Category				Document No. SS5-1
Category	Chapter	1	General Provisions	Document No. SS5-1
	Paragraph	4	Prevention of Electric Power Disasters	
	Clause	9	Prevention of Electric Power Disasters	
Title	Installation of fire-extinguishing Equipment (1/2)			

Fire prevention equipment described below should be installed at substations and switching stations.

1. Clearance or a firewall between transformers
As for high-voltage transformers, the clearance should be as follows. If a firewall is installed between transformers, the clearance is not necessary.

Clearance between a Transformer and Other Transformers or Buildings

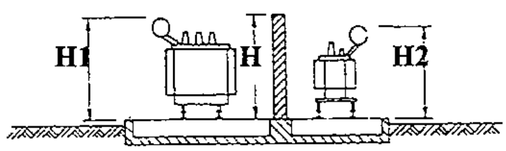
Liquid Volume	With other transformers [m]	With fireproof buildings [m]	With non-fireproof buildings [m]
Over 1,000 L, but not exceeding 2,000 L	3	3	7.6
Over 2,000 L, but not exceeding 20,000 L	5	5	10
Over 20,000 L, but not exceeding 45,000 L	10	10	20
Over 45,000 L	15.2	15.2	30.5

IEC61936-1: Power installations exceeding 1kV a.c. - Part1: Common rules

The firewalls should be installed as follows,
a. The firewalls should be self-supporting and withstand fire for one hour.
b. The height and length are the value shown in following figure.

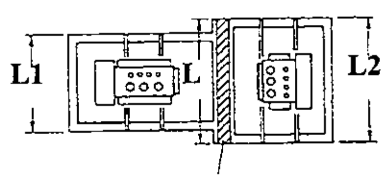
Reference to IEC 619361 Ed1/CVD (IEC TC99)

H: Height



H≧H1 (withH1>H2)

L: Length



L≧L2 (withL2>L1)

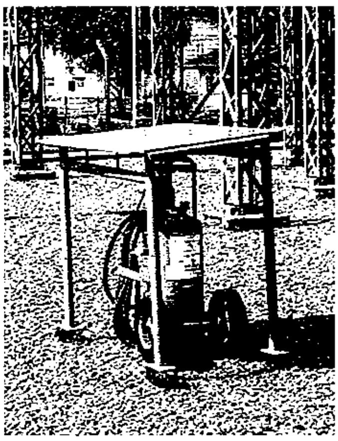
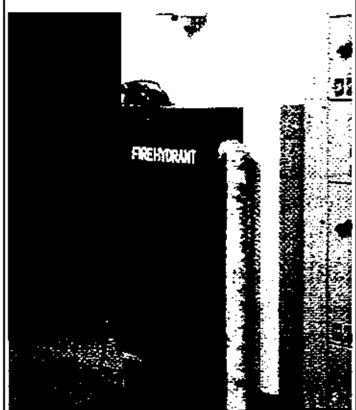
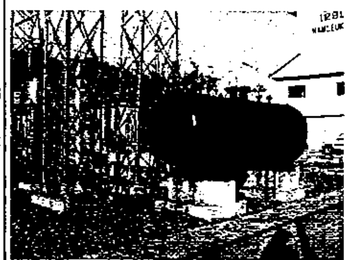
Remarks	Revisions	
	2003/Nov.	Original

Category				Document
Category	Chapter	1	General Provisions	Document No. SS5-2
	Paragraph	4	Prevention of Electric Power Disasters	
	Clause	9	Prevention of Electric Power Disasters	

Title	Installation of fire-extinguishing Equipment (2/2)

2. Appropriate extinguishers

Appropriate fire-extinguishing equipment should be applied according to size and importance of substations.

Fire extinguisher	Hydrant	Sprinkler system
Small-scale fire	Large-scale fire	Transformer
		 

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	1	General Provisions	Document No. SS6-1
	Paragraph	4	Prevention of Electric Power Disasters	
	Clause	9	Prevention of Electric Power Disasters	
Title	Temperature-rise limit of Transformers (1/2)			

The temperature-rise limit of transformers is as follows, according to **IEC 60076-2: Power transformer-Part: Temperature rise.**

Temperature-rise Limits for Oil-immersed Type Transformers

Temperature-rise limit at the top of insulation oil	**60K**
Temperature-rise limit of a winding (Normally measured by the resistance)	**65K**, For transformers identified as ON.. or OF.. **70K**, For transformers identified as OD..

The temperature-rise limits are valid for transformers with solid insulation designed as class A according to IEC 85, and immersed in mineral oil or synthetic liquid with fire point not above 300°C (first code letter:O)

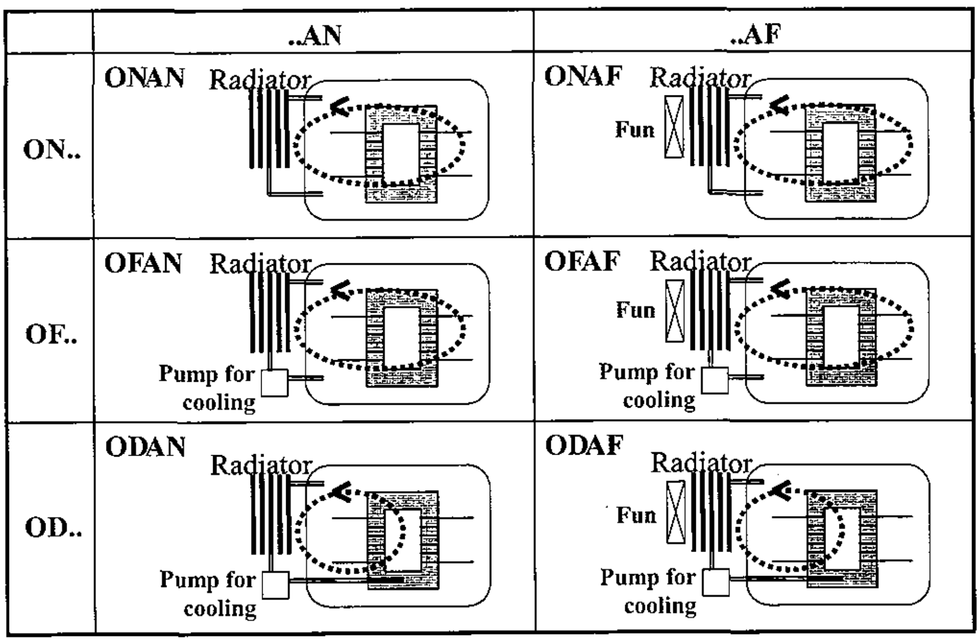
Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	1	General Provisions	Document No. SS6-2
	Paragraph	4	Prevention of Electric Power Disasters	
	Clause	9	Prevention of Electric Power Disasters	
Title	Temperature-rise limit of Transformers (2/2)			

[supplementary explanation]

ONAN: Oil-immersed naturally cooled type,**OFAN**: Forced-oil naturally-cooled type

Order of symbol	Explanation	Symbol	Kind of cooling medium and its circulation mechanism
First letter	Internal cooling medium in contact with winding and core	O	Mineral Oil or synthetic liquid with fire point of 300 ℃ or below.
		A	Air
		G	Gas (e.g. sulfur hexafluoride SF6)
Second letter	Circulation mechanism for internal cooling medium	N	Natural (Natural thermo-siphon flow through cooling equipment and in winding)
		F	Forced circulation through cooling equipment, thermo-siphon flow winding
		D	Forced circulation through cooling equipment, Directed from them into at least the main winding
Third letter	External cooling	A	Air
		W	Water
Fourth letter	Circulation mechanism for external cooling medium	N	Natural convection
		F	Forced circulation (cooling fans, blowers, pumps)



AN : No Fun

ON : Circulation is natural and not forced.

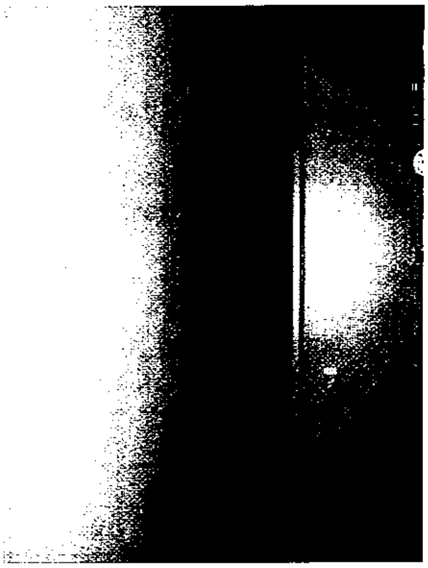
OF : There is a forced circulation system through cooling equipment, but not any forced circulation system into winding.

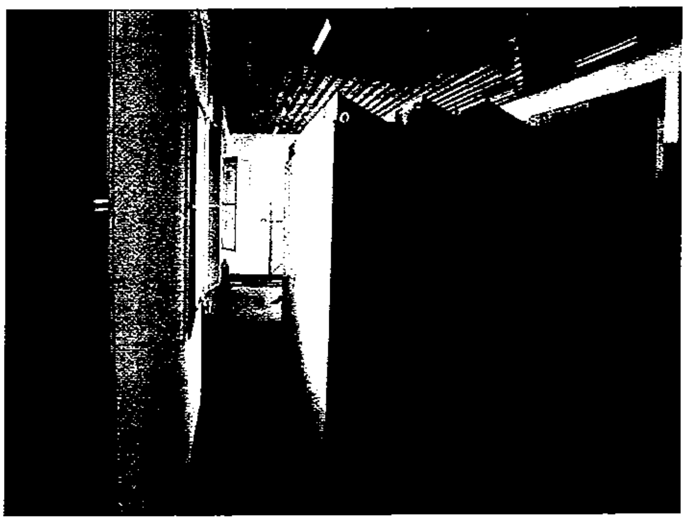
OD : There is not only a forced circulation system through cooling equipment, but also a forced circulation system into winding.

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	1	General Provisions	**Document No. SS7-1**
	Paragraph	4	Prevention of Electric Power Disasters	
	Clause	10	Prevention of Accidents Caused by Electric Power Facilities	
Title	Safety of Personnel (1/3)			

1. Patrol Aisles
   Patrol aisles and other maintenance spaces should be taken to enable operators/workers to operate and safely carry out maintenance.
   Width of an aisle should be 800mm wide or more in accordance with **IEC 61936-1** (behind metal-closed equipment needs 500mm).





Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	1	General Provisions	**Document No.SS7-2**
	Paragraph	4	Prevention of Electric Power Disasters	
	Clause	10	Prevention of Accidents Caused by Electric Power Facilities	
Title	Safety of Personnel (2/3)			

2. Prevention of contact with facilities
   Appropriate measures should be taken to prevent operators/workers from easily contacting live parts of facilities.

   a. Installation of protective fences or walls

   b. Installation of signs at the entrances/exits

   c. Installation of a locking device or another appropriate device at the entrances/exits

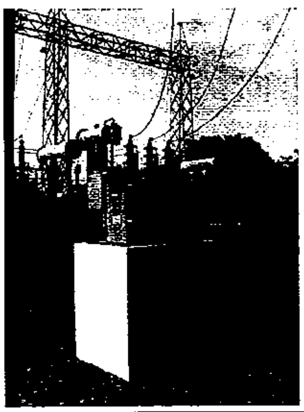
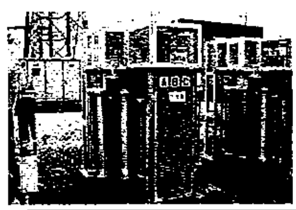
   [Supplementary Explanation of " a. Installation of protective fences or walls "]
   Appropriate measures listed below should be taken where the height of live parts of electrical equipment is N+2,250 mm or less.
   These are based on **IEC 619361 Ed1/CVD (IEC TC99).**

Minimum insulating clearance

Highest voltage for equipment [kV]	Minimum line-to-ground insulating clearance N[mm]
123	1100
245	1900

Distance/clearance from fence or wall to live

Structure of protective fence or wall	Protective barrier clearance [mm]
Wall without opening	N
Fence (Highest Voltage is 52kV or less)	N+80
Fence (Highest Voltage is over 52kV)	N+100

Live parts is higher than N+2,250mm	Live parts is lower than N+2,250mm
HTrB is installed on the stand. 	HTrB is enclosed by the metal-fence 
	Live parts on the HTrB is covered by the wire mesh. 

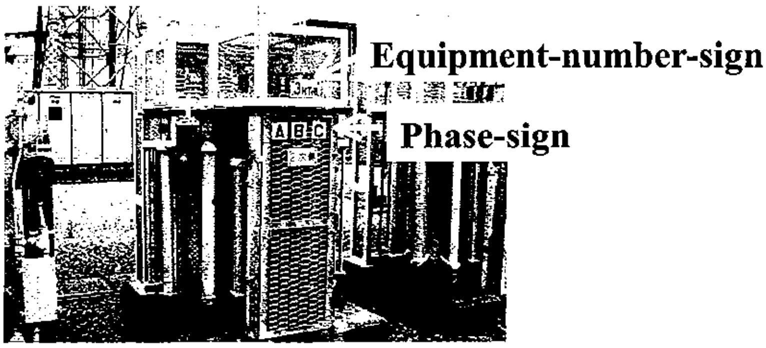
HTrB: Station service transformer

Remarks	Revisions	
	2003/Nov.	Original

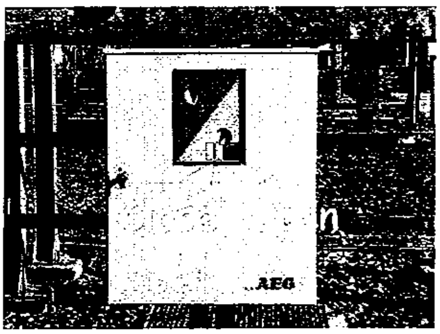
Category	Chapter	1	General Provisions	Document No.SS7-3
	Paragraph	4	Prevention of Electric Power Disasters	
	Clause	10	Prevention of Accidents Caused by Electric Power Facilities	
Title	Safety of Personnel (3/3)			

1. Countermeasures for failures of maintenance
   Appropriate measures should be taken to prevent operators/workers from doing faulty maintenance and/or operation, as follow.

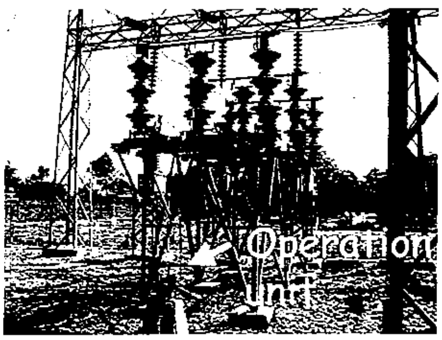
(1) Provision of clear phase-signs and equipment-number-signs



(2) Provision of indicators showing switching status



(3) Provision of interlock system



Remarks	Revisions	
	2003/Nov.	Original

Category				Document No. SS8
	Chapter	1	General Provisions	
	Paragraph	4	Prevention of Electric Power Disasters	
	Clause	11	Safety of Third Persons	

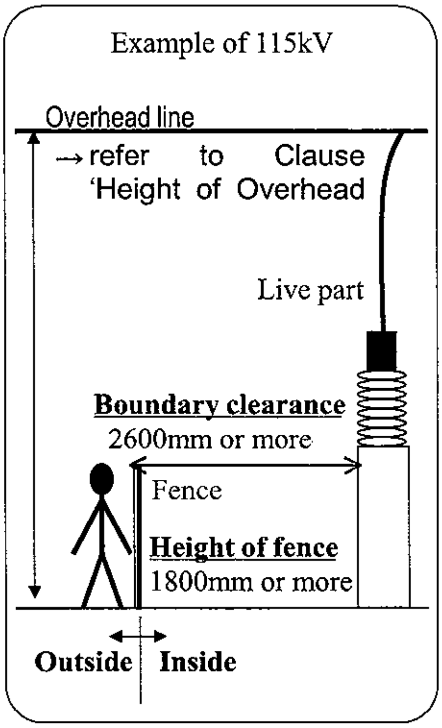
Title	Safety of Third Persons

1. Following measures should be taken to prevent the danger of third persons at substations and switching stations.

(1) External fences and walls

Height of external fences or walls should not be lower than 1,800 mm. Boundary clearance should not be smaller than the values described in following table. These values are base on **IEC 619361 Ed1/CVD (IEC TC99)**.

Nominal voltage [kV]		Boundary clearance [mm]	Minimum line-to-ground insulating clearance N[mm]
160 kV or less	115	Wall: N+1,000	1100
Over 160kV	230	Fence: N+1,500	1900



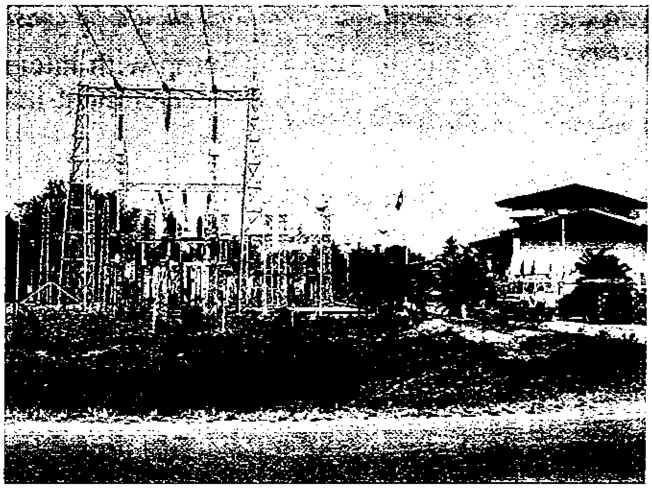
(2) Signs to make third persons recognize danger should be installed at the entrances/exits.

(3) Locking devices or other appropriate devices should be installed at the entrances/exits.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	1	General Provisions	Document No. SS9
	Paragraph	4	Prevention of Electric Power Disasters	
	Clause	12	Prevention of Failures of Electric Power Facilities from Natural Disasters	
Title	Floods Design for Substations			

1. Electrical equipment should be installed not to suffer damage from submersion due to foreseeable floods.
   The ground level should be decided, based on past records of floods.



(Landfill)

2. Following measures should be taken by the following methods not to suffer damage to electrical equipment from rainwater under the normal conditions.
   (1) Installation of drainage facilities.
   (2) Waterproofing of buildings in which electrical equipment is installed.

(Drainage facilities)

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	1	General Provisions	Document No. SS10-1
	Paragraph	6	Preservation of Environment	
	Clause	14	Compliance with the Environmental Standards	
Title	Mitigation Measures for Environmental Impact (1/2)			

1. Appropriate measures should be taken to prevent outflow and seepage of insulation oil, referring to **IEC 619361 Ed1/CVD (IEC TC99)**, as followings;

The quantity of insulating liquid in equipment, the volume of water from rain and fire protection system, the proximity to watercourses and soil conditions should be considered in the selection of a containment system.

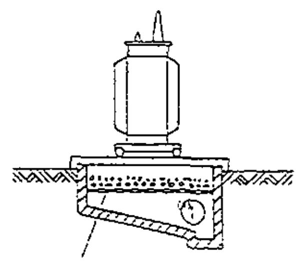
·Tanks

·Sump with integrated-catchment-tank for the whole fluid (see the following figure)

·Sump with separate catchment-tank. Where there are several sumps, the drainpipes may lead to a common catchment-tank; this common catchment tank should then be capable of holding the fluids of the largest transformer. (see the following figure)

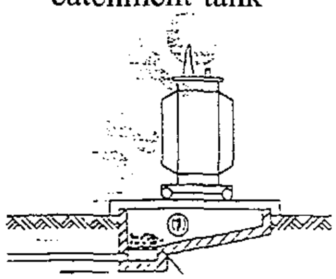
·Sump with integrated common catchment-tank for several transformers. It should be capable of holding the fluids of the largest transformer.

Sump with integrated catchment-tank

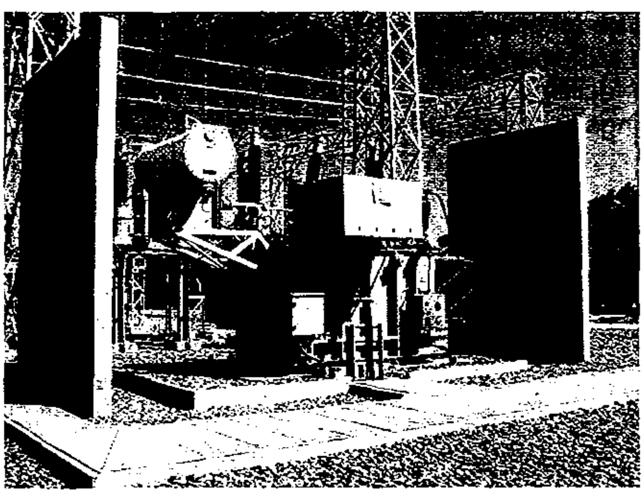


Gravel layer for fire protection

Sump with separate catchment-tank



Gravel layer for fire protection



Remarks	Revisions	
	2003/Nov.	Original

Category				Document No. SS10-2
Category	Chapter	1	General Provisions	Document No. SS10-2
	Paragraph	6	Preservation of Environment	
	Clause	14	Compliance with the Environmental Standards	
Title	Mitigation Measures for Environmental Impact (2/2)			

2. Electrical equipment, for which insulation oil containing polychlorinated biphenyl is used, must not be installed.

Although PCB (polychlorinated biphenyl) is chemically stable, it has the toxicity which causes a skin obstacle and a liver obstacle. It is a substance with a possibility of not only polluting environment, but also accumulating to people through fishes etc because of remaining without decomposing for a long period of time when it is emitted into environment.

3. For electrical equipment that uses SF6 gas, appropriate measures shall be taken so that SF6 gas is not emitted into the atmosphere.

Since SF6 is one of Global Warming Gas (CO2, N2O, CH4, HFCs, PFCs, SF6), discharge of SF6 gas should be controlled as much as possible in consideration of global environment.

Remarks	Revisions	
	2003/Nov.	Original

Category				
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. SS11
	Paragraph	5	Transmission and Distribution Facilities	
	Clause	36	Protection against Over-current	
		37	Protection against Ground Faults	
Title	Protective Relay system			

1.Circuit Breaker

The circuit breaker should hold sufficient capacity for intercepting current.

2.Protective Relay System

The system should be sufficiently sensitive to distinguish internal fault from external fault.

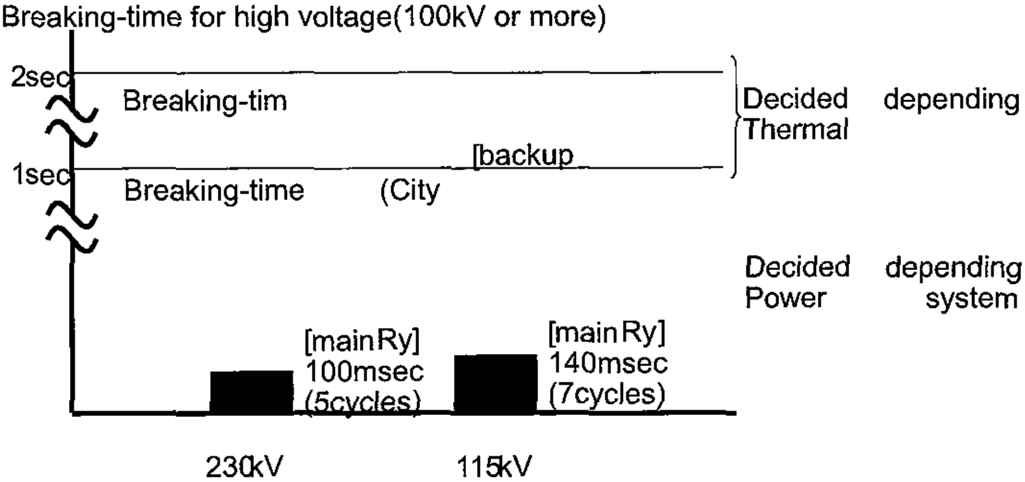
The main relay should clear quickly the fault within a definite operation time in order to keep the power system stability including circuit breaker interruption time.

If the main relay responsible to the fault fails to clear it,the backup relay should clear,but with a longer operation time, which will give a bigger disturbance to the power system.

(1) Regular use state

Circumference temperature should be 40 ℃ or less and −10 ℃ or more, referring to IEC61936-1.

(2) Breaking-time for high voltage(100kV or more)

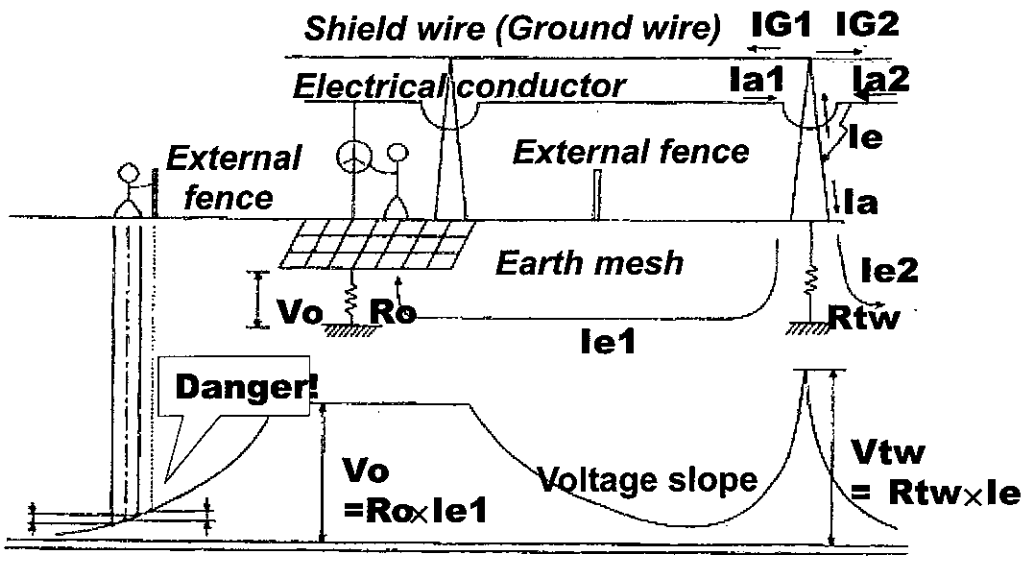


Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. SS12-1
	Paragraph	5	Transmission and Distribution Facilities	
	Clause	39	Classification of Grounding for Electrical Lines	
Title	Grounding for Substations (1/4)			

1. Purpose of Grounding

Purpose of Grounding is to prevent workers' electric shock from lightning surge or any other abnormal voltages occurring in the system, as well as to protect electrical devices and low voltage circuits. Grounding should be designed to have so low grounding resistance as to satisfy allowable step-voltage and touch-voltage.

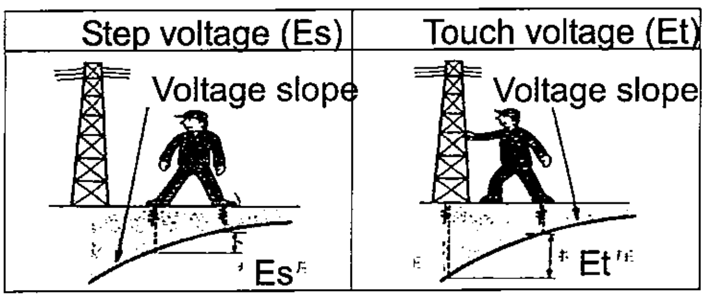


- Legend -

Ia: Ground Fault Current, **IG**: Ground Wire Current, **Ie**: Earth Current

Ia = IG + Ie

R0: Earth Resistance

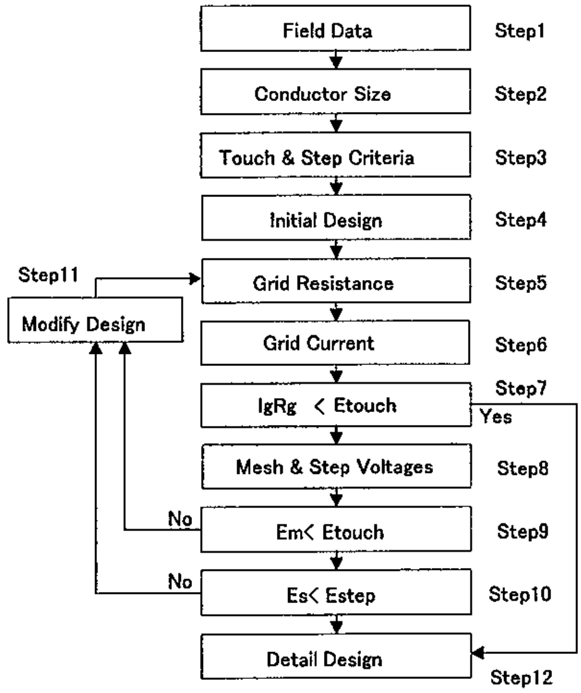


Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. SS12-2**
	Paragraph	5	Transmission and Distribution Facilities	
	Clause	39	Classification of Grounding for Electrical Lines	
Title	Grounding for substations (2/4)			

2. Design Procedure

Design procedure is provided in IEEE Std 80 or IEC61936-1, as shown on the right.



IEEE's Design Procedure

3. Example of Grounding Design

An example of grounding design based the IEEE procedure is described below.

Step1. Field data

(1) Surface Resistivity

Surface Resistivity is shown in following table.

Sample: $\rho s= 1000\ \Omega\text{-m}$

Range of earth resistivity

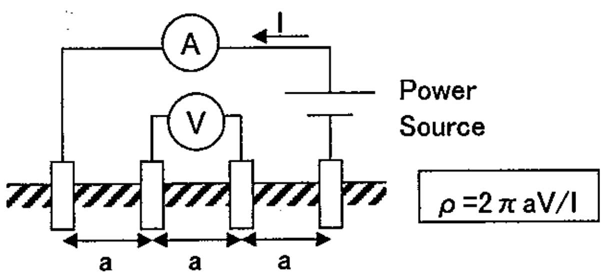
Type of earth	Average resistivity (Ω-m)
Wet organic soil	10
Moist soil	10^2
Dry soil	10^3
Bed rock	10^4

(2) Ground Resistivity

Ground Resistivity is measured like following figure.

Sample: $\rho s= 50\ \Omega\text{-m}$

four-pin-method



(3) Grounding Current

Grounding current should be Estimated on the basis of system's Short circuit capacity taking shunting (ground wire) to substation of about 40% into consideration.

Remarks	Revisions	
	2003/Nov.	Original

Category				Document
	Chapter	2	Technical Standards of Electric Power Facilities	No. SS12-3
	Paragraph	5	Transmission and Distribution Facilities	
	Clause	39	Classification of Grounding for Electrical Lines	
Title	Grounding for substations (3/4)			

Sample: Short circuit capacity=25kA, Grounding Current=25kA*40%=10kA, t (Duration)=1sec

Step2. Conductor Size

Conductor size is decided in accordance with the grounding current.

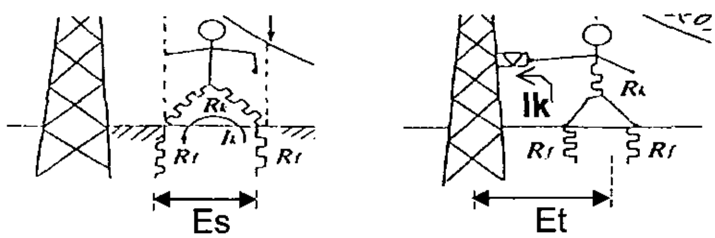
Step3. Touch and Step Criteria

Ik (allowable body current IEEE) $=0.116/\sqrt{t}$

$Es = (Rk + 2Rf)\ Ik = (1000+6\rho s)*0.116/\sqrt{t} \quad =812\ V$

$Et = (Rk + Rf/2)\ Ik = (1000+1.5\rho s)*0.116/\sqrt{t} \quad$ **=290 V**

Sample: Rk (human body resistance)=1000Ω, Rf =3ρs



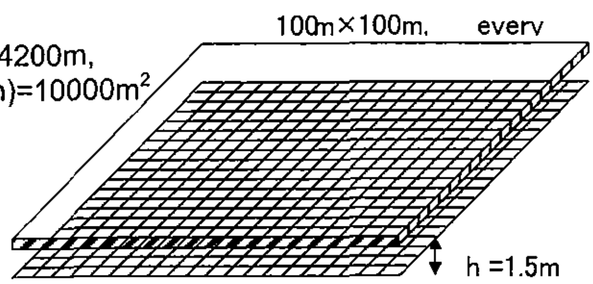
Step4- 7. Rough Calculation

Rough calculation of grounding design should be carried out for the step 4-7 as follows.

$$Rg\ (\text{substation ground resistance}) = \rho * \left[\frac{1}{L} + \frac{1}{\sqrt{(20A)}}\left(1 + \frac{1}{1+h\sqrt{(20/A)}}\right)\right]$$

$$=0.23\ \Omega$$

Sample :
L (total buried length of conductors)=4200m,
A (area occupied by the ground mesh)=10000m²
h (depth of the mesh) =1.5m



Remarks	Revisions	
	2003/Nov.	Original

Step8- 10. Calculation of Mesh Voltage and Estimation

Calculation of Mesh Voltage and Estimation of the voltage should be carried out for the step 8-10 as follows.

Em (Mesh Voltage)= ρ *Km*Ki*I/L=50*0.40*3.75*16000/4200= 286V < Etouch 290V [OK]

$$Km = \frac{1}{2\pi}\left[\ln\left(\frac{D^2}{16hd}+\frac{(D+2+h)^2}{8Dh}-\frac{h}{4d}\right)+\frac{Kii}{Kh}*\ln\left(\frac{8}{\pi(2n-1)}\right)\right]=0.40$$

n (number of parallel lines)=21

$Kii=1/(2*n)^{2/n}=0.7$

$Kh=\sqrt{(1+h/h0)}=1.6$ (h0: grid reference depth=1)

D (separation)=5

d (diameter)=0.016

Ki = 0.644+0.148n = 3.75

4. Countermeasures to Improve Grounding

In the case that the result of estimation is unsatisfied, countermeasures described below should be taken.

(1) *Grounding rods should be used when grounding mesh cannot be extended* although grounding resistance is high.
(2) The interval of a mesh should be contracted.
(3) Surface layer with high resistance should be installed.
(4) A part of grounding current should be made to shunt toward other circuits.
(5) Material to decrease grounding resistance should be used.
(6) Grounding current should be restricted.
(7) Entry should be forbidden.

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. SS13-1**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	48	Surge Arresters	
Title	Installation of surge arresters (1/2)			

1. Installation points for surge arresters

Surge arresters should be installed at points listed below in high-voltage electrical circuits at substations and switching stations except for cases where there is no risk of damage to such electrical equipment.

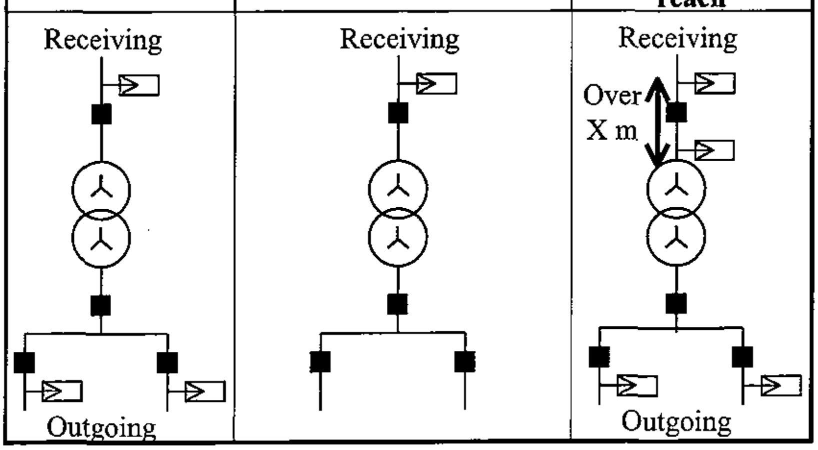
a. Receiving and outgoing points on overhead electrical lines at substations

b. Receiving points on the HV and MV user's sites to which power is supplied from high-voltage and medium voltage overhead electrical lines.

c. Other points where installation of surge arresters are effective. For instance, installation of a surge arrester near a transformer might be necessary after detailed calculation of a valied reach of the suege arresters mentioned above in the article a and b.

Installation points for surge arresters

a. Receiving and outgoing points on overhead electrical lines in the Stations	b. Receiving points on the HV or MV user' s sites to which power is supplied from high-voltage or medium voltage overhead electrical lines	c. Other points *Over protective reach*



X: Protective reach of surge arrester

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. SS13-2
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	48	Surge Arresters	
Title	Installation of surge arresters (2/2)			

2.Performances of surge arresters

The performances of surge arresters to be installed at substations and HV user's sites should conform to the following provisions, IEC60099 and other relevant IEC.

a. Rated voltage

The rated voltage of surge arresters should be chosen so that the surge arrester can perform the prescribed operating duties under the condition of over voltages that temporarily occur at stations and HV and MV user's sites due to a single-line earth fault and load rejection.

b. Nominal discharge current

Nominal discharge current of surge arresters at high-voltage substations should be no less than 10 kA.

Nominal discharge current of surge arresters

Installation point of the surge arrester		Nominal discharge current
Surge arresters to be installed in high-voltage electrical circuits		10 kA
Surge arresters to be installed in medium- voltage electrical circuits	It is unnecessary to treat switching surge.	5 kA
	It is necessary to treat switching surge	10 kA
Surge arresters to be installed in medium voltage electrical circuits to be connected with an overhead distribution line to be installed on the top of an overhead transmission electrical line		10 kA

Referring to IEC 60099

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	1	General Provisions	Document No. TL1
	Paragraph	1	Definitions	
	Clause	1	Definitions	
Title	Main Components of Transmission Line			

Main components of high-voltage lines are as follows.

1.Supporting structure

"Supporting structure" means a structure to support ground wires, conductors and so on.

2.Foundation

"Foundation" means an underground structure designed to support the supporting structure.

3.Conductor

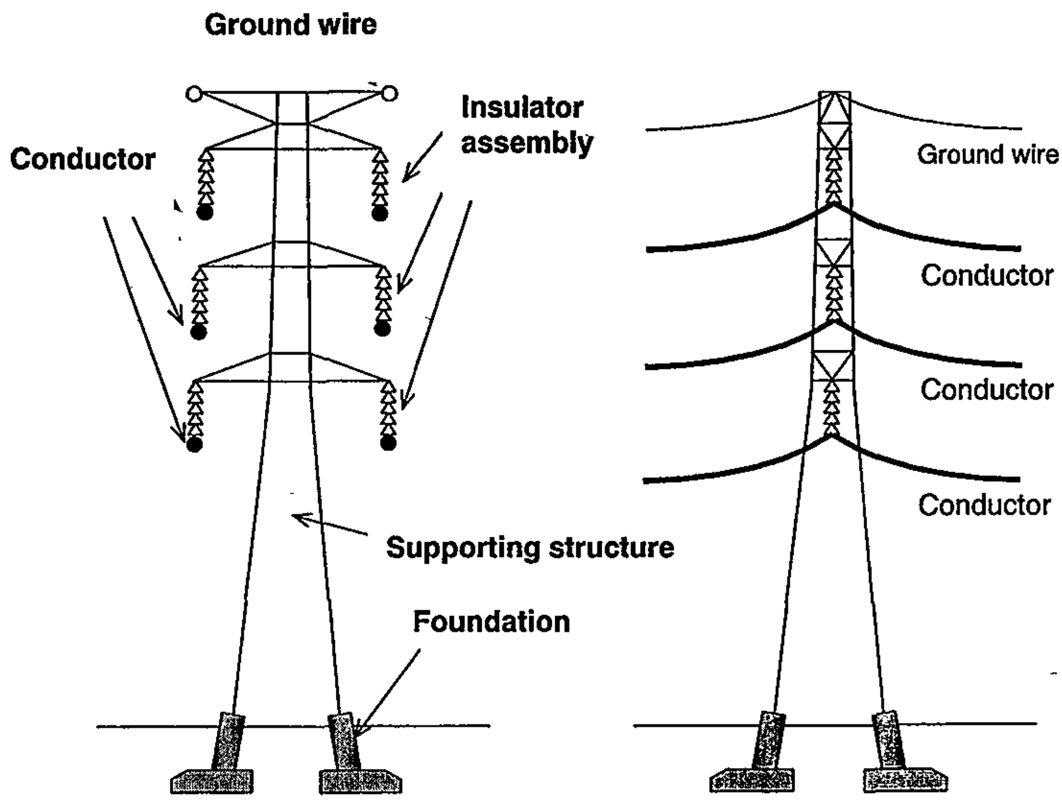
"Conductor" means an electrical conductor to transmit electricity.

4.Ground wire

"Ground wire" means metal wires, generally installed on the top of a supporting structure to protect electrical lines from damage by lightning.

5.Insulator assembly

"Insulator assembly" means a set which consists of insulator discs and the fittings.

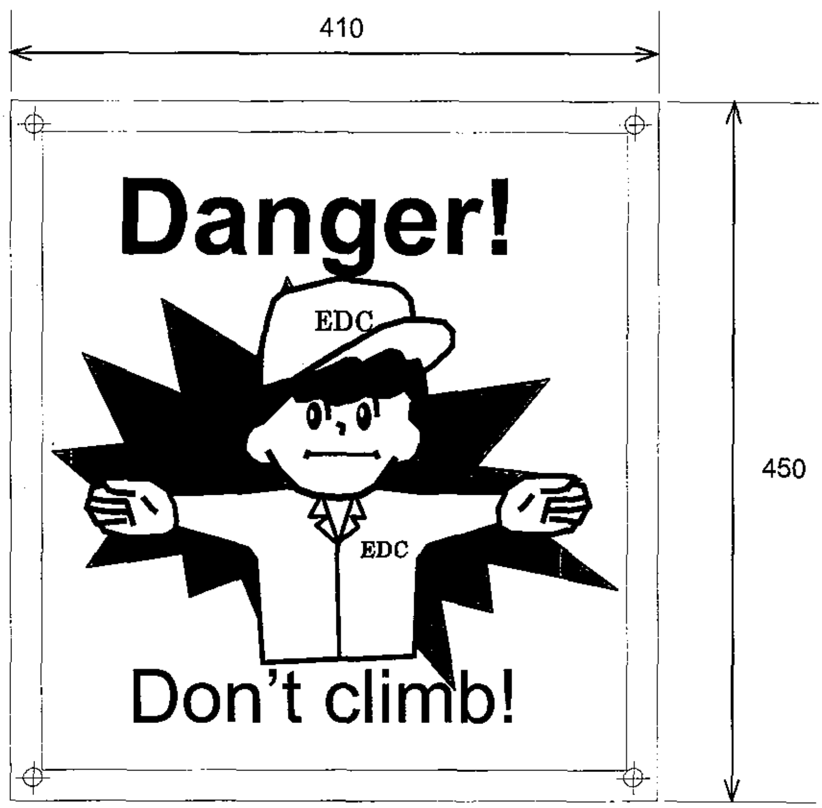


Remarks	Revisions	
	2003/Nov.	Original

Category				Document No. TL2
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	5	Transmission and Distribution Facilities	
	Clause	32	Prevention of Climbing on Supporting Structures	
Title	An Example of a Warning Sign			

1.Installation of sign(Danger plate)

An example of a danger plate is as follows.

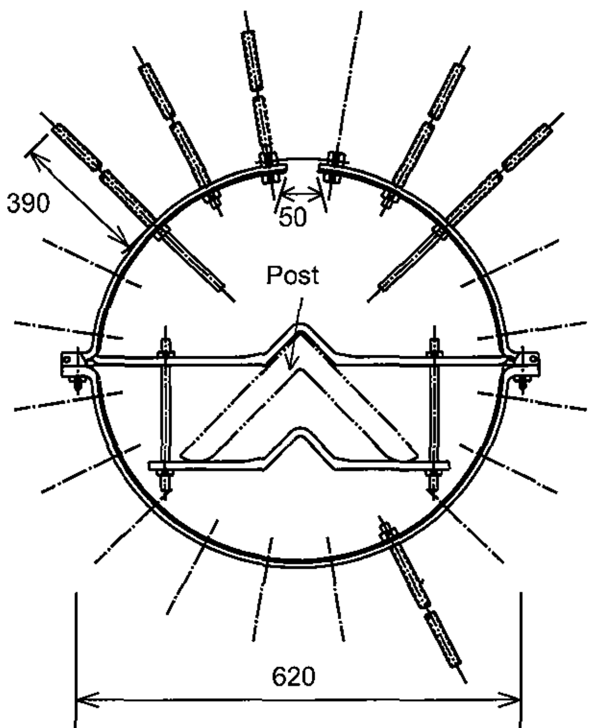


Remarks	Revisions	
Referring to the standards of the KANSAI Electric Power Co., Inc.		
	2003/Nov.	Original

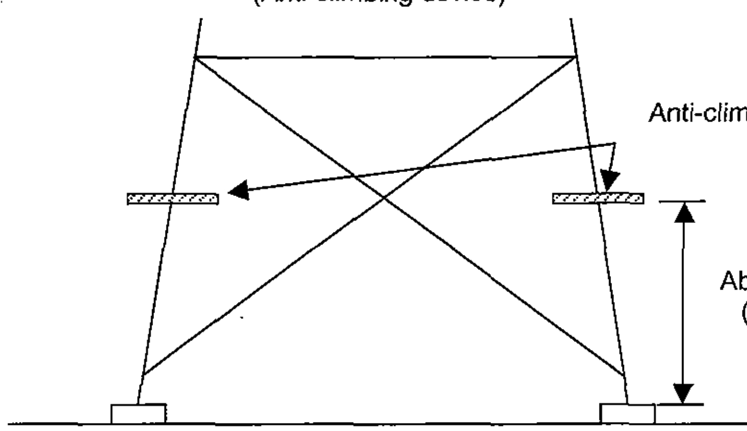
Category				Document No. TL3
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL3
	Paragraph	5	Transmission and Distribution Facilities	
	Clause	32	Prevention of Climbing on Supporting Structures	
Title	An Example of a Device to Prevent Third Persons from Climbing			

1.Installation of anti-climbing device

An example of anti-climbing device is as follows.



(Anti-climbing device)



(Installation position)

Remarks	Revisions	
	2003/Nov.	Original

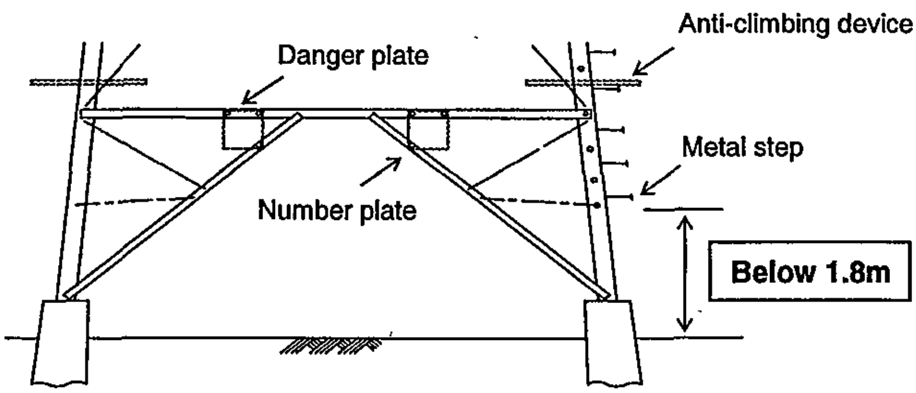
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL4
	Paragraph	5	Transmission and Distribution Facilities	
	Clause	32	Prevention of Climbing on Supporting Structures	
Title	An Example of Arrangement of a "Danger sign", "Anti-climbing Devices" and "Steps"			

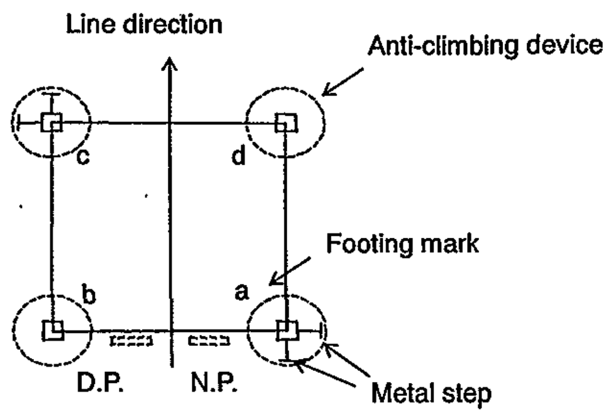
1. Steps
   No steps shall be installed with height of 1.8m or below at each leg of supporting structures.

2. An example of arrangement of "a danger plate", "anti-climbing devices" and "steps" is as follows.

   Points to be considered are as follows;

   a. For adults, signs which simply and obviously describe danger of electricity are necessary.
   b. For children, who could not read the signs, devices that physically prevent from climbing are necessary.





Remarks	Revisions	
	2003/Nov.	Original

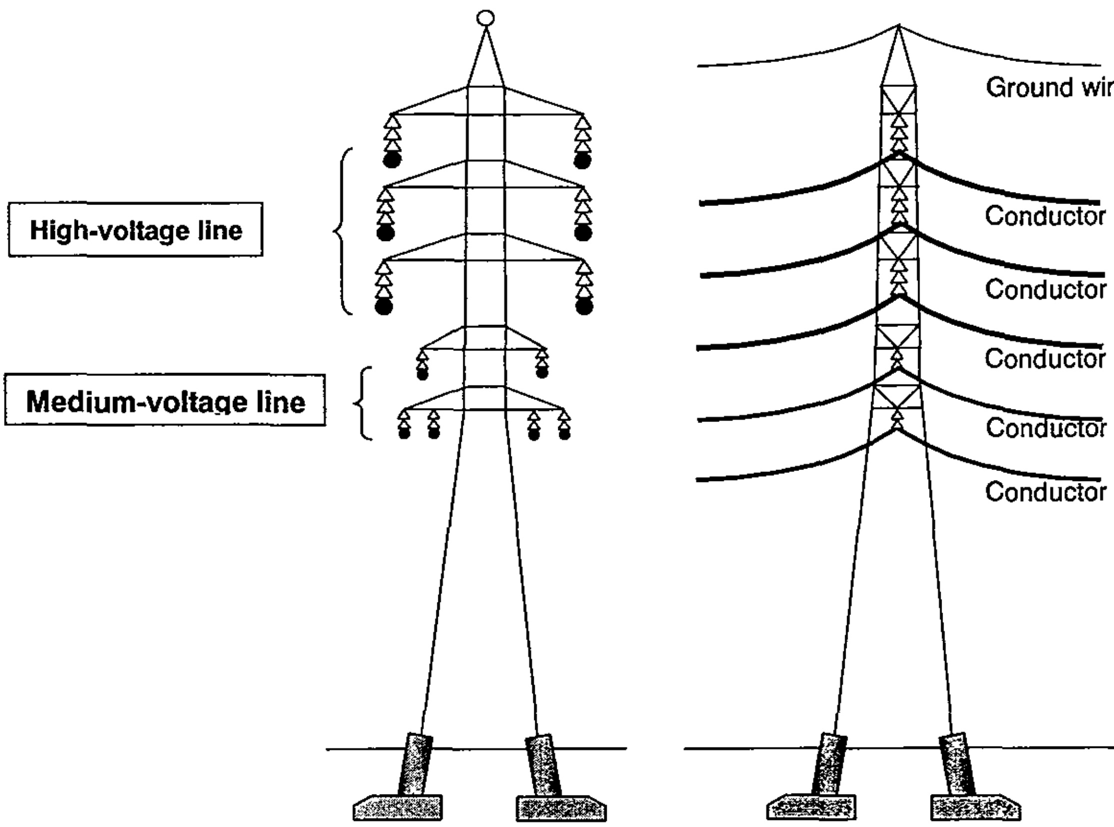
Category				Document No. TL5
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	5	Transmission and Distribution Facilities	
	Clause	34	Side by Side Use and Joint Use of Electrical Lines or Communication Lines	

Title	Side by Side Use and Joint Use of High-voltage Lines and Other Lines

Medium-voltage lines shall be installed under high-voltage lines and on separate cross arms. An example of arrangement of high-voltage lines and medium-voltage lines is as follows.

High-voltage lines and low-voltage lines shall not be installed at the same supporting structure, taking into account danger and/or interruption due to electrostatic and electromagnetic induction.

High-voltage lines and communication lines shall not be installed at the same supporting structure.



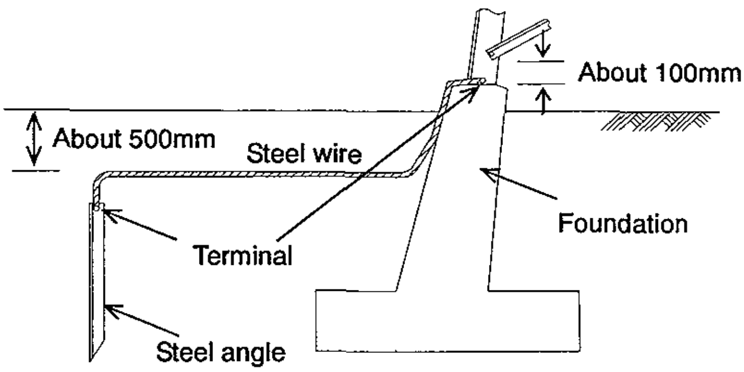
Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL6
	Paragraph	5	Transmission and Distribution Facilities	
	Clause	39	Classification of Grounding for Electrical Lines	
Title	Installation of Grounding			

1.Earthing steel angle

Tower-footing resistance can be reduced by installation of an earthing steel angle to each tower leg. The tower-footing resistance shall be less than 10 Ω. A galvanized steel wire of 38 mm^2 (7/2.6) is used for connection of the earthing steel angle and the leg.

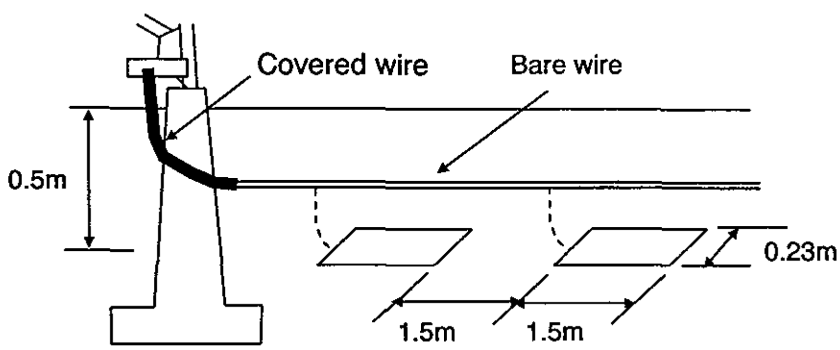
Normally the galvanized steel wire is radically buried while being extended from the leg at the depth of about 0.5m from the ground surface.



2.Grounding sheets

There might be some sites with high tower-footing resistance, where the installation of the earthing angle is not enough to reduce the resistance

In this case, such a countermeasure as application of grounding sheets is applied. The grounding sheets are fixed on counterpoise wires. Furthermore, in case that the grounding sheets are not enough, the grounding by boring to a deep layer should be applied.

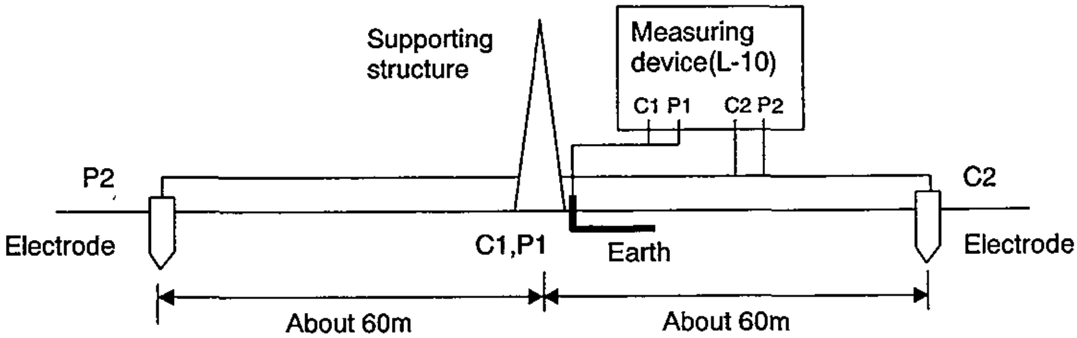


Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL7
	Paragraph	5	Transmission and Distribution Facilities	
	Clause	39	Classification of Grounding for Electrical Lines	
Title	Measuring of Tower-footing Resistance			

1. Measuring Method

The following figure shows a typical measuring method of tower-footing resistance. In the figure, L-10 type (YOKOGAWA ELECTRIC CORPORATION) Measuring Device is used.



2. Notes of the Measuring

Notes on the measuring are as follows.

a. Distance between a tower and electrodes should be more than 60m long.
b. Electrodes should be installed deeply.
c. Measuring should not be done in case that ground surface is moist.
d. Electrodes should be extended at right angles to the transmission line.

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. TL8**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	40	Design of Supporting Structures of Overhead High-voltage Line	
Title	Assumed Maximum Wind Velocity			

Supporting structure and foundation of overhead high-voltage lines shall be designed in consideration of wind pressure based on the assumed maximum wind velocity.

30m/s is appropriate for the maximum wind velocity for tower design, based on records in Cambodia.

Records of wind velocity for 5 years are as follows.

Observation point	Direction	Wind velocity [m/s]	Date
Pochentong (1998-2002)	W	24	29.AUG.1999
	W	20	27.JUN.2000
	W	20	25.JUN.2001
Siem Reap (1998-2002)	NW	26	25.MAY.1998
	W	24	21.JUN.1997
	W	24	24.JUN.1997
Sihanoukville (1994-1998)	SW	25	1.SEP.1995
	SW	18	2.JUN.1994
	N	18	20.NOV.1994

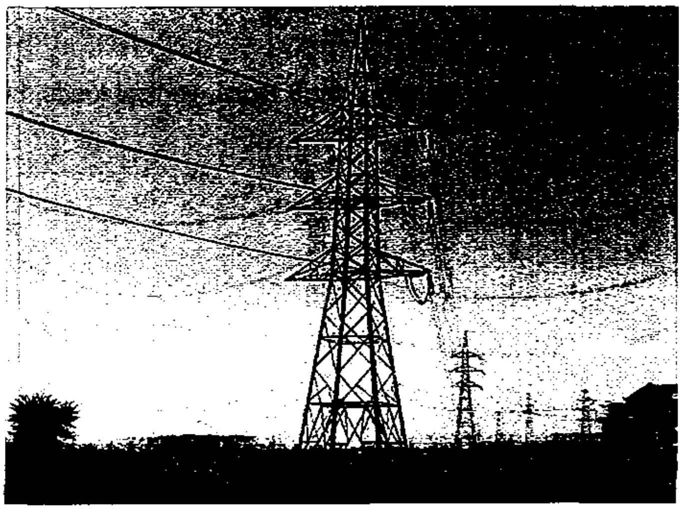
(Reference; Ministry of Water Resources and Meteorology)

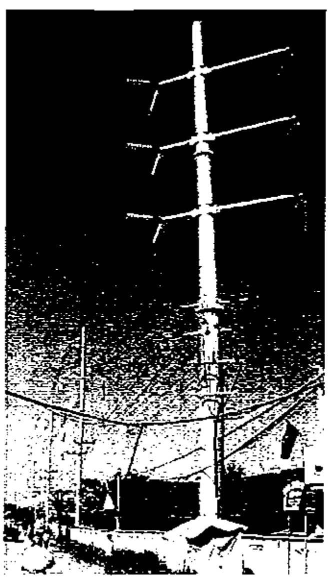
However, the quantity of the records that we can get is not enough because the assumed maximum wind velocity for high-voltage lines should be decided with about 50 years return period, taking into account reliability required. Therefore, the figure 30m/s suggested should be changed according to rolling up of the records.

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. TL9**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	40	Design of Supporting Structures of Overhead High-voltage Lines	
Title	Kinds of Supporting Structures			

Kinds of supporting structures are as follows.

Steel tower


Steel pole	Concrete pole
	

Remarks	Revisions	
	2003/Nov.	Original

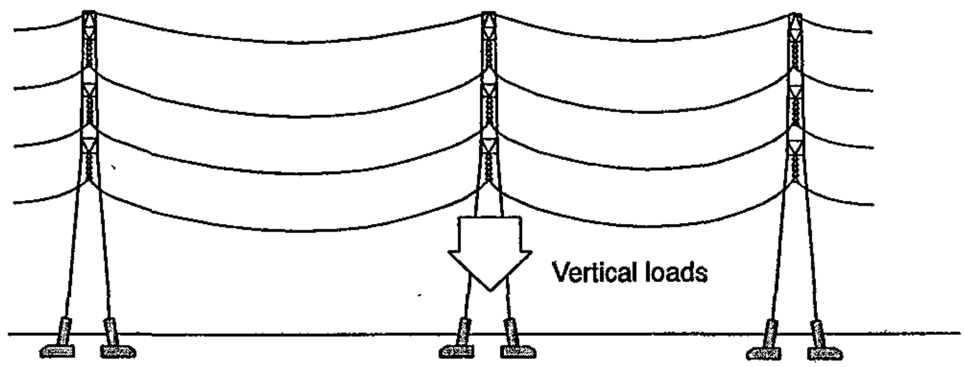
Category				Document
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL10-1
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	40	Design of Supporting Structures of Overhead High-voltage Lines	
Title	Design of Supporting Structures (1/11)			

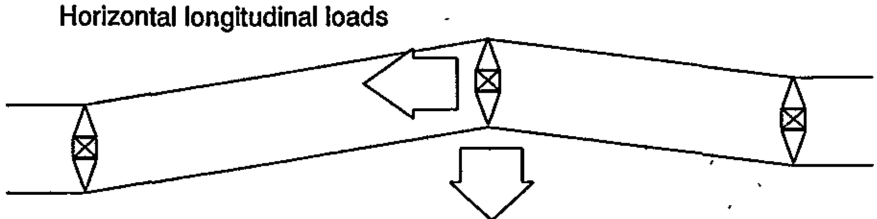
1. Application

The Documents No.TL10-2 to No.TL10-11 describe a design method for high-voltage lines, while design for medium and low voltage lines are described in the other proper articles in Electrical Power Technical Standards and the Guidebook.

2. Kind of loads

Loads for supporting structures are classified by 3 types, vertical loads, horizontal transverse loads and horizontal longitudinal loads, as follows.





Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. TL10-2**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	40	Design of Supporting Structures of Overhead High-voltage Lines	
Title	Design of Supporting Structures (2/11)			

3. Subdivision of loads

The loads are subdivided as follows

Type of Load	*Contents*	*Symbol*
Vertical loads	Weight of the supporting structure	Wt
	Weight of the conductors and the ground wires and the accessories supported by the supporting structure	Wc
	Weight of the insulator strings and the fittings supported by the supporting structure	Wi
	A vertical component of the maximum tension of the guy wires supporting the supporting structure, if any	Ws
Horizontal transverse loads	Wind pressure of the supporting structure under the maximum wind velocity	Ht
	Wind pressure of the conductors and the ground wires supported by the supporting structure under the maximum wind velocity	Hc
	Wind pressure of the insulator strings and the fittings supported by the supporting structure	Hi
	A horizontal transverse component of the maximum tension of the conductors and the ground wires supported by the supporting structure and the guy wires supporting the supporting structure, if any	Ha Hs
Horizontal longitudinal loads	Wind pressure of the supporting structure under the maximum wind velocity	Ht'
	A horizontal longitudinal component of the unbalanced maximum tension of the conductors and the ground wires supported by the supporting structure and the maximum tension of the guy wires supporting the supporting structure, if any	P Ws'

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL10-3
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	40	Design of Supporting Structures of Overhead High-voltage Lines	
Title	Design of Supporting Structures (3/11)			

4. Vertical loads

(1)"Wt"

"Wt" is weight of the supporting structure.

(2)"Wc"

"Wc" is calculated by the following formula.

$$Wc = (Wc' \times S \times g) \times n + T1 \tan \delta 1 + T2 \tan \delta 2 \text{ [N]}$$

where, Wc':Unit weight of a conductor [kg/m]

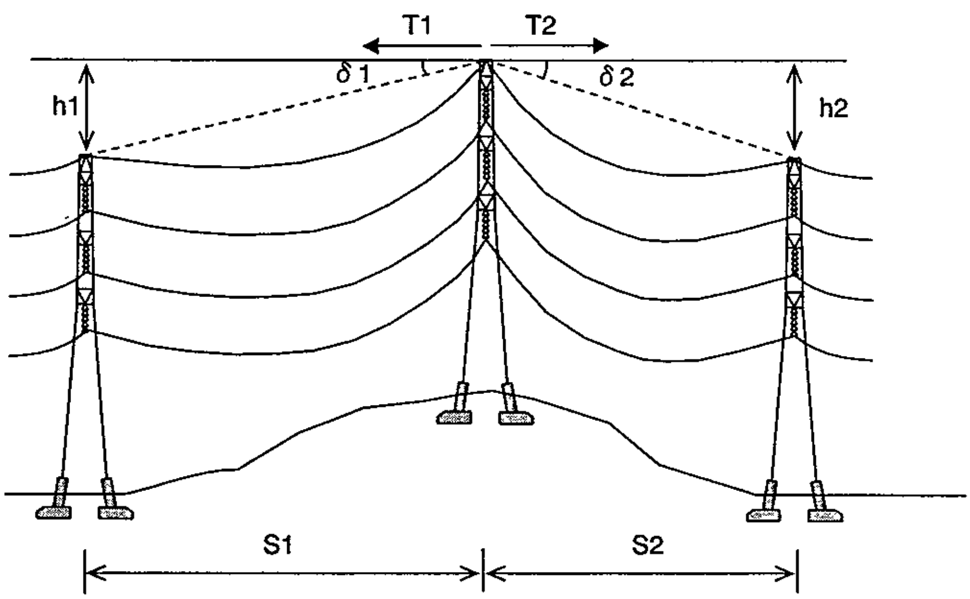
S :Weight span, (S1+S2)×0.5[m]

g :apparent gravity, 9.8[m/s^2]

n :Number of conductors

T1, T2 :Horizontal component of the maximum working tension of conductors or ground wires [N]

δ1, δ2 :A vertical angle of a line which is drawn between supporting points of adjacent supporting structures



Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL10-4
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	40	Design of Supporting Structures of Overhead High-voltage Lines	
Title	Design of Supporting Structures (4/11)			

(3)"Wi"

"Wi" is calculated as follows.

$$Wi = (a \times N + I) \times g \ [N]$$

where, a :Weight of an insulator disc [kg]

N :Number of insulator discs

I :Weight of fittings for the insulator discs [kg]

g : apparent gravity, 9.8[m/s^2]

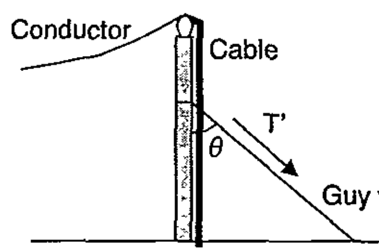
(4)"Ws"

"Ws" is calculated as follows, if any.

$$Ws = T' \times \cos\theta \ [N]$$

where, T' :Maximum tension of a guy wire[N]

θ :angle between a supporting structure and a guy wire



(5)Others

Furthermore, 200kg could be considered for each cross arm as dead loads, which consist of weights of linemen and their tools.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL10-5
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	40	Design of Supporting Structures of Overhead High-voltage Lines	
Title	Design of Supporting Structures (5/11)			

5. Horizontal transverse loads

(1)"Ht"

"Ht" is calculated multiplying a wind pressure by the sum of the projected areas of all members of transverse face. Wind pressure "P" is obtained from the following equation.

$$P = (1/2 \times \rho \times V^2) \times C \times g \ [N/m^2]$$

where, P: Wind pressure

ρ :Air density[kg・sec^2/m^2]

V: Design wind velocity [m/s]

C: Coefficient of air resistance

g: Apparent gravity, 9.8[m/s^2]

Height[m]	Ht [N/m^2]	
	Concrete pole (Circle type) Steel pole (Circle type)	Steel tower Single steel pole
~40	450	1600
~50	480	1700
~60	500	1800

(2)"Hc"

"Hc" Is calculated as follow.

$$Hc = Ww \times D \times S \times n \times 10^{-3} \times g \ [N]$$

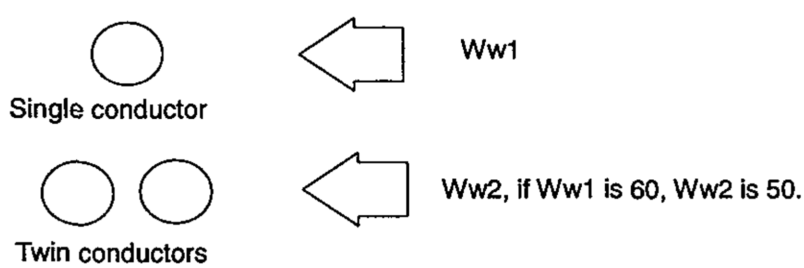
where, Ww : Wind pressure, where Ww for twin or quad bundle conductors are 90 % of Ww for a single conductor

D: Diameter of conductor [mm]

S: Weight span [m]

n: Number of conductor

g: apparent gravity, 9.8[m/s^2]



Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL10-6
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	40	Design of Supporting Structures of Overhead High-voltage Lines	
Title	Design of Supporting Structures (6/11)			

Type of conductor	Diameter [mm]	Weight span [m]	Number of conductor	Hc [N]
ACSR 410	28.5	300	1	5027
ACSR 810	38.4	300	1	6774

(3)"Hi"

"Hi" is calculated multiplying a wind pressure by the sum of the projected areas of insulator assembly of transverse face.

The wind pressure of the standard insulator strings is as follows.

Number of insulator discs	Hi [N]	
	115kV	230kV
8	250	–
15	–	400

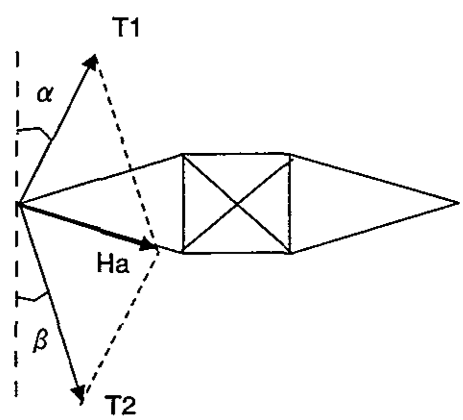
(4)"Ha"

"Ha" is calculated as follow.

$$Ha = T1\sin\alpha + T2\sin\beta \ [N]$$

where, T1,T2 :Horizontal component of maximum working tension of conductors[N]

α , β :Horizontal angle of conductors



Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL10-7
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	40	Design of Supporting Structures of Overhead High-voltage Lines	
Title	Design of Supporting Structures (7/11)			

(5)"Hs"

"Hs" is calculated as follow, if any.

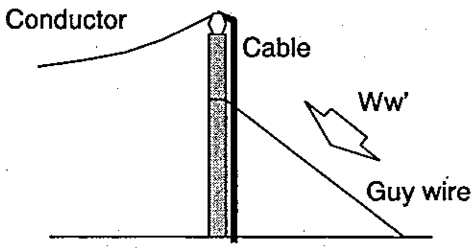
$$Hs = Ww' \times D' \times S' \times 10^{-3} \times g \text{ [N]}$$

where, Ww': Wind pressure (Single conductor 100[kg/m^2])

D': Diameter of guy wire [mm]

S': Length of guy wire [m]

g :apparent gravity, 9.8 [m/s^2]



6.Horizontal longitudinal loads

(1)"Ht'"

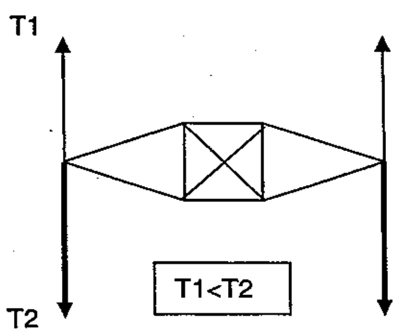
"Ht'" is calculated multiplying a wind pressure by the sum of the projected areas of all members of longitudinal face.

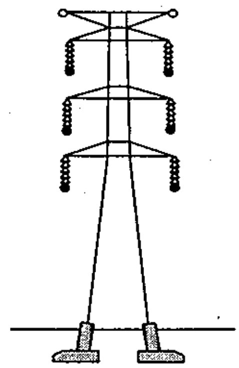
(2)"P"

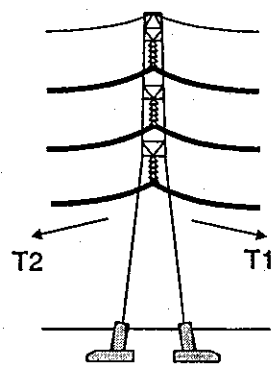
A horizontal longitudinal component of the unbalanced maximum working tension of conductors and ground wires is considered.

Points to be considered are as follows

a. Unbalanced loads
b. Assumption of a case where a conductor would be broken.

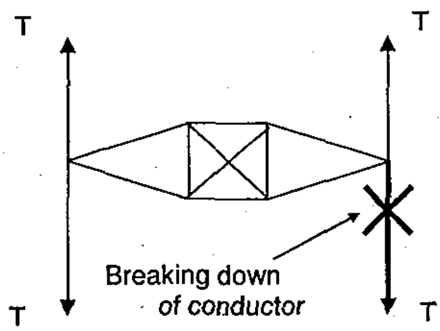


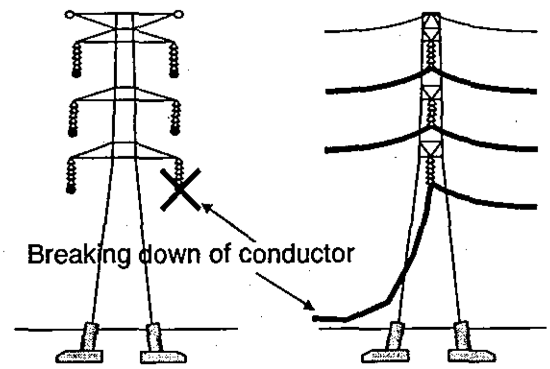




Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. TL10-8**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	40	Design of Supporting Structures of Overhead High-voltage Lines	
Title	Design of Supporting Structures (8/11)			





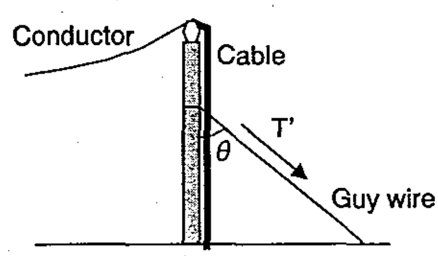
(3)"Ws'"

"Ws'" is calculated as follow, if any.

$$Ws' = T' \times \sin\theta \ \text{[N]}$$

where, T' :Maximum tension of guy wire[N]

θ :angle between supporting structure and guy wire



Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. TL10-9**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	40	Design of Supporting Structures of Overhead High-voltage Lines	
Title	Design of Supporting Structures (9/11)			

7. Oblique wind for bigger towers

Regarding relation between direction of wind and the intensity of the wind pressure, wind with direction of 60 degree to lines might be the most severe (pessimum) condition for tall towers with large cross arms, though normally perpendicular direction (90 degrees to lines) of wind is the most severe.

Therefore, towers with voltage of 230kV or more should be designed taking into account the oblique direction wind.

Generally, an oblique wind pressure is derived, multiplying coefficients by the 90-degree-wind pressure.

Items		Coefficients (in case of square tower)
Wind pressure load to steel tower	Wind pressure load to body	1.6
	Wind pressure load to cross arm	0.5 (for the wind pressure in the direction of electrical line)
Wind pressure load to strung wire		0.75

Remarks	Revisions	
	2003/Nov.	Original

Category				
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL10-10
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	40	Design of Supporting Structures of Overhead High-voltage Lines	
Title	Design of Supporting Structures (10/11)			

8.Combination of loads

Combination of loads is as follows.

Classification of supporting structure	Type	Design cases		Combination of assumed loads									
		Load condition	Wind direction	Vertical load			Horizontal transverse load				Horizontal longitudinal load		
				W_t	W_c W_I	W_s	H_t	H_c H_I	H_a	H_s	H'_t	P	W'_s
Concrete pole Steel pole	Tension & Suspension Type Tower	Normal	Horizontal transverse	O	O	O	O	O	O	O			
			Horizontal longitudinal	O	O	O			O		O		O
	Dead-end Type Tower	Normal	Horizontal transverse	O	O	O	O	O		O		O	
			Horizontal longitudinal	O	O	O					O	O	O
Steel tower Single steel pole	Tension & Suspension Type Tower	Normal	Horizontal transverse/60°	O	O	O	O	O	O	O			
			Horizontal longitudinal	O	O	O			O		O		O
		Abnormal	Horizontal transverse	O	O	O	O	O	O	O		O	
			Horizontal longitudinal	O	O	O			O		O	O	O
	Dead-end Type Tower	Normal	Horizontal transverse	O	O	O	O	O		O		O	
			Horizontal longitudinal	O	O	O					O	O	O
		Abnormal	Horizontal transverse	O	O	O	O	O		O		O	
			Horizontal longitudinal	O	O	O					O	O	O

where, Dead-end type: Supporting structure with a large unbalanced load in the horizontally longitudinal direction, e.g. the first tower from a substation.

Abnormal Condition:

An assumption for tower design where any one or two of conductors and ground wires will be broken down

Notes: Circles "O" indicate the assumed loads to be considered at the same time.

The wind direction that brings the bigger assumed load should be selected.

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. TL10-11**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	40	Design of Supporting Structures of Overhead High-voltage Lines	
Title	Design of Supporting Structures (11/11)			

9.Safety factors

Safety factors of supporting structures are as follows.

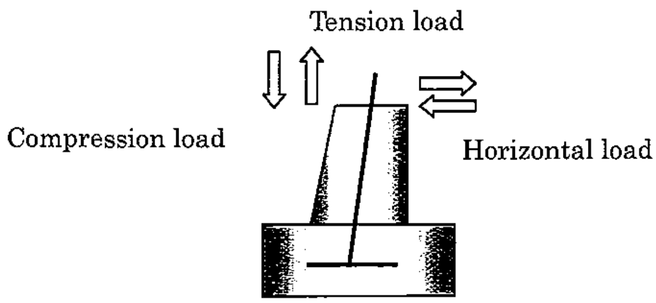
Classification of supporting structure	load condition	Safety factor
Concrete pole Steel pole	Normal	2.0
Steel tower	Normal	1.5
	abnormal	1.0

Remarks	Revisions	
	2003/Nov.	Original

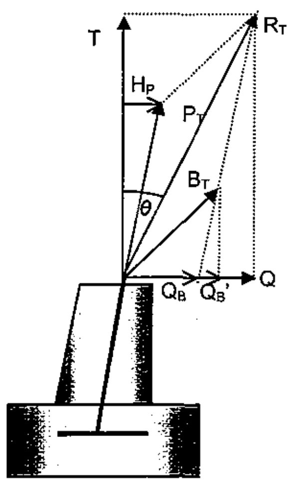
Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. TL11-1**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	40	Design of Supporting Structures of Overhead High-voltage Lines	
Title	Design of Foundations (1/5)			

1.Kinds of loads of foundation

Kinds of loads of foundation are as follows.



Formation of the detailed loads is as follows.



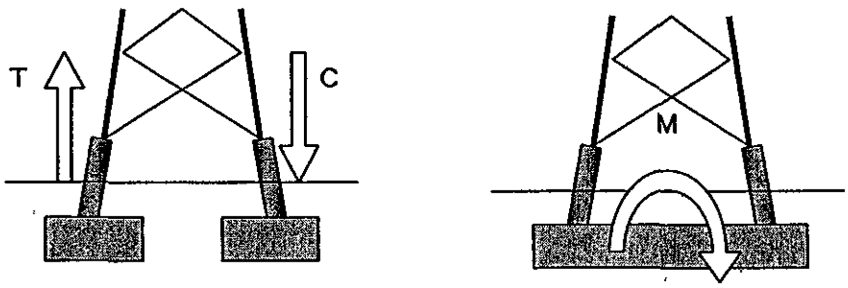
P_T : A load of a post (kN)
B_T : A load of a breath (kN)
H_P : A horizontal component of P_T (kN)
Q_B': A horizontal component of B_T (kN)
R_T : A resultant of P_T and B_T (kN)
T : Tension load (kN)
Q : Horizontal load (kN)
θ : An angle of a post to the vertical line

Remarks	Revisions	
	2003/Nov.	Original

Category				
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL11-2
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	40	Design of Supporting Structures of Overhead High-voltage Lines	
Title	Design of Foundations (2/5)			

2.Kinds of loads

There are 2 types of foundation from viewpoint of design.
One is foundation to be designed with a compression load and a tension load (vertical-load foundation).
And the other is foundation to be designed with a moment load



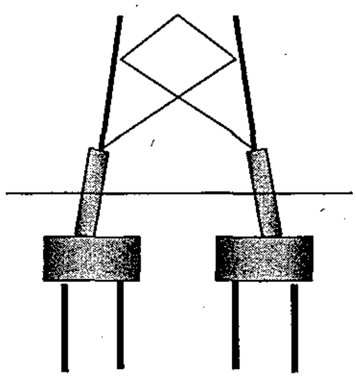
(Vertical-load foundation) (Moment-load foundation)

A foundation type should be decided on the basis of results of such geological study as the Standard Penetration Test. The foundation types are as follows.

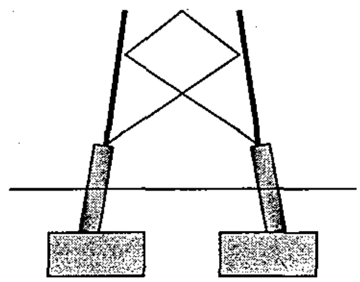
Foundation type	Value of N	Condition
Anchor foundation	–	Rock
Pad and chimney foundation	20~	Normal ground
Caisson type pile foundation	12~	Normal ground
Mat foundation	~19	Soft ground
Pile foundation	~19	Soft ground

Remarks	Revisions	
	2003/Nov.	Original

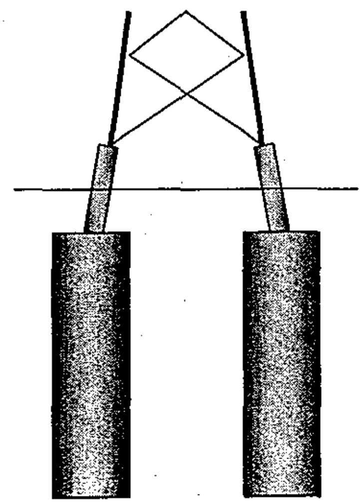
Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. TL11-3**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	40	Design of Supporting Structures of Overhead High-voltage Lines	
Title	Design of Foundations (3/5)			



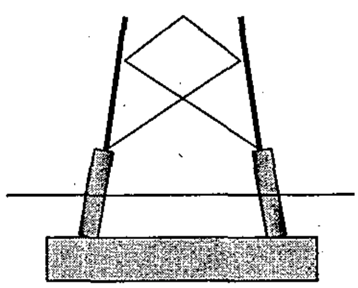
(Anchor foundation)



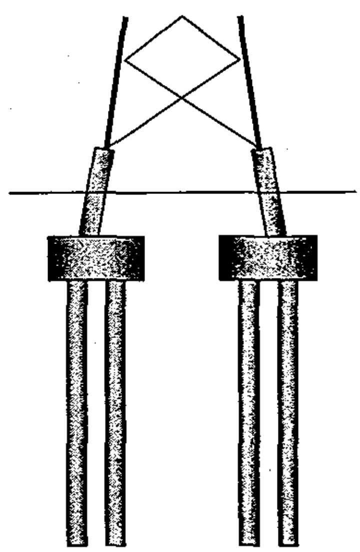
(Pad and chimney foundation)



(Caisson type pile foundation)



(Mat foundation)



(Pile foundation)

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL11-4
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	40	Design of Supporting Structures of Overhead High-voltage Lines	
Title	Design of Foundations (4/5)			

3. An example of calculation of foundation stability

[Design condition]

T=1,500[kN] , C=1,650[kN] , Q= 82.5[kN]

Angle of soil against tension loads: θ =30°

Equivalent unit weight of soil: γ '=16.0[kN/m^2]

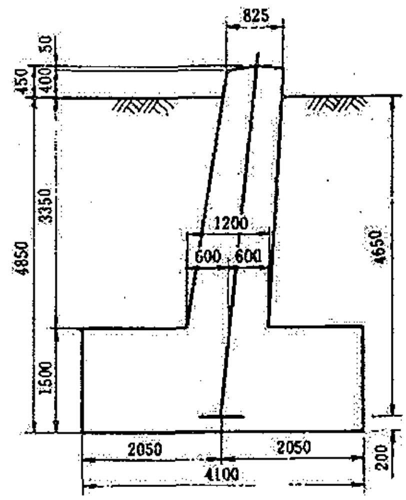
Compression strength of foundation base:

q '=588[kN/m^2]

Compression strength of foundation side:

q_s' =392[kN/m^2]

Unit weight of reinforced concrete: γ_c=24.0[kN/m^3]



[Calculation of foundation weight]

Volume of chimney of foundation: V_{c1}=3.054[m^3]

Volume of chimney of foundation above the ground:

V_{c1}'=0.224[m^3]

Volume of pad of foundation: V_{c2}=19.803[m^3]

Weight of foundation:

G=(V_{c1}+V_{c2})×γ_c=(3.054+19.803)×24.0=548.6[kN]

[Examination against compression strength]

$$\frac{q'}{F_1 \cdot F_2} \geqq \frac{C+G+W_s}{A}$$

$$\frac{C+G+W_s}{A} = \frac{1650+548.6+662.4}{13.2} = 216.74[\text{kN}] < \frac{q'}{F_1 \cdot F_2} = \frac{588}{2.0} = 294[\text{kN}] \quad \text{ok}$$

$$\text{Ws} = \{\frac{\pi \times 4.1^2 \times 3.35}{4} - (3.054-0.224)\} \times 16.0 = 662.4[\text{kN}]$$

[Examination against tension strength]

$$\frac{G}{F_1} + \frac{\gamma'\left(V_e - V_c'\right)}{F_1 \cdot F_2} \geqq T$$

$$\frac{G}{F_1} + \frac{\gamma'\left(V_e - V_c'\right)}{F_1 \cdot F_2} = \frac{548.6}{1.5} + \frac{16.0 \times (191.32 - 22.64)}{2.0} = 1{,}715.16[\text{kN}] < 1{,}500[\text{kN}] \quad \text{ok}$$

$$\text{V}_e = \frac{\pi}{4} \cdot \text{D}'\left(\text{B}^2 + 2 \cdot \text{B} \cdot \text{D}' \cdot \tan\theta + \frac{4}{3} \cdot \text{D}'^2 \cdot \tan^2\theta\right)$$

$$= \frac{\pi}{4} \times 4.85 \times \left(4.1^2 + 2 \times 4.1 \times 4.85 \times \tan 30° + \frac{4}{3} \times 4.85^2 \times \tan^2 30°\right) = 191.32[\text{kN}]$$

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL11-5
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	40	Design of Supporting Structures of Overhead High-voltage Lines	
Title	Design of Foundations (5/5)			

[Examination of horizontal strength]

$$\frac{q_f' \cdot A_f'}{F_1 \cdot F_2} \geqq Q$$

$$\frac{q_f' \cdot A_f'}{F_1 \cdot F_2} = \frac{392 \times 4.1 \times 1.5}{2.0} = 1{,}205.4[\text{kN}] > 82.5[\text{kN}]$$

4. Safety factors of a foundation

Allowing strength " P_a" is calculated as follows.

$$P_a = \frac{1}{F_1 \cdot F_2} P_y \left(= \frac{1}{1.5 F_1 \cdot F_2} P_u \right)$$

P_a : Allowing strength (kN)
P_y : Capitulating strength (kN)
P_u : Maximum strength (kN)
F_1 : Safety factor against the loads
F_2 : Safety factor against the ground

Assumed loads	Safety factors	
	F_1'	F_2
Long-term load	1.5	1.33
Short-term load calculated by instantaneous wind velocity against the maximum wind velocity	1.0	1.33
Short-term load calculated by average wind velocity against the maximum wind velocity	1.5	1.33

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. TL12-1**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	41	Safety Factor of Fittings for Conductors and/or Ground Wires of Overhead High-voltage Lines	
Title	Kinds of Insulators (1/2)			

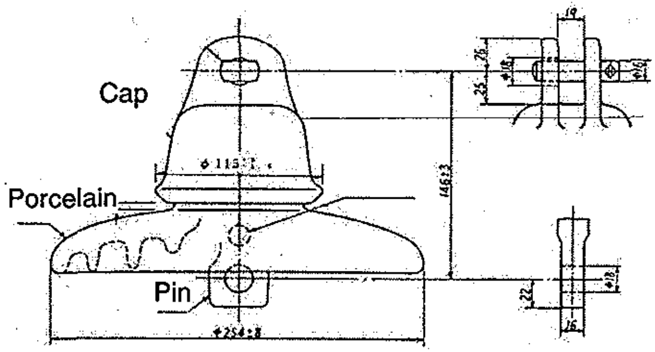
Kinds of Insulators are as follows.

- Insulators
  - Suspension insulator
    - Crevice type insulator
    - Ball-socket type insulator
  - Long-rod insulator

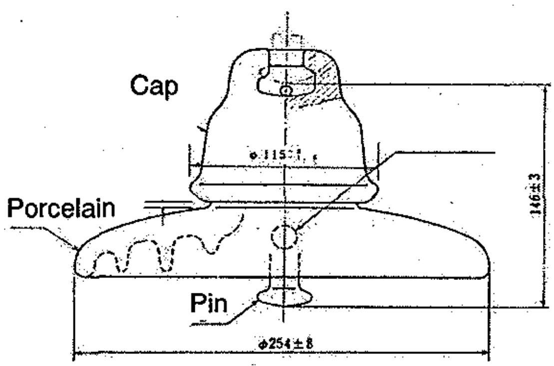
1.Suspension Insulator

There are two types of suspension insulators, one is a crevice type and the other is a ball-socket type.

Properties of the suspension insulators should comply with IEC standards (e.g., IEC60305, IEC60120 and IEC60471) or equivalent.



Crevice type insulator



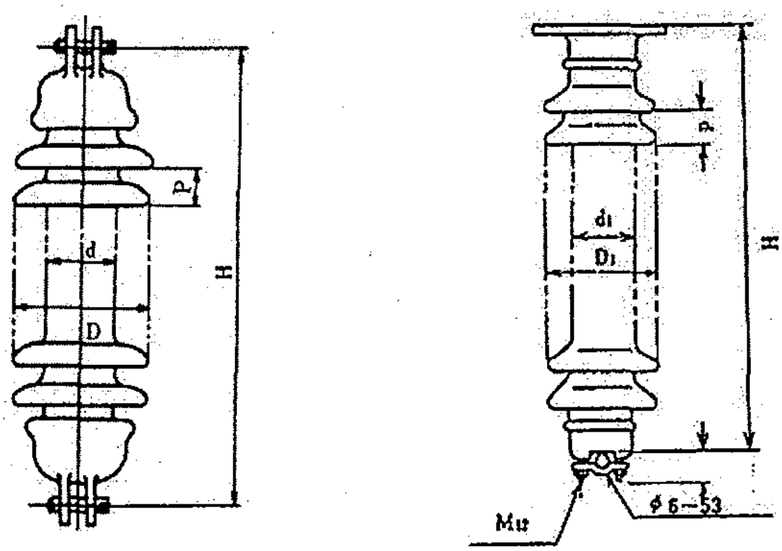
Ball-socket type insulator

Remarks	Revisions	
	2003/Nov.	Original

Category				
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL12-2
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	41	Safety Factor of Fittings for Conductors and/or Ground Wires of Overhead High-voltage Lines	
Title	Kinds of Insulators (2/2)			

2.Long-rod insulator

Properties of long-rod insulators should comply with IEC standards (e.g., IEC60443, IEC60120 and IEC60471) or equivalent.



Long-rod insulator

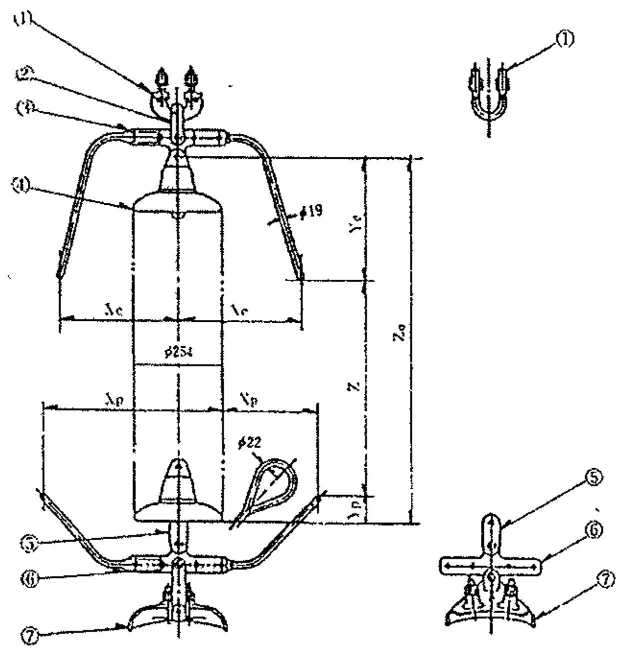
Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL13-1
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	41	Safety Factor of Fittings for Conductors and/or Ground Wires of Overhead High-voltage Lines	
Title	Kinds of Insulator Assemblies (1/2)			

Kinds of Insulator assemblies are as follows.

- Assembly for conductors
  - Suspension assembly
  - Tension assembly
- Assembly for ground wires
  - Suspension assembly
  - Tension assembly

1.Suspension assembly for conductor
An example of a suspension assembly is as follows.

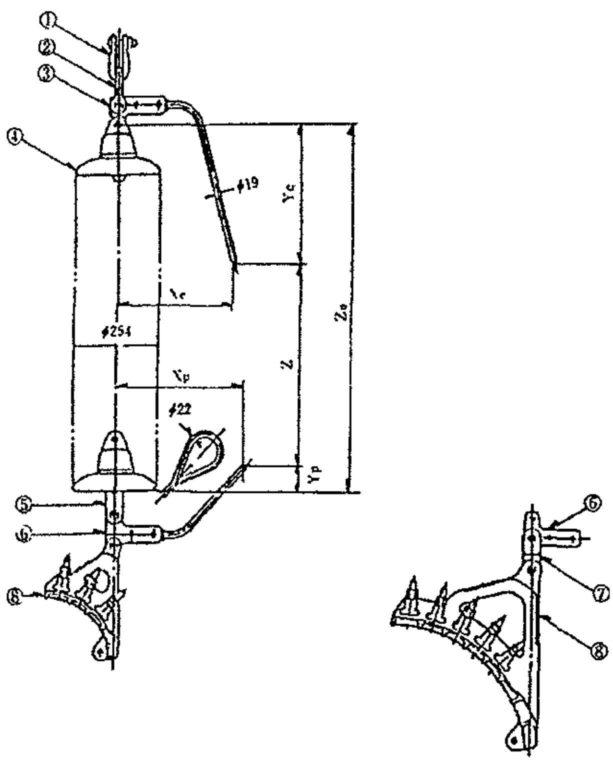


Remarks	Revisions	
	2003/Nov.	Original

Category				Document No. TL13-2
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	41	Safety Factor of Fittings for Conductors and/or Ground Wires of Overhead High-voltage Lines	
Title	Kinds of Insulator Assemblies (2/2)			

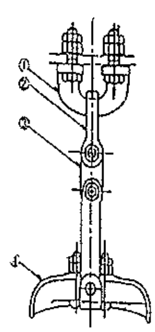
2.Tension assembly for conductor

An example of a tension assembly is as follows.

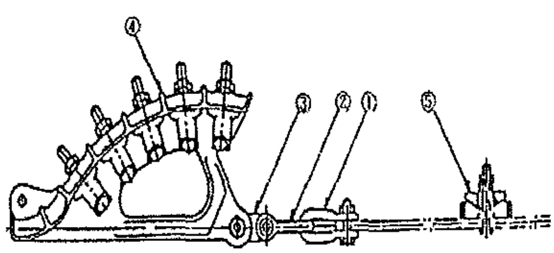


3.Assemblies for ground wires

Examples of assemblies for ground wires are as follows.



(Suspension assembly)



(Tension assembly)

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. TL14**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	41	Safety Factor of Fittings for Conductors and/or Ground Wires of Overhead High-voltage Lines	
Title	Insulator Strength			

A safety factor of insulator assemblies for overhead transmission lines shall be no less than 2.5.

The safety factor is derived as follows:

a. For tension insulator assemblies

[Safety factor] = [Tensile breaking strength] / [Assumed maximum tension at a supporting point]

b. For suspension insulator assemblies

[Safety factor] = [Tensile breaking strength] / [Assumed maximum resultant of vertical loads and horizontal transverse loads]

c. For supporting insulator assemblies, such as Long-rod insulator assemblies

[Safety factor] = [Bending breaking strength] / [Assumed maximum load perpendicular to the axis of the insulator assembly]

The following table shows foreign countries' standards for reference.

	Safety factor based on U.T.S.
Technical Standard: Japan	No less than 2.5
National Electrical Safety Code(NESC): U.S.A.	No less than 2.0 against tensile No less than 2.5 against bend
The Electricity (Overhead Lines) Regulations: U.K.	No regulation
VDE0210: Germany	No less than 3.3

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. TL15**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	41	Safety Factor of Fittings for Conductors and/or Ground Wires of Overhead High-voltage Lines	
Title	Safety Factor of Fittings for Conductors and Ground Wires			

Safety factor for tensile strength (the maximum tensile strength, breaking strength) of fittings of conductors and ground wires for overhead high-voltage lines shall be 2.5 or more.

Foreign countries' standards are described below for reference.

	Safety factor based on yield strength
Technical Standard: Japan	No less than 2.5
National Electrical Safety Code(NESC): U.S.A.	No less than 2.0 against tensile No less than 2.5 against bend
The Electricity (Overhead Lines) Regulations: U,K.	No regulation
VDE0210: Germany	No less than 3.3

Remarks	Revisions	
	2003/Nov.	Original

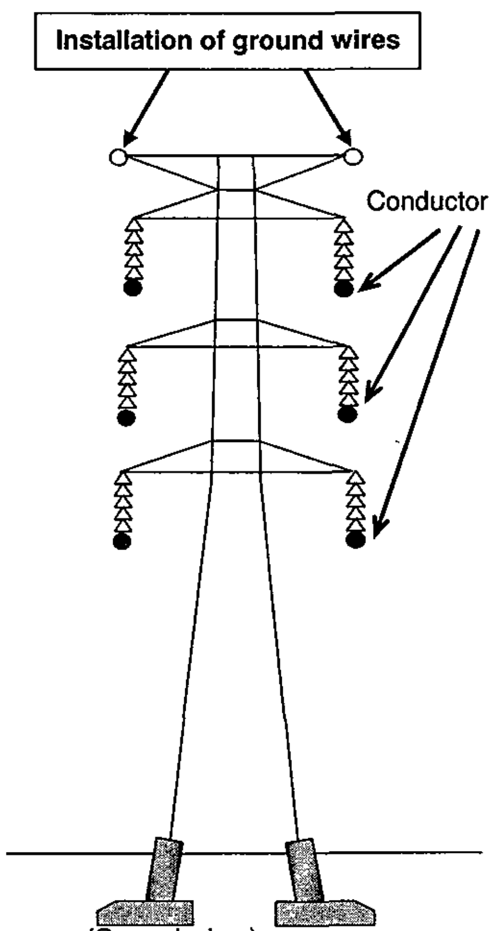
Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. TL16**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	42	Protection against Lightning for Overhead High-voltage Lines	
Title	Protection against Lightning			

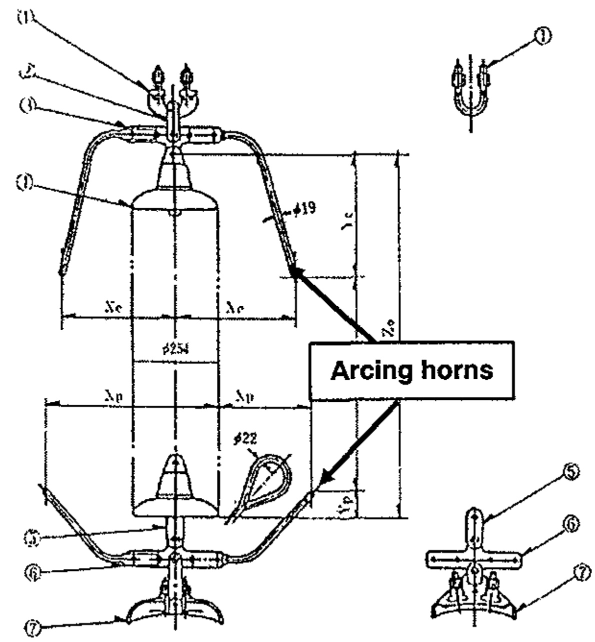
The following measures shall be taken for overhead high-voltage lines to decrease the number of electrical faults, and to protect equipment from damage by the faults

1.Installation of ground wires

2.Installation of arcing horns

3.Decreace of tower-footing resistance
No less than 10 Ω





(An example of a set of arching horns for a single conductor)

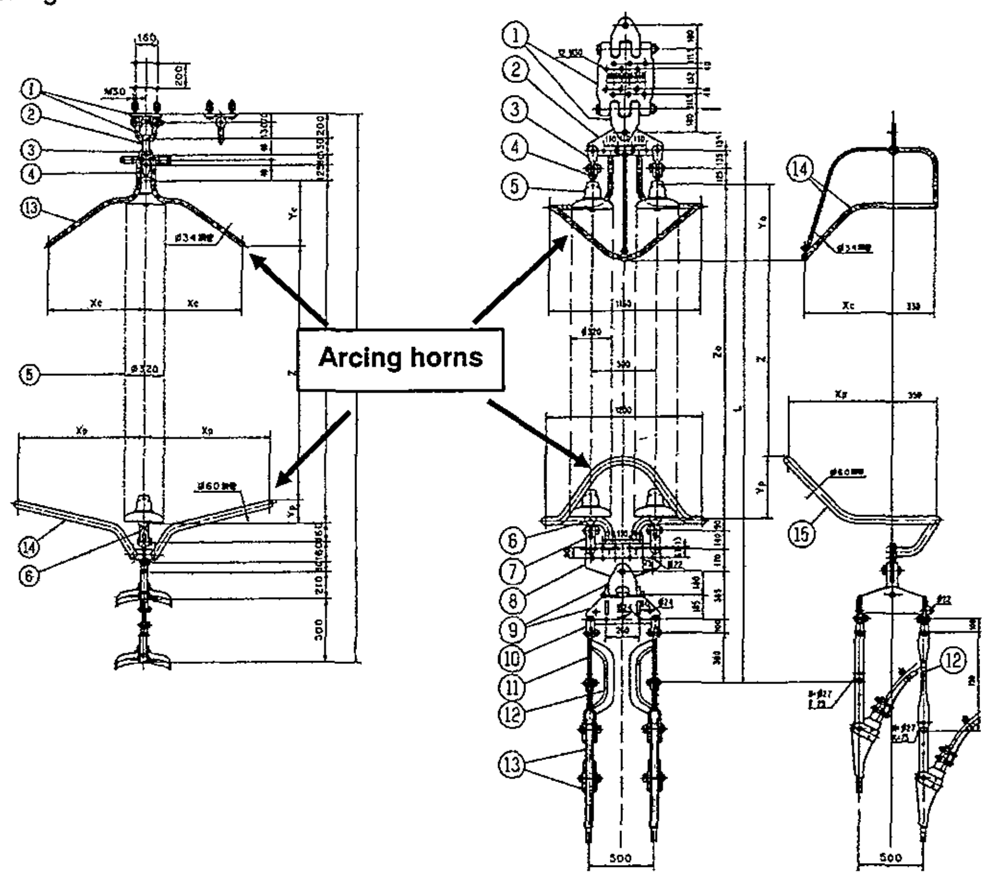
Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL17
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	42	Protection against Lightning for Overhead High-voltage Lines	
Title	Arcing Horns			

Arcing horns shall be installed to protect overhead high-voltage lines against lightning

When lightning strikes an electrical line, insulators are occasionally destroyed. Normally, damage of insulators is caused by follow-current (50Hz), after the lightning stroke and not the lightning surge itself. Application of arcing horns, which move the arcs of the lightning surge on a surface of an insulator assembly to the end of the arcing horns, is the effective and economical countermeasure.

The gap of the arcing horns must be decided to withstand at least switching-surge, and so that the critical cascading flashover voltage of the horn gap can be predominant over one of the insulator string.



(Suspension type) (Tension type)

(An example of a set of arching horns for a quadruple conductor)

Remarks	Revisions	
Referring to the standards of KANSAI Electric Power Co., Inc.		
	2003/Nov.	Original

Title	Kinds of Conductors

Properties of solid wires (hard-drawn aluminum wire, zinc-coated steel wire, aluminum-clad steel wire, etc.) that compose an electrical conductor should comply with following IEC standards.

IEC60889 Hard-drawn aluminum wire for overhead line conductors
IEC60888 Zinc-coated steel wires for stranded conductors
IEC61232 Aluminum-clad steel wires for electrical purposes

Cross section of a typical stranded wire (ACSR) is as follows.

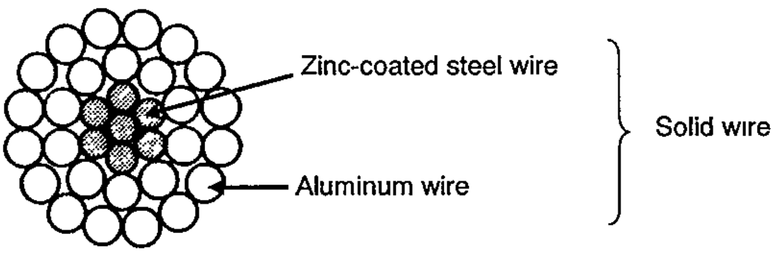


Fig.1 Cross section of stranded wire (ACSR410mm^2)

Where corrosion of conductors and ground wires is expected due to such pollution as salt, Aluminum Conductor Aluminum Clad Steel Wire Reinforced (ACSR/AS) should be adopted.

A size of a conductor should be decided in consideration of the following points.

a. Loading current
b. Short-circuit current
c. Mechanical strength

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL19
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	43	Bare Conductors of Overhead High-voltage Lines	
Title	Current-carrying Capacity			

Current-carrying capacity of overhead high-voltage lines can be computed by the following equations.

$$I = \sqrt{\frac{\left\{Hw + \left(Hr - \frac{Ws}{\pi\theta}\right)\eta\right\}\pi D\theta}{\beta \cdot R}}$$

where, $$Hw = \frac{0.00572}{\left(273 + T + \frac{\theta}{2}\right)^{0.123}} \cdot \sqrt{\frac{V}{D}}$$

$$Hr = 0.000567\frac{\left(\frac{273+T+\theta}{100}\right)^4 - \left(\frac{273+T}{100}\right)^4}{\theta}$$

$$R = R_{20}\{1 + \alpha(t - 20)\}$$

$$\theta = t - T$$

I	:Current-carrying capacity (A)
Hw	:Coefficient of conventional heat dissipation (W/°C. cm^2)
Hr	:Coefficient of radiative heat dissipation (W/°C. cm^2)
R	:Conductor resistance at the conductor temperature t (ohm/cm)
R_{20}	:Conductor resistance at 20°C (ohm/cm)
θ	:Temperature rise of conductor (°C)
t	:Conductor temperature (°C)
T	:Ambient temperature (°C)
Ws	:Solar radiation energy (W/cm^2), assumed to be 0.13
η	:Surface coefficient, assumed to be 0.9
D	:Overall diameter of conductor (cm)
V	:Wind velocity (m/sec)
α	:Temperature coefficient of resistance (per °C), assumed to be 0.004
β	:AC/DC resistance ratio, assumed to be 1.0

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. TL20-1**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	43	Bare Conductors of Overhead High-voltage Lines	
Title	Sag of Conductors (1/4)			

(1) Calculation of Tension of Conductors

A tension of a conductor is calculated based on the quadratic approximation, as follows:

In the following equation, subscript 1 and 2 mean the Conditions, respectively.

Condition 1

$L_1 = S\,[1 + (w_1/T_1)^2\,(S^2/24)]$ ...1)

Condition 2

$L_2 = S\,[1 + (w_2/T_2)^2\,(S^2/24)]$ ...2)

where,

L = Length of conductor[m]

T = Tension of the conductor[kg]

S = Span[m]

w = Load of conductor [kg/m]

where,

$$w = \sqrt{W_c^2 + Pw'^2}$$

Wc : Mass of Conductor[kg/m]

Pw' : Wind Pressure of Conductor

$Pw' = d \times Pw \times 10^{-3}$[kg/m]

Pw = Wind Pressure of Conductor[kg/m^2]

d = Diameter of Conductor[mm]

Remarks	Revisions	
	2003/Nov.	Original

On the other hand, expansion of conductor is described as follows:

$$L_2 - L_1 = \left\{ (t_2 - t_1)\varepsilon + \frac{T_2 - T_1}{A \cdot E} \right\} L_1 \quad \ldots 3)$$

where,

$(t_2 - t_1)\varepsilon$	=	Length difference by temperature change
$\frac{T_2 - T_1}{A \cdot E}$	=	Length difference by tension change
t	=	Temperature[°C]
ε	=	Coefficient of linear expansion[/°C]
A	=	Sectional area of conductor (total)[mm²]
E	=	Modulus of elasticity[kg/mm²]

In the above equations from 1) through 3), assuming as follows:

$$\left\{ (t_2 - t_1)\varepsilon - \frac{T_2 - T_1}{A - E} \right\} \frac{S^3 \cdot w_1^2}{24 T_1^2} = 0$$

The following equation 4) is derived.

$$\frac{S^2 w_2^2}{24T_2^2} - \frac{S^2 w_1^2}{24T_1^2} - (t_2 - t_1)\varepsilon + \frac{T_1 - T_2}{A \cdot E} = 0 \quad \ldots 4)$$

In the above equation, assuming as follows;

$$K = \frac{T_1}{A} - \frac{S^2 \cdot w_1^2 \cdot E}{24 T_1^2}$$

$$M = \frac{S^2 \cdot w_2^2 \cdot E}{24 A^2}$$

$$f_2 = \frac{T_2}{A}$$

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL20-3
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	43	Bare Conductors of Overhead High-voltage Lines	
Title	Sag of Conductors (3/4)			

The following equation is derived.

$$\frac{M}{f_2^2}-f_2=-K+\varepsilon\left(t_2-t_1\right)E$$

$$f_2^2\left[f_2-\left\{K-\varepsilon\left(t_2-t_1\right)E\right\}\right]=M \quad \ldots 5)$$

(2) Example of the Calculation

Physical constants of each conductor are assumed as follows.

		ACSR 429
Calculated Sectional Area A	[mm^2]	484.5
Overall Diameter d	[mm]	28.62
Mass per meter Wc	[kg/m]	1.621
Coefficient of Linear Expansion ε	[/°C]	1.954×10^{-5}
Modulus of elasticity E	[kg/mm^2]	7987

As the "Condition 1" mentioned in (1), when following values are selected,

Span	S [m]	350
MWT	T_1[kg]	3,400
Temperature	t_1 [°C]	10
Wind Pressure	P_{w1} [kg/m^2]	40
W1[kg/m] ACSR429	1.984	

"Condition 2" (tension of conductor) mentioned in (1) is derived as follows;

Conductor	Input			---			Answer	
	t2 [°C]	P_{w2} [kg/m^2]	w_2 [kg/m]	K	M	K-ε (t_2 - t_1) E	f_2 [kg/m·mm^2]	T_2 [kg]
ACSR 429	30	0	1.621	-6.871	456.338	-9.992	5.439	2.635
	75	0	1.621	-6.871	456.338	-17.015	4.596	2.227
	90	0	1.621	-6.871	456.338	-19.356	4.384	2.124

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL20-4
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	43	Bare Conductors of Overhead High-voltage Lines	
Title	Sag of Conductors (4/4)			

(3)Sag Calculation

Sags are described with the result of the tension calculation mentioned in (1) and (2), and the following equation.

$$Sag = \frac{S^2 \cdot w}{8 \cdot T}$$

(4)Sag Template Calculation

Sag Template is made on the basis of the assumption in which all spans between two tension towers have the same tension.

$$T = \frac{S_1^2 \cdot w}{8 \cdot Sag_1} = \frac{S_2^2 \cdot w}{8 \cdot Sag_2}$$

Basic Span 350 m

Conductor ACSR 429 mm² Zebra (90 °C)

$$\frac{S_1^2 \cdot w}{8 \cdot Sag_1} = \frac{S_2^2 \cdot w}{8 \cdot Sag_2} \rightarrow \frac{350^2}{11.37} = \frac{S_2^2}{Sag_2}$$

$$\boxed{Sag_2 = \frac{11.69}{350^2} = S_2^2 = 9.543 \times 10^{-5} S_2^2}$$

According to this relation, Sag Template for Basic Span 350 m is prepared.

Sag Template for ACSR 429 mm² for Basic Span 350 m and 90 °C

Span (m)	Sag (m)
200	3.82
250	5.96
300	8.59
350	11.69
400	15.27
450	19.32
500	23.86

Remarks	Revisions	
	2003/Nov.	Original

Category				Document No. TL 21
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	43	Bare Conductors of Overhead High-voltage Lines	
Title	Safety Factor of Conductors			

A safety factor of conductors and ground wires for overhead high-voltage lines shall be no less than 2.5 to the tensile strength (ultimate tensile strength; breaking strength).

Foreign countries' standards are described below for reference.

	Safety factor based on U.T.S.
Technical Standard: Japan	No less than 2.5
National Electrical Safety Code(NESC): U.S.A	No less than 1.67
The Electricity (Overhead Lines) Regulations: U.K.	No less than 2.0-2.5
VDE0210: Germany	No less than 2.3-2.5

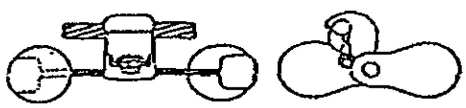
Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. TL22**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	42	Protection against Lightning for Overhead High-voltage Lines	
		43	Bare Conductors of Overhead High-voltage Lines	
Title	Measures for Aeolian Vibration			

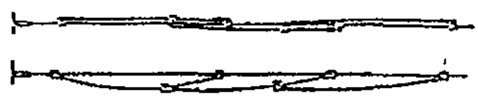
The following measures shall be taken to prevent aeolian vibration for overhead high-voltage lines.

1.Installation of vibration dampers
Examples of dampers are shown as follows.

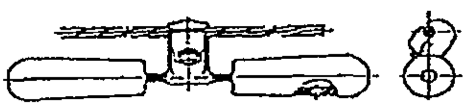
2.Installation of armor rods
An example of armor rods is shown as follows.



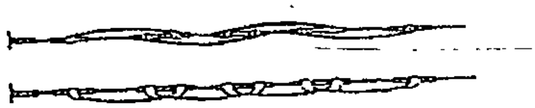
Double Torsional Damper



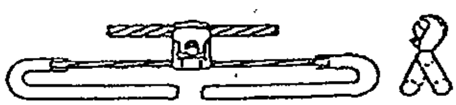
Bate Damper



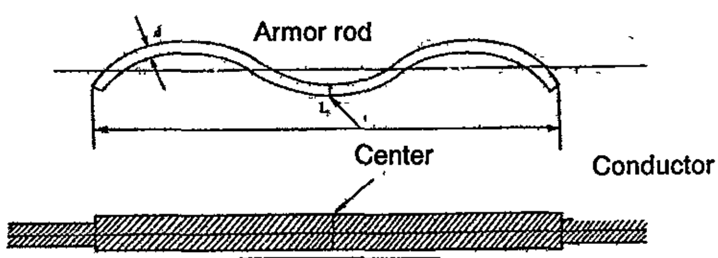
Stock Bridge Damper



Christmas Tree Damper



Vibration Less Damper



Armor rods

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. TL23**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	43	Bare Conductors of Overhead High-voltage Lines	
Title	Connection of Conductors			

For connections of conductors and ground wires of high-voltage lines, compression type sleeves shall be used. And checking of the condition before and after the compression is one of major jobs of the construction supervision, shown as follows.

(Before joint)

(After joint)

An example of jointing of conductors

Remarks	Revisions	
Referring to the standards of KANSAI Electric Power Co., Inc.		
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. TL24**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	43	Bare Conductors of Overhead High-voltage Lines	
Title	Kinds of Ground wires			

Properties of solid wires (hard-drawn aluminum wire, zinc-coated steel wire, aluminum-clad steel wire, etc.) that compose an ground wire should comply with following IEC standards.

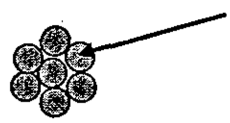
IEC60889 Hard-drawn aluminum wire for overhead line conductors
IEC60888 Zonic-coated steel wires for stranded conductors
IEC61232 Aluminum-clad steel wires for electrical purposes

Cross section of a typical stranded wire (GSW and AS) is as follows.

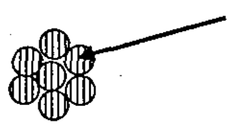
Where corrosion of conductors and ground wires is expected due to such pollution as salt, Aluminum Clad Wire (AS) should be adopted.. For an example in Kansai Area in Japan, Galvanized Steel Wire (GSW) applies in areas of more than 30km away from seacoast.

A size of a ground wire should be decided in consideration of the following points.

a. Mechanical strength
b. Current-carrying capacity against inductive current
c. Countermeasures of electromagnetic induction against communication lines



(GSW55mm^2)



(AS55mm^2)

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. TL25**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	43	Bare Conductors of Overhead High-voltage Lines	
Title	Safety Factor of Ground Wires			

A safety factor of conductors and ground wires for overhead high-voltage lines shall be no less than 2.5 to the tensile strength (ultimate tensile strength; breaking strength).

Foreign countries' standards are described below for reference.

	Safety factor based on U.T.S.
Technical Standard: Japan	No less than 2.5
National Electrical Safety Code(NESC): U.S.A	No less than 1.67
The Electricity (Overhead Lines) Regulations: U.K.	No less than 2.0-2.5
VDE0210: Germany	No less than 2.3-2.5

Remarks	Revisions	
	2003/Nov.	Original

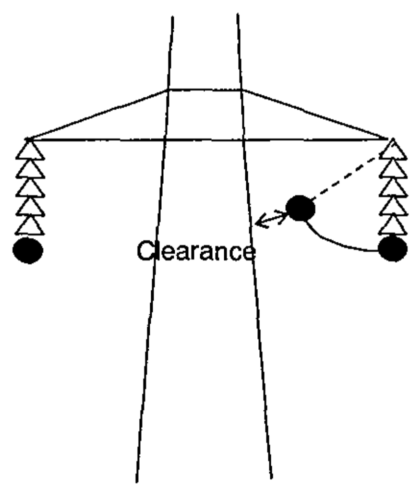
Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. TL26**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	44	Clearance among Bare Conductors and Supporting Structures of Overhead High-voltage Lines	
Title	Clearance among Bare Conductors and Supporting Structures, Arms, Guy Wires or Pole Braces			

Clearance between a conductor and a supporting structure should be decided in accordance with the switching surge voltage, taking into account the swing of the conductors. Normally, the switching surge voltages are decided as follows.

Nominal voltage :V[kV]	115	230
Highest equipment voltage :Vm=V×1.2/1.1[kV]	125.5	250.9
Peak value of line to ground voltage :Vm×√(2/3)[kV]	102.5	204.9
Switching surge multiple	2.8	2.8
Switching surge voltage[kV]	287.0	573.7
Insulating drop coefficient	1.1	1.1
Required withstand voltage[kV]	316	631
Clearance[m]	0.68	1.44

where, switching surge multiple is following;

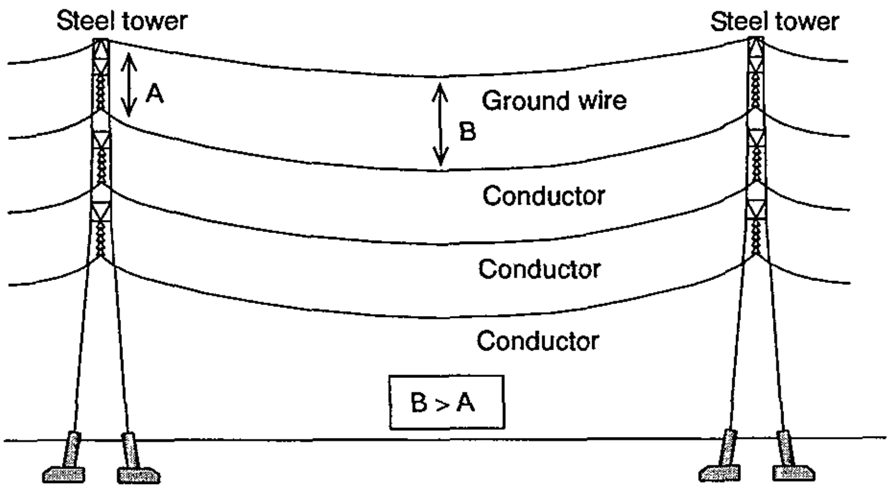
Type of neutral grounding	Multiple
Neutral reactor grounding	3.3
Neutral direct grounding	2.8
Neutral resistance grounding	2.0



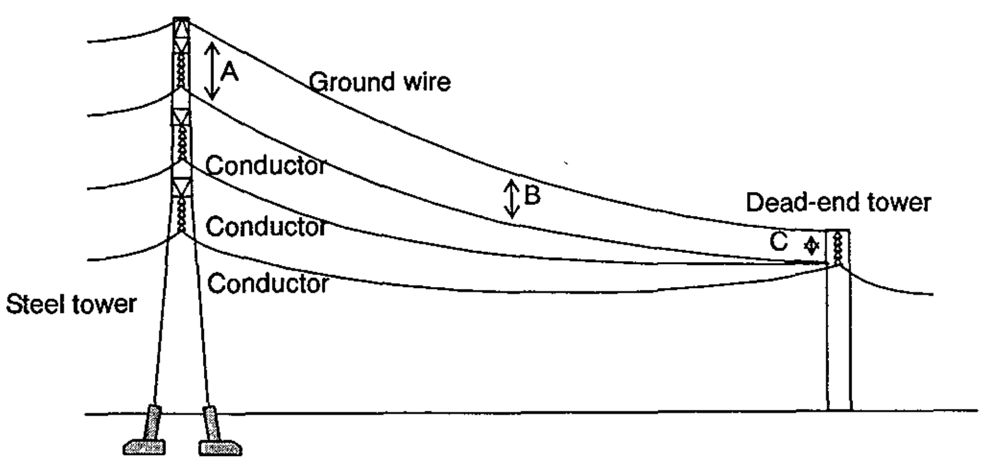
Remarks	Revisions	
	2003/Nov.	Original

Category				Document
	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL27
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	44	Clearance among Bare Conductors and Supporting Structures of Overhead High-voltage Lines	
Title	Clearance among Ground Wires and the Nearest Conductor			

Clearance between a ground wire and a conductor shall be designed as B>A, in any cases to be designed.



In the case of the end span to substations, as shown in the following figure, clearance should be designed as A > B > BC.

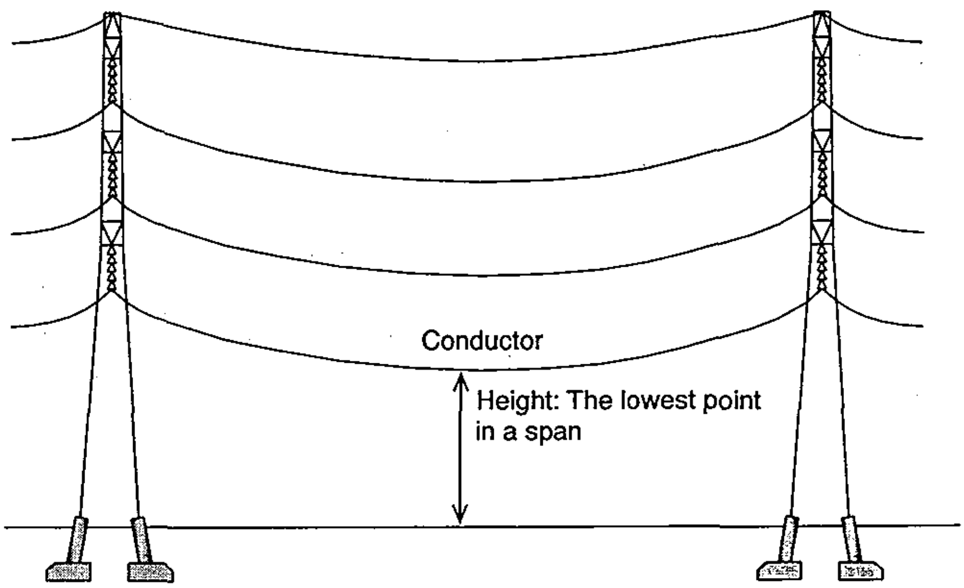


Remarks	Revisions	
	2003/Nov.	Original

Category				
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL28-1
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	45	Height of Overhead High-voltage Lines	
Title	Height of Conductors (1/4)			

1. Height of Conductors in and around Urban Area

An example of height of conductors of overhead high-voltage lines in and around urban area is as follows.



Voltage [kV]	Height [m]
115	No less than 7.0
230	No less than 7.7

The Heights shall be kept at any points in a span. Furthermore, height of conductors in urban area shall be decided that an electric field at the height of 1 m from the ground is 3kV/m or less in compliance with Clause 47. Normally, the latter height, decided by the electric field, is dominant for extra-high voltage lines.

The Heights have been decided, taking into account foreign countries' standards, and *Technical Standards for distribution lines and current conditions in Cambodia*. Foreign countries' standards are described below for reference.

Voltage [kV]	Heights [m]			
	Japan	U.S.A(NESC)	France	Germany
115	6.0	6.1	6.6	-
230	6.8	6.8	7.1	7.7

- Remark: Definition of "urban area" is different in the countries.

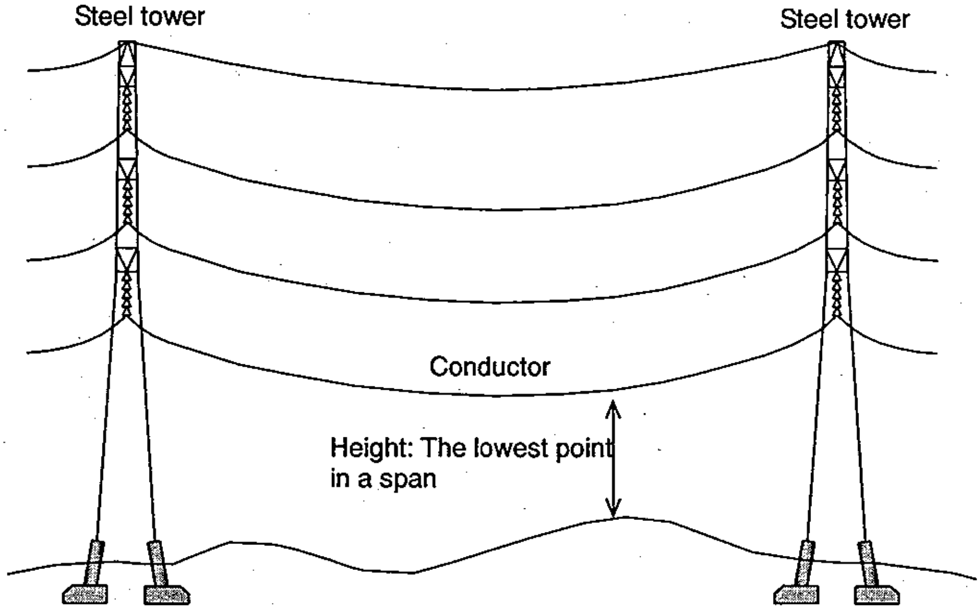
Remarks	Revisions	
	2003/Nov.	Original

Category				Document No. TL28-2
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	45	Height of Overhead High-voltage Lines	

Title	Height of Conductors (2/4)

2. Height of Conductors in Areas where Third Persons hardly Approach

An example of height of conductors of overhead high-voltage lines in areas where third persons hardly seem to approach, such as a mountainous area, is as follows.



Voltage[kV]	Height[m]
115	No less than 6.0
230	No less than 6.7

The Heights of conductors shall be kept at any points in a span.

The Heights have been decided, taking into account Japanese standard, and Technical Standards for distribution lines and current conditions in Cambodia. Japanese standard is described below for reference.

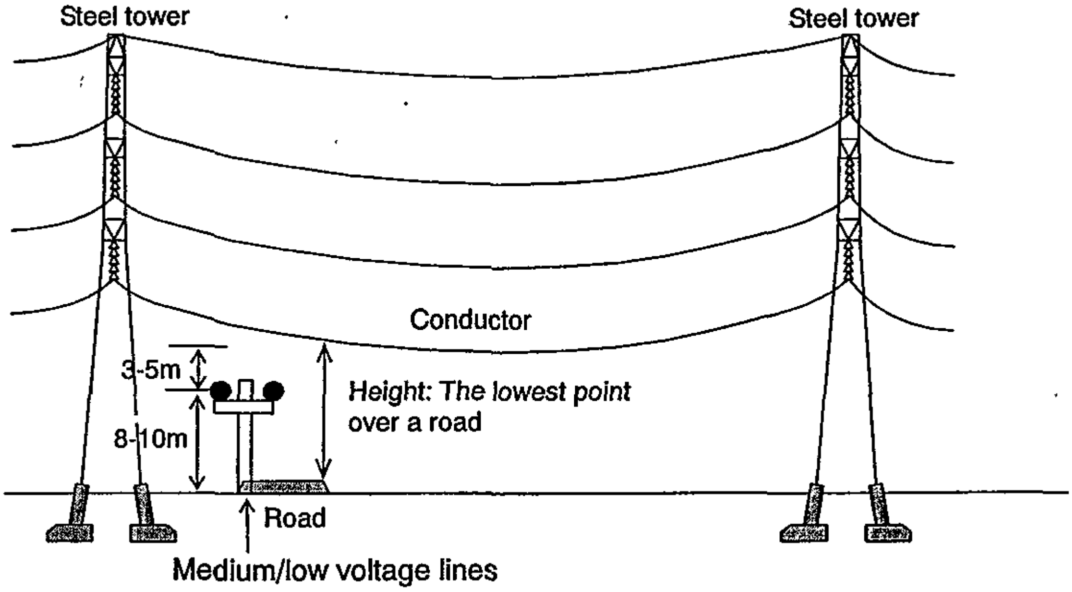
Voltage [kV]	Heights [m]
	Japan
115	5.0
230	5.9

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL28-3
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	45	Height of Overhead High-voltage Lines	
Title	Height of Conductors (3/4)			

3. Height of Conductors crossing over Roads and/or Railways

Height of conductors of overhead high-voltage lines crossing roads, such main roads as national roads, and/or railways should be decided taking into account possibility of construction of distribution line along the roads and/or railway, show as below.



Voltage[kV]	Height[m]
115	No less than 13.5
230	No less than 14.2

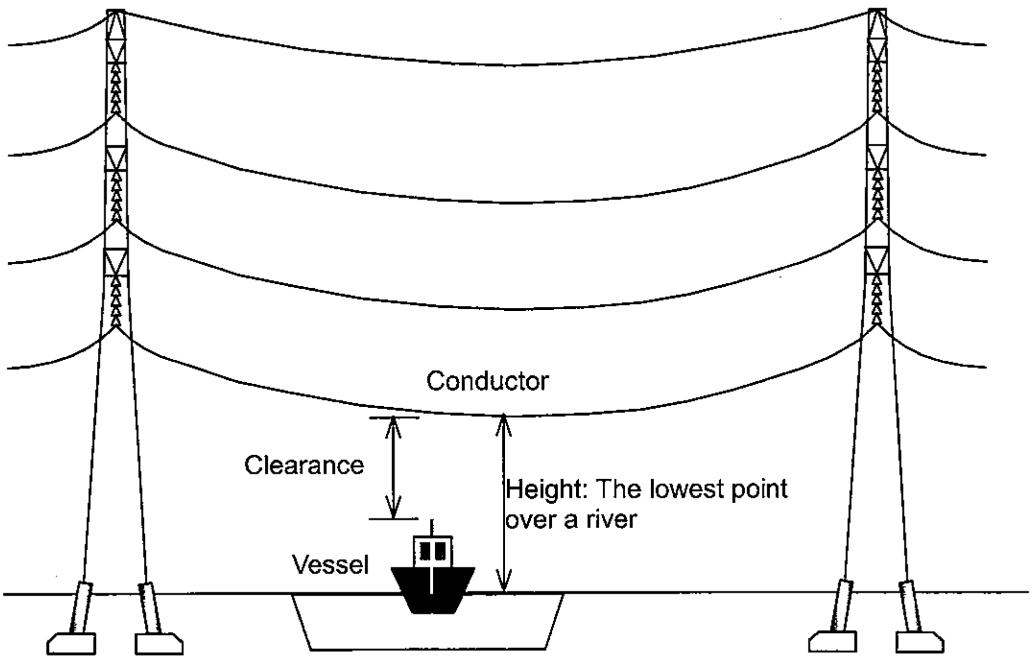
Where a high-voltage line crosses over such a major road as National Roads, the height of the conductors should be decided so that distribution lines and/or houses can be constructed along the roads. Appropriate design as shown in the above figure, in which the line crosses over the road near the supporting structure and not at the biggest sagging point, can make height of the supporting structure not so high.

Remarks	Revisions	
	2003/Nov.	Original

Category				Document No. TL28-4
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	45	Height of Overhead High-voltage Lines	
Title	Height of Conductors (4/4)			

4. Height of Conductors crossing Rivers and/or Seas

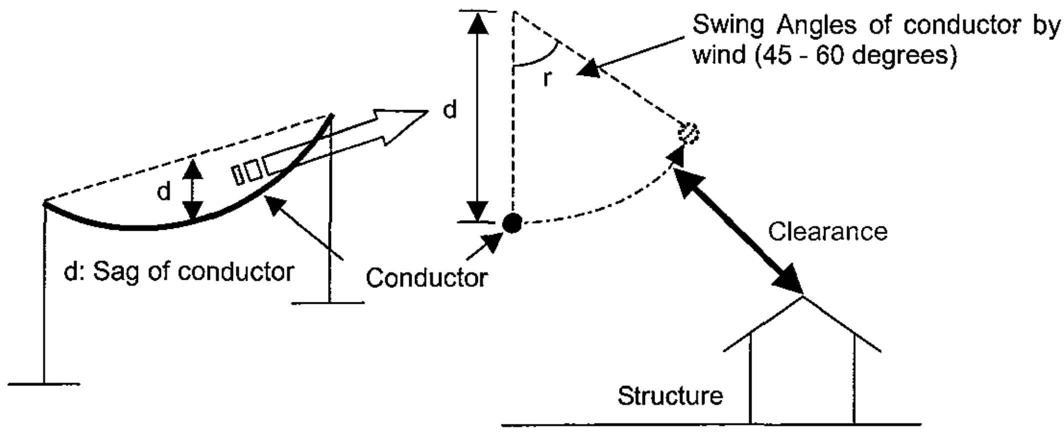
An example of height of conductors of overhead high-voltage lines crossing rivers and/or seas is as follows.



Voltage[kV]	Height or Clearance [m]
115	Height: No less than 6.0 Clearance: No less than 3.5m
230	Height: No less than 6.7 Clearance: No less than 4.2m

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	***Document* No. TL29-1**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	46	Clearance among Overhead high-voltage Lines and Other Facilities or Trees	
Title	Clearance among Conductors and Others (1/3)			

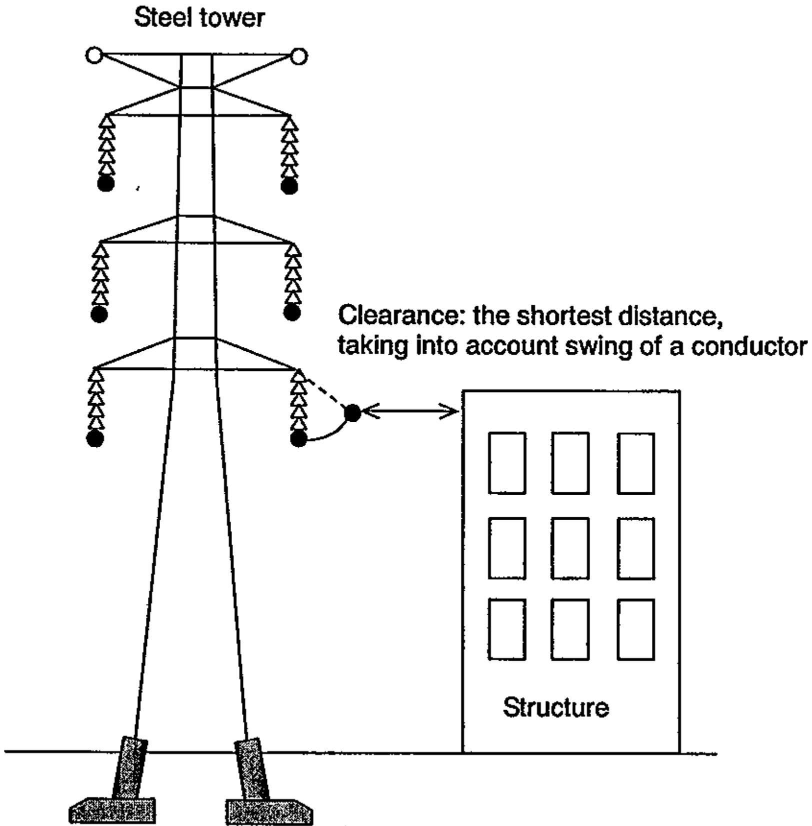


Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL29-2
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	46	Clearance among Overhead high-voltage Lines and Other Facilities or Trees	
Title	Clearance among Conductors and Others (2/3)			

1. Clearance among Conductors and Other Facilities

An example of clearance among each conductor of overhead high-voltage lines and other facilities is as follows.



Voltage[kV]	Clearance[m]
115	3.5
230	4.2

The Clearances have been decided, taking into account foreign countries' standards and Technical Standards for distribution lines and current conditions in Cambodia. Foreign countries' standards are described below for reference.

Voltage [kV]	Clearances [m]			
	Japan	France	U.S.A(NESC)	Germany
115	4.2	3.9 (3.6)	4.6 (1.9)	-
230	6.0	4.7 (4.2)	5.3 (2.6)	5.7 (3.7)

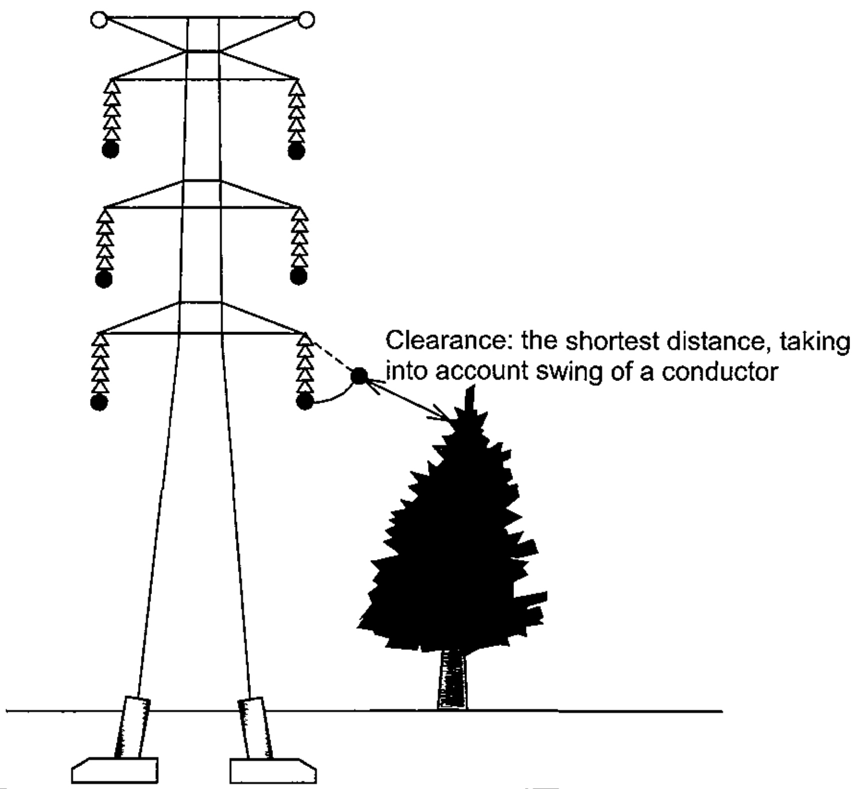
Remark: ( ) is clearance when conductors are swinging.

Remarks	Revisions	
	2003/Nov.	Original

Category				
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL29-3
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	46	Clearance among Overhead high-voltage Lines and Other Facilities or Trees	
Title	Clearance among Conductors and Others (3/3)			

2. Clearance among Conductors and Trees

An example of clearance among each conductor of overhead high-voltage lines and trees is as follows.



Voltage[kV]	Clearance[m]
115	2.5
230	3.2

The Clearances have been decided, taking into account foreign countries' standards, and Technical Standards for distribution lines and current conditions in Cambodia. Foreign countries' standards are described below for reference.

Voltage [kV]	Clearances [m]		
	Japan	France	Germany
115	2.8	1.9 (1.3)	-
230	4.1	2.8 (1.6)	3.2

Remark: ( ) is clearance when conductors are swinging.

Remarks	Revisions	
	2003/Nov.	Original

Category				
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No. TL30-1
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	47	Prevention of Danger and Interference due to Electrostatic Induction and Electromagnetic Induction	
Title	Measures for Electrostatic and Electromagnetic Inductive Interference (1/3)			

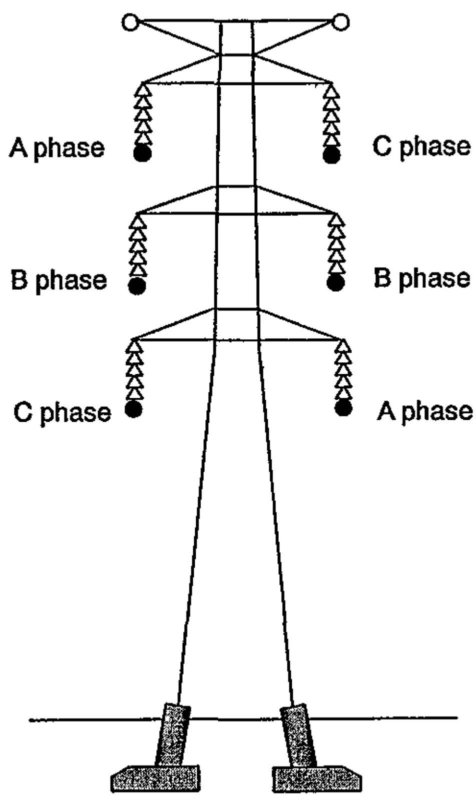
The electric field caused by overhead high-voltage lines at 1m above the ground surface shall be 3kV/m or less. The following table shows the feelings when touching metal materials charged by Electrostatic Induction.

Electric field[kV/m]	The feeling
Less than about 3	No feeling almost
About 3 – 6	Feeling a little
More than about 6	Feeling

Measures for electrostatic inductive interference are as follows.

1.Making height of towers higher

2. Adoption of reversed phase-formation



An example of reversed phase-formation

Remarks	Revisions	
	2003/Nov.	Original

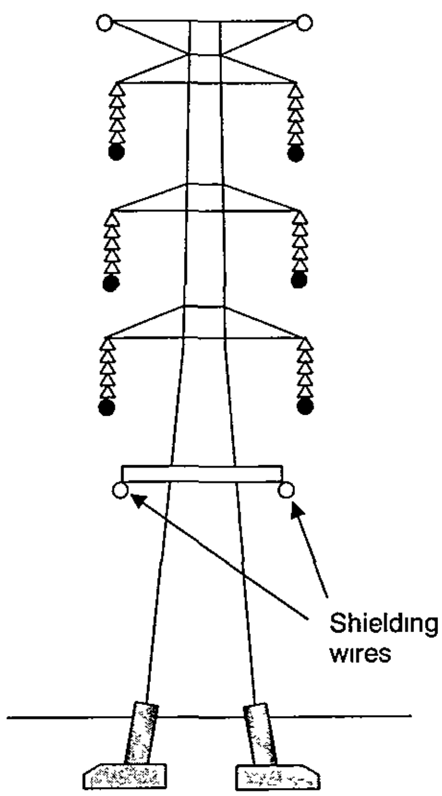
Category				Document No. TL30-2
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	47	Prevention of Danger and Interference due to Electrostatic Induction and Electromagnetic Induction	
Title	Measures for Electrostatic and Electromagnetic Inductive Interference (2/3)			

Measures for electromagnetic inductive interference are as follows.

1. Installation of shielding wires

2. Making clearance bigger

3. Adoption of Electromagnetic shielding cables for low-voltage lines and/or communication lines

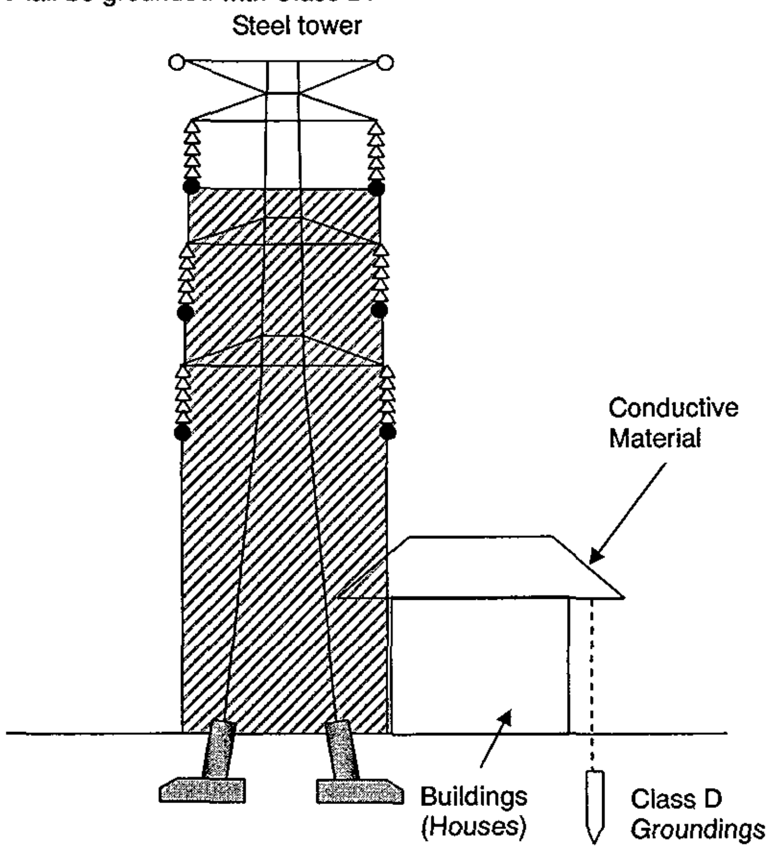


Installation of shielding wires

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No. TL30-3**
	Paragraph	6	Transmission and Distribution Facilities (High Voltage)	
	Clause	47	*Prevention of Danger and Interference due to* Electrostatic Induction and Electromagnetic Induction	
Title	Measures for Electrostatic and Electromagnetic Inductive Interference (3/3)			

Basically, Neither buildings nor houses should be constructed under overhead high-voltage lines. However, if the construction is unavoidable, the conductive materials on the surface of the buildings or houses shall be grounded with Class D.



Remarks	Revisions	
	2003/Nov.	Original

JICA

GUIDEBOOK
FOR
POWER ENGINEERS

English Edition

VOL. No.6
MEDIUM & LOW VOLTAGE DISTRIBUTION SYSTEM

Dec. 2003

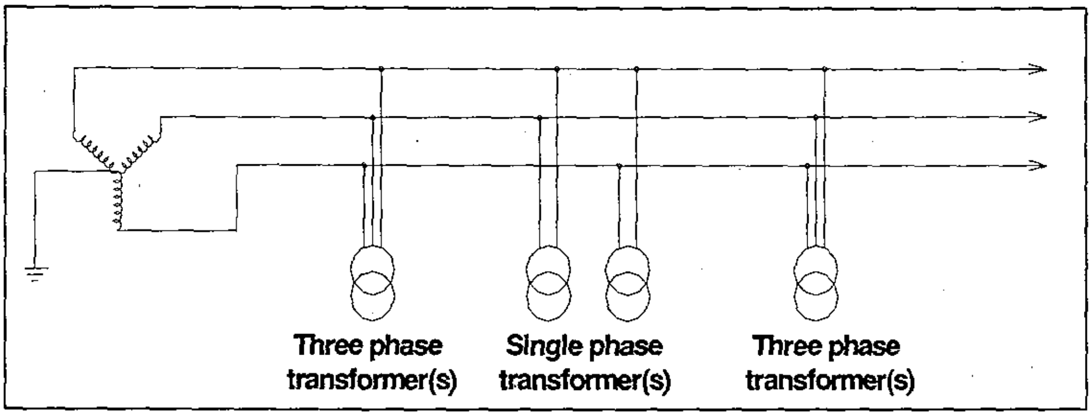
MINISTRY OF INDUSTRY, MINES AND ENERGY
ELECTRICITY AUTHORITY OF CAMBODIA
ELECTRICITE DU CAMBODGE

Contents of Medium & Low Voltage Distribution System

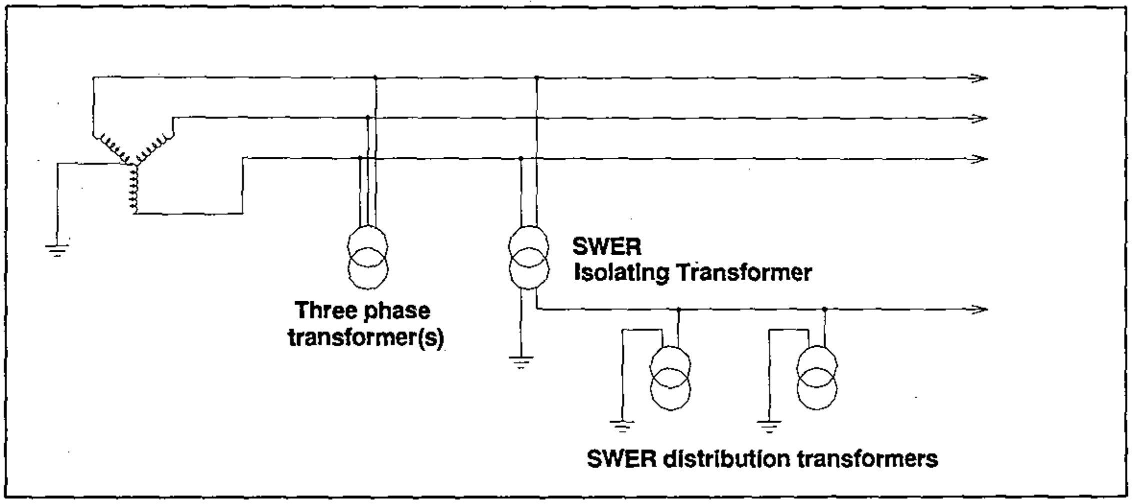
Document No.	Title
DS25	Single-line Earth Fault Current
DS26	Setting Depth of Supporting Structure
DS27	Wind Load
DS28	Calculation of Safety Factor of Foundation
DS29	Calculation of Strength of Iron-reinforced Concrete Pole and Steel Pole
DS30	Strength Test for Iron-reinforced Concrete Pole
DS31	Calculation of Strength of Wooden Pole
DS32	Installation of Guy
DS33	Calculation of Strength of Guy
DS34	Types of Conductors for Overhead Line
DS35	Connection Methods of Conductors
DS36	Cables for Overhead Line
DS37	Installation Conditions of MV/LV Transformer
DS38	Medium-voltage Over Current Circuit Breaker
DS39	Property of Fuses as Medium-voltage Over Current Circuit Breaker
DS40	Installation Position of Switchgear
DS41	Lightening Damage
DS42	Installation of Lightning Arrester
DS43	Height of Overhead Line
DS44	Clearance between Overhead Line and Structure of Building
DS45	Clearance between Overhead Line and Tree
DS46	Adjacency and Crossing of Overhead Line
DS47	Sag of Line
DS48	Composition of Overhead Distribution System
DS49	Diagram of Distribution Substation
DS50	Vehicle for Distribution Work
DS51	Interconnection of Privately Owned Power Generators

Category				Document
	Chapter	1	General Provisions	Document No.DS1-1
	Paragraph	3	Quality of Electric Power	
	Clause	6	Voltage	
Title	Distribution System (1/2)			

Three-Phase, Three-wire System



SWER System

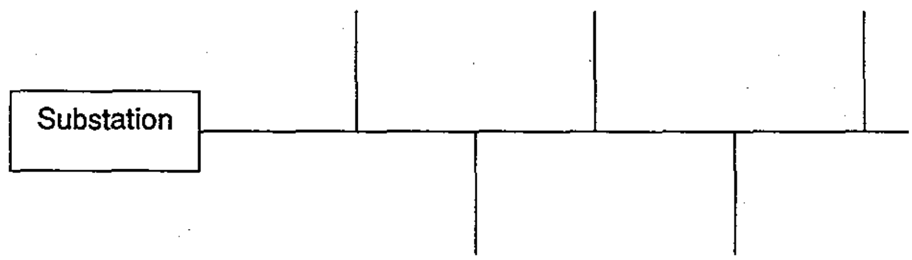


Remarks	Revisions	
Resource: EDC document		
	2003/Nov.	Original

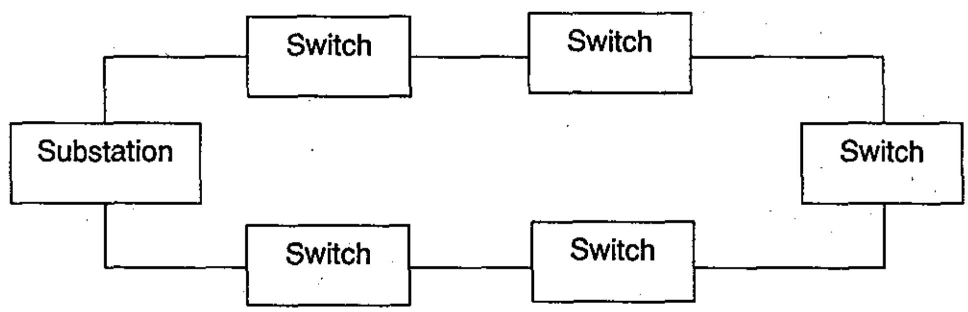
Category	Chapter	1	General Provisions	Document No.DS1-2
	Paragraph	3	Quality of Electric Power	
	Clause	6	Voltage	
Title	Distribution System (2/2)			

Medium-voltage Distribution System

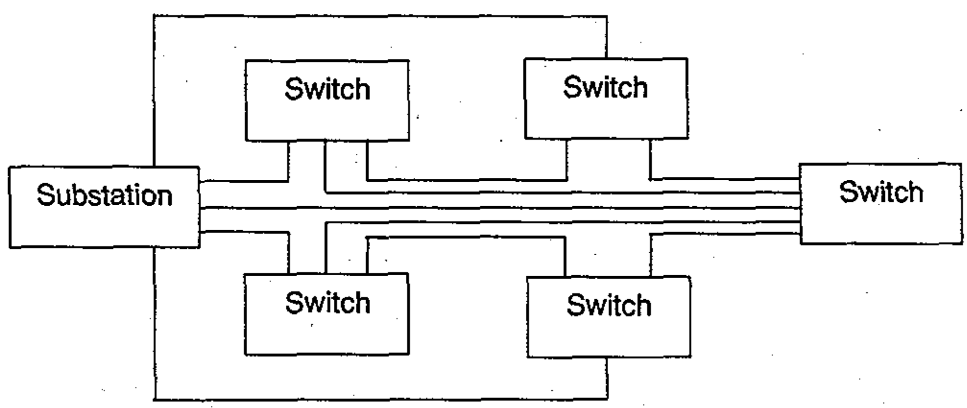
1. Radial Distribution System



2. Ring Distribution System



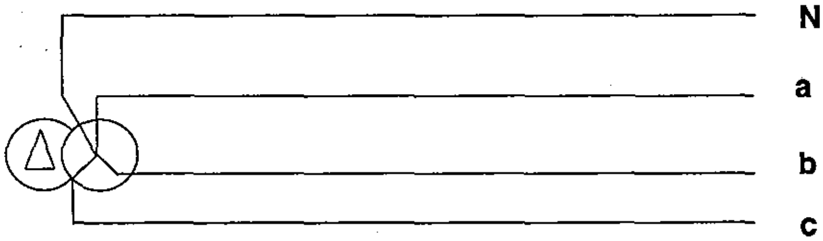
3. Network Distribution System



Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.DS2-1
	Chapter	1	General Provisions	
	Paragraph	3	Quality of Electric Power	
	Clause	6	Voltage	
Title	Low-voltage Supply System (1/3)			

Low-voltage Supply System



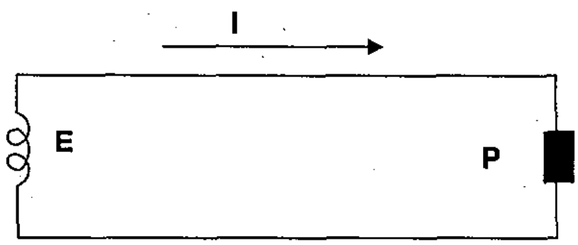
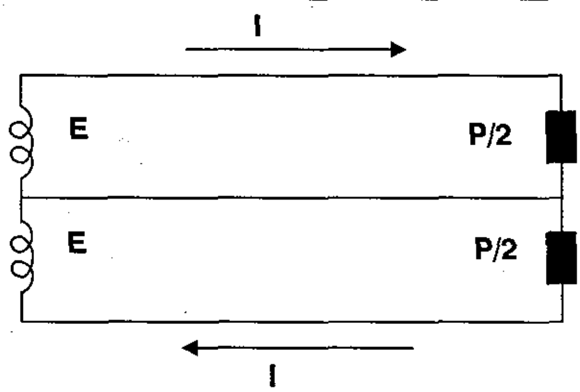
	Nominal Voltage	Variation of Voltage
a-N, b-N, c-N	220V	From 207V to 244V
a-b, b-c, c-a	380V	From 360V to 424V

Nominal voltage is conventional nominal voltage in used in Cambodia. And the variation of voltage is decided considering the conformity with IEC low-voltage standard, assuming the usage of imported apparatuses.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	1	General Provisions	Document No.DS2-2
	Paragraph	3	Quality of Electric Power	
	Clause	6	Voltage	
Title	Low-voltage Supply System (2/3)			

Current of Each Distribution System

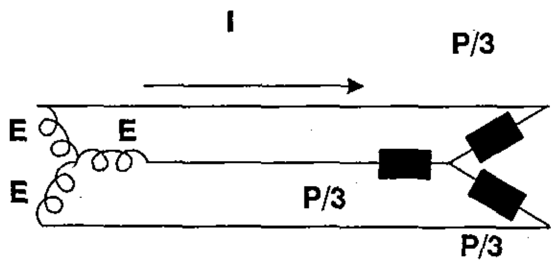
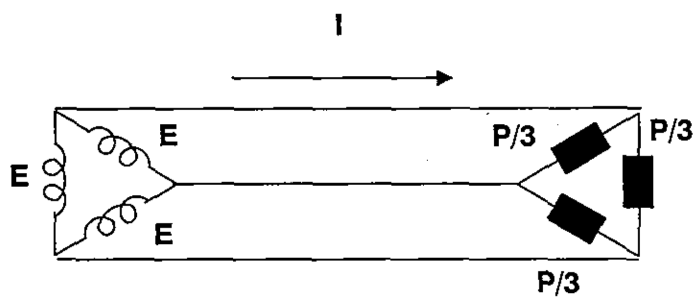
Distribution System	Current in Phase Line
	$I = \dfrac{P}{E\cos\theta}$
	$I = \dfrac{P}{2E\cos\theta}$

*Loads are assumed to be balanced.

Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.DS2-3
	Chapter	1	General Provisions	
	Paragraph	3	Quality of Electric Power	
	Clause	6	Voltage	
Title	Low-voltage Supply System (3/3)			

Current of Each Distribution System

Distribution System	Current in Phase Line
	$I = \dfrac{P}{3E\cos\theta}$
	$I = \dfrac{P}{\sqrt{3}\,E\cos\theta}$

* Loads are assumed to be balanced.

Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.DS3
	Chapter	1	General Provisions	
	Paragraph	3	Quality of Electric Power	
	Clause	6	Voltage	
Title	Management of Voltage			

Licensees have to control the supply voltage at the receiving point in accordance with the Electric Power Technical Standard.

As the voltage fluctuates always, the conformity of the supply voltage to the Electric Power Technical Standard shall be certified not just when it is measured, but also anytime.

On the other hand, it is difficult and not realistic to monitor the supply voltage, other than the outgoing voltage at a substation or a power station. Therefore the supply voltages to customers will be managed by assumption of a voltage drop or measuring it in case of necessary.

Generally the voltage of distribution line is managed by the assumption considering electrical characteristics of distribution lines and demand. When distribution facilities are designed, the voltage of the end of the lines based on the assumed demand will be within the target voltage.

To put it concretely, licensees decide the target voltages at the end of medium-voltage lines, the branching point from a main low-voltage line or the primary side of a meter. The designs of facilities will be made considering the voltage to be in conformity with each target voltage. When the voltage at each point will be out of the target by the increase of demand, such countermeasures as the scale up of conductors, the installation of boosters, the change of low-voltage networks, or the change of tap of transformers will be done. In case of the installation of boosters or the change of tap, licensees also have to examine that the voltage at the time of minimum demand will not exceed the maximum voltage regulated the Electric Power Technical Standard.

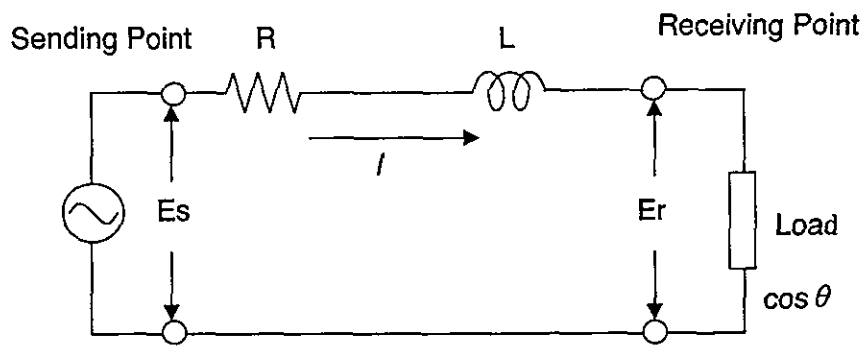
After the expansion of distribution facilities, the change of distribution network, and the supply to bulk customers, licensees should measure voltages of some critical points and examine the conformity with the Electric Power Technical Standard. In addition, the supply voltage should be measured regularly, because the total residential demand will increase gradually. The voltage, fluctuating all the time, should be measured not at a spot but for a long term enough for examination, including both a low demand period and a high demand period.

Even when there are enough capacities in transformers in a substation, conductors and other facilities, for new large customers, if the supply voltages for some customers will be out of regulated voltage taking the new demand into consideration, licensees should not supply to the new large customers before a countermeasure construction works to avoid bad influence to other customers.

Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.DS4
	Chapter	1	General Provisions	
	Paragraph	3	Quality of Electric Power	
	Clause	6	Voltage	
Title	Ferranti Effect			

Generally the power factor of a load is lagging power factor. Therefore the voltage of receiving point is less than that of sending point (Fig 1). However on the long -distance medium-voltage distribution line the capacitance of the line become larger. When the load is very small at the long-distance line, the power factor may be leading power factor because of the big charging current (Fig 2). In this case, the voltage of receiving point is larger than that of sending point. This phenomenon is called Ferranti Effect and on the occasion of managing voltage, it is necessary to take it into consideration.



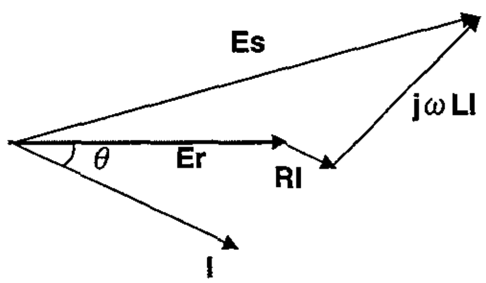


Fig.1 Normal Condition

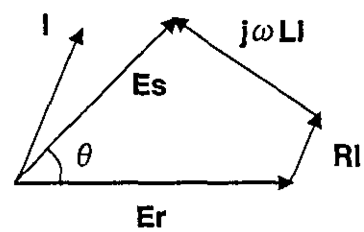
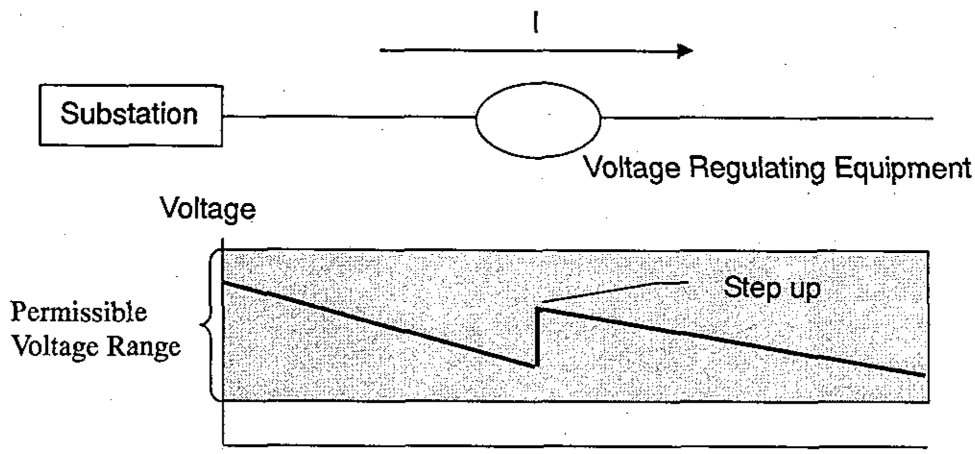


Fig.2 Ferranti Effect

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	1	General Provisions	Document No.DS5
	Paragraph	3	Quality of Electric Power	
	Clause	6	Voltage	
Title	Voltage Regulating Equipment			



Since the voltage will fluctuate by the change of the load, it is difficult to maintain the voltage within the regulated range on the long-distance medium-voltage distribution line. In such case, a voltage regulating transformer is installed to adjust the voltage in accordance with the load. The example circuit of a voltage regulating transformer is shown in Fig 1.

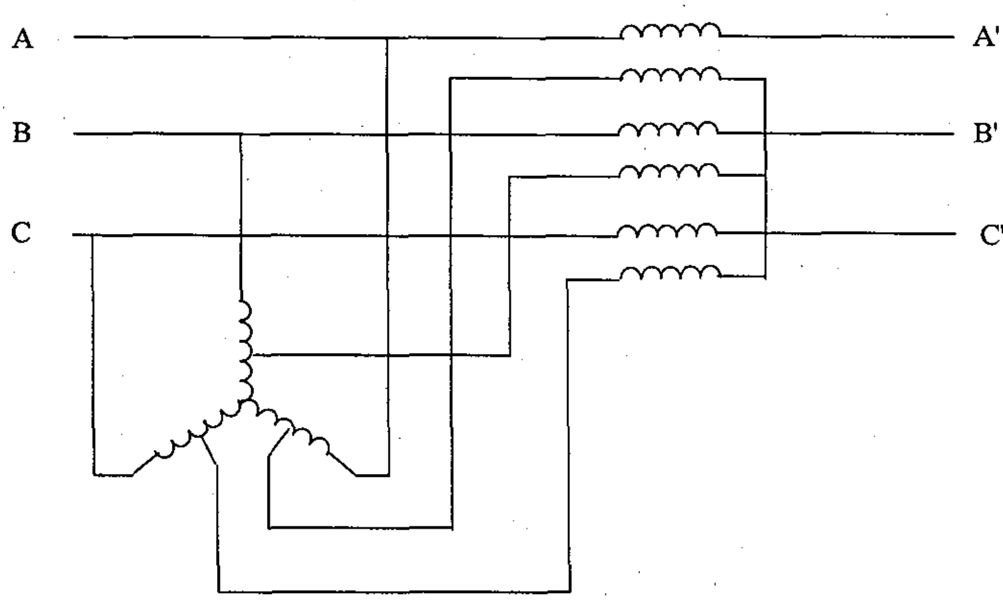


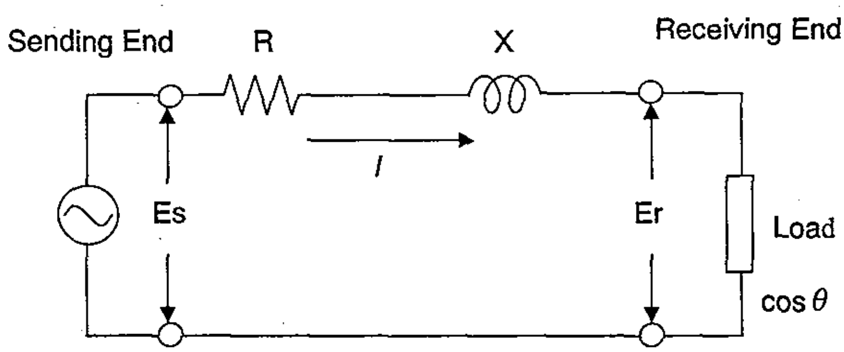
Fig.1 Example of Voltage Regulating Transformer

Remarks	Revisions	
	2003/Nov.	Original

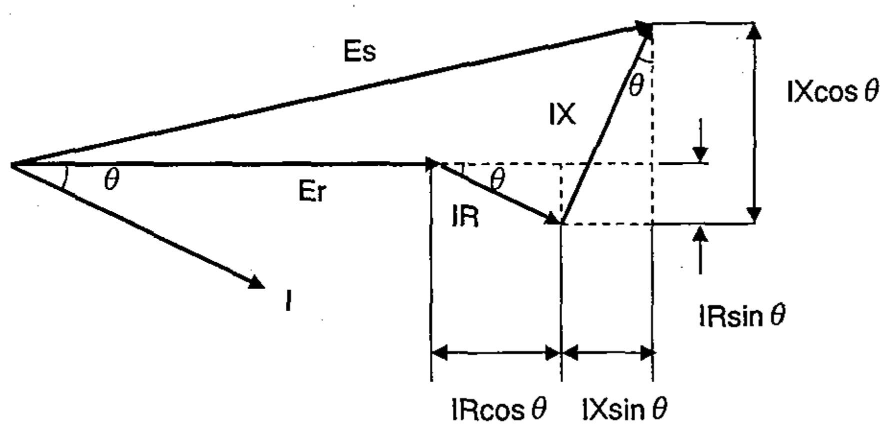
Category	Chapter	1	General Provisions	Document No.DS6-1
	Paragraph	3	Quality of Electric Power	
	Clause	6	Voltage	
Title	*Calculation of Voltage Drop (1/2)*			

For the design of distribution network the voltage drop is calculated based on the demand.

The vector diagram of voltage drop for the equivalent circuit is generally shown as follows;



Equivalent Circuit



Vector Diagram

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	1	General Provisions	Document No.DS6-2
	Paragraph	3	Quality of Electric Power	
	Clause	6	Voltage	
Title	Calculation of Voltage Drop (2/2)			

$$Es = \sqrt{(Er+IR\cos\theta+IX\sin\theta)^2+(IX\cos\theta-IR\sin\theta)^2}$$

$$\fallingdotseq Er+IR\cos\theta+IX\sin\theta$$

Therefore the voltage drop is given the following formula.

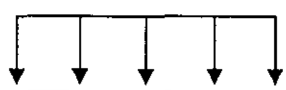
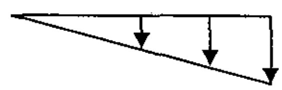
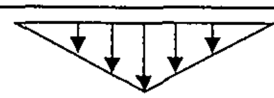
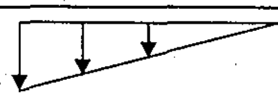
$$e = Es - Er$$
$$= I(R\cos\theta+X\sin\theta)$$
$$= I \times Re$$

Re: Equivalent resistance.

The approximate voltage drop for each load distribution model is as follows;

$$e = f \times IRe$$

f: Dispersal load factor

Model of dispersal load		***Dispersal load***
Concentrating on the end of line		1
Distributing equally on the line		0.5
Increasing, so that it goes to the end of line		0.67 (=2/3)
Becoming the maximum in the middle of line		0.5
Decreasing, so that it goes to the end of line		0.33 (=1/3)

The line voltage drop is given as follows;

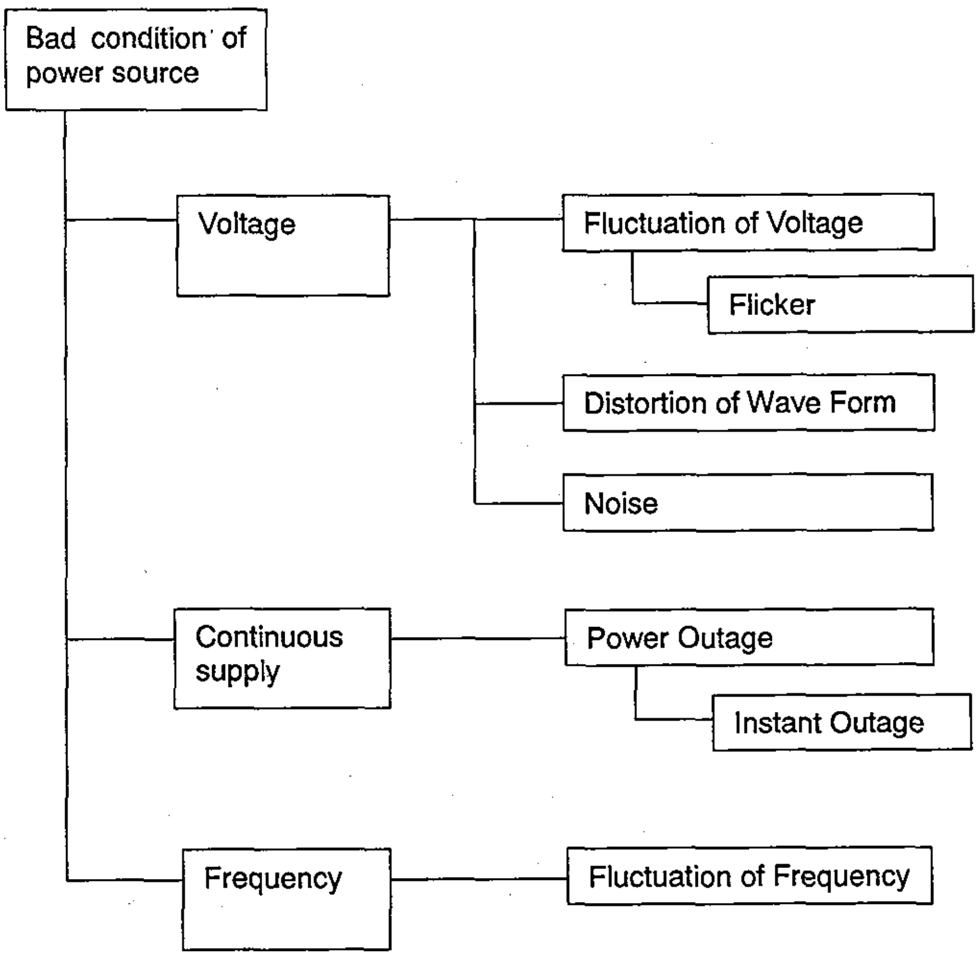
Single phase two wires system: $v = 2e$

Three phases three wires system: $v = \sqrt{3}\, e$

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	1	General Provisions	Document No.DS7
	Paragraph	3	Quality of Electric Power	
	Clause	6	Voltage	
Title	Quality of Power			

The quality of power is evaluated by following items.



Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	1	General Provisions	Document No.DS8
	Paragraph	3	Quality of Electric Power	
	Clause	6	Voltage	
Title	Flicker			

When in an instance the demand changes large, the voltage will also fluctuate intensely. If the fluctuation is too intense, the brightness of lamps and fluorescent lights will change, and twinkling will be felt depending on the difference of the voltage and its time of change. This phenomenon is called "flicker" and following influence may happen on apparatuses.

1. Twinkling on lightening apparatuses
2. Damage on electronic apparatuses
3. Noise on communication apparatuses etc.

The typical facilities that generate flicker are a welding machine, an electric furnace, an elevator and a pressing machine.

The sensible annoying is different depending on the voltage and the frequency. "Pst" measured by flicker meters provided in IEC61000-4-15 indicates the digitalization of the annoying. In IEC61000-2-2, there shows a curving line that shows the relation between frequencies and limitations of changes of voltages.
Generally the limitation of flicker is shown as follows;

Pst $\leqq$ 1

Raising the size of conductors or installing an exclusive line for a customer with the source of flicker is an example of countermeasures against flicker.

Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.DS9
Category	Chapter	1	General Provisions	Document No.DS9
	Paragraph	3	Quality of Electric Power	
	Clause	-	Others	
Title	Planning of distribution facility			

Distribution facilities are installed near the buildings, on the public roads or in the private sites. Therefore when licensees plan distribution facilities, they should consider not only the economy (cost) but also the safety or the efficiency for maintenance,
As far as the economy is concerned, both initial costs and running costs such as maintenance costs and energy losses should be considered.
The reduction of technical losses lead to the reduction of the expansion costs of generation, transmission and distribution facilities as well as the reduction of fuel costs for consolidated licensees, because the reduction of technical loss contributes to the increase of the margin of the capacities of facilities.
As well, for the distribution licensees the reduction of technical loss means the reduction of the expansion costs of distribution facilities and electricity purchase costs from generation licensees.
Technical loss is classified into the resistance loss caused from conductors, and the iron loss and copper loss from transformers.

The resistance loss is given by

$$P = N \times I^2 \times R \ \text{(W)}$$

Where
N: The number of conductor
(Single phase two wires = 2, Three phases three wires = 3)
I: Current (A)
R: Impedance of conductors

The power loss is given by

$$W = P \times T \ \text{(Wh)}$$

Where
T: Hour

Iron loss of transformers with same characteristic is constant, not depending on loads. On the other hand, copper loss, like resistance loss, generated by the current increases in proportion to the square of currents.

Generally, when power companies supply to new low-voltage customers, they are likely to expand low-voltage lines considering only initial costs. However, it is desired that expansion of facilities should be done to meet the increase of demand in the future, and considering the long-term costs.

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	1	General Provisions	**Document No.DS10**
	Paragraph	3	Quality of Electric Power	
	Clause	-	Others	
Title	Demand Forecast by Distribution Licensee			

Licensees should expand their distribution facilities to meet the assumed future demand.

Demand forecasting will be done considering the following items totally.

a. Historical trend of demand
b. Economic index
c. Demand of bulk customers (now and future)

Maximum demand will be decided in consideration of the assumed demand, the demand factor and the diversity factor.

Demand Factor = Maximum Demand / Installed Capacity

Diversity Factor = Σ Maximum Demand of each load / Maximum Demand

Demand factor and diversity factor will be assumed based on the past records regarding real demands or contract demands and installed capacities.

Distribution facilities will be expanded considering both current and voltage at the maximum demand.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	1	General Provisions	Document No.DS11-1
	Paragraph	3	Quality of Electric Power	
	Clause	-	Others	
Title	Power Factor (1/2)			

The power of AC circuit is as follows;

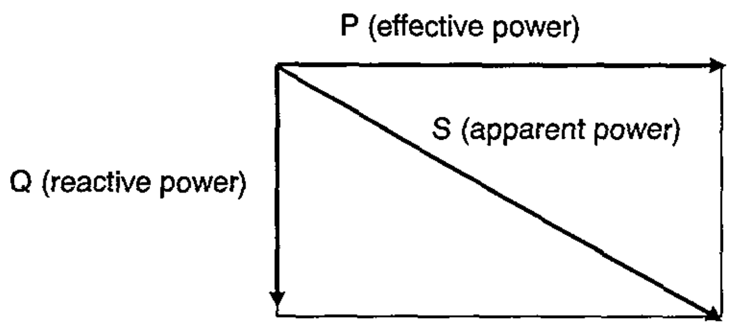
P = VI cos θ (W)

P is called effective power. On the other hand, the charged power in reactor is called reactive power and is given by the following;

Q = VI sin θ (var)

The composition of P and Q is called apparent power and is given by the following;

S = VI (VA)



θ is the difference of phases on current and voltage. Therefore even when VI is constant, P changes in proportion to cos θ. cos θ. is called power factor and the less the power factor is, the more the loss increases. Generally power factor should be no less than 85%.

To improve the power factor, a capacitor is connected to load and parallel (Fig.1 and 2).

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	1	General Provisions	Document No.DS11-2
	Paragraph	3	Quality of Electric Power	
	Clause	-	Others	
Title	Power Factor (2/2)			

θ

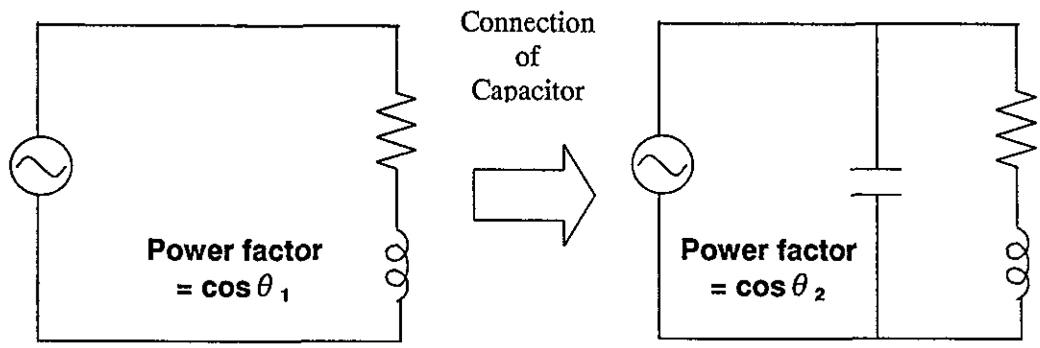
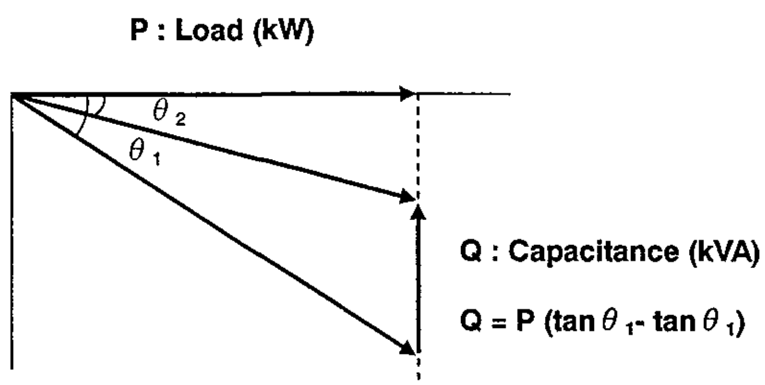


Fig.1 The circuit without capacitance

Fig.2 The circuit with capacitance



The effects by the improvement of power factor are as follows;

1. Reduction of capacity of facilities
2. Reduction of energy loss
3. Reduction of voltage drop

Remarks	Revisions	
	2003/Nov.	Original

Category				
	Chapter	1	General Provisions	Document No.DS12
	Paragraph	4	Prevention of Electric Power Disasters	
	Clause	9	Prevention of Electric Power Disasters	
Title	Medium-voltage Dielectric Tests			

1. Dielectric Tests for Medium-voltage Facilities

Medium-voltage facilities shall be withstand when the test voltage is applied at the parts given in the following table for 10 minutes continuously

Facility		***Applied parts***	***Test Voltage***
Transformer	7000V or less	Between the winding to be tested, and the other winding, the iron core and the case	1.5 times the maximum voltage
	More than 7000V		1.25 times the maximum voltage
Switchgear Circuit breaker Instrument transformer etc.	7000V or less	Between charged part and the ground	1.5 times the maximum voltage
	More than 7000V		1.25 times the maximum voltage

2. Dielectric Test for Medium-voltage Line

Medium-voltage lines shall withstand a test made by impressing the voltage given in following table, between the line and the ground for 10 minutes.

Maximum-voltage	***Test voltage***
7000V or less	1.5 times of maximum-voltage
More than 7000V	1.25 times of maximum-voltage

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	1	General Provisions	**Document No.DS13-1**
	Paragraph	4	Prevention of Electric Power Disasters	
	Clause	9	Prevention of Electric Power Disasters	
Title	Voltage Tests for 22kV Transformer (1/2)			

1 Lightning impulse test

The primary winding of transformer shall be tested, whether it has sufficient dielectric strength to withstand the definite voltage of positive and negative polarities. This test shall be repeated 3 times. The test voltage is given in following table.

Voltage wave form		1/40 μs
Crest values of voltages	Full wave voltage	150kV
	Chopped wave voltage	165kV

2 Withstand voltage test

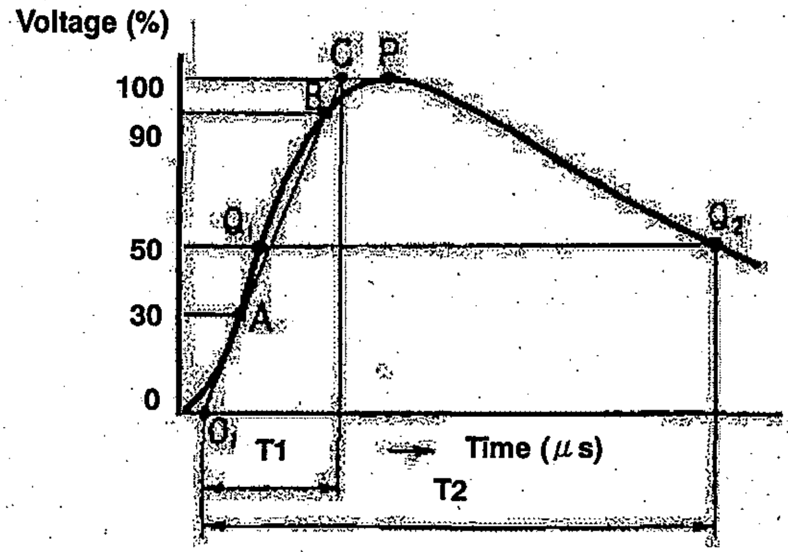
The transformer shall be tested whether it is able to withstand the voltage nearly sinusoidal waveform at 50 Hz for 1 minute. The applied parts and the test voltage are given in following table.

Applied parts	*Test voltage*
Between the primary winding and the ground, the secondary winding and the iron core being connected to the ground	50,000V
Between the secondary winding and the ground, the primary winding and the iron core being connected to the ground	4,000V

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	1	General Provisions	Document No.DS13-2
	Paragraph	4	Prevention of Electric Power Disasters	
	Clause	9	Prevention of Electric Power Disasters	
Title	Voltage Tests for 22kV Transformer (2/2)			

Impulse Wave Form



T1: Duration of wave front
T2: Duration of wave tail

* Wave form is indicated as T1/T2 μs

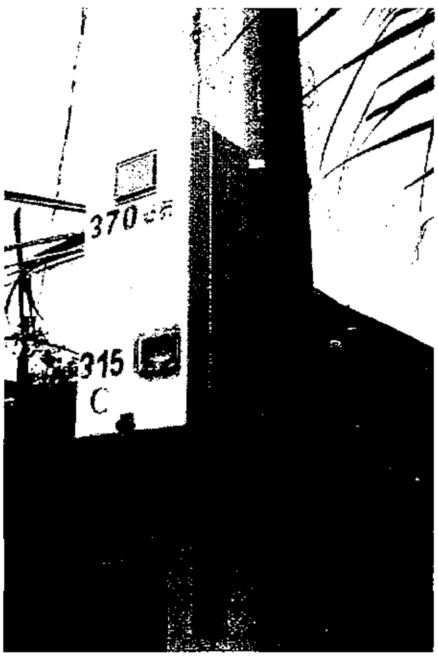
Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.DS14
	Paragraph	1	General	
	Clause	20	Accuracy of Power Meters	
Title	Power Meter			

The accuracy of power meters for trading electricity shall be in conformity with Clause 20 of the Electric Power Technical Standards in Cambodia.
The accuracy shall be confirmed not only when the meter is manufactured but also regularly after it is installed. Power meters shall be sealed for the third person not to handle them.

The power meter shall be installed in manners as follows;

1 It is installed to be measured easily.
2 It is not an obstacle to the third person, when it is installed at a supporting structure on the public street.
3 It is in the water proof boxes, when it is installed outside a house and there is a risk to splash rain on it.



Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.DS15-1
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	5	Transmission and Distribution Facilities (Common)	
	Clause	31	Property of Conductors	
Title	Performance of Conductors (1/2)			

1. Abbreviations of Conductors

Name Abbreviation	*Conductor Type*
Cu	Copper (97% IACS)+
AAC	All Aluminium Conductor
AAAC1120	All Aluminium Alloy (1120) Conductor
AAAC(6201)	All Aluminium Alloy (6201) Conductor *
GZ	Galvanised Steel
AZ	Aluminised Steel
AC	Aluminium Clad Steel

+ = International Annealed Copper Standard
* = Alloy 6201 is also known as Almelec and Aldrey

2. Properties of Conductor Materials

Code	*Conductivity (%IACS)*	*Resistivity ($\mu\Omega m$)*	*Temperature Coefficient of Resistance* (per °C)*	*Modulus of Elasticity (GPa)*	*Coefficient of Linear Expansion (per °C)*
IACS Cu	100	0.01724	0.00393	100	17.0×10^{-6}
Cu	97	0.01777	0.00381	124	17.0×10^{-6}
AAC	60.9	0.0283	0.00403	68	23.0×10^{-6}
AAAC/1120	58.8	0.0293	0.00390	68	23.0×10^{-6}
AAAC/6201	52.5	0.0328	0.00360	70	23.0×10^{-6}
GZ	1.0	0.17	0.0044	193	11.5×10^{-6}
AZ	1.15	0.15	0.0044	193	11.5×10^{-6}
AC	20	0.085	0.0036	162	12.9×10^{-6}

3. Properties of Single Conductors

Single conductors shall have the conductivity and tensile strength equal to the tensile strength per unit area multiplied by its sectional area confirming to related IEC standards. The tensile strength of hard-drawn copper wires shall have properties given in following table.

Diameter of single conductors: d (mm)	Tensile strength (N/mm^2)
0.4 or more, and 12.0 or less	(462-10.8d) or more

Remarks	Revisions	
	2003/Nov.	Original

Category				
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.DS15-2
	Paragraph	5	Transmission and Distribution Facilities (Common)	
	Clause	31	Property of Conductors	
Title	Performance of Conductors (2/2)			

Copper or Aluminum

The differences on characteristics between copper and aluminum are as follows;

1. The electrical conductivity of the hard drawn copper wire is about 96-98%, and that of hard drawn aluminum wire is about 61%. The resistance per unit area of the aluminum wire is about 1.6 times of that of the copper wire
2. The relative density to water of copper is about 8.9, and that of aluminum is about 2.7. The weight of an aluminum wire is about 50-55% of that of a copper wire with equivalent electrical performance.
3. The tensile strength of a copper wire is about 340-470N/mm^2, and that of an aluminum wire is about 160-180N mm^2. Therefore the tensile strength of an aluminum wire is about 75% of that of a copper wire with equivalent electrical performance.

Licensee should choose conductors taking into account their characteristics.

Remarks	Revisions	
	2003/Nov.	Original

Category				Document No.DS16
	Chapter	2	Technical Standards of Electric Power Facilities	
	Paragraph	5	Transmission and Distribution Facilities (Common)	
	Clause	31	Property of Conductors	
Title	Dielectric Strength and Insulation Resistance of Insulated Conductor			

The insulated conductors shall have the following dielectric strength and insulation resistance.

1. **Dielectric strength test of medium-voltage insulated conductors**
   After immersion in fresh water for 1hour, medium-voltage cross-linked polyethylene (XLPE) insulated conductors shall withstand the test of impressing AC 25,000V between the conductor and the ground for 1 minute.

2. **Dielectric strength test of low-voltage insulated conductors**
   After immersion in fresh water for 1 hour, low-voltage polyvinyl chloride (PVC) insulated conductors shall withstand the test of impressing the AC 3,500V between the conductor and the ground for 1 minute.

3. **Insulation resistance**
   After completion of the dielectric strength test, the insulation resistance of insulated conductors shall be no less than the values given in table, when impressed DC current of 100V for 1 minute.

Type of Insulating Materials	***Insulation resistance (Mega ohms-km)***	***Volume resistivity (ohms-cm)***
XLPE	$R=3.665\times10^{-12}\rho\log_{10}(D/d)$	2.5×10^{15}
PVC		5×10^{13}

Where
ρ :Volume resistivity
D :Outside diameter of the insulator (mm)
d :Inside diameter of the insulator (mm)
When D/d is 1.8 or more, D/d is 1.8 for calculation.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.DS17
	Paragraph	5	Transmission and Distribution Facilities (Common)	
	Clause	31	Property of Conductors	
Title	Insulator Thickness of Insulated Conductors			

The insulator thickness of low-voltage insulated conductors shall be no less than the values given in following table.

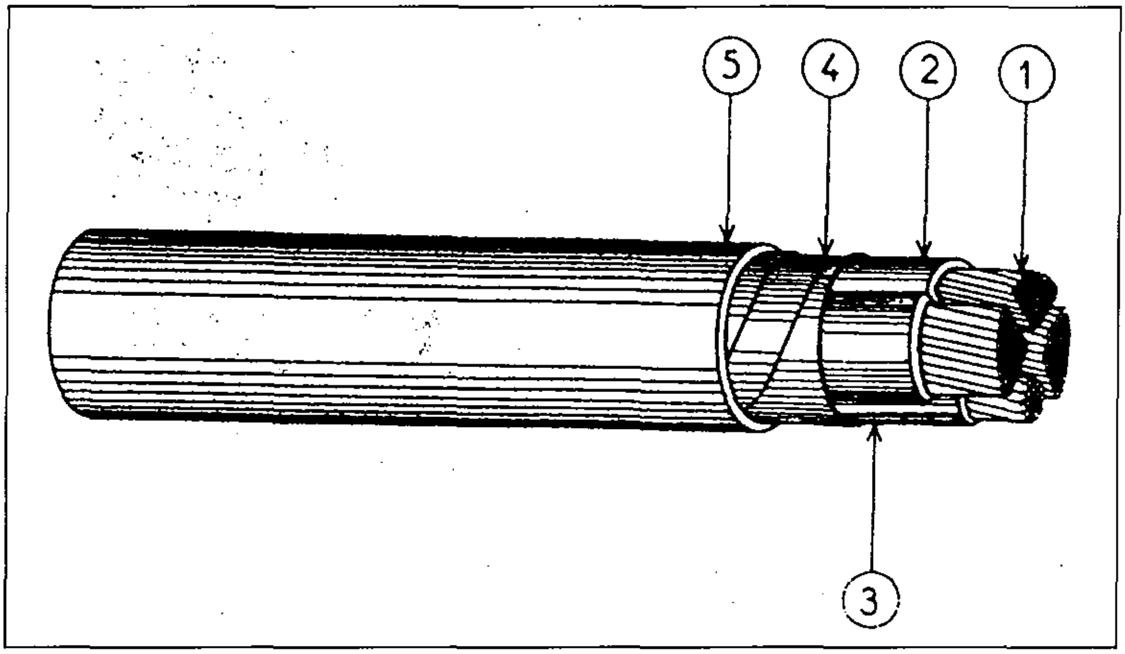
Conductors		***Thickness of insulators (mm)***	
Twisted conductors (Nominal sectional area: mm^2)	Single conductors (Diameter: mm)	PVC insulator	XLPE insulator
0.75 or more, and 3.5 or less	0.8 or more, and 2.0 or less	0.8	0.8
More than 3.5, and 5.5 or less	More than 2.0, and 2.6 or less	1.0	1.0
More than 5.5, and 8 or less	More than 2.6, and 3.2 or less	1.2	1.0
More than 8, and 14 or less	More than 3.2, and 4.0 or less	1.4	1.0
More than 14, and 30 or less	More than 4.0, and 5.0 or less	1.6	1.2
More than 30, and 38 or less		1.8	1.2
More than 38, and 60 or less		1.8	1.5
More than 60, and 80 or less		2.0	1.5
More than 80, and 100 or less		2.0	2.0
More than 100, and 150 or less		2.2	2.0
More than 150, and 250 or less		2.4	2.5
More than 250, and 400 or less		2.6	2.5
More than 400, and 500 or less		2.8	3.0
More than 500, and 725 or less		3.0	3.0
More than 725, and 1000 or less		3.2	3.5
More than 1000, and 1400 or less		3.5	3.5
More than 1400, and 2000 or less		4.0	4.0
More than 2000		4.5	4.5

The insulator thickness of medium-voltage insulated conductors shall be no less than the values given in following table.

Nominal sectional area (mm^2)	***Thickness of insulators (mm)***
22 or more, and 38 or less	2.5
More than 38, and 150 or less	3.0
More than 250, and 500 or less	3.5

Remarks	Revisions	
	2003/Nov.	Original

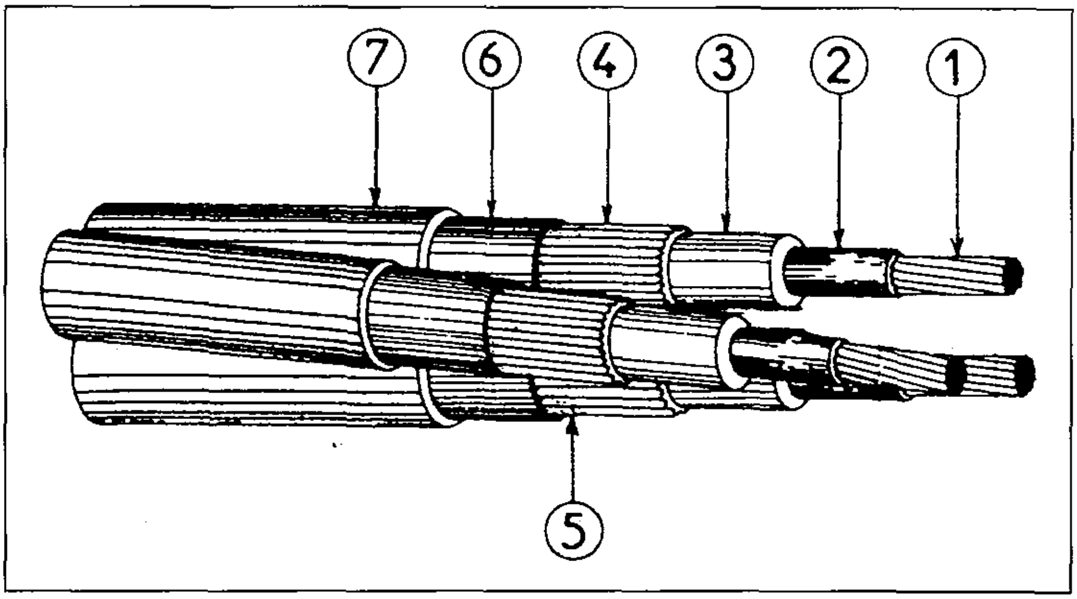
Category				Document No.DS18
Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.DS18
	Paragraph	5	Transmission and Distribution Facilities (Common)	
	Clause	31	Property of Conductors	
Title	Configuration of Low-voltage XLPE Cable			



① Conductor
② XLPE (Cross Linked Polyethylene) insulator
③ Lead cover for neutral line
④ Shield tape layer
⑤ External cover (Poly vinyl chloride)

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.DS19
	Paragraph	5	Transmission and Distribution Facilities (Common)	
	Clause	31	Property of Conductors	
Title	Configuration of Medium-voltage XLPE Cable			



① Conductor
② Internal semiconductor
Internal semiconductor is for prevention of the corona discharge between the conductor and the XLPE insulator.
③ XLPE (Cross Linked Polyethylene) insulator
④ External semiconductor
External semiconductor is for prevention of the corona discharge between the XLPE insulator and the shield metallic tape layer.
⑤ Waterproof
⑥ Shield metallic tape layer
Shield metallic tape layer is for prevention of the induction and the electrical shock. To prevent the electrical shock shield metallic tape must be grounded.
⑦ Sheath
Sheath is to protect the insulator against the mechanical force.

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.DS20**
	Paragraph	5	Transmission and Distribution Facilities (Common)	
	Clause	33	Safety Factor of Bare Conductors and Ground Wires of Overhead Electrical Lines	
Title	Tensile Strength of Overhead Conductors			

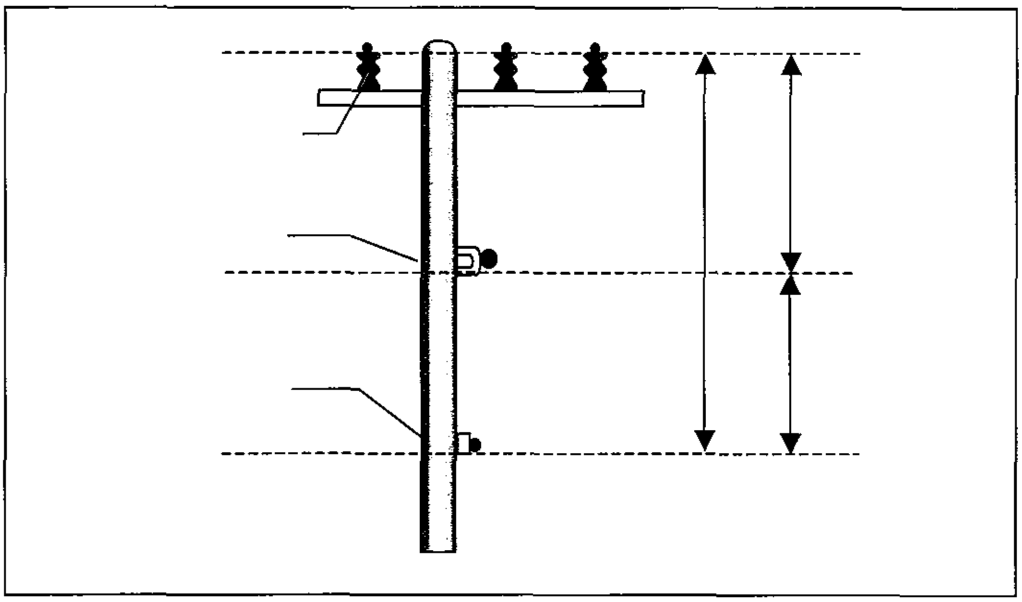
Overhead conductors shall be with a tensile strength no less than the values given in following table.

	Low-voltage		Medium-voltage
	300V or less	More than 300V	
Urban area	3.44kN	8.01kN	21.67kN
Other area	3.44kN	5.26kN	8.71kN

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.DS21
	Paragraph	5	Transmission and Distribution Facilities (Common)	
	Clause	34	Side by Side use and Joint Use of Lines	
Title	Clearance on Side by Side Use and Joint Use of Lines			

The minimum clearance of each lines at a supporting structure is give by the following figure and table. The clearance is dicided taking working space into consideration.



Recommended Minimum Clearance

(Unit: m)

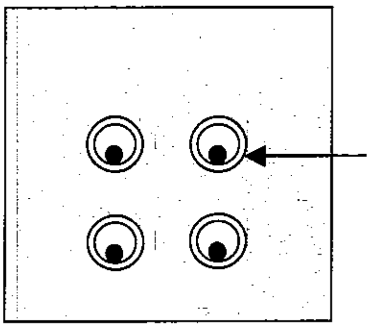
A	*Medium-Voltage Line*	*Cable*	*Low-Voltage Line*	0.5
		Others		1.2
B	*Medium-Voltage Line*	*Cable*	*Communication Line*	0.5
		Others		2.0
C	*Low-Voltage Line*	*Cable*	*Communication Line*	0.3
		Insulated Conductor		0.75

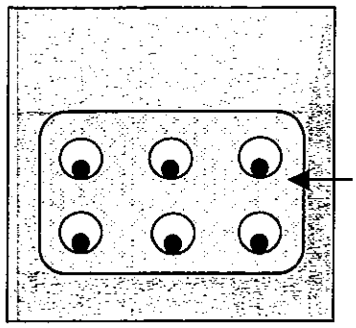
Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.DS22-1
	Paragraph	5	Transmission and Distribution Facilities (Common)	
	Clause	35	Underground Lines	
Title	Installation Methods of Underground Line (1/3)			

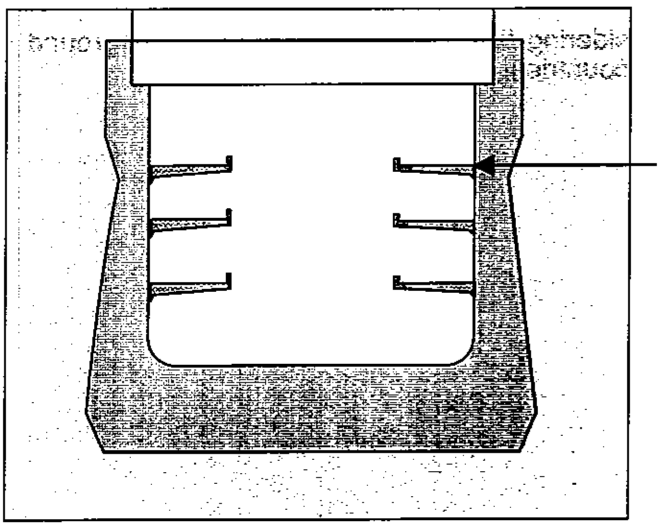
1. Examples of installation method of underground lines

Draw-in conduit system





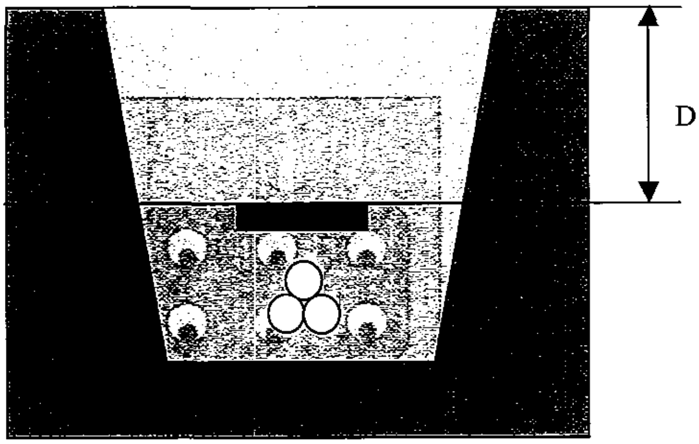
Culvert system



Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.DS22-2**
	Paragraph	5	Transmission and Distribution Facilities (Common)	
	Clause	35	Underground Lines	
Title	Installation Methods of Underground Line (2/3)			

2. The depth of underground lines of direct burial system



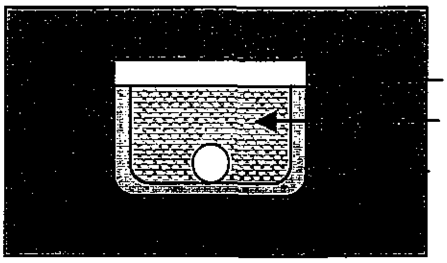
At a place where there is a danger of receiving pressure from vehicles or other objects	D = 1.2 m or more
Other place	D = 0.6m or more

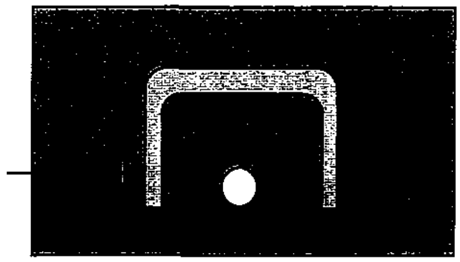
* The value of D is decided considering the present situation of underground lines in Cambodia and the result in other countries.

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.DS22-3**
	Paragraph	5	Transmission and Distribution Facilities (Common)	
	Clause	35	Underground Lines	
Title	Installation Methods of Underground Line (3/3)			

Other protection method (Trough type)





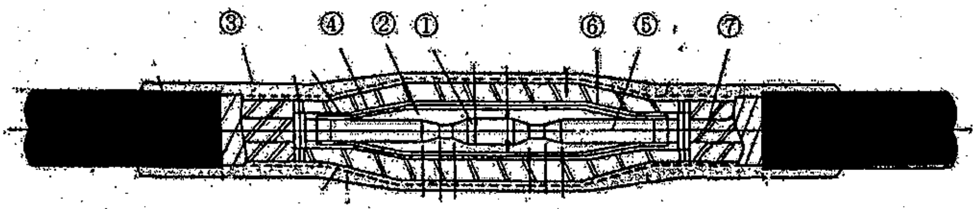
Aside from this, before installation of underground facilities, licensees have to get permission from a local government who manages the road structure to install underground facilities. In this case, licensees should notice the local government regarding the location of facilities including the depth of them.

As "Underground" is shared such utilities as power companies, telecommunication companies, water companies, or gas companies etc.. Each company must manage the location of its underground facilities by drawings or other proper measures.

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.DS20
	Paragraph	5	Transmission and Distribution Facilities (Common)	
	Clause	35	Underground Lines	
Title	Connection of Medium-voltage Cables			

An example of connecting method of Cables



①Connecting pipe
②Adhesive polyethylene tape
③Waterproof tape
④Lead tape
⑤Cross linked polyethylene
⑥Semi-conductive fusion bonding tape
⑦Shied metallic tape

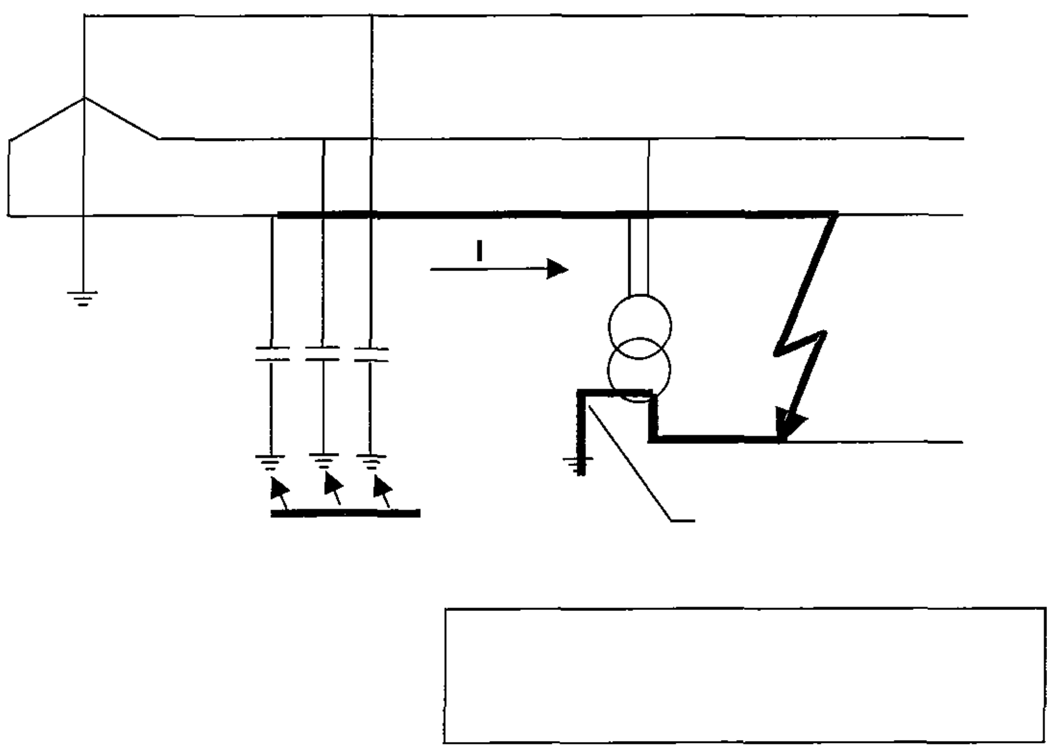
Connecting devices for cables shall be required to have the equivalent performance to the connected cables
In concrete, requirements are as follows;

1. The device shall be to withstand external forces that will be exerted under the use conditions.
2. The device shall be in good order when it is applied the current equivalent to the permissible current of the connected cables.
3. The device shall prevent water and moisture from entering into the connected cables.

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.DS24-1**
	Paragraph	5	Transmission and Distribution Facilities (Common)	
	Clause	39	Classification of Grounding for Electrical Lines	
Title	System Grounding (1/2)			

The current will flow to the earth through the system grounding, when a medium-voltage line breaks down and gets in touch with a low-voltage line. In this case the voltage to the earth of low-voltage line will increase in proportion to the single-line earth fault current and the resistance of the system grounding. Therefore, the value of resistance of the system grounding shall be the level to protect low-voltage apparatuses from the damage caused by the increase of the voltage to the earth.



Where

I: Single-line earth fault current

The maximum value of 10 ohms in Class B is decided based on the present condition in Cambodia. And the minimum value of 5 ohms is set up since it is very difficult to get the value less than 5 ohm

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.DS24-2
	Paragraph	5	Transmission and Distribution Facilities (Common)	
	Clause	39	Classification of Grounding for Electrical Lines	
Title	System Grounding (2/2)			

When a medium-voltage line contacts a low-voltage line, the voltage of the low-voltage line will increase. Therefore if human being gets in touch with the low-voltage line, it is more dangerous compared with the normal situation.
According to some experiment, the relation between he limit charged period and current to a human being is given by following formula.

$$I = 165 / t^{1/2} \text{ (mA)}$$

If human being get in touch with a charged part, the link between the current and the influence to human being is reported as follows;

Current (mA)	Influence to human being
1.2	Human being will feel electrical shock.
3.5	Human being will feel stiff slightly.
8.0	Human being will feel stiff and will not be able to get away from the charged part.
12.0	Human being will feel stiff and will not be able to bear more than 30 seconds.
20.0	Human being will not be able to get away from the charged part and to bear more than 15 seconds.
100.0	Human being will be fatally wounded.

Remarks	Revisions	
	2003/Nov.	Original

Category	**Chapter**	2	Technical Standards of Electric Power Facilities	**Document No.DS25-1**
	Paragraph	5	Transmission and Distribution Facilities (Common)	
	Clause	39	Classification of Grounding for Electrical Lines	
Title	Single-line Earth Fault Current (1/2)			

The single-line earth fault current used for calculation of resistance to earth for class B grounding should be derived from actual measurement in principle. However, it is difficult to measure realistically. In that case, the single-line earth fault current can be calculated by following formula.

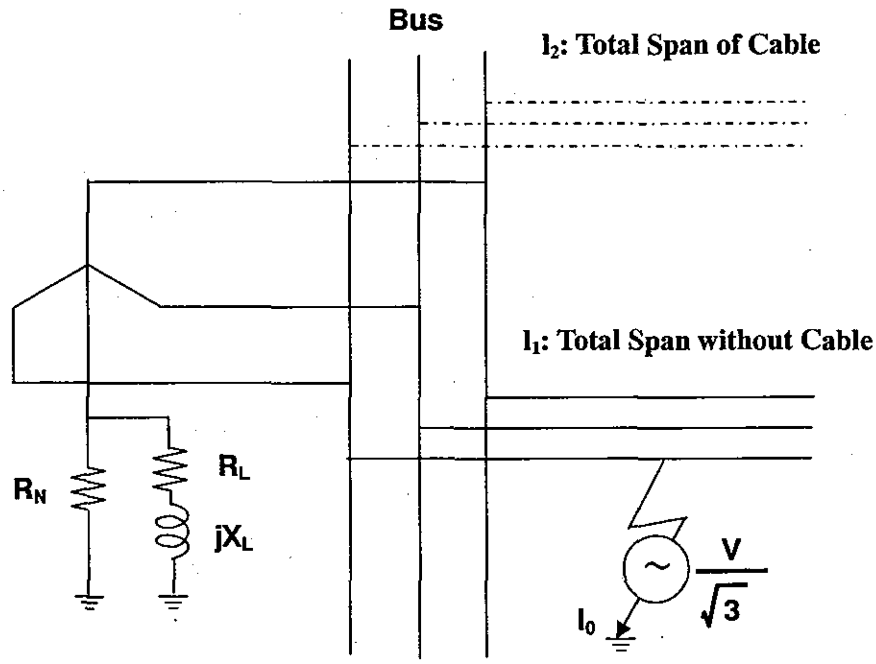
$$I_0 = \frac{V}{\sqrt{3}}\sqrt{\left[\frac{1}{R_N}+\frac{R_L}{R_L{}^2+X_L{}^2}\right]^2+\left\{3\omega(C_1 l_1+C_2 l_2)\times 10^{-6}-\frac{X_L}{R_L{}^2+X_L{}^2}\right\}^2}$$

Where

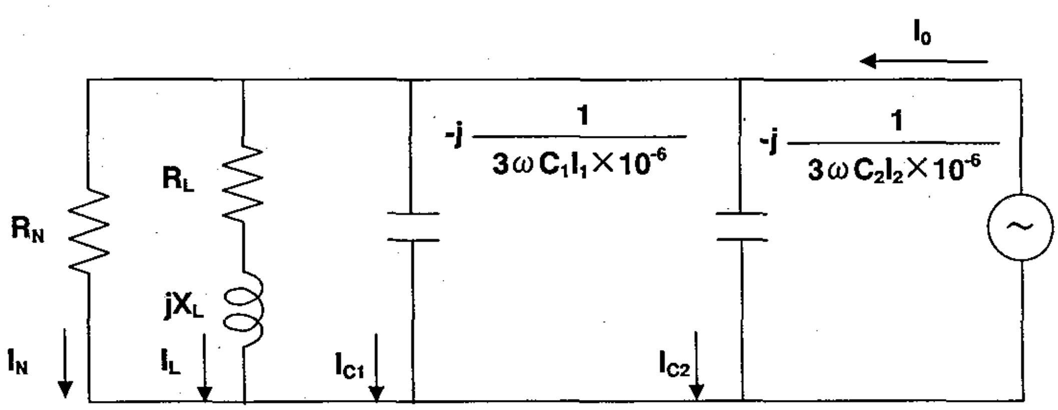
I_0: Single-line earth fault current (A)
V: Maximum voltage (V)
R_N: Value of resistance of resister used for neutral grounding (Ω)
R_L: Value of resistance of reactor used for neutral grounding (Ω)
X_L: Value of inductive reactance of reactor used for neutral grounding (Ω)
ω:Angular frequency (=100π)(rad/s)
l_1:Total span of medium-voltage lines without cables connected to one bus(km)
l_2:Total span of medium-voltage lines of cables connected to one bus(km)
C_1:Electrostatic capacity to ground of l_1 per one phase(μF/km)
C_2:Electrostatic capacity to ground of l_2 per one phase(μF/km)

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.DS25-2
	Paragraph	5	Transmission and Distribution Facilities (Common)	
	Clause	39	Classification of Grounding for Electrical Lines	
Title	Single-line Earth Fault Current (2/2)			



Medium-voltage Distribution System

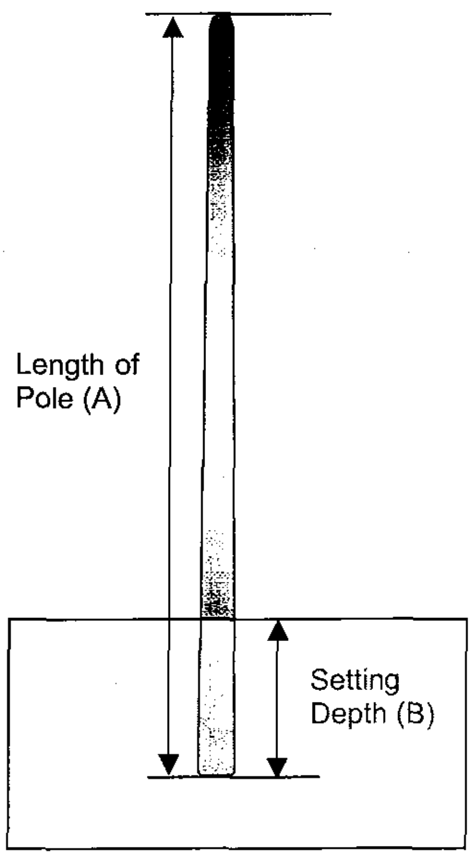


Equivalent Circuit

Remarks	Revisions	
	2003/Nov.	Original

Category	Chapter	2	Technical Standards of Electric Power Facilities	Document No.DS26
	Paragraph	7	Transmission and Distribution Facilities (Medium and Low Voltage)	
	Clause	49	Supporting Structures	
Title	Setting Depth of Supporting Structure			

The setting depth of supporting structures defined in Article 49-1 of Technical Standard are as follows;



	A (m)	B (m)
Wooden pole, Iron pole, Iron-reinforced concrete pole	7	1.2
	8	1.4
	9	1.5
	10	1.7
	11	1.9
	12	2.0
	13	2.2
	14	2.4
	15	2.5
	16	
Iron-reinforced concrete pole	17	2.8
	18	
	19	
	20	

* The value of B is decided based on the calculation considering the worst situation of each condition.

Remarks	Revisions	
	2003/Nov.	Original