-2-3.

Article 459. Protection for Grounding Faults

For generator-transformer in which generator is over 30MW, ground fault protective relay is often equipped at circuit of generator and covering entire stator winding.

For generator with capacity up to 30MW, it is necessary to equip protective relay which covers 85% stator winding.

The protective relay shall trip for interruption with duration not longer than 0.5 second for all blocks without branches at voltage of generator and with branches to auxiliary transformer. In blocks which have relations with auxiliary power system, or relations with consumers which are supplied with electricity from branch of generator and transformer, if ground fault capacitive current is 5A or more, it is necessary to install ground fault short circuit protective relay which will trip to interrupt stator winding of generator, and two-phase ground fault protection as applied for generator connected to

busbar (refer to the article 439). In case that ground fault capacitive current is lower than 5A, ground fault protection can be applied as that one for the blocks without branches at generator voltage and trip for sending signals.
In case that circuit breaker is equipped in generator circuit, it is necessary to supplement earth fault signaling circuit at the generator's voltage side of block's transformer.
For protection of indirectly cooled generator-transformer block which includes one generator and one transformer without circuit breaker at the generator voltage side, it is necessary to install master differential protection relay for entire block. In case that circuit breaker is available at generator voltage side, it is necessary to equip separate differential protection relay for generator and one more for transformer.
In case of using block with 2 transformers, or two generators - one transformer without circuit breaker at generator voltage side (booster block), in each generator and transformer with capacity of 125MVA or more, it is necessary to equip separate vertical differential protective relays on each generator and transformer. In case that built-in current transformer is not available at low-voltage side of transformer, it is allowed to share differential protection relay for two transformers.
For block with generator which has directly cooled winding bar, separate vertical deferential protection relay should be equipped for generator. In this case, if circuit breaker is available in generator circuit, it is necessary to install separate differential protection relay for transformer (or for each transformer if the block has generator operated with two transformers, in case that built-in current transformer is not available at input of low-voltage side of these transformers, it is allowed to share differential protection relay for all transformers of the block). In case without circuit breaker, in order to protect transformer, it is necessary to either equip individual differential protection or sharing the differential protection in the block (for the block with one generator and one transformer, the best thing is to share the differential protection for entire block).
At high-voltage side of transformer, differential protection of transformer (block) can be connected to built-in current transformer in transformer of the block. In this case, in order to protect the bus in between circuit breaker at high-voltage side and the block of transformer, it is necessary to equip separate protective relays.
Separate differential protection relay of generator shall be selected in accordance with 3-phase relay diagram and starting current as mentioned in the article 437.
For the backup of the above-mentioned differential protection relays, for the block with directly cooled winding bars of generator with capacity exceeding 160MW, it shall equip backup differential protection relays covering generator, transformer and bus at the high-voltage side.
It also should equip backup differential protection relay for directly cooled winding bars of generator with capacity lower than 160MW.
In case that using backup differential protection relay for the block without circuit breaker in generator circuit, it is necessary to equip separate main differential protection relays for generator and transformer.
In case that circuit breaker is available in generator circuit, backup differential protection relay shall trip with time of 0.35 - 0.5 second.

Article 460. Differential Relays for Branches

As stipulated in Technical Regulation.

Article 461. Overload and Overcurrent Protection

For the block which has directly cooled winding bar generator with capacity exceeding 160MW, it is necessary to equip negative sequence current protection relay with dependent integral in combination with permissible negative sequence overload current protection relay of protected generator. Protection relay shall trip to break circuit breaker of generator, if the circuit breaker is not available, protection relay will trip to interrupt entire block. For backup protection relay for neighboring components of the block, the above-mentioned protection relay shall has time independent particularity to trip for disconnecting the block from power grid and 2-level time in accordance with the article 463.

For the block, which has directly cooled winding bar generator with capacity less than 160MW, and for the block with indirectly cooled winding hydraulic turbine - generator with capacity over 30MW, negative sequence current protection shall have time level, or with time dependent particularity. In this case, at all levels of protection, one or multi-time level can trip (refer to the article 463). Time level or time dependent particularity shall be combined with particularity of permissible negative sequence overload current of generator (refer to the article 441).

For the block which has indirectly cooled generator with capacity over 30MW, it is necessary to equip the protection relay in accordance with the requirements stipulated in the article 441).

Apart from protection of breaking trip, all blocks which have generator over 30MW shall be equipped with signaling protector for negative sequence overload current in accordance with the stipulations in the article 441.

Article 462. Setting Value of Protection for Outside Short Circuit Currents

For the block which has generator with capacity over 30MW, symmetric external short circuit protection shall be operated as mentioned in the article 442. In this case, for hydraulic turbine - generator, starting voltage of protection relay is about 0.6 - 0.7 nominal voltage. For the block which has generator with backup exciter, the above-mentioned protection shall be operated with inlet current relay at high-voltage side of the block.

For the block which has generator with capacity of 60MW and above, the above-mentioned protection shall be replaced by distance protection. For the block which has directly cooled winding generator, backup differential protection relay (refer to the article 459) is allowed to be replaced with 2-level distance protection relay to keep from multi-phase short circuit.

The first level of this protection relay, nearby backup protection, oscillation-protecting interlock shall be available and the protection relay will trip as mentioned in the article 463 with the duration not longer than 1 second. The first level also shall secure covering entire transformer of the block, while securing selectivity with protection relays of neighboring components. It shall equip backup protection relay for the first level of generator protection if the block is equipped with separate differential protection relays for generator and transformer.

The second level of protection relay, remote backup protection shall trip as mentioned in the article 463.

Even the backup differential protection relay is available, in order to improve efficiency of remote backup protection, it'd better to set 2-level distance protection. Both levels of distance protection relay shall trip as mentioned in the article 463.

For the block, which as generator with capacity of lower than 30MW, external short circuit protection relay shall be also tripped set up in accordance with the regulation about generator mentioned in the article 442. Tripping parameter of protection relay to hydraulic generator shall be in accordance with the article 442.

For the generator-transformer block with circuit breaker at generator circuit, in case that backup differential protection relay of the block is not available, it is necessary to equip over-current protection relay at the high-voltage side of the block as backup protection for main protection relays of transformer in case that the block operates without generator.

Article 463. Back-up Protection for Generator-Transformer Blocks

Backup protection relay of generator-transformer block shall consider the following requirement:

1. At generator voltage side of transformer, protection relay will not be equipped but protection relay of generator will be used.
2. Remote backup protection relay shall have 2-level time, the first one - separating diagram at high-voltage side of the block (e.g. disconnecting circuit breaker which connects busbar and sectionalizing breaker), the second one - disconnecting the block from the power grid.
3. The nearby backup protection relay shall trip to interrupt the block (or generator) from the power grid, extinguishing magnetic flux of generator and stopping the block in cases as required in the article 470.
4. Each level of protection relay or backup protection relay of the block, depending on their tasks, when they are used as remote and nearby backup protection, they can have one, two or three time levels.
5. Voltage starting circuit of protection relay in accordance with the article 462 should be installed at the generator voltage side and power grid one.
6. Main and backup protection systems generally have separated output relay and DC supply power source supplied from various automatic circuit-breakers.

Article 464. Symmetric Overload Protection

For the block, which has a generator with symmetric overload protection of stator, protection which applies to the generator operating on the busbar shall be applied. (refer to the article 444)

For hydraulic turbine - generators without on-duty staff, apart from sending signals on symmetric overload of stator circuit, it is necessary to equip time independent protection relay with duration longer than that of tripping for interrupting the block (or generator), and shorter than tripping for reducing load. Such protection relays can be replaced with corresponding devices in excitation regulating system.

Article 465. Overload Protection for Exciter Circuits

For generators exceeding 160MW, which have directly cooled winding bars, the excitation current overload protection of rotor winding shall be arranged with time dependent integral in accordance with permissible overload factor of generator caused by the excitation current.

In case that the protection relay cannot be connected to rotor current circuit (e.g. in case of using non-carbon brush exciter), it is allowed to use time independent protection relay which is reacting by high voltage at the excitation circuit.

Protection relay shall be capable of tripping at short time to reduce excitation current. In case that overload limiter is available at overload reducing excitation regulator, protection shall be applied at the same time for this limiter as well as rotor protection. It is also allowed to use overload limiter in automatic excitation regulator to operate for load reduction (at two-level time) and disconnect generator. In this case, installation of time dependent integral protection relay may not be necessary.
For directly cooled winding bar generator with capacity of lower than 160MW and indirectly cooled hydraulic generator with capacity over 30MW, protection relay should be set as stipulated in the article 444.
In case that excitation group-regulator is available at generators, it is necessary to apply time dependent protection system.
In case that generator operates together with backup exciter, rotor overload protection relay shall be set up at operating mode. If it is impossible to use time dependent protection system, it is allowed to use time independent protection system for backup exciter.

Article 466. Overvoltage Protection for Generator blocks

For the block which has generator with capacity of 160MW and above, in order to prevent the high increase of voltage while operating in non-load regime, it is necessary to equip high voltage increase protector, this protector will automatically block in case that generator operates in power grid. When the protective relay trips, it secures extinguishing of magnetic flux of generator and exciter.
For the block which has hydraulic turbine - generator, in order to prevent voltage from increase in case that generator is suffered from sudden loss-of-load, it is necessary to equip high increase voltage protector. This protector shall trip to disconnect the block (or generator) and extinguish magnetic flux of generator. This protector is allowed to trip to stop generator unit.

Article 467. Protection for Grounding Faults at Exciter Circuits

As stipulated in Technical Regulation.

Article 468. Protection for Asynchronous and Loss of Field of Exciters

For generators with directly cooled winding bars exceeding 160MW and for hydraulic turbine generators, a protective relay shall be equipped for the asynchronous mechanism and loss of excitation.
This protective relay shall also be equipped at generators with directly cooled winding bars with capacity lower than 160MW. For these generators, it is allowed to attach automatic asynchronous detector in case that automatic magnetic extinguishing device is interrupted (without using protector for asynchronous protection).
In case that generator losses excitation and switches over to asynchronous mode, protective devices and automatic magnetic extinguishers shall send signals of excitation loss and automatically switch auxiliary loads in branch of loss-excitation generator to other standby source.
All hydraulic steam - generators and steam turbine-generators and other generators are not allowed to operate in asynchronous mode in case that power system is in shortage of reactive power and the above-mentioned equipment shall be disconnected from power grid by their trips.

Article 469. Backup Protection for Failure of Circuit Breakers

Backup failed-to-operate (FTO) protection equipment with voltage of 110kV and above in power plants shall be operated as follows:

1. In order to prevent wrong interruption of some blocks due to trips of backup protectors in case that non-full phase regime fault in one of blocks happens due to the failure-to-operate of circuit breaker with phase-by-phase driver, when interrupting circuit breaker of power plant which has directly cooled winding bar generator, it needs to equip device for speeding up the starter of standby FTO protective device (e.g. with zero sequence current protector of transformer of the block at the side of high ground fault current power grid).

FTO standby protective device is often calibrated to trip for interruption of circuit breaker after 0.3 second.

2. For power plant in which generator - transformer - power line block has common circuit breaker (e.g. one and half circuit breaker diagram or polygonal diagram), it is necessary to equip remote breaking device to interrupt circuit breaker and lock auto-recloser at other end once FTO standby protective device trips in case it is started from the block's protector. In addition, FTO standby protective device trips to stop the frequency-generating component of high-frequency protector.

Article 470. Stand-by Device for Inner Faults

The protective relay of the stator of the power generator and transformer of the block for inside faults, and the protective relay of the generator rotor when tripping to interrupt shall disconnect fault components from the power grid, extinguish the magnetic flux of the exciter of the generator, and start up the standby device.

If the interruption by protective relay causes the outage of auxiliary power system connected to branch of the block, the protective relay also has to interrupt working circuit breaker of auxiliary supply source to switch automatically to use backup supplying source by standby auto-closer.

Backup protective relay of generator and transformer of the block shall trip in case that external short circuit happens in accordance with the article 463, from item 2 to item 4.

In thermal power plants in which steam system is also operating at block diagram, in case of tripping for interruption of block due to inside faults, it is necessary to stop entire block. In case where external short circuit happens, as well as protector trips in cases where operation of the block can be quickly recovered, at that time, the recovered block should be switched to asynchronous mode if technological equipments allow this.

For hydropower plant, in case where fault happens inside block, apart from disconnection of the block, generator unit shall be stopped. In case that disconnecting the block due to external faults, generator unit shall be stopped, too.

Article 471. Cooperation of Protection Relays for Transmission Lines and Blocks

For generator-transformer-line block, main protective relay of the line and backup protective relay from the side of power system shall be operated based on requirements of this Chapter on line protection. From the block side, backup protective function for line shall be performed by backup protective relay of the block. Block protection shall be performed in accordance with the above-mentioned requirements.

Trip of block protective relay to break circuit breaker and start-up FTO standby protective device from power system side shall be transmitted by high frequency channel or telecommunication line to two remote breaking mechanisms which are backup system for each other. In addition, it is necessary to let the block protective relay trip and stop frequency generating component of high-frequency protective relay at the same time.

For the block which has steam turbine - generator protection shall be arranged according to block diagram. Trip signal from power system side to other end of signaling line of busbar protective relay (in case where using double busbar), or trip of FTO standby protective device (in case where using one and half circuit breaker diagram or polygonal diagram) to switch the block to non-load mode, or extinguish magnetic flux and stop the block by remote interrupter. In addition, it's better to use remote interrupter to speed up magnetic extinguishment in generator, and to switch off auxiliary circuit in case where backup protective relay from power system trips.

In case non-full phase circuit breaker from power grid side has high earth fault current, it shall speed up start of FTO protective device as mentioned in the article 469 item 1.

Chapter 5-2-5 Protection of Overhead Lines and Cables with Isolated Neutral

Article 472. Relay Components for Overhead line and Cables with Isolated Neutral

As stipulated in Technical Regulation.

Article 473. Equipped with Short Circuit Protection Relays

As stipulated in Technical Regulation.

Article 474. Operation Time of Short Circuit Protection

For cable lines without reactance with one-side supplying source from busbar of power plant, it is necessary to equip timeless quick-break protective relay and its tripped zone will be defined based on conditions of short circuit breaking and residual voltage in busbar lower than 0.5 - 0.6 U_{dd}. For that purpose, protective relay is allowed to trip unselectively in combination with auto-recloser or standby automation which takes responsibility to readjust entirely or partly network suffered from unselective trip of the protective relay. It is allowed equipping the above-mentioned quick-break protective relays on overhead line from busbar of transformer substation which feeds the big synchronous motors.

If in cable line without reactance with one-side supplying source, quick-break protective relay cannot be installed according to requirements on selectivity, in order to secure quick-act, it is necessary to equip protective relays as mentioned in the article 475, point 2 or 3. It is allowed to use such protective relays for auxiliary power lines of power plant.

Article 475. Selectivity of Short Circuit Protection

For a single line fed by two supply power sources, the protective relay shall be set as one for a single line fed by one supply source. In addition, the following specification shall be considered.

To simply protective relays and ensure their selective trip, it is allowed to use the automatic separator to separate the system into radial subsystems in case of faults and then recover automatically.
In case that current protection, directional or non-directional, with time level does not satisfy requirements on sensitivity and high speeding, it is allowed to use the following protections:

1. The simplest distance protection.
2. Current transversal differential protection (for double lines(parallel lines)).
3. Vertical differential protection for short lines. If separate secondary cable (pilot-wire) shall be arranged only for differential circuit, the secondary cable length shall be not longer than 3 km.

For protections mentioned in point 2 and point 3, current protection will be used as backup protection.

Article 476. Protection against Grounding Faults

In general, single-phase earth fault protection shall be applied for zero sequence current transformers. The protective relay shall operate at stable earth fault short circuit, but it is also allowed to use the devices to display temporary earthed fault signal.
Single-phase ground fault protective relay which trips for interruption timelessly according to technical safety requirements, will interrupt only components feeding power to faulted network. In this case, for backup protection, zero sequence protective relay will be used with the time of 0.5 second to disconnect all related power network in busbar system (sections), or feeding transformer.
In general, it is not allowed to step up compensation current for the relay trip in grounded neutral network through arc suppression coil (e.g. by changing tap of arc suppression coil).

Article 477. Relay Components for Parallel Transmission Lines with Isolated Neutral

For parallel lines fed by two and more supply sources, as well as at the head with supply source of parallel one-side feeding lines, it is possible to use protective relays as those used for single line.
To speed up short circuit breaking, especially in case of using level current protective relay or level current combined under voltage relay at the line fed by two supply sources, it is possible to add directional power protective relay in parallel lines. This protection can be used in the form of separate directional current protection or only being the step-up circuit of existing protective relays (over-current relay, distance protective relay) together with directional power tester in the parallel lines.
At the head of parallel lines fed by one supply source, in general, it is necessary to equip directional transversal differential relay.

In case of applying protection for parallel lines with voltage of 6 - 15kV, it is necessary to comply with the above mentioned regulations.

If the above mentioned protection does not satisfy requirement on high speed (refer to the article 480), and directional power testing protective relay is not available in parallel line fed by two supplying sources and at the initial of parallel line fed by one supplying source, it is necessary to set directional transversal differential protector as the main protector (if two lines operate in parallel).
In this case, in one-line operating mode as well as in standby mode when two lines are operated, it's better to use multi-level protector as mentioned in the article 474, 475. It is allowed to connect this protector or its individual level to overall current of two lines (e.g. backup level to improve sensitivity

in case of short circuit happens at neighboring components). It is also allowed to use directional transversal differential protector to support level current protector to reduce time for interrupting short circuit in protected line, in case of following requirement on high speed (refer to the article 480), it is not required to equip such protector.

Chapter 5-2-6 Protection of Overhead Lines and Cables with Efficient Earthed Neutral

Article 478. Relay Components for Overhead lines and Cables with Efficient Earthed Neutral

As for the function of digital protective relay, if possible, it should implement the following recording and metering function in order to analyze the fault condition and confirm the right operation of the relay and current analog input quantities. But the following items are example of recommended recording items. Therefore, actual specification shall be decided in consultation with manufacturer.

1. Recording function

Fault recording is started by a tripping signal, and the following items are recorded for one fault:

- Date and time of fault occurrence
- Faulted phase
- Tripping phase
- Tripping mode
- Fault location *1
- Relevant events *2
- Power system quantities *3

Notes:

*1 Fault location : The distance to the fault point calculated by the fault locator

*2 Relevant events : Such events as auto-reclose, re-tripping following the reclose-on-to-a fault or auto-reclose and tripping for evolving faults are recorded

*3 Power system quantities : The following power system quantities in pre-faults and post-faults are recorded.

- Magnitude and phase angle of phase voltage
- Magnitude and phase angle of phase current
- Magnitude and phase angle of phase voltage for auto-reclose
- Magnitude and phase angle of symmetrical component voltage
- Magnitude and phase angle of symmetrical component current

2. Metering function

It should implement the metering function which performs continuous measurement of the analog input quantities in order to confirm the current power system condition and the ratio of CT andVT. The measurement data shown below is updated every second and displayed on the LCD of the relay front panel or on the local or remote PC.

- Magnitude and phase angle of phase voltage (Va,Vb,Vc)
- Magnitude and phase angle of phase current at the local terminal (Ia, Ib, Ic)

- Magnitude and phase angle of phase voltage for autoreclose
- Magnitude and phase angle of symmetrical component voltage (V1,V2,V0)
- Magnitude and phase angle of symmetrical component current at the local terminal (I1, I2, I0)
- Active power and reactive power
- Frequency

Article 479. Countermeasures for Power Swing and Asynchronous

Protective relays shall have a power swing blocking function in case that the network is likely to suffer from oscillation or asynchronous conditions which causes the wrong trip of protective relay. If the protective relay is calibrated by oscillation time (about 1.5 - 2.0 seconds), it is not necessary to build in power swing blocking function for the protective relays. (refer to the article 426)

Article 480. Instantaneous Short Circuit Protection for 110kV to 500kV Power Lines

For 500kV lines, the main protective relay shall operate instantly when short circuit happens at any point in protected sections of the line.

For long 500kV lines, in order to protect the line from overvoltage in case loss-of-load due to the protective relay tripping for interruption of one circuit breaker of the line, if necessary, interlocks shall be installed to break other circuit breakers of this line at the side of supplying source.

For 110 - 220kV lines, the selection of main protective relay, including necessity to use high speeding protective relay in case of short circuit happening at any point in protected sections, and consideration of the stable operation of power system. If calculation for the stability of power system does not require higher standards, the mentioned requirements are sufficient in case of 3-phase short circuit occurs but residual voltage on busbar of power plant and transmission substation is lower than 0.6 - 0.7 Udđ, instantaneous tripping protective relay will be applied. Lower residual voltage (lower than 0.6 Udđ) can be accepted for 110kV lines and for less important 220kV lines (in power network with many branches and loads are supplied with electricity from many sources), including important 220kV lines which are suffered from short circuit but not much load is reduced.

Protection for underground cable lines with voltage of 110kV and or more shall be applied as protection for overhead lines. In case of oil-filled power cable, it is necessary to equip devices for monitoring oil leakage and protecting oil pressure from high increase.

In selection of protective relay for 110 - 220kV, apart from requirements on maintaining stable operation of power system, the following conditions shall be considered:

1. In case where the time-interruption of fault can break the operation of important loads, timeless interruption shall be used (e.g. the faults when residual voltage in busbar of power plant and transmission substation is lower than 0.6 Udđ, if time-interruption is used, load shedding can be occurred due to the sudden drop of voltage). Or the faults when residual voltage is 0.6 Udđ and higher, if time-interruption is used, technological process can be broken).
2. In case high speed auto-reclosing is necessary, high speed protective relay shall be installed to ensure to interrupt instantaneously two sides of faulty line.
3. In case where using time-interruption for faults with the current several times higher than nominal current, conductor can be overheated.

It is allowed to use high speed protective relay for complicated power grid even the above-mentioned requirements are not available if it needs to ensure selectivity.

When evaluating the satisfaction of requirements on stability based on residual voltage according to the above mentioned, the following instructions shall be complied with:

1. For the single connecting system among power plants or power systems, residual voltage (as above mentioned) shall be checked at busbar of transmission substation and power plant which are in this connecting system, in case the short circuit occurred in line comes from this busbar, except the line which forms the connecting system. For single connecting system which has part of parallel line sections, it is necessary to perform additional check in case the short circuit occurs in each parallel section.
2. In case that power plants or power systems are connected by some connecting systems, residual voltage (as above mentioned) shall be checked at the busbar of the power plants and transmission substations in this connecting system when short circuit occurs in connecting systems, in the lines which are fed by this busbar, even in the lines fed by busbar of connecting substation.
3. Residual voltage shall be checked if short circuit happens at the end of tripped area at one level of the protector at stage fault breaking mode, i.e. after interrupting the breaker at the opposite side of the line by instantaneous protective relay.

Article 481. Relay Components for Transmission Lines in Radial Networks of 220kV and more

For lines of 220kV and more with one supply source, in order to protect the line from multi-phase short circuit, it'd be better to equip level current protective relay or level current with under voltage protective relay. If these protective relays cannot meet requirements on sensitivity or quick-act (refer to the article 480), e.g. on the initial sections of the line, or in the reasonable conditions of combination with protective relays of neighboring sections, the use of level distance protective relay is the most appropriate way. In this case, timeless quick-break current protective relay will be used as the auxiliary protective relay.

To be protected from earth fault short circuit, level zero sequence protective relay, with or without directional, is often used. Generally, the protective relays are often installed at the power source side.

For the line composed of some consecutive sections, for simplification, it is allowed to use level under-voltage current protective relay with unselective trip (multi-phase short circuit protection), and level zero sequence current protective relay (ground fault short circuit protection) in combination with sequence auto-reclosing.

Article 482. Relay Components for Transmission Lines in Loop Networks of 220kV and more

For single line of 220kV and more with two or more supply sources (multi-supplying sources - tapped lines), with or without loop connection, as well as for line in closed loop with one supplying source, to be protected from multi-phase short circuit, it is necessary to use distance protector (3-level (time stepped distance relay) relay is used as priority) as main protector (for 110 - 220kV line) and as backup relay if line has differential relay.

High speed tripping relay will be used as auxiliary protector. In particular case, it is allowed to use high speed tripping relay when 3-phase short circuit occurs near the location where the relay is installed; in case quick-break protector trips at other operating mode which cannot meet the requirement on sensitivity (refer to the item 6 of article 431).
In order to protect against ground short circuit fault, it is usually to use directional or non-directional zero level sequence current relay.

It'd be better to use 1-level directional current protector as the main protector against multi-phase short circuit occurred at the power receiving terminal of loop network with one supply source. For other single lines (mainly overhead lines of 110kV), exceptionally, it is allowed to use level current protector or level current and under voltage protector, in case of necessity, such protectors shall be directional. The protectors are only necessarily installed at the side of power supply source.

Article 483. Relay Components for Parallel Transmission Lines with Efficient Earthed Neutral

For parallel lines fed by two or more power supply sources, as well as for the head of supply sources of parallel line fed with one supply sources, it is possible to use the protective relays as the protective relays applied for single lines (refer to the article 481, 482).
To speed up ground fault short circuit breaking, especially short circuit in between phases in the line fed by two supply sources, it is possible to use auxiliary protective relay with directional power tester in parallel lines. This protection can be carried out in the form of separate directional current protection (relay connected to zero sequence current or to phase currents) or only being the step-up circuit of existed protective relays (zero sequence current protective relay, over-current protective relay, distance protective relay, etc.) together with directional power tester on parallel line.
In order to increase sensibility of zero sequence protective relay, it is allowed to put out additional protective relay from working mode when breaking circuit breaker of parallel line.
At the head of two parallel lines fed by one supply source, in general, it is possible to equip directional transversal differential relay.
In case the protective relay as above mentioned cannot meet the requirement on quick-break (refer to the article 480), it is possible to use directional transversal differential protective relay as the main protective relay (in case where two lines operate in parallel) at the beginning side of supply source of two 110 - 220kV parallel lines which are fed by one supply source, and on main 110kV line of distribution network operating in parallel with two supply sources.
At the operating mode of one line as well as at standby mode in case of operating two lines, protective relays will be used as mentioned in the article 481 and 482. This protective relay or its individual level is allowed to connect to overall current diagram of two lines (e.g. the final protection level of zero sequence current protective relay) to improve its sensitivity when faults happen at the neighboring components.
It is allowed to use directional transversal differential protective relay as auxiliary protective relay for level current protection in 110kV parallel line to reduce time of breaking faults on protected line, id according to quick-act conditions (refer to the article 480) such protective relay is not compulsory.

Article 484. Alternative Relay Components for Instantaneous Protection

If the protection as mentioned in the article 482 and 483 cannot meet requirement on quick-act (refer to the article 480), it'd be better to use high-frequency protective relay and vertical differential protective relay as main protective relays for lines which are fed by two power supply sources.

For 110 - 220kV line, it'd better to use built-in high-frequency lock distance protective relay and zero sequence directional current protective relay as main protective relay if that use is reasonable under conditions of sensitivity (e.g. in line with branches) or that use makes the protection become simple.

In case of necessity to use secondary cable for vertical differential protective relay, it shall base on the results of techno-economic calculations.

It is necessary to equip the exclusive devices for testing secondary circuit of the protective relays.

For high-frequency protection of 500kV line, it is necessary to add transmitter of high-frequency signals to breaking or processing operation of level backup protective relay.

It is allowed to use breaking signal transmitter to speed up operation of multi-level protective relay of 110 - 220kV lines in case where quick-act is required (refer to the article 480) or sensitivity is required (e.g. on line with branches).

When using main protective relays as mentioned in this article, the following protective relays shall be used as backup protections:

- For multi-phase short circuit protection, distance protective relay is often used, mainly 3-level one.
- For ground fault short circuit protection, level directional current protective relay and non-directional zero sequence current protective relay are often used.

In case main protective relay needs to stop the operation for long duration, as mentioned in this article, in case this protective relay is required to trip for quick-break of the faults (refer to the article 480), it is allowed to speed up unselectively of backup short circuit protective relays in between phases (e.g. check of value of positive sequence voltage).

1)

Article 485. Reliability of Protection Relays for 500kV Transmission Lines

Main protections, quick-act level backup multi-phase short circuit protection and measuring device of one-phase auto-recloser for 500kV line shall be carried out to secure their normal function (with given parameters) in powerful transient electromagnetic condition and too high capacity of conductor. For that purpose, it is necessary to have the following equipments:

- In measurement and protection circuit of one-phase auto-reclosing, it is necessary to have solutions to limit the influence of electromagnetic transience (e.g. low-frequency filtering).
- In high-frequency phase differential protective relay installed on the line with length over 150 km, it is necessary to equip device for compensating capacitive current of the line.

In case where connecting quick-act protective relays to overall current diagram of 2 current transformers and more, if it is impossible to meet the requirements mentioned in the article 433, it'd be better to use special measures to prevent wrong operation of the protective relay in case of external short circuit or to attach to the circuit of line one current transformer for supplying power to the protective relay.

Among protective relays of 500kV lines with series compensation device, it is necessary to have measures to prevent the wrong trip in case of external short circuit occurred due to influence of the above-mentioned device. E.g. it is possible to use negative sequence directional power relay or to transmit signals for processing.

In case of using one-phase auto-reclosing, protective relay shall be operated so that:

1. In case one-phase ground fault short circuit occurs, especially 2-phase ground fault short circuit, only one phase is sure to be disconnected (after that, auto-reclosing operates).
2. Failed operation of auto-recloser in case of the faults mentioned in point 1 occurred, one or 3 phases will be disconnected, depending on whether the existence of long-term non-full phase mode of the line is permissible or not.
3. In case other faults occur, the protective relay will operate to interrupt all 3 phases.

Article 486. Relay Components for 15-35kV Distribution Lines

As stipulated in Technical Regulation.

Chapter 5-2-7 Protection of Compensating Capacitors

Article 487. Protection Components of Shunt Capacitors at OPL

As stipulated in Technical Regulation.

Article 488. Protection Components of Shunt Capacitors at Substations

As stipulated in Technical Regulation.

Article 489. Relay Components for Series Capacitors

As stipulated in Technical Regulation.

Chapter 5-2-8 Protection of Busbars

Article 490. Protection Components for Busbars of 110kV or more

In case that current transformer is build in circuit breaker, busbar differential protective relay and protective relays of components connected to busbar (line protective relay) shall use current transformers from different sides of circuit breaker so that the circuit breaker faults are located in protected zone.

In case that the current transformer is not existed in circuit breaker, for economy, it'd be better to use external current transformer which is in one side of circuit breaker, and current transformers should be so arranged that circuit breaker is in the protected zone of busbar differential protective relay. At that time, in protective relay of double busbar, fixed allocated components shall use two current transformers of sectionalized circuit breaker.

Article 491. Protection Components for 35kV Busbars

For busbar of 35kV of power plant and transmission substation, it is necessary to equip particular protective relay in the following cases:

- In accordance with requirements mentioned in the article 480.

- For system with double busbar or sectionalized busbar, if using particular protective relay laid in busbar circuit breaker (or sectionalized circuit breaker), or protective relay laid in components feeding this busbar system cannot meet reliability in supplying electricity to consumers (with taking into account of ability to meet with auto-recloser and standby automation).
- For busbar of closed distribution equipment, requirements on protective relay are allowed to be lower (e.g. for the power network with high ground fault short circuit current, only short circuit protective relay is needed) because fault probability is lower than that of open distribution equipment.

Article 492. Differential Relays for Busbars of more than 110kV or more

To protect busbar of power plant and transmission substation with voltage of exceeding 110kV, it would be better to use instantaneous differential current protective relay, which covers entirely components connecting busbar or section of busbar. The protection shall be special current relay which is calibrated according to transient current and unbalanced stable current (e.g. relay connected through saturated current transformer, braking-coil relay).

In case where connecting 500kV transformer through two or more circuit breakers, differential current protective relay should be used for busbar.

For double busbar system of power plant and transmission substation with voltage of 110kV or more, each component connected to busbar will have one circuit breaker and shall use differential protective relay. Busbar protective relay shall be capable to react by switching connection in clamp series in case where fixed allocation is changed, accordingly shifting components from this busbar system to another one.

Above mentioned differential relay shall be operated with the perfection tester of secondary circuit of current transformer; this relay shall trip with definite time and separate protection and sending of signals if circuit is not perfect.

In loop circuit breaker of 110kV and above, in case that busbar circuit breaker (or sectionalized circuit breaker) is available, it is necessary to equip the following protective relays (for using in case of checking or repairing protective relays, circuit breakers and current transformers of any components connected to busbar):

- 3-level distance protective relay and quick-break current protective relay for multi-phase short circuit protection.
- 4-level zero sequence directional current protective relay for ground fault short circuit protection.

At the same time, busbar circuit breaker or sectionalized circuit breaker (to separate busbar system or busbar section in case that protective relay for failing to operate protection of circuit breaker is not available, or expel or protect operating busbar, and for improving efficiency of remote backup protective relay) shall have the following protections:

- 2-level current protective relay for multi-phase short circuit protection.
- 3-level zero sequence protective relay for ground fault short circuit protection.

It is allowed to install more complex protective relays in busbar circuit breaker (or sectionalized circuit breaker) if necessary in order to improve efficiency of remote backup protective relay.

On busbar circuit breaker (or sectionalized circuit breaker), with voltage of 110kV and above, which is used for bypass function, there shall be protective relays installed similar to those of loop circuit

breaker and busbar circuit breaker (or sectionalized circuit breaker) in case that they separately operate.
It would better to anticipate the ability to switch main quick-act protective relay of line of 110kV and above to loop circuit breaker.
Busbar circuit breaker (or sectionalized circuit breaker) with voltage of 6 - 35kV there shall be 2-level current protective relay for multi-phase short circuit protection.

Article 493. Protection for 6-10kV Busbars with Generators

For busbar which has section of 6 - 10kV of power plants, a 2-level time non-full phase differential protective relay shall be used. the first level is in the form of quick-breaking by current and voltage, or distance protective relay, the second level is in the form of over-current protective relay. The protective relay shall trip to disconnect supply sources and auxiliary transformer.
If the 2nd level of protection is not sensitive enough when short circuit happens differential protected zone of feeding line with reactance (high load in busbar at generator voltage, circuit breakers of feeding lines are laid behind reactors), it is necessary to use particular over-current protective relay with or without voltage starter attached circuit of reactor. Trip of these protective relays to disconnect feeding components shall be controlled by auxiliary devices, starting in case where short circuit occurs. In this case, sectionalized circuit breaker shall be equipped with protective relay to clear the faults between reactor and circuit breaker. This protective relay will be put in operation when the sectionalized circuit breaker has been disconnected. In case where feeding components are switched to reserve busbar system, it is necessary to have non-full differential protective relay which operates on principles of fixed allocation of components.
If regime of shifting feeding component from this busbar system to another one operates frequently, it is allowed to use particular distance protective relays for all feeding components, excluding generator.

For sectionalized busbar system of 6 - 10kV of power plant which has generator up to 12MW, it is allowed not to use individual protective relay. In this case, for clearance of short circuit in busbar, over-current protective relay of generator will be used.

For sectionalized single and double busbar system of 6 - 10kV of step-down transmission substation, individual protective relay is often not used. For clearance of faults in busbar, external short circuit protective relay of transformer installed in sectionalized circuit breaker, or in busbar circuit breaker, will be used. To improve sensitivity and speed up operation of busbar protective relay of big transmission substations, it is allowed to connect protective relay to overall current diagram of electricity feeding components. In case where reactor is arranged in line from busbar of transmission substation, busbar protective relay is allowed to operate as busbar protective relay of power plant.
For operation of busbar differential protective relay, it is possible to install current transformer at both sides of sectionalized circuit breaker of 6 - 10kV, if structure permitted without needing auxiliary cells.
In case that individual difference protective relay is used as busbar protective relay, current transformers of this protective relay in circuit of sectionalized circuit breaker shall be arranged in between busbar section and reactor.

Article 494. Protection Range

As stipulated in Technical Regulation.

Chapter 5-2-9 Protection of Synchronous Compensators

Article 495. Protection Components for Synchronous Compensators

Protective relay of synchronous compensator, which directly operates on busbar, shall be equipped similarly to that for corresponding generator but with some differences as follows:

1. Symmetric overload protective relay, which trips for sending signals, shall be locked to keep from operation if that protective relay can trip when synchronous compensator starts.
2. Under-voltage protective relay, which trips for interruption of circuit breaker of synchronous compensator, shall have starting voltage of protective relay is from 0.1 to 0.2 U_{dd} and operate in 10 seconds.
3. It is necessary to equip protective relay for tripping in case that transmission substation is suffered from short time power loss (e.g. dead cycle of auto-reclosing of feeding line).
   Protection should be carried out in the form of low-frequency protection and disconnection of circuit breaker of synchronous compensator, or auto-magnetic extinguisher. It is also allowed to carry out protection according to other principle (e.g. reacting by speed of frequency decrease)
4. For synchronous compensator with capacity of 50 MVar and above, it is necessary to equip the protective relay to trip for disconnecting synchronous compensator or sending the signals in case excitation lost or exciting current decreases lower than permissible limit. For synchronous compensator, which can switch to operate at negative exciting current mode, it is allowed not to use the above-mentioned protective relay.
5. For synchronous compensator, which operates according to transformer block, it is necessary to equip ground fault protective relay in stator winding; this protective relay will be installed at the low voltage side of the transformer.
   In case the ground fault exceeds 5A, it is allowed not to use arc suppression coil and but use 2-level time protective relay in which long level time will trip for interrupting circuit breaker of synchronous compensator, short time level will trip for sending signals.

In case the ground fault current is lower than 5A, 1-level time protective relay is used and trips for sending signals. For synchronous compensator with capacity of 50 MVar and above, it is necessary to use protective relay to trip for sending signals or for interruption.

For transmission substation without on-duty staff, protection for overload of synchronous compensator will be carried out with time independent particularity and sending signals with shorter time-level and reducing exciting current. At longer time level, the protective relay will trip for interrupting synchronous compensator (if exciting regulator cannot prevent long overload).

Article 496. Protection for Grounding Faults for Synchronous Compensators

As stipulated in Technical Regulation.

Chapter 5-2-10 Protection of Underground Cable Lines

Article 497. Relay Components for Underground Cables

As stipulated in Technical Regulation.

Article 498. Protection against Earth Faults for Underground Cable Lines

If underground cables have high capacitance to the ground, the malfunction of protective relays due to the transient oscillation current of the cable may happen in case of external faults of protective areas. Therefore, it is desirable to consider the following.

- Install the compensating reactor for the cable near the target cables.
- Tripping the circuit breaker after transient oscillation current decreases
- If the active current of the fault current is smaller than the charging current of the cable, it is desirable to install neutral grounding resisters at the both ends of the cable, to increase the active current of the fault current.

Chapter 5-3 Control Systems

Chapter 5-3-1 Control equipment and Auto-reclosers

Article 499. Functions of Automation and Remote Control

As stipulated in Article 499 in Technical RegulationVol.1.

In power system and electrical equipment which can be installed with auto-control devices, even if the auto-control devices do not obey the application scope of this chapter but other regulations, the operation of such auto-control devices shall coordinate with operations of auto-control devices subject to requirements mentioned in this chapter.

In even customer's power network, automatic devices are recommended to be equipped in case that interruption of electric power supply due to trip by protective relays and auto-control devices cannot be acceptable.

Article 500. Application Conditions of Auto reclosers

1. The following items should be considered in order to decide whether auto-recloser can be applied to overhead cable line with voltage up to 35kV or not.
   (1) It should be checked whether auto-reclose affects cable line by switching operation of circuit breaker. (e.g. open arc at cable line where several transformers are connected)
   (2) It should be checked whether protective relay for cable line can be calibrated to ensure selective trip in case of fault

   Auto-recloser should not be applied to underground cable line. Generally, since most of the faults which occur at underground cable line are permanent fault, such faults cannot be extinguished by temporarily interrupting the fault part from power line. Therefore, auto-reclose should be carried out in case of fault at underground cable line.
2. Auto-reclose of bus-bar of a power plant or a substation shall obey either the following requirements.
   (1) Automatic forced charging of bus-bar

   Bus-bar is charged by operation voltage through one circuit breaker from one of the live power lines which are connected to the bus-bar.

(2) Automatic restore of diagram

First, bus-bar is charged by operation voltage through one circuit breaker from one of the live power lines which are connected to the bus-bar. After this charging is completed, remaining power outage components are charged one by one. This type auto-recloser should be equipped at the substation without on-duty stuff.

For substation which has two step-down transformers operating independently, auto-recloser for bus-bar should be equipped at low voltage side or medium voltage side of transformer and in combination with auto-switching device. In case of fault inside the transformer, the auto-switching device interrupts the fault transformer and auto-recloser shall not operate. In case of other faults, auto-recloser interrupts the fault transformer.

For substation which has two step-down transformers operating in parallel on the bus-bar, auto-switching device can be added to auto-recloser if either one of the two transformers is in standby mode.

3. Auto-reclose of transformers shall obey the following requirement

Auto-recloser should be equipped at substation which has one step-down transformer with capacity of more than 1MVA and circuit breaker for over-current protection at the power source side of the transformer. If disconnection of the transformer causes power outage at consumers, the auto-recloser is allowed to operate in case that the transformer is disconnected due to operation of short circuit protective relay attached to the circuit breaker at its power source side.

In addition to the above, it shall be confirmed that the protective relay for fault inside the transformer does not operate.

4. Auto-reclose of motors disconnected for self-start-up of key motors shall obey the requirement stipulated in Article 509.

Auto-recloser shall be equipped at bypass circuit breaker, busbar circuit breaker and section circuit breaker.

Article 501. Cases Auto recloser not be allowed to operate

If a circuit breaker is interrupted as soon as this circuit breaker is closed by auto-recloser or manual operation, this circuit breaker shall not be reclosed because the electrical fault is considered to remain.

In case of electrical fault inside a transformer and a rotary machine such as generator, rotary compensator and motor, auto-reclose is prohibited because such electrical fault is considered to remain. For the same reason, in case of electrical fault in an underground cable, auto-reclose is prohibited.

As for the loads shed from the power gird due to by frequency decrease, auto-reclose of such loads is prohibited in order to avoid frequency decrease again.

Article 502. Operation Period Requirements

3-phase auto-recloser with 2time trips should be applied to overhead line, especially to single power line supplied with power from one side.

As for overhead power line with voltage up to 35kV, which is not equipped with standby power source, 3-phase auto-recloser with 2time trips should be applied to such power line preferentially.

In power grid with isolated neutral or neutral point grounded through compensator, the second time of auto-reclose should be locked in case that earth fault occurs (voltage at the neutral point increases

excessively) after the first time of auto-recloser. The duration between the first time and second time of auto-reclose shall not be smaller than 20 seconds.
The duration between the first auto-reclose and the second auto-reclose shall be decided based on the circuit breaker operating sequence duty. Therefore, the performance of the circuit breaker shall satisfy the requirement on the auto-reclose.

Article 503. Operation Time Requirements

As for the power line supplied with power from both sides, operation time of 3-phase auto-recloser shall be decided in consideration of ability to non-simultaneously interrupt two circuit breakers at the both ends. In this case, the operation time of buck-up protective relay should not be considered. And operation time of non-simultaneous interrupt of circuit breakers at the both ends by vertical differential protective relay shall not be considered.
In order to enable 3-phase auto-recloser to operate efficiently, the operation of the 3-phase auto-recloser can be delayed, if such delay of operation of 3-phase auto-recloser is acceptable.
If the both ends of a power line are still connected electrically in case that the power line is interrupted by protective relay, auto-recloser without synchronous check should be equipped at this power line.

Article 504. Required Application Conditions for Single Transmission Lines

The type and function of auto-recloser should be selected based on individual conditions of power system and electrical equipment.
Quick-act auto-recloser and 3-phase quick-act auto-recloser should be installed in power line in order to automatically reclose in case that the angle between electromotive force vectors of the power systems to be connected is small. 3-phase quick-act auto-recloser can be used if the requirements below are satisfied.

- The performance on opening and closing of circuit breaker meets requirements on quick-act auto-recloser
- After re-energized, parallel power lines can operate synchronously and largest electromagnetic moment of synchronous generator or compensator is lower than electromagnetic moment in case that 3-phase short circuit occurs at the terminal of the synchronous generator or compensator..

  The largest electromagnetic moment will be calculated based on the maximum allowable deviated angle between two electromotive force vectors of power systems at 3-phase quick-act auto-reclosing.
  When back-up protective relay operates, 3-phase quick-act auto-recloser shall not operate. Moreover, when auto-switching device for the circuit breaker operates, 3-phase quick-act auto-recloser shall not operate or shall operate with time-delay. In order to ensure the stability of the power system, 3-phase quick-act auto-recloser shall not be applied in case that the failure of operation of the 3-phase quick-act auto-recloser causes several interrupts by protective relays.

Asynchronous auto-recloser can be applied in the case following cases are satisfied..

(1) Electromagnetic moment of generator or synchronous compensator in case of asynchronous energizing is lower than electromagnetic moment in case that 3-phase short circuit occurs at output terminal of the generator or compensator. It should be checked whether asynchronous auto-recloser can be applied or not by initial calculation result of short circuit in case that the

transformer is energized at angle of 180 degree.

(2) Maximum current which flows through transformer in case that the transformer is energized at angle of 180 degree is lower than short circuit current at output terminal of the transformer

(3) Re-synchronization can be ensured after asynchronous auto-reclose. If asynchronous mode continues for long time after asynchronous auto-reclose, countermeasures to prevent or break such asynchronous mode shall be taken.

When asynchronous auto-recloser is applied, measures to avoid its unnecessary trip shall be taken. For that purpose, the circuit breaker should be closed according to the designated order on auto-reclosing.

Auto-recloser for auto-synchronization can be applied in power line to energize the power line in case that the phase displacement angle is allowed.

Auto-recloser can be operated in the following way.

First, either end of the power line shall be energized, and second, 3-phase auto-recloser with accelerator without check of line voltage, 3-phase auto-recloser with check of no-voltage on the line, or auto-recloser for auto-synchronization can be applied. Auto-recloser for auto-synchronization can be applied under the condition that the other end of the power line is energized successfully.

In order to implement auto-synchronization, device to synchronize voltage, frequency and phase displacement on the line can be applied in case of unchanged angular displacement.

Auto-recloser should be arranged so that it can change the sequence for energizing circuit breakers at the two ends of the power line.

As for power line with potential transformer to check voltage on the power line for 3-phase auto-recloser, protective relay which operate by line voltage or phase voltage, negative and zero sequence voltage.

As for single power line supplied from two power supply sources connected to power system with small capacity power plants, 3-phase auto-recloser with automatic self-synchronization of hydraulic turbine generator can be applied.

As for power line supplied from two power supply sources of which both terminals are connected through other power lines, auto-recloser should be equipped to such power lines.

1. In case that two or three connecting power lines can be interrupted at the same time

- Asynchronous auto-recloser can be mainly applied to power line with voltage from 110kV to 220kV if the above-mentioned conditions on application of asynchronous auto-recloser are satisfied.

- Synchronous auto-recloser can be applied if the above-mentioned conditions on application of asynchronous are not satisfied.

At important power lines of which the both terminals are connected through other power lines, if asynchronous auto-recloser cannot be applied to the two of them due to failure of the above-mentioned conditions on application of asynchronous auto-recloser, 1-phase auto-recloser, quick-act 3-phase auto-recloser or auto-recloser for auto-synchronization can be applied. In this case, 1-phase auto-recloser and 3-phase quick-act auto-recloser should be used together with synchronous auto-recloser.

2. In case that the both terminals of the power line are connected by the other no less than 4 power lines and two among the these connecting power lines is difficult to interrupt simultaneously, asynchronous auto-recloser should be applied.

As for auto-recloser with synchronous check, first auto-reclose at one terminal of the power line should be carried out with voltage check and synchronous check. And second auto-reclose at the other terminal should be carried out with only synchronous check. In such way of auto-reclose, the order of the auto-reclose shall be changeable.

Several types of 3-phase auto-recloser at the same time on power line such as 3-phase quick-act auto-recloser or 3-phase auto-recloser with synchronous check can be used. Different types of auto-recloser can be applied to each terminal of power line as follows.

- 3-phase auto-recloser with voltage check is applied to one terminal.
- 3-phase auto-recloser with voltage check and synchronous check is applied to the other terminal

In case that auto-reclose causes asynchronous energizing of synchronous compensators and that such energizing is unallowable for these synchronous compensators, in order to avoid supplying electric power from such synchronous compensators to fault point, the synchronous compensator should be disconnected from power system in case of power outage or should be made to operate without voltage by extinguishing its magnetic field. After voltage is recovered by successful operation of auto-recloser, the synchronous compensator should be energized or synchronized again automatically.

For a transformer substation where synchronous compensator is installed, the measures to avoid wrong operation of automatic load shedder by frequency during operation of auto-recloser should be taken.

Article 505. Condition of Single Phase Auto-reclosers

One-phase auto-recloser shall be arranged so that it can be kept from operation in case of loss of power supply, and it has to make automatically the protective relay on the power line operate to interrupt all phases of the power line without operating auto-recloser.

Fault phase in case of earth fault shall be indentified by selector. Such device can be used as auxiliary protective relay of one-phase auto-recloser in case that 3-phase auto-recloser, 3-phase quick-act auto-recloser or operator energizes circuit breaker from either side of the power line.

The operating time of one-phase auto-recloser shall be calibrated according to the time sufficient to extinguish arc and for deionization at the field around 1 phase earth fault point in non-full phase mode, provided that the protective relays at the both terminals don't operate for interruption.

1-phase auto-recloser can be combined with 3-phase auto-recloser. 3-phase auto-recloser should be prohibited to operate in case that 1-phase auto-reclose is not successful. In such case, 3-phase auto-reclose should be implemented at the either terminal of the power line with voltage check on the power line with time delay.

As for the decision of operating procedure of auto-recloser which is composed of 1-phase auto-recloser ant 3-phase auto-recloser, the operating procedure shall be considered based on the actual operation method of the relevant power lines and in reference to Article 504.

Article 506. Required Functions to Prevent Malfunction of Circuit Breakers

When auto-recloser fails to operate properly, the other circuit breakers are prohibited to be closed. If the other circuit breakers are closed in this case, the circuit breaker which failed to operate at auto-reclose will be energized again, and accordingly, the range of the electrical failure will be extended. In order to avoid such extension of the electrical failure, the aforesaid operation of the circuit breaker is strictly prohibited.

Chapter 5-3-2 Auto Switching Power Supply Devices

Article 507. Application Conditions of Auto Switching Power Supply Devices

Auto switching power supply device can be applied if the application of the device enables simplification of protective relay system or diagram of power system or reduction of short circuit current.

Article 508. Reliability Improvement Requirements

Auto switching power supply device shall secure its ability to operate in case of outage or short circuit on busbar of components which have the auto switching power supply device.

When circuit breaker of normal supply source is interrupted, auto switching power supply device shall instantly energize circuit breaker of standby source. In this case, the auto switching power supply device shall secure to operate one time.

The device shall operate on the following conditions.

- If complicated devices are not required, the auto switching power supply device shall check the open/close status of circuit breaker connected to the component.
- In order to improve the operation of auto switching power supply device in case that supplying lines from normal power source are interrupted due to outage of the power source or the operation in case that circuit breaker at receiving side is interrupted, the auto switching power supply device shall be equipped with voltage starter. In receiving electricity from standby power source at outage of normal power source, the voltage sensor shall interrupt circuit breaker from receiving side.

Voltage starter shall comply with the following requirements.

- Under-voltage component of the voltage starter of the auto switching power supply device, which operates in case of outage of power source, shall be calibrated according to voltage decrease due to start of motor or external short circuit fault. Operating voltage of voltage starter should be decided based on self-starting condition of motor. Operating time of the voltage starter shall be longer than the time to interrupt in case of external short circuit fault, and moreover, should be longer than operating time of auto-recloser at supply side.
- Under-voltage component of the voltage starter shall avoid its wrong operation in case that the high and/or low voltage side or potential transformer is broken. In case of using automatic circuit breaker to protect the low-voltage side of the potential transformer, the voltage starter shall be prohibited to operate
- However, in case that auto switching power supply device is applied to 6kV-10kV distribution network and additional voltage transformer is required, the above-mentioned requirement is not necessarily satisfied.

If the operating time of the starter of auto switching power supply device is longer than permissible time, other type of starter should be adopted. If starter by frequency is adopted, the starter shall operate to interrupt circuit breaker at supply source side in definite time under the condition that the frequency at the supply source side decreases to the designated value and the frequency at standby source side remains normal.

In order to accelerate the operation of auto switching power supply device at transformer or short distance power line, protective relay to interrupt the power line should be equipped at not only circuit breaker at supply side but also at that at receiving side. For important case such as power supply to auxiliary equipment at power plant, circuit breaker at receiving side shall be interrupted as soon as circuit breaker at supply side is interrupted.

Auto switching power supply device for auxiliary equipment in power plant, which energizes one of disconnected power sources as standby power source, shall have ability to disconnect other online power sources.

In order to prevent standby power sources from being energized in case of short circuit as well as overloaded, alleviation of self-start and recovery to normal diagram by simple devices after de-energizing due to faults or operation of automatic device, auto switching power supply device and auto-recloser should be applied in combination. Auto switching power supply device shall operate in case that faults occur inside normal power supply source. On the other hand, auto-recloser shall operate in case of other faults. After auto-recloser or auto switching power supply device operates successfully, the original electrical diagram shall be recovered automatically.

Article 509. Required Functions of Observance of Overload

If unallowable overload occurs on standby power source or self-startup motor cannot start during operation of auto switching power supply device, load shedding shall be considered. First, unimportant loads are disconnected when auto switching power supply device operates. Furthermore, important loads are disconnected temporarily. In this case, these important loads shall be auto-reclosed after auto switching power supply finishes its operation.

In addition to the above, when auto switching power supply device operates, the measures to avoid re-energizing the equipment which has been disconnected by automatic load shedder by frequency shall be considered and taken.

When auto switching power supply device operates for energizing circuit breaker, protective relay for the circuit breaker should have function of acceleration of its operation, considering that short circuit fault may still remain. In this case, the measures to prevent the standby power source from being disconnected due to such acceleration of the protective relay. As for the circuit breakers of standby power source used for only power plant, such acceleration of protective relay should be curried out in case that the operating time of the protective relay exceeds from 1.0 to 1.2 seconds. And the operating time should be adjusted to 0.5 seconds. As for other electrical equipment, the operating time should be adjusted based on specific conditions respectively.

Article 510. Required Functions of Prevention of Asynchronous Conditions

In order to avoid the current from synchronous compensators to short circuit fault point in case of outage of power supply source, disconnection of synchronous compensators and motors should be adopted. And in order to prevent the standby power source from being energized before disconnecting synchronous electrical equipment, the operating time of auto switching device can be delayed. However, in this case, it shall be considered whether such delay of operating time is acceptable or not.

As for a transformer substation, where synchronous compensator or motor is installed, the measures to avoid wrong operation of automatic load shedder when auto switching power supply device operates

Chapter 5-3-3 Auto-synchronization of Generators

Article 511. Synchronization Mode

Accurate synchronization is the synchronization in which the voltages, frequencies and phase differences at both sides of synchronization point are synchronized with very little differences. This synchronization method can hardly cause adverse affect on the power gird at the connection of power systems.

Auto synchronization is the synchronization in which the voltages, frequencies and phase differences at both sides of synchronization point are synchronized with allowable differences. This synchronization method is likely to cause certain influence on the power gird at the connection of power systems.

All generators shall be equipped with suitable synchronization devices. As for hydraulic turbine-generator, these devices are placed in central control hall or local control cubicle. As for steam turbine-generator, they are placed in main control room or block control room. Regardless of the mode of synchronization, if necessary, generator can be equipped with accurate synchronization manually in combination with the protection lock against asynchronous energizing.

Article 512. Accurate Synchronization Application Conditions

Accurate synchronization is applied in the following cases.

(1) Steam turbine-generator with indirectly cooled wiring and capacity more than 3MW, which is connected to the busbar without transformer, in case that its transient current is larger than $3.5*I_{max}$ (I_{max}: maximum operating current in normal operation)

(2) Steam turbine-generator with directly cooled wiring

(3) Hydraulic turbine-generator with capacity of 50MW and above

When accurate synchronization is applied as key mode to put generator in parallel operation, auto-accurate synchronization or semi-auto accurate synchronization device should be applied. As for generators with capacity up to 15MW, manual accurate synchronization in combination with protective device against asynchronous energizing.

Switchyard between main power gird and power plant, where synchronization should be carried out between components of power system, shall be equipped with manual or semi-auto accurate synchronization device.

Article 513. Application Conditions of Auto-synchronization

When auto-synchronization is applied as key mode to put generator in parallel operation, auto-synchronization device should be applied to hydraulic turbine-generator, and manual or semi-auto synchronization device should be applied to steam turbine-generator.

Chapter 5-3-4 Auto-control Exciter Systems, Auto-control of Reactive Power, Auto-voltage Regulators

Article 514. Required Functions of Auto-control Exciter Systems, Auto-control of Reactive Power, Auto-voltage Regulators

In order to maintain voltage and static and dynamic stability on the power system, voltage regulator shall be installed at the power network properly. The reactive power which this voltage regulator generates shall be adjusted automatically or by control signal from load dispatch center according to voltage variation on the power grid. This purpose is to stabilize the stability of the power system in case of electrical fault as well as normal operation.

The voltage regulators shown below can be applied to the power system.

- Excitation system of synchronous generator
- Synchronous compensator
- Shunt reactor
- Static power condenser

Article 515. Application and Range Requirements

Forced relay-type exciter can be applied to only synchronous generator and compensators with capacity lower than 2.5MW. However, generator which operates independently or in small power system is not included in the above.

Synchronous motors shall be equipped with auto-controlled exciter system, auto-controllers of reactive power or auto-voltage regulator according to their specifications or conditions.

Excitation controllers shall comply with technical conditions in the excitation system of the equipment.

Article 516. Improved Reliability Requirements

When auto-controlled exciter, auto-controller of reactive power, auto-voltage regulator and other device of excitation system are connected to voltage transformer, the following requirements shall be considered.

(1) In case that auto-controlled exciter, auto-controller of reactive power or auto-voltage regulator connected to voltage transformer with fuse at its primary side, the following requirements shall be satisfied.

- As for auto-controlled exciter, auto-controller of reactive power or auto-voltage regulator and other devices of excitation system, if outage of supply power sources can cause overload to them or decrease of their excitation to unallowable limit, they shall be connected to secondary circuit of voltage transformer without fuse or automatic circuit breaker.
- As for forced relay-type exciter shall be arranged so that it is prevented from wrong operation in case that one of fuses at primary side of voltage transformer is broken.

(2) In case that auto-controlled exciter, auto-controller of reactive power or auto-voltage regulator connected to voltage transformer without fuse at its primary side, the following requirements shall be satisfied.

- As for auto-controlled exciter, auto-controller of reactive power or auto-voltage regulator and other devices of excitation system shall be connected to secondary circuit of voltage transformer with automatic circuit breaker.
- The auxiliary contact of automatic circuit breaker shall be used to remove overload or decrease of voltage to unallowable limit every time automatic circuit breaker is interrupted.

In principle, measurement equipment or instrument shall not be connected to the voltage transformer which is already connected to auto-controlled exciter, auto-controller of reactive power or auto-voltage regulator and other devices of excitation system. However, in exceptional case, the aforesaid connection is allowed. But, in this case, the measurement equipment or instrument shall be connected through individual automatic circuit breaker or fuse.

Combined excitation equipment should be connected to current transformer at the output terminal of synchronous generator or compensator.

Article 517. Sensitivity of stimulation for hydro-generators

As for auto-controlled exciter, auto-controller of reactive power, auto-voltage regulator of hydraulic turbine-generator, over-voltage protective relay shall not operate in case that load is shed suddenly under the condition that the governor operates normally. If necessary, the auto-controlled exciter, auto-controller of reactive power and auto-voltage regulator can be equipped with quick-act excitation reducer.

As for directly cooled synchronous generator with capacity of 15MW and above and synchronous compensator with capacity of 5MVar and above in power plants and transformer substation without on-duty stuff, control panel shall be equipped with automatic overload limiter with time delay. The automatic load limiter shall not impede forced excitation during allowable time decided for each equipment respectively.

As for generator with capacity of 100MW and above and synchronous compensator with capacity of 100MVar and above, quick-act excitation system should be equipped to such electrical equipment.

However, depending on the role of power plant in power system, other type of excitation system or slow-act excitation system can be adopted.

Article 518. Required Functions of Excitation Regulators

For synchronous compensator with regulated non-transposed excitation system, regulated values shall be adjusted from almost zero rotor current value. For synchronous compensator with transposed excitation system, regulated values shall be adjusted from the maximum negative value of exciting current.

When a generator is connected to the block of transformer, this generator shall be able to supply loss current due to voltage loss inside the transformer.

Transformers with on-load tap changer at distribution substation or auxiliary system of power plant shall be equipped with regulator for the tap changer.

For transformer substation where transformers or autotransformers with regulator for the tap changer operate in parallel, master auto-controlling system for the entire substation or group controlling system shall be equipped in order to resolve unbalanced current among the transformers.

Compensator capacitors shall be equipped with corresponding auto-controlling regulator.

Chapter 5-3-5 Auto-control Frequency and Active Power

Article 519. Required Functions of Auto-control Frequency and Auto Power

The active power generated by each power plant shall be adjusted automatically or by load dispatch center. The purposes are as follows.

- Frequency deviation on the power system is limited within the allowable value.
- Power flow on each power line in the power system is adjusted appropriately in order to maintain stability of the power system.

Article 520. Frequency Fluctuation Requirements

The speed regulation of the auto-control frequency and active power system equipped in generator shall be selected appropriately in order to restrain frequency fluctuation on the power gird and adjust the distribution of load among generators rationally in case of load fluctuation on the power grid. The speed regulation is defined as the following equation.
Moreover, the value of this speed regulation shall be adjustable at the site because this value has to be adjusted according to the conditions on power plants and loads.

$$\alpha = \frac{(N_2 - N)/N_n}{(P_1 - P_2)/P_n}$$

N1, N2: Rotating speed before and after load change respectively
P_1, P_2: Output of generator before and after load change respectively
N_n: Rated rotating speed
P_n: Rated output of generator

Article 521. Required Components

Controlling signal shall be received from auto-controlled frequency and active power system of higher dispatch level.
Equipment for auto-control of frequency and active power in load dispatch centers shall detect actual deviation against stipulated mode, establish and transmit controlling operation to lower level load dispatch centers and power plants which are involved in power auto-control process.
Auto power regulator at power plant shall satisfy the following requirements.

- To receive and set up controlling operations which come from higher load dispatch level and establish signals for controlling action at power plant level.
- To establish controlling action for each block of generator unit
- To maintain power of each block according to received controlling action

Devices for auto-control of frequency and active power shall be able to change their specific parameters in case that controlled equipment changes its operating mode, and shall be equipped with signaling indicator, interlock and protective device to avoid disadvantageous action in case that normal operating mode of controlled object is changed or inside faults of devices happen. The aforesaid components are also used to remove adverse affect which prevent protective relays from currying out their functions.

Remote control facilities shall ensure sending information on power flow to other power system which this power system is connected to, and transmitting control signals from auto active power control device to controlled equipment as well as transmitting necessary information to senior management agencies.

For hydropower plant, power control system shall be equipped with auto devices to secure the start and stop of generator unit, and if necessary, such auto devices can switch generator unit to either synchronous compensation mode or generation mode, depending on conditions and operation method.

In hydropower plants of which output power is decided according to water flow condition, auto power regulator by water flow shall be equipped.

Chapter 5-3-6 Auto-prevention of Disturbances

Article 522. Required Functions of Auto-prevention of Disturbances

A device for auto-prevention of disturbance can make change of operation mode of series and shut compensation devices and other devices of power transmission line such as shunt reactor, auto-excitation regulator of generator, etc. It also will reduce active power of power plant in case that fault mentioned at the below items (1) and (2) occurs. Therefore, this device limits amount of power to avoid further load shedding by frequency in power system or other adverse affect on power system.

The device for auto-prevention of disturbance can be applied in the following cases.

(1) Normal power lines as well as fault power lines are disconnected when protective relay and one-phase auto-recloser operate at one phase earth fault. Such situation can occur on heavy load power lines. Automatic devices can be applied if the failure of operation of the automatic devices doesn’t cause further load shedding.
(2) Power line is de-energized when protective relay operates at multi-phase short circuit.
(3) Circuit breaker fails to be interrupted at switching of standby device in case that short circuit occurs in normal operation mode of power system.
(4) Asynchronous power lines are separated from power system in normal operation mode.
(5) Serious power shortage or redundancy occurs at one of parts connected to integrated power system.
(6) There are quick-act auto-reclosers or auto-reclosers operating in normal diagram and normal modes.

Auto-out-of-step protective device can be used for the following purpose.

(1) To disconnect partly generators of hydropower plant, and to disconnect generator of thermal power plant, if necessary.
(2) To reduce or increase output of steam turbine-generator promptly at permissible rate of thermal power plant
(3) To shed partially load of consumers which can endure transient outage
(4) To dived power system
(5) To reduce promptly and transiently load on turbine rotor.

Priority of control signal of the device for auto-prevention of disturbance shall be decided according to influence caused by each operation or phenomenon.

Chapter 5-3-7 Auto-elimination of Asynchronous Mode

Article 523. Required Functions of Auto-elimination of Asynchronous Mode

The device for auto-eliminating asynchronous mode shall carry out methods to alleviate synchronous loading conditions as follows at first.

- To increase promptly load of turbine or to reduce part of load of consumers
- To reduce output of generator or to de-energize generators partly

Automatic separation of power system at assigned points shall be only carried out after asynchrony occurs if the aforesaid measures cannot recover the synchrony to power system after passing some stipulated oscillation periods or in case that asynchronous mode lasts longer than allowable duration.

Chapter 5-3-8 Auto-prevention of Frequency Decrease

Article 524. Required Functions of Auto-prevention of Frequency Decrease

The functions of the device for auto-prevention of frequency decrease are as follows.

- To energize standby system automatically by frequency
- To shed load automatically by frequency
- To shed load further
- To re-energize outage parts after recovery of frequency

In case that frequency decreases, firstly, standby source shall be automatically energized to reduce load shedding or outage duration of electricity supply to consumers. Energizing standby source includes the measures below.

- To connect spinning reserve in thermal power plant to power grid.
- To start up automatically hydraulic turbine-generators which are in standby
- To switch automatically online hydraulic turbine-generators from compensation mode to generation mode
- To start up automatically gas turbine

Article 525. Load Shedding in the event of Frequency Decrease

Automatic load shedders by frequency must be equipped in substations in power system. These devices can be also equipped at consumers' sites, but are managed by the power sector.

Amount of load to be shed shortage occurs shall be indentified based on the efficiency in case that any power shortage occurs. Sequence of load shedding shall be considered so that it causes minimum loss due to outage. If necessary, several automatic load shedders by frequency with multi-level operation can be applied. Important loads are usually shed lastly.

Automatic load shedder by frequency shall be operated in combination with auto-recloser and auto switching power supply device.

Further load shedding device shall be applied if automatic load shedding by frequency is not sufficient at both amount of load to be shed and shedding speed.

Power system management unit will decide the necessity of further load shedding, amount of load to be shed and detailed method of load shedding.
Power plants or generators are disconnected to make balance between generated power and load. The generators which supply electricity to auxiliary system of the power plant are also disconnected. The purposes are as follows.

- To maintain power supply to auxiliary system of power plant
- To prevent electricity lost in entire power plant in case that device for auto-prevention of frequency decrease fails to operate
- To ensure supply of electricity to very important consumers
- To replace further load shedding in case that separation of power plant is more preferable than further load shedding

Necessity to apply further load shedding method, amount of load to be shed and energized, calibration level of time, frequency and other parameters for frequency decrease limiter shall be decided based on actual operation of power system.

Article 526. Re-energizing after Load Shedding

In arranging devices and allocating load by order, outage parts should be re-energized after the recovery of frequency considering importance of load, ability to reduce amount of load by automatic load shedder by frequency, complexity and delay time of recovering power lines which are not equipped with automation equipment.
Usually, sequence of re-energizing outage parts after recovery of frequency is decided according to the reverse order of the sequence for load shedding by automatic load shedder by frequency.

Chapter 5-3-9 Auto-prevention of Frequency Increase

Article 527. Required Functions of Auto-prevention of frequency Increase

The auto-tripping protective relay shall firstly disconnect some generators of hydropower plants. Secondly, thermal power plants from hydropower plants, but the remaining load for the thermal power plants should be as close as the capacity of the thermal power plant.
For the power system where only hydropower plants exist, device to prevent frequency from increasing due to electrical faults shall be equipped to such power system.
For the power system where only thermal power plants exist, device to prevent the duration of frequency increase from exceeding the allowable value for the load of the generator unit.

Chapter 5-3-10 Auto-prevention of Voltage Decrease

Article 528. Required Functions of Auto-prevention of Voltage Decrease

Auto-prevent voltage decrease devices not only monitor voltage on power system but also check other parameters such as voltage variable rate, etc. In addition, these devices should have function to intensify forced excitation for synchronous electrical equipment and forced compensators, or to de-energize reactors.

Chapter 5-3-11 Auto-prevention of Voltage Increase

Article 529. Required Functions of Auto-prevention of Voltage Increase

Auto-prevent voltage increase devices shall operate in allowable duration of over-voltage, and these devices shall be calibrated based on the duration and oscillation of over-voltage. Firstly, these devices shall energize shunt reactors. If power plant or transformer substation have shunt reactor which is connected to the busbar directly without circuit breaker, or connection of reactor does not satisfy the requirement on decrease of voltage, these devices shall de-energize the line which cause unallowable voltage increase.

If necessary, values and direction of reactive power in power transmission lines shall be checked.

Chapter 5-3-12 Auto-prevention of Overload of Electrical Equipment

Article 530. Required Functions of Auto-prevention of Overload of Electrical Equipment

Auto-prevention overload device shall reduce load of power plant. This device sheds load and divides power system, and, finally, de-energize overloaded electrical equipment. At this time, the measures to keep stability from being broken shall be taken.

Chapter 5-3-13 Remote Telecontrol Systems

Article 531. Required Functions of Telecontrol System

Remote control system includes remote control, remote signals, telemetry and control system.

Volume of electrical equipment to be controlled remotely shall be defined based on technical standard of a power sector or amounted volume of equipment.

Regarding the above, supervisory and control items of dispatch centers are shown in the Table 531-1 for reference.

Firstly, remote control system is used for acquiring information on operation mode, conditions on main switchgear equipment and changes of status in case of electrical fault, and also used for checking the implementation of commands on energizing or de-energizing. Moreover, remote control system also facilitates suitable operation for power system and equipment.

In order to select items to be observed or controlled in a substation without permanent on-duty stuff, necessity of the items to be controlled or observed and ability to control and observe of the remote control system shall be considered.

Table 531-1 [Reference] Outline of supervisory and control items of load dispatch center system [Japanese case]

Function	Item	Remarks
Supervisory	- Status of electrical equipment (such as circuit breaker ON/OFF, generator, etc.) - Power system (national grid) - Power plant (such as hydropower plant and thermal power plant) - Reservoir water level and river flow - Meteorological phenomenon - Electrical fault - Operating condition of electrical equipment	
Control (operation)	- Manual / Automatic operation	- Generator of hydropower plant - Switchgear of transmission line and distribution line - Protective relay - Load regulator - Voltage regulator, power factor regulator - Switching of telemetering equipment - Automatic frequency controller - Alarm system of discharge from reservoir
Record	- Status of electrical equipment (such as circuit breaker, generator, etc.) - Power flow - Load dispatching - Operation of electrical equipment	Including operation record of this system
Transmission of information	- Operating condition of electrical equipment - Electrical fault - Meteorological phenomenon	
This system management	- Operation of system - Operation of auxiliary equipment of system - Record of this system trouble - Management of data transmission of system	

Table 531-2 [Reference] Supervisory Items at Substation

Equipment	Item	With permanent stuff	Remote control		Remarks
			Controlled power system	Load dispatch center	
Gas insulated equipment	Gas pressure	○	○	○	
Pressure oil supply equipment Air compressor	Oil / Air pressure	○	○	○	
Main transformer	Voltage	○	○	○	
	Current or electric power	○	○	○	Recorder can be applied as alternated
	Temperature	○	○	○	ditto
Compensator	Voltage	○	○	○	ditto
	Current or reactive power	○	○	○	ditto
	Temperature of stator wiring	○	○	○	ditto
	Temperature of bearings	○	○	○	ditto
Synchronization system	Voltage	○	○	○	ditto
	Frequency	○	○	○	ditto
	Synchronism detection	○	○	○	ditto
Bus	Zero sequence voltage or voltage at neutral point	○			Only in case that earth fault has to be observed
Power capacitor or shunt reactor	Current of reactive power	○	○	○	
Transmission line	Current or electric power	○	○	○	
Distribution line	Current	○	○	○	
DC control circuit	Voltage	○	○	○	
Station service transformer	Current	○	○	○	
Oil immersed equipment	Oil level	○	○	○	
Electrical meter	Reactive power / power factor	○	○	○	The meter is installed at the point suitable for measurement.
	Watt-hour meter	○	○	○	ditto

Remote control system shall have necessary devices for setting operation mode of power system reliably and economically. For a power system with remote control system, remote control operation as well as interruption by protective relays or automatic devices shall not require additional on-site operations.

As for large substations and power plants with many generators as well as power systems far from control center, if possible, remote control system should be equipped inside such power systems.

Quantity of remote control equipment shall satisfy the requirement on control method of each power system.
As for electrical equipment to be controlled remotely by one load dispatch center, the operation procedures by operator shall be the same among such electrical equipment.

Article 532. Information Signal Requirements

Remote signals from power systems under control and observation by some load dispatch centers shall be regularly transmitted to higher level load dispatch centers by forwarding or transmitting the signals selectively from lower level load dispatch centers. Such signals are usually transmitted with no more than one forwarding level.
In order to transmit remote signals on conditions and status of electrical equipment, on auxiliary contact of electrical equipment or contact of repeat relay shall be used.

Article 533. Required Functions of Remote Control Systems

Main parameters on electricity or operating condition are indispensable for selecting and setting optimal operation mode of entire power system as well as preventing or removing electrical faults which occurs in power system. Telemetry on salient parameters as well as necessary parameters shall be transmitted, accumulated and recorded continuously.
Telemetry to higher level load dispatch centers should be transmitted with no more than one forwarding level. As for parameters which don’t need to be checked frequently, telemetry shall be carried out periodically or by request from operator.
In order to implement telemetry, requirement on on-site data reading shall be considered. Generally, sensors used for metering on site should be placed on meter panel as long as sufficient measurement accuracy is ensured.

Article 534. Requirements for Communication Lines

Telemetry on necessary parameters for frequency and power flow auto-control system shall be carried out continuously.
Long communication and signal line for metering power flow and transmitting remote control signals to major power plant or group of power plants should be equipped with double independent remote control channels.
Remote control equipment shall have protective relays which can interrupt auto-regulation system in case that fault occurs inside the equipment or remote control channels.
Remote control equipment shall be capable of providing changeover function between remote control and on-site control in the following cases.

- Simultaneous interruption of all remote control circuits and remote signals by devices which can display the interrupted circuits clearly.
- Interruption of all remote control circuits and remote signals of each component by special cramp bank, testing box and other devices which can display the interrupted circuit clearly.

Measuring equipment such as sensors (including remote measurement sensors) fixed at the electrical measurement instruments shall be installed in accordance with the requirement on measuring electricity.

When remote control channel is formed, the following channels can be utilized.

- channels for other purpose or power lines (underground cable line, overhead line or optical cable line)
- micro wave channels along transmission lines and distribution network
- loudspeaker broadcasting channel
- communication signal channel

When remote control channels are selected by using existing channels or making new ones, the requirements on reliability shall be considered carefully.

In order to utilize remote control equipment and communication channels effectively, the following measures can be adopted.

(1) Telemetry on power flow on some parallel power lines with same voltage is applied by summing up these powers

(2) Common device is used to measure the same kind of parameters on telemetry. Consequently, at load dispatching center, one meter can be applied to measure various parameters. However, in this case, these parameters shall not be transmitted simultaneously.

(3) In order to reduce volume of signals on telemetry, analog telemeters are replaced with digital signals which indicate whether measured value exceeds its limit on the parameter.

(4) In order to secure simultaneous no-interruption of transmission of signals on telemetry and remote signals, combined remote control equipment shall be used.

Power supply source of remote control equipment are shared for devices of communication channel and remote control system.

- At the point where AC current is consumed for operation, if standby power sources are available at this point, individual standby source for remote control equipment is required.
- In case that the remote control system does not have standby power source, standby power source for remote control system is not required, in principle.
- At power station where battery is used as power source, standby power source for remote control system shall be supplied through converter.
- Electricity for remote control equipment at load dispatch station of united power system and power companies shall be supplied from power sources separated from the power system. Moreover, these power sources are commonly used for communication system and remote control system.

When electrical fault occurs at main power source and causes power outage in it, switch-over to standby power source shall be operated automatically.

All remote control equipment and remote control cubicles shall be located at the places convenient for operation, and external contacts of remote control equipment shall be arranged so that secondary circuits can be connected to these external contacts.

Chapter 5-4 Secondary Circuits

Article 535. Applicable Scope

As stipulated in Technical Regulation.

Article 536. Applied Voltage

Regarding the control cable in the secondary circuits, a copper conductor cable shall be used in the power plants, substations and industrial enterprises. In addition, requirements on mechanical durability shall meet the following items.

- Secondary cable core connected to electrical cubicles and/or equipment by screwing shall have cross section area not smaller than 1.5mm^2 (in 5A - 2.5mm^2 current circuit); for unimportant secondary circuits, wires of checking circuit and signaling circuit are allowed to have cross section area of 1mm^2).
- For secondary circuit with operating voltage of 100V and above, cable line which is connected by tin soldering shall have its cross section area not smaller than 0.5mm$^{2.}$
- For secondary circuit with operating voltage up to 60V, cable line which is connected by tin soldering shall have its diameter not smaller than 0.5mm (cross section area of 0.197 m^2). Communication devices and remote control equipment and similar circuits should be connected by screwing.

Connection of single core cable (by screwing or tin soldering) shall be only used in stationary parts of equipment. Connection of cable core to components of mobile equipment or by plug in (plug, connection boxes, etc.) as well as connection to electrical cubicles and equipment located in vibration places shall use flexible multi-core cables.

Article 537. Requirements for Cross-Section, Accuracy and Mechanical Durability

Regarding the selection of the cross-section of secondary circuit cable, the following requirements shall be satisfied:

1. Current transformers and operating circuit shall have accuracy:
   - As mentioned in Chapter 2-6 - for meters.
   - For power measuring converter to in order to have input data to computer - in accordance to Chapter 2-6, as for technical meters.
   - Accuracy class shall be not lower than 3 - for meters at panel-board and current and power measuring converters used in measuring circuits.
   - Usually, error limitation is 10% - for protecting circuit (refer to Chapter 5-2).
2. For voltage circuit, voltage loss from voltage transformer (in case that all protective relays and meters are in operation, voltage transformer is at maximum load) to:
   - Electricity meter and measuring converting devices to input data in computer - shall not exceed 0.5%.
   - Electricity meter of the line connecting power systems - shall not exceed 0.25%.
   - Technical data collectors - shall not exceed 1.5%.
   - Meter in panel-board and power sensor for measuring circuits - shall not exceed 1.5%.
   - Protection cubicle - shall not exceed 3% (refer to Chapter 5-2).

   In case that coordinating to supply electricity to the above-mentioned components by same cable core, its cross section area shall be selected based on minimum voltage loss value.
3. For switching current circuits, voltage loss from supply source:
   - To control cubicle or unreinforced magnetic control winding - shall not exceed 10% at maximal load current.

- To reinforced magnetic control winding - shall not exceed 20% reinforced current.

4. For voltage circuits of excitation auto-controlling equipments, voltage loss from voltage transformer to measuring components shall not exceed 1%.

Article 538. Sharing Cable Cores

It is allowed to share multi-core cable for controlling, measuring, protecting and signaling circuits of AC and DC current, as well as for power circuits feeding the small consumers (e.g. motors of valves).
In order to avoid increasing reactance of cable core, it is necessary to divide secondary circuit of current transformer and voltage transformer so that in any mode, total current of such circuits in each cable line is equal to zero.
It is allowed share cable for various circuits, except standby ones.
Secondary circuits for control, protection systems voltage of 220kV or more must be physically separate.

Article 539. Cable Installation

Usually, secondary cable is connected to concentrated clamp bank, however, two terminals of secondary conductors should not be connected to one screw.
It is allowed to directly connect cable to outlet of measuring transformer. Cable connected to clamps shall be corresponding to cross section area of cable core.

It is allowed extending secondary cable if cable line is longer than length of cable on cable drum of manufacturer. Connection of metal armored cables is made by closed connection boxes or exclusive clamp bank.
Non-metal sheathed cables shall be connected by mediate clamp bank or exclusive connection boxes.
It is prohibited to connect secondary circuit by twisting without any welding.

At mechanical durability condition, layout of electric current circuit inside cubicle, panel-board, control desk, control box, etc, as well as inside driving cabinet of circuit breaker, disconnector and other equipments, shall use conductor or cable with cross section area not smaller than:

- 1.5mm^2 for single core in case of connection by screw.
- 0.5mm^2 for single core in case of connection by welding.
- 0.35mm^2 for multi-core in case of connection either by welding or screwing if the core has terminal. If there is proof for operation safety, it is allowed to make connection by welding flexible cable's core with cross section area smaller than 0.35mm^2, but not smaller than 0.2mm^2.
- 0.19mm^2 for cable core in case of connection by welding in electricity circuit with voltage not higher than 60V (panel-board, dispatch control panel, remote control equipments, etc.).

Connection of single-core cable to fixed components of equipments shall be made by screwing or welding. Connection of cable core to mobile components or detachable components of equipments (jack or connectors, etc) should be made by flexible cable.
When connecting cable by welding, it is necessary to ensure no mechanical force at the connection joint.
In case cable shall go through entrance, it is necessary to use flexible cable with cross section area not smaller than 0.5mm^2. It is allowed to use single-core cable with cross section area not smaller than 1.5mm^2, provided that at the connecting point cable is twisted.

Cross section area of conductor on equipment panel and fabricated elements is identified at the requirements on timeless short circuit protection for securing long-term load permissible currents as specified in Chapter 2-4. In addition, for circuit which comes from current transformer, it is necessary to satisfy heat resistance requirement. Conductor and cable used shall be insulated with flame-resistant material.

Equipment in the same cubicle, panel-board can be connected directly by terminals or intermediate clamps.
Terminals of circuits which can be connected to testing devices or tools, if necessary, should be arranged on clamp bank or in testing boxes.

It is necessary to equip mediate clamps in the following cases:

- Connecting conductor to cable.
- Gathering circuits with the same-name (gathering ends of tripping circuits, ends of voltage circuits, etc.).
- It is necessary to connect to mobile or portable testing, measuring devices which do not have testing boxes or similar components.

Terminal clamps of associated circuit or different devices shall be separated to the particular clamp bank.
In clamp bank, terminals of the line are not allowed to be closely placed to each other because if they touch each other it will cause fault or wrong operation.
When arranging various protective relays or various devices of the same circuit in cubicle, power supply from pole of switching circuit through concentrated clamp series as well as the allocation of circuits to different cubicles shall be operate independently from each type of protective relay or equipment. If breaking circuits of individual protective relay does not have connector, connection of these circuits to outlet protective relay or to breaking circuit of circuit breaker shall be through particular terminal clamps. Then, connection of these above-mentioned circuits inside cubicle should be carried out without depending on protective relay type.

In operation, in order to check and test protection circuit and automation, it is necessary to equip testing boxes or clamps of measuring wire terminals, ensuring not needing separation of conductor or cable from switching current source, voltage transformer and current transformer with possibility to bypass prior current.
Periodical outage of protective relays and automation equipments according to working regime of power network, conditions on selectivity or other reasons shall be performed by operators using exclusive means in order to disconnect them from operation regime.

Article 540. Cable Connection Method

As stipulated in Technical Regulation.

Article 541. Circuit Insulation

Regarding the insulation of components in secondary circuits, check of insulation of DC and AC operating circuit shall be performed on each independent source (including isolated transformer) without grounding.

Devices for checking insulation shall secure to send signals in case that insulation value is lower than specified values. For DC circuit, it is necessary to measure insulating resistance of poles. No need to check insulation on operating circuit without branching circuits.

Article 542. Circuit Protective Measures

Feeding source for secondary circuit of each connection shall pass through individual fuse or automatic circuit-breaker (automatic circuit-breaker is given priority).

Feeding source for protecting relay circuit and circuit breaker's controlling circuit of each connection shall pass through individual fuse or automatic circuit-breaker, without contacting other circuits (signaling circuit, electronic interlocking, etc). It is allowed to share feeding circuit for controlling circuit breaker and signal lights indicating circuit breaker's position.

Circuit with voltage of 220kV or more, generator (or generator block) with capacity of 60MW or more shall be fed with individual switching current (passing through individual fuse or automatic circuit-breaker) for main and standby protection circuits.

In case of series connection of automatic circuit-breaker and fuse, the fuse shall be in front of automatic circuit-breaker from power supply source side.

Article 543. Signal Systems in the event of an Abnormal Operation or Fault

As stipulated in Technical Regulation.

Article 544. Grounding in Secondary Circuits of Current Transformers

Grounding in secondary circuit of current transformer should be carried out at the point nearby current transformer in clamp bank or on poles of current transformer.

For protection system, in case that some current transformers are connected together, grounding shall be made at only one point. In this case, it is allowed grounding through disruptive protective relay with voltage not over 1kV and 100ohm-resistor to release electrostatic discharge.

Secondary winding of isolated mediate current transformer is allowed not to be grounded.

Article 545. Grounding in Secondary Circuits of Voltage Transformers

Secondary coil of voltage transformer shall be grounded at neutral point or at one of terminals of winding which is required to be grounded.

Secondary winding of voltage transformer shall be grounded nearby voltage transformer, in clamp bank or on the pole of voltage transformer.

It is allowed to share grounding of secondary circuits of some voltage transformers in one distribution equipment to common grounding bars. In case that these grounding bars are connected with other distribution equipments and are located in various halls (relay cubicles of distribution equipments with various voltage levels), generally, such bars are not required to be connected together.

For voltage transformers which are AC power supply sources for operation, in case that there are no requirements on grounding one of poles of operating circuit, grounding for protection of secondary winding of voltage transformer shall be connected through disruptive protective relay.

PART 6 EARTHING

Chapter 6-1 Purpose of earthing

Article 546. Applicable Scope

The regulation in this part stipulates the requirements on grounding system of AC power grid and electrical equipment. Grounding system of DC power grid and electrical equipment shall be designed on a case-by-case basis.

Article 547. Need for Earthing Systems

The requirements on performance of grounding system are as follows.
1.Agrounding conductor enables earth fault current to pass through it without any trouble about its limit on temperature rise and mechanical strength.
2.Agrounding conductor can bear mechanical force and possess a resistance to corrosion.
3.Agrounding system has to restrain temperature rise, voltage potential difference and fault current passing through the grounding system to protect electrical equipment from damage.
4.Agrounding system has to restrain step voltage, touch voltage and transition voltage potential within their permissible values.
The performance of a grounding system about the above-mentioned issues is dependent on the grounding method of the neutral point and amplitude of earth fault current and its duration. And a grounding system shall ensure safety for persons including the public.
The specification of a grounding system such as size of grounding conductor, arrangement of grounding electrodes and etc. is decided based on the conditions below.
1. Amplitude of earth fault current
2. Duration of earth fault
3. Soil characteristic

Article 548. Common Earthing Systems

If high-voltage grounding system is located adjacent to low-voltage grounding system, potential of the low-voltage grounding system increase according to the potential rise of the high-voltage grounding system in case of earth fault in the high-voltage grounding system. The measures to avoid such potential rise of the low-voltage grounding system are as follows.

- All high-voltage grounding systems and all low-voltage grounding system are connected mutually.

or

- High-voltage grounding system is electrically-isolated from low-voltage grounding system completely.

In any case, touch voltage, step voltage, transition voltage potential and impressed voltage on electrical equipment in low-voltage grounding system shall be restrained within permissible values respectively.
[Low-voltage electrical equipment located in a high-voltage substation]
If low-voltage grounding system is surrounded by only high-voltage grounding system, both of the grounding systems shall be connected electrically.

[Low-voltage electrical equipment connected to a high-voltage substation]

If low-voltage electrical equipment installed in the high-voltage substation supplies electricity to outside the high-voltage substation, the connection of both of the grounding systems shall obey the requirements shown in the following table.

Table 548　Minimum requirements for interconnection of low-voltage and high-voltage grounding systems

<table>
<tr><th colspan="2">Type of low-voltage grounding system</th><th>Requirement</th></tr>
<tr><td colspan="2" rowspan="2">TT</td><td>For $t_F \leq 5s \quad EPR \leq 1{,}200V$</td></tr>
<tr><td>For $t_F > 5s \quad EPR \leq 250V$</td></tr>
<tr><td colspan="2">TN</td><td>$EPR \leq X \times U_T$</td></tr>
<tr><td rowspan="2">IT</td><td>With protective conductor</td><td>$EPR \leq X \times U_T$</td></tr>
<tr><td>Without protective conductor</td><td>Not applicable</td></tr>
</table>

t_F: duration from outbreak of earth fault to its interruption

U_T: permissible touch voltage shown in Figure 548

EPR: Electrical Potential Rise

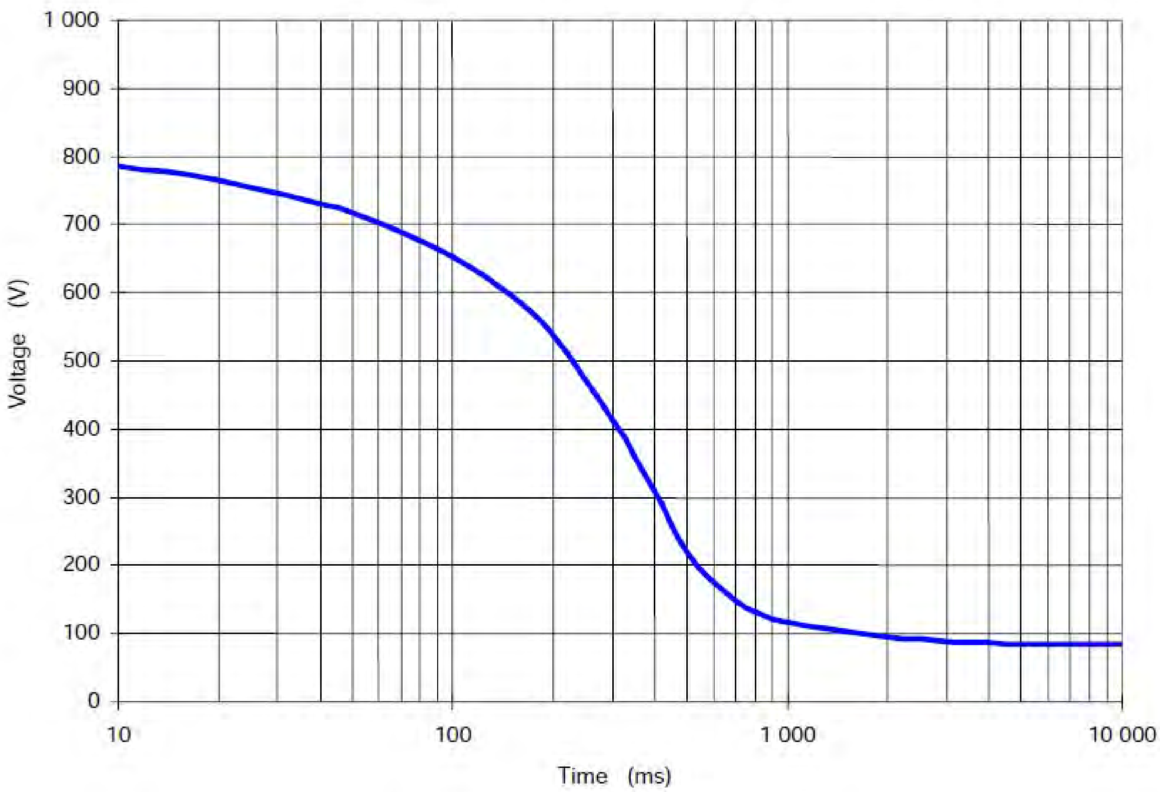


Figure 548　Permissible touch voltage U_T

X is usually selected as 2. If neutral conductor of low-voltage grounding system is grounded at only high-voltage grounding system, X is selected as 1. If neutral conductor of low-voltage grounding system is grounded at several points in addition to high-voltage grounding system, X is selected as from 2 to 5 according to soil characteristic such as soil resistivity.

If low-voltage grounding system is TT method, voltage applied to low-voltage electrical equipment shall be considered mainly. If low-voltage grounding system is TN method, touch voltage and transition voltage shall be considered mainly. If low-voltage grounding system is IT method, touch voltage and voltage applied to low-voltage electrical equipment in case of short-circuit between high-voltage electrical equipment and low-voltage electrical equipment.

Chapter 6-2 Components to be Earthed in Power Networks

Article 549. Earthing Method of Neutral of Overhead Lines with voltage up to 1kV

In low-voltage power system (up to 1kV) connected to high-voltage power system, touch voltage shall be restrained within the permissible value which is stipulated at Article 567. In addition to this, earth potential rise on low-voltage grounding system caused by earth potential rise on high-voltage grounding system in case of earth fault on the high-voltage grounding system shall be restrained within permissible potential rise of low-voltage electrical equipment.

The above-mentioned permissible earth potential rise on low-voltage grounding system is as follows.

- Impressed voltage: In case that fault time is not more than 5 seconds, EPR=<1,200V. In case that fault time is more than 5 seconds, EPR=<250V.
- Touch voltage: EPR=< $X \times U_T$

  X can be selected from 1 to 5 according to neutral grounding method and soil characteristic such as soil structure as follows.

  - Neutral conductor or protective neutral conductor is grounded at only high-voltage grounding system : X=1
  - Other than the above : X=2
  - Neutral conductor or protective neutral conductor is grounded additionally : X is from 2 to 5.

  U_T can be obtained from Figure 548.

Figure 549 shows the case that neutral conductor is grounded additionally. In such case, X can be selected as larger value.

In this regard, if grounding resistance of low-voltage grounding system is difficult to obey the above-mentioned grounding resistance by grounding the neural conductor independently due to soil characteristic, the neutral conductor shall be grounded repeatedly. The grounding conductor shall be put into an electric conduit which has weather resistance and self extinguishment performance from 75cm underground to 2m above ground from the viewpoint of avoidance of damage and public safety.

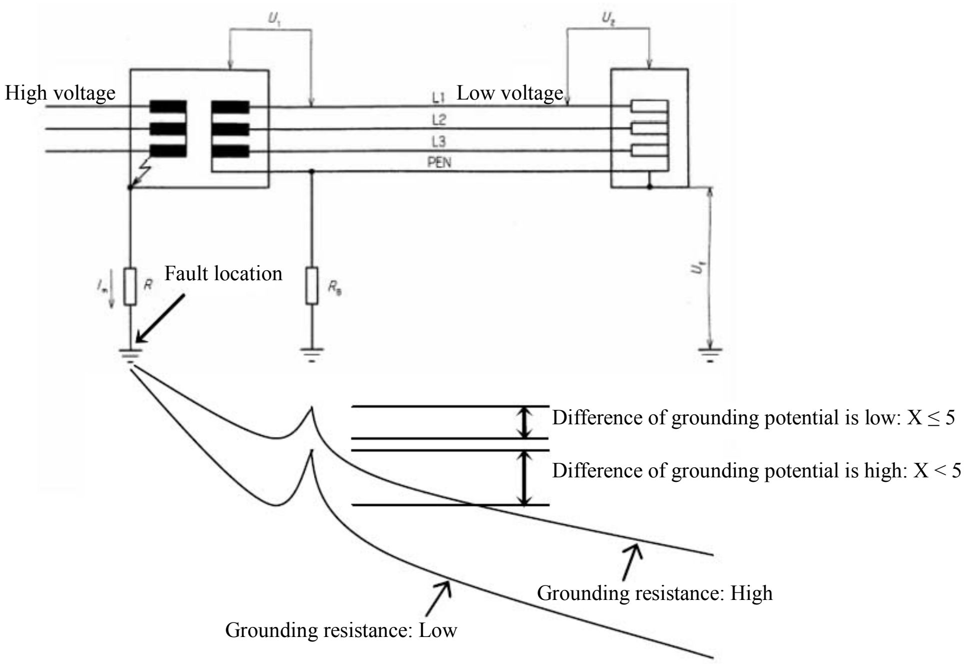


Figure 549 Grounding method of neutral conductor

Article 550. Earthing of Power Cable Lines

Cross-sectional areas of grounding conductors for power cable lines shall comply with the requirements in Chapter 6-8 in Technical RegulationVol.1 and Guideline. Also the cross-sectional area shall not be less than $6mm^2$.

Metal parts and steel bars of power cable lines and other cable structures shall be connected each other and connected to the covers of their connection boxes by flexible copper conductors.

Metallic enclosures and covers of the connection boxes or lightning arresters on poles shall be connected to grounding system of the lightning arresters. Metallic covers of cables are prohibited to be used as grounding conductors.

Article 551. Earthing for Oil-Filled Cable Lines

As stipulated in Technical Regulation.

Article 552. Earthing Neutral Conductors and Poles

Neutral conductors of overhead power lines with voltage up to 1kV shall be grounded at intervals from 200m to 250m.

Cross-sectional area of grounding conductors shall comply with the requirements in Chapter 6-8 in Technical Regulation and Guideline, moreover, diameter of the grounding conductor shall not be less than 6mm.

Ground resistance of ground conductors shall comply with the requirements in Technical Regulation and Guideline, furthermore, the ground resistance of the grounding conductor shall not be more than 50 ohm.

Article 553. Additional Earthing Requirements

Ground resistance of grounding conductor of overhead lines with voltage up to 1kV shall comply with the requirements in Technical RegulationVol.1 and its Guideline, moreover, the ground resistance shall not be more than 30 ohm.

The distance between each grounded point shall not be more than the following values.

- 200m: for the area where thunderstorm occurs not more than 40 hours in a year.
- 100m: for the area where thunderstorm occurs more than 40 hours in a year.

The distance from grounded points of the end poles to grounded points of overhead power lines shall not be more than the following values.

- 100m: for the area where thunderstorm occurs from 10 to 40 hours in a year
- 50m: for the area where thunderstorm occurs more than 40 hours in a year

The place to be grounded

- The building where many people may gather such as schools, theaters, hospitals, etc.
- The places with high economic values such as animal breeding facilities, warehouses, workshop, etc.

Article 554. Earthing of Overhead Power Lines with Voltage Exceeding 1kV

1. Ground resistance of pole

(1) The ground resistance of pole with lightning conductors or lightning arresters, etc. shall not be more than the value shown in the following table.

(2) The ground resistance of pole of overhead power line with voltage from 6kV to 22kV in populated area and overhead power line with 35kV shall not be more than the values shown in the following table.

Table 554-1 Maximum ground resistance of pole

Resistivity of soil ρ (Ωm)	Maximum ground resistance (Ω)
Up to 100	10
Exceeding 100 to 500	15
Exceeding 500 to 1000	20
Exceeding 1000 to 5000	30
Exceeding 5000	$6 \times 10^{-3} \rho$

(3) The ground resistance of pole of overhead power line with voltage from 6kV to 22kV in non-populated area shall not be more than the values shown in the following table.

Table 554-2 Maximum ground resistance of pole

Resistivity of soil ρ (Ωm)	Maximum ground resistance (Ω)
Up to 100	10
Exceeding 100	0.3ρ

(4) The ground resistance of pole with main transformers, potential transformers, disconnectors, fuses or other devices shall comply with the following requirements.

- The ground resistance of pole of overhead power line with voltage from 6kV to 35kV accompanied with large earth fault current and overhead power line with voltage from 110kV to 500kV shall not be more than the values shown in Table 554-1.

- The ground resistance of pole of overhead power line with voltage from 6kV to 35kV accompanied with low earth fault current shall comply with the requirement in article 552 and 568 in Technical RegulationVol.1 and its Guideline.

2. Utilization of reinforced concrete foundation

For overhead power line across the area where resistivity of soil is not more than $500\,\Omega m$, the reinforcing steel buried in reinforced concrete foundation are permitted to be utilized as neutral ground or to be combined with artificial grounding equipment. However, in case of the area where the resistivity of soil exceeds $500\,\Omega m$, the reinforcing steels in the reinforced concrete foundation are prohibited to be utilized as natural grounding conductor, and the ground resistance shall not be more than the value shown in Table 554-1 by installing artificial grounding equipment.

If reinforced concrete foundation is utilized as natural grounding conductor (except the requirement in article 290), it shall comply with the following requirements.

- The foundation shall not be covered with non-conductive paint, etc.
- Metallic connectors shall be applied to connect anchor bolts to foundation frames. The electrical conductivity of reinforced concrete foundations shall be measured in two months after the foundations are constructed.

3. Utilization of reinforced pole

The reinforcing steels are permitted to be utilized as grounding conductors, which are connected to each other or grounding equipment physically and electrically.

4. Grounding for pedestal and lightning conductor

The pedestal for fixing insulators to arm bars of pole and lightning conductor shall be connected to grounding conductors or reinforced concrete foundations.

5. Grounding conductor for overhead power line with voltage exceeding 1kV

Cross-sectional area of grounding conductors on pole of overhead power line with voltage exceeding 1kV shall not be less than $35mm^2$. Single-core conductors with diameter not less than 10mm and galvanized single-core steel conductor with diameter not less than 6mm are also permitted to be used. Grounding conductor on reinforced concrete and metal pole shall be connected by welding, bolting or pressure bonding.

Article 555. Earthing in Crossing Spans

The ground resistances of metallic pipelines, bridges, nets, fences, aerial transport cable lines and wires hanging traffic signals in the span where overhead power lines cross shall not be more than 10 ohm.

Article 556. Earthing of Metal Objects near Overhead Power Lines

1. Scope of ground

The scope of ground for metal objects below overhead power line shall comply with the following requirements.

- 220kV: The scope is the width space within 25m along the overhead power line measured horizontally from the outer edge of conductor.
- 500kV: The scope is the width space within 60m along the overhead power line measured horizontally from the outer edge of conductor.

2. Target structure for grounding

- Houses and structures with metallic roofs insulated to the ground. (except metal structures beneath the roofs)
- Houses and structures with metallic roof (including all metal parts such as walls, girders, beams, rafters and doors insulated to the ground)
- Metallic structures insulated to ground and installed outside houses and structures (e.g. iron frames, iron pipes TV antennas, clotheslines)

3. Requirement for grounding system below overhead power line

(1) Grounding rod

Grounding rod shall be round steel with diameter not less than 16mm (equivalent square steels) or angle steel with the size not smaller than 40mm*40mm*4mm. Grounding rod shall have the length not less than 1m and be piled so that the distance from the ground to the head of them is from 0.1m to 0.15m. Also, grounding rods are prohibited to be painted on the surface, and connection parts between them and grounding conductors shall be made of coppers or be galvanized at corrosive areas.

(2) Grounding conductor

Grounding conductor shall be used with flexible copper conductors with cross-sectional area not less than 16mm2, steel rods with diameter not less than 6mm or steel plates not smaller than24mm*4mm. Galvanized or stainless steel conductors are permitted to be used as grounding conductors. Also, grounding conductor shall be connected to grounding rods by welding, bolting or pressure bonding.

Chapter 6-3 Components to be Earthed in Electrical Equipment

Article 557. Components to be Earthed

(1) Metal base or enclosure of electrical equipment connected to the power gird shall be grounded. And, even if power transformer or instrument transformer doesn't have enclosure, its iron core shall be grounded. However, when such electrical equipment is surrounded by fence to prevent person from contacting such electrical equipment or is installed on an insulated base, the above-mentioned requirement cannot be applicable.

Usually, live part of electrical equipment is insulated from its metal base and metal enclosure. However, since short-circuit between the live part and the metal base or the metal possibly happens, the metal base and the metal enclosure shall be grounded in order to avoid danger caused by potential rise on such part due to leakage current from the live part to the metal base or the metal enclosure.

Because large capacitor and neutral grounding resistor cannot be grounded, such electrical equipments shall be surrounded by protective fence and installed on insulated base instead of grounding.

(2) Neutral point of the power gird can be grounded in order to ensure necessary performance of protective relays and restrain potential rise caused by earth fault. As for power grid with voltage less than 300V or equal, if its neutral point is difficult to be grounded, any one phase conductor can be grounded instead of grounding neutral point.

Grounding method of the neutral point can be selected among direct grounding and grounding through reactor or resistor from the viewpoint of ensuring detection of earth fault and disconnection of fault part. On the other hand, grounding through an instrument transformer which has large impedance is not included in the grounding method of neutral point.

(3) Transformer which connects high-voltage power gird or middle-voltage power grid to low-voltage power grid shall be grounded in the following way.

- Grounding at the neutral point of the low-voltage side
- Grounding at any one phase conductor (if the neutral point is difficult to be grounded in the transformer with low-voltage side of less than 300V)
- Grounding at metal plate between high-voltage side and low-voltage side (if low-voltage side grid is isolated)

In transformer which connects low-voltage grid to high-voltage grid, the potential in the low-voltage grid may increase excessively in case that short-circuit between low-voltage grid and high-voltage gird happens. To reduce the potential rise in the low-voltage gird in such case, low-voltage grid shall be grounded.

Generally, grounding of the low-voltage grid should be done at the neutral point. However, if the neutral point is difficult to be grounded due to delta connection or single-phase transformer, grounding of the low-voltage grid can be done at any one phase conductor. The reason is that, in such case, current unbalance in case of earth fault does not need to be considered.

On the other hand, grounding at any one phase conductor of transformer with low-voltage side of more than 300V causes considerable current unbalance in case of earth fault. Therefore, in such transformer, the neutral point of low-voltage grid shall be grounded. If low-voltage gird have to be connected in delta connection, such transformer shall have metal plate between high-voltage side and low-voltage side to isolate these two grids.

(4) The secondary circuit of high-voltage or middle-voltage instrument transformer shall be grounded. This purpose is that potential rise on the secondary circuit has to be restrained within permissible value in case of short-circuit between the primary circuit and the secondary circuit.

(5) If performance of grounding or protective disconnection according to the regulation is difficult to be implemented, electrical equipment with insulation platform is allowed to be used.

The ungrounded parts of the insulation platform must not contact its grounded parts. Additionally, the ungrounded parts must not contact grounded parts of other equipment or structures of other buildings.

(6) Surrounding fence of electrical equipment must not be grounded. However, if an overhead line of 110kV or more is connected to the equipment, the surrounding fence must be grounded by grounding clamps whose length is from 2m to 3m and these grounding clamps must be buried deeply at places adjacent to piers of the fence along its perimeter with the interval of 20 - 50m.

In order to make surrounding fence electrically isolated from grounding device, the distance between the fence and grounding device arranged along the fence shall not be less than 2 m. Grounding electrodes, metal sheath cables, metal pipes extending out of the area surrounded by the fence shall be arranged at the middle point of the piers of the fence at the depth of 0.5m or more.

Article 558. Protection of Transformers with primary coil voltage above 1kV and secondary coils to 1kV

Refer to item (3) of Guideline 557.

Chapter 6-4 Components Exempt from Earthing

Article 559. Components Exempt from Earthing

In case that earth fault doesn't cause danger to people, grounding work can be omitted. Such cases are as follows.

a) Electrical equipment with voltage of less than 380V or equal is installed on an insulated base.
- An insulated base is dry wooden floor, floor covered with linoleum, stone, etc. Concrete floor is not included.
- However, in wet condition, this stipulation cannot be applied.

b) A metal enclosure of machine is connected to a grounded metal base electrically, and accordingly, its ground resistance is less than required value.

c) Metal enclosures of cable pipes or cable troughs are connected electrically to each other, and accordingly, its ground resistance is less than required value.

d) A rail of an electrical railway is used for a part of electrical circuit.
- In order to prevent leakage current from causing electrical corrosion to metal structures around the rail, the rail shall not be grounded.
- The ground resistance of the rail shall be increased by insert gravel or wooden plate between the rail and ground.

e) Portable electrical tool with a double insulation

f) Electrical equipment with voltage to ground of not more than 42V is installed inside a switchboard room or a cubicle under dry condition.
- In such situation, ground resistance can be considered to be high sufficiently.

Chapter 6-5 Protection against Earth Faults

Article 560. Protective Breaking Time on Effective Earthed Neutral

The power grid shall be equipped with a protective relay, which interrupts the fault part in case of earth fault on the power grid in order to avoid danger caused by the earth fault and interruption in electric power supply.

a) The earth fault protective relay shall be equipped on the power line used to supply power to the machine with voltage of more than 60V, which has a metal enclosure. The earth fault protective relay shall interrupt fault part automatically in case of earth fault. However, this requirement is not applied to lighting circuit and control circuit.

b) When power line is connected to low-voltage side of an insulation transformer, of which voltage is not more than 300V, and this power line is not grounded, it is not necessarily equipped with the earth fault protective relay.

c) When power line with voltage of more than 300V is connected to middle-voltage or high-voltage power line via transformer, the earth protective relay shall be equipped on this power line. However, this requirement is not applied to power plants or substations.

d) Middle-voltage or high-voltage power line shall be equipped with the earth fault protective relay according to the following table.

Table 560 Earth fault protective relay to be equipped on middle-voltage or high-voltage power line

Location	Power line to be interrupted	Remarks
Transmission end of power plant or substation	Outgoing power line from power plant or substation	
Receiving end of substation	Load side of the receiving end	
Distribution transformer	Load side of the distribution transformer	When earth fault protective relay is equipped on the power source side of the distribution transformer, this requirement is not applied.

e) When middle-voltage or low-voltage power line supply power to the equipment used for public security such as traffic signal, emergency lighting, etc., this power line is not necessarily equipped with the earth fault protective relay under the condition that alarm signal is sent to dispatching control center in case of earth fault.

The breaking time is summation of the two durations below.
- Operation time of the earth fault protective relay: From detection of fault to transmitting signal for interruption
- Operation time of circuit breaker: from receiving the signal to finishing interruption

If the following requirements on protection against earth fault are satisfied, isolated earthed points are allowed to be used for electrical power line with voltage up to 1kV.
a. Power line shall be equipped with protective devices in combination with insulation tester of the power line. Circuit breaker or fuse can be used for protection.
b. It is possible to detect earth fault quickly and extinguish it timely. Automatic circuit breaker which interrupts the fault part shall be equipped.

Article 561. Detection of Earth Faults in Transformers with Isolated Neutral

Power line with isolated neutral point shall be equipped with earth fault protective relay in accordance with Article 564.
Main protective relay shall be a ground directional relay in order to enable selective trip for earth fault. Since operating sensitivity of the ground directional relay is maybe insufficient for earth fault with large ground resistance at the fault point, ground overvoltage relay shall be equipped on the power line as a back-up relay.
For isolated neutral electrical equipment, the setting value of one-phase ground protective relay shall be determined according to calculated earth-fault current.
At the determination of setting value of the protective relay or fuse, the calculated earth-fault current shall not be less than 1.5 times of the setting value of protection relay or 3 times of the rated current of fuse wire.

Article 562. Detection of Earth Faults in Transformers with Earthed Neutral

Power line with effective grounded neutral shall be equipped with earth fault protective relay in accordance with Article 564.

Main protective relay shall be a ground directional relay in order to enable selective trip for earth fault. Since operating sensitivity of the ground directional relay is maybe insufficient for earth fault with large ground resistance at the fault point, ground over-current relay shall be equipped on the power line as a back-up relay

Article 563. Special Protection

a) Regarding important load which is considered not to be interrupted in case of earth fault, the power line with isolated neutral point connected to an insulation transformer should supply electric power to such load. In such power supply method, the interruption of load in case of earth fault is not necessary in accordance with the item b) of Article 564. However, in such power supply method, the alarm signal in case of earth fault shall be transmitted to dispatching control center.
b) In low-voltage power line with directly grounded neutral point, earth fault current shall be interrupted quickly in order to avoid adverse affect on communication lines caused by the earth fault current.
c) If ground resistance of a portable electric tool does not satisfy the required value, such portable electric tool shall be used on an insulated base or double insulation shall be applied to such electric tool.

Article 564. Breaking Time in the event of Earth Faults

In grounding system, step voltage, touch voltage and transition voltage shall be restrained under the permissible values based on duration of interruption of earth fault. In this case, this duration is summation of the operating time of main protective relay and operating time of circuit breaker.
On the other hand, regarding the voltage applied to electrical equipment in case of earth fault, the duration of interruption of the earth fault is summation of operating time of back-up protective relay and operating time of circuit breaker.
Regarding the earth fault to be considered in the above cases, refer to Article 574.

Chapter 6-6 Earth Resistance Requirements of Earthing System

Article 565. Earth Resistivity Measurement

Soil characteristic shall be investigated through geological survey.
Because measured soil resistivity varies according to time of measurement, measurement of soil resistivity shall be done at several times and at several positions in a substation
Generally speaking, soil resistivity increase when weight of moisture content .in the soil exceeds 22% of weight of the soil. Therefore, if moisture content in the soil varied excessively in a substation, grounding conductor shall be buried more deeply to avoid the affect of variation of the moisture content.
If grounding electrodes need to be buried deeply to obtain required grounding resistance, soil resistivity at several points in vertical direction shall be measured. This measurement of soil resistivity is carried out in the following way. The distance between measurement points is about from 0.2m to 0.5m.

As mentioned above, soil resistivity varies according to the moisture content in the soil and the temperature of the soil. In this regard, soil resistivity can be considered to vary all through the year. Therefore, the soil resistivity for design of grounding system should be the highest among the measured values all through the year.

Article 566. Assurance of Security

Voltage of grounding equipment shall not be higher than 10kV in case that earth-fault current flows through the grounding equipment. If power transmission from grounding equipment to outside of building and fences surrounding the electrical equipment doesn't occur, voltage of grounding equipment is allowed to be higher than 10kV. If the voltage of grounding equipment is higher than 5kV, measures to protect insulation of communication cable lines and remote controlling system from electrical equipment shall be arranged. Additionally, the measures on prevention of transmitting dangerous voltage to outside of boundary of electrical equipment shall be also available.

When a low-voltage grounding system is adjacent to a high-voltage grounding system, potential of the low-voltage grounding system increases excessively due to potential rise of the high-voltage grounding system in case of earth fault in it. In such case, the voltage applied to the low-voltage electrical equipment shall not be more than permissible applied voltage of the low-voltage electrical equipment.

(1) In case that low-voltage grounding system is surrounded by high-voltage grounding system

The low-voltage grounding system shall be connected to the high-voltage grounding system completely.

(2) In case that low-voltage electrical equipment adjacent to high-voltage grounding system supply electricity outside the high-voltage grounding system (for example, low-voltage distribution equipment installed in high-voltage substation)

In order to check whether the low-voltage grounding system and the high-voltage grounding system can be connected to each other, the voltage applied to the low-voltage electrical equipment shall be considered based on the permissible values stipulated in Article 552. According to grounding method of the low-voltage electrical equipment, items shown below shall be considered.

Table 566 Items to be considered in each case

Type of grounding system	Items to be considered
TN method	- Touch voltage - Transition voltage
TT method	- Voltage applied to low-voltage electrical equipment
IT method	- Touch voltage - Voltage applied to low-voltage electrical equipment in case of short-circuit between low-voltage and high-voltage

- In case that low-voltage grounding system is TT method

In TT method, touch voltage is not necessary considered, because grounding of low-voltage electrical equipment is separated from high-voltage electrical equipment and accordingly potential rise of high-voltage electrical equipment in case of earth fault is not applied. On the other hand, the voltage applied to the low-voltage electrical equipment shall satisfy the permissible value in Table 552.

When the voltage applied to the low-voltage electrical equipment during interrupting time of earth fault satisfy the requirements for this low-voltage electrical equipment regarding the applied voltage, the neutral conductor of low-voltage electrical equipment can be connected to the high-voltage grounding system. (See Figure 570-1)

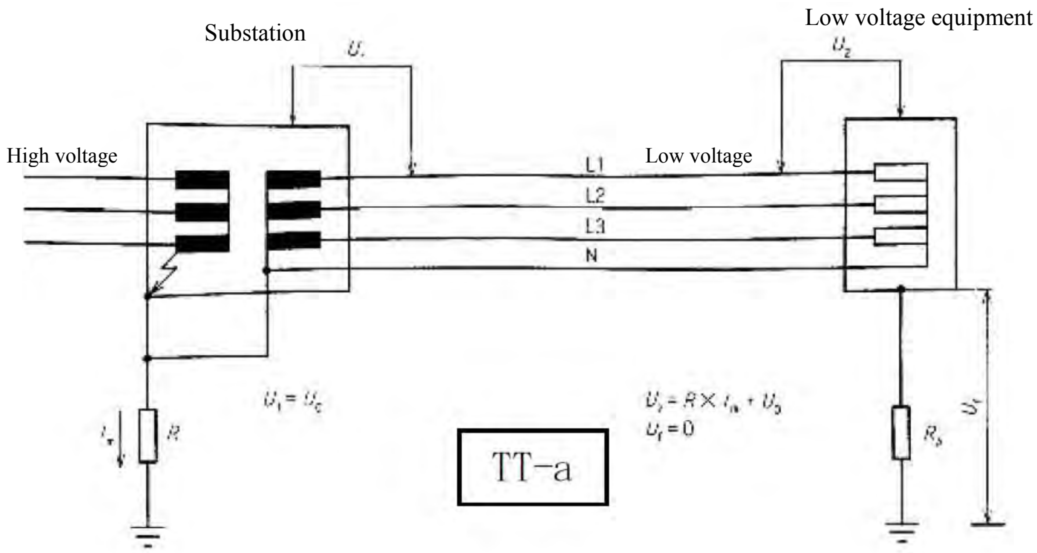


Figure 566-1 Grounding method of neutral conductor of low-voltage electrical equipment

However, when the above-mentioned condition is not satisfied, the neural wire shall be grounded through grounding electrode isolated from high-voltage grounding system. (See Figure 570-2)

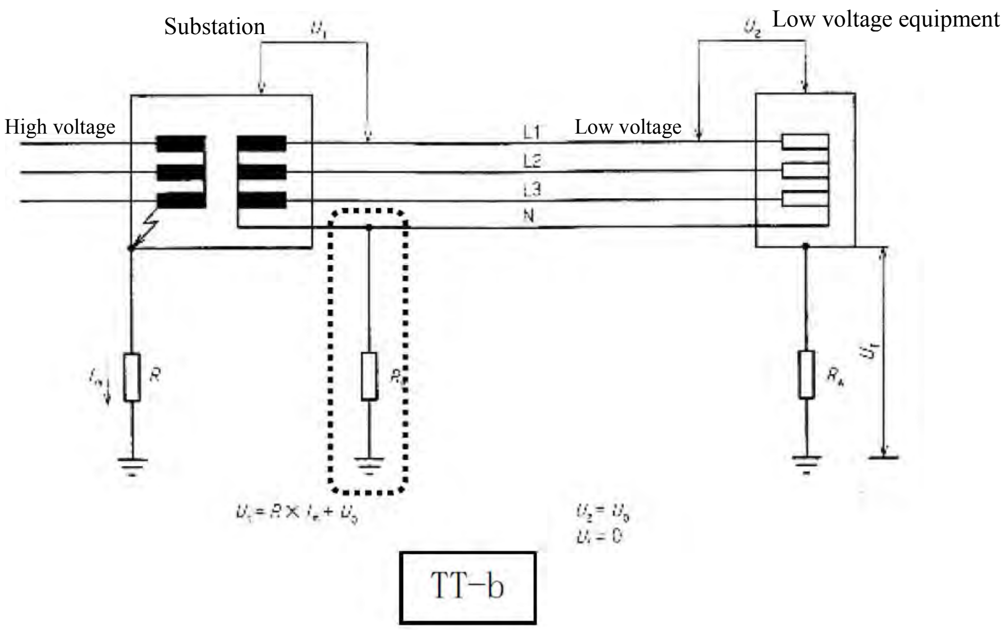


Figure 566-2 Grounding method of neutral conductor of low-voltage electrical equipment

- In case that low-voltage grounding system is TN method

Touch voltage shall satisfy permissible value stipulated in Table 552. Usually, the value, X, is selected as 2. When the neutral conductor of the low-voltage electrical equipment is grounded at only high-voltage grounding system, X is selected as 1. When the neutral conductor of the low-voltage electrical equipment is grounded at several points in addition to the high-voltage grounding system, X can be selected as from 2 to 5, which is dependent on the soil condition in the substation. UT shall be decided based on Figure. The figure below indicates the case that the neutral conductor is grounded at only high-voltage grounding system. In this case, X is selected as 1.
In addition to the above requirement, when the transition voltage from the high-voltage electrical equipment, which is applied to the enclosure of low-voltage electrical equipment, is interrupted within the time shown in Figure 572-3, the neutral conductor can be connected to the high-voltage grounding system.

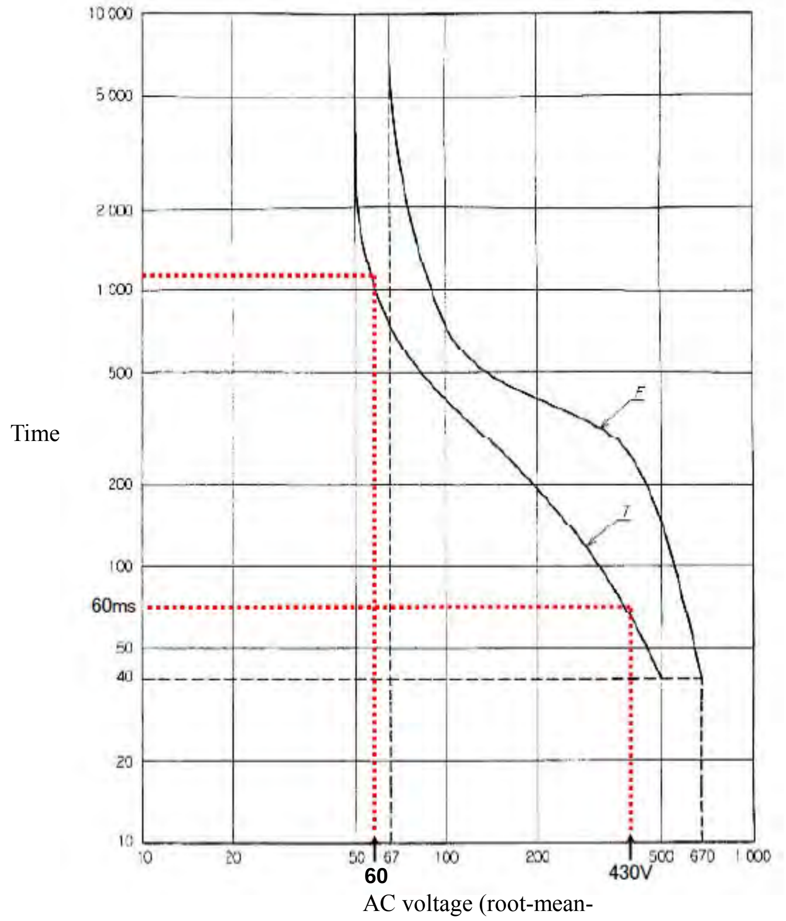


Figure 566-3 Grounding method of neutral conductor of low-voltage electrical equipment

However, when the above-mentioned condition is not satisfied, the neural wire shall be grounded through grounding electrode isolated from high-voltage grounding system. (See Figure 566-4)

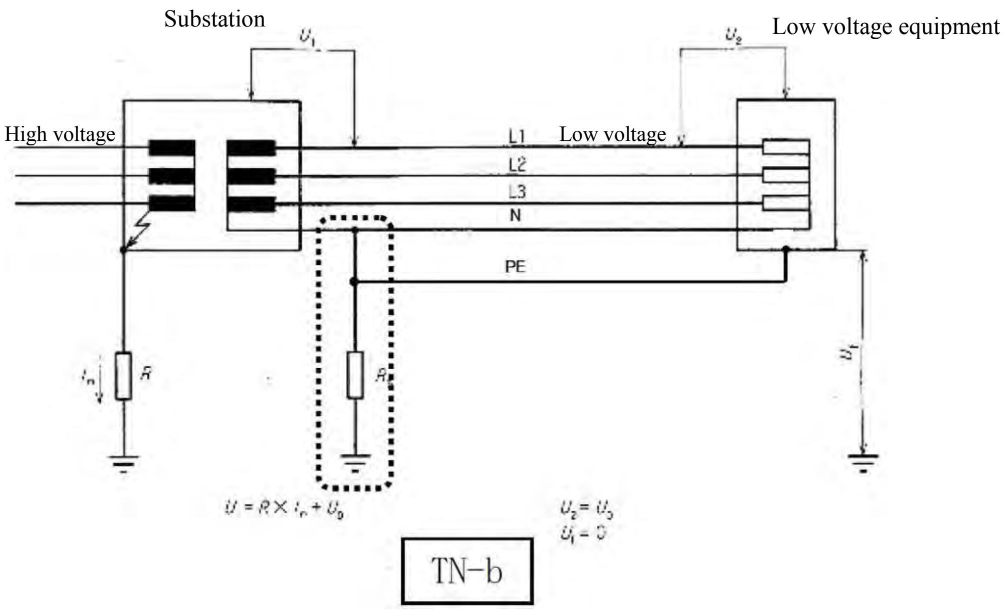


Figure 566-4 Grounding method of neutral conductor of low-voltage electrical equipment

- In case that low-voltage grounding system is IT method

  Regarding touch voltage, when the protective conductor is installed, the same requirements as TN method shall be satisfied. Otherwise, touch voltage is not necessarily considered.

  In addition to the above, the voltage applied to the low-voltage electrical equipment in case of short-circuit between the low-voltage electrical equipment and the high-voltage electrical equipment shall be considered and restrained under the permissible voltage of the low-voltage electrical equipment, because, in such case, high voltage is applied to the low-voltage electrical equipment directly.

- Protection of communication cable

  Insulation protection measures for communication cable lines and remote controlling system from electrical equipment must be arranged. Additionally, the measures on prevention of transmitting dangerous voltage to outside of boundary of electrical equipment must be available too.

Article 567. Touch and Step Voltages

Permissible values of touch voltage and step voltage can be calculated by the following equations. In these equations, a body weight is estimated at 50kg.

Step voltage

$$E_{step} = \left(R_B + 2R_f\right)\cdot I_B$$

For body weight of 50kg

$$E_{step50} = \left(1000 + 6C_s \cdot \rho_s\right)\frac{0.116}{\sqrt{t_s}}$$

For body weight of 70kg

$$E_{step70} = \left(1000 + 6C_s \cdot \rho_s\right)\frac{0.157}{\sqrt{t_s}}$$

Where

R_B: Resistance of human body in Ω

R_f: Ground resistance of one foot (with presence of the substation grounding system ignored) in Ω

I_B: Rms magnitude of the current through body in A

C_s: surface layer derating factor

T_s: duration of shock current in seconds

Cs is calculated by the following equation.

$$C_s = 1 - \frac{0.09\left(1 - \frac{\rho}{\rho_s}\right)}{2h_s + 0.09}$$

Where

ρ : surface material resistivity in Ωm

ρ_s : resistivity of earth beneath surface material in Ωm

h_s: thickness of surface material in m

Touch voltage

$$E_{touch} = \left(R_B + \frac{R_f}{2}\right) \cdot I_B$$

For body weight of 50kg

$$E_{touch50} = \left(1000 + 1.5C_s \cdot \rho_s\right)\frac{0.116}{\sqrt{t_s}}$$

For body weight of 70kg

$$E_{touch70} = \left(1000 + 1.5C_s \cdot \rho_s\right)\frac{0.157}{\sqrt{t_s}}$$

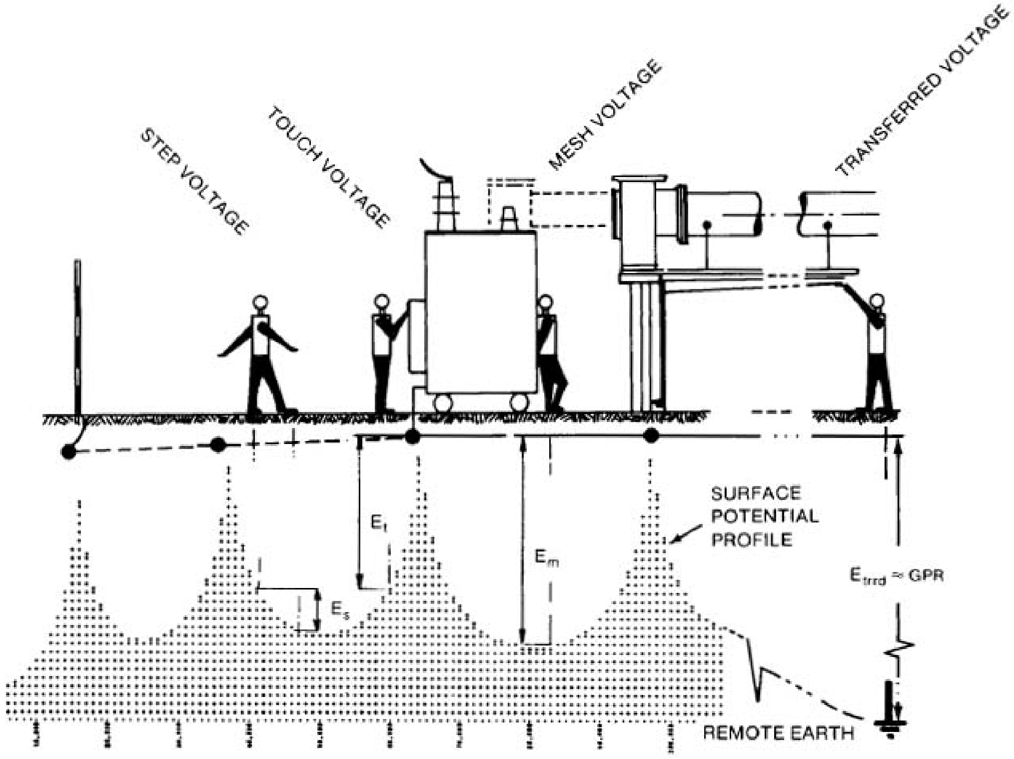


Figure 567 Touch voltage and step voltage

Article 568. Resistance of Grounding System

Grounding system of substation and electrical equipment with voltage of more than 1kV or equal shall be designed in accordance with the following requirements
Touch voltage and step voltage shall be calculated based on the specifications of actual grounding system. These calculation results shall not be exceed the permissible touch voltage and step voltage.
The common procedure is as follows:
(1) Determine the soil model and the grounding grid area

Soil model at construction sector is determined based on the results of the geological survey in the area. Then the grounding grid area is determined taking into account the layout of electrical equipment in substations and other conditions

(2) Calculate the resistivity of the soil

Since the resistivity of the soil is essential for the calculation of the touch voltage and step voltage as well as the resistance of the soil by the following equations in the model of land has been defined in clause (1).

Soil resistivity model and the two-layer soil model is the most common use. Two-layer soil model is often a good approximate estimate of soil structure is the multi-layer soil model can be used for more complex soil conditions.

Apparent resistivity of a homogeneous soil can be calculated from the following equation

$$\rho_{a(av1)} = \frac{\rho_{a(1)} + \rho_{a(2)} + \rho_{a(3)} + \cdots + \rho_{a(n)}}{n}$$

In that:

$\rho_{a(1)} + \rho_{a(2)} + \rho_{a(3)} + \cdots + \rho_{a(n)}$: Apparent resistivity measured at different intervals in the four-pin plug or method at different depths in place spindles on the ground method, in Ωm

n: total number of measurements

Apparent resistivity of the two soil layers is calculated from the following equation::

$$\rho(a) = \rho_1 \left[1 + 4\sum_{n=1} \frac{K^n}{\sqrt{1+\left(2n\frac{h}{a}\right)^2}} - \frac{K^n}{\sqrt{4+\left(2n\frac{h}{a}\right)^2}} \right]$$

In that:

h: The first layer height

ρ_1 : The first layer resistivity

ρ_2: Deep layer resistivity

$K = \frac{(\rho_2 - \rho_1)}{(\rho_2 + \rho_1)}$: Reflection coefficient

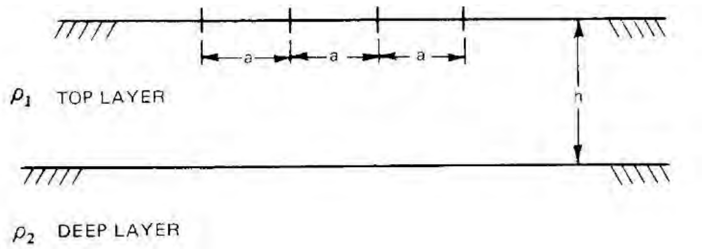


Figure 568-1 Two-layer land

(3) The calculation of the ground wire

The temperature increase briefly in the grounding wire or the wire size required is a function of the current in the wire, can be calculated from the following equation:

$$I = A_{mm^2}\sqrt{\left(\frac{TCAP \cdot 10^{-4}}{t_c \alpha_r \rho_r}\right)\ln\left(\frac{K_0 + T_m}{K_0 + T_a}\right)}$$

Or

$$A_{mm^2} = I\frac{1}{\sqrt{\left(\frac{TCAP \cdot 10^{-4}}{t_c \alpha_r \rho_r}\right)\ln\left(\frac{K_0 + T_m}{K_0 + T_a}\right)}}$$

In that:

I: Effective 1-phase short-circuit current (rms), kA

Amm2: wire cross section,mm2

Tm: temperature allows the largest,

Ta: ambient temperature,

Tr: the reference temperature for the material constants,

α_0 : Temperature coefficient of resistivity at 0°C, 1 /

α_r : Temperature coefficient of resistivity at reference temperature Tr, 1 /

ρ_r : The resistivity of the ground wire at the reference temperature Tr,

K0: 1/α_0 or (1/α_0)- Tr , ^oC

tc: the current time, s

TCAP: heat capacity / unit volume selected from Table 572, J / (cm3)

Table 568 Material constants

Description	The conductivity of the material (%)	α_r Factor at 20 ^oC (1/ ^oC)	K0 at 0 ^oC (^oC)	Melt temperature T_m (^oC)	ρ_r 20 ^oC ($\mu\Omega \cdot cm$)	TCAP heat capacity [J/(cm^3 ^oC)]
Copper Soft annealed pulling	100.0	0.00393	234	1083	1.72	3.42
CopperTrade pulling hard	97.0	0.00381	242	1084	1.78	3.42
Copper clad steel wire	40.0	0.00378	245	1084	4.40	3.85
Copper clad steel wire	30.0	0.00378	245	1084	5.86	3.85
Copper clad steel wire	20.0	0.00378	245	1084	8.62	3.85
EC type aluminum	61.0	0.00403	228	657	2.86	2.56
Aluminum alloy 5005	53.5	0.00353	263	652	3.22	2.60
Aluminum alloy 6201	52.5	0.00347	268	654	3.28	2.60
Aluminum clad steel wire	20.3	0.00360	258	657	8.48	3.58
Steel, 1020	10.8	0.00160	605	1510	15.90	3.28
Pile of stainless steel	9.8	0.00160	605	1400	17.50	4.44
Galvanized steel poles	8.6	0.00320	293	419	20.10	3.93
Stainless Steel	2.4	0.00130	749	1400	72.00	4.03

The above equations reflect two basic assumptions:

a) Complete heat is retained in the wire (adiabatic process)

b) The results of the specific heat (SH) and specific gravity (SW), TCAP, is approximately constant for SH increase and SW decreased at speed nearly equal. For most materials, these assumptions can be applied on a wide range of reasonable time of the incident in a few of seconds

TCAP can be calculated for the whole materials not listed in Table 572 from the specific heat and specific gravity. Specific heat, SH, cal / ($grams \times^o C$) and SW, gram/cm3 related to the heat capacity per unit volume, J / ($cm^3 \times^o C$) as follows.

4.184J = 1 calorie

Thus, TCAP is determined by the:

TCAP[cal/($cm^3 \times^o C$)] = SH [cal/($grams \times^o C$)] ・SW (gram/cm^3)

or

TCAP[J/($cm^3 \times^o C$)] = 4.184(J/cal) ・SH[cal/($grams \times^o C$)] ・SW (gram/cm^3)

(4) Calculate the resistance of the grounding system

Following equation is used to calculate the loss resistance of the grounding system of homogeneous land cover extreme horizontal and vertical. This equation combined resistance of the grid, earthing piles and general soil resistance to calculate the total resistance of the system, Rg.

$$R_g = \frac{R_1 R_2 - R_m{}^2}{R_1 + R_2 - 2R_m}$$

In that:

R1: the resistance of the wires of the mesh, Ω

R2: resistance grounding of all piles, Ω

Rm: mutual resistance between the grid and the piles, Ω

Each resistor is calculated as follows:,

$$R_1 = \frac{\rho}{\pi L_c}\left[\ln\left(\frac{2L_c}{a'}\right) + \frac{k_1 \cdot L_c}{\sqrt{A}} - k_2\right]$$

In that:

ρ : The resistance of the soil,

LC: The total length of the wires connected to the grid, m

a ': for wire buried at the depth h m, or the wires on the ground, in m

2a: wire diameter, m

A: area covered by wire, m2

k1, k2: the coefficient

$$R_2 = \frac{\rho}{2\pi n_R L_R}\left[\ln\left(\frac{4L_R}{b}\right) - 1 + \frac{2k_1 \cdot L_r}{\sqrt{A}}\left(\sqrt{n_R} - 1\right)^2\right]$$

in that

Lr: length of each piles m

2b: piles diameter, m

nR: number of piles placed in area A

$$R_m = \frac{\rho}{\pi L_c}\left[\ln\left(\frac{2L_c}{L_r}\right) + \frac{k_1 \cdot L_c}{\sqrt{A}} - k_2 + 1\right]$$

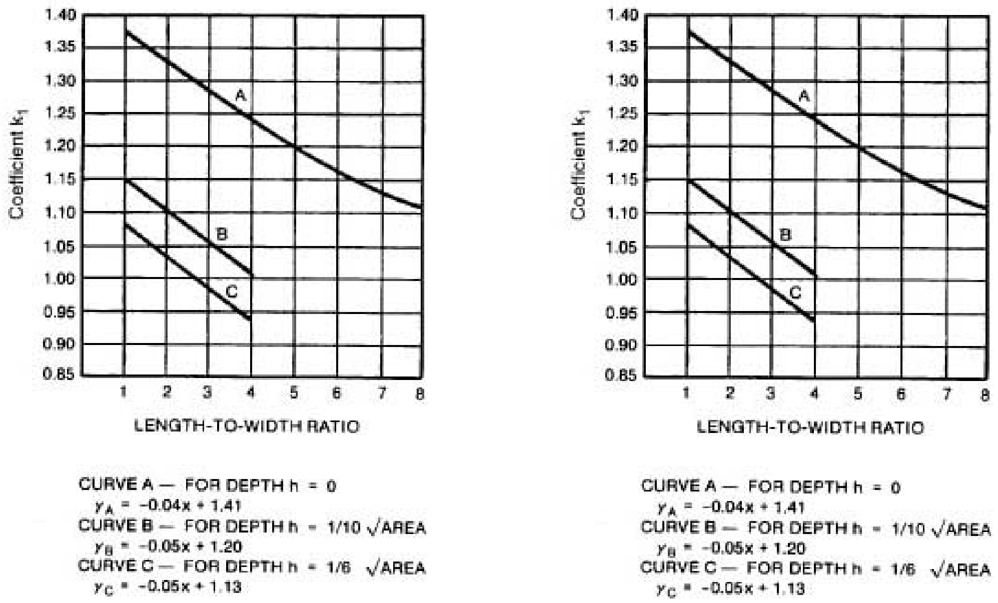


Figure 568-2 Two coefficients k1 and k2

(5) The touch voltage and step voltage

Mesh voltage (voltage touch) is a product of coefficient Km geometry, the correction coefficient, Ki, calculated for a number of errors when making assumptions derived from Km, soil resistivity, , and the average current per unit of useful length of wire buried grounding system

$$E_m = \frac{\rho \cdot K_m \cdot K_i \cdot I_G}{L_M}$$

Coefficient Km geometry is as follows:.

$$K_m = \frac{1}{2\pi}\left[\ln\frac{D^2}{16\cdot h\cdot d} + \frac{(D+2\cdot h)^2}{8\cdot D\cdot d} - \frac{h}{4\cdot d}\right] + \frac{K_{ii}}{K_h}\cdot\ln\left[\frac{8}{\pi(2\cdot n-1)}\right]$$

For grounding grid poles along the perimeter, or the grounding grid piles placed in the corners as well as along the perimeter and throughout the grid area

Kii = 1

For grid with no ground piles or network only have a few ground piles, not placed in the corners or along the perimeter

$$K_{ii} = \frac{1}{(2\cdot n)^{\frac{2}{n}}}$$

$$K_h = \sqrt{1+\frac{h}{h_0}}$$ h_0 = 1m (reference depth of grid)

Effective number of parallel wires in a given grid, n, can be applied to the rectangular grid or free-shaped representation for some of the parallel equivalent of a rectangular grid.

$n = n_a \cdot n_b \cdot n_c \cdot n_d$

In that:

$$n_a = \frac{2 \cdot L_c}{L_p}$$

nb = 1 for the square grid

nc = 1 for square, rectangles mesh

nd = 1 for squares, rectangles mesh and L-shaped

mesh with other pictures

$$n_b = \sqrt{\frac{L_p}{4 \cdot \sqrt{A}}}$$

$$n_c = \left[\frac{L_x \cdot L_y}{A}\right]^{\frac{0.7 \cdot A}{L_x \cdot L_y}}$$

$$n_d = \frac{D_m}{\sqrt{L_x^2 + L_y^2}}$$

Lc: the total length of wire in the horizontal grid, m

L_p: length of the perimeter of the grid, m

A: area of the grid, m2

L_x: the greatest length of the grid in the X direction, m

L_y: the greatest length of the grid in the Y direction, m

D_m: the greatest distance between any two points on the grid, m

D: distance between two parallel conductors, m

h: depth of the wires of the grid, m

d: diameter of the wires of the grid, m

Not rule coefficients, Ki, is used along with the number n above is:

$$K_i = 0.644 + 0.148 \cdot n$$

For grid no ground piles or network only a little ground piles scattered in the grid, but not in the corners or along the perimeter of the grid, the effective buried length, LM, is

$L_M = L_C + L_R$

in that

LR: total length of all ground piles, m

For ground grid with piles arranged at the corners, as well as along the perimeter and throughout the grid, length buried utility, LM, is

$$L_M = L_C + \left[1.55 + 1.22\left(\frac{L_r}{\sqrt{L_x^2 + L_y^2}}\right)\right] L_R$$

in that

Lr: length of each piles, m

Calculated Voltage step is the product of the geometric coefficient, Ks, the adjustment coefficient, Ki, ground resistivity, and the average current per unit length of wire buried grounding system (IG / LS).

IG = $S_f D_f C_p I_{nm}$
In which:

$$E_s = \frac{\rho \cdot K_s \cdot K_i \cdot I_G}{L_S}$$

For grids with or without ground piles <useful length of the wire, L_S, is

$$L_S = 0.75 \cdot L_C + 0.85 \cdot L_R$$

Largest voltage step is assumed to occur over a distance of 1 m, starting at and stretching out wire perimeter at the corner divided by 2 of the most far corner of the net. For the buried length is 0.25m <h <2.5 m, Ks, is

$$K_s = \frac{1}{\pi}\left[\frac{1}{2 \cdot h} + \frac{1}{D + h} + \frac{1}{D}\left(1 - 0.5^{n-2}\right)\right]$$

(6) Evaluation of the touch voltage and step voltage was calculated

Results calculated touch voltage and step voltage are compared with their permitted values.
Whether the principle of the above, the resistance of the earthing device must not be higher than 0.5 in the area of ground resistivity of not more than 500 throughout the year.This requirement does not apply to equipment grounding pole of the OPL and substations with voltage of 35kV or less.

For substations with voltage of 35kV or less, in measured ground resistance throughout the year must be calculated by the following formula, but not higher than 10:
a) If the ground is used for both high-voltage electrical equipment with more or less than 1kV

$$R_{nd} = \frac{125}{I_{cd}}$$

In this case, to satisfy the requirements for grounding electrical equipment with voltage up to 1kV.
b) If the device is only used for ground electrical equipment with voltages from 1kV or more

$$R_{nd} = \frac{250}{I_{cd}}$$

In it,
Rnd: The largest ground Resistor when taking into account the change in resistivity of the soil throughout the year, Ω
ICD: Current earth fault calculations,A.

Grounding resistance of electric equipment with voltage less than or equal to 1kV must comply with the following requirements.
Neutral ground resistance of the generator or transformer or power output of one phase in the whole year, not more than 2Ω or 4Ω, corresponding to voltage 660V or 380V (phase voltage is 380V or 220Vin the case of single-phase power supply).Resistor value also applies to many points for ground the neutral wire of OPL.

Ground resistivity of the of multipolar ground (even the natural ground) to the neutral wire of the OPL in the year must not be higher than 5 Ω or 10Ω, corresponding to the line voltage is 660V or 380V (phase voltage is 380V or 220V single-phase power supply in case).

For devices with isolated neutral, resistance of ground electrical equipment must not be larger than 4Ω.

Chapter 6-7 Calculation of Earth Fault Current

Article 569. Calculation of Earth Fault Currents

Determination of maximum earth fault current

To calculate ground resistance at a substation, earth fault current which flow through the grounding system at the substation shall be determined.

1. The earth fault current which flows on the transmission line connected to the substation is calculated based on configuration of the power gird.
2. According to estimated impedances of transformers, neutral point, transmission lines, grounding wires, etc., the earth fault current which flows into the grounding system of the substation is calculated based on the aforesaid earth fault current.

1. Earth fault current at power gird with directly grounded neutral point.

The bigger one among the calculated current in the following two cases is selected as the earth fault current which flows into the grounding system of the substation in the power gird with directly grounded neutral point.

(1) Case of earth fault outside the substation

Earth fault current which flows into the grounding system in the substation consists of the earth fault current which flows through the earth and the earth fault current which flows into the substation from grounding wire of the transmission line connected to the substation. (Refer to Figure 573-1). Both earth fault currents flow to the power gird through the neutral point of the transformer.

Maximum earth fault current which flows through the grounding system is calculated by the following equation.

$$I_E = (1-\eta)\, I_N$$

Where

I_E: Maximum earth fault current which flows through the grounding system

η : Division factor between grounding wire and grounding device of transmission tower

I_N: Maximum earth fault current which flows to the neutral point of the transformer

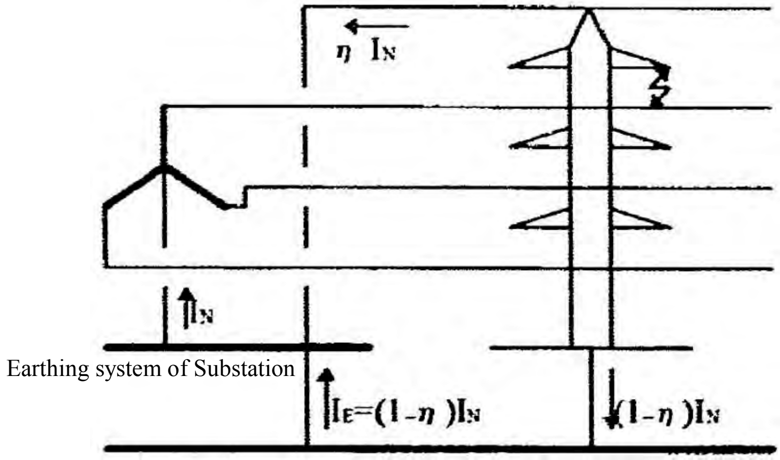


Figure 569-1 Earth fault outside substation

(2) Case of earth fault inside the substation

Earth fault current which flows out of the grounding system of the substation consists of the earth fault current which flows to the grounding system, that which flows to grounding wire and that which flows to the neutral point of the transformer.

The earth fault current that flows to the grounding system, which is used for design for grounding system, is calculated by the following equation.

$I_E = (1-\eta)(I_F-I_N)$

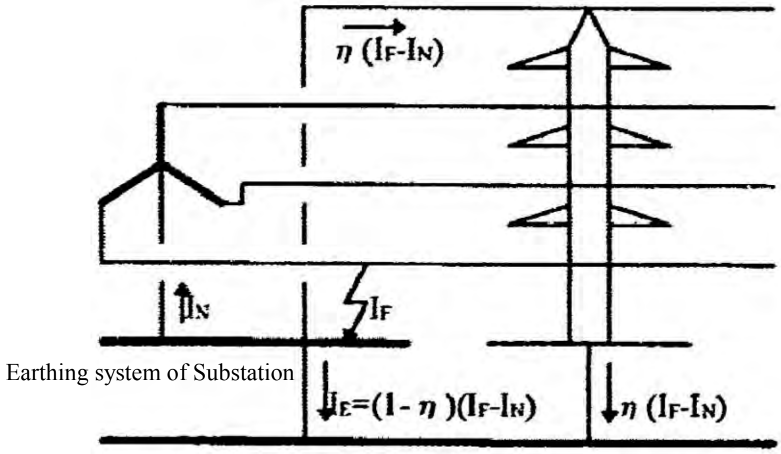


Figure 569-2 Earth fault inside substation

Many different types of faults may occur in the system. It may be difficult to determine which fault type and location will result in the greatest flow of current between ground grid and surrounding earth because no simple rule applies.

In determining the applicable fault types, consideration shall be given to the probability of occurrence of the fault. Multiple simultaneous faults, even though they may result in higher ground current, need not be considered if their probability of occurrence is negligible. It is recommended, for practical reasons, that investigation be confined to single-line-to-ground and line-to-line-to-ground faults.

In the case of a line-to-line-to-ground fault, the zero sequence fault current is

$$I_0 = \frac{E \cdot (R_2 + jX_2)}{(R_1 + jX_1) \cdot [R_0 + R_2 + 3R_f + j(X_0 + X_2)] + (R_2 + jX_2) \cdot (R_0 + 3R_f + jX_0)}$$

where:

I_0 is the symmetrical rms value of zero sequence fault current in A
E is the phase-to-neutral voltage inV
R_f is the estimated resistance of the fault in Ω (normally it is assumed $R_f = 0$)
R_1 is the positive sequence equivalent system resistance in Ω
R_2 is the negative sequence equivalent system resistance in Ω
R_0 is the zero sequence equivalent system resistance in Ω
X_1 is the positive sequence equivalent system reactance (subtransient) in Ω
X_2 is the negative sequence equivalent system reactance in Ω
X_0 is the zero sequence equivalent system reactance in Ω

The values R1, R2, R0, X1, X2 and X0 are computed looking into the system from the point of fault. In case of a single-to-ground fault, zero sequence fault current is

$$I_0 = \frac{E}{3R_f + R_1 + R_2 + R_0 + j(X_1 + X_2 + X_0)}$$

In many cases, the effect of the resistance terms in equation above is negligible. For practical purpose, the following simplified equations are sufficiently accurate and more convenient.

Zero sequence current for line-to-line-to-ground fault

$$I_0 = \frac{E \cdot X_2}{X_1 \cdot (X_0 + X_2) + (X_2 + X_0)}$$

Zero sequence current for line-to-ground fault

$$I_0 = \frac{E}{X_1 + X_2 + X_0}$$

Effect of overhead ground wires and neutral conductors

Where transmission line overhead ground wires or neutral conductors are connected to the substation ground, substantial portion of the ground fault current is diverted away from the substation ground grid. Where this substation exists, the overhead ground wires or neutral conductors should be taken into consideration in the design of the ground grid.

Connecting the substation ground to overhead ground wires or neutral conductors, or both, and through them to transmission line structures or distribution poles, will usually have the overall effect of increasing the GPR at tower bases, while lessening it at the substation. This is because each of the nearby towers will share in each voltage rise of the substation ground mat, whatever the cause, instead of being affected only by a local insulation failure or flashover at one of the towers. Conversely, when such a tower fault does occur, the effect of the connected substation system should decrease the magnitude of gradients near the tower bases.

2. Earth fault current at power gird with isolated neutral point.

Earth fault current at power grid with isolated neutral point is based on actually measured earth fault current. If this measured value is not obtained, the earth fault current is calculated with reference to the equations shown in Table 573.

Table 569 [Reference] Earth fault current at power grid with isolated neutral point

Category	Power line	Equation of earth fault current	Remarks
Isolated neutral point	Power line without cable	$I_1 = 1 + \frac{\frac{V}{3}L - 100}{150}$ First decimal place of the second term is rounded up. When I_1 is less than 2, I_1 is set to 2.	I_1:Earth fault current in A V: Nominal voltage of power line divided by 1.1 L: Total length of high-voltage or middle-voltage power line connected to the same busbar except cable power line in km. (In case of 3phase-3wire, the length is multiplied by 3, and in case of single phase-2wire, the length is multiplied by 2.) L': Total length of high-voltage or middle- voltage cable power line connected to the same busbar in km
	Cable power line	$I_1 = 1 + \frac{\frac{V}{3}L' - 1}{2}$ First decimal place of the second term is rounded up. When I_1 is less than 2, I_1 is set to 2.	
	Both cases	$I_1 = 1 + \frac{\frac{V}{3}L - 100}{150} + \frac{\frac{V}{3}L' - 1}{2}$ When the second term or the third term is minus number, it is set to zero. First decimal place of I_1 is rounded up. When I_1 is less than 2, I_1 is set to 2.	
Neutral point grounded through reactor		$I_3 = \sqrt{\left(\frac{\frac{VR}{\sqrt{3}}}{R^2+X^2}\right)^2 + \left(I_1 - \frac{\frac{VX}{\sqrt{3}}}{R^2+X^1} \times 10^3\right)}$ First decimal place of I_3 is rounded up. When I_3 is less than 2, I3 is set to 2.	I_3: Earth fault current in A I_1: Earth fault current in above case in A V: Nominal voltage of power line inkV R: Resistance of reactor connected to neutral point in Ω X: Reactance of reactor connected to neutral point in Ω

Article 570. Calculation Method of Earth Fault Currents

The following conditions of power grid shall be satisfied in calculation of earth fault current.

- All generators operate under normal conditions.
- All transmission lines and distribution lines operate under normal conditions.
- Future plan of extension of power gird is considered.

The following earth faults shall be considered in calculation of earth fault current. However, earth fault at two points distant from each other in different phases is considered when such earth fault may happen. (See Figure 574)

- Earth fault at three phases
- Earth fault at two phases
- Earth fault at one phase

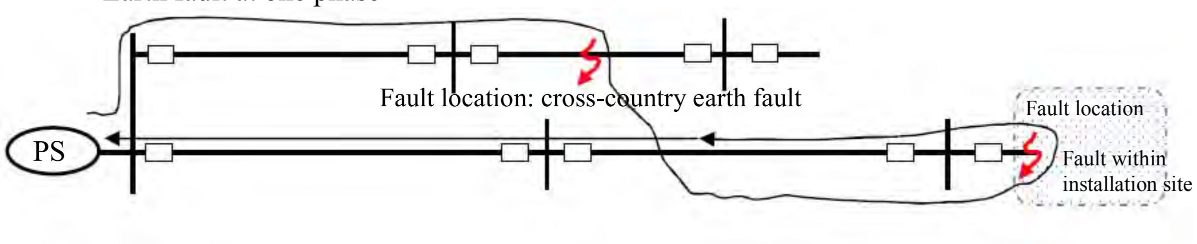


Figure 570 Earth fault at two points distant from each other in different phases

Chapter 6-8 Earthing Conductors

Article 571. Connection between Neutral Wire and Earth Mesh

Refer to Article 576.

Article 572. Cross-section and Material of Earthing Conductors

The minimum cross-sectional area of grounding conductor with voltage of more than 1kV is decided in accordance with Table 576-1 .and table 576-2.

Considering adverse affect of erosion and corrosion on the grounding conductor, the cross-sectional eathed poles should be more than the values below.

- Copper: 16mm2
- Aluminum: 35mm2
- Iron: 50mm2

The minimum cross-sectional area of grounding conductor with voltage of up to 1kV is decided as below.

- Steel conductor with its tensile strength of not less than 2.46kN, or soft copper wire with its diameter of not less than 4.0mm and its cross-sectional area of not less than $14mm^2$
- Insulated wire or cable with copper core, of which cross-sectional area is not less than $8mm^2$

Pole earthing and grounding wire have to withstand erosion, electric corrosion and oxidation. When deciding on the minimum cross-sectional area of the pole grounding, mechanical strength and resistance to erosion and corrosion must be considered. Minimum cross-sectional area of the pole earthing are given in Table 576-2

Table 572-1 The smallest size of the ground wire and neutral protection wire

Name	Copper	Aluminum	Steel		
	Indoor Outdoor Under ground	Indoor Outdoor	Indoor	Outdoor	Under ground
Bare conductor: Cross-section-area,mm^2 Diameter,mm	 4 -	 6 -	 - 5	 - 6	 - 10
Cross-section-area isolated wire,mm^2	1.5(*)	2.5	-	-	-
Cross-section--area earthing core and earthed neutral of cable or multi-core wire in common cover with phase core,mm^2	1	2.5	-	-	-
Wing thickness of steel corner,mm	-	-	2	2,5	4
Steel Cross-section-area bar,mm2	-	- -	24 3	48 4	48 4
Thickness,mm	-	2.5	2.5	2.5	3.5
Tube:	-	-	1.5	2.5	Not allowed

Note(*): When placing the wire in the tube, the cross-section-area of the neutral protecting is permitted by 1mm2 if the phase wire has the same cross-section.

Table 572-2 Minimum size of grounding electrode

Material		Kind of conductor	Minimum size		
			Diameter (mm)	Cross-sectional area (mm^2)	Thickness (mm)
Steel	Zinc galvanized	Rectangular plate		90	3
		Pipe	25		2
		Round steel	16		
		Round steel (horizontal)	10		
	With lead sheath	Round steel (horizontal)	8		
	With copper sheath	Round steel	15		
Copper	Bear	Rectangular plate		50	2
		Round shape (horizontal)		25	
		Pipe	20		2
	Zinc galvanized	Rectangular plate		50	2
	With copper sheath	Round shape		25	

Article 573. Temperature Rise Requirements

Grounding conductor shall enable earth fault current to flow through it safely. Especially, at connection point of grounding conductor, its thermal characteristic as well as its mechanical strength shall be considered.

Connection point of grounding conductor shall withstand temperature rise due to earth fault current without any problem.

Fastening bolt, pressure bonding and welding can be adopted as connection method of grounding conductor.

However, soldering method cannot be adopted as connection method of grounding conductor because melting point of solder is about 180°C.

Article 574. Cross-section of Earthing Conductors at Isolated Neutral

Refer to Article 576.

In production workshop, steel bar used as main grounding conductor shall have cross-sectional area not less than $100mm^2$. As for round steel bar, it shall have the same cross-sectional area.

Article 575. Cross-section of Earthing Conductors at Effective Earthed Neutral

Regarding cross-sectional area of grounding conductor, the requirement in Article 576 and the requirements below shall be satisfied.

- Permissible current of the grounding conductor shall not be lower than 3 times of the nominal current at the nearest fuse
- Permissible current of the grounding conductor shall not be lower than 3 times of the maximum breaking current

And half of minimum cross-sectional area of the phase conductors

In addition to the above, in order to protect power gird by fast-operating circuit breaker, cross-sectional area of grounding conductor shall be determined so that permissible current of the grounding conductor is not lower than the transient current multiplied by dispersion coefficient and reserve factor. The reserve factor shall be 1.1. As for the dispersion coefficient, unless otherwise specified, it shall not be lower than 1.4 in case that the rated current of the circuit breaker is up to 100A, or shall not be lower than 1.25 in case that the rated current of the circuit breaker is more than 100A.

If above-mentioned requirements are not satisfied, additional measures shall be taken. Shortening breaking time of earth fault by quick operating protective relay can be considered.

Chapter 6-9 Installation Method of Earthing Systems

Article 576. Earthing Electrodes and Earthing Rings

When earth fault current flows into grounding electrode, electric potential is distributed on the ground surface around the grounding electrode, and accordingly, the electric potential gradient is formed on the ground surface. Such electric potential gradient shall be reduced from the viewpoint of security for people and electrical equipment because excessive electric potential cause shock hazard.

Since electric potential distribution and electric potential gradient vary depending on shape and arrangement of grounding electrode, these factors shall be considered. The following shapes of grounding electrode can be selected.

- Half-sphere
- Plate
- (Vertical) Rod
- (Horizontal) Bar

Article 577. Material of Electrodes

Grounding electrode shall satisfy the conditions below.

(1) Grounding electrode has sufficient conductivity not to cause potential difference in the grounding electrode.
(2) Grounding electrode does not melt down by earth fault current.
(3) Grounding electrode withstands erosion and corrosion.

Article 578. Voltage Leveling

Electric potential gradient in case of earth fault becomes bigger as earth fault current which flows into the grounding electrode becomes bigger. In order to reduce the electric potential gradient, the following items are considered.

(1) around electrical equipment

Auxiliary grounding mesh is installed. The distance between conductors of the auxiliary grounding mesh is smaller than that of main grounding mesh.

(2) around surrounding fence of substation

- the surrounding fence is installed at the location distant from the outer edge of main grounding mesh
- the grounding electrodes are buried deeply around the outer edge of main grounding mesh

Grounding equipment shall be installed according to the following requirements.

- Grounding conductors shall be installed at the depth of not less than 0.8m.
- One grounding ring shall be arranged horizontally, surrounding the grounded neutral of transformer.
- When grounding equipment is installed out of protective fence for electrical equipment, horizontal grounding electrodes shall be arranged around the grounding equipment at the depth of not less than 1m. In this case, grounding ring shall be in polygonal shape with obtuse angle.

When grounding equipment of industrial electrical equipment is connected to high-voltage grounding system with effective grounded neutral, measures for voltage leveling around the industrial building or the area where industrial electrical equipment is installed shall be taken according to one of the following requirements.

- One grounding ring surrounding the industrial building or the area where industrial electrical equipment is installed shall be arranged and this grounding ring shall be connected to the grounding equipment of industrial electrical equipment. This grounding ring shall be buried at the depth of 1m and 1m distant from the foundation of the building or perimeter of the area where the industrial electrical equipment is installed.
- Reinforcing bar in concrete foundation can be used as grounding conductor if its ground resistance satisfies the required ground resistance.

Article 579. Arrangement of Earthing Electrodes

Grounding mesh is appropriate way to reduce ground resistance of substation. Grounding mesh is usually formed by connecting grounding electrodes and buried grounding conductors to each other. The reason is that ground resistance of grounding mesh is lower than that in case that grounding electrodes are not connected to each other.

On connecting grounding electrodes and grounding conductors to each other, the conditions below shall be considered.

(1) Reinforcing bars in buildings and foundation block, water pipes, etc. with sufficient conductivity are connected to grounding mesh. However, in this case, measures to protect them from electrical corrosion shall be taken.
(2) Auxiliary grounding mesh is installed at the part with large electric potential gradient.
(3) Material with high resistance such as asphalt or gravel is laid on the ground surface to increase touch resistance between human foot and ground.
(4) Material to reduce ground resistance is put into the ground.
(5) If measures to reduce ground resistance cannot be taken, measures to prohibit access to such part shall be taken.

To form grounding mesh, the following manner is applied.

- Regarding arrangement of grounding electrodes lengthwise, the grounding electrodes are arranged between electrical equipment at the depth of not less than 0.8m. In this case, the grounding electrodes shall be more than 1.0m distant from foundation or base of the electrical equipment.
- Regarding arrangement of grounding electrodes crosswise, the grounding electrodes are arranged at convenient location for installation work between electrical equipment at the depth of not less than 0.8m.
- Grounding electrodes are arranged along the perimeter of the grounding mesh so that the grounding electrodes form a closed ring.

When grounding equipment of electrical equipment with voltage of more than 1kV and effective grounded is installed at the area with its resistivity of higher than 500 Ωm all through the year, the measures below shall be considered.

- Grounding electrode is buried deeper if the soil resistivity decreases as the depth is deeper.
- The area where grounding electrodes is extended if the soil with low resistivity exists nearby.
- Material to reduce soil resistivity is used.

Article 580. Prohibited Usage of Soil as an Alternative to Neutral

The ground is not allowed to be used as alternative of phase conductor or neutral conductor because the current which flows through the ground cause electric corrosion to near metal structures in this case.

Article 581. Installation of Earthing Conductors

Grounding conductor and neutral conductor shall have sufficient cross-sectional area so that their mechanical strength is ensured and their temperature rise is restrained within permissible value. Therefore, cable sheath shall not be used for alternative of grounding conductor or neutral conductor. (Refer to Article 576)

All parts of metal structure inside a building shall be grounded in order to avoid potential difference inside the building.

Article 582. Earthing Conductors on Effective Earthed Neutral

Generally, an insulated wire or a cable is used for neutral conductor of low-voltage power line. However, if case or support structure of busbar is used as working conductor and/or protective neutral conductor, an insulated wire or a cable is not required for such conductor.

In production hall, normal environment, metal structure, pipe, enclosure and support structure of busbar are allowed to be used as working neutral conductor in the following cases.

- supply of single phase electricity to singe load with voltage up to 42V
- supply of single phase electricity to breaking coil of magnetic contactor or starter
- supply of single phase electricity to lighting equipment or single control circuit

Article 583. Mechanical and Chemical Protection of Earthing Conductors

Chemical erosion effect depends on soil structure and moisture content, acidity and conductivity of soil. Therefore, these factors shall be measured before selection of material of grounding electrode. And the cross-sectional area of grounding electrode shall be selected in consideration of adverse affect of chemical erosion.

Article 584. Signage and Paint for Earthing Conductors

Bare grounding conductors and structures of aboveground grounding devices shall be painted in violet or black. The joint or branch points of grounding conductors shall be painted with two color lines, violet or black, which are 150mm far from each other.

Article 585. Connection of Earthing Conductors

The overlapped length of welded part of the grounding conductor at the connection point shall be more than or equal to 2 times of width of connecting rectangular shaped conductor, or 6 times of diameter of round shaped conductor.

On overhead power line, the connection method of neutral conductor shall be the same as the above-mentioned method. However, instead of the above-mentioned stipulation, the connection method of phase conductor can be applied to the connection of the neutral conductor.

In humid rooms or room with corrosive vapor or gas, grounding conductor shall be connected each other by welding. If connection by welding is impossible, grounding conductor can be connected with bolt. In this case, the connection part shall be painted with protective paint. Moreover, such connection part shall be located to make visual check done easily

When grounding conductor is connected to pipes, it should be connected at the terminal attached to the pipes by welding. If welding cannot be applied, connection by band or bolt can be applied. Before connection, the contact surface of the pipe shall be cleaned.

When grounding conductor is connected to metal structures, it should be connected by welding. When grounding conductor is connected to electrical equipment or machines, it should be connected to them by bolt. If there is much vibration at the connection part, the measures to prevent the bolt from coming loose shall be taken.

If grounding conductor or protective neutral conductor is connected to movable equipment or needs to be removed sometimes, flexible conductor shall be applied.

Neutral point of transformer and generator, which is directly grounded through capacitive current compensator, shall be connected to main grounding system.

Grounding system for electrical equipment and that for lightning protection system shall be separated.

Chapter 6-10 Alternatives to Earthing Conductors

Article 586. Alternatives to Earthing Conductors

(1) When, in ferroconcrete building or steel framed building, the steel frame or reinforcing steel in this building is used as a grounding conductor or a grounding electrode, the part of such steel shall be buried underground and all the steels shall be connected each other firmly in order to equalize the voltage on the steels. In this case, the following conditions shall be satisfied.

- The touch voltage on conductive part of the building shall not exceed 50V in case that one-phase earth current flows through the grounding system. Therefore, steel frames or reinforcing steels shall be connected each other.
- In addition to the above, the touch voltage on metal parts of electrical machine installed in the building shall not exceed 50V.
- Moreover, the touch voltage on the metal parts of external wall of the building adjacent to the above-mentioned building shall not exceed 50V.

(2) the steel frame or reinforcing steel in the building of which ground resistance is not more than 2ohm, can be used as grounding electrode of the grounding system for the power gird with isolated neutral point.

(3) If the following conditions are satisfied, embedded metal water pipeline with ground resistance no more than 3ohm, can be used as a grounding electrode.

- Grounding conductor shall be connected to metal water pipe at the point where the diameter of the water pipe is more than 75mm or equal
- If there is the connection point between grounding conductor and metal water pipe at the water consumer side from the water meter, bypass conductor shall connect the both sides of the water meter.
- If the connection point between grounding conductor and metal water pipe is exposed to the public, this connection point shall be protected by appropriate cover.
- The metal used to connect grounding conductor and metal water pipe shall have performance of keeping the connecting part from electrical corrosion.

Article 587. Priority of Natural Objects as Earthing Conductors

Natural conductors made of conductive materials, which will always remain in/on the structure and will not be modified (e.g. interconnected steel-reinforcement, metal framework of the structure) may be used as parts of grounding system

Other natural components can only be considered as being additional to grounding system.

Steelwork within reinforced concrete structure is considered to be electrically continuous provided that the major parts of interconnections of vertical and horizontal bars are welded or otherwise security connected. Connections of vertical bars shall be welded, clamped or overlapped a minimum of 20 times their diameters and bound or otherwise securely connected.

Steel conduits for electrical conductors, box and other structures which are used as ground conductor or protection neutral conductor shall be connected with each other tightly.

- In case that the steel conduits are arranged without cover, the sleeves can be used to connect on minimum paint layer or other tight connectors can be used.
- In case that the steel conduits are arranged with cover, only sleeves for tight connection can be used on minimum paint layer.
- In case that long screw joint is applied for connection, lock nuts are applied to the both sides of the joint part.

In both cases such as with cover and without cover in the power line with earthed neutral point, the conduit shall be connected to the sleeve or the connector at two points on the both sides of it by welding

Interconnected reinforcing steel in concrete foundations or other suitable underground metal structures should preferably be used as a grounding electrode. When the metallic reinforcement in concrete is used as a grounding electrode, special care shall be exercised at the interconnections to prevent mechanical splitting of the concrete. In case that the conduit is arranged without cover, lock nuts cannot be adopted.

Chapter 6-11 Earthing of Mobile Electrical Equipment

Article 588. Earthing of Mobile Electrical Equipment

The enclosure of mobile generator shall be grounded.

The neutral point of the generator shall be grounded in order to avoid danger such as electrical shock and damage to the electrical equipment caused by earth fault current. Moreover, the protective device such as earth leakage breaker or earth fault protective relay shall be installed at the generator in order to detect earth fault and interrupt the earth fault current.

Article 589. Earthing of Enclosures of Mobile Electrical Equipment

The enclosure of mobile electrical equipment shall be grounded.

Flexible conductor shall be used as a grounding conductor. The grounding conductor shall be connected to the enclosure of the mobile electrical equipment firmly in order to avoid disconnection of the grounding conductor.

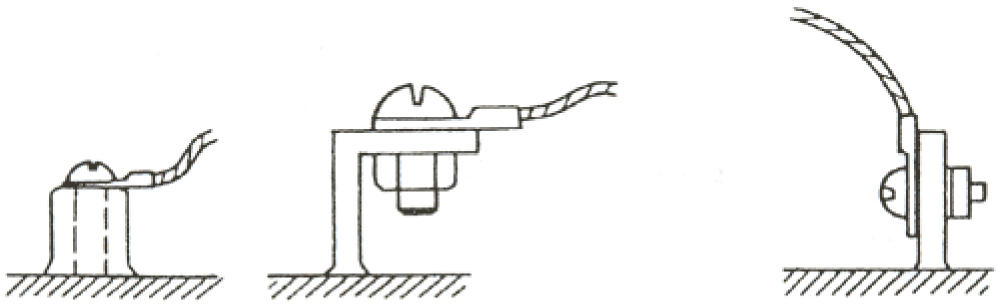


Figure 589 Connecting method of grounding conductor

Article 590. Alternatives to Earthing

Refer to Article 564 – Article 568.

Article 591. Conditions not Requiring Earthing

As for generator and motor, connection between the metal enclosure and metal base can be considered as grounding. In this case, at the contact surface between its metal enclosure and the metal base, paint shall be removed from the surface and the surface shall be cleaned and fattened in order to ensure electrical good connection.

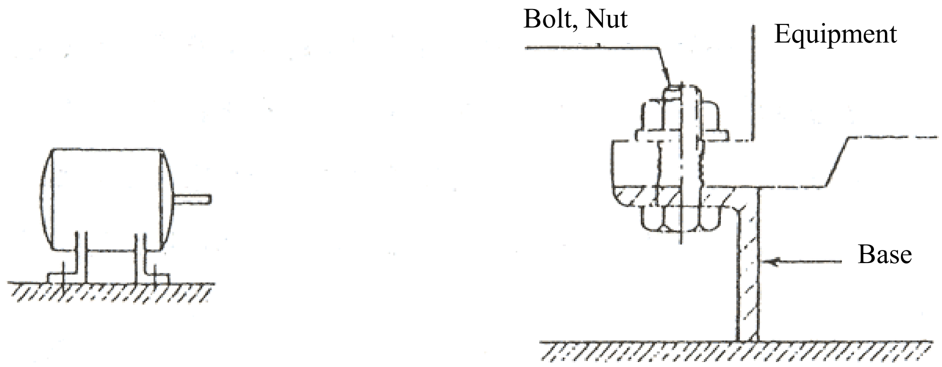


Figure 591 Connection between metal enclosure and metal base

Article 592. Earthing Conductors for Mobile Electrical Equipment

The following conductors can be used as conductor which connects enclosures of power supply source to the enclosure of the mobile electrical equipment.

a) The fifth core of cable cores in 3-phase power network with neutral conductor.

b) The fourth core of cable cores in 3-phase power network with neutral conductor

c) The third core of cable cores in single-phase power network

Annex II.2.1 (I.3A)

Rated electricity currents and some technical parameters of XLPE and EPR 24kV, one phase and 3 phase cables

Technical parameters of XLPE 24kV 3 phase copper core cables

Cross section area of cable (mm^2)	Resistance of core		Self induction coefficient (mH/km)	Capacitance of cable (μF/km)	Rated current in earth at 20°C (A)	Rated current in air at 30°C (A)	Nominal short circuit current at 1s (kA)	Test voltage (kV/5 minutes)
	DC at 20°C (Ω/km)	AC at 20°C (Ω/km)						
3x35	0.524	0.668	0.373	0.110	120	113	5.04	30
3x50	0.387	0.493	0.358	0.117	170	163	7.30	30
**	0.641	0.822			134	127	4.65	
3x70	0.268	0.342	0.340	0.128	210	201	10.08	30
**	0.443	0.568			164	157	6.51	
3x95	0.193	0.246	0.325	0.138	250	242	13.68	30
**	0.320	0.410			195	189	8.83	
3x120	0.153	0.195	0.315	0.146	284	278	17.28	30
**	0.253	0.324			222	217	11.16	
3x150	0.124	0.158	0.305	0.155	321	317	21.60	30
**	0.206	0.264			251	247	13.95	
3x185	0.099	0.126	0.297	0.163	358	356	26.64	30
**	0.164	0.210			282	281	17.21	
3x240	0.075	0.096	0.285	0.176	411	415	34.56	30
**	0.125	0.160			325	327	22.32	
3x300	0.060	0.077	0.279	0.184	462	472	43.20	30
**	0.010	0.128			368	376	27.90	

(**) Aluminum core

Technical parameters of cable Cu/Al - XLPE - 24kV - 3 phase

Cross section area of cable (mm^2)	DC at 20°C (Ω/km)		Self induction coefficient (mH/km)	Capacitance of cable (μF/km)	Rated current in earth at 20°C (A)	Rated current in air at 30°C (A)	Nominal short circuit current at 1s (kA)	Test voltage (kV/5 minutes)
	DC at 20°C (Ω/km)	AC at 90°C (Ω/km)						
3x50	0.387	0.493	0.399	0.100	164	205	7.20	45
**	0.641	0.822			130	151	4.65	45
3x70	0.268	0.342	0.378	0.109	202	245	10.08	45
**	0.443	0.568			158	180	6.51	45
3x95	0.193	0.246	0.361	0.117	234	280	13.68	45
**	0.320	0.410			182	217	8.83	45
3x120	0.153	0.195	0.350	0.123	270	320	17.28	45
**	0.253	0.324			208	247	11.16	45
3x150	0.124	0.158	0.338	0.131	304	356	21.60	45
**	0.206	0.264			234	281	13.95	45
3x185	0.099	0.126	0.328	0.137	338	415	26.64	45
**	0.164	0.210			265	327	17.21	45
3x240	0.075	0.096	0.314	0.148	390	472	34.56	45
**	0.125	0.160			307	376	22.32	45

(**) Aluminum core

Technical parameters of cable Cu/Al - XLPE - 24kV - 3 phase

Cross section area of cable (mm^2)	DC at 20°C (Ω/km)		Self induction coefficient (mH/km)	Capacitance of cable (μF/km)	Rated current in air at 30°C (A)	Rated current in air at 30°C (A)	Nominal short circuit current at 1s (kA)	Test voltage (kV/5 minutes)
	DC at 20°C (Ω/km)	AC at 90°C (Ω/km)						
3x240	0.0754	0.098	0.287	0.176	411	415	33.80	30
**	0.125	0.162	0.287	0.284	325	327	22.2	30

(**) Aluminum core

Technical parameters of cable Cu/Al - XLPE - 24kV - 1 phase

Cross section area of cable (mm^2)	DC at 20°C (Ω/km)		Self induction coefficient (mH/km)	Capacitance of cable (μF/km)	Rated current in earth at 20 °C (A)	Rated current in air at 30°C (A)	Nominal short circuit current at 1s (kA)	Test voltage (kV/5 minutes)
	DC at 20°C (Ω/km)	AC at 90°C (Ω/km)						
1x35	0.514	0.655	0.541	0.142	154	136	5.04	30
1x50	0.379	0.483	0.523	0.155	180	279	7.2	30
**	0.628	0.805			141	217	4.65	
1x70	0.262	0.334	0.500	0.174	219	347	10.08	30
**	0.435	0.558			171	270	6.51	
1x95	0.189	0.241	0.482	0.193	2	420	13.68	30
**	0.313	0.401			203	328	8.83	
1x120	0.150	0.191	0.471	0.207	293	483	17.28	30
**	0.248	0.318			230	378	11.16	
1x150	0.122	0.156	0.459	0.225	320	540	21.60	30
**	0.202	0.259			254	425	13.95	
1x185	0.097	0.124	0.450	0.242	359	614	26.64	30
**	0.161	0.206			285	485	17.21	
1x240	0.074	0.094	0.436	0.271	410	718	34.56	30
**	0.122	0.156			329	573	22.32	
1x300	0.059	0.075	0.429	0.290	455	813	43.20	30
**	0.098	0.125			368	652	27.90	
1x400	0.046	0.059	0.418	0.325	494	904	57.60	30
**	0.076	0.098			408	740	37.20	

(**) Aluminum core

Technical parameters of cable Cu/Al - XLPE - 24kV - 3 phase

Cross section area of cable (mm^2)	Core resistance		Self induction coefficient (mH/km)	Capacitance of cable (μF/km)	Rated current in earth at 20°C (A)	Rated current in air at 30°C (A)	Nominal short circuit current at 1 s (kA)	Test voltage (kV/5 minutes)
	DC at 20°C (Ω/km)	AC at 90°C (Ω/km)						
3x35	0.521		0.424	0.12	164	173	5.0	
**	0.868				127	139	3.3	
3x50	0.387		0.406	0.13	194	206	7.2	
**	0.641				148	161	4.7	
3x70	0.268		0.388	0.14	236	257	10.1	
**	0.443				179	199	6.6	
3x95	0.193		0.364	0.16	283	313	13.6	
**	0.320				214	242	8.9	
3x120	0.153		0.346	0.18	322	360	17.2	
**	0.253				246	280	11.3	
3x150	0.124		0.333	0.19	362	410	21.5	
**	0.206				246	318	14.1	
3x185	0.099		0.323	0.21	409	469	26.5	
**	0.164				308	365	17.4	
3x240	0.075		0.313	0.23	474	553	34.3	
**	0.125				358	425	22.6	
3x300	0.060		0.301	0.25	533	629	42.9	
**	0.100				398	481	28.2	
3x400	0.047		0.291	0.28	597	717	57.2	
**	0.078				446	553	37.6	

(**) Aluminum core

Technical parameters of cable Cu/Al - XLPE - 24kV - 1 phase

Cross section area of cable (mm^2)	DC at 20°C (Ω/km)		Self induction coefficient (mH/km)	Capacitance of cable (μF/km)	Rated current in earth at 20°C (A)	Rated current in air at 30°C (A)	Nominal short circuit current at 1 s (kA)	Test voltage (kV/5 minutes)
	DC at 20°C (Ω/km)	AC at 90°C (Ω/km)						
1x240	0.074	0.094	0.436	0.271	490		34.56	30
1x300	0.059	0.075	0.429	0.290			43.20	30
1x400	0.046	0.059	0.418	0.325			57.60	30

Technical parameters of cable Cu/Al - XLPE - 24kV - 3 phase

Cross section area of cable (mm^2)	DC at 20°C (Ω/km)		Self induction coefficient (mH/km)	Capacitance of cable (μF/km)	Rated current in earth at 20°C (A)	Rated current in air at 30°C (A)	Nominal short circuit current at 1 s (kA)	Test voltage (kV/5 minutes)
	DC at 20°C (Ω/km)	AC at 90°C (Ω/km)						
3x240	0.0754	0.0980	0.320	0.287		718	107.8	30
3x300	0.059	0.075	0.429	0.290		813	43.20	30
3x400	0.046	0.059	0.418	0.325		904	57.60	30

Technical parameters of cable Cu/Al - XLPE - 24kV - 3 phase

Cross section area of cable (mm^2)	Core resistance		Self induction coefficient (mH/km)	Capacitance of cable (μF/km)	Rated current in earth at 20°C (A)	Rated current in air at 30°C (A)	Nominal short circuit current at 1 s (kA)	Test voltage (kV/5 minutes)
	DC at 20°C (Ω/km)	AC at 90°C (Ω/km)						
3x240	0.0754	0.0777	0.301	0.288	425	718	109.0	30

Underground cable Cu-EPR - 24kV - 3x24

(Protected with gas bag)

Cross section area of cable (mm^2)	Core resistance		Self induction coefficient (mH/km)	Capacitance of cable (μF/km)	Rated current in earth at 20°C (A)	Rated current in air at 30°C (A)	Nominal short circuit current at 1 s (kA)	Test voltage (kV/5 minutes)
	DC at 20°C (Ω/km)	AC at 90°C (Ω/km)						
3x240	0.0754	0.0981	0.306	0.325	569	718	108	30

Underground cable Cu-EPR - 24kV - 3 phase

(Protected with two steel layers)

Cross section area of cable (mm^2)	Core resistance		Self induction coefficient (mH/km)	Capacitance of cable (μF/km)	Rated current in earth at 20°C (A)	Rated current in air at 30°C (A)	Nominal short circuit current at 1 s (kA)	Test voltage (kV/5 minutes)
	DC at 20°C (Ω/km)	AC at 90°C (Ω/km)						
3x35	0.524	0.67	0.377	0.136	180	190	5	30
**								
3x50	0.387	0.49	0.362	0.149	210	225	7	30
**								
3x70	0.268	0.34	0.344	0.169	260	280	10	30
**								
3x95	0.193	0.25	0.328	0.190	310	330	13.5	30
**								
3x120	0.153	0.20	0.318	0.206	350	380	17	30
**								
3x150	0.124	0.16	0.310	0.220	390	430	21.5	30
**								
3x185	0.0991	0.13	0.300	0.243	440	485	26.5	30
**								
3x240	0.0754	0.10	0.289	0.270	505	560	34	30
**								
3x300	0.0601	0.08	0.281	0.294	570	630	43	30
**								
3x400	0.047		0.273	0.326				30
**								

Technical parameters of cables - XLPE - 24kV - 3 phase

Cross section area of cable (mm2)	Core resistance		Self induction coefficient (mH/km)	Capacitance of cable (μF/km)	Rated current in earth at 20°C (A)	Rated current in air at 30°C (A)	Nominal short circuit current at 1 s (kA)	Test voltage (kV/5 minutes)
	DC at 20°C (Ω/km)	AC at 90°C (Ω/km)						
1x35	0.524		0.377	0.136	185			30
**					140			
1x50	0.387		0.362	0.140	220			30
**	0.641				170			
1x70	0.268		0.344	0.169	265			30
**	0.443				205			
1x95	0.193		0.328	0.190	320			30
**	0.320				240			
1x120	0.153		0.318	0.206	360			30
**	0.253				275			
1x150	0.124		0.310	0.220	405			30
**	0.206				300			
1x185	0.0991		0.300	0.243	460			30
**	0.164				340			
1x240	0.0754		0.289	0.270	535			30
**	0.125				385			
1x300	0.0601		0.281	0.294	605			30
**	0.01				430			
1x400	0.047		0.273	0.326	690			30
**	0.0778				475			

Technical parameters of cables - XLPE - 24kV - 3 phase

Cross section area of cable (mm^2)	Core resistance		Self induction coefficient (mH/km)	Capacitance of cable (μF/km)	Rated current in earth at 20°C (A)	Rated current in air at 30°C (A)	Nominal short circuit current at 1 s (kA)	Test voltage (kV/5 minutes)
	DC at 20°C (Ω/km)	AC at 90°C (Ω/km)						
1x35	0.524	0.655	0.49	0.16	179	197	5.18	30
1x50	0.387	0.483	0.466	0.17	212	235	7.36	30
**	0.641	0.805			164	182	4.89	
1x70	0.268	0.334	0.447	0.2	259	293	10.26	30
**	0.443	0.558			201	227	6.81	
1x95	0.193	0.241	0.424	0.22	309	354	13.88	30
**	0.320	0.401			239	275	9.19	
1x120	0.153	0.191	0.407	0.24	349	408	17.49	30
**	0.253	0.318			273	317	11.58	
1x150	0.124	0.156	0.399	0.25	390	461	21.81	30
**	0.206	0.259			304	359	14.43	
1x185	0.0991	0.124	0.387	0.28	440	527	26.86	30
**	0.164	0.206			344	411	17.76	
3x240	0.0754	0.0981	0.373	0.31	508	621	34.78	30
**	0.125	0.156			400	488	22.98	
1x300	0.0601	0.075	0.359	0.33	571	708	43.41	30
**	0.100	0.125			450	557	28.67	
1x400	0.047	0.059	0.353	0.37	602	811	57.79	30
**	0.0778	0.098			486	645	38.14	

Technical parameters of cables - XLPE - 24kV - 3 phase

Cross section area of cable (mm^2)	Core resistance		Self induction coefficient (mH/km)	Capacitance of cable (μF/km)	Rated current in earth at 20°C (A)	Rated current in air at 30°C (A)	Nominal short circuit current at 1 s (kA)	Test voltage (kV/5 minutes)
	DC at 20°C (Ω/km)	AC at 90°C (Ω/km)						
3x35	0.524		0.377	0.136	171	173	5.18	30
3x50	0.387		0.362	0.149	202	206	7.36	30
**	0.641				154	161	4.49	
3x70	0.268		0.344	0.169	246	257	10.26	30
**	0.443				191	199	6.81	
3x95	0.193		0.328	0.190	295	313	13.88	30
**	0.320				228	242	9.19	
3x120	0.153		0.318	0.206	335	360	17.49	30
**	0.253				260	280	11.58	
3x150	0.124		0.310	0.220	376	410	21.81	30
**	0.206				292	318	14.43	
3x185	0.0991		0.300	0.243	425	459	26.86	30
**	0.164				331	365	17.76	
3x240	0.0754		0.289	0.270	492	553	34.78	30
**	0.125				385	425	22.98	
3x300	0.0601		0.281	0.294	554	629	43.41	30
**	0.01				437	481	28.67	
3x400	0.047		0.273	0.326	625	554	57.79	30
**	0.0778				495	437	38.14	

Underground cables - XLPE - 14kV - 3 phase

Cross section area of cable (mm^2)	Core resistance		Self induction coefficient (mH/km)	Capacitance of cable (μF/km)	Rated current in earth at 20°C (A)	Rated current in air at 30°C (A)	Nominal short circuit current at 1 s (kA)	Test voltage (kV/5 minutes)
	DC at 20°C (Ω/km)	AC at 90°C (Ω/km)						
3x35	0.524	0.668		0.157			5.0	
3x50	0.387	0.494		0.172			7.2	
3x70	0.268	0.342		0.195			10.0	
3x95	0.193	0.247		0.216			13.6	
3x120	0.153	0.196		0.236			17.2	
3x150	0.124	0.159		0.255			21.5	
3x185	0.099	0.127		0.276			26.5	
3x240	0.075	0.098		0.308			34.3	
3x300	0.060	0.079		0.342			42.9	
3x400	0.047	0.063		0.38			57.2	

B - Conversion coefficient of load current of XLPE cables

1. Cable directly buried in earth

Conversion coefficient of cable load carrying capacity according to earth temperature

Earth temperature (°C)	20	25	30	35	40
Conversion coefficient	1.08	1.04	1.00	0.96	0.91

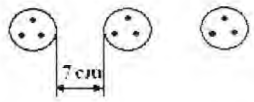
Current conversion coefficient for cable by earth resistivity

Earth resistivity (°C cm/W)	70	100	150	250
Conversion coefficient	1.12	1.0	0.87	0.7

Current conversion coefficient of cable by its buried depth

Depth of cable placement	50	70	100	120	160	200
Conversion coefficient	1.02	1.0	0.98	0.97	0.95	0.94

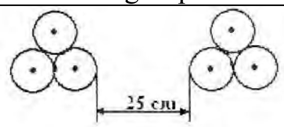
Conversion coefficient for group of multi-core cables

Shape								
Group number	1	2	3	4	5	6	8	10
Conversion coefficient	1.0	0.86	0.76	0.71	0.67	0.64	0.60	0.57

Conversion coefficient for group pf cables arranged on one plane

Shape								
Group number	1	2	3	4	5	6	8	10
Conversion coefficient	1.00	0.87	0.77	0.73	0.70	0.68	0.65	0.63

Conversion coefficient for group one-core cables arranged in triangle

Shape								
Group number	1	2	3	4	5	6	8	10
Conversion coefficient	1.00	0.89	0.82	0.78	0.75	0.73	0.70	0.68

2. Cables placed in air

Conversion coefficient by air temperature

Air temperature (^oC)	20	25	30	35	40	45	50
Conversion coefficient	1.08	1.04	1.00	0.96	0.91	0.87	0.82

Conversion coefficients for one-phase cables arranged on one plane

Distance to wall ≥ 2cm Distance between cables is equal to diameter d of cable		**Number of circuits**			**Picture (trang 95)**
		1	**2**	**3**	
		Conversions coefficient			
Cables buried in earth		**0.92**	**0.89**	**0.88**	
Cables placed on racks	Number of racks				Picture (trang 95)
	1	0.92	0.89	0.88	
	2	0.87	0.84	0.83	
	3	0.84	0.82	0.81	
	6	0.82	0.80	0.79	
Cables placed on racks	Number of racks				Picture (trang 95)
	1	1.00	0.97	0.96	
	2	0.97	0.94	0.93	
	3	0.96	0.93	0.92	
	6	0.94	0.91	0.90	
Arranged near to wall		0.94	0.91	0.89	Picture (trang 95)
Arranged near to wall		0.89	0.86	0.84	Picture (trang 95)

Current conversion coefficient for one phase cables in 3-phase power system and arranged in triangle

Distance to wall ≥ 2cm Distance between cables is equal to 2d of cable		**Number of circuits**			**Picture (trang 96)**
		1	**2**	**3**	
		Conversion coefficient			
Cables buried in earth		**0.95**	**0.90**	**0.88**	
Cables place on racks	Number of racks	0.90	0.90	0.88	Picture
	1	0.85	0.85	0.83	
	2	0.83	0.83	0.81	
	3	0.81	0.81	0.79	
	6				
Cables place on racks	Number of racks	1.00	0.98	0.96	Picture
	1	1.00	0.95	0.93	
	2	1.00	0.94	0.92	
	3	1.00	0.93	0.90	
	6				
Arrangement without conversion of current					**Picture**

Conversion coefficient for single core cables placed on one plane

Distance to wall ≥ 2cm Distance between cables is equal diameter d of cable		Number of circuits					Picture trang 97
		1	2	3	6	9	
		Conversion coefficient					
Cables buried in earth		0.95	0.90	0.88	0.85	0.84	
Cables placed on racks (limited air ventilation)	Number of racks						Picture
	1	0.95	0.90	0.88	0.85	0.84	
	2	0.90	0.85	0.83	0.81	0.80	
	3	0.88	0.83	0.81	0.79	0.78	
	6	0.86	0.81	0.79	0.77	0.76	
Cables placed on racks	Number of racks						Picture
	1	1.00	0.98	0.96	0.93	0.92	
	2	1.00	0.95	0.93	0.90	0.89	
	3	1.00	0.94	0.92	0.89	0.88	
	6	1.00	0.93	0.90	0.87	0.86	
Cables placed near to the wall		1.00	0.93	0.90	0.87	0.86	Picture
Arrangement to ensure load carrying capacity of cables	Distance to wall > 2 cm	Distance between cables > 2d					Picture

Conversion coefficient for one-core aluminum cables arranged on one plane

Cables adjacent to wall		Number of circuits					Picture trang 98
		1	2	3	6	9	
		Conversion coefficient					
Cables placed in ground		0.90	0.84	0.80	0.75	0.73	
Cables placed on racks (limited air ventilation)	Number of support racks						Picture
	1	0.95	0.84	0.80	0.75	0.73	
	2	0.95	0.80	0.76	0.71	0.69	
	3	0.95	0.78	0.74	0.70	0.68	
	6	0.95	0.76	0.72	0.68	0.66	
Cables placed on racks	Number of support racks						Picture
	1	0.95	0.84	0.80	0.75	0.73	
	2	0.95	0.80	0.76	0.71	0.69	
	3	0.95	0.78	0.74	0.70	0.68	
	6	0.95	0.76	0.72	0.68	0.66	
Cables placed on structure or near to wall		0.95	0.78	0.73	0.68	0.66	Picture

Annex II.2.2 (I.3B)

Checking power transmission capacity of conductor

Permissible power transmission current in electrical conductor according to heating conditions by transmission current and solar radiation is calculated in the following formula:

$$I = \sqrt{\frac{\left[h_w + \left(h_r - \frac{W_s}{\pi.\theta}\right).\eta\right]\pi.d.\theta}{R_{20dc}.\beta\left[1+\alpha\left(T+\theta-20\right)\right]}}$$

Where:

I : permissible transmission current (A).

D: External diameter of conductor (cm).

θ: Permissible temperature increase on conductor (°C).

T: Air temperature corresponding to time point of checking transmission capacity and highest air temperature id selected.

α: Index of resistance increased by temperature (1/ °C).

R20dc: Conductor resistance is 20°C for DC current (Ω/cm)

Ws: Solar radiation (W/cm)

η: Thermal generation index (0.9).

β: Ratio of AC resistance to DC resistance

v: Calculated wind speed (m/s)

hw: Convection heat dissipation factor calculated by experimental Rice formula as follows:

$$hw = 0.000572.\frac{\sqrt{\frac{v}{d}}}{\left(273+T+\frac{\theta}{2}\right)^{0.123}} \quad \text{(W/ °C . cm2)}$$

hr: Radiation heat dissipation factor (Stefan-Boltzmann law) calculated by the following formula:

$$hr = 0.000567.\frac{\left(\frac{273+T+\theta}{100}\right)^4 - \left(\frac{273+T}{100}\right)^4}{\theta} \quad \text{(W/ °C . cm2)}$$

The values selected for calculation

1. Solar radiation energy: referring calculation data of countries in the region:

   Ws = 0.1 W/cm2

2. Calculation wind speed:

   v = 0.6 m/s

3. Air temperature T is dependent on the time of checking permissible transmission current. In order to check permissible transmission current in the most unfavorable conditions, the air temperature of T = 40°C is selected as the highest air temperature, suitable forVietnam conditions.

4. Resistance increase factor due to temperature depends on material of conductor

   1) For steel core aluminum conductor: $\alpha = 0.00403$
   2) For steel core aluminum alloy conductor: $\alpha = 0.00360$
   3) For copper conductor: $\alpha = 0.00393$

5. Ratio β between AC resistance and DC resistance can be refer to values given in Table 1 for normal steel core aluminum conductor.

6. Permissible temperature increase on conductor θ depends on permissible temperature on conductor and air temperature T(= 40°C inVietnam conditions).

   1) For steel core aluminum conductor, steel core aluminum alloy: permissible temperature on conductor can reach 90°C in normal conditions, that means:

   θ = 90°C - 40°C = 50°C

   2) For thermal superconductor (TAL): permissible temperature of conductor can reach 150 degrees Celsius in normal operation conditions, that means:

   θ = 150°C - 40°C = 110°C

   3) For thermal extra-super conductor (ZTAL): permissible temperature of conductor can reach 210°C in normal operation conditions, that means:

   θ = 210°C - 40°C = 170°C

The power transmission capacity of conductor depends very much on constraint conditions at the time of test. For example, if test is carried out in night time, the air temperature is 25°C, solar radiation energy is Ws = 0, transmission capacity of conductor is significantly increased compared with test in daytime.

Table 1 Ratio AC /DC (RAC /RDC) of reinforced steel core aluminum conductor (ACSR type)

Temperature [°C]	60		70		80		90		RDC at 20 °C [Ohm/km]
Frequency [Hz]	50	60	50	60	50	60	50	60	
240mm^2 RAC /RDC	1.002	1.003	1.002	1.003	1.002	1.003	1.002	1.002	0.1200
330mm^2 RAC /RDC	1.004	1.006	1.004	1.006	1.004	1.005	1.004	1.005	0.0888
410mm^2 RAC /RDC	1.007	1.010	1.006	1.009	1.006	1.009	1.006	1.008	0.0702
610mm^2 RAC /RDC	1.032	1.039	1.041	1.048	1.045	1.052	1.048	1.055	0.0474
810mm^2 RAC /RDC	1.048	1.063	1.056	1.070	1.060	1.073	1.061	1.074	0.0356
Temperature [°C]	100		110		120				RDC at 20°C [Ohm/km]
Frequency [Hz]	50	60	50	60	50	60			
240mm^2 RAC /RDC	1.002	1.002	1.002	1.002	1.001	1.002			0.1200
330mm^2 RAC /RDC	1.003	1.005	1.003	1.004	1.003	1.004			0.0888
410mm^2 RAC /RDC	1.005	1.008	1.005	1.007	1.005	1.007			0.0702
610mm^2 RAC /RDC	1.050	1.055	1.051	1.056	1.052	1.057			0.0474
810mm^2 RAC /RDC	1.062	1.074	1.063	1.074	1.063	1.074			0.0356

Annex II.2.3 (I.3C)

Selection of lightning conductor

Lightning conductors are selected to mainly meeting thermal stability conditions when one phase short circuit happens. Permissible short circuit current in lightning conductor is calculated in the following formula:

$$I = \frac{K.S}{\sqrt{t}}$$

Where:

I: Permissible short circuit current.

t: time of short circuit

S: cross sectional area of lightning conductor (mm^2).

K: constant dependent on material of lightning conductor:

For steel core aluminum conductor: k = 93.

For zinc galvanized conductor: k = 56.

For aluminum covered conductor: k= 91-117.

The above conductors are usually used as lightning conductors in combination with optical fiber cables.

Lightning conductor's capability to thermally stabilize when short circuit of one phase is compared to $k.A^2.s$.

e.g. permissible short circuit in lightning conductor is calculated equal to I = 10 kA, duration of short circuit is t = 0.5 s, thermal withstanding capacity of lightning conductor will be:

$$(10kA)^2.0.5s = 50\ kA^2.s$$

in practice, diagrams can be used for calculating permissible instantaneous current and comparing it with short circuit current $I_N^{(1)}$ of one phase of power system in one check location. The thermal stability is ensured when $I \leq I_N^{(1)}$.

Instantaneous permissible current of steel core conductor

Electric current intensity (kA)

Cross section area (mm^2)

Time (s) / Cross section area	0.1	0.2	0.3	0.4	0.5	0.6	0.7
0	0.00	0.00	0.00	0.00	0.00	0.000	0.00
10	1.77	1.25	1.02	0.89	0.79	0.72	0.67
20	3.54	2.50	2.04	1.77	1.58	1.45	1.34
30	5.31	3.76	3.07	2.66	2.38	2.17	2.01
40	7.08	5.01	4.09	3.54	3.17	2.89	2.68
50	8.85	6.26	5.11	4.43	3.96	3.61	3.35
60	10.63	7.51	6.13	5.31	4.75	4.34	4.02
70	12.40	8.77	7.16	6.20	5.54	5.06	4.69
80	14.17	10.02	8.18	7.08	6.34	5.78	5.35
90	15.94	11.27	9.20	7.97	7.13	6.51	6.02
100	17.71	12.52	10.22	8.85	7.92	7.23	6.69
110	19.48	13.77	11.25	9.74	8.71	7.95	7.36
120	21.25	15.03	12.27	10.63	9.50	8.68	8.03
130	23.02	16.28	13.29	11.51	10.30	9.40	8.70
140	24.79	17.53	14.31	12.40	11.09	10.12	9.37
150	26.56	18.78	15.34	13.28	11.88	10.84	10.04
160	28.33	20.04	16.36	14.17	12.67	11.57	10.71
170	30.10	21.29	17.38	15.05	13.46	12.29	11.38
180	31.88	22.54	18.40	15.94	14.26	13.01	12.05
190	33.65	23.79	19.43	16.82	15.05	13.74	12.72
200	35.42	25.04	20.45	17.71	15.84	14.46	13.39

Values of instantaneous currents (kA)

Instantaneous permissible current of steel core aluminum conductor and aluminum covered steel conductor

Electric current intensity (kA)

Cross section area (mm^2)

Time (s) / Cross section area	0.1	0.2	0.3	0.4	0.5	0.6	0.7
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	2.94	2.08	1.70	1.47	1.32	1.20	1.11
20	5.88	4.16	3.40	2.94	2.63	2.40	2.22
30	8.82	6.24	5.09	4.41	3.95	3.60	3.33
40	11.76	8.32	6.79	5.88	5.26	4.80	4.45
50	14.70	10.40	8.49	7.35	6.58	6.00	5.56
60	17.65	12.48	10.19	8.82	7.89	7.20	6.67
70	20.59	14.56	11.89	10.29	9.21	8.40	7.78
80	23.53	16.64	13.58	11.76	10.52	9.60	8.89
90	26.47	18.72	15.28	13.23	11.84	10.81	10.00
100	29.41	20.80	16.98	14.70	13.15	12.01	11.12
110	32.35	22.87	18.68	16.18	14.47	13.21	12.23
120	35.29	24.95	20.38	17.65	15.78	14.41	13.34
130	38.23	27.03	22.07	19.12	17.10	15.61	14.45
140	41.17	29.11	23.77	20.59	18.41	16.81	15.56
150	44.11	31.19	25.47	22.06	19.73	14.01	16.67
160	47.05	33.27	27.17	23.53	21.04	19.21	17.79
170	50.00	35.35	28.86	25.00	22.36	20.41	18.90
180	52.94	37.43	30.56	26.47	23.67	21.61	20.01
190	55.88	39.51	32.26	27.94	24.99	22.81	21.12
200	58.82	41.59	33.96	29.41	26.30	24.01	22.23

Values of instantaneous currents (kA)

Annex III.1 (II.1)

IP code

Coding system is a system presenting protection level provided by a component which shields against contact with dangerous parts, penetration of solid matters or water from outside and additional information of protection.

IP arrangement

For instance: IP 23CH — IP 2 3 C H

Coded letters
(International protection) — IP

First characteristic number
(from 0 to 6, or letter X) — 2

Second characteristic number
(from 0 to 8, or letter X) — 3

Auxiliary letter (freely selected)
(Alphabets:A, B, C, D) — C

Additional letter (freely selected)
(Alphabets: H, M, S, W) — H

- If indication of characteristic numbers, these numbers can be replaced by letter "X". (or can be replaced by letter "XX" if omitted two characteristics)
- Auxiliary and additional letters can be omitted without replacement with letters.
- If more additional letters used, alphabetical order must be applied.
- If a shielding component generated different protection levels for different arrangement, corresponding protection levels must be indicated by manufacturers in documents related to installation and arrangement.

Elements of IP code and their meanings

Table II.1 Brief description of elements of IP code

Element	Number or letter	Meaning for protection of equipment	Meaning for protection of persons
Coded capital letters	IP	-	-
The first characteri-stics letter	 0 1 2 3 4 5 6 7 8	Preventing water penetration: - Not protected - Water vertically falling - Water falling with angle of 15^o. - Jet water in small drops - Jet water in rain form - Jet water in ray form - Pressured water jet - Temporary submerse in water - Permanent submerse in water	-
Auxiliary Letter (freely selected)	 A B C D	-	Protection against contact to dangerous parts: - By hand arch - Fingers - Tools - Rope
Additional Letter (freely selected)	 H M S W	Additional information for: - High pressure equipment - Movable during water testing - Fixed during water testing - Weather conditions	

Annex III.3 (II.4)

Annex III.3.1 (II.4.1)

Table III.3.1-1 Conductor sag and deviation due to wind of cable 4x95mm^2 with pulling force of 2.75kN at head of pole

Pole span, m	Sag, m										Deviation (a) due to wind m
	Temperature, ^oC										
	5	10	15	20	25	30	35	40	-5	80	
18	0.20	0.20	0.21	0.22	0.23	0.24	0.24	0.25	0.18	0.30	0.22
20	0.24	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.22	0.38	0.28
22	0.29	0.31	0.32	0.33	0.34	0.35	0.36	0.38	0.26	0.45	0.34
24	0.35	0.36	0.38	0.39	0.41	0.42	0.43	0.45	0.31	0.65	0.39
26	0.41	0.43	0.44	0.46	0.48	0.49	0.51	0.52	0.37	0.63	0.47
28	0.47	0.49	0.52	0.54	0.55	0.57	0.59	0.61	0.43	0.74	0.54
30	0.54	0.57	0.59	0.61	0.64	0.66	0.68	0.70	0.49	0.84	0.62
32	0.62	0.65	0.67	0.70	0.72	0.75	0.77	0.80	0.56	0.96	0.70
34	0.70	0.73	0.76	0.79	0.82	0.84	0.87	0.90	0.63	1.08	0.79
35	0.74	0.77	0.81	0.84	0.87	0.90	0.92	0.95	0.67	1.15	0.84
36	0.78	0.82	0.85	0.88	0.92	0.95	0.98	1.01	0.71	1.22	0.89
38	0.87	0.91	0.95	0.99	1.02	1.06	1.09	1.12	0.79	1.36	0.99
40	0.97	1.01	1.05	1.09	1.13	1.17	1.21	1.24	0.97	1.50	1.10
42	1.07	1.11	1.16	1.20	1.25	1.29	1.33	1.37	0.96	1.66	1.21
44	1.17	1.22	1.27	1.32	1.37	1.42	1.46	1.50	1.06	1.82	1.34
46	1.28	1.34	1.39	1.45	1.50	1.55	1.60	1.64	1.16	1.99	1.46
48	1.39	1.45	1.52	1.57	1.63	1.69	1.74	1.79	1.26	2.17	1.59
50	1.51	1.58	1.64	1.71	1.77	1.83	1.89	1.94	1.37	2.35	1.72
52	1.63	1.71	1.78	185	1.91	1.98	2.04	2.10	1.48	2.54	1.86
54	1.76	1.84	1.92	1.99	2.06	2.13	2.20	2.27	1.59	2.74	2.01
56	1.90	1.98	2.06	2.14	2.22	2.30	2.37	2.44	1.71	2.95	2.16
58	2.03	2.13	2.21	2.30	2.38	2.46	2.54	2.62	1.84	3.16	2.32
60	2.18	2.27	2.37	2.46	2.55	2.64	2.72	2.80	1.97	3.39	2.48
62	2.32	2.43	2.53	2.63	2.72	2.82	2.90	2.99	2.10	3.62	2.65
64	2.48	2.59	2.70	2.80	2.90	3.00	3.10	3.19	2.24	3.86	2.83
66	2.63	2.75	2.87	2.98	3.09	3.19	3.29	3.39	2.38	4.10	3.01
68	2.80	2.92	3.05	3.16	3.28	3.39	3.50	3.60	2.53	4.36	3.19
70	2.96	3.10	3.23	3.35	3.47	3.59	3.71	3.82	2.68	4.62	3.38

Table III.3.1-2 Conductor sag and deviation due to wind of cable 4x95mm^2 with pulling force of 4kN at head of pole

Pole span, m	Sag, m										Deviation (a) due to wind m
	Temperature, ^{o}C										
	5	10	15	20	25	30	35	40	-5	80	
26	0.28	0.30	0.31	0.33	0.34	0.36	0.37	0.38	0.25	0.47	0.34
28	0.33	0.35	0.36	0.38	0.40	0.41	0.43	0.44	0.29	0.55	0.39
30	0.38	0.40	0.42	0.44	0.46	0.47	0.49	0.51	0.34	0.63	0.45
32	0.43	0.45	0.48	0.50	0.52	0.54	0.56	0.58	0.38	0.71	0.52
34	0.49	0.51	0.54	0.56	0.59	0.61	0.63	0.65	0.43	0.80	0.58
36	0.55	0.57	0.60	0.63	0.66	0.68	0.71	0.73	0.48	0.90	0.65
38	0.61	0.64	0.67	0.70	0.73	0.76	0.79	0.81	0.54	1.00	0.73
40	0.67	0.71	0.74	0.78	0.81	0.84	0.87	0.90	0.60	1.11	0.80
42	0.74	0.78	0.82	0.86	0.89	0.93	0.96	0.99	0.66	1.23	0.88
44	0.52	0.86	0.90	0.94	0.98	1.02	1.06	1.09	0.72	1.35	0.98
45	0.85	0.90	0.94	0.99	1.03	1.07	1.10	1.14	0.76	1.41	1.02
46	0.89	0.94	0.99	1.03	1.07	1.11	1.15	1.19	0.79	1.47	1.07
48	0.97	1.02	1.07	1.12	1.17	1.21	1.26	1.30	0.86	1.60	1.16
50	1.05	1.11	1.16	1.22	1.27	1.32	1.36	1.41	0.93	1.74	1.25
52	1.14	1.20	1.26	1.32	1.37	1.42	1.48	1.53	1.01	1.88	1.36
54	1.23	1.29	1.36	1.42	1.48	1.54	1.59	1.64	1.09	2.02	1.47
56	1.32	1.39	1.46	1.53	1.59	1.65	1.71	1.77	1.17	2.18	1.59
58	1.42	1.50	1.57	1.64	1.71	1.77	1.84	1.90	1.26	2.4	1.70
60	1.52	1.60	1.68	1.75	1.83	1.90	1.97	2.03	1.35	2.51	1.81
62	1.62	1.71	1.79	1.87	1.95	2.03	2.10	2.17	1.44	2.68	1.93
64	1.73	1.82	1.91	2.00	2.08	2.16	2.24	2.31	1.53	2.86	2.06
66	1.84	1.94	2.03	2.12	2.21	2.30	2.38	2.46	1.63	3.04	2.20
68	1.95	2.06	2.16	2.25	2.35	2.44	2.53	2.61	1.73	3.23	2.33
70	2.07	2.18	2.29	2.39	2.49	2.59	2.68	2.77	1.83	3.42	2.47
72	2.19	2.31	2.42	2.53	2.63	2.74	2.83	2.93	1.94	3.62	2.61
74	2.31	2.44	2.56	2.67	2.78	2.89	2.99	3.10	2.05	3.82	2.76
76	2.44	2.57	2.70	2.82	2.93	3.05	3.16	3.27	2.16	4.03	2.91
78	2.57	2.71	2.84	2.97	3.09	3.21	3.33	3.44	2.28	4.24	3.07
80	2.70	2.85	2.90	3.12	3.25	3.38	3.50	3.62	2.39	4.47	3.24

Table III.3.1-3 Conductor sag and deviation due to wind of cable 4x95mm² with pulling force of 5kN at head of pole

Pole span, m	Sag, m										Deviation (a) due to wind m
	Temperature, °C										
	5	10	15	20	25	30	35	40	-5	80	
38	0.49	0.50	0.52	0.63	0.66	0.56	0.57	0.50	0.46	0.68	0.53
40	0.54	0.56	0.57	0.59	0.60	0.62	0.64	0.65	0.51	0.76	0.57
42	0.60	0.61	0.63	0.65	0.67	0.68	0.70	0.72	0.56	0.84	0.62
44	0.65	0.67	0.69	0.71	0.73	0.75	0.77	0.79	0.61	0.92	0.69
46	0.71	0.74	0.76	0.78	0.80	0.82	0.84	0.86	0.67	1.00	0.75
48	0.78	0.80	0.83	0.85	0.87	0.89	0.91	0.94	0.73	1.09	0.82
50	0.84	0.87	0.90	0.92	0.95	0.97	0.99	1.02	0.79	1.19	0.88
52	0.91	0.94	0.97	1.00	1.02	1.05	1.07	1.10	0.85	1.28	0.96
54	0.98	1.02	1.05	1.07	1.10	1.13	1.16	1.18	0.92	1.38	1.03
56	1.06	1.09	1.12	1.16	1.19	1.22	1.25	1.27	0.99	1.49	1.11
58	1.14	1.17	1.21	1.24	1.27	1.30	1.34	1.37	1.06	1.60	1.20
60	1.22	1.25	1.29	1.33	1.36	1.40	1.43	1.46	1.14	1.71	1.28
62	1.30	1.34	1.38	1.42	1.45	1.49	1.53	1.56	1.21	1.82	1.37
64	1.38	1.43	1.47	1.51	1.55	1.59	1.63	1.66	1.29	1.94	1.46
66	1.47	1.52	1.56	1.61	1.65	1.69	1.73	1.77	1.38	2.07	1.55
68	1.56	1.61	1.66	1.70	1.75	1.79	1.84	1.88	1.46	2.19	1.65
70	1.65	1.71	1.76	1.81	1.85	1.90	1.95	1.99	1.55	2.32	1.75
72	1.75	1.81	1.86	1.91	1.96	2.01	2.06	2.11	1.64	2.46	1.84
74	1.85	1.91	1.96	2.02	2.07	2.12	2.18	2.23	1.73	2.60	2.95
76	1.90	1.96	2.02	2.07	2.13	2.18	2.24	2.29	1.78	2.67	2.00
78	1.95	2.01	2.07	2.13	2.19	2.245	2.30	2.35	1.82	2.74	2.06
	2.06	2.12	2.18	2.24	2.30	2.36	2.42	2.47	1.92	2.89	2.17
80	2.16	2.23	2.30	2.36	2.42	2.48	2.54	2.60	2.02	3.04	2.28
82	2.27	2.34	2.41	2.48	2.54	2.61	2.67	2.73	2.12	3.19	2.39
84	2.38	2.46	2.53	2.60	2.67	2.74	2.80	2.87	2.23	3.35	2.52
86	2.50	2.58	2.65	2.73	2.80	2.87	2.94	3.01	2.34	3.51	2.64
88	2.62	2.70	2.78	2.86	2.93	3.01	3.08	3.15	2.45	3.68	2.76

Table III.3.1-3 (continued)

Pole span, m	Sag, m										Deviation (a) due to wind m
	Temperature, °C										
	5	10	15	20	25	30	35	40	-5	80	
90	2.74	2.82	2.91	2.99	3.07	3.14	3.22	3.30	2.56	3.85	2.88
92	2.86	2.95	3.04	3.12	3.20	3.29	3.37	3.44	2.67	4.02	3.02
94	2.99	3.09	3.18	3.27	3.35	3.44	3.52	3.60	2.80	4.20	3.15
96	3.12	3.22	3.32	3.41	3.50	3.59	3.67	3.76	2.92	4.38	3.29
98	3.26	3.36	3.46	3.55	3.65	3.74	3.83	3.92	3.05	4.57	3.43
100	3.39	3.50	3.60	3.70	3.80	3.89	3.99	4.08	3.17	4.76	3.56
102	3.53	3.64	3.74	3.85	3.95	4.05	4.15	4.24	3.30	4.95	3.71
104	3.67	3.78	3.89	4.00	4.11	4.21	4.31	4.41	3.43	5.15	3.86
106	3.81	3.93	4.04	4.16	4.27	4.37	4.48	4.58	3.56	5.35	4.01
108	3.95	4.08	4.20	4.31	4.43	4.54	4.65	4.76	3.70	5.55	4.16
110	4.10	4.23	4.35	4.48	4.60	4.71	4.83	4.94	3.84	5.76	4.32
112	4.25	4.39	4.52	4.64	4.76	4.89	5.00	5.12	3.98	5.97	4.47
114	4.41	4.54	4.68	4.81	4.94	5.06	5.18	5.30	4.12	6.19	4.64
116	4.56	4.71	4.84	4.98	5.11	5.24	5.37	5.49	4.27	6.41	5.80
118	4.72	4.87	5.01	5.15	5.29	5.42	5.56	5.68	4.42	6.63	4.97
120	4.88	5.04	5.18	5.33	5.47	5.61	5.75	5.88	4.57	6.86	5.15
122	5.05	5.21	5.36	5.51	5.66	5.80	5.94	6.08	4.72	7.09	5.32
124	5.22	5.38	5.54	5.69	5.84	5.99	6.14	6.28	4.88	7.33	5.49
126	5.39	5.55	5.72	5.88	6.03	6.19	6.34	6.48	5.04	7.57	5.67
128	5.56	5.73	5.90	6.07	6.23	6.39	6.54	6.69	5.20	7.81	5.85
130	5.73	5.91	6.09	6.26	6.42	6.59	6.75	6.90	5.36	8.06	6.04
132	5.91	6.10	6.28	6.45	6.62	6.79	6.96	7.12	5.53	8.31	6.23
134	6.09	6.28	6.47	6.65	6.83	7.00	7.17	7.34	5.70	8.57	6.47
136	6.28	6.47	6.66	6.85	7.03	7.21	7.39	7.56	5.87	8.82	6.65
138	6.46	6.67	6.86	7.05	7.24	7.43	7.61	7.78	6.05	9.09	7.86
140	6.65	6.68	7.06	7.26	7.45	7.64	7.83	8.01	6.22	9.35	7.06

Annex III.3.2 (II.4.2)

Table III.3.2-1 Technical data of twisted conductor (aluminum conductor) cables

Parameter	Unit	Nominal cross section area of conductor,mm^2							
		16	**25**	**35**	**50**	**70**	**95**	**120**	**150**
Number of cores		2/4	2/3/4	2/3/4	2/3/4	4	2/4	4	4
Conductor type		Round area, stranded and pressed							
Number of aluminum fibers in one core		7	7	7	7	19$^{(*)}$	19$^{(*)}$	19$^{(*)}$	19$^{(*)}$
Minimal diameter of core	mm	4.5	5.8	6.8	8.0	9.6	11.3	12.8	14.1
Maximal diameter of core	mm	4.8	6.1	7.2	8.4	10.1	11.9	13.5	14.9
Maximal DC resistance of conductor at 20 ^{o}C	Ω/km	1.910	1.200	0.868	0.641	0.443	0.320	0.253	0.206
Minimal breaking force (LKD)	kN	2.2	3.5	4.9	7.0	9.8	13.3	16.8	21.0
Minimal average thickness of insulation (measured at normal point)	mm	1.3	1.3	1.3	1.5	1.5	1.7	1.7	1.7
Minimal thickness of insulation (measured at any point)	mm	1.07	1.07	1.07	1.25	1.25	1.43	1.43	1.43
Maximal thickness of insulation (measured at any point)	mm	1.9	1.9	1.9	2.1	2.1	2.3	2.3	2.3
Maximal diameter of conductor (not included protruded part)	mm	7.9	9.2	10.3	11.9	13.6	15.9	17.5	18.9
Minimal load for insulation adhesion -X-90&X-FP-90 - for X-FP-90	 kg kg	 + +	 + +	 + +	 100 +	 140 +	 190 110	 240 +	 300 +

Notes: (*): Permissible tolerance of 1 for aluminum conductor; “+”: not determined yet

Table III.3.2-2 Technical data of 2-core, 3-core, aluminum conductor cable

Parameter	Unit	Nominal cross section area of conductor, mm^2							
		16	**25**	**35**	**50**	**95**	**25**	**35**	**50**
Number of cores		2	2	2	2	2	3	3	3
Maximal calculated diameter of cable	mm	15.8	18.4	20.6	23.8	31.8	19.8	22.2	25.6
Specific weight of cable (approximate)	kg/m	0.14	0.20	0.26	0.35	0.68	0.30	0.39	0.53
Maximal AC resistance of conductor at 180 ^oC	Ω/km	2.37	1.49	1.08	0.796	0.398	1.49	1.08	0.796
Positive sequence reactance(1) of cable at 50 Hz	Ω/km	0.094	0.088	0.085	0.084	0.078	0.088	0.085	0.084
Maximal continuous working temperature	^oC	80	80	80	80	80	80	80	80
Maximal continuous working current	A	96	125	155	185	285	105	125	150
Minimal breaking load of cable (LKD)	kN	4.4	7.0	9.8	14.0	2606	10.5	14.7	21.0
Elasticity module	GPa	59	59	59	59	59	59	59	59
Longitudinal expansion coefficient	$10^{-6}/^oC$	23	23	23	23	23	23	23	23
Minimal bending radius of conductor	Mm	30	40	60	70	95	40	60	70
Minimal bending radius of cable	mm	95	110	125	145	285	120	135	155
Maximal value of maximal working tensile force(2) (28% of LKD)	kN	1.23	1.96	2.74	3.92	7.45	2.94	4.12	5.88
Maximal value of normal tensile force (18% of LKD)	kN	0.79	1.26	1.76	2.52	4.79	1.89	2.65	3.78

Notes: (1) In most cases, this value is used for zero sequence reactance.
(2) For most projects, lower values can be used.

Table III.3.2-3 Technical data of 4-core, aluminum conductor cable

Parameter	Unit	Nominal cross section area of conductor,mm²							
		16	**25**	**35**	**50**	**70**	**95**	**120**	**150**
Number of cores		4	4	4	4	4	4	4	4
Maximal calculated diameter of cable	mm	19.1	22.2	24.9	28.7	32.8	38.4	42.2	45.6
Specific weight of cable (approximate)	kg/m	0.28	0.40	0.52	0.70	0.96	1.35	1.66	2.02
Maximal AC resistance of conductor at 180 ^{o}C	Ω/km	2.37	1.49	1.08	0.796	0.551	0.398	0.315	0.257
Positive sequence reactance(1) of cable at 50 Hz	Ω/km	0.102	0.095	0.092	0.092	0.086	0.085	0.084	0.082
Maximal continuous working temperature	^{0}C	80	80	80	80	80	80	80	80
Maximal continuous working current	A	78	105	125	150	185	225	260	285
Minimal breaking load of cable (LKD)	kN	8.8	14.0	19.6	28.0	39.2	53.2	67.2	84.0
Elasticity module	GPa	59	59	59	59	56	56	56	56
Longitudinal expansion coefficient	$10^{-6}/^{0}C$	23	23	23	23	23	23	23	23
Minimal bending radius of conductor	mm	30	40	60	70	80	95	105	115
Minimal bending radius of cable	mm	115	135	150	160	285	345	380	410
Maximal value of maximal working tensile force(2) (28% of LKD)	kN	2.46	3.92	5.49	7.84	11.0	14.9	18.8	3.5
Maximal value of normal tensile force (18% of LKD)	kN	1.58	2.52	3.53	5.00	7.10	9.60	12.1	15.1

Notes: (1) In most cases, this value is used for zero sequence reactance.

(2) For most projects, lower values can be used.

Table III.3.2-4 Main technical data of twisted cable, force bearing neutral , aluminum conductor

Nominal cross section area	Conductor					Average thickness of insulation sheath	Core	
	Number of fibres	Resistivity at 20 °C	Diameter of conductor		Minimal breaking force		Outer diameter	
			Minimal	Maximal			Minimal	Maximal
mm^2		Ω/km	mm	mm	daN	mm	mm	mm
1. Phase conductor								
25	7	1.200	5.8	6.3	300	1.4	8.6	9.4
35	7	0.868	6.8	7.3	420	1.6	10.0	10.9
50	7	0.641	7.9	8.4	600	1.6	11.1	12.0
70	12	0.443	9.7	10.2	840	1.8	13.3	14.2
95	19	0.320	11.0	12.2	1140	1.8	14.6	15.7
120	19	0.252	12.0	13.1	1440	1.8	15.6	16.7
150	19	0.206	13.9	15.0	1800	1.7	17.3	18.6
2. Force bearing neutral conductor								
54.6	7	0.630	9.2	9.6	1660	1.6	12.3	13.0
70	7	0.500	10.0	10.2	2050	1.5	12.9	13.6
95	19	0.343	12.2	12.2	2750	1.6	15.3	16.3

Annex III.3.3 (II.4.3)

Table III.3.3-1 Conductor tension, sag of twisted cable, Aluminum conductor 4x25mm^2

Pole span, m	Conductor sag at ambient temperature, cm			
	0 ^{0}C	20 ^{0}C	30 ^{0}C	40 ^{0}C
Stretching stress 30 N/mm^2				
20	16	29	34	38
30	35	50	57	63
40	68	84	92	99
50	110	127	135	144
60	163	180	188	196
Stretching stress 40 N/mm^2				
20	11	24	30	35
30	23	40	48	54
40	42	63	72	80
50	73	95	105	114
60	112	135	145	155
Stretching stress 60 N/mm^2				
20	6	15	21	27
30	13	27	35	43
40	22	41	51	61
50	34	56	69	80
60	54	81	94	107

Table III.3.3-2 Conductor tension, sag of twisted cable, Aluminum conductor 4x35mm^2

Pole span, m	Conductor sag at ambient temperature, cm			
	0^0C	20^0C	30^0C	40^0C
Stretching stress 30 N/mm^2				
20	16	28	33	38
30	29	46	53	59
40	52	71	80	87
50	87	107	116	125
60	126	149	159	168
Stretching stress 40 N/mm^2				
20	11	24	30	35
30	22	39	47	54
40	35	56	66	75
50	55	80	92	102
60	86	113	124	136
Stretching stress 60 N/mm^2				
20	05	14	21	27
30	12	26	35	43
40	21	39	50	60
50	32	54	85	98
60	44	71	137	153

Table III.3.3-3 Conductor tension, sag of twisted cable, Aluminum conductor 4x50mm2

Pole span, m	Conductor sag at ambient temperature, cm			
	0^0C	20^0C	30^0C	40^0C
Stretching stress 30 N/mm^2				
20	16	28	33	38
30	29	46	53	59
40	52	71	80	87
50	87	107	116	125
60	126	149	159	168
Stretching stress 40 N/mm^2				
20	11	24	30	35
30	22	39	47	54
40	35	56	66	75
50	55	80	92	102
60	86	113	124	136
Stretching stress 60 N/mm^2				
20	05	14	21	27
30	12	26	35	43
40	21	39	50	60
50	32	54	85	98
60	44	71	137	153

Table III.3.3-4 Cable 3x70mm2 + 1x54.6mm2

Pole span, m	Tension force of neutral conductor, daN						
	10°C	15°C	20°C	25°C	30°C	35°C	40°C
10	180	160	140	125	115	105	95
15	195	175	160	150	140	130	120
20	215	200	190	180	170	160	150
25	225	210	200	190	185	180	170
30	225	220	210	200	195	185	180
35	220	210	200	195	190	185	180

Pole span, m	Sag of force bearing neutral conductor, daN						
	10°C	15°C	20°C	25°C	30°C	35°C	40°C
10	8	9	10	11	12	14	15
15	16	17	20	21	23	25	26
20	27	29	31	33	35	37	39
25	40	43	45	47	49	52	54
30	58	61	63	66	68	70	72
35	83	86	88	91	93	96	98
40	108	111	114	117	119	122	125

Table III.3.3-5 Cable 3x70mm2 + 1x70mm2

Pole span, m	Tension force of neutral conductor, daN						
	10°C	15°C	20°C	25°C	30°C	35°C	40°C
10	167	146	129	116	105	97	90
15	193	175	161	148	138	129	122
20	213	198	185	174	164	156	148
25	228	215	204	194	185	177	170
30	240	229	219	211	202	195	183
35	250	240	232	224	216	210	203
40	258	249	242	234	228	222	216

Pole span, m	Sag of force bearing neutral conductor, daN						
	10°C	15°C	20°C	25°C	30°C	35°C	40°C
10	9	10	11	13	14	15	16
15	17	19	21	22	24	26	27
20	28	30	32	34	36	38	40
25	40	43	45	47	50	52	54
30	55	58	60	63	65	68	70
35	72	75	78	81	83	86	89
40	91	94	97	100	103	106	109

Table III.3.3-.6 Cable 3x150mm2 + 1x70mm2

Pole span, m	Tension force of neutral conductor, daN						
	10°C	15°C	20°C	25°C	30°C	35°C	40°C
10	196	179	165	153	142	134	126
15	224	211	199	189	180	172	165
20	244	233	223	215	207	200	193
25	257	248	241	233	227	220	214
30	267	260	253	247	241	236	231
35	273	268	262	257	252	248	243
40	278	274	269	265	261	257	253

Pole span, m	Sag of force bearing neutral conductor, daN						
	10°C	15°C	20°C	25°C	30°C	35°C	40°C
10	12	13	14	16	17	18	19
15	23	24	26	28	29	31	32
20	38	40	41	43	45	46	48
25	56	58	60	62	63	65	67
30	78	80	82	84	86	88	90
35	104	106	108	110	113	115	117
40	133	135	138	140	142	144	147