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Design of Thermal Power Facilities

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« Electrical Facility »

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List of Acronyms/Abbreviations

AC	Alternating Current
ANSI	American National Standards Institute
APC	Automatic Plant Control
AVQR	Automatic Voltage & Q Regulator
AVR	Automatic Voltage Regulator
BFP	Boiler Feed water Pump
CRT	Cathode Ray Tube
CO	Carbon monOxide
CO_2	Carbon diOxide
CV	Control Valve or governing valve
CT	Current Transformer
CVCF	Constant Voltage Constant Frequency
DB	Data Base
DC	Direct Current
DCS	Distributed Control System
DS	Disconnecting Switch
EHC	Electric Hydraulic Control
EMC	ElectroMagnetic Compatibility
EMS	Energy Management System
ETD	Embedded Temperature Detector
FA	Full arc Admission
FBC	Fluidized bed combustion boiler
FCB	Fast Cut Back
FDF	Forced Draft Fan
FW	Fire Wall
GW	Gate Way
HMI	Human Machine Interface
ICV	InterCept valve
IDF	Induced Draft Fan
IEC	International Electro-technical Commission
IEEE	Institute of Electrical and Electronics Engineers
IP code	International Protection code
ISO	International Organization for Standardization
JEC	Japanese Electrotechnical Committee
JEM	Japan Electrical Manufacturer
JIS	Japan Industrial Standards

HRSG	Heat Recovery Steam Generator
LTB	Low pressure Turbine Bypass valve
MFT	Master Fuel Trip
MSV	Main steam Stop Valve
NFPA	National Fire Protection Association
NH_3	Ammonia
NO	Nitrogen monOxide
NOx	Nitrogen Oxides
OA	Office Automation
PA	Partial arc Admission
PAF	Primary Air Fan
PCB	Polychlorinated Biphenyl
PLC	Programmable Logic Controller
PSS	Power System Stabilizer
SIL	Safety Integrity Level
SOx	Sulfur Oxides
SCADA	Supervisory Control And Data Acquisition
SSO	Single Sign On
TCVN	Vietnamese National Standard
VT	Voltage Transformer
VDT	Visual Display Terminal
WDT	Watch Dog Timer

Chapter 1 Comparison between technical guideline and technical regulation of electrical facility

The article number of this guideline is shown in the Table-1 contrasted technical guideline with technical regulation for easy understanding.

Table- 1 Comparison between technical guideline and technical regulation of electrical facility

Technical Guideline		Technical Regulation
Article	Title	Article - Paragraph
Article 1	**Terms and definitions**	**-**
Article 16	**Prevention of electric shock and fire**	**Article 16** **Prevention of electric shock and fire**
Article 16-1	Prevention of electric shock and fire on electrical facilities	Article 16-1
Article 16-2	Insulation of electric power line	Article 16-2
Article 16-3	Insulation of the low voltage electric power line	Article 16-2
Article 16-4	Insulation of the electric power line whose voltage is exceeding 1kV	Article 16-3
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Article 16-6	Wire and cable	Article 16-3,5 Article 231-2,3 Article 238-4,5
Article 16-7	Connection of cables and wires	Article 16-6
Article 16-8	Class and installation of grounding	Article 16-11
Article 16-9	Grounding of the electric power line required for security or facility	Article 16-10,11
Article 16-10	Thermal resistance of electric machinery and apparatuses	Article 16-7
Article 16-11	Prevention of the hazard of the electric machinery and apparatuses whose voltages are exceeding 1kV	Article 16-8
Article 16-12	Installation of equipment which generates electric arc	Article 16-9
Article 16-13	Grounding of the second side electric power line of a instrument transformer	Article 16-10,11 Article 17-1
Article 16-14	Grounding of metal enclosure and similar of electrical equipment	Article 16-10,11
Article 16-15	Grounding of metal shield of a underground cable	Article 16-10,11
Article 17	**Prevention of abnormality and protective measures for the contact between the voltage of exceeding 1kV, and low voltage**	**Article 17** **Prevention of abnormality and protective measures**
Article 17-1	Prevention of abnormality and protective measures for the contact between the voltage of exceeding 1kV, and low voltage	Article 17-1 Article 16-10

Technical Guideline		Technical Regulation
Article	Title	Article - Paragraph
Article 17-2	Prevention of abnormality and protective measures for the contact between high voltage and very high voltage	Article 17-2 Article 16-10,11
Article 17-3	Installation of the transformer which transforms from very high voltage to low voltage directly	Article 17-3
Article 17-4	Performance of the over-current circuit breaker installed in low voltage electric power line	Article 17-4
Article 17-5	Performance of the over-current breaker installed in the electric power line whose voltage is exceeding 1kV	Article 17-4
Article 17-6	Exception in installation of an over-current breaker	Article 17-4
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Article 18	**Prevention of electrical and magnetic interference**	**Article 18** **Prevention of electrical and magnetic interference**
Article 18-1	Prevention of electrical and magnetic interference	Article 18-1
Article 18-2	Prevention of the trouble in high frequency usage facilities	Article 18-2
Article 19	**Prevention of power supply disturbance**	Article 19 Prevention of power supply disturbance
Article 20	**Prevention of public pollution**	Article 20 Prevention of public pollution
Article 20-1	Prevention of insulation oil leakage	Article 20-6
Article 20-2	Prohibition of installing electric machinery and apparatuses using polychlorinated biphenyl	Article 20-8
Article 231	**Prevention of electrical shock and fire**	**Article 231** **Prevention of electrical shock and fire**
Article 231-1	Separation between the overhead wire whose voltage is not less than 11kV and the supporting	Article 231-1
Article 231-2	Preventing electrification at a overhead wire	Article 231-2
Article 231-3	Installation of underground electric power line	Article 231-3 Article 237-7,8
Article 231-4	Insulation of low voltage electric power line	Article 231-4
Article 231-5	Prevention of entry of persons other than the handling person to a power station	Article 231-5
Article 231-6	Installation of an underground box	Article 231-6 Article 237-7,8
Article 231-7	Prevention of ascending the supporting facilities of overhead electric power line	Article 231-7
Article 231-8	The height of an overhead wire whose voltage is not less than 11kV	Article 231-8

Technical Guideline		Technical Regulation
Article	Title	Article - Paragraph
Article 231-9	The height of the supporting wire across a road	Article 231-9
Article 231-10	Prevention of an induction trouble	Article 231-10
Article 231-11	Prevention of an induction trouble through weak-electric-current electric power line	Article 231-11
Article 231-12	Prevention of an induction trouble in communication facilities for power security	Article 231-12
Article 231-13	Display of phase, rotation direction	Article 231-13
Article 232	**Prevention of danger to other power wires, other facilities and similar**	**Article 232** **Prevention of danger to other power wires, other facilities and similar**
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Article 233	**Prevention of danger by collapse of support of overhead power wires**	**Article 233** **Prevention of danger by collapse of support of overhead power wires**
Article 233-1	Prevention of danger by collapse of support	Article 233-1
Article 233-2	Prevention of danger by collapse of support of overhead wire whose voltage is not less than 11kV	Article 233-2
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Technical Guideline		Technical Regulation
Article	Title	Article - Paragraph
		similar
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Article 235	**Prohibition of dangerous facilities**	**Article 235** **Prohibition of dangerous facilities**
Article 235-1	Restriction of installation of a oil switch	Article 235-1
Article 236	**Prevention of electrical and magnetic interference**	**Article 236** **Prevention of electrical and magnetic interference**
Article 236-1	Prevention of electromagnetic interference	Article 236-1
Article 236-2	Prevention of induction trouble to underground wires of weak current	Article 236-2
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Article 237-9	Installation of a communication wire for power security	Article 237-13
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Article 237-11	Installation of battery equipment	Article 237-15
Article 238	**Prevention of electric shock, fire, and similar**	**Article 238** **Prevention of electrical shock and fire, and similar**
Article 238-1	Prevention of electric shock, fire, and similar by electric wiring	Article 238-1
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Technical Guideline		Technical Regulation
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Article 238-6	Prohibition on use of a contact conductor for voltage of not less than 11kV use	Article 238-6
Article 238-7	Insulating performance of low voltage power lines	Article 238-7
Article 238-8	Prevention of electrical shock, fire and the similar by electrical equipment	Article 238-8
Article 238-9	Installation of electrostatic precipitator whose voltage is not less than 11kV	Article 238-9
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Article 239-1	Low voltage building electrical wiring in close proximity or crossing with communication wires, pipes, or similar	Article 239-1,2
Article 239-2	Building electrical wiring whose voltage is medium and less than 11kV in close proximity or crossing with the other building electrical wirings whose voltages are medium and less than 11kV, pipes, or similar	Article 239-1,2
Article 240	**Protection measures to abnormal condition**	**Article 240** **Protection measures to abnormal condition**
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Article 240-2	Installation of an over-current circuit breaker in low voltage building main line	Article 240-1
Article 240-3	Installation of an overload protection device of a motor	Article 240-2
Article 240-4	Installation of an over-current and ground fault circuit breaker for flexible reeling and trailing cables for voltage of medium and less than 11kV use	Article 240-3 Article 240-4
Article 240-5	Installation of an over-current and ground fault circuit breaker for voltage of medium and less than 11kV contact conductor	Article 240-3 Article 240-4
Article 241	**Prevention of electrical and magnetic interference**	**Article 241** **Prevention of electrical and magnetic interference**
Article 241-1	Prevention of electromagnetic interference by high frequency current	Article 241-1
Article 242	**Installation restrictions on specific location**	**Article 242** **Installation restrictions on specific location**

Technical Guideline		Technical Regulation
Article	Title	Article - Paragraph
Article 242-1	Installation in an area with much dust	Article 242-1
Article 242-2	Installation in hazardous areas where a potential for explosion exists by flammable gas, combustible dust, etc	Article 242-2
Article 242-3	Installation in hazardous areas where a potential for insulation degradation exists by corrosive gas, etc.	Article 242-3
Article 242-4	Prohibition on installation of the very high voltage electrical equipment in hazardous areas	Article 242-4
Article 242-5	Prohibition on installation of a contact conductor in hazardous areas	Article 242-5,6,7
Article 243	**Installation of special equipment**	**Article 243** **Installation of special equipment**
Article 243-1	Prohibition on installation of an electric heater for a pipeline, etc	Article 243-1
Article 243-2	Installation of cathodic protection system	Article 243-2
Article 244	**General provision**	**Article 244** **General provision**
Article 245	**Measurement equipment for boiler**	**Article 245** **Measurement equipment for boiler**
Article 245-1	Measurement equipment for boiler	Article 245 Measurement equipment for boiler
Article 245-2	Automatic unit controller for boiler	(Addition as recommendations)
Article 246	**Measurement equipment for steam turbine**	**Article 246** **Measurement equipment for steam turbine**
Article 246-1	Measurement equipment for steam turbine	Article 246 Measurement equipment for steam turbine
Article 246-2	Automatic controller for steam turbine	(Addition as recommendations)
Article 247	**Measurement equipment for gas turbine**	**Article 247** **Measurement equipment for gas turbine**
Article 247-1	Measurement equipment for gas turbine	Article 247 Measurement equipment for gas turbine
Article 247-2	Automatic control systems for combined cycle power stations	(Addition as recommendations)

Technical Guideline		Technical Regulation
Article	Title	Article - Paragraph
Article 248	**Measurement equipment for generator**	**Article 248** **Measurement equipment for generator**
Article 248-1	Measurement equipment for generator	Article 248 Measurement equipment for generator
Article 248-2	Automatic control systems for generator	(Addition as recommendations)
Article 249	**Measurement equipment for major transformer**	**Article 249** **Measurement equipment for major transformer**
Article 250	**General provision**	**Article 250** **General provision**
Article 251	**Protection for boiler**	**Article 251** **Protection for boiler**
Article 252	**Protection for steam turbine**	**Article 252** **Protection for steam turbine**
Article 253	**Protection for gas turbine**	**Article 253** **Protection for gas turbine**
Article 254	**Protection for generator and major transformers**	**Article 254** **Protection for generator and major transformers**
Article 255	**Protection for major auxiliary machinery**	**Article 255** **Protection for major auxiliary machinery**
Article 256	**Unit interlock for power plant**	**Article 256** **Unit interlock for power plant**
Article 257	**General provision**	**Article 257.** **General provision**
Article 258	**SCADA/EMS system**	**Article 258** **SCADA/EMS system**
Article 258-1	SCADA/EMS system	Article 258 SCADA/EMS system
Article 258-2	Distributed Control System (DCS)	(Addition as reference)

Chapter 2　Each Items of Guideline

Section 1　General of the Electrical Facilities

Article 1.　Terms and definitions

1. Fire-retardancy

   It is fire-resistant nature which does not spread even if flame is applied.

2. Fire-retardancy with self extinction

   It is fire-retardant nature which goes out automatically, if the flame is removed.

3. Incombustibility

   It is fire-retardant nature which it does not burn even if flame is applied.

4. Fire resistance

   It is incombustible nature which is not remarkably transformed or destroyed in the status that it is heated by the flame

5. Contact countermeasure

   Measures should be taken such as installing a fence, a wall, etc., so that people do not approach or contact the facilities.

Article 16.　Prevention of electric shock and fire

Article 16-1.　Prevention of electric shock and fire on electrical facilities

1. Article16 paragraph 1 of the design technical regulation shows the provisions that human body must not be harmed and facilities must not be damaged, as essential principles of the technical regulation to be complied with.

(Explanation)

Manufacturers and installers should design and install facilities considering following items for the prevention of electric shock and fire.

1) Measures for wrong operation.

   -To use a switch that can open and close the load current in place of a disconnector

   -To use a switch whose contacts do not wear or melt down wrong operation by wrong operation.

   -To install an interlock which prevent opening during the load current flows in a disconnector

   -To use a special key for the purpose of preventing accidental operation

2) Wide space

To install wide space for operation not to be affected by arc

3) enclosure and barriers

To install enclosure and barriers not to be affected by arc

4) Location of operation

To install operation switches at the remote location

5) Equipment

To install the current limiting device or to install the equipment to emit arc to the opposite side

Article 16-2 Insulation of electric power line

1. The electric circuit should be insulated from the ground except for the parts of following items.

(1) a grounding point in the case of giving a grounding according to the provision of this guideline

(2) a part where insulation is unavoidable such as a testing transformer, a joint reactor for power-line carriers, a positive pole for electric anticorrosion, and an electrode of an electrode type surface relay

2. The electric power line is required that it is fully insulated according to the operating voltage in principle, because various troubles such as a fire by a leakage current and hazard of electrification arise if not fully insulated.

Article 16-3. Insulation of the low voltage electric power line

1. The low voltage power line which is divided with a switch or an over-current circuit breaker (except a part provided in the preceding article, paragraph 1, and electrical equipment provided in Article 16-5) in the place where current-using equipment is installed should be insulated to conform to either of following items for every electric power line.

(1) Insulation should be based on Article 238 paragraph 7 of the technical regulation.

(2) When insulation-resistance measurement is difficult, the leakage electric current in the status that the operating voltage of relevant electric power line is applied, should be not more than 1 mA.

2. Insulation whose electric power line is conformed to low voltage of operating voltage in the area other than electricity usage (except for the electric power line provided in the parts of the preceding article, paragraph 1, or except for the electric power line stipulated in Article 16-5) should follow the provision of the preceding paragraph correspondingly.

Article 16-4. Insulation of the electric power line whose voltage is exceeding 1kV

1. The electric power line whose voltage is exceeding 1kV (except for the electric power line provided in the parts of the Article16-2, paragraph 1, or except for the electric power line stipulated in Article 16-5) should be insulated to conform to either of following items.

(1) It is required to withstand the voltage specified in Table-2 when it is applied between the electric power line and the ground (if it is in a multi-core cable, between insulated conductors and also between insulated conductors and the ground) for 10 minutes continuously.

(2) In the electric power line of the alternating current which uses cables, it is require to withstand the double DC voltage of the test voltages specified in Table-2, when it is applied between the electric power line and the ground (if it is in a multi-core cable, between insulated conductors and also between insulated conductors and the ground) for 10 minutes continuously.

Table- 2 Insulation of electric power line whose voltage is exceeding 1kV

Maximum voltage of the electric power line	Electric power line	Applied voltage for tests
Not more than7,000V	-	1.5 times as high as maximum operating voltage
Exceeding 7,000Vand not more than 60,000V	neutral-grounding type electric power line whose maximum voltage is not more than 15,000V（limited to what has a neutral conductor and multiple grounding to the neutral conductor.）	0.92 times as high as maximum operating voltage
	Except the above	1.25 times as high as maximum operating voltage
Exceeding 60,000 V and not more 170,000V	isolated neutral system	1.25 times as high as maximum operating voltage
	neutral-grounded system	1.1 times as high as maximum operating voltage
Exceeding 170,000V	solidly grounded neutral system	0.64 times as high as maximum operating voltage

Remarks: What grounds a neutral point using a voltage transformer is regarded as isolated neutral system.

Article 16-5. Insulation of the electric power line with machinery

1. Electric power line of a transformer should conform to following insulation performance (except for a testing transformer, an instrument, and other special intended usage, and the same in this chapter)

(1) When the test voltage specified in the center column of the Table-3 is applied with the method specified in the front right column, electric power line should withstand.

Table- 3 Insulation of transformers

<table>
<tr><th colspan="5">Classifications of transformer windings</th><th>Test voltage</th><th>Test method</th></tr>
<tr><td colspan="5">Maximum voltage ,not more than 7,000V</td><td>1.5 times as high as maximum operating voltage（In case of less than 500V,500V）</td><td>*1</td></tr>
<tr><td rowspan="2">Electric power line whose maximum voltage exceeding7,000V, and not more than60,000V</td><td colspan="4">Maximum voltage is not more than 15,000V and connected to electric power line whose neutral-point is grounded(limited to what is equipped with neutral line and multiple ground)</td><td>0.92 times as high as maximum operating voltage</td><td>*1</td></tr>
<tr><td colspan="4">Other than above</td><td>1.25 times as high as maximum operating voltage</td><td>*1</td></tr>
<tr><td rowspan="5">Electric power line whose maximum voltage exceeding60,000V, and not more than170,000V</td><td colspan="4">Connected to electric power line of isolated neutral system</td><td>1.25 times as high as maximum operating voltage</td><td>*1</td></tr>
<tr><td rowspan="4">Connected to electric power line of grounded neutral system</td><td rowspan="3">Star connection</td><td rowspan="2">Connected to electric power line of solidly grounded neutral system</td><td>Directly grounded at a neutral-point</td><td rowspan="2">0.72 times as high as maximum operating voltage</td><td>*2</td></tr>
<tr><td>Grounded with a arrester at a neutral point</td><td>*3</td></tr>
<tr><td colspan="2">Other than above and grounded with a arrester at a neutral point</td><td rowspan="2">1.1 times as high as maximum operating voltage</td><td>*4</td></tr>
<tr><td colspan="3">Other than above</td><td>*1</td></tr>
<tr><td>Electric power line whose maximum voltage exceeding170,000V</td><td>Connected to electric power line of grounded neutral system</td><td>Star connection</td><td>Connected to electric power line of solidly grounded neutral system</td><td>Directly grounded at a neutral-point</td><td>0.64 times as high as maximum operating voltage</td><td>*2</td></tr>
<tr><td colspan="7">*1: Test voltage is applied between the winding to be tested and other windings, an iron core, and a tank, for 10 minutes continuously.
*2: Grounding the neutral terminal of the winding to be tested, one arbitrary terminal of other windings (it is each winding when there are two or more windings), and a core, and a tank (enclosure), test voltage is applied for 10 minutes continuously between one arbitrary terminal and the ground other than the neutral terminal of the winding to be tested.
*3: Grounding the neutral terminal of the winding to be tested, one arbitrary terminators of other windings (it is each winding when there are two or more windings) , an iron core, and a tank</td></tr>
</table>

Classifications of transformer windings	Test voltage	Test method
(enclosure), test voltage is applied for 10 minutes continuously between one arbitrary terminal and the grounds other than the neutral terminal of the winding to be tested, moreover, 0.3 time as high as the voltage of the maximum voltage is applied for 10 minutes continuously between the neutral terminal and the ground . *4: Grounding one arbitrary terminators of the winding to be tested except the neutral terminal, one arbitrary terminators of other windings (it is each winding when there are two or more windings), an iron core, and a tank (enclosure), test voltage of three-phase alternating current is applied for 10 minutes continuously between each terminal and the grounds other than the neutral terminal of the winding to be tested. However, when it is difficult to apply the test voltage of a three-phase alternating current, the test voltage of single-phase ac may be applied continuously between one arbitrary terminal and the ground other than the neutral terminal of the winding to be tested, moreover, 0.64 time as high as the voltage of the maximum voltage may be applied for 10 minutes continuously between the neutral terminal and the ground.		

Remark: What grounds a neutral point using a voltage transformer is regarded as isolated neutral system.

2. A rotating machine should have an insulation performance which conforms to either of following items.

(1) When test voltage specified in Table-4 is applied between the winding and the ground for 10 minutes continuously, a rotating machine should withstand this voltage.

(2) In the case of a rotating machine, when the dc voltage 1.6 times as high as the test voltage specified in the Table-4 is applied between the winding and the ground for 10 minutes continuously, a rotating machine should withstand this voltage.

Table- 4 Insulation of a rotating machine

Voltage of the electric power line	Test voltage
Maximum voltage ,not more than 7,000V	1.5 times as high as maximum voltage （In case of less than 500V,500V）
Maximum voltage ,exceeding 7,000V	1.25 times as high as maximum voltage （In case of less than 10,500V,10,500V）

3. A switch, a circuit breaker, a power-capacitor, an inductive-voltage-regulator, an instrument transformer, and other equipment {except for what is specified by paragraph from 1 to 2, (hereinafter referred to as “equipment and similar” in this paragraph)}, the connecting wire (cable) and busbar (it is limited to what composes the electric power line) of machine equipment which are installed in electric power line should have a insulation performance which conforms to either of following items.

(1) The equipment should conform to the following.

1) In the case of electric power line of low voltage, when test voltage specified in Table-5 is applied between electric power line and the ground (if it is in a multi-core cable between insulated cores and between an insulated core and grounds), electric power line should withstand this voltage.

Table- 5 Insulation of a switch and circuit-breaker

Classification of the electric power line	Test voltage
Alternating current	1.5 times as high as maximum AC operating voltage （In case of less than 500V,500V）
Direct current	DC voltage:1.5 times as high as maximum DC operating voltage or AC voltage:1 time as high as maximum DC operating voltage (In case of less than 500V,500V)

2) In the case of electric power line whose voltage is exceeding 1kV, it should be conformed to the provision of the preceding article, paragrph1, item 1.

(2) In the case of the AC connecting wire (cable) or AC busbar in the machine equipment using cables, it should be conformed to the provision of the preceding article item 2.

(3) In case of electric power line of equipment and similar, relevant equipment should conform to the either of followings.

1) Grounding system voltage transformer which conforms to IEC 61869-3 ed1.0 Instrument transformers - Part3: Additional requirements for inductive voltage transformers or "6.3 Dielectric strength" in JIS C 1731-2(1998) "instrument transformers for testing purpose and used with general instrument part II: Voltage Transformers

2) Lightning-surge absorption type capacitors which conform to followings

a. Operating voltage should be the voltage of exceeding 1kV.

b. When voltage specified in Table-6 is applied, AC for 1 minute and also DC for 10 seconds, between a terminal whose voltage is exceeding 1kV, and the grounded enclosure, they should withstand this voltage.

Table- 6 Insulation of lightning-surge absorption type capacitors

Classifications of Operating voltage（kV）	Classifications	AC voltage（kV）	DC voltage（kV）
3.3	A	16	45
	B	10	30
6.6	A	22	60
	B	16	45
11	A	28	90
	B	28	75
22	A	50	150
	B		125
	C		180

Remarks: A is the case of other than B or C
B is the case that intrusion of a lightning surge is little or, abnormal voltage is restricted to low enough by protective devices, such as a surge arrester
C is the case installed outside of the protection by protective devices, such as a surge arrester

3) Arresters which conform to either of followings.

a. IEC 60099-4 ed2.2 Surge arresters - Part 4: Metal-oxide surge arresters without gaps for a.c systems.

b. JEC 2371-2003 “insulator type arrestor” published by Institute of Electrical Engineers of Japan

c. JEC 2372-1995 “a gas insulation tank type arrester” published by Institute of Electrical Engineers of Japan

d. JEC 2373-1998 “a gas insulation tank type line arrester (for 3.3-154-kV systems)” published by Institute of Electrical Engineers of Japan

Article 16-6. Wire and cable

1. For electric power line (except for the electric power line in electric machinery and apparatuses) of a low or high operating voltage, cables which conform to either of following items should be used.

(1) To have thermal and electric and mechanical performance equivalent to the cable which has a metal electric shielding layer according to the operating voltage by the standards of Table-7. In addition,, these cables should have the fire retardancy which conforms to the vertical tray flame test (vertical flame spread) specified by IEC 60332-3-21 ed1.0, IEC 60332-3-22 ed1.1, IEC 60332-3-23 ed1.1, the IEEE 383-1974 or IEEE 1202-1991 or IEEE 1202-2006, or fire retardancy equivalent to this or more ,in principle.. The cable, used for the location whose ambient temperature will be not less than 60°C, should have the thermal resistance of not less than 80°C.

Table- 7 Standards for cables whose voltages are less than 11kV

Number	Rev.	Title
IEC 60227-5 ed3.0	2011	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V - Part 5: Flexible cables (cords) Note: excluding cords
IEC 60227-7 ed1.2	2012	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V - Part 7: Flexible cables screened and unscreened with two or more conductors
IEC 60245-4 ed3.0	2011	Rubber insulated cables - Rated voltages up to and including 450/750 V - Part 4: Cords and flexible cables Note: excluding cords
IEC 60502-1 ed2.1	2009	Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV) - Part 1: Cables for rated voltages of 1 kV (Um = 1,2 kV) and 3 kV (Um = 3,6 kV)
IEC 60502-2 ed2.0	2005	Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV) - Part 2: Cables for rated voltages from 6 kV (Um = 7,2 kV) up to 30 kV (Um = 36 kV)
JIS C3312	2000	600 V Grade polyvinyl chloride insulated and sheathed portable power cables
JIS C3327	2000	600V Rubber insulated flexible cables Note: excluding class 1 rubber insulated flexible cables

Number	Rev.	Title
JIS C3342	2000	600V Polyvinyl chloride insulated and sheathed cables
JIS C3361	2009	600 V Polyvinyl chloride insulated cables
JIS C3362	2009	600 V Cross-linked polyethylene insulated cables
JIS C3363	2009	600 V Ethylene-propylene rubber insulated cables
JIS C3364	2009	Control cables
JIS C3401	2002	Control cables
JIS C3605	2002	600V Polyethylene insulated cables
JIS C3606	2003	High-voltage cross-linked polyethylene insulated cables
JIS C3621	2000	600V Grade ethylene-propylene rubber insulated cables
JIS C3662-4	2003	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750V - Part 4 : Sheathed cables for fixed wiring
JIS C3663-4	2007	Rubber insulated cables - Rated voltages up to and including 450/750V - Part 4: Cords and flexible cables Note: excluding cords

2. The cable whose voltage is not less than 11kV, used for wires in electric power line whose operating voltage is not less than 11kV (except for the electric power line in electric machinery and apparatuses) should use what conforms to each of following items.

(1) To withstand the temperature in normal usage condition.

(2) To have a metal electric shielding layer or metallic coating on the insulated center

(3) To be the hybrid cables used a weak-electric-current style wire as power security communication wires (cable).

3. Except for the case of cables, the wire used for overhead electric line whose voltage is not less than 11kV should be stranded conductor whose tensile strength is of not less than 8.71 kN or hard-drawn copper stranded conductors wire whose cross section is not less than 22 mm^2.

4. Except for the case of cables, the overhead wire whose voltage is not less than 11kV should be installed by sagging so that the safety factor over the tensile strength becomes not less than the value specified in the Table-9 when the load specified in Table-8 is added.

Table- 8 Assumed weight on the wire

Temperature	Direction	
	Vertical	Horizontal
mean temperature	Weight of wire	980Pa to the vertical projection area of the wire
minimum temperature	Weight of wire	490Pa to the vertical projection area of the wire

Table- 9 Safety factor

Classifications of wires	Safety factor
hard-drawn-copper-wire or heat-resistant copper alloy wire	2.2
Others	2.5

5. The overhead ground wire used for overhead electric power line whose voltage is not less than 11kV should be based on each of following items.

(1) To the overhead ground wire, a bare wire with not less than 8.01 kN of tensile strength or a bare hard-drawn copper wire not less than 5 mm in diameter should be used and installed according to the provision of the preceding paragraph.

(2) At the point other than support points, the space of the overhead cable and overhead ground wire whose voltage is not less than 11kV should be more than the space at the support point.

(3) When overhead ground wires are connected to each other, a connecting pipe and other apparatus should be used.

6. The compensating lead wire which conforms to the followings should be used.

(1) The compensating lead wire should have thermal, electric, and mechanical performance more than or equivalent to what is specified in the standards of Table-10.

Table- 10 Standards for extension and compensating cables

Number	Rev.	Title
IEC 60584-3 ed2.0	2007	Thermocouples - Part 3: Extension and compensating cables - Tolerances and identification system
JIS C1610	1995	Extension and compensating cables for thermocouples

7. An optical fiber cable which conforms to the followings should be used.

(1) An optical fiber cable should have optical, electric, and mechanical performance more than or equivalent to what is specified in the standards of Table-11.

Table- 11 Standards for optical fiber cables

Number	Rev.	Title
IEC 60794 series	-	Optical fiber cables (Indoor cables, Outdoor cables, Aerial optical cables along electrical power lines)
JIS C6870 series	-	Optical fiber cables (Indoor cables, Outdoor cables)

8. A mineral insulated thermocouple cable which conforms to the followings should be used.

(1) A mineral insulated thermocouple cable should have thermal, electric, and mechanical performance more than or equivalent to what is specified in the standards of Table-12.

Table- 12 Standards for mineral insulated thermocouple cables

Number	Rev.	Title
IEC 61515 ed1.0	1995	Mineral insulated thermocouple cables and thermocouples

Article 16-7. Connection of cables and wires

1. When connecting wires, so that the electric resistance of a wire may not be increased and, should be based on each of following items.

(1) When connecting bare wire each other, or bare wires and insulated cables, connection should be based on each of following items.

1) The tensile strength of a wire should not be decreased not less than 20%. However, when connecting a jumper wire, or other tensions added to a wire is small remarkable compared with the tensile strength of the wire, this is not applied.

2) At the connecting section, connecting pipe should be used, or connecting section should be brazed.

3) When connecting tough-rubber sheathed cables to each other, or cables to each other, or both of these things, a cord connector, and a splice box and other apparatus should be used.

(2) In connecting the electric conductor in which electrochemical properties differ, electrolytic corrosion prevention is required in the connecting section, such as connecting the conductors between using aluminum (the alloy of aluminum is included.) and using copper (a copper alloy is included.).

Article 16-8. Class and installation of grounding

1. Class A grounding should be based on each of following items.

(1) The grounding-resistance value should be not more than 10 ohms.

(2) Grounding conductors should conform to the followings.

1) Electric current should be flown safely in the case of a failure.

2) It should be a metal wire of not less than 2.46 kN of tensile strengths which is hard to corrode easily, or an annealed copper wire not less than 4 mm in diameter.

a. When installing grounding conductors at the location with the possibility that people may touch, insulated wire should be used for the grounding conductors.

(3) Grounding conductors should not be installed to the supporting structure which installs the lightning-rod lot grounding line.

(4) By the potential difference generated between the grounds of the near in the case of a failure, grounding pole (a ground net is included) should be installed so that there is no risk of causing a hazard to a person or other facilities.

2. Class B grounding should be based on each of following items.

(1) The grounding-resistance value should be not more than 5 ohms.

(2) Grounding conductors should conform to following items.

1) Electric current should flow safely in the case of failure.

2) It should be made of a metal wire of not less than 2.46 kN of tensile strengths which is hard to corrode easily, or an annealed copper wire not less than 4 mm in diameter.

(3) It should be installed applying the paragraph 1 from item 1 to item 3 correspondingly.

3. Class C grounding should be based on each of following items.

(1) The grounding-resistance value should be not more than 10 ohms.

(2) Grounding conductors should conform to followings.

1) Electric current should flow safely in the case of failure.

2) They should be made of a metal wire of not less than 0.39 kN of tensile strengths which is hard to corrode easily, or made of an annealed copper wire not less than 1.6 mm in diameter.

(3) Paragraph 1 from item 3 to item 4 should be applied to install correspondingly.

4. Class D grounding should be based on each of following items.

(1) The grounding-resistance value should be not more than 100 ohms.

(2) Paragraph 3, item 2 should be applied to the grounding conductors.

(3) Paragraph 1 from item 3 to item 4 should be applied to install correspondingly.

5. In order to determine the functional requirements of a grounding system, the duration and magnitude of ground fault current should be specified.

Grounding system should satisfy the functions of followings

-To suppress voltage of the equipment within the allowable value to human body, livestock or other facilities. In the case that high voltage grounding system is equipped nearby low voltage grounding system, abnormal voltage intrusion from high voltage to low voltage should be considered.

-To have mechanical strength to withstand corrosion

-To withstand current flow thermally when the fault current of the maximum value flows

The current value for human safety is referred to IEC/TS 60479-1 Ed.4.0 2005.

Article 16-9. Grounding of the electric power line required for security or facility

1. In the case that ensuring operation of the protective devices for electric power line, restrain of abnormal voltage, or degradation of the voltage to ground, is required. Grounding can be performed at the location stipulated following items other than provisions based on the interpretation of this article.

(1) Neutral point (one terminal of the electric power line can be grounded in the case that electric power line whose operating voltage is not more than 300V, and that grounding at a neutral point is difficult.)

2. By provision of paragraph 1, grounding should be based on each of following items.

(1) A grounding pole (a ground net is included) should be installed so that there is no risk of giving a hazard to a person, livestock, or other facilities by the potential difference generated between its neighborhood and the grounds in the case of failure.

(2) Grounding conductors should be the metal wire specified that tensile strengths is not less than 2.46 kN and being hard to corrode easily ,or annealed copper wire of not less than 4 mm in diameter (in the case of low voltage electric power line , they should be the metal wire specified that tensile strengths is not less than 1.04 kN and being hard to corrode easily ,or annealed copper wire of not less than 2.6 mm in diameter), moreover, should be specified so that electric current flow safely in the case of failure.

(3) Grounding conductors should be installed so that there is no risk of being damaged.

(4) The resistor or a reactor, or others connected to grounding conductors should be specified so that electric current flow safely in the case of failure.

(5) Grounding conductors and the resistor or a reactor, or others connected to grounding conductors installed so that no persons other than a handling person can enter, or measure of contact prevention should be taken.

3. In the case of low voltage electric power line, the grounding at the location specified in the same paragraph 1 according to the provision of the item 1, installation can be based on each of following items, not on the paragraph 2.

4. Grounding conductors should be the metal wire specified that tensile strengths is not less than 1.04 kN and being hard to corrode easily ,or annealed copper wire of not less than 2.6mm in diameter, moreover, should be specified so that electric current flow safely in the case of failure.

(1) Article16-8 paragraph 1 item 3 should be applied to installing grounding conductors.

5. In order to protect the stabilizing windings of a transformer, or unused windings, or the built-in windings of a voltage regulator, from abnormal voltage, its windings can be grounded, if necessary.
In this case, the grounding should be based on class A grounding.

6. In the case of electric power line whose operating voltage is not more than 250V and connected to an electronic instrument or the case of other facilities, the electric power line can be grounded, unless there is a risk of fire, or other hazards.

Article 16-10. Thermal resistance of electric machinery and apparatuses

1. A transformer, a breaker, a circuit breaker, a power capacitor or a instrument transformer, and other electric machinery installed in the electric power line, and apparatuses should withstand the heat generated in the usual usage state, when thermal resistance is checked according to the

provisions of international standards, a national standard, and an industrial organization standards.

Article 16-11. Prevention of the hazard of the electric machinery and apparatuses whose voltages are exceeding 1kV

1. Articles16 paragraph 8 of the technical regulation shows the provisions as fundamental principle which should be complied as a technical regulation, stipulating that installation should be performed to prevent a person from touching the electric machinery and apparatuses of the voltage of exceeding 1kV easily, because it is dangerous.

Article 16-12. Installation of equipment which generates electric arc

1. A line switch, or a circuit breaker, or an arrester, or other equipment similar to these for the voltage of exceeding 1kV (stipulated "circuit breaker etc." in this article), which generates an electric arc during the operation, should be installed by each of either of following items.

(1) Equipment which generates an electric arc should be isolated from wooden walls or a ceiling or other inflammabilities by surrounding parts using the fire resistant substance.

(2) Separation from wooden walls or ceilings or other inflammabilities should be not less than the value specified in the Table-13.

Table- 13 Separation from wooden walls or ceilings or other inflammabilities

Classifications of operating voltage of a circuit breaker etc.	Separation
Less than 11kV	1m
Not less than 11kV	2m

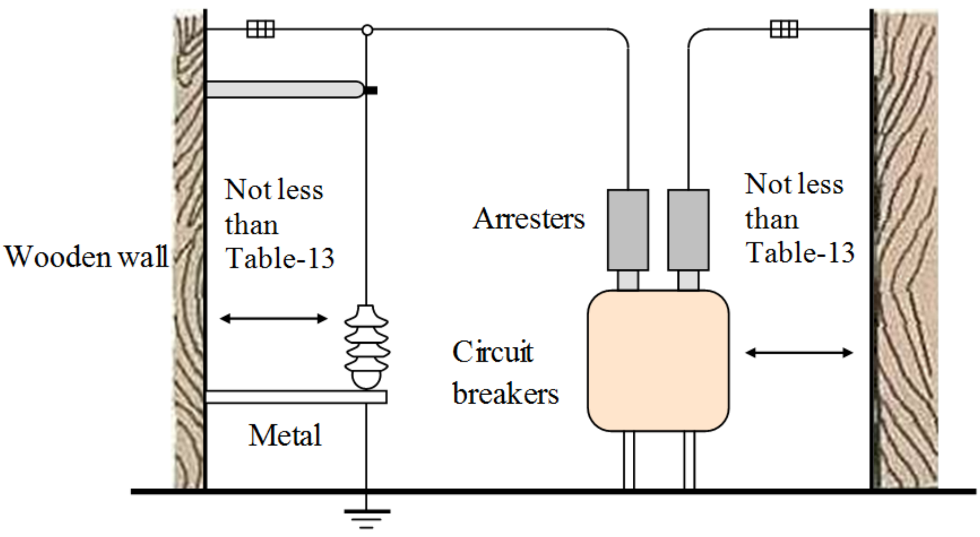


Fig- 1 Separation from wooden walls or ceilings or other inflammabilities

Article 16-13. Grounding of the second side electric power line of an instrument transformer

1. Class D grounding should be performed to the second side electric power line of an instrument transformer whose voltage is less than 11kV.

2. Class A grounding should be performed to the second side electric power line of an instrument transformer whose voltage is not less than 11kV.

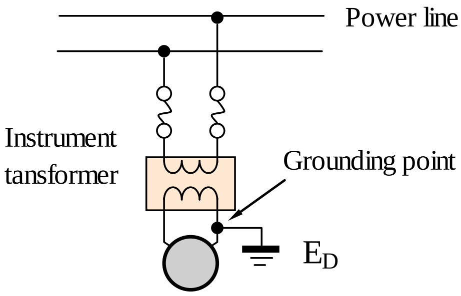


Fig- 2 Grounding of the second of an instrument transformer

Article 16-14. Grounding of metal enclosure and similar of electrical equipment

1. The metal stand and enclosure (stipulated “metal enclosure etc.” in this article) (In case of an instrument transformer, core) should be grounded according to Table-14. However, this is not applied, when fences etc are installed in order not to be touched by people, or when an insulating stand is installed.

Table- 14 Grounding of the metal stand and enclosure

Classifications of operating voltage of electrical equipment		Grounding
Low voltage	Not more than300V	Class D grounding
	Exceeding300V	Class C grounding
Exceeding 1kV		Class A grounding

Article 16-15. Grounding of metal shield of a underground cable

1. Class D grounding should be performed in underground electric power line of following items.

(1) Metal body parts used for protection unit such as covered-conduit which contains underground cable

(2) A wire-splicing box

(3) Metal body used for shield of underground cable

2. Following items may not be based on the provisions of the preceding paragraph.

(1) Metal fittings to support one cables

(2) Segments where corrosion-proof measure is taken in the each item of preceding paragraph

(3) The metal duct line in the parts where underground cable is installed by the duct line system.

Article 17. Prevention of abnormality and protective measures for the contact between the voltage of exceeding 1kV, and low voltage

Article 17-1. Prevention of abnormality and protective measures for the contact between the voltage of exceeding 1kV, and low voltage

1. To the transformer connecting the voltage of exceeding 1kV, and low voltage electric power line, Class B grounding should be performed at every point of installation based on following items.

(1) Grounding should be performed at a point of either of followings

1) A neutral point of low voltage side

2) When the operating voltage of low voltage electric power line is not more than 300V and it is difficult to ground at the neutral point of low voltage side, it is a terminal of lower voltage side

3) In the case low voltage electric power line is not grounded, they are metal contact prevention plates installed between the winding whose voltage is exceeding 1kV, and the winding of low voltage

Article 17-2. Prevention of abnormality and protective measures for the contact between the voltage of less than 11kV and the voltage of not less than 11kV

1. In the electric power line whose voltage is less than 11kV of medium voltage connected to electric power line whose voltage is not less than 11kV by a transformer, discharging unit should be installed in a pole near the terminator so that electric power line can be discharged when 3 or fewer times voltage of operating voltage is applied to the transformer.

   However, this is not applied when installing the arrester discharging when 3 or fewer times voltage of operating voltage is applied, in the bus conductor of power line whose voltage is less than 11kV of medium voltage.

2. Class A grounding should be performed to the equipment which conforms to preceding items.

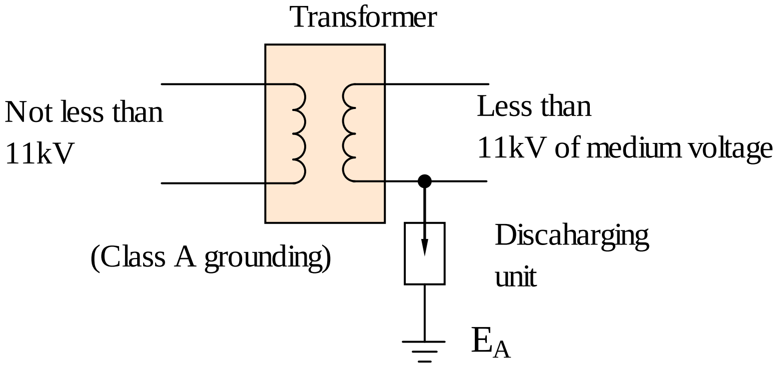


Fig- 3 An example of installation of discharging unit

Article 17-3. Installation of the transformer which transforms from voltage of not less than 11kV to low voltage directly

1. The transformer which transforms from the voltage whose voltage is not less than 11kV to low voltage directly should not be installed except for each of following items.

(1) A transformer whose operating voltage is not more than 100,000V, equipped with metal contact prevention plates performed class B grounding

(2) A transformer whose operating voltage is not more than 35,000V equipped with the devices which shutdown the transformer from electric power line when windings of the voltage whose voltage is not less than 11kV and low voltage contact with each other.

Article 17-4. Performance of the over-current circuit breaker installed in low voltage electric power line

The over-current circuit breaker installed in low voltage electric power line should have the capability of shutting down short-circuit current which passes through the point installed.

1. The molded case circuit breaker installed in low voltage electric power line as an over-current breaker should conform to each of following items.

(1) It should not operate automatically with a 1 time as much electric current as rated electric current.

(2) In the case the electric current of 1.25 times and double precision of a rated current according to the classifications of rated current in the left column of Table-15, it should operate automatically within the time in the right column of the table, respectively. Moreover, it should be capable of shutting down every short circuit which occurs everywhere in the protecting area.

Table- 15 Operating time of over-current breaker

Classifications of rated current	Time	
	In the case 1.25 times as much as rated current flows	In the case 2 times as much as rated current flows
Not less than 30A	60miniutes	2miniutes
Exceeding 30A and not less than 50A	60miniutes	4miniutes
Exceeding 50A and not less than 100A	120miniutes	6miniutes
Exceeding 100A and not less than 225A	120miniutes	8miniutes
Exceeding 225A and not less than 400A	120miniutes	10miniutes
Exceeding 400A and not less than 600A	120miniutes	12miniutes

Classifications of rated current	Time	
	In the case 1.25 times as much as rated current flows	In the case 2 times as much as rated current flows
Exceeding 600A and not less than 800A	120miniutes	14miniutes
Exceeding 800Aand not less than 1000A	120miniutes	16miniutes
Exceeding 1000Aand not less than 1200A	120miniutes	18miniutes
Exceeding 1200Aand not less than 1600A	120miniutes	20miniutes
Exceeding 1600A and not less than 2000A	120miniutes	22miniutes
Exceeding 2000A	120miniutes	24miniutes

2. The overload protection unit should be installed in combination with an over-current breaker, and breaker only for a short-circuit protection in the low voltage electric power line should be used only for the low voltage electric power line to a motor, and conformed to each of following items.

(1) Overload protection unit should conform to followings.

1) When over-current generates with the possibility of damaging a motor by fire, this should be shut down automatically.

2) An electromagnetic switch which conforms to or has the performance more than IEC 60947-4-1.ed3.0 Low-voltage switchgear and controlgear - Part 4-1: Contactors and motor-starters - Electromechanical contactors and motor-starters, or JIS C 8201-4-1 (2007) -- "Low voltage switchgear and controlling-device part 4 -1: -- electric-machine type contactor and the motor starter: -- ".

(2) The breaker only for short-circuit protections should conform to followings.

1) Overload-protection unit should have the capability of shutting down the relevant short-circuit current before the facility is damaged by fire.

2) The breaker should not operate automatically with a 1 time as much electric current as the rated current.

3) The setting electric current should be not more than 13 times of the rated current.

4) When 1.2 times as much electric current as the setting electric current flows, the breaker should operate automatically within 0.2 second.

(3) Overload-protection unit and the breaker only for a short-circuit protection, or the fusing only for a short-circuit protection should be installed into the box for exclusive use.

Article 17-5. Performance of the over-current breaker installed in the electric power line whose voltage is exceeding 1kV

The over-current breaker installed in electric power line whose voltage is exceeding 1kV should conform to each of following items.

1. The over-current circuit breaker installed in the voltage of exceeding 1kV electric power line should have the capability of shutting down short-circuit current which passes through the point where it is installed. Moreover, it should be capable of shutting down every short circuit which occurs everywhere in the protecting area.
2. The over-current circuit breaker should have the unit which displays the switching condition according to the activation. However, this is not applied when switching condition can be checked easily.

Article 17-6. Exception in installation of an over-current breaker

1. An over-current breaker should not be installed at the each point of following items

(1) A grounding-conductor

(2) Neutral conductor in a multiple-wire-system

(3) The wire at grounded side in the low voltage electric power line which partly grounded according to the provisions of Article17-1 paragraph 1 item 2.

(Explanation)

In the grounding circuit or the neutral line of electric circuit, installing an over-current circuit breaker is prohibited because the grounding does not work and disconnecting from the ground may cause danger.

2. In the case conforming to each of following items, installation may not be based on the either provisions of the preceding paragraph.

(1) When each pole is shut down simultaneously, in the case that an over-current breaker connected to neutral conductor in a multiple-wire-system activates.

(2) When an over-current breaker is grounded using a resistor, a reactor, etc. according to Article 19 paragraph 1 of each item ,the relevant grounding conductor will not be non-grounded by the activation of the over-current breaker.

Article 17-7. Installation of ground-fault shutdown device

To the electric power line whose voltage is exceeding 1kV, a ground-fault shutdown device, which shut down the electric power line automatically when a ground fault occurs in the point shown at the left column of the Table-16 or the point close to this, should be installed.

However, this is not applied when it conforms to right column in the relevant table.

Table- 16 Installation of ground-fault shutdown device

Where to install a ground-fault shutdown device	Electric power line	The case that a ground-fault shutdown device is not required to install
Outlet of the power station	Electric power line from the power station	If electric power line from the power station is regarded as the extension of the either power station or the substation, a ground-fault shutdown device is not required to install, on the condition that the device which shut down the electric power line of power source side during being grounded is installed by equipping a instrument transformer to the bus conductors etc.

Remarks: Outlet means the place where electric current flows out from the power station in the case of failure or normal condition.

(Explanation)

A ground-fault shutdown device is a circuit breaker which detects zero-phase current /voltage or over current when there is a ground fault in the circuit. Depending on the purpose of protection, there are the following four methods.

1) By differential relays or over current relays, the circuit of ground-fault is shut down.
2) By installing the detection unit of ground-fault at the neutral point or the secondary side of the transformer, the he secondary circuit of the transformer is shut down automatically.
3) By installing the detection unit of ground-fault at the entrance of the circuit, the circuit is shut down automatically.
4) By installing the detection unit to each machine or branch points, the part of the circuit is shut down automatically.

Fig-4 shows an example of installation of ground-fault shutdown devices at a power station.

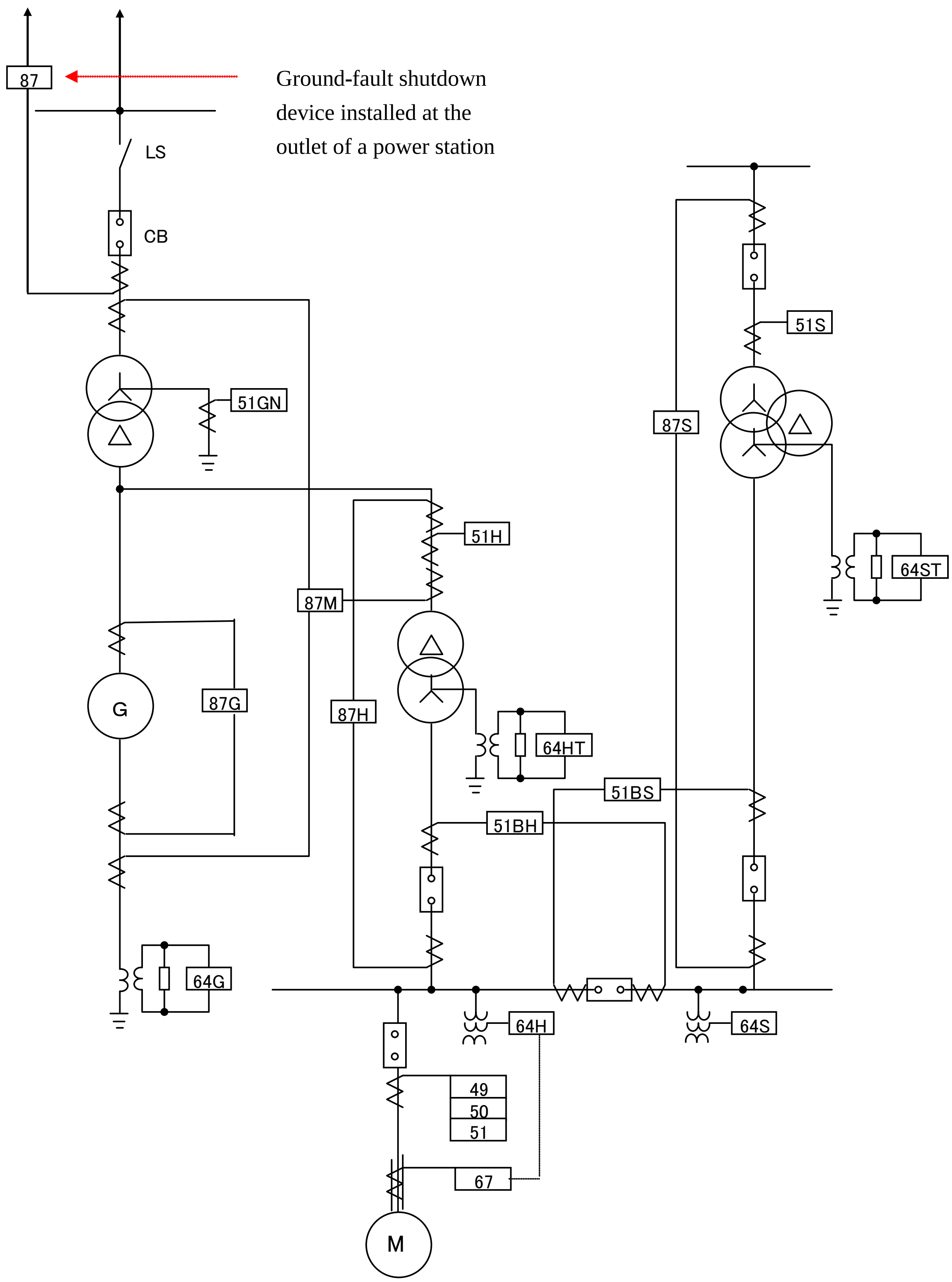


Fig- 4 An example of installation of ground-fault shutdown devices

Article 18. Prevention of electrical and magnetic interference

Article 18-1. Prevention of electrical and magnetic interference

Article18 of technical regulation paragraph 1 shows the provisions that electrical or magnetic interference should not be generated, as essential principles of the technical regulation to be complied with.

Electrical and magnetic interference means to inhibit the operation of other equipment, or to affect the human body more than a certain level.

1. Sources of electrical and magnetic interference

   The sources of electrical and magnetic interference are abnormal voltages such as lightning surge, switching surge of the main circuit, switching surge of the DC circuit, or noise from motor drivers.

   Each surge induces abnormal voltage in the control circuit as described below.

(1) Lightning surge

Following cases are considered to be the cause of lightning surge intrusion into the control circuit.

1) Abnormal voltage is induced in the control circuit by lightning surge current flows through the bus or, the grounding wire.

2) Abnormal voltage is induced in the secondary circuit of the instrument transformer from primary side by lightning surge current flows.

3) Lightning surge current flows to the grounding system, where the electrical ground potential rise at the inflow point, and high voltage is induced at control cables installed in the vicinity.

4) Back discharge from the grounding equipment to transmission line occurs by the lighting to the grounding equipment.

(2) Main circuit switching surge

Abnormal voltage is in the control circuit is induced by opening and closing of the main circuit or abnormal voltage intrude through the grounding system.

(3) Switching surge by opening and closing the DC circuit

High surge voltage of greater than 2000V may occur when contact capacitive or inductive loads in the DC circuit open and close.

(4) Motor drive systems

Harmonic currents generated in the inverter will be emitted via transformers or induction.

2. Measures for electrical and magnetic interference

   Measures for electrical and magnetic interference should be taken considering importance of facility, cost and safety.

(1) Examples of measures for surge

Followings are examples of measures for surge intrusion in the control circuit.

-Proper grounding reduces transient surge impedance and potential gradient from the ground. Therefore, voltage of the control panel side may not rise significantly by the lightning surge.

-Surge intrusion can be reduced by installing surge absorbing capacitors in the secondary circuit of CT.

-Surge intrusion can be reduced by installing surge absorbers or noise cutting transformers, or photo detectors in the secondary circuit of transducers.

(2) Examples of measures for motor drive systems

Following are example of measures. Advices from the manufacture are recommended to be taken.

-Harmonic current can be reduced by installing reactors DC side or AC side or both sides of the inverter.

-Harmonic current can be reduced by installing high power factor converter. Input current waveform is corrected to the sine wave in the switching converter section and harmonic current is suppressed.

-Harmonic current can be reduced by installing capacitors in combination with reactors. There is an idea of installing in high- voltage side or low-voltage side, however installing in the low voltage side is more effective, in general.

-Harmonic current can be reduced by installing two transformers such as star-star or delta-delta and star-delta connection whose phase angle is different from 30 degrees .These transformers reduce harmonic currents of the low-order.

In detail, measures for motor drive systems are referred to IEC 61800-3.

-Grounding of motor drive systems is recommended to be separated from the grounding of control devices to prevent noise intrusion to the control devices.

(3) Examples of measures for both motor drive systems and surge

1) - Surge intrusion harmonic current can be reduced by using a shielded cable whose shield is grounded.

As for double sides grounding, the shield is grounded at both ends to cancel the magnetic flux that intersects with the inner strand to reduce electromagnetic induction. This induction may cause malfunction or damage of equipment connected to the cable.

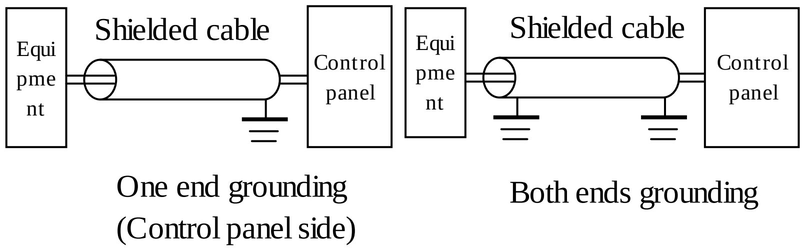


Fig- 5 Grounding methods of cable shield

The order of shield effect is roughly this, one end grounding (equipment side) one end grounding (the control panel side) grounding at both ends.
However, one end grounding at the equipment side is not performed, because there is a voltage rise due to reflections. Some network standard describes that grounding of shield at both ends is not recommended in order to prevent the noise from the ground loop current which is caused by induction between shield and cable core.

In addition, in the case of a longer length of the shield wire of the cable, the installation is recommended to be thick, straight and short line, and be grounded at the mid-point in order to decrease the self-inductance of the shield, because the effect of reducing the surge is reduced by self-inductance of the shield especially for high-frequency component included in the surge.

For this reason, some network standards recommend both ends grounding.(or multiple points)

Thus, in principle, shorter cable installation and one end grounding (the control panel side) are recommended in some cases, however, advices from the manufacture are should be taken for electrical and magnetic interference to the control signals.

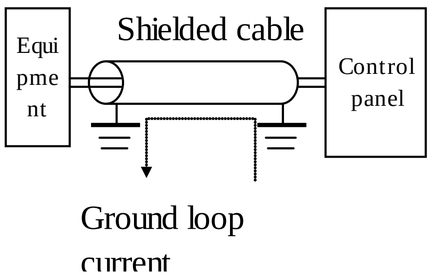


Fig- 6 Ground loop current

2) Appropriate installation of control cables

One of the causes is the electromagnetic induction. For this reason, the electromagnetic coupling between the noise source and control cables is recommended to be reduced by the methods such as using metal shielded separation or shielded conduit, or by installation separated enough.

It is also necessary to install control cables separated from transformers and not to be affected by electromagnetic induction from transformers, especially in the case of reactors or unbalanced phase transformers.

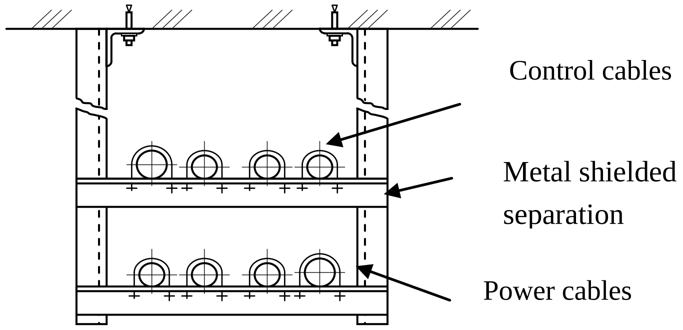


Fig- 7 An example of appropriate installation

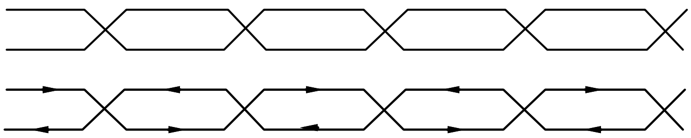
3) Using special cables in the control circuit

-Using optical cables

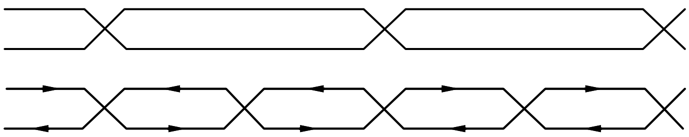
Optical signals are not affected by electromagnetic induction. However; installation of cables requires a lot of cares such as bending radius, moisture, tension, pressure, due to weakness of cable compared with metal cables.
Moreover, connection between cables should be checked at the connectors.

-Using twisted pair cable

Twisted pair cable is the cables in which two conductors of a single circuit are twisted together for the purposes of canceling out electromagnetic interference (EMI) from external sources. However, the pitch of the twist should be noticed to cancel interference, therefore advices from the manufacture in charge of transmission section are recommended to be taken.



(a) Same pitch



(b) Different pitches

Fig- 8 Twisted pair cables

4) Using the circuit with the function of noise reduction

Following is the example of the circuit with the function of noise reduction considering following items.

-To install a varistor parallel to the 52 (AC Circuit Breaker) coil in order to cut the noise emission by opening and closing

-To install a varistor to cut the noise intruded from outside

Fig-9 shows an example of circuit with the function of noise reduction.

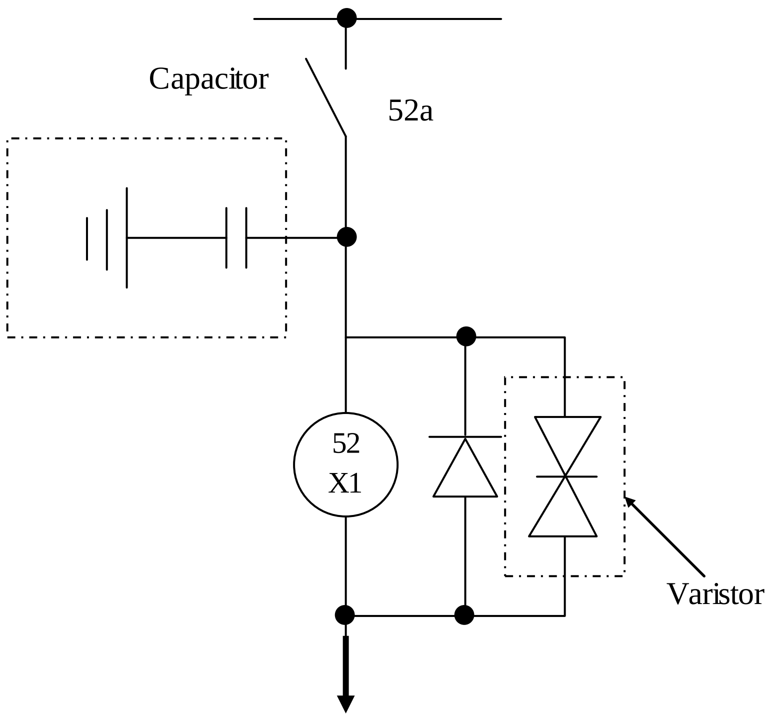


Fig- 9 An example of circuit with the function of noise reduction

Article 18-2. Prevention of the trouble in high frequency usage facilities

1. High frequency current leaked from the high frequency usage facilities to other high frequency usage facilities should be the value not more than is -30dB (1 mW is defined as 0 dB.), when it measures for more than 10 minutes continuously twice or more with the measuring equipment according to the following measuring equipment or this, the mean value of the largest value of the measured value of each time.

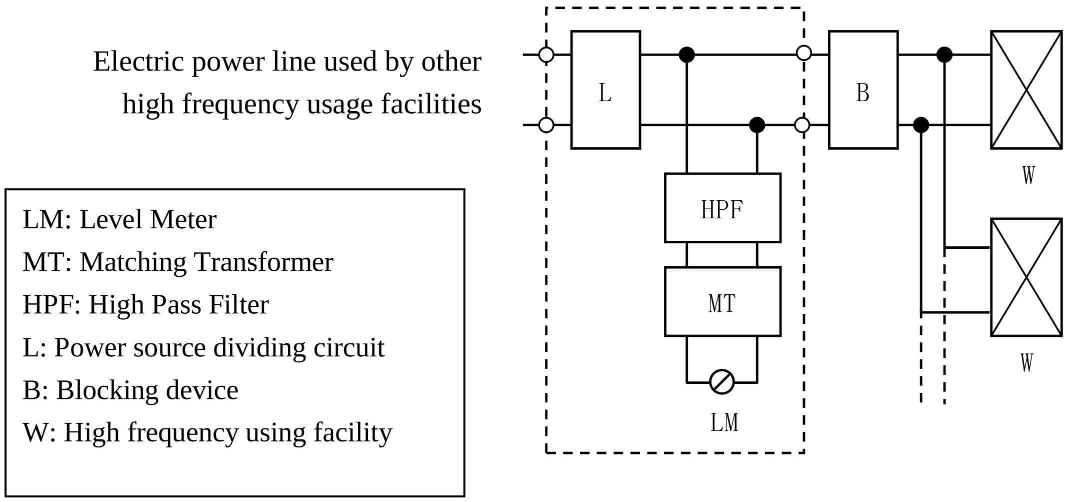


Fig- 10 Measuring circuit of power line carrier equipment

Article 19. Prevention of power supply disturbance

1. Article19 paragraph 1 of Technical regulation shows the provisions that power supply should not be disturbed extremely by the destruction of facilities, as essential principles of the technical regulation to be complied with.

Article 20. Prevention of public pollution

Article 20-1. Prevention of insulation oil leakage

1. At the location where a transformer which is connected to a neutral-grounding type electric power line is installed, in order to prevent the insulation oil leakage and penetration to underground, an oil spill preventing facilities should be installed.
2. The oil accommodation capacity of an oil spill preventing facilities should be not less than the capacity calculated with the following formula.

Outdoors: Oil accommodation capacity = 50% oil capacity of the relevant transformer + the amount of initial water (amount of water for 20 minutes) + water for fire- engine (not less than 40 m^3)

Indoor: Oil accommodation capacity = 50% oil capacity of the relevant transformer

Article 20-2. Prohibition of installing electric machinery and apparatuses using polychlorinated biphenyl

1. The insulation oil containing polychlorinated biphenyl polychlorinated biphenyls (PCBs) should be less than that of the quantity of the polychlorinated biphenyl contained in the insulation oil is things other than the insulation oil which is not more than 0.5 mg per 1 kg of samples.

Section 2 Installation of the Electrical Facilities for the Power Supply

Article 231. Prevention of electrical shock and fire

Article 231-1. Separation between the overhead wire whose voltage is not less than 11kV and the supporting

1. The separation between the overhead wire whose voltage is not less than 11kV (except for a cable) and the supporting, or steel crossarms, or a strut, or a stay should be not less than the value specified in Table-17.

Table- 17 Separation between an overhead wire whose voltage is not less than 11kV and the supporting

Classifications of operating voltage	Separation
Less than 15,000V	0.15m
Not less than 15,000V and less than 25,000V	0.20m
Not less than 25,000Vand less than35,000V	0.25m
Not less than 35,000Vand less than50,000V	0.30m
Not less than 50,000V and less than 60,000V	0.30m
Not less than 60,000V and less than 70,000V	0.40m
Not less than 70,000V and less than 80,000V	0.45m
Not less than 80,000V and less than 130,000V	0.65m
Not less than 130,000V and less than 160,000V	0.90m
Not less than 160,000V and less than 200,000V	1.1m
Not less than 200,000V and less than 230,000V	1.3m
Not less than 230,000V	1.6m

Article 231-2. Preventing electrification at a overhead wire

1. Article231 paragraph 2 of the technical regulation specifies that when an overhead wire whose voltage is not than 11kV is installed in the neighborhood of a building, a rubber-insulated wire

etc. must be used in order to prevent the death or injury of the worker by contacting a charged wire accidentally.

Article 231-3. Installation of underground electric power line

1. When an underground electric power line is installed, underground electric power line should use a cable, and should install it with a duct line system, a covered-conduit type, or a direct laying system.
   In addition, a cable duct may be included in a covered-conduit type.

2. When an underground electric power line is installed by a duct line system, installation should be based on each of following items.

(1) The pipe which contains one wire should withstand the pressure of the vehicle or other heavy loads which are added to this.

(2) Following items should be displayed at the underground electric power line whose voltage is exceeding 1kV. However, if it is underground electric power line whose voltage is medium and less than 11kV, this is not applied.

   1) To display the name and voltage of wires

   2) To display at the intervals of approximately 2m

3. When an underground electric power line is installed by a covered-conduit type, installation should be based on each of following items.

(1) Covered-conduit should withstand the pressure of the vehicle or other heavy loads which are added to this.

(2) A flameproof measure should be taken by either of followings.

   1) A flameproof measure should be taken to an underground cable by either of followings.

      a. An underground cable is equipped with the shield which conforms to IEC 60332-1 ed1.0 “Tests on electric and optical fiber cables under fire conditions - Part 1: Test for vertical flame propagation for a single insulated wire or cable”, or has more performance.

      b. An underground cable is covered with the spread-of-a-fire preventing tape, a spread-of-a-fire preventing sheet, a spread-of-a-fire preventing paint, and others similar to these which conform to preceding item “a.”

      c. An underground cable is contained in the pipe or trough which conforms to either of the following.

   2) Automatic firefighting equipment should be installed in a covered conduit.

4. When installing underground direct laying system type electric power line whose operating voltage is less than 11kV, installation should be based on each of following items.
   In addition, the underground electric power line whose voltage is not less than 11kV should not be installed with a direct laying system.

(1) At a location with a possibility that it may be subject to the pressure of a vehicle and other heavy loads, the embedding depth of the underground cable should be not less than 0.6 m, at the location of others, it should be not less than 1.2 m.
In order to protect underground cables from an impulse, installation should be based on either of followings.

1) An underground cable should be contained in a strong trough or other protections.

2) In the case of installation at the location without a possibility that it may be subject to the pressure of a vehicle or other heavy loads, the upper part of the underground cable should be covered with a strong board or a pipe.

3) In the installation of an underground cable, the cable with amour, which is specified in the 5th paragraph, should be used. An underground cable should be displayed according to the provision of the paragraph 5.

5. Amours specified in paragraph 4.item 1, 3) should conform to following specification.

(1) Outside diameter of the metallic conduit should not decrease not less than 5%, when the load of 294.2 kN per project area of 1 m^2 of the conduit axis is applied to the right-angled orientation to the board in the condition that two steel plates are located in parallel, and they sandwiches the material between them .

Article 231-4. Insulation of low voltage electric power line

1. Technical regulation Article 231 of the paragraph 2 specifies insulation of low voltage electric power line. The leakage current is recommended to be limited to the 1/2000 on the basis of the maximum electric current of the electric power line. This is because in low voltage electric power line, the leakage current flows such as the surface discharge or contact with others are usually more important issue than breakdown.

2. The value above is for one of all wires, therefore, when the operating voltage is applied between the ground and all wires; the allowable leakage current is as follows:

(1) Single-phase two-wire system: Maximum current for usage ×1/2000×2

(2) Three-phase three-wire system: Maximum current for usage ×1/2000×3

Article 231-5. Prevention of entry of persons other than the handling person to a power station

1. The power station which is installed a machine or equipment, or a bus conductor etc (hereafter “the machine or equipment etc.” in this article), etc of the voltage of exceeding 1kV in the outdoors should take the measure that any persons other than a handling person do not enter the premises by each of following items.
However, this is not applied to the point without a possibility that people may enter according to the conditions of the land.

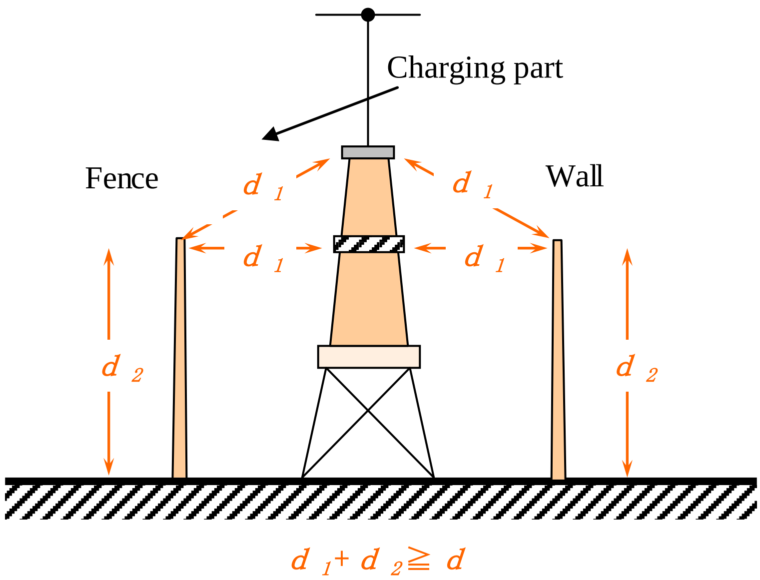
(1) A fence, or a wall, etc should be installed.

(2) Sum of a height of a fence, wall, etc and a distance from a charging part to the fence, wall, etc should be not less than the value of Table-18.

Table- 18 Sum of a height of a fence, wall, etc and a distance from a charging part to the fence, wall, etc.

Classifications of operating voltage	Sum of a height of a fence, wall, etc and a distance from a charging part to the fence, wall, etc.
Not more than 35,000V	5m
Exceeding 35,000Vand Not more than 160,000V	6m
Exceeding 160,000V	(6+c) m

Remarks: c is the value which is divided the difference between operating voltage and 160,000V by 10,000V (round up at the decimal points) and also multiplied 0.12 by the result



1.Not more than 35kV:
d is not less than 5m
2.Exceeding 35kV and not more than160kV
d is not less than 6m
3.Exceeding 160kV
d is not less than 6+(A-160)/10 *0.12 (m)

Where A is working voltage(kV)
round up at the decimal points

Fig- 11 Distance from a charging part to a fence, wall, etc.

(3) Prohibition of entering should be indicated at the entrance.

(4) Measures should be taken to restrict entering or exiting of persons other than a handling person, such as installing and using locking mechanism at the entrance.

2. The power station which installs a machine or equipment etc. of the voltage of exceeding 1kV indoors should take the measure that any persons other than a handling person do not enter the premises by each of following items.
However, this is not applied to the inside of the fence or a wall installed according to a provision of the preceding paragraph.

(1) Prevention should be based on either of followings.

1) A strong wall should be installed.

2) A fence, or a wall, etc should be installed. Moreover sum of a fence or a wall walls etc height, and of the distance between charging part and fence, or wall walls etc should be not less than the value of Table-18.

(2) Provisions of the preceding paragraph of No3 and 4 items should be applied.

3. When installing a power station which installs the machine or equipment whose voltage is exceeding 1kV on the premises of a factory etc., by each of following items, installation may not be based on a provision of the paragraph 1and paragraph 2.

(1) A fence, or a wall, etc should be installed around the border of the power station so that general public do not enter

(2) Danger should be indicated

(3) The machine or equipment whose voltage is not less than 11kV should be installed by followings.

1) The machine or equipment should be installed indoor and at the location where the measure is taken so that no persons other than a handling person cannot enter and exit.

2) Cables should be used for the wires whose voltages are medium and less than 11kV attached to the machine or equipment, and should be installed in the height of not less than 4.5 m on surface of the ground so that there is no risk that people may touch the machine or equipment.

3) The machine or equipment should be installed so that it is contained in a box made of concrete or a metal box which is grounded with class D grounding and also the live parts are not exposed.

4) Contact countermeasure should be taken to the machine or equipment whose live parts are not exposed.

(4) The machine or equipment whose voltage is not less than 11kV should be installed by followings.

1) The machine or equipment should be installed indoor and at the location where the measure is taken so that no persons other than a handling person cannot enter and exit.

2) The machine or equipment should be installed in the height of not less than 5 m on the surface of the ground and the height of live parts is not less than the value specified in Table-18 so that there is no risk that people may touch the machine or equipment.

3) The machine or equipment should be installed so that it is contained in a metal box grounded with class A grounding and live parts are not exposed.

4) Contact countermeasure should be taken to the machine or equipment whose live parts are not exposed.

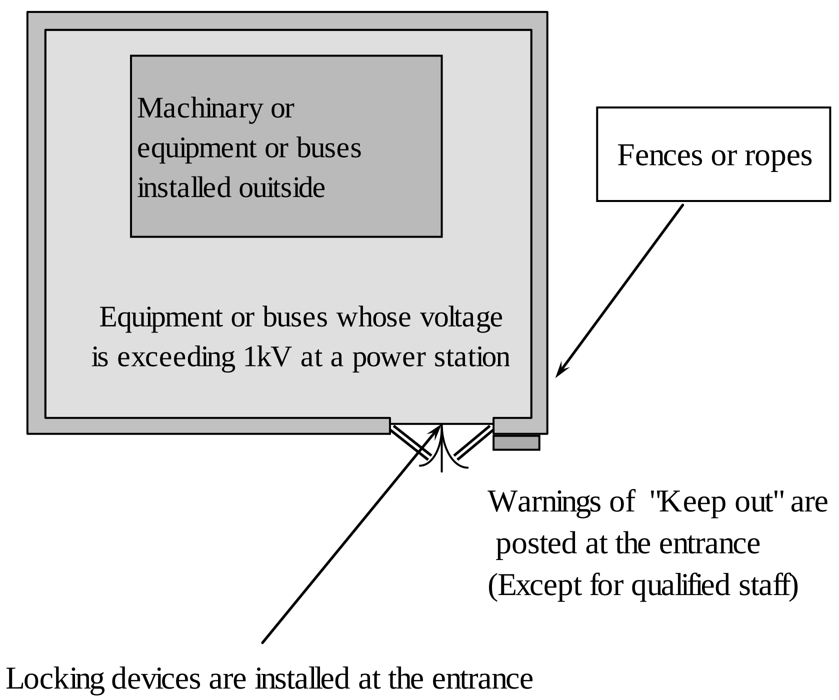


Fig- 12 Installation of machinery or equipment or buses installed outdoors

Article 231-6. Installation of an underground box

1. Installation of an underground box used for the underground electric power line should be based on each of following items.

(1) An underground box should be the structure of withstanding the pressure t of a vehicle and other heavy loads.

(2) An appropriate device to diffuse or ventilate should be installed for underground boxes whose volume is not less than1 m^3 if there is a risk of intrusion and combustion by the gas of explosiveness or flammability.

(3) The lid of underground boxes should be installed so that any persons other than a handling person cannot open easily.

Article 231-7. Prevention of ascending the supporting facilities of overhead electric power line

1. When a handling person installs the tools for scaffolds etc., which are used for ascent and descent of the supporting facilities of overhead electric power line, they should be installed in the height of not less than 1.8 m.
   However, this is not applied when it conforms to either of following items.

(1) Structure of the tools for scaffolds is to be stored inside.

(2) Equipment for prevent from ascending the supporting facilities are installed

(3) When a fence, a wall, etc. are installed so that any persons other than a handling person may not enter

Article 231-8. The height of an overhead wire whose voltage is not less than 11kV

1. The height of an overhead wire whose voltage is not less than 11kV should be not less than the value specified in Table-19.

Table- 19 The height of an overhead wire whose voltage is not less than 11kV

Classifications of operating voltage	Height from the ground
Not more than 35,000V	5m
Exceeding 35,000Vand Not more than 160,000V	6m
Exceeding 160,000V	(6+c) m

Remarks: c is the value which is divided the difference between operating voltage and 160,000V by 10,000V（round up at the decimal points ）and also multiplied 0.12 by the result

Article 231-9. The height of the supporting wire across a road

1. As for supporting equipment of overhead wires, the height of the supporting wire across a road should be not less than 5m above the surface of the road.

Article 231-10. Prevention of an induction trouble

1. Overhead wire whose voltage is not less than 11kV should be installed so that the field strength should be ≤ 5kV/m at any point, and ≤ 1kV/m at 1m from the ground inside the house at any point, and also installed so that there is no possibility of giving a hazard to people by static induction in the normal usage condition. The objective is to prevent the electric shock by the static induction of overhead electric power line whose voltage is not less than 11kV and not to give displeasure to people.
   This is because of electrostatic induction.

   As preventive measures, following items may be considered.
   -To install the transmission lines high enough clearance from the ground level

-In the case of 2 line transmission lines, to reverse the phase sequence of both lines
-To install the shield wire

In addition, ≤ 5kV/m is the value ICNIRP (International Commission on Non-Ionizing Radiation Protection) recommends and this value is also adopted in some European countries.

Article 231-11. Prevention of an induction trouble through weak-electric-current electric power line

1. Overhead wires whose voltages are not less than 11kV should be installed so that there is no possibility of giving a hazard on people by static induction through weak-electric-current electric power line(except for communication facilities for power security)

Article 231-12. Prevention of an induction trouble in communication facilities for power security

1. Articles 231 of the technical regulation, paragraph 12, specifies that facilities should be installed so that there is no possibility that induced voltage gives a hazard on working people or the person in communication.
   This is because very high induced voltage generates in case of the failure at an overhead wire and there is fear of electrification.
   Thus, when the telephone line for power security communication is installed with the parallel system, it is desirable to be installed by the voltage of less than 11kV.

   As preventive measures, following items may be considered.
   -To shutdown the failed power line quickly
   -In the case of neutral grounding, to increase resistance of neutral grounding or to install an arc reactor to the neutral grounding
   -To install the arrestors in the communication line

Article 231-13. Display of phase, rotation direction

1. Since it is important how people recognize at the time of an operation, maintenance, and inspection, it is appropriate that equipment or an electric conductor is displayed under the easy and concrete rules which people can judge as intuitively as possible.
2. Identifications of phase or polarity should be displayed based on the not only standards of each electric facility, but also the unified color or symbol at the points (the surface of a panel or an enclosure) of the main frame of an electric facility legibly.
   This is for the purpose of removing an error, preventing a hazard and performing a quick disposition in a supervisory, operation, maintenance, and inspection.
   This should be applied to the main circuit of an alternating current and a direct current, and the secondary circuit of an instrument transformer. These rules should be unified at every power station.

   An example of identifications of phase is shown in Fig-13.

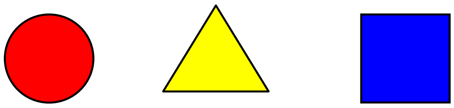


Fig- 13 Identifications of phase

3. When the rotation direction is decided, rotating direction should be indicated in the points (a frame or an enclosure) where the main frame of a motor is legible with an arrow.

Article 232. Prevention of danger to other power wires, other facilities and similar

Article 232-1. Installation of an overhead service wire whose voltage is not less than 11kV

1. An overhead service wire whose voltage is not less than 11kV should be installed on the basis of following items.

(1) The wire of not less than 8.71 kN of tensile strengths, or the wire with cross section of not less than 22 mm^2 made of hard-drawn copper stranded conductor wire should be used, and installed according to a provision of Article 16-6, paragraph 4.

1) The separation of a wire, a supporting structure, etc. should apply to the provision of Article 231-1.

2) The separation of wires should be based on the provision of Article 231- 1.

3) The height of wires should be based on the provision of Article 231- 8.

Article 232-2. Approach between overhead wires whose voltages are not less than 11kV and buildings

1. When an overhead wire whose voltage is not less than 11kV is installed close to a building, separation between overhead wire whose voltage is not less than 11kV and building parts should be not less than the value specified in Table-20.

Table- 20 Separation between overhead wires and buildings whose voltages are not less than 11kV

Classifications of operating voltage	Separation
Not more than 35,000V	3m
Exceeding 35,000V	(3+c) m

Remarks: c is the value which is divided the difference between operating voltage and 35,000V by 10,000V（round up at the decimal points ）and also multiplied 0.15 by the result

2. When an overhead wire whose voltage is not less than 11kV is installed at the distance of not less than 3m from a building, the overhead wire whose voltage is not less than 11kV should be installed according to the specification of Table-21.

Table- 21 Construction whose voltage is not less than 11kV for security

Classifications of wires	Separation
A Stranded conductor whose tensile strength is not less than14.51kN or hard-drawn copper stranded conductor whose cross section is not less than $38mm^2$ at the cross section	Not more than 150m
others	Not more than 100m

3. An overhead wire whose voltage is not less than 11kV should not be installed at the distance of less than 3m from a building.

4. In the measurement of horizontal distance between overhead wires whose voltages are less than 11kV and buildings is not less than 220,000V of operating voltage, the reference point of the relevant buildings which are measured should be the point located nearest horizontal distance between the relevant buildings and overhead wires whose voltages are not less than 11kV.

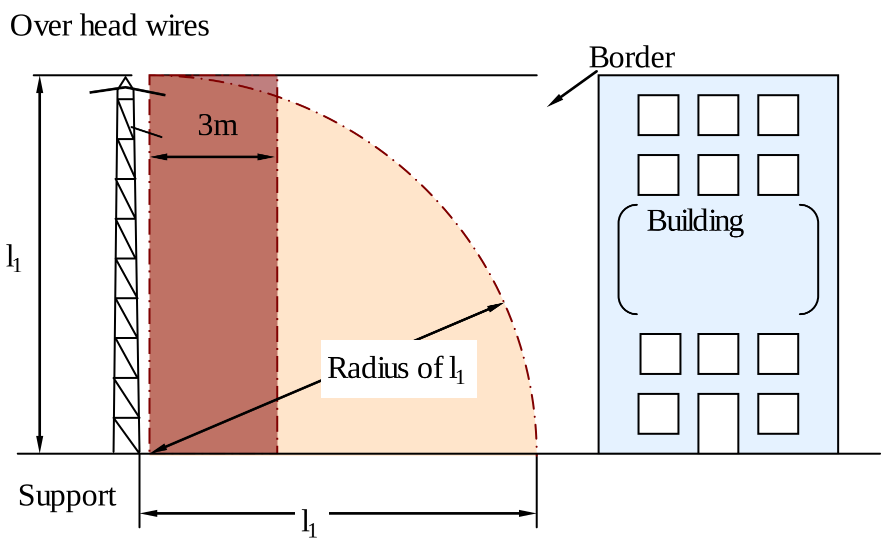


Fig- 14 An example of approach

Article 232-3. Approach or cross between the overhead wire whose voltage is not less than 11kV and the road

1. When an overhead wire whose voltage is not less than 11kV is installed at the distance of not less than 3m from a building, installation should be based on following items.

(1) An overhead wire whose voltage is not less than 11kV should be installed on the basis of the provisions of Article 232-2 paragraph 2.

(2) The separation between an overhead wire whose voltage is not less than 11kV and the road etc should be installed on the basis of the provisions of Article 232-2 paragraph 1.

2. An overhead wire whose voltage is not less than 11kV should not be installed at the distance of less than 3m from the road etc.

3. When overhead wires whose voltages are not less than 11kV are installed above at the road etc in crossing condition, the separation among overhead wires whose voltage is not less than 11kV should be not more than 100m.

Article 232-4. Approach or cross between an overhead wire whose voltage is not less than 11kV and voltage of less than 11kV or their support

1. When an overhead wire whose voltage is not less than 11kV is installed, approaching or crossing with other overhead wires whose voltage is less than 11kV or overhead wires of weak current (hereafter an "overhead wire whose voltage is less than 11kV." in this article), separation between an overhead wire of whose voltage is not less than 11kV and an overhead wire whose voltage is less than 11kV should be not less than the value specified in Table-22.

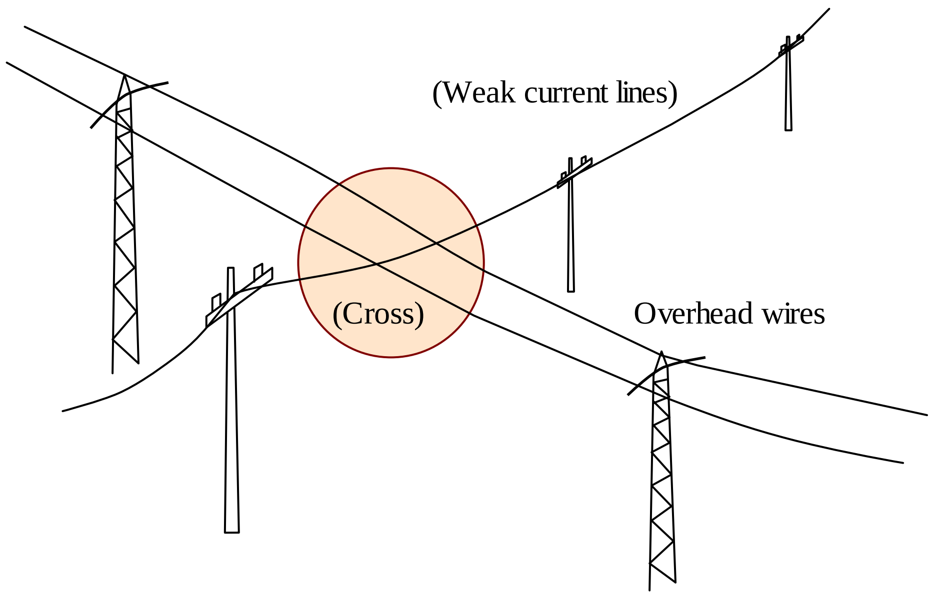


Fig- 15 An example of cross

Table- 22 Separation between over head wires whose voltages are not less than 11kV and over head lines whose voltages are less than 11kV or and supporting equipment

Classifications of operating voltage in over head lines whose voltages are not less than 11kV	Separation
Exceeding 35,000V and not more than60,000V	2m
Exceeding 60,000V	(2+c) m

Remarks: c is the value which is divided the difference between operating voltage in over head lines whose voltages are not less than 11kV and 60,000V by 10,000V (round up at the decimal points) and also multiplied 0.12 by the result

2. When an overhead wire whose voltage is not less than 11kV is installed at the distance of not less than 3m from an overhead wire whose voltage is less than 11kV etc, installation should be based on Article 232-2 items 2.

3. An overhead wire whose voltage is not less than 11kV should not be installed at the distance of less than 3m from an overhead wire of low voltage.

4. When an overhead wire whose voltage is not less than 11kV is installed crossing with other overhead wires whose voltages are less than 11kV, an overhead wire whose voltage is not less than 11kV should be installed above overhead wires whose voltages are less than 11kV, moreover, installation should be based on following items.

5. The separation among overhead wires whose voltages are not less than 11kV should be not more than 100m.

Article 232-5. Approach or cross between an overhead wire whose voltage is not less than 11kV and voltage of less than 11kV or their support

1. When an overhead wire whose voltages are not less than 11kV approaches other overhead wires whose voltages are not less than 11kV or their support or overhead grounded wires, the separation among them should be not less than the value specified in Table-23.

Table- 23 Separation between over head wires whose voltages are not less than 11kV

Over head wires whose voltages are not less than 11kV	Other over head wires whose voltages are not less than 11kV			support or over head wires of other over head lines
Classifications of operating voltage	Not less than 35,000V	Exceeding 35,000Vand not more than 60,000V	Exceeding 60,000V	
not more than 60,000V	2 m		(2+c) m	2 m
Exceeding 60,000V	(2+c) m			

Remarks: c is the value which is divided the difference between operating voltage in over head lines whose voltages are not less than 11kV and 60,000V by 10,000V (round up at the decimal points) and also multiplied 0.12 by the result

2. An overhead wire whose voltage is not less than 11kV should be installed not to be crossed with other overhead wires whose voltages are not less than 11kV or overhead ground wires.

Article 232-6. Approach or cross between an overhead wire whose voltage is not less than 11kV and other facilities

1. When an overhead wire whose voltage is not less than 11kV is installed approaching or crossing with facilities other than overhead wires whose voltages are less than 11kV, or other overhead wires of whose voltage is not less than 11kV, such as buildings, weak current electric power line of roads (hereinafter referred to as “other facilities“ in this article) the separation between an overhead wire whose voltage is not less than 11kV and other facilities should be not less than the value specified in Table-24.

Table- 24 Separation between over head wires whose voltages are not less than 11kV and other facilities

Classifications of over head wires whose voltages are not less than 11kV	Separation
Exceeding 35,000V ,not more than 60,000V	2 m
Exceeding 60,000V	(2+c) m

Remarks: c is the value which is divided the difference between operating voltage in over head lines whose voltages are not less than 11kV and 60,000V by 10,000V (round up at the decimal points) and also multiplied 0.12 by the result

2. When an overhead wire whose voltage is not less than 11kV is installed at the distance of not less than 3m from otter facilities, and there may be danger that overhead wires in overhead electric power line is cut-off or do people harm by contacting with other facilities, overhead wire whose voltage is not less than 11kV should be installed on the basis of the provision of Article 232-2 second paragraph.

3. An overhead electric power line whose voltage is not less than 11kV should not be installed at the distance of less than 3m from other facilities.

Article 232-7. Approach between an overhead wire whose voltages are not less than 11kV and plant

1. The separation between an overhead wire whose voltage is exceeding 35,000V and plant should be not less than the value specified in Table-24 of preceding article.

Article 232-8. Approach or cross between an underground cable and other underground cables

1. When an underground cable of low voltage is installed approaching or crossing with underground cables whose voltage is medium and less than 11kV, installation should be based on the each of following items. However, this is not applied to inside the underground box.

(1) The separation among underground cables should be not less than the value specified as follows:

1) The separation between underground cables of low voltage and underground cables whose voltages are medium and less than 11kV is 0.15m

2) The separation between underground cables whose voltages are less than 11kV, and underground cables whose voltages are not less than 11kV, is 0.3m

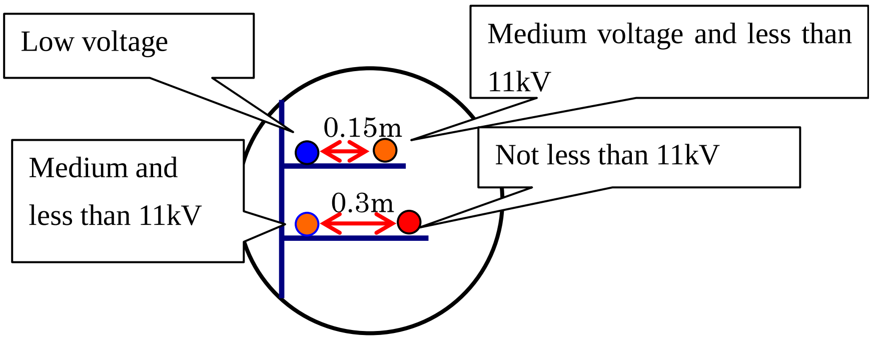


Fig- 16 Separation between underground cables

(2) The strong fire-resistant barriers should be installed among underground cables.

1) One of underground cables should conform to either of followings.

a. coated with the incombustible

b. contained in strong and incombustible pipes

(3) Each of underground cables should conform to either of followings.

1) coated with the material with fire-retardancy and self extinction

2) contained in strong pipes with fire-retardancy and self extinction

2. When an underground cable of low voltage is installed approaching or crossing with underground cables whose voltages are medium and less than 11kV, installation should be based on the each of following items.

(1) The separation between an underground cable whose voltage is not less than 11kV, and underground cable of weak current should be not less than the value specified in Table-25.

Table- 25 Separation between underground cables and underground cables of weak current

Classifications of over head wires	Separation
Less than 11kV	0.3m
Not less than 11kV	0.6m

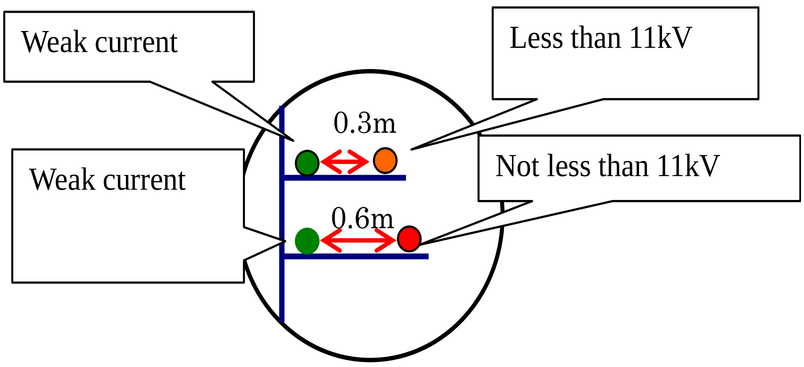


Fig- 17 Separation between underground cables and weak current cables

(2) The strong fire-resistant barriers should be installed between underground cables and underground cables of weak current etc.

(3) An underground cable should be contained in strong pipes with incombustibility and self extinction, and installed so that the relevant pipe does not contact directly to underground cables of weak current etc.

3. When an underground cable whose voltage is not less than 11kV is installed approaching or crossing with gas pipes, or petroleum pipes, or the pipes which contains the combustibles or the poisons (hereafter a "gas pipe etc." in this article) ,installation should be based on the each of following items.

(1) The separation between an underground cable and gas pipes etc should be not less than 1m.

(2) The strong fire-resistant barriers should be installed between an underground cable and gas pipes etc.

(3) An underground cable should be contained in strong pipes with fire-retardancy and self extinction, and installed so that the relevant pipe does not contact directly to gas pipes etc.

4. When an underground cable whose voltage is not less than 11kV is installed approaching or crossing with water pipes, or other pipes other than gas pipes (hereafter a "water pipe etc." in this article) ,installation should be based on the each of following items.

(1) The separation between an underground cable and water pipes etc should be not less than 0.3m.

(2) The strong fire-resistant barriers should be installed between an underground cable and water pipes etc.

(3) An underground cable should be installed by being contained in strong pipes with fire-retardancy and self extinction.

(4) A water pipe etc. is with incombustibility or coated with the material with incombustibility and self extinction.

5. In the provisions from item 1 to 4, “incombustibility “and “incombustibility and self extinction” should be based on the each of following items.

(1) “Coated material with fire-retardancy and self extinction” should conform to or have the performance more than combustion test specified in IEEE Std. 383-1974.

(2) “Pipes with fire-retardancy and self extinction” should conform to the test specified in the Japanese technical regulations committee standards JESC E7003 (2005) "Test method of fire retardancy with self extinction for the pipe or trough which contains an underground cable."

Article 232-9. Prohibition of parallel installation of an overhead wire whose voltage is not less than 11kV and less than 11kV

1. It is prohibited that an overhead wire whose voltage is less than 11kV is installed on the support of electric power line whose voltage is not less than 11kV because not only there may be the danger by contact but also static induction trouble may be caused by abnormal voltage intrusion

into the voltage of less than 11kV side during failure of overhead electric power line at the voltage of not less than 11kV side.

Article 232-10. Prohibition of installation of machines and equipment etc of low voltage on the support of electric power line whose voltage is not less than 11kV

1. It is prohibited that machines and equipment are installed on the support of electric power line whose voltage is not less than 11kV in the area above overhead wires whose voltage is not less than 11kV, because there may be the danger by the contact among machines, equipment and overhead wires whose voltage is not less than 11kV, or there may be abnormal voltage intrusion into the machines and equipment by the electric potential rise of a steel tower caused by the failure such as thunder shock etc.

Article 233. Prevention of danger by collapse of support of overhead power wires

Article 233.-1. Prevention of danger by collapse of support

1. The strength of the supporting structure of overhead electric power lines, such as a steel-tower, a pillar and its foundation, should be based on technical regulations of the Ministry of Construction.

Article 233-2. Prevention of danger by collapse of support of overhead wire whose voltage is not less than 11kV

1. Article 233 is a provision that specifies prevention of danger by collapse of support of overhead wire whose voltage is not less than 11kV and requires consideration in designing.

Article 234. Prevention of danger by high pressure gas and similar

Article 234-1. Installation of pressure vessels for gas insulated equipment

1. Pressure vessels used for gas insulated equipment should conform to following items.

(1) The segment which is subject to the pressure of the insulating gas exceeding 100 kPa, and subject to the open air, should withstand and should have no leakage in the test that 1.5 times the water pressure of maximum allowable working pressure (it is a 1.25 times as much as maximum allowable working pressure when it is difficult to apply the water pressure continuously for 10 minutes) is applied continuously for 10 minutes.
However, this is not applied to gas insulated equipment which they are not connected with a compressor, and withstand and have no leakage in the test that 1.25 times the water pressure of maximum allowable working pressures applied continuously for 10 minutes.

(2) If a equipment has a gas-compressor, safety valves, which activate not more than maximum working pressure and conforms to or have the performance more than International-Organization-for-Standardization 4126-1:2004 Safety devices for protection against

excessive pressure—Part 1: Safety valves, or Japanese Industrial Standards B 8210 (1994) " the spring relief valves for steams, or gas." ,should be installed at the last stage of the compressor, or at the point close to the pipe which leads the gas and the gas insulation equipment, or at the point close to the pipe which leads the gas.

(3) The equipment with a possibility of breakdown due to pressure decrease of insulating gases should be installed the unit which notifies the pressure decrease of insulating gases, or measures the pressure of insulating gas.

(4) Insulating gases should not be inflammable, or corrosive or toxic.

2. The pressure vessel used for the compressor used for a circuit switch or a circuit breaker should be based on each of following items.

(1) The compressor should withstand and should have no leakage in the test that 1.5 times the water pressure of maximum allowable working pressure (it is a 1.25 times as much as maximum allowable working pressure when it is difficult to apply the water pressure continuously for 10 minutes) is applied continuously for 10 minutes.

(2) An air tank should conform to the provision of proceeding item, and also be based on the followings.

  1) Allowable stress and structure of the material and the material itself should conforms to or have the performance more than “the structure of pressure vessel - generals" of Japanese Industrial Standards B 8265(2003)" (there is an addendum at JISB 8265 (2008)).

  2) Tank capacity should be capable of what can connect and shut down the circuit not less than once continuously in the condition that there is no supply of air at working pressure.

  3) When the material which does not have the anti-corrosion characteristic is used, it should be painted outside for anticorrosive.

(3) A pipe to flow compressed air should be based on the provision of item (1) and preceding item (2) 1).

(4) The pipe which is connected to air compressors, or connected to air tanks, or leading compressed air should be installed to prevent from arising residual stress by welding and being applied excessive load by the fastening of a screw.

(5) Safety valves, which activate not more than maximum working pressure and also conform to or have the performance more than International-Organization-for-Standardization 4126-1:2004 Safety devices for protection against excessive pressure - Part 1: Safety valves, or Japanese Industrial Standards B 8210 (1994) " the spring relief valves for steams, or gas." ,should be installed at the last stage of the compressor, or at the point close to the pipe which leads the gas and at the gas insulation equipment, or at the point close to the pipe which leads the compressed air.
However, if it is in the compressed-air unit of less than 1 MPa of pressure, it can be replaced with the safety device which operates at the pressure not more than maximum allowable working pressure.

(6) When the pressure of a main air tank decreases, the equipment to recover pressure automatically should be installed.

(7) A pressure gauge with the highest scale of not less than1.5 and not more than 3 times of working pressure should be installed at the air tank or the point close to this.

3. The low-temperature application limits of the pressure vessel should be 0℃.

Article 234-2. Installation of pressurizing equipment for underground electric power line

1. Pressurizing equipment on cables in underground electric power line using compressed gas should conform to following items.

(1) The pipe which leads compressed gas or compressed oil, tanks for pressurizing gas and oil, and a compressor, should withstand and should have no leakage in the test that 1.5 times the oil pressure of maximum allowable working pressure (it is a 1.25 times as much as maximum allowable working pressure when it is difficult to apply the oil pressure continuously for 10 minutes) is applied continuously for 10 minutes.

(2) The pipe which is connected to air compressors, or connected to air tanks, or leading compressed air should be installed to prevent from arising residual stress by welding and being applied excessive load by the fastening of a screw.

(3) The device to measure the pressure of compressed gas or compressed oil should be installed to pressure equipment.

(4) Compressed gases should not be inflammable, or corrosive or toxic.

(5) A device which supplies compressed gas automatically, and what has a possibility that a pressure may rise remarkably when a regulator breaks down, should be based on the followings.

1) Material , its allowable stress, and structure for pressure pipes of maximum allowable working pressure of not less than0.3MPa or for pressure tanks, should conform to or have the performance more than Japanese Industrial Standards B 8265(2003)"pressure vessel -1.generals" (addendum at Japanese Industrial Standards B 8265 (2008)).

2) Safety valves, which activate not more than maximum working pressure and also conform to or have the performance more than International-Organization-for-Standardization 4126-1:2004 Safety devices for protection against excessive pressure—Part 1: Safety valves, or Japanese Industrial Standards B 8210 (1994) " the spring relief valves for steams, or gas." ,should be installed at the pressure tank ,or at the point close to the tank and at the last stage of the compressor, or at the point close to the pressure pipe.
However, if it is in the compressor of less than 1 MPa of pressure, it can be replaced with the safety device which operates at the pressure not more than maximum allowable working pressure.

Article 234-3. Installation of a hydrogen cooled generator

1. Hydrogen cooled generators or the hydrogen cooling equipment should be conformed to the following items.

(1) Hydrogen transport facilities such as pipes or valves should have the structure which can prevent hydrogen leakage.

(2) Transporting pipes for hydrogen should be made with copper or seamless steal, and should have mechanical strength to endure the hydrogen explosion at the pressure of the atmosphere.

(3) Generators should have hermetic structure and should have mechanical strength to endure the hydrogen explosion at the pressure of the atmosphere.

(4) A glass window equipped in a generator should have the structure which cannot be damaged easily.

(5) Shaft seal part of a generator should be equipped with either a nitrogen seal device or a hydrogen emitting device so that hydrogen leaked from seal part can be emitted to outside safely.

(6) Generators should be equipped with facilities which can inlet hydrogen to the generator safely and can emit hydrogen to outside safely.

(7) When hydrogen purity decreases to the range of approximately from 85 to 90%, an alarm system is activated so that the generator maintains safety.

(8) When hydrogen pressure fluctuates, an alarm system should be activated so that the generator maintains safety.

(9) Generators should be equipped with the hydrogen temperature meter.

(10) Pipes for hydrogen emitting from inside the generator to outside, following measures should be taken in order to prevent fire by hydrogen ignition.

1) To install not to pile up foreign substances such as stain or mist

2) To ground emitting pipes and surrounding metal structures in order not to accumulate static electricity

3) To install to the direction of no combustibles area

4) To install wire nettings to prevent back-fire

In addition, for the installation of a hydrogen cooled generator, operation and maintenance guideline (Article252, Article253, Article256, and Article257) is referred.

Article 235. Prohibition of dangerous facilities

Article 235-1. Restriction of installation of a oil switch

1. It is specified that there may a possibility of doing harm to people when oil leaks from an oil switch installed in the support of an overhead electric power line according to internal-short-circuit failure.

Article 236. Prevention of electrical and magnetic interference

Article 236-1. Prevention of electromagnetic interference

1. Overhead electric power line should be installed not to generate the wave which has a possibility of generating the wave which gives continuous and serious interference to the facility of a radio equipment,

2. The object of this article is preventing the continuous and serious electromagnetic interference, and neither a temporary or momentary thing nor a slight thing .This catastrophic failure means making communication impossible by decreasing a signal-to-noise ratio, or giving serious jamming.
   Moreover, the trouble by the radio wave directly from electric machinery and apparatuses is the target of this article. Examples of measures are shown in Article18-1 of this guideline.

Article 236-2. Prevention of induction trouble to underground wires of weak current

1. Underground wires of weak current should be installed by the suitable method such as fully separating from underground electric power line, not to be troubled by the induction, such as described in Fig-19 “Cable box installation”.

Article 237. Prevention of power supply disturbance

Article 237-1. Protection device for generator

1. A generator should be installed the devices to shut down automatically from the electric power line in the following cases.

(1) Generator over-current

(2) Generator internal failure

(3) In the case of steam turbines of a rated output exceeding 10000kW and also gas turbines equipped with the common thrust bearing in a combined cycle plant, thrust bearing wear or high thrust bearing temperature
   In addition, Article254 of this guideline is referred in detail.

Article 237-2. Protection device for transformer whose voltage is not less than 11kV

1. Protection devices for transformer whose voltage is not less than 11kV should be installed, on the basis of following items.

(1) Protection devices specified in Table-26 should be installed.
   However, a protection device which shuts down from the electric power line is not required if the facility is installed so that the generator is used as the power source of the transformer and shut down automatically, when internal failure of a transformer occurs.

Table- 26 Protection devices for the transformer whose voltage is not less than 11kV

Bank capacity etc	Working condition	Classifications of the device
Not less than 5MVA and Not more than 6.3MVA	Internal failure of a transformer	Automatic shutdown or alarming device
Not less than 6.3MVA	The same as above	Automatic shutdown device

For the forced cooling type (cooling system which controls circulation of coolant enclosed in order to cool windings and iron core of transformer directly.) transformers whose voltages are not less than 11kV, an alarming device should be installed when a cooling device breaks down, or when the temperature of a transformer rises remarkably.

In addition, Article254 of this guideline is referred in detail.

Article 237-3. Mechanical strength of a generator, a transformer, a bus conductor, and supporting insulator

1. Because a generator, a transformer, a bus conductor, and supporting insulator, are subject to mechanical shock by the electromagnetic force of inrush electric current at the time of the short-circuit of electric power line, it is required that these equipment should be designed enough in consideration of the electromagnetic force by short-circuit current, and should be constructed.

   Mechanical strength should be calculated about the each case of the equipment, considering the maximum instantaneous value containing transient current etc.

   The standard of separation between the phase and separation from the ground of bare wires are referred to Table-27.

Table- 27 Separation between the phase and separation from the ground of bare wires

Nominal voltage	Outdoor		Indoor	
	Separation between the phase	Separation from the ground	Separation between the phase	Separation from the ground
3,300V	0.5m	0.25m	0.25m	0.1m
6,600V	0.5m	0.25m	0.25m	0.12m
11,000V	0.6m	0.3m	0.3m	0.18m
22,000V	0.7m	0.4m	0.45m	0.3m
66,0000V	1.5m	0.85m	1.0m	0.73m
110,000V	2.3m	1.4m	-	-
220,000V	3.6m	2.3m	-	-
500,000V	8.0m	8.0m	-	-

Remark: 1) This is not applied to closed type power distribution panel, gas insulated apparatus.
Remark: 2) This is not applied to leading wire to connecting with electric machines and equipment.
Remark 3) This is not applied in case of cable supply and when there is no possibility of surge intrusion from outside.

Article 237-4. Mechanical strength of generator rotating part

1. Article 237, paragraph 4 of the technical regulation specifies mechanical-strength of a generator rotating part.
   It is required that a generator is designed and constructed, considering this item enough.
   Since an emergency speed governing device is installed in a turbine, it is necessary the mechanical strength of the rotating part withstands at the speed the governing device operates.

Article 237-5. Mechanical strength of turbine generator for the vibration at bearings or pedestals

1. Article 237, paragraph 5 of the technical regulation specifies mechanical strength of a generator for the vibration of the shaft or the bearing, and the limit of the vibration is the same as what is required for the steam turbine which drives a generator.

Article 237-6. Prohibition of installing a power station which is not monitored continuously

1. Article 237, paragraph 6 of the technical regulation specifies that in principle installing a power station which is not monitored continuously from the viewpoint on security that the quick and suitable measure by the engineer for shutting down a power station safely and correctly is not expectable when abnormal condition arises.

Article 237-7. Installation of arresters

1. Arresters should be installed, at the point of or close to, the inlet or outlet of the overhead wire of a power station in the electric power line whose voltage is exceeding 1kV.
2. When it conforms to either of following items, it may not be based on a provision of the preceding paragraph.

(1) When the wire length connected directly to the point of preceding paragraph is short

(2) In the electric power line of operating voltage exceeds 60,000V, when the number of overhead wires connected at all times is not less than 5 in the case the number of electric power line is not more than 7, when the number of overhead wires connected at all times is not less than 4 in the case the number of electric power line is not more than 8.
In these cases, when the overhead wires of two or more lines are installed by the same support, the number of overhead electric power lines is calculated as 1.

3. The arrester installed in the electric power line whose voltage is exceeding 1kV should be grounded by class A grounding.
4. Explanation

   The point where an arrester should be installed changes according to the each power station from viewpoints of layout, importance, insulating strength, etc. of the equipment which should be protected ,therefore, expression of " at the point of or close to " is used.

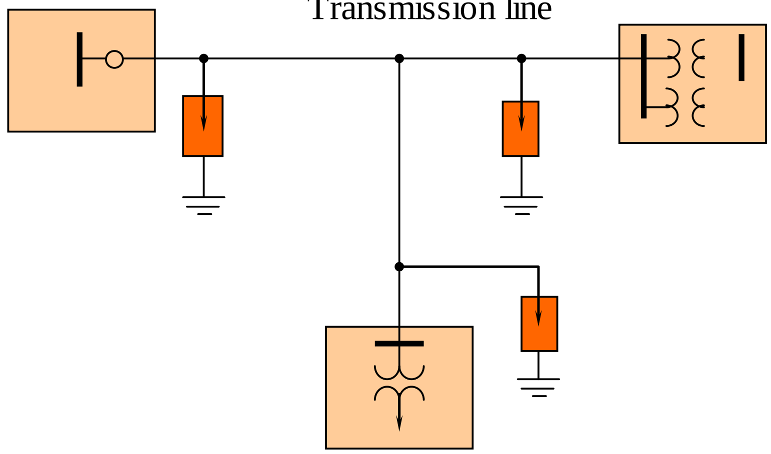


Fig- 18 An example of arrester installations

Article 237-8. Installation of facilities for power security communication

1. Facilities for power security communication should be installed in the point where each of following items specifies.

(1) Between a power station and the load dispatching center
However, following cases are excluded.

1) Output of the power station is less than 2,000 kW.

2) There is no necessity for urgent notification to the load dispatching center on security

(2) Facilities belonging to the same electric system ,such as a substation which urgent notification to the load dispatching center is required on security, a place which has the similar function to a substation and transforms whose voltages are not less than 11kV, a power-generation control center, and between a substation control center and a switching station.

(3) Between the fire departments etc. which have the necessity for an urgent notification on security.

Article 237-9. Installation of a communication wire for power security

1. A communication wire for power security, with a possibility of getting the pressure or the remarkable mechanical shock from the heavy load, should be installed at a location by either of following items.

(1) A suitable protection unit should be installed.

(2) The communication wire should be coated to withstand the pressure or the remarkable mechanical shock.

2. An overhead communication wire for power security should be installed by either of following items.

(1) A cable should be used for a communication wire, and installation should be based on followings.

1) A cable is supported by supporting wires.

2) A supporting wire is stranded and made of metal. However, this is not applied to supporting an optical fiber cable.

3) A supporting wire is what is with tensile strength of not less than 5.93 kN or made of galvanizing stranded iron with a cross section of not less than 22 mm^2.

(2) A communication wire should be what is with tensile strength of not less than 2.30 kN or a hard-drawn copper wire (except for a cable) of not less than 2.6 mm in diameter.

(3) An optical fiber cable is installed using overhead ground wires.

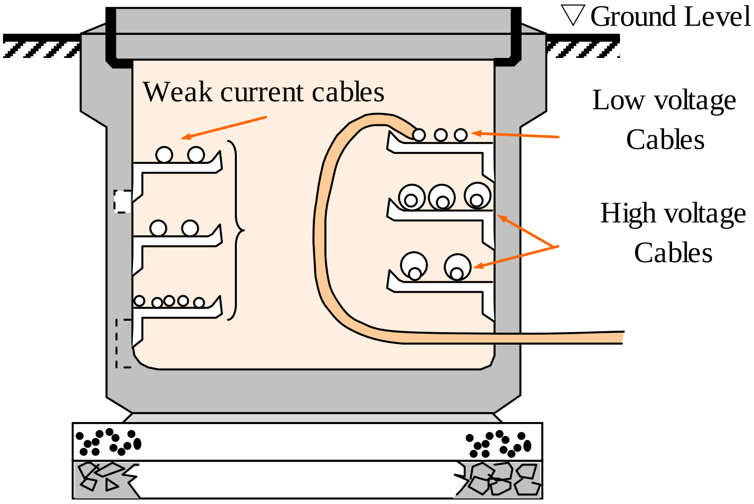
3. When a power security communication wire is installed in a covered conduit, installation should be based on either of following items.

(1) A communication wire should be coated with the material which conforms to or have the performance more than IEC 60332-1 ed1.0 Tests on electric and optical fiber cables under fire conditions - Part 1: Test for vertical flame propagation for a single insulated wire or cable.

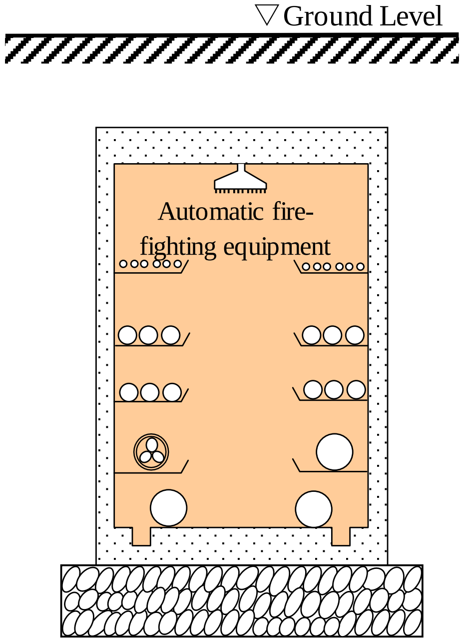
(2) A communication wire should be coated with the tape for preventing spread of fire which conforms to the provision of the paragraph 1.

(3) A communication wire should be contained and installed in a pipe or a trough.

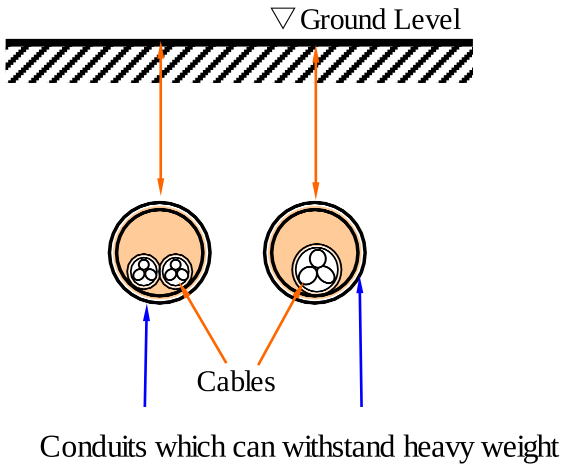
(4) Automatic firefighting equipment should be installed in the covered conduits.



Cable box installation



Conduit system



Installation by conduits

Fig- 19 Examples of cable installation underground

Article 237-10. Installation of a steel-tower which supports the antenna for wirelesses, etc

1. Strength of a steel-tower, a pillar, and its foundation, which supports antennas for wirelesses, should be based on the technical regulation of the Ministry of Construction.

2. As for power communication equipment for security, stable and firm facilities are desirable from the standpoint that required communication on security and operation are secured during natural disaster, etc.

In the present communication technology, wireless communication agrees with this solution most. If the strength of a steel-truss pole or a reinforced concrete pole, or, a steel-tower which support an antenna, a passive reflector, etc., is weak, this objective cannot be attained. Therefore; Article 237 of the technical regulation paragraph 14 is specified.

Article 237-11. Installation of battery equipment

1. Battery equipment should be designed in consideration of each of following items.
   In addition, the battery which is the stable power source is used as the control source of a power station, and emergency power source in case of an outage.
   As a category of battery, the vented lead battery, the control-valve type lead battery, and the alkaline battery are mainly used.

(1) Battery equipment should be installed only for the unit exclusively.
Since a storage battery is an important power source on security, it should be installed for every unit.

(2) Battery equipment should be installed to operate important auxiliaries for not less than1 hour, in principle.

(3) The battery equipment should be operation status of each load or auxiliaries during power-source loss should be considered for every unit.
The capacity of the battery should be determined, considering the load from outage to receiving power in the power station by classifying into continuous load, interrupting load, momentary load, etc., and by summing the load current according to each time zone.
Examples of important auxiliaries are the emergency sealing oil pump for a hydrogen cooled generator, a main turbine emergency bearing oil pump, a BFPT emergency bearing oil pump, a unit control computer, a uninterruptible power supply for a control, a direct-current control source, etc.

(4) Ventilation system of enough capacity is recommended to be installed in the battery room to prevent hydrogen explosion because hydrogen may be generated from batteries though they are sealed type.

(5) Measures for acid are recommended to be taken in the battery room because strong acid is used in batteries.
For example, the floor is coated against acid and wash stands are installed.

Section 3 Electrical Facilities in Demand Site

Article 238. Prevention of electric shock, fire, and similar

Article 238-1. Prevention of electric shock, fire, and similar by electric wiring

1. Article 238, paragraph 1 of design technical regulation provides security principle corresponding to difference of installation location, installation condition, and operating voltage of electrical wiring. And the installation condition means a kind of a power wire or cable to be used and an installation method.

Article 238-2. Installation of a flexible reeling and trailing cable

1. A flexible reeling and trailing cable (which is not fastened down to the structural members excluding electric wiring of the inside of current-using equipment) for low voltage use should conform to matters listed in the following items.

(1) A flexible reeling and trailing cable should be a cabtyre cable, nominal cross-sectional area of conductor of which is greater than 0.75 mm^2, however, this does not need to apply to a designated cable for an elevator or electric welding.

(2) Type of cabtyre cable should be selected corresponding operating voltage and installation condition.

2. It should be used a plug and socket outlet or similar device to connect cable conductors between indoor flexible reeling and trailing cable and indoor electrical wiring for low voltage use, however, this does not need to apply to this cable supported from messenger wire.

3. The provision of preceding paragraph 1 should apply mutatis mutandis to the flexible reeling and trailing cable for medium voltage and voltage of less than 11kV use.

4. A flexible reeling and trailing cable for medium voltage and voltage of less than 11kV use should be tightly connected with electrical equipment by tightening the bolt firmly or other methods.

Article 238-3. Prohibition of installation of a flexible reeling and trailing cable for voltage of not less than 11kV use

1. Article 238, paragraph 3 of design technical regulation provides prohibition of installation of a flexible reeling and trailing cable for voltage of not less than 11kV use, because this cable which directly supplies power using voltage of not less than 11kV to electrical equipment may cause risk to personnel or other equipment. In addition, electric power is ordinary supplied to mobile equipment such as a coal unloader, stacker and reclaimer for coal handling by the flexible reeling and trailing cable for medium voltage and voltage of less than 11kV use.

Article 238-4. Appropriate use of a wire and cable

1. Article 238, paragraph 4 of design technical regulation provides that a wire and cable must have enough strength and insulation performance. It should be determined to select a type of wires and cables after careful thought because required wire and cable strength is associated with

installation condition, and insulation performance is different according to a type of insulation material and thickness. The type of wires and cables is referred to Article 16-6.

Article 238-5. Use restriction of a bare wire

1. A bare wire should not be used as indoor power wire for medium voltage and voltage of less than 11kV use; however, this does not need to apply runway contact conductors to supply electric power to indoor mobile equipment for medium voltage and voltage of less than 11kV use such as an overhead travelling crane.

Article 238-6. Prohibition on use of a contact conductor for voltage of not less than 11kV use

1. Article 238, paragraph 6 of design technical regulation provides prohibition on use of a contact conductor for voltage of not less than 11kV use, because live parts of the contact conductor are exposed and the voltage is very high with high risk to personnel or other equipment.

Article 238-7. Insulating performance of low voltage power lines

1. Article 238, paragraph 7 of design technical regulation provides that insulation resistance associated with insulating performance of low voltage power lines is uniform value corresponding to each operating voltage to decide whether insulation resistance is good or bad easily. These values are determined because there is not risk of electric shock to the human body or fire, even though leakage current of approximately 1 mA is caused in the low voltage power line. The pass/fail criteria for insulation resistance are useful for maintenance of the low voltage power line when insulation resistance is measured and each low voltage power line which is possible to be isolated by a switch or an over-current circuit breaker must conform to the provided insulation resistance value.
2. When it is difficult to measure insulation resistance of low voltage power line, each leakage current of the low voltage power line should be maintained at not more than 1 mA corresponding to the each operating voltage provided in the Table 20, Article 238, paragraph 7 of design technical regulation.

Article 238-8. Prevention of electrical shock, fire and the similar by electrical equipment

1. The live parts of low voltage electrical equipment installed indoors should not be exposed, however, this does not need to apply that the live parts of an electric welding machine and electrolytic bath which are unavoidable to expose the live parts, or electrical equipment installed in the place where only qualified personnel can have access.

Article 238-9. Installation of electrostatic precipitator whose voltage is not less than 11kV

1. An electrostatic precipitator whose voltage is not less than 11kV and its power supply system whose voltage is not less than 11kV should conform to matters listed in the following items.

(1) A switch to disconnect power supply should be installed in an easy point to open and close near the transformer whose voltage is not less than 11kV and which supplies power to an electrostatic precipitator whose voltage is not less than 11kV in primary power line of the transformer.

(2) A transformer whose voltage is not less than 11kV and which supply power to an electrostatic precipitator whose voltage is not less than 11kV, rectifier and auxiliary electrical equipment whose voltage is not less than 11kV should be installed in the place where only qualified personnel can have access.

(3) A transformer whose voltage is not less than 11kV and which supply power to an electrostatic precipitator whose voltage is not less than 11kV should conform to the provision in Article 16-5, paragraph 1.

(4) A cable whose voltage is not less than 11kV from a transformer whose voltage is not less than 11kV to the rectifier, and from the rectifier to a discharge electrode should conform to matters listed in the following items.

1) A cable whose voltage is not less than 11kV should be protected by appropriate protective installation such as a conduit.

2) Metal part of protective installation for the cable such as a conduit, and metal sheath of the cable should be grounded by class A grounding.

(5) When there is any risk of electric shock to the human body, the secondary power line of the transformer should be equipped with a device to discharge residual electric charge.

(6) When an electrostatic precipitator whose voltage is not less than 11kV and its power supply system whose voltage is not less than 11kV are installed outside of a building, the electrostatic precipitator whose voltage is not less than 11kV and the cable whose voltage is not less than 11kV from the rectifier whose voltage is not less than 11kV to a discharge electrode should conform to matters listed in the following items.

1) A live part of the electrostatic precipitator whose voltage is not less than 11kV should be protected by appropriate protective installation not to be touched.

2) The cable whose voltage is not less than 11kV from the rectifier whose voltage is not less than 11kV to the discharge electrode should conform to matters listed in the following items.

a. The cable whose voltage is not less than 11kV should be laid in durable cable duct or tray.

b. The durable cable duct or tray prescribed in the preceding item should be equipped with durable lids which only qualified personnel can take off.

Article 239. Prevention of danger to other electrical wirings, other facilities, and similar

Article 239-1. Low voltage building electrical wiring in close proximity or crossing with communication wires, pipes, or similar

1. When low voltage building electrical wiring is in close proximity or crossing with communication wires, water pipes, gas pipes, or the similar, the low voltage building electrical wiring should be installed not to contact with these things.
2. When leakage current occurs in the material parts of indoor telephone lines, water pipes, gas pipes, air pipes, steam pipes or the similar, there is risk of an electric shock, damage to the other facilities or fire. It is a reliable and simple method to keep low voltage building electrical wiring away from these things to prevent the risk.

Article 239-2. Building electrical wiring whose voltage is medium and less than 11kV in close proximity or crossing with the other building electrical wirings whose voltages are medium and less than 11kV, pipes, or similar

1. When building electrical wiring whose voltage is medium and less than 11kV is in close proximity or crossing with the other building electrical wiring whose voltage is medium and less than 11kV, communication wires, water pipes, gas pipes, or the similar, building electrical wiring whose voltage is medium and less than 11kV should be kept at least 0.15 m away from these things, however, this does not need to apply that when a cable is used as the building electrical wiring whose voltage is medium and less than 11kV and;

   - when a fire-resistant durable separating wall is installed between the cable and these things or;
   - when the cable is installed in a fire-resistant conduit or;
   - when the other building electrical wiring whose voltage is medium and less than 11kV is a cable.

Article 240. Protection measures to abnormal condition

Article 240-1. Installation of a switch in entry point of low voltage building line

1. A switch to disconnect power supply should be installed in an easy point to open and close near an entry point in the low voltage building line.

Article 240-2. Installation of an over-current circuit breaker in low voltage building main line

1. An over-current circuit breaker to protect a low voltage building main line should be installed in power source side of the low voltage building main line.
2. A rated current of the over-current circuit breaker prescribed in the preceding paragraph should be less than allowable current of the low voltage building main line.

Article 240-3. Installation of an overload protection device of a motor

1. A motor should be equipped with an overload protection device to disconnect power supply automatically when over-current occurs with risk of motor burning.
2. The functions of protective equipment are recommended to be added according to necessity from following items

(1) Ground fault

(2) Overvoltage or under voltage

(3) Difference of phase (or rotating direction)

(4) Voltage / frequency (To prevent over excitation)

(5) Disconnection of one phase power line

Article 240-4. Installation of an over-current and ground fault circuit breaker for flexible reeling and trailing cables for voltage of medium and less than 11kV use

1. A designated switch and over-current circuit breaker should be installed in each pole (excluding neutral pole of a polyphase line in the over-current circuit breaker) of the power line which supplies power to a flexible reeling and trailing cable for voltage of medium and less than 11kV use and a device to disconnect power supply automatically when ground fault occurs should be installed in the power line. However, the designated switch does not need to be installed if a function of open and close is incorporated in the over-current circuit breaker.

   Ground fault circuit breakers equipped in the area where human may access should be set to operate so that the product of leakage (residual) current and time (second) is less than allowable contact voltage (50V) as described in IEC60364-4-41.

   In general, the ground fault circuit breakers are recommended to set to operate when the leakage (residual) current increases up to 30mA as described in IEC60364-4-41, because continuous current over this value may kill a person as described in IEC/TS 60479-1.

Article 240-5. Installation of an over-current and ground fault circuit breaker for voltage of medium and less than 11kV contact conductor

1. A designated switch and over-current circuit breaker should be installed in each pole (excluding neutral pole of a polyphase line in the over-current circuit breaker) of a power line which supplies power to indoor contact conductor for voltage of medium and less than 11kV use and the designated switch should be installed in an easy point to open and close near the contact conductor. However, the designated switch does not need to be installed if a function of open and close is incorporated in the over-current circuit breaker.
2. A device to disconnect power supply automatically when ground fault occurs should be installed in the power line provided in the preceding paragraph, however, this does not need to apply to that a designated isolation transformer is installed in power source side of the power line within 1 km from the source side of connection point of the contact conductor for voltage medium and

less than 11kV use and alarm systems an alarm of which is activated in the case that a ground fault alarm is installed.

Article 241. Prevention of electrical and magnetic interference

Article 241-1. Prevention of electromagnetic interference by high frequency current

1. When there is risk that high frequency current which affects function of radio equipment with continuous and serious interference or interruption occurs, a capacitor with suitable capacitance should be used in appropriate circuit of electrical equipment such as fluorescent light fittings to prevent electromagnetic interference. An example of the suitable capacitance is 0.006 to 0.5 micro F.
2. An indoor contact conductor for voltage of medium and less than 11kV use should be installed so that there is not risk that it causes continuous and serious interference or interruption to the function of radio equipment that a collector travels on the contact conductor. An example of measure is shown in Fig-17 of this guideline.

Article 242. Installation restrictions on specific location

Article 242-1. Installation in an area with much dust

1. Electrical equipment whose voltage is less than 11kV and which is installed in an area where much dust is suspended in the air excluding the area provided in Article 242-2, paragraph 2 should conform to the provisions of Zone 22 of IEC 60079-14 ed4.0 (Explosive atmospheres Part 14: Electrical installations design, selection and erection).
2. The area where much dust is suspended in the air means that an area in which an explosive dust atmosphere is not likely to occur, and there is much risk to prevention of thermal radiation, insulation degradation and deterioration of switching performance of electrical equipment.
3. In design and installation, IP Code should be considered. IP Code is defined in international standard IEC 60529, which classifies and rates the degrees of protection provided against the intrusion of solid objects (including body parts like hands and fingers), dust, accidental contact, etc
4. (Explanation)

   IP code is described such as IP68. First number shows the degree of protection against solid foreign particles, ranging from 1 to 6. Second number shows the degree of protection against the intrusion of water, ranging from 1 to 8. In the case of installation in an area with much dust, first number of IP code is recommended to be considered.

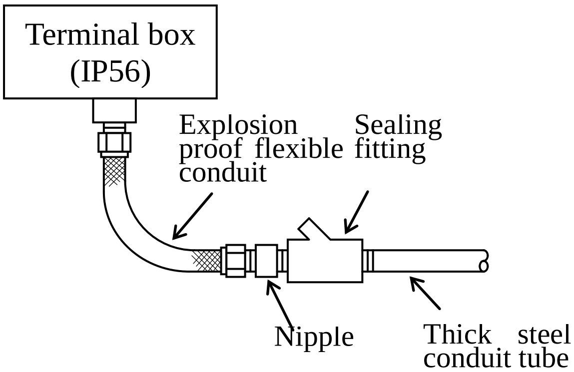


Fig- 20 An example of installation in an area with much dust

Article 242-2. Installation in hazardous areas where a potential for explosion exists by flammable gas, combustible dust, etc.

1. Electrical equipment whose voltage is less than 11kV and which is installed in an area that flammable gas or vapour of flammable substance is leaked or accumulated and there is a risk that an explosion can occur if a source of ignition by electrical equipment is present should be installed according to the standard in the following items (1) or (2).

(1) Zone 0, 1 or 2 (corresponding to installation location) of IEC 60079-14 ed4.0 (Explosive atmospheres Part 14: Electrical installations design, selection and erection)

(2) Zone 0, 1 or 2 (corresponding to installation location) of JIS C 60079-14（2008）Electrical apparatus for explosive gas atmospheres - Part 14: Electrical installations in hazardous areas (other than mines)

(3) The flammable gas means that gas at ambient temperature forms an explosion gas atmosphere with air in certain proportions and an explosion can occur if a source of ignition is present. Examples of the flammable gases are hydrogen, coal gas, methane, ethane, propane, etc.

(4) The flammable substance means that its vapour forms an explosion gas atmosphere with air in certain proportions and an explosion can occur if a source of ignition is present. In general, flash point of the flammable substance is at or below 40°C but a substance having a flash point above 40°C is included in the flammable substance when temperature of the substance is greater than its flash point under existing conditions. Examples of the flammable substances are crude oil, heavy oil, etc.

2. Electrical equipment whose voltage is less than 11kV and which is installed in an area where there is combustible dust (This is combustible dust such as pulverized coal and has a risk that an explosion can occur when it is suspended in air and is ignited.) and a risk that an explosion can occur if a source of ignition by electrical equipment is present should conform to the provisions of Zone 20, 21 or 22 (corresponding to installation location) of IEC 60079-14 ed4.0 (Explosive atmospheres Part 14: Electrical installations design, selection and erection).

3. Low voltage electrical equipment which is installed in an area (excluding the area provided in Article 241-1 and preceding paragraph) to store hazardous materials such as flammable liquid including petroleum should conform to matters listed in the following items.

(1) A cable should be installed through a conduit or other protection accessory.

(2) A cable should be firmly connected with electrical equipment not to loosen the connection by vibration and to make sure the electrical connection.

(3) Electrical equipment which has potential to cause electric spark or arc, or potential to rise in temperature remarkably under normal operating condition should be installed so that there is not a risk of ignition of hazardous materials.

(4) The hazardous materials such as flammable liquid including petroleum means gear oil, cylinder oil, lubricant oil, turbine oil, machinery oil, etc.

4. In general, electrical equipment is not installed in Zone 0 or Zone 20.

5. (Explanation)

The methods of protection are summarized in Table-28.

Table- 28 Methods of protection

Method	Type of protection
Designed to prevent any ignition from arising	Ex e: Increased Safety Ex n :Non Sparking
Designed to limit the ignition energy of the circuit	Ex i Intrinsic Safety (ia, ib)
Designed to prevent the flammable mixture reaching a means of ignition	Ex m Encapsulation Ex p Pressurization Ex o Oil immersion
Designed to prevent any ignition from spreading	Ex d Flameproof Enclosure Ex q Powder Filling

Note: "Ex "means explosion proof.

The hazardous areas are classified in Table-29.

Table- 29 Hazardous areas classification

Zone	Description	Examples of protection used
Zone 0 (Zone 20 for dust)	Zone in which an explosive atmosphere is continuously present for long periods.	Ex i (ia, ib)
Zone 1 (Zone 21 for dust)	Zone in which an explosive atmosphere is likely to occur in normal operation, typically between 10 and 100 hours per year.	Ex i (ia, ib) ,Ex p, Ex q, Ex m, Ex d, Ex e
Zone 2 (Zone 22 for dust)	Zone in which an explosive atmosphere is not likely to occur in normal operation, and if it occurs it will exist only for a short time, typically less than 10 hours per year. (Zone 2 is often referred to as the remotely hazardous area.)	Ex i (ia, ib) ,Ex p, Ex q, Ex m, Ex d, Ex e, Ex n

Article 242-3. Installation in hazardous areas where a potential for insulation degradation exists by corrosive gas, etc.

1. A discharge lamp, such as a fluorescent lamp and mercury lamp, that an operating voltage of lamp circuit exceeds 300V should not be installed in the area provided in Article 242-1, Article 242-2 of technical guideline and Article 242 paragraph 3 of technical regulation.

Article 242-4. Prohibition on installation of the electrical equipment whose voltage is not less than 11kV in hazardous areas

1. Electrical equipment whose voltage is not less than 11kV should not be installed in the area provided in Article 242-1 and Article 242-2.
2. The preceding paragraph provides that installation of electrical equipment whose voltage is not less than 11kV is prohibited in the area where there is a risk of electric shock, fire, or etc. because the energized electrical equipment whose voltage is not less than 11kV may cause discharge.

Article 242-5. Prohibition on installation of a contact conductor in hazardous areas

1. A contact conductor should not be installed in the area provided in Article 242-1 and Article 242-2.
2. A contact conductor whose voltage is medium and less than 11kV should not be installed in the area provided in Article 242, paragraph 3 of technical regulation.
3. The preceding paragraph 1 provides that installation of the contact conductor is prohibited in the area provided in Article 242-2, where there is a high risk of explosion or fire, and in the area provided in Article 242-1, where there is a risk of electric shock or fire because the contact conductor may cause electric spark or arc flash.
4. The preceding paragraph 2 provides that installation of contact conductor whose voltage is medium and less than 11kV is prohibited in the area provided in Article 242, paragraph 3 of technical regulation, where there are corrosive gases or liquids, because poor contact with a current collector caused by corrosion of the contact conductor may cause electric spark or arc flash.

Article 243. Installation of special equipment

Article 243-1. Prohibition on installation of an electric heater for a pipeline, etc

1. An electric heater for a pipeline, etc should not be installed in the area provided in Article 242-1 and Article 242-2.
2. The preceding paragraph provides that installation of the electric heater for a pipeline, etc to heat petroleum such as crude oil, heavy oil is prohibited in the area where there is a risk of explosion or fire caused by its heating.

Article 243-2. Installation of cathodic protection system

1. Cathodic protection system, which cathodic protection current flows between sacrificial anode installed underground or underwater and the metal parts of equipment (excluding underground or underwater installation), using external eclectic power source to prevent corrosion of the metal parts of equipment should conform to matters listed in the following items.

(1) An operation voltage of cathodic protection circuit (from its power supply unit to the anode or protected equipment) should be at not more than 60 V dc.

(2) The anode should conform to one of the matters listed in the following items.

1) The anode (including electrical conducting material around the anode, if required) should be laid underground and its depth should be 0.75 m or over.

2) The anode should be installed in the location where there is not a risk of being touched easily and conform to one of the matters listed in the following items.

a. The difference of potential between the anode installed underwater and its surrounding any point within 1 m should be less than 10 V.

b. Appropriate fence should be installed around the anode to prevent personnel from touching it and visible signs warning of danger should be posted.

(3) The difference of potential on the ground or underwater between any point 1m away each other (excluding any point within 1m from the anode installed underwater and any point inside of the fence provided preceding paragraph (2) 2) b.) should be less than 5 V.

(4) A power supply unit of the cathodic protection system should conform to matters listed in the following items.

1) The power supply unit should be installed inside a durable metal enclosure and be grounded by class D grounding.

2) An isolation transformer should be used as a transformer and have performance to withstand that a test voltage of 1000 V ac is continuously applied between one of windings and the other windings, iron core and enclosure for 1 minute.

3) An operating voltage of primary power line should be low voltage.

4) A switch and an over-current circuit breaker should be installed in each pole of the primary power line (excluding neutral pole of a polyphase line in the over-current circuit breaker), however, the switch does not need to be installed if a function of open and close is incorporated in the over-current circuit breaker.

Section 4 Measurement Equipment

Article 244. General provision

In the event of the failure, to minimize the risk is important in order to ensure the safety.

In the normal condition, a thermal plant is controlled by control devices and monitored by operators. When abnormal condition occurs, an operator may take measures for alarms. Measurement equipment is necessary to notify the plant conditions to an operator, to control the plant, and to protect the plant. This concept is shown in Fig-21.

Thus, Article 244 of the design technical regulation is provided.

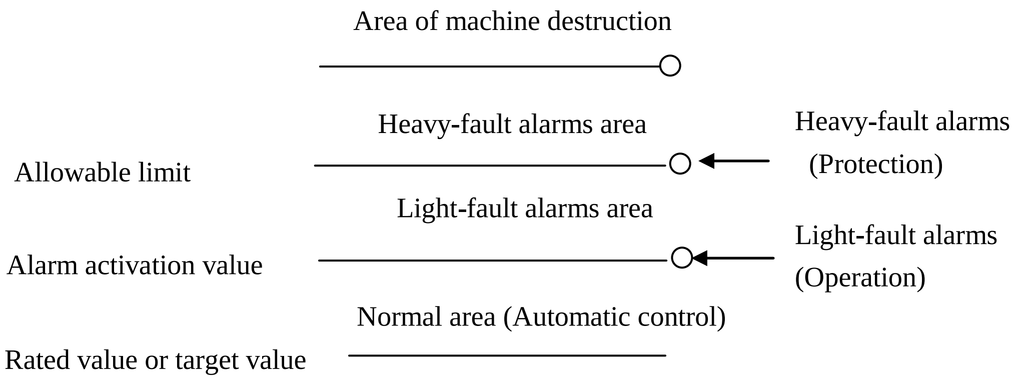


Fig- 21 Concept of operation, control and protection

The aim of this section is to specify necessity or desirable measuring or record list item as a measurement device for safe operation, facility maintenance, and condition monitoring. Moreover, except for the case which is defined legally or especially mentioned, it does not specify the plant location, the detection place, the detection methodology, the measurement duration, the instrument specification, the recording method, etc.

In addition, refer to "Article 258-1 SCADA/EMS system" for supervisory units.

The principle of selecting items is as follows:

1. What the technical regulations impose is taken as the mandatory list item.
2. Following items are taken as recommendations.

(1) Items required for security reservation

(2) Items required for stable operation of the main machines

(3) Items desirable for records in relation to security matter

(4) Items of effective reference in finding abnormal condition for stable operation of the main machines

(5) Items required for the performance management of the main machines

(6) Items desirable to record for the operation and its management

As for the measurement and control circuit, functional isolation of the circuit is necessary to prevent the wrong activation of the equipment caused by signal errors associated with the failures or wrong connection of measurement circuit. This is because the control circuit operates the equipment directly (such as circuit breaker operation), and measurement circuits supply the operation and control signals.

This functional isolation may be achieved by considering the interface between measurement and control circuit, such as designing interlock and circuit configuration and/or equipping redundant system.

Article 245. Measurement equipment for boiler

Article 245-1. Measurement equipment for boiler

1. General

Measurement items from 1 to 17 in Article 245 of the design technical regulation are essential to boiler security or protection and they should be monitored, and maintained within allowable or specified or designed value during the boiler operation.

These items from 1 to 17 are also recommended to be recorded because they are effective reference in finding abnormal condition for stable operation of the boilers, especially items from 1 to 8, 13, 16, and 17.

These measurement objectives are mainly, temperatures, pressures, and flow quantities, therefore their methods are explained later.

For the environmental protection instrumentation, sulfur oxide and nitrogen oxide concentrations must be measured and recorded continuously by the certificated analyzers which are calibrated periodically using certificated concentration gas according to QVCN.

Documents of these certifications are to prove the accuracy of the measured value; therefore, traceability to the international or national standard is needed.

In HRSG's case, sulfur oxide and nitrogen oxide concentrations do not need to be measured because there is no combustion at HRSG's and they have already been measured at the exhaust gas of gas turbines etc.

Followings are recommendations items of measurement equipment for boiler.

A: Circulation boiler

B: Once-through boiler

C: HRSG without supplementary fuel to exhaust gas and exhaust gas re-firing

D: Fluidized bed combustion boiler (FBC)

Table- 30 Measurement Equipment for Boiler (Recommendations)

№	Operating condition	Boiler type				Remarks
		A	B	C	D	
1	Boiler feed-water pressure	X	X	X	X	
2	Boiler feed-water temperature	X	X	X	X	
3	Super heater spray flow	X	X	X	X	
4	Re-heater spray flow	X	X	X	X	This is applied to boilers with re-heaters.
5	Burner atomization medium pressure	X	X	-	X	
6	Re-heater outlet steam pressure	X	X	-	X	This is applied to boilers with re-heaters.
7	Boiler outlet oxygen concentration	X	X	X	X	
8	Boiler water quality	X	X	X	X	PH, Silica, conductivity etc
9	Boiler feed-water quality	X	X	X	X	PH, Silica, conductivity etc
10	Air heater outlet gas temperature	X	X	-	X	This is applied to boilers with air heaters.
11	Air heater inlet gas temperature	X	X	-	X	This is applied to boilers with air heaters.
12	Air heater outlet air temperature	X	X	-	X	This is applied to boilers with air heaters.
13	Air heater inlet air temperature	X	X	-	X	This is applied to boilers with air heaters.
14	Air temperature	X	X	X	X	
15	Draft at the forced draft fan outlet	X	X	-	X	
16	Draft at forced draft fan outlet	X	X	-	X	
17	Draft at the wind box	X	X	-	X	
18	Draft at the boiler outlet	X	X	-	X	
19	Air heater inlet and outlet different pressure	X	X	-	X	This is applied to boilers with air heaters.
20	Draft at the induced draft fan outlet	X	X	-	X	This is applied to boilers with induced draft.
21	Draft at induced draft fan outlet	X	X	-	X	This is applied to boilers with induced draft.

2. Temperature measurement

In thermal power plants, temperatures measuring equipment is very important for safe and efficient operation, and exact maintenance.

In many cases, thermocouples are widely used because they have wide measurement rage and easy indication. A thermo resistance method is used for the object like the sea water or atmosphere temperature in which a temperature survey span will be 100 degrees or less, and the winding temperature of a generator or a transformer in which induced current may flow.

As for the thermometer in the filled system, temperature is measured as a deictic meter and a deictic controller of 300 degrees or less.

For temperature measurement, JIS Z8710 is referred.

(1) Thermocouple

Thermocouples are one pair of metal wires based on the Seebeck effect through which a thermoelectric current flows and which a thermoelectromotive force generates between two metals, when the both ends of two sorts of different metal wires (strand) are combined and the temperature of two events differs.

The size and the polarity of this thermoelectromotive force change with categories of the temperature difference and joint metal wire of an event.

A thermocouple is boiled by the configuration material of a metal wire, and is classified.

In thermal power plants, T(Copper/copper-nickel), J(Iron /copper-nickel),

E (Nickel-chromium/copper-nickel) and K (Nickel-chromium/nickel-aluminum) are used.

For maintenance or control efficiency, two or less kinds of thermocouples are chosen in the case of the same plant

Specifications in details are shown in JIS-C1602, or IEC 60584-1, and IEC 60584-2.

For compensating cables of thermocouples, JIS C 1610, or IEC 60584-3 are referred.

The thermoelectromotive-force output from a thermocouple is inputted into a temperature converter in the compensating lead wire which uses a thermocouple and a metal wire of the same kind, and changed into the signal level required for a control or a supervisory unit after cold junction compensation and linear correction.

Hereafter, the metal-sheathed thermocouple with a protector tube and the metal-sheathed thermocouple which are used in thermal plants are explained.

(2) A thermocouple with a protector tube

As for selecting material of a protector tube, it is common to choose the same material of the pipes to be measured.

Moreover, in the case of the exhaust gas and air temperature measurement, stainless steel is commonly used.

Since the resonance force, fluid pressure, etc. are applied, the protector tube of thermocouple requires sufficient strength for these forces.

The longer clearance between the protector tube and the metal-sheathed-thermocouple becomes, the more response time takes.

A response time can be brought forward by putting in temperature conduction medias (silver powder etc.) or reducing clearance.

When a response time is required, grounded type thermocouple is used for response time improvement, by contacting the thermocouple and the target for measurement directly. On the other hand, in the case of the system which receives an induced current, or has the possibility of explosion, the grounded type cannot be used.

Since there is no uniformity of temperature in a measurement fluidic when target for measurements are water or steam, the some insertion length of a thermocouple may be required.

In the case of air and an exhaust gas, since the temperature of a fluidic is uneven, insertion length to near the center of a duct is required with 3-4 thermocouples, and mean temperature is measured in many cases.

(3) A metal sheathed thermocouple

Since thermocouples for boiler wall are used under severe conditions, such as corrosive gas, the high temperature and vibration, its reliability is indispensable. A metal sheathed thermocouple is suited for these circumstances. The one of the end is a detection pad welded on the tube. The other end consists of the compensating lead wire for a splicing, and the compression approximation attaches it to the penetration part with a boiler casing part. Nickel-chromium/copper-nickel element is used in many cases.

Concerning thermocouples, JIS-C1605, IEC 60584-1, IEC 60584-2, IEC 60584-3 etc are referred.

(4) Electric resistance thermometer

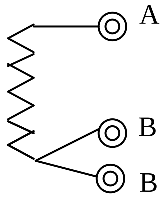
Temperature measurement using electric resistance thermometer applies the proportional change of electric resistance associated with temperature change.

Platinum is generally used because the electric-resistance alteration of platinum is linear as compared with other metals, its temperature coefficient is also large, it is chemically and physically stable more, and high purity is easy to be obtained also industrially. Three wire system or four wire system electric resistance thermometer whose nominal value is 100 ohm at 0 degree is generally used, and three wire system is widely used, while four wire system is used for accurate measurement.

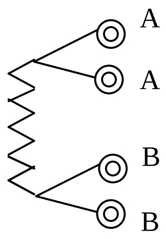
An electric resistance thermometer also has a metal-sheathed sensor with a protector tube, and a metal-sheathed resistance thermometer sensor, as well as a thermocouple .The electric resistance thermometer with a protector tube is used for the temperature of a air or fluidic, and the metal-sheathed electric resistance thermometer sensor is used for a winding measurement of a generator and a transformer.

An electric resistance thermometer shows higher accuracy in normal temperature range compared with thermocouples.

Concerning resistance thermometer sensors, JIS C 1604, IEC 60751 are referred.



Three wire system



Four wire system

Fig- 22 Resistance thermometer sensors

(5) Thermometers

As for filled thermometers, the liquid and the gas expansion type is generally used in thermal plants. A filled thermometer consists of a temperature sensing part, a capillary tube, and a Bourdon tube and indicates by using volume change of liquid or gas. This type requires ambient temperature correction.

Bimetal type, which uses expansion difference between the two metals, is also used in thermal plant due to the cost or no correction requirement associated with ambient temperature.

3. Pressure measurement

To measure pressure as electrical signal, there are strain-gauge type, electrostatic capacitance type, and electrostatic capacitance type.

(1) Strain gauge type pressure transmitter

At the strain-gauge installed at the measurement spot, pressure is detected as an alteration of the electric resistance which is a result of distortion caused by pressure alteration.

(2) Electrostatic capacitance type pressure transmitter

Pressure distorts the diaphragm and this distortion is measured as an alteration of the capacitance between the fixed electrode and the diaphragm whose gap is filled with liquid.

(3) Semiconductor type pressure transmitter

Pressure applied on the diaphragm is received by semiconductor sensors thorough filled water and measured as alteration of the electric resistance, using piezoresistive effect.

(4) Resonant frequency type pressure transmitter

The transmitter consists of the pressure-receiving unit with the oscillator and the transmission unit.

When pressure is applied on the diaphragm, the oscillator receives force and resonant frequency increases with tensile or decreases with compressive force.

This frequency is detected and transduced to electrical signal.

4. Flow measurement

Flow measurement system in thermal plants are difference pressure type, positive displacement type , area type, electromagnetic type, ultrasonic type, Karman-vortex type, mass type, etc.

(1) Differential pressure type flow meter

For process instrumentation, differential pressure type flow meters are used more broadly because they have simple architecture and handling, and are supported from still more reliable measurement data and standards.

The differential pressure type flow meter is used for the measuring of water, steam, and combustion air in the thermal plants.

If a When the fluidic flows in the reduction area , velocity of the fluidic which passes through the throttled point will be increased, and its pressure will decrease.

At this time, relationship between the flow velocity and pressure difference of reduction area is decided uniquely. The velocity is proportional to the square root of the pressure difference of the reduction area. Flow quantity can be measured by measuring difference pressure, in this way.

1) An orifice

The orifice meter has simple structure, which consists of a flat orifice plate with a circular hole.

Therefore, it is inexpensive and easy to manufacture with relatively precise measurement.

The orifice is fundamental restrictor and there are a corner taps, vena taps and flange taps.

A corner taps is a system which takes out the pressure difference immediately after just before an orifice plate, and even if the static pressure distribution is partial, it can take out the difference pressure averaged by the ring room.

The tap for the upstream side is located at a distance of approximately the pipe diameter and that for the downstream is located in a position of the lowest of pressure position. The structure can be the easiest.

A flange taps measures difference pressure from the defined place distant from the plate side 25 mm. This type is used for small pipes.

In thermal plants, an orifice is used for a low temperature and pressure measurement.

Corner taps are used for drain system and a low pressure auxiliary vapor system.

Since the diameter becomes large, the vena taps is used for measurement of fuel flow.

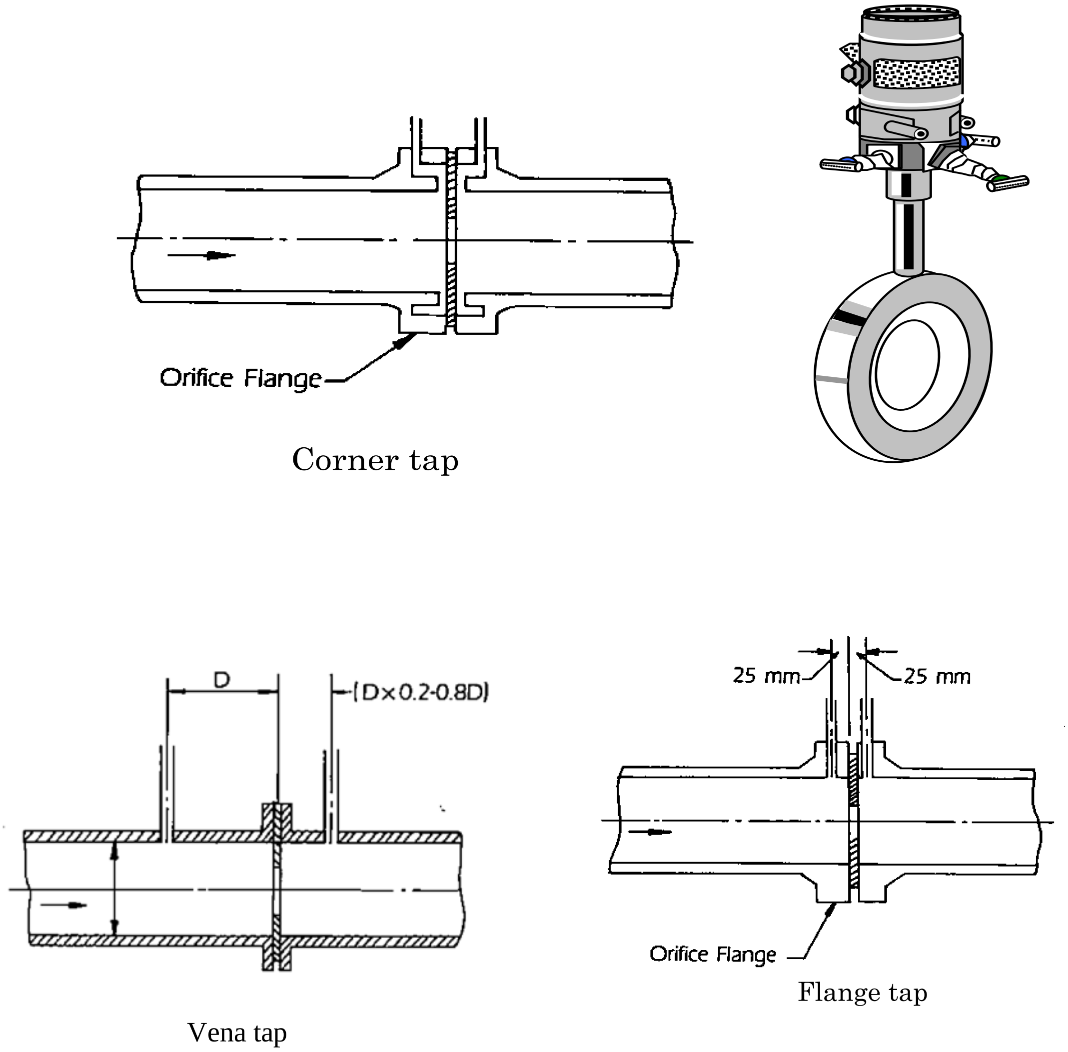


Fig- 23 Type of orifice

2) Flow nozzle

There are a quarter-circle nozzle, an ISA 1932 nozzle which was developed by the International Federation of the National Standardizing Associations (later succeeded by the International Organization for Standardization (ISO)), and a long radius nozzle in flow nozzles.

The quarter-circle nozzle is used for the object whose the numbers of lei nozzles is low.

The ISA 1932 nozzle and the long-radius nozzle are suitable for the fluidic measurement of the high temperature and the high pressure system due to their durability.

In a thermal-power-generation plant, a long-radius nozzle is used for a measurement of high pressure and high temperature feed water and main steam, or the high temperature auxiliary steam in many cases.

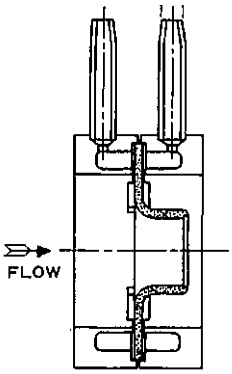


Fig- 24 ISA 1932 flow nozzle

3) The Venturi tube

The Venturi tube consists of a contraction pipe, a throat part, and an enlarging member, and there are a nozzle type and a cone type. The Venturi tubes are more expensive to construct than a simple orifice plate which uses the same principle as a tubular scheme. The greatest characteristic of the Venturi tube is that there is the least pressure loss in the restrictors.

In the thermal plants, the Venturi tube is used for air flow or exhaust gas flow measurement.

In using the restrictor, in order to reduce the error, it is required to take the direct length of the restrictor at upstream side and downstream side is required to be specified.

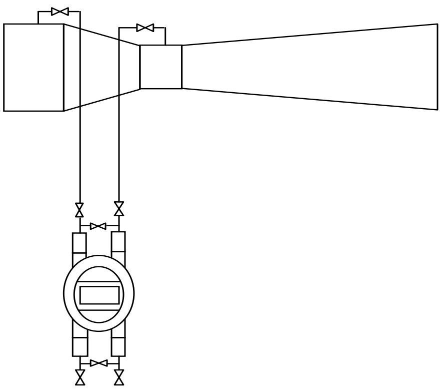


Fig- 25 The Venturi tube

4) Components of differential pressure type flow meters

The differential pressure type flow meter consists of a restrictor and the differential pressure transmitter.

When there is a volume-to-contain alteration of a measurement fluidic with temperature and pressure such as gaseous stream flow measurement, the specific gravity correction is required after temperature and pressure are measured.

The difference pressure generated in the restrictor is changed into electric information by the differential pressure transmitter.

Since difference pressure is proportional to the square of a stream flow, the flow signal which indicates a line to the flow can be acquired by square-root computing. This function is built in some transmitters. In using without this function, square-root computing unit is required.

As for the differential pressure transmitter, the two-wire-system electronic semiconductor system is used.

The unit computers etc. have been performing the static pressure properties correction in the supercritical once-through boiler in order to reduce the error of feed water flow meter associated with static pressure alteration.

By using the compound semiconductor transmitter which built in the static pressure sensor, it becomes an error below ±0.2% as the transmitter simplex, and the correction of static pressure has become unnecessary.

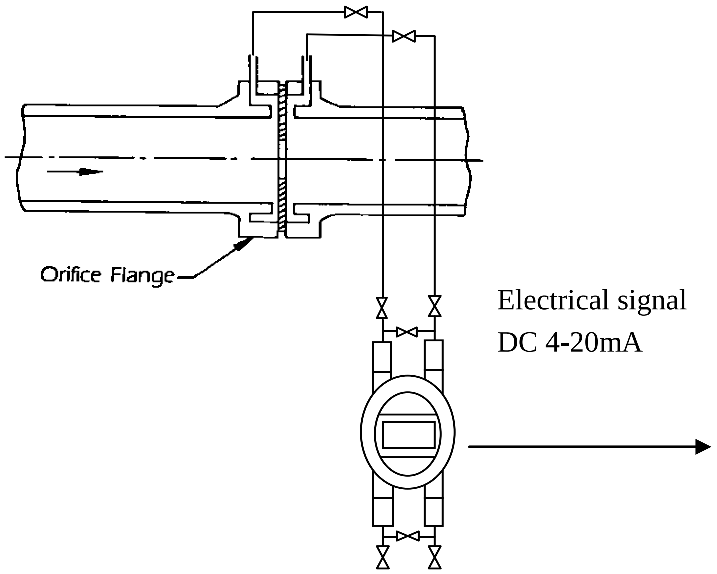


Fig- 26 Transmitter and restrictor

(2) Positive displacement-meters

A positive displacement meter measures flow quantity by counting the number of pushing out the fixed volume fluid moved with the difference pressure between fluidic inlet and outlet.

There are the elliptical toothed-gear type, oval gear type and root type.

They are used for measurement of the liquid fuel (crude or heavy oil, light oil) of a thermal-power-generation plant, or for measurement of a make-up-water flow in many cases.

Displacement meters have the characteristic of high accuracy which is almost ±0.2% at full scale, with little pressure loss.

It is important to notice followings in using positive displacement meters.

- To install vents is required because the air bubbles in a liquid cause error.

- To install filters is required because toothed gears are damaged by contaminants.

- When measuring many fuels by one meter, to correct errors is required because of error changes associated with the viscosities.

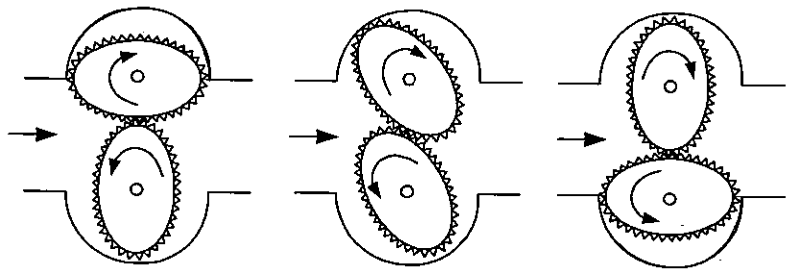


Fig- 27 Oval gear type meter

(3) Area type flow meters

An area type flow meter consists of a taper tube installed perpendicularly and of a float stored in the tube.

When a fluidic is passed upwards from the bottom, a flow is throttled by float and difference pressure generates before and after the float.

A float stands still in the place which rises in response to upward power with this difference pressure, and balances the effective weight of an operation part.

Since the area which the fluidic passed and the climbing length of the float have fixed relationship, flow is measured from the place of the float.

It is used for a measurement of the liquid fuel (crude or heavy oil, light oil) of thermal plants in many cases.

Area type flow meters have the characteristics that there is comparatively little requirement for direct part, there is little pressure loss and a measurement for the number of low lei nozzles is possible.

It is important to notice followings in using positive area meters.

- To install vents is required because the air bubbles in a liquid cause error.

- Perpendicular installation of the taper is required.

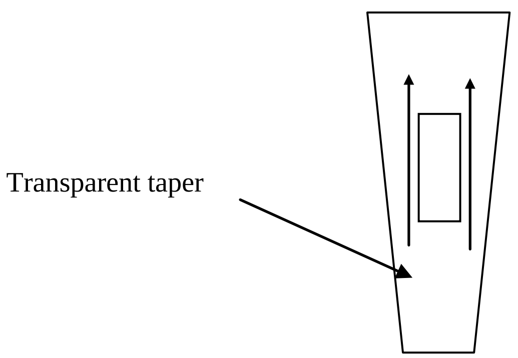


Fig- 28 Area type flow meter (Float type)

(4) Electromagnetic flow meters

Electromagnetic flow meters are often used for a slurry-like measurement in thermal power generation plants.

If electric conductive fluidic flows through the inside of the measurement pipe where magnetic field is applied to the flow direction, electromagnetic induction voltage which is proportional to the mean flow velocity of fluidic will be induced according to the theorem of Faraday's.

An electromagnetic flow meter has large measurement range compared with other flow meters, with no pressure loss.

As an important matter on an activity, it is required to select suitable electrode materials with the temperature and the pressure of a target fluidic and to select the proper diameter for precise measurement.

This type is suited for measurement of hydrochloric acid or sulfuric acid.

Concerning electromagnetic flow meters, JIS B 7554 is referred.

(5) Ultrasonic flow meter

Ultrasonic flow meters are used for a measurement of the sea water of the large diameter pipe in power generation plants in many cases.

Ultrasonic flow meters measure the difference of the transit time of ultrasonic signal propagating along and against flow direction. The fluid is measured without touching the liquid because the detector is clamped on the outer pipe wall. Thus, there is no risk of contamination or corrosion.

5. Concentration measurement

In order to prevent environmental pollution, exhaust gas concentration from a boiler or a gas turbine should be measured. Moreover, for higher boiler or gas turbine efficiency, operation with low excessive air is necessary.

O_2, CO analyzers are used for combustion monitor and control, NOx, SO_2 ,NH_3 analyzers are used as emission monitors in thermal power stations.

The analyzers consist of a sampling part which samples an exhaust gas, and an analysis part which analyzes the exhaust gas. It is important to keep exhaust gas component from melting into moisture by condensation of moisture, and also from being blocked by dust etc, therefore, it is necessary to heat the detection pipes and sampling probes continuously and purge sampling probes periodically.

Moreover, since the effect of the coexistence gas in the exhaust gas may generate error, it is required to reduce this effect as much as possible.

The exhaust gas is measured by inserting sampling probes in the boiler duct. Since the fluidic in the duct is uneven, it is desirable to install the probe made into insertion length of center of the duct, and also install about several probes to measure mean-value.

Hereafter, typical analyzers are explained.

(1) O_2 analyzer

There are a zirconia type, magnetic wind type, etc in O_2 analyzers.

For combustion control, zirconia types with direct insertion type are used overwhelmingly because there are various advantages that sampling equipment are not necessary, quick response time is acquired by inserting a sensor into an exhaust gas directly, and they also excel in maintenance.

If zirconia is heated by the high temperature, it will work as an electrolyte to oxygen ion, and will let only oxygen ion pass.

If electrodes are attached to both sides of this zirconia element, the electromotive force is generated by oxygen ion conduction. Oxygen concentration is measured by detecting this electromotive force.

The principle and configuration of the zirconia analyzers are shown in Fig-29.

The magnetic wind type is used for O_2 conversion of NOx analyzers.

The magnetic wind type is a system which applies that paramagnetism of oxygen is greater compared with the gas of others and its magnetization is decreased by the temperature rise.

Resistance change cooled by magnetic wind is detected using the bridge circuit.

In addition, O_2 concentration in combustion control is to be evaluated based on dry condition which does not contain moisture.

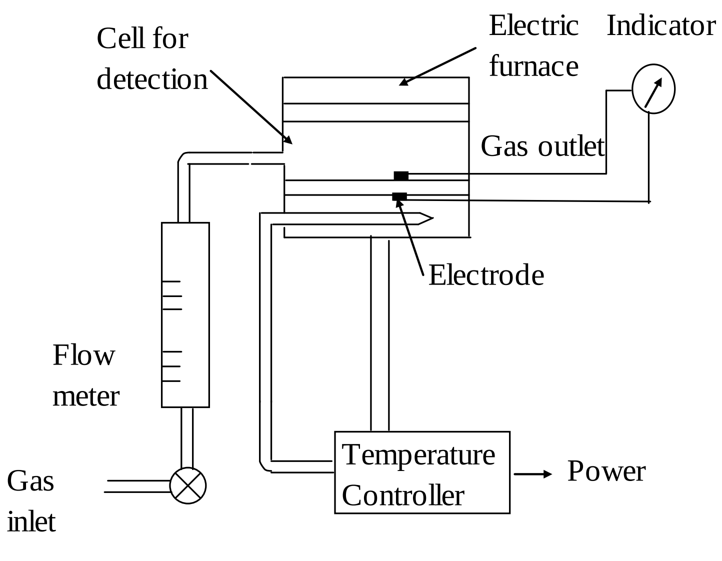


Fig- 29 Principle and configuration of the zirconia

(2) Infrared type analyzers (NOx, SO_2 CO analyzer)

NOx analyzers or SO_2 analyzers must be the certificated analyzers which are calibrated periodically using certificated concentration gas in order to prove accuracy.

For NOx analyzers, infrared type and chemiluminescence type are generally used.

Infrared type also can measure SO_2 and CO by changing wave length of infrared ray ,according to the gas.

The principle of infrared type is to detect the film movement caused by infrared ray absorption difference between detection cell and reference cell, using capacitor microphone.

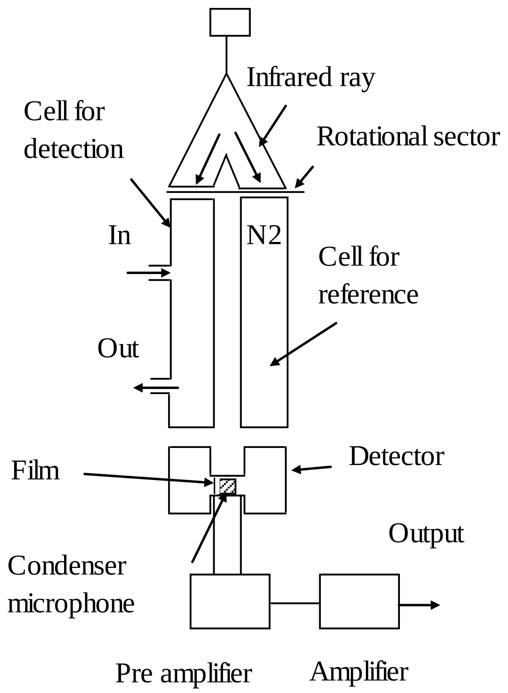


Fig- 30 Principle of the infrared analyzers

(3) Chemiluminescence type

The principle of chemiluminescence type is that O_2 reacts with NO which is transformed from NO_2 in the converter, and chemiluminescence reaction with the intensity of the light is detected.

Chemiluminescence type is also used for NH_3 analyzers. This is indirect measurement system which changes NH_3 into NO or NOx, and measures the difference of NOx in the exhaust gas.

The principle and configuration of chemiluminescence type is shown in Fig-31.

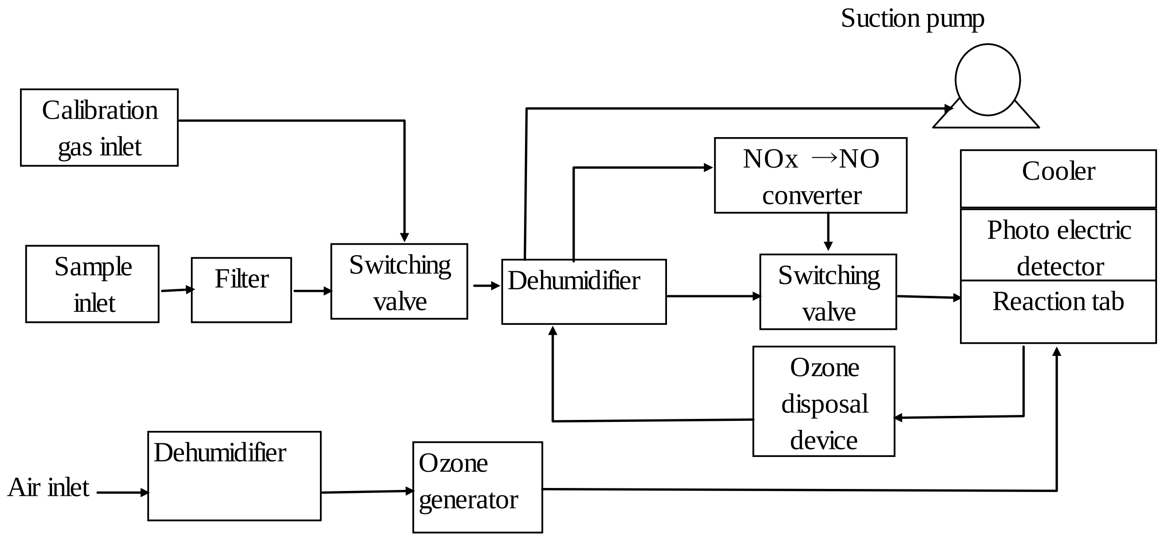


Fig- 31 Principle and configuration of chemiluminescence type analyzers

Article 245-2. Automatic unit controller for boiler

1. General

In the normal condition, a thermal plant is controlled by control devices and monitored by operators.

Items in this clause specify necessity or a desirable automatic-control list items as automatic controllers in order to maintain security and function to an operator and facilities, and do not specify the automation facility in connection with plant operation.

Even if an automatic controller is not based on a specific unit, the facility should just be automatically achieved by a certain method.

For example, if a certain unit achieves another function as a result while main function is achieved, it is not necessary to equip the control unit for the achievement of latter function.

Moreover, when the control is not achieved by the specific unit but synthetically achieved by a computer, it is not necessary to equip a unit for exclusive use.

In addition, the control function described here is general; therefore it is not necessarily to be depended on these items if it has the same function. Moreover, relevant control unit may be omitted according to the configuration of the plant or the characteristic.

Automatic controllers which are required for the stable operation and functional maintenance of main and auxiliary facilities were taken into the recommendation list items as automatic controller.

However, automatic controllers can be omitted in the case of 10,000 kW or less of outputs, as long as enough security is ensured.

Following systems are recommendations for automatic control systems.

2. Automatic control systems for conventional thermal power stations

Table- 31 Automatic control systems for Boiler (Recommendations)

№	Automatic control systems	Remarks
1	Automatic-start/stop control	This is applied when automatic start/stop control is required.
2	Unit total control	This is applied when the boiler and the turbine are required to be controlled totally.
3	Fast cut back operation control	This is applied when the unit is required to keep operation independent of the power system during outage.
4	Load run back operation control	This is applied when the unit is required to keep operation during the abnormal condition of main and auxiliary machines.

(1) Automatic-start/stop control-system

This system judges the timing of an actuation from the status of the plant at the time of start-up and shutdown, and controls by giving the operational command to the main and auxiliary machines, load set demand.

(2) Unit total control

Basic control concept for drum boiler and once-through boiler is as follows:

1) Drum Boiler

Main steam pressure deviation is adjusted by fuel flow control.

Main steam temperature deviation is adjusted by super-heater spray control.

Reheat steam temperature deviation is adjusted by gas recirculation or gas distribution control.

Drum water level deviation is adjusted by feed water flow control.

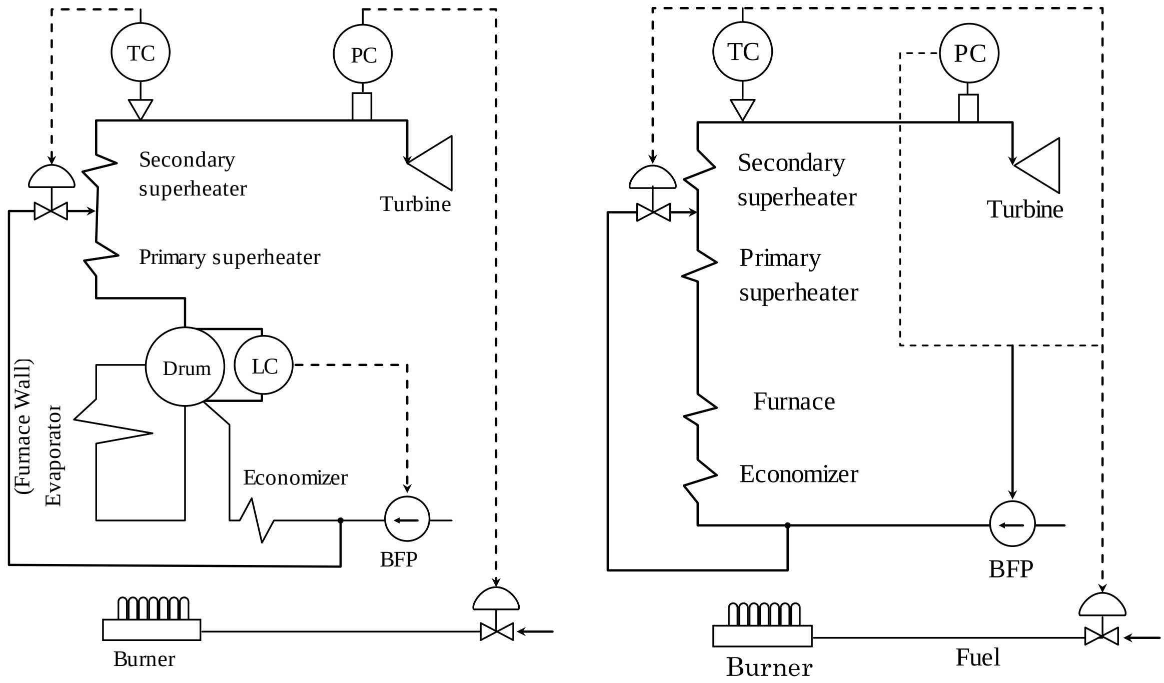
2) Once-through Boiler

Main steam pressure deviation is adjusted by fuel flow control and feed water flow control.

Main steam temperature deviation is adjusted by fuel flow control and super-heater spray control.

Reheat steam temperature deviation is adjusted by gas recirculation or gas distribution control.

By making the master command signal from the load demand, both boiler input and turbine governing valve are controlled in parallel.



(BFP: Boiler Feed- water Pump)

(TC: Temperature Control LC: Level Control PC: Pressure Control)

Drum Boiler Once-through Boiler

Fig- 32 Configuration of boiler control

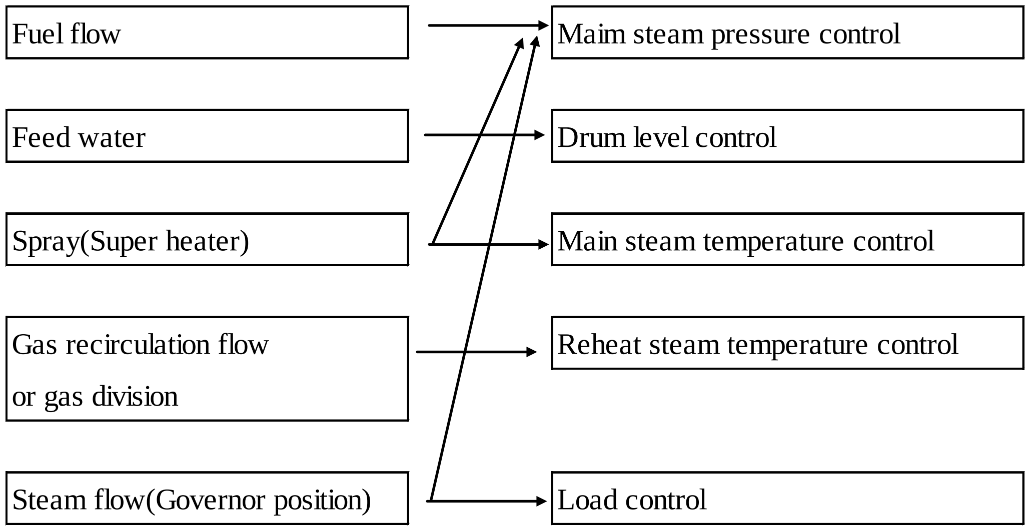


Fig- 33 Relationship between boiler control and process values (Drum boiler)

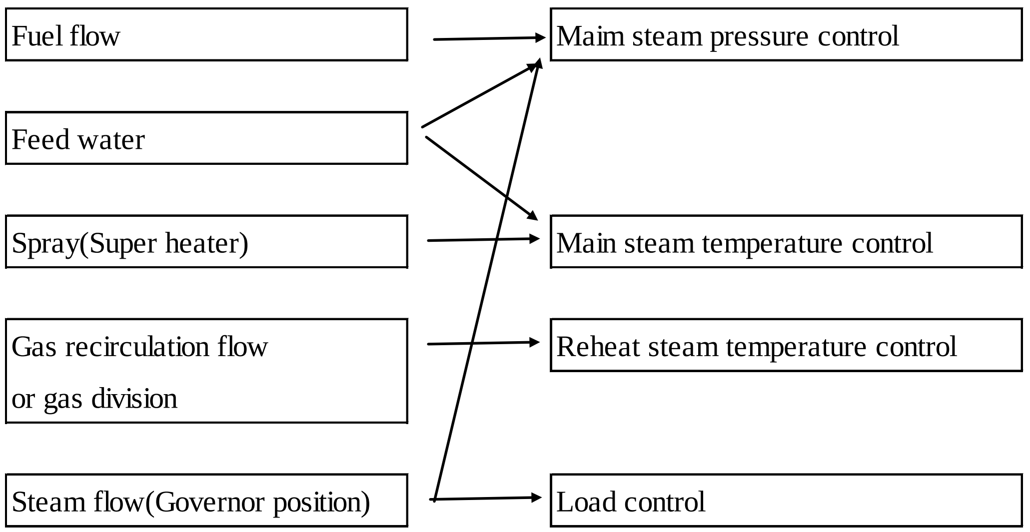


Fig- 34 Relationship between boiler control and process values (Once –through boiler)

Cooperative control, boiler follow control, and turbine follow control are the features of unit control methods.

a. Unit total control (Cooperative control)

   This control is suitable for supercritical once-through boiler unit control. Load is controlled by the turbine governor valve, boiler feed water, and boiler fuel. Main steam pressure is controlled by feed water.

Since the boiler load is changed by the load demand signal while the governor valve moves quickly within the stable limit of boiler in response to the load demand, higher capability for load change can be obtained.

b. Boiler follow control

This control is suitable for drum boiler unit control due to large heat capacity of the drum boiler.

Load is controlled by the turbine governor valve, and main steam pressure is controlled by boiler fuel.

Since the large energy storage of the boiler is utilized as an energy damper with the governor valve having quick response performance, the rising and falling characteristics of generator output to the demand is fast.

This enables AFC (Automatic Frequency Control) operation.

However, when the governor valve movement becomes too large to follow the load demand, the incoming and outgoing steam flow exceeds the allowable amount of storage energy of the boiler as a result, and the unit might fall into unstable condition due to mutual interference between generator output control and boiler control.

c. Turbine follow control

This control is suitable for mono-tube boiler unit control.

Load is controlled by boiler fuel and main steam pressure is controlled by the turbine governor valve. Because energy storage of the boiler is not utilized, the unit is operated under steady state condition in response to the load demand. Therefore, the unit operation is quite stable and movement to this control is recommended when the deviation of main steam pressure is too large during cooperative or boiler follow control.

However, since the generator output is controlled by boiler input, the load response is affected by boiler time constant. In addition, the intermediate and low pressure turbine output, which accounts for 70%of total output of turbine, is affected by the variation of reheat steam flow, so that the load change is delayed further. Therefore, AFC (Automatic Frequency Control operation is difficult actually.

It is very general to switch from “Cooperative control” to “Boiler follow” when the turbine is not automatic, and to switch from “Cooperative control” to “Turbine follow” when the boiler is not automatic.

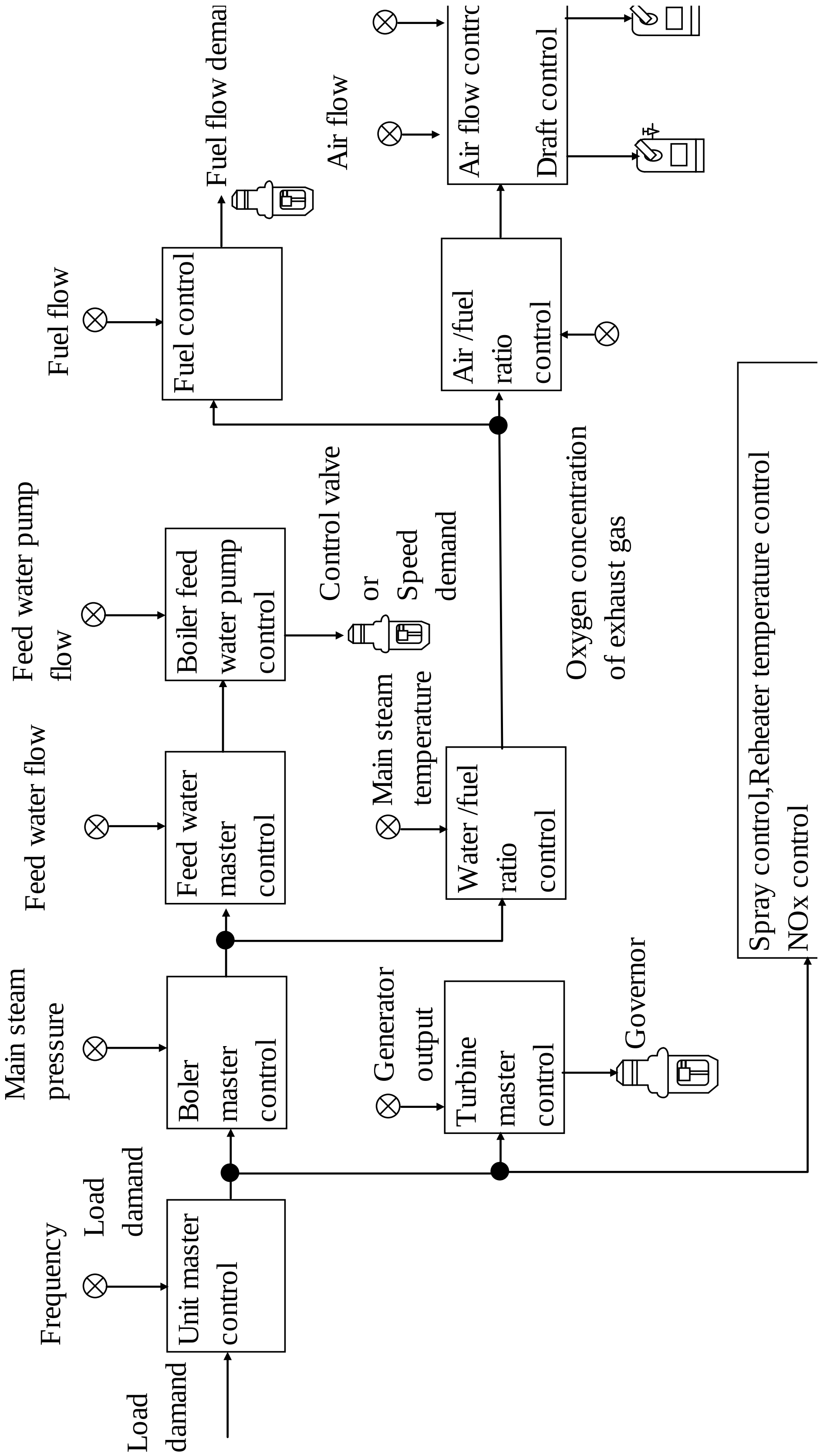


Fig- 35 An example of Automatic Plant Control (abstract)

(3) Fast cut back operation control

During outage, the load of the generator decreases rapidly or may be lost. However, in order to recover the grid system, some power stations may be required to keep operation by reducing the generator load to auxiliary power or no load. This is called “fast cut back operation control system”.

The units with this control function are able to operate in the load of no load or auxiliary power and also may be able to operate the boiler alone during the turbine trip. Therefore, this function contributes to the stable grid system operation by preparing for next parallel in.

In addition, since pulverized coal firing has an operational problem during low load concerning the boiler combustion and a mill operation, system which can enable stable operation of the boiler such as turbine bypass system is generally adopted.

In installing fast cut back operation control system, following points are taken into consideration.

1) Quick reduction of fuels and stable combustion

In the case of boilers with re-heaters, if condition shifts into independent or boiler isolated operation, steam will not flow into the re-heater, therefore the amount of fuels is required to be decreased quickly in order to prevent burning of the re-heater.

Moreover, in the case of a liquid or a gaseous fuel burner, proper burner supply pressure is to be maintained and in order to secure stable combustion, a burner is promptly extinguished one by one to the specified number.

Corresponding to the decrease of fuel, air flow is also reduced to specified air quantity.

However, this is not applied if the boiler has a re-heater cooling system.

2) Prevention of main steam pressure abnormal rise

If the load is cut suddenly, main steam pressure rises rapidly by the turbine governing valve will be narrowed down quickly, and since the heat capacity of the boiler is large, main steam pressure temperature rises.

To prevent this pressure sudden rise, turbine bypass valves and power control valves are actuated.

3) Feed-water flow control

For circulation boilers, basically, feed-water flow is reduced according to the boiler load. However, feed-water flow may be increased temporarily according to the drum level, because the drum level may descend rapidly after fast cut back control.

For once-through boilers, in order to prevent the abnormal rise of the main steam pressure by the too much water supply, feed-water flow is reduced quickly, securing the minimum flow.

(4) Load run back operation control

When some main or auxiliary machines become not ready to use, load-run-back-operation control-system, which reduce unit output of stable operation for the purpose of continuing operation, may be activated.

Generally at the time of load run-back operation, the load is controlled by the method of lowering load equivalent to the target by the designated rate.

Although the followings are mentioned as examples of load-run-back-operation factors, the load-run-back-operation control system itself may not be applied, considering the effect on the facilities for combustion during the run-back operation.

1) Trip of induced-draft-fan or forced draft fan

Since the forced or induced draft fans do not have stand-by machines in general, it becomes impossible to supply an equivalent amount of air for combustion to the normal state, or to discharge combustion gas.

Therefore, the load run-back operation is activated by trip of induced-draft-fan or forced draft fan.

2) Trip of boiler feed water pump

Water supply to the boiler will decrease rapidly if one out of two or more boiler-feed water-pumps trips.

Therefore, the load run-back operation is activated by trip of boiler feed water pump.

3) Trip of mills

In the case of pulverized-coal-firing boilers, the amount of fuels to the boiler will decrease rapidly if one out of two or more mills trip.

Therefore, the load run-back operation is activated by trip of a mill.

4) Trip of primary air fan

In the case of pulverized-coal-firing boilers, two primary air fans and two or more mills may be combined. In this system, capacity of supplying pulverized coal will decrease rapidly if one of the primary air fans trips during two or more operation.

Therefore, the load run-back operation is activated by trip of a primary air fan.

5) Trip of stator cooling-water facility

If the cooling facility of stator cooling loses, the load run-back operation is activated to the load the generator operates without stator cooling-water.

6) Restriction during transmission-system failure

When the capacity of transmitting electricity is restricted by the outage, the generator output is limited to the transmitting capacity.

7) Others

A load-run-back-operation control may also be activated if other main auxiliaries, such as, a gas recirculating fan, a gas mixing fan, a condensate pump, and a condensate booster pump, trip.

3. Automatic control devices for conventional thermal power stations

It is desirable to install following control devices.

A: Circulation boiler

B: Once-through boiler

C: HRSG without supplementary fuel to exhaust gas and exhaust gas re-firing

D: Fluidized bed combustion boiler (FBC)

Table- 32 Automatic control devices for Boiler (Recommendations)

№	Automatic control devices	Boiler type				Remarks
		A	B	C	D	
1	Feed-water control	X	X	X	X	
2	Combustion control	X	X	X	X	Air rich control is included.
3	Super-heater outlet steam temperature control	X	X	X	X	This is applied to boilers with super-heaters whose outlet steam temperature should be maintained.
4	Re-heater outlet steam temperature control	X	X	X	X	This is applied to boilers with re-heaters.
5	Furnace draft control	X	X	-	X	This is applied to boilers with induced draft fans.
6	Starting bypass control, turbine bypass control	X				This is applied to boilers installed turbine bypass system or starting bypass system
7	Feed water pump recirculation control	X				This is applied to the case feed water pump recirculation control is necessary.
8	Fuel oil temperature control	X		-		This is applied to boilers which require oil temperature control.
9	Fuel pressure control	X		-		This is applied to boilers which require oil temperature control.
10	Fuel burner atomizing medium pressure control	X		-		This is applied to boilers which require atomizing medium pressure control.
11	Mill air temperature control	X		-		This is applied to pulverized-coal-firing boilers.
12	Mill air flow control	X		-		This is applied to pulverized-coal-firing boilers.

№	Automatic control devices	Boiler type				Remarks
		A	B	C	D	
13	Wind box/furnace difference pressure control	X		-		This is applied to boilers which require box/furnace difference pressure control by transmitting excessive air during the load less than boiler minimum air flow.
14	O_2control	X		-		This is applied to boilers which require excessive air control.
15	Cross limit control	X	X	-	X	This is applied to adjust the unbalance between fuels, feed-water, and air.
16	Combustion control	-	-	-	X	This is applied to fluidized bed combustion boilers which require ratio control between fuel and air.
17	Hot stove combustion control	-	-	-	X	This is applied to fluidized bed combustion boilers equipped with a hot stove.
18	Combustion control of cells	-	-	-	X	This is applied when the load is adjusted by the number of cells
19	Fluidized bed temperature control	-	-	-	X	-
20	Fluidized bed level control	-	-	-	X	-

The main control devices in steam power plants are explained as follows:

(1) Feed water control

This control is a control which maintains the weight valance of the steam flow which flows out from a boiler, and the feed-water steam flow supplied to a boiler, and maintains the magnetic drum storage or the water-separator water level at the rated value.

Or a control which adjusts water supply (simultaneously the amount of fuels, an air quantity, and the amount of steams), and also maintains all or either of the generator output, steam pressure and main steam temperature at the rated value by the demand output of the unit.

(2) Combustion control

This control is a control which is for adjusting the amount of fuels and air quantity which are supplied to a boiler, and for maintaining main steam pressure at the rated value, according to the stream flow from a boiler.

Or a control which adjusts the amount of fuels, and the air quantity (simultaneously water supply and the amount of steams), and maintains all or either of generator output, the main steam pressure and main steam temperature at the rated value by the demand output of the unit.

An air precedence control is a control which precedes air prior to the fuel in the transient states during the load change in order to prevent shortage of air, etc. This control makes air quantity increase prior to the fuel during load increase, and decreases the amount of fuels, so that the air quantity for combustion always does not run short.

Generally it is called air rich control, and installed in order to maintain the continuous stability of combustion.

(3) Super-heater outlet steam temperature control

This control is a control which maintains main steam temperature at the rated value by adjusting the ratio of the water supply to a boiler, and the amount of fuels, or adjusting the amount of sprays to the super-heater.

(4) Re-heater outlet steam temperature control

This control is a control which adjusts the amounts of heat conductions to the re-heater (the amount of gas recycling, the amount of gas splitting, etc.), or the amount of sprays to the re-heater, and maintains reheat steam temperature at the rated value.

(5) Furnace draft control

This control is a control which adjusts the amount of combustion gas discharged from a boiler and maintains the pressure in a furnace at the rated value by induced draft fans.

(6) Starting bypass control, turbine bypass control

This control is a control which leads the steam to the condenser, using the facility which bypasses the part or all of the boiler and the turbine, in case of start-up control to the predetermined load, or rapid load cutting down in order to obtain steam whose pressure and temperature is suitable for the steam turbine.

(7) Feed water pump recirculation control

This control is a control which adjusts feed-water-pump flow rate by recirculation valve control.

(8) Fuel oil temperature control

This control is a control which adjusts the amounts of heating, such as steam, in order to make the viscosity suitable for the combustion, and maintains the temperature of fuel oil when fuel with viscosity is used.

(9) Fuel oil pressure control

This control is a control which adjusts pressure at the rated value by installing a fuel pressure control valve in addition to a flow control valve when high pressure of fuel is required to be reduced or outlet pressure of a displacement fuel oil pump is required to be maintained.

(10) Fuel burner atomizing medium pressure control

This control is a control which l which adjusts the injection media pressure at the rated value due to the injection amount.

(11) Mill air temperature control

This is a control which adjusts the amount of inflow of the cold air and heat air to a mill, and maintains the air temperature of the mill at the rated value in order to obtain pulverized coal firing.

(12) Mill air flow control

This is a control which adjusts air flow to a mill to the proper value corresponding to the amount of boiler inputs, or the amount of coal so that transportation air required for pulverized coal stable firing is obtained.

(13) Wind box/furnace difference pressure control

This control is applied to boilers which require box/furnace difference pressure control by transmitting excessive air during the load less than boiler minimum air flow.

(14) O_2control

This is a control which adjusts O_2 at the specified values for the purpose of O_2 controls, with low excessive air.

(15) Cross limit control

Cross limit control is a limiting control for maintaining the valance, when unbalance arises among feed water, fuel flow, and air flow due to a bad condition of the auxiliary, or the control.

This control is a protecting activation which adjusts each manipulated variable to the safety side and within allowable value automatically in order to maintain safe valance of combustion.

Following activations are general.

1) Amount of combustion (fuel, air) demand decrease activation due to feed water decrease to prevent high steam temperature or high steam pressure

2) Feed water demand decrease activation due to amount of combustion (fuel, air) decrease in the case of drum boilers(referred to **Note1*) to maintain steam temperature or steam pressure

3) Fuels flow demand decrease activation due to air flow decrease to prevent high steam temperature or high steam pressure

4) Feed water demand increase activation due to fuel flow increase to prevent high steam temperature

5) Air flow demand increase activation due to fuel flow increase to prevent explosion

   In many cases, items of 3) 5) are used as an air rich control in the combustion control.

   **Note1:*

   - *For once through boilers, feed water is not reduced generally for protection of boilers.*
   - *Air flow demand decrease activation is not applied generally because excessive0_2 is not dangerous for a boiler.*

- *Fuels flow demand increase activation is not applied generally because excessive fuel is dangerous for a boiler.*

(16) Hot stove combustion control

This is a control which adjusts the combustion by the fuels for start-up (light oil etc.),until it becomes more than an ignition point of main fuel (coal etc.). A hot blast stove will stop after reaching both the main fuel ignition points and spontaneous combustion of bed material.

(17) Combustion control of cells

This is a control which adjusts the fuel flow, or evaporation because the inside of the fluidized bed is divided into two or more cells, and fuel flow (the amount of coal)can be controlled by the number of the cell.

(18) Fluidized bed temperature control

This is a control which adjusts the fuel flow to maintain fluidized bed temperature.

In addition, in the case of a circulating fluidized bed system, it is common to select from the following system according to specification, such as an external regenerator to apply.

1) Adjust the percentage of the bed material between the low temperature which performed the heat recovery through the external regenerator, and the bed material in the hot state, in the process which the bed material collected by the cyclone separator is again circulated to a combustor.

2) Adjust the air distribution supplied to the combustor.

(19) Fluidized bed level control

In the case of the circulating fluidized bed system, normal circulation of bed material is maintained by maintaining fluidized-bed difference pressure within fixed limits. Difference pressure is controlled within fixed limits by throwing or extracting bed material.

Article 246. Measurement equipment for steam turbine

Article 246-1. Measurement equipment for steam turbine

1. General

The following instruments required in Article 246 of the design technical regulation are employed to monitor operating conditions during start-up, normal operation and shutdown.

2. Mandatory instruments to be measured

(1) Turbine speed

Turbine speed is required to be measured to control the turbine speed because over-speed is one of the most dangerous conditions that can occur in a turbine.

Speed is a measurement of shaft rotation per minute. During start up, speed is an important measurement because it indicates the operator when to notice for rotor critical frequencies, holding the speed stable during heat soak and for generators to accurately match the synchronous frequency before connecting to the power grid.

Therefore, speed indication at the control panel is recommended to be equipped for start up and shut down operation.

For measurement, electromagnetic pick-ups are generally used.

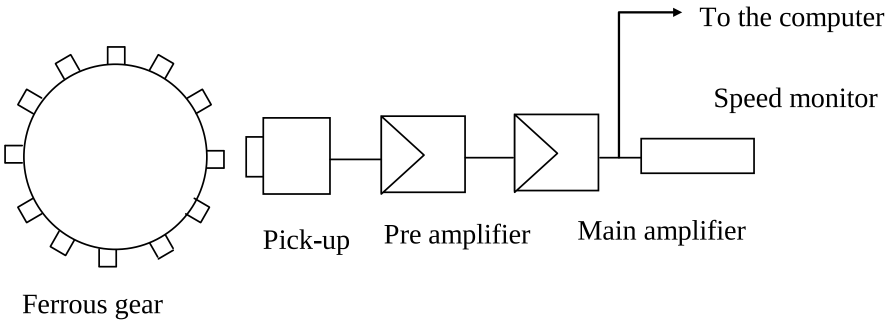


Fig- 36 An example of a turbine speed measurement

(2) Main steam pressure

(3) Reheat steam pressure

(4) Main steam temperature

(5) Reheat steam temperature

From (2) to (5) items are required to be measured due to following reasons.

- These items are critical to turbine protection and used to the management of turbine operating hours according to the designed conditions for operation.
- Main steam pressure before the main stop valve is controlled at the designated value by the turbine governor.

(6) Exhaust steam pressure of turbine

This item is measured because last stage turbine blades are stressed by exhaust steam pressure which may be approximately equal to the condenser vacuum.

(7) Lubricant oil inlet pressure at bearing

This item is installed to prevent bearing deterioration by heat.

(8) Metal temperature of bearing or lubricant oil outlet temperature at bearing

When bearing inlet temperature is not adjusted properly, the viscosity of bearing oil is not kept properly and there is a risk of causing the steam turbine vibration or bearing deterioration.

For this reason, measuring of bearing inlet temperature is essential.

This is measured by thermocouples or resistance thermometers.

If bearing temperature is measured directly, it can be supervised more promptly, and operation for the bearing temperature change can be more prompt than measuring of bearing outlet oil temperature.

(9) Governor valve position

Valve position is required to be measured to provide information of the current turbine load. It is provided in the form of a percentage, 0%, correlates to a valve closed and 100% correlates to a valve open. The potentiometer type sensor or differential transformer is generally used.

The potentiometers are voltage dividers with three terminations and two of them are connected to the ends of a resistive element and one is connected to a moving contact.

The differential transformer consists of the primary coil, the secondary coil and core. Its output can be obtained as secondary coil voltage caused by core movement.

(10) Amplitude of vibration

According to Article 246 and 247, the turbine and the generator vibration are required to be measured for protection. A vibration measuring device in the case the rated output exceeds 10,000 kW, or a vibration measuring device which records automatically (the record by electronic media is included) in the case the rated output is not less than 400,000 kW, must be equipped.

In addition, it is also recommended to install the unit recorder for the importance of vibration monitoring when rated output is less than 400,000 kW.

Vibration measurement is nearly always in terms of velocity or displacement and can be obtained by integrating output of accelerometer or a velocity detector.

The electro dynamic velocity sensors with velocity transducer is simple and easy to fit to a turbine but has limited frequency range and phase response because of magnet supported on a soft spring suspension system.

On the other hand, the accelerometers have wide frequency range, but require more careful installation due to the direct contact on the rotor. If velocity or amplitude data are required, the acceleration data can be integrated (velocity) or double integrated (amplitude). Some accelerometer signal conditioners have built-in integrators for that purpose.

Because of vibration frequency range, accelerometer may be widely used especially for gas turbines.

(11) Condenser vacuum, condenser level

These items are measured for turbine and condenser protection.

3. Recommended instruments to be measured

Following instruments are recommendations to be measured.

Table- 33 Measurement Equipment for steam turbine (Recommendations)

№	Operating condition	Remarks
1	Case expansion	
2	Shaft position	
3	Differential expansion	
4	Rotor eccentricity	
5	Phase or phase angle	
6	Turbine casing metal temperature	
7	Gland steam pressure	
8	Control oil pressure	
9	Exhaust steam temperature of the turbine	
10	Extraction pressures and temperatures	
11	Temperatures and pressures at high and middle pressure casing outlet	

Followings are details of recommendations.

(1) Case expansion

Steam temperature varies greatly between startup, operation, and shutdown.

Case expansion is a measurement of how much the turbine's case expands from its fixed point outward as it is heated.

As a unit is taken from its cold condition to its hot and loaded state, the thermal changes in the casings will be expanded.

The Casing expansion scale measures the movement relative to a fixed point such as a foundation. It indicates expansion and contraction of the casings during starting and stopping period, and for changes in load, steam temperatures.

The potentiometer type sensor or differential transformer is generally used as the case expansion meter.

(2) Shaft position

This item is recommended because in order to supervise abnormal condition for the turbine security, such as bearing wear, the relative axis from the pedestal to the thrust collar of the thrust bearing is important.

A shaft position meter measures the relative axial position of the turbine rotor with respect to the fix point. Wear on the thrust bearings or pressure difference associated with load change results in an axial movement of the turbine rotor. When axial movement exceeds the certain value, the turbine will be deteriorated by the contact between stationary part and moving blades.

Shaft position is measured by detecting the inductance change between the shaft and the oscillating coil.

(3) Differential expansion

When steam is admitted to a turbine, both the rotating parts and the casings will expand. Because of its smaller mass, the rotor will heat faster and therefore expand faster than the casings.

Axial clearances between the rotating and the stationary parts are provided to allow for differential expansion in the turbine, but contact between the rotating and stationary parts may occur if the allowable differential expansion limits are exceeded. The purpose of the differential expansion meter is to chart the relative motion of the rotating and stationary parts. It gives a continuous indication of the axial clearance while the turbine is in operation.

As the rotating and stationary parts become equally heated after a transient condition, the differential expansion will decrease.

(4) Rotor eccentricity

When a turbine has been shut down, the rotor will tend to bow due to uneven cooling if the upper half of the casing enclosing the rotor is at a higher temperature than the lower half. By rotating the rotor slowly on turning gear, the rotor will be subjected to more uniform temperature, thereby minimizing bowing.

Measurement method is the same as the shaft position meter.

(5) Phase or phase angle

Phase is a measure of the relationship of how one vibration signal relates to another vibration signal and is commonly used to calculate the placement of a balance weight. This parameter is monitored periodically to determine changes in the rotor balance condition. Phase angle measurements can be installed using an eddy current probe system.

(6) Turbine casing metal temperature

This item is recommended because thermal stress can be reduced by safe start up supervising the temperature , temperature difference and heat stress of main valve and casing metal, and also because water induction is supervised by a turbine casing up and down half metal temperature difference .

(7) Gland steam pressure

When gland steam pressure is not adjusted properly, maintaining gland seal of the steam turbine normally becomes impossible, and there is a risk such as air suction from the gland.

For this reason, the measuring of gland steam pressure is a recommendation item.

(8) Control oil pressure

Decrease of control oil pressure may cause turbine speed control failure because governing valve is actuated by hydraulic system.

Moreover, if oil leak from hydraulic system occurs, fire may be caused.

For this reason, the measuring of control oil pressure is a recommendation item.

(9) Exhaust steam temperature of the turbine

This item is recommended to protect the low pressure exhaust room using the spray.

Low pressure exhaust room temperature may rise when turbine load is none or light due to the windage loss of the turbine.

(10) Extraction pressures and temperatures

These items are recommended because they are required for the performance management of the steam turbines, and as for back pressure turbines, these items are the objective of control.

(11) Temperatures and pressures at high and middle pressure casing outlet

This item is recommended for casing protection by checking the steam temperatures and pressures within the allowable value of design during operation.

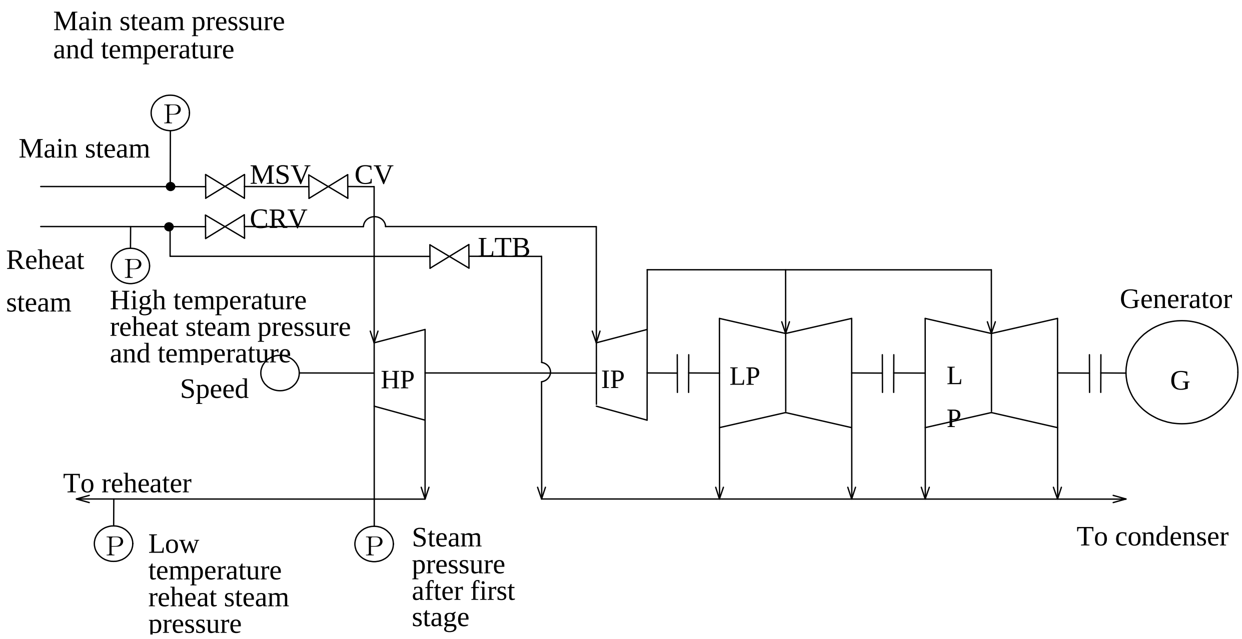


Fig- 37 An example configuration of control valves and sensors

The meters of speed, shaft position, differential expansion, expansion, rotor eccentricity vibration, valve position, and metal temperature, etc are called turbine supervisory instruments.

They are shown in Fig-37 and Fig-38.

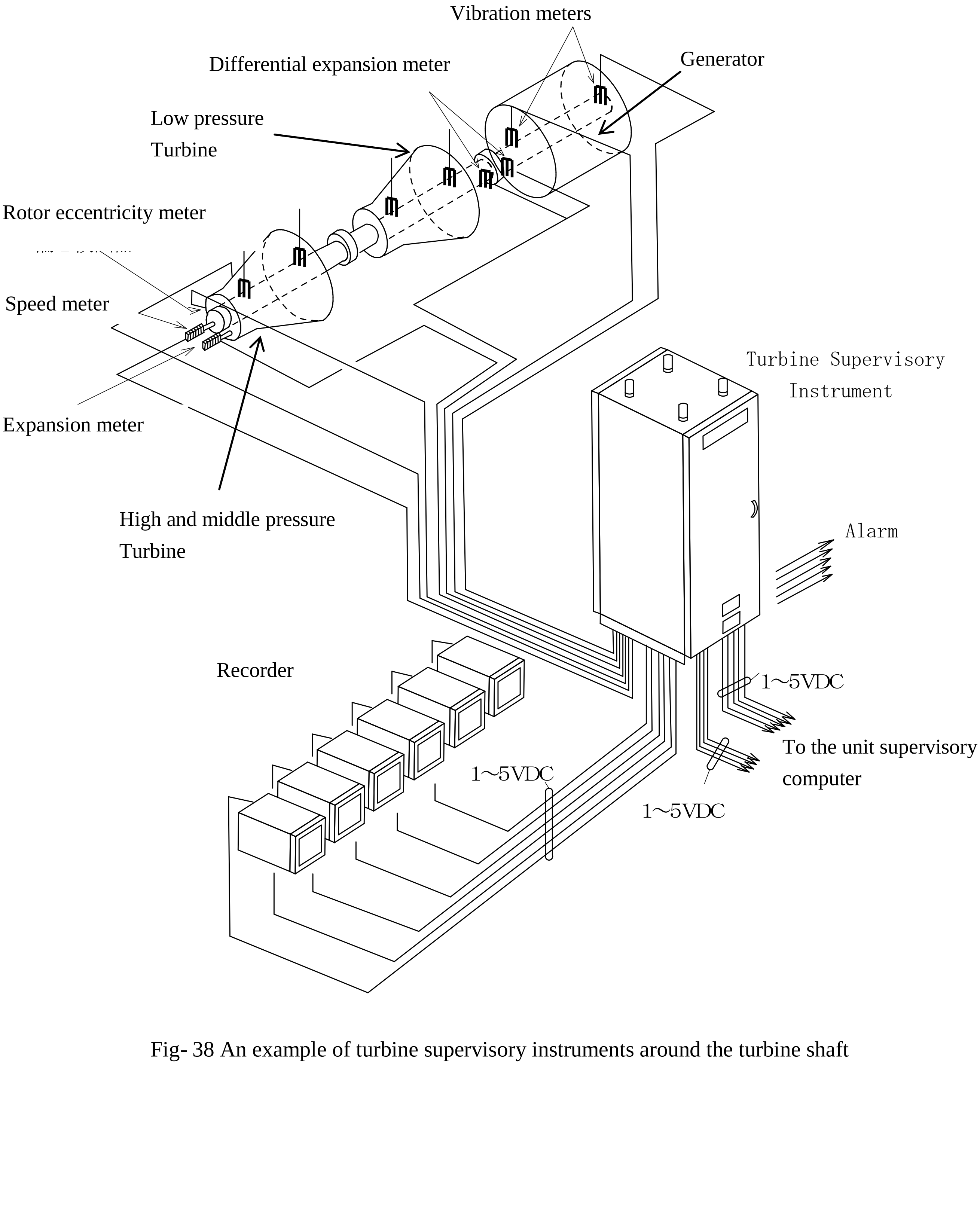


Fig- 38 An example of turbine supervisory instruments around the turbine shaft

Article 246-2. Automatic controller for steam turbine

1. EHC (Electric Hydraulic Control)

   Article 32 of the technical regulation requires that turbine speed and load must be controlled for security and safety .This means the rotating speed and steam turbine output load fluctuation should be prevented by adjusting the amount of steam which flows into a steam turbine other than the steam turbine combined with an induction generator.

   Therefore, high speed processing is required to the processor of EHC.

   Moreover, this control device should have the ability to reduce the rotation speed and reduce the rated load below the emergency governor speed.

   There are two types of control for turbines, one is electric hydraulic control and the other is mechanical hydraulic control. EHC is widely used for its quick and functional characteristics.

   EHC consists of a processing units for controlling valves such as governing valves and the intercept valve (ICV), turbine bypass valves , main steam stop valves (MSV) and of safety device parts carrying out turbine trip automatically by detecting the abnormal condition.

   Control operation part is classified into a speed control, load control, and valve position control as shown in Fig-34.

   Speed control function calculates the speed deviation signal using the speed signal which is detected at the speed meter, speed setting value, and speed rate setting value, and outputs the result to the load control.

   The speed deviation signal inputted into the load control is transformed to steam flow order signal according to the load control signal limited by the governor or load limiter, and the result is outputted to the main stop valve (MSV) ,governing valves (CV) , and the intercept valve (ICV).

   High temperature reheat steam pressure control function calculates and outputs low pressure turbine bypass valve (LTB) steam flow order induced from the deviation of the pressure between set point decided by the load, and reheat steam pressure.

   As for valve position control, deviation signal between position order from the load control part and the real valve position is calculated, and the servo current for adjusting valve position is outputted for each valve.

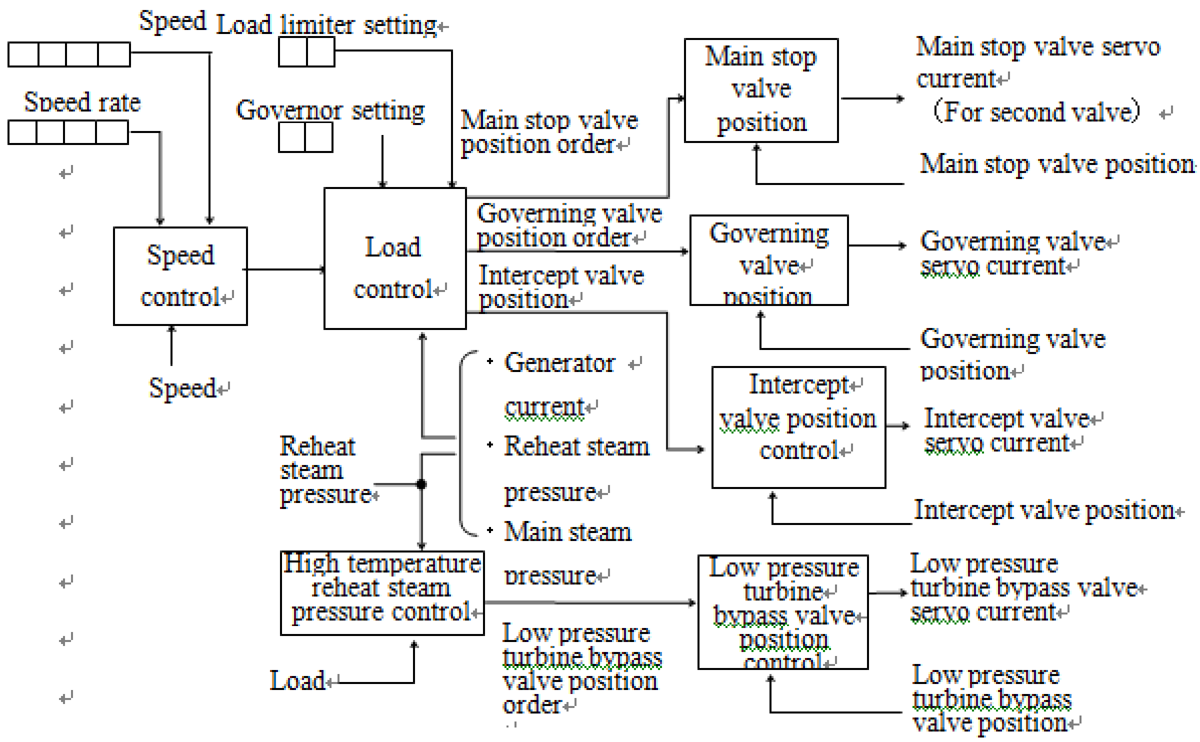


Fig- 39 An example of Electric Hydraulic Control flow

Table- 34 Examples of EHC control function

№	function	contents
1	Speed governing	This is a turbine governor's most fundamental function. The turbine output load is changed by the deviation of the rated and real speed according to the permanent speed variation.
2	Speed up control	Turbine speed up control generates speed up order value from target speed setting and the rate set of a speed up, and adjusts CV opening with the deviation of this order value and measured speed. The target speed and target acceleration are set at the main turbine EHC control panel or the unit computer.(during unit start up)
3	Load control	By the governor or the load limiter control, the turbine load is controlled to the target load at the load change rate smoothly.
4	Load restriction	A turbine output load can be restricted aside from the load control function and speed governing function. The automatic follow-up control of governor and load limiter is possible.
5	Governor and load limiter mode switching	The load limiter control from a governor control or its reverse changeover control is possible.
6	Auto synchronization	After a turbine reaches the rated speed, the turbine speed is raised slightly higher than the system frequency in response to the parallel in signal in order to protecting the turbine.
7	Nonlinear compensation between a valve position and stream flow	The relationship between the lift of a control valve and stream flow is compensated and linearized.

№	function	contents
8	CV mode changeover (FA/PA switching)	Operation between the full arc admission which can heat thick metal part equally and the partial arc admission which rises partial load efficiency can be switched automatically.
9	CV warming	The governing valve is warmed by opening and closing the secondary valve.
10	Valve test	Valve can be tested during operation. In addition, in order to prevent the load change during CV valve test correction control is performed using 1st stage pressure of the turbine.

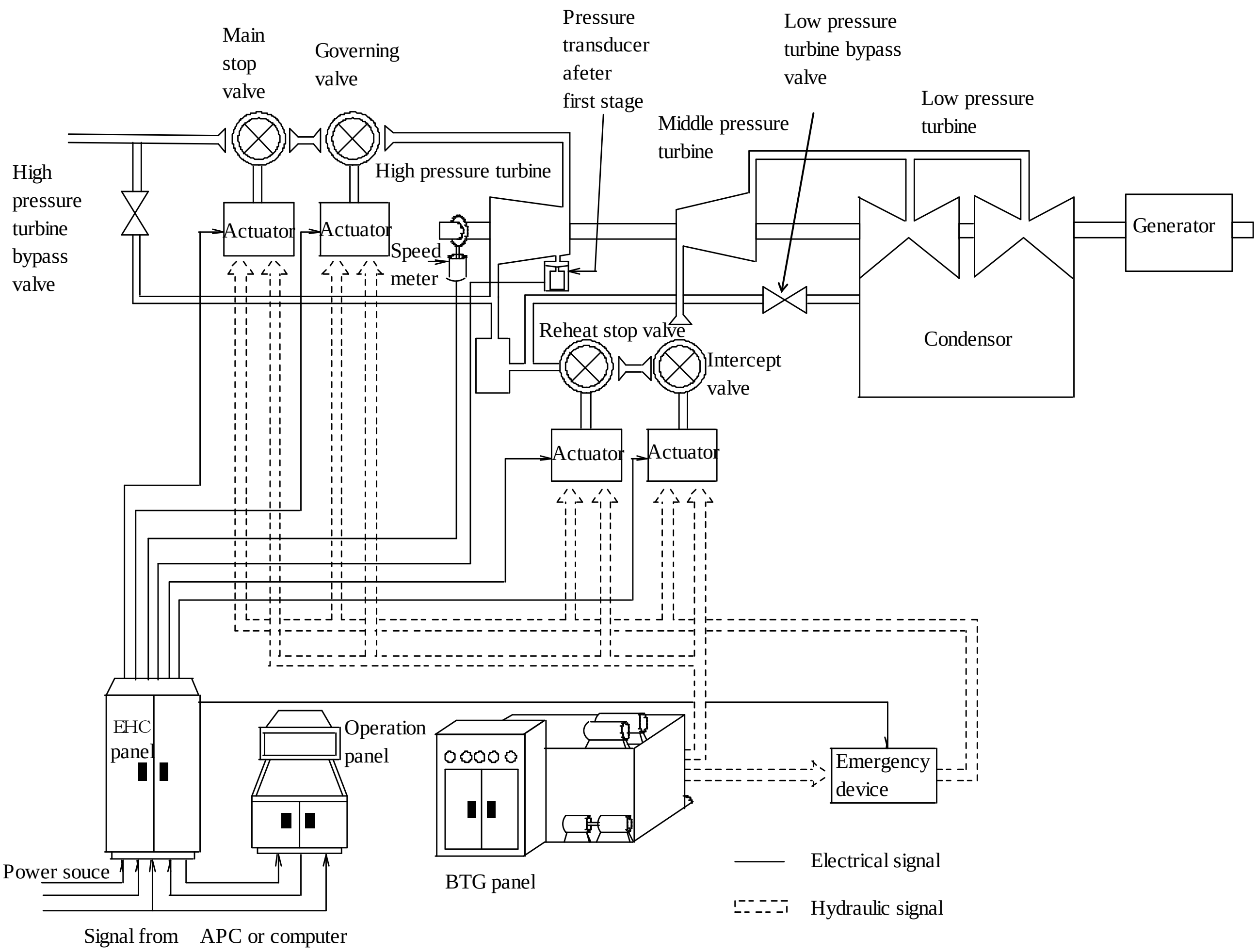


Fig- 40 An example of turbine control system

2. Other control devices

Followings are the recommended control devices for a steam turbine other than EHC(turbine speed and load control).

(1) Extraction pressures control

This is a control which adjusts amount of steam to maintain the steam-extraction pressure at the rated value.

It is combined with the speed governing device in many cases.

(2) Back-pressure control

This is a control which adjusts back pressure at the rated value by adjusting the amount of steams which flows into the steam turbine.

(3) Bearing inlet oil temperature control

This is a control which adjusts bearing inlet oil temperature by adjusting the circulating water flow.

If the temperature is not adjusted properly, viscosity of bearing oil is not kept properly, and this may cause temperature rise at the bearing and steam turbine vibration.

(4) Gland steam control

This is a control which maintains the gland steam condition in the rated value regardless of the load change.

If gland steam pressure is not adjusted properly, seal at the gland part becomes impossible, and leak of gland steam or gland suction from a gland part to the turbine may be caused.

Since air suction from a gland causes condenser vacuum degradation, gland steam condition l is recommended to be controlled properly and automatically.

(5) Condenser level control

This is a control which adjusts both or either of the amount of condenser inflow (make-up water) , the amount of outflows(condensate), and maintains the water level at the rated value.

(6) Deaerator level control

This is a control which maintains the water level at the rated value by adjusting the amount of condensate inflow to the deaerator.

(7) Feed water heater level control

This is a control which maintains the water level at the rated value by adjusting the amount of drain which flows out from feed water heater water.

Article 247. Measurement equipment for gas turbine

Article 247-1. Measurement equipment for gas turbine

1. General

The following instruments required in Article 247 of the design technical regulation are employed during start-up, normal operation and shutdown.

Measurement items from 1 to 6 in Article 247-1 of the design technical regulation are essential to security or protection of a gas turbine and they should be monitored, and maintained within allowable or specification or designed value during the gas turbine operation.

These items from 1 to 6 are also recommended to be recorded because they are effective reference in finding abnormal condition for stable operation of the gas turbine.

(1) Gas turbine speed

Turbine speed is required to be measured to control the turbine speed because over-speed is one of the most dangerous conditions that can occur in a turbine. Gas turbine speed can be detected not only at the same shaft directly but also at the shaft which is mechanically slowed down with the gear system.

Therefore, detection at the generator shaft or at the gear shaft or the method by the generating frequency of a synchronous generator is regarded as gas turbine speed.

2. Mandatory instruments to be measured

(1) Compressor outlet pressure

The compressor outlet pressure with the highest pressure in the gas turbine system is to be measured as measurement of the air for operation, or gas.

If the compressor of the gas turbine has two or more stages or shafts, outlet discharge pressure with highest may just be measured the pressure of the vent of the higher in the thing of two or more shafts.

In addition, also in the case of gas turbines which do not have air for operation, or compressors, it is important to install a pressure measurement device suitable for it.

(2) Lubricant oil inlet pressure at the bearing

This item is installed to prevent bearing deterioration by heat.

(3) Metal temperature of bearing or lubricant oil outlet temperature at bearing

When bearing temperature is not adjusted properly, the viscosity of bearing oil is not kept proper and there is a risk of causing the steam turbine vibration or bearing deterioration.

For this reason, measuring of bearing temperature is essential.

This is measured by thermocouples or resistance thermometers.

If bearing temperature is measured directly, it can be supervised more promptly, and operation for the bearing temperature change can be more prompt than measuring of bearing outlet oil temperature.

(4) Amplitude of vibration

According to Article 246 and 247of the design technical regulation, the turbine and the generator vibration are required to be measured for protection.

In addition, velocity of vibration can be a substitute of amplitude.

Because of vibration frequency range, accelerometer may be widely used especially for gas turbines. If velocity or amplitude data are required, the acceleration data can be integrated (velocity) or double integrated (amplitude).

(5) Fuel flow

In order to operate and control the gas turbine and the generator within the rated output, fuel flow is to be measured and recommended to be recorded.

(6) Sulfur oxide and nitrogen oxide concentrations

These items are referred to the guideline of “Article 246-1 Measurement equipment for boiler”.

3. Recommended instruments to be measured

Following instruments are recommendations.

Table- 35 Measurement Equipment for Gas Turbine (Recommendations)

№	Operating condition	Remarks
1	Difference pressure at inlet filter	
2	Compressor inlet air temperature	
3	Exhaust gas pressure at gas turbine outlet	
4	Exhaust gas temperature at gas turbine outlet or gas temperature inlet gas temperature	If direct measurement is impossible, exhaust gas temperature may be calculated from inlet gas temperature.
5	Lubricant oil inlet temperature at bearing	
6	Control oil pressure	

(1) Difference pressure at inlet filter

When an unusual pressure drop occurs in inlet filter, there is a risk of surging etc.

For this reason, the measurement of difference pressure at inlet filter is a recommendation item.

(2) Compressor inlet air temperature

In order to operate and control the gas turbine, air temperature is recommended to be measured because air density changes according to air temperature.

(3) Exhaust gas pressure, temperature

Exhaust gas pressure and temperature are recommended to protect the gas turbine from high pressure or high temperature. If direct measurement of exhaust gas is impossible, it may be calculated from inlet gas temperature.

(4) Lubricant oil inlet temperature at bearing

As stipulated before, when bearing inlet temperature is not adjusted properly, the viscosity of bearing oil is not kept properly and there is a risk of causing the gas turbine vibration or bearing deterioration. Therefore, lubricant oil inlet temperature at bearing is recommended in addition to the mandatory item “Metal temperature of bearing or lubricant oil outlet temperature at bearing”.

(5) Control oil pressure

Decrease of control oil pressure may cause turbine speed control failure because fuel control valve is actuated by hydraulic system.

Moreover, if oil leak from hydraulic system occurs, fire may be caused.

For these reasons, the measuring of control oil pressure is a recommendation item.

Article 247-2. Automatic control systems for combined cycle power stations

1. Automatic control systems for combined cycle

It is desirable to install following control systems.

Table- 36 Automatic control systems for combined cycle (Recommendations)

№	Automatic control systems	Remarks
1	Automatic-start/stop control	This is applied when automatic start/stop control is required.
2	Load distribution control	This is applied when the generating load is required to be distributed to every shaft and required to be controlled totally.
3	Fast cut back operation control	This is applied when the unit is required to keep operation independent of the power system during outage.
4	Load run back operation control	This is applied when the unit is required to keep operation during the abnormal condition of main and auxiliary machines.

The concept of automatic control systems for combined cycle is shown in following figures.

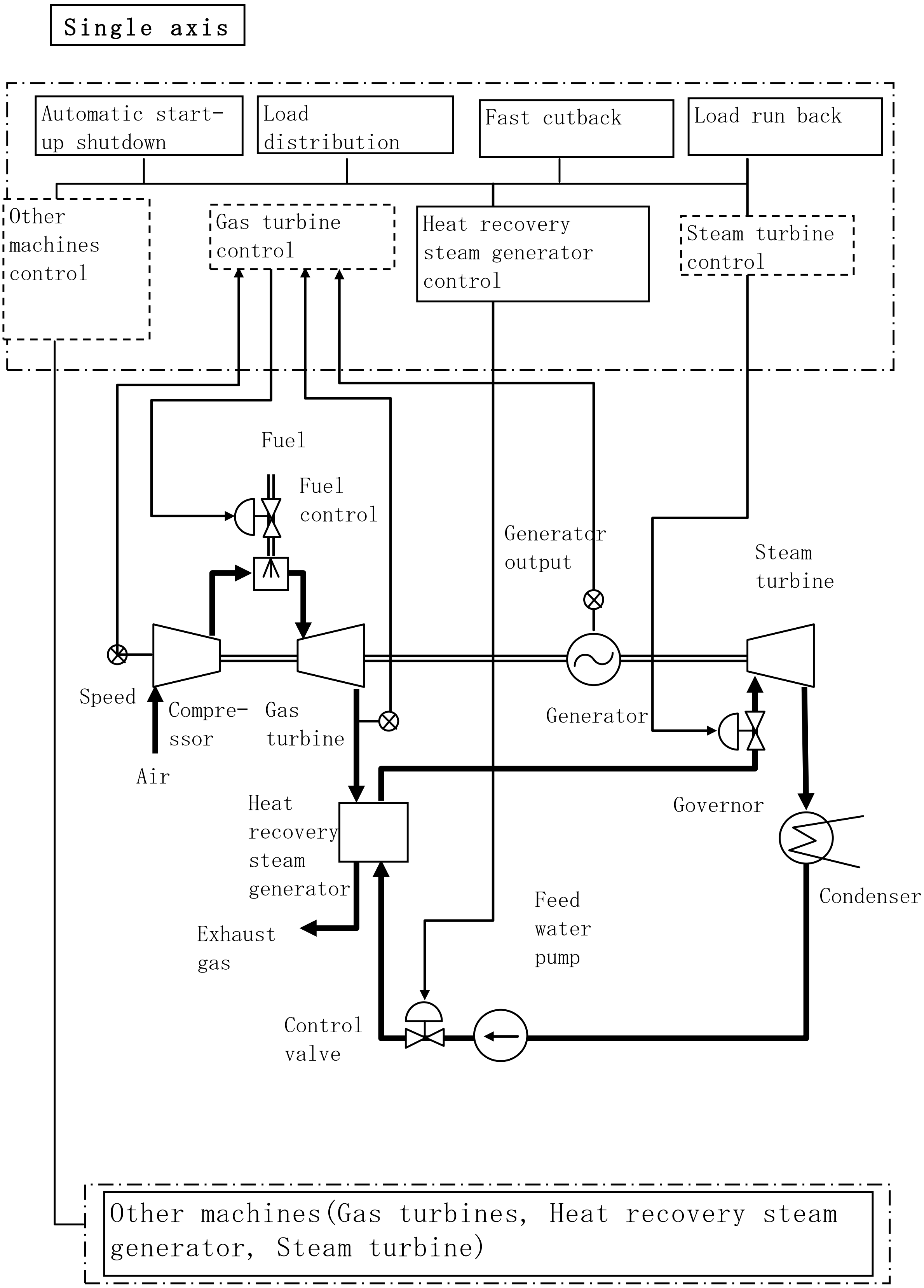


Fig- 41 The concept of automatic control systems for combined cycle (Single axis)

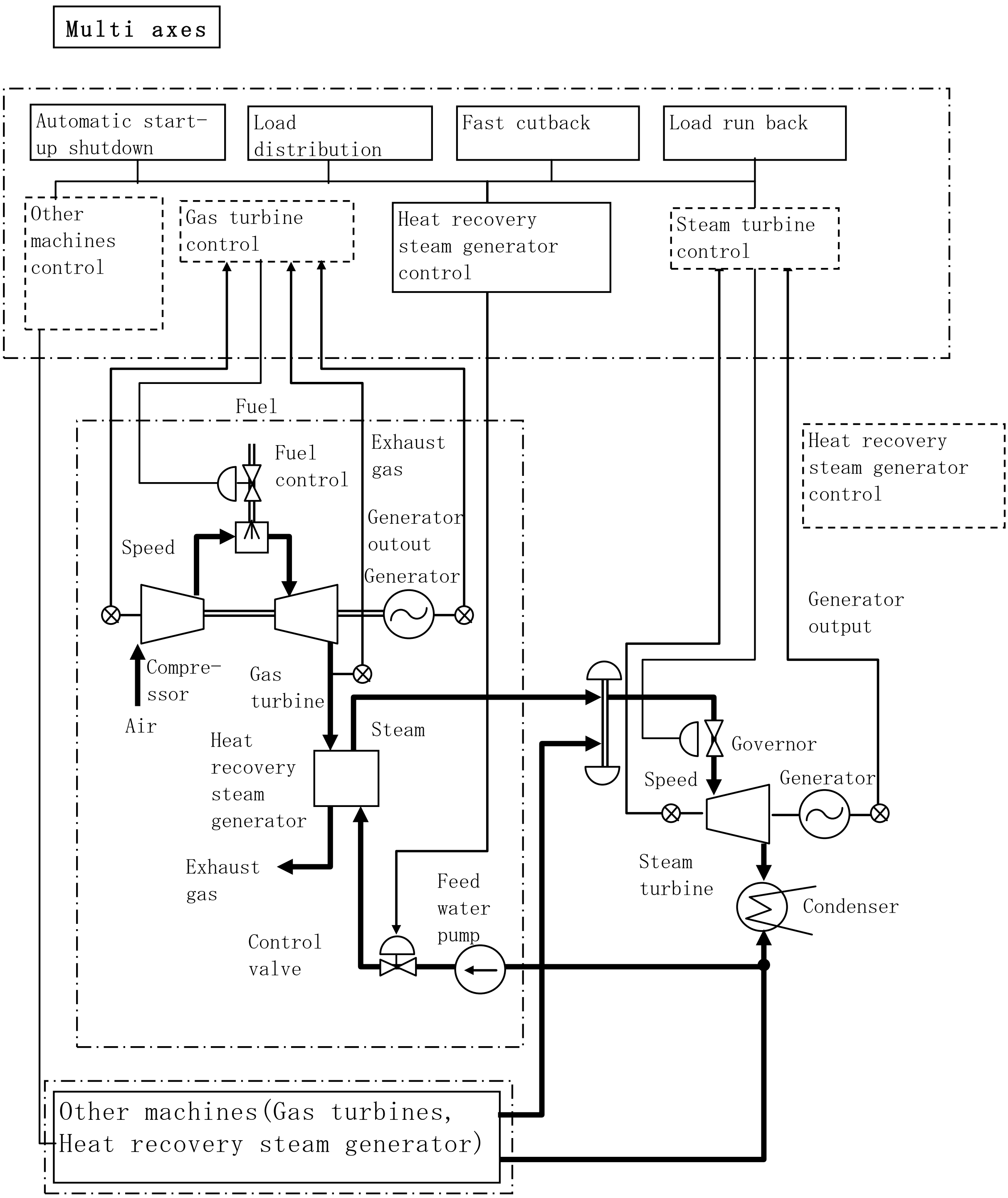


Fig- 42 The concept of automatic control systems for combined cycle (Multi axes)

(1) Automatic-start/stop control-system

This system judges the timing of an actuation from the status of the plant at the time of start-up and shutdown, and controls by giving the operational command to the main and auxiliary machines, load set demand.

(2) Load distribution control-system

Since combined cycle plants consist of gas turbines, steam turbines, and heat recovery steam generator, the optimum load distribution of each axis may be required in consideration of the total performance of the whole unit.

The load demand is received for every axis from the central load dispatching center, or received total of the unit. In the latter case, automatic controller performs optimum load distribution control by calculating efficiency in every axis and combining it.

(3) Fast cut back operation control

As stipulated guideline of Article 245-2, “fast cut back operation control system “is the system to recover the grid system during outage by decreasing the load of the generator rapidly or cutting the load.

The units with this control function are able to operate in the load of no load or auxiliary power and also may be able to operate the boiler alone during the turbine trip. Therefore, this function contributes to the stable grid system operation by preparing for next parallel in.

In addition, in the case of unit with two or more axes, if two or more axes share the load within the power station, unit efficiency not only falls by the load reduction, but also stable operation may not be able to be maintained.

For this reason, one axis is made to share the load in the power station and it is common to shut down the remaining axes automatically or to reduce the remaining axes to no-load.

Moreover, in the fast cut back operation control, the governing valve of a turbine is throttled down so quickly that steam pressure rises rapidly.

Thus, it is common to operate a turbine bypass valve in order to prevent rapid increase of steam pressure.

(4) Load run back operation control

During the load run-back operation of combined cycle power generation plant, it is general that unit load of the unit is reduced to the predetermined load, or in the case of unit with two or more axes, it may be by shutting down some axes.

1) Low fuel gas pressure

Operation under the condition of low fuel gas pressure may cause flame off or may not be able to generate load demanded .In order to prevent this, the load is reduced to the load where stable combustion is possible by low fuel gas pressure detection.

2) Restriction during transmission-system failure

When the capacity of transmitting electricity is restricted by the outage, the generator output is limited to the transmitting capacity.

3) Others

A load-run-back-operation control may also be activated to protect facilities in the case of trip of auxiliaries which have no stand-by.

2. Automatic control devices for combined cycle power stations

It is desirable to install following control devices shown in Table-37.

However, in the case of gas turbine excluding the gas turbine which is coupled with induction generator in Article 39 of the design technical regulation, the governor must have the ability to reduce the rotation speed to below the emergency speed, thereby reduce the rated load when the maximum load exceeds the rated load".

Therefore, the devices for speed governing and load control should be installed.

Table- 37 Automatic control devices for combined cycle (Recommendations)

№	Automatic control devices	Remarks
1	Speed control	Speed governing (mandatory) Load control (mandatory) Speed up control Load restriction Governor and load limiter mode switching Auto synchronization, etc
2	Gas temperature control	
3	NOx control	This is applied when the unit is required to reduce NOx emission.
4	Compressor control	This is applied to the gas turbine which controls the air flow of the compressor.

(1) Speed control

According to, Article 39 of the design technical regulation, the rotating speed and gas turbine output load fluctuation should be prevented by adjusting the amount of fuels which flows into a gas turbine other than the gas turbine combined with an induction generator.

Moreover, this device must have the capability to make the maximum speed in the rated load interception not more than the speed the emergency speed governing device operates.

In addition, in the case of the gas turbine of 1 axis combined cycle type ,it is general to control the speed by the gas turbine speed governing device which controls the fuel flow equipment, and. As for the steam turbine speed governing device, it is common to have only an over-speed protection device.

(2) Gas temperature control

This is the control to prevent a remarkable rise of gas temperature by restricting the fuel flow which flows into the gas turbine

(3) NOx control

This is the control to reduce the NOx emission in the exhaust gas.

There are dry NOx control which adjusts a combustion air flow, and wet NOx control which injects water or steam to a combustor.

(4) Compressor control

This is the control which adjusts the air flow of the compressor, and prevents the surging of the compressor.

Article 248. Measurement equipment for generator

Article 248-1. Measurement equipment for generator

1. General

In addition to the items required in Article 248 of the design technical regulation, following measurement items are recommended to be equipped.

Table- 38 Measurement Equipment for Generator (Recommendations)

№	Operating condition	Remarks
1	Frequency	
2	Power factor	
3	Rotor winding temperature	This is not applied to generators with rotating rectifiers.
4	Sealing oil pressure	This is applied to hydrogen cooled generators.
5	Hydrogen purity or hydrogen density	This is applied to hydrogen cooled generators.
6	Stator cooling water conductivity	This is applied to generators whose stator is cooled by water.
7	Stator cooling water pressure	This is applied to generators whose stator is cooled by water.
8	Field current or excitation voltage	This is not applied to generators with rotating rectifiers.
9	Synchronism detection	
10	Electric-energy	Integration of power
11	Reactive-energy	Integration of reactive power
12	Direct current controlling circuit voltage	
13	Zero phase voltage, or a neutral-point electric current	

2. Details

What should be mentioned specially among the measuring devices shown in Article 248 of the design technical regulation and Table-38 are explained as follows:

(1) Voltage, current, power, reactive power

These items are specified at the generator rating, therefore these are essential for the generator protection and also used for exciter control as stipulated guideline of operation and maintenance at Article 251,262.

Moreover, the voltmeter can be common with synchronism detection devices.

In addition, meters of power and reactive power may be used for transaction of electricity.

In designing, protection devices for the secondary circuits of electrical measurement circuit, protections are required for instrument transformers. It is necessary for the secondary circuit of CT to prevent open circuit, for the secondary circuit of VT to prevent short circuit. Moreover, the load of the secondary circuit is recommended to be considered carefully for accurate measurement. Electrical transducers may be used to reduce the load of the secondary circuit.

The specification of instrument transformers for measurement should be different from those for protections because operating voltages and current are different from the rated value during the failure.

In the case of direct acting indicating type meters, IEC 60051-2, IEC 60051-3 are referred.

As for electrical transducers, IEC 60688 is referred.

(2) Metal temperature of bearing or lubricant oil outlet temperature at bearing

These items are essential for the bearing protection of the generator.

If bearing metal temperature is measured directly, the temperature change of the bearing can be detected more promptly than the measurement of lubricant oil outlet temperature at bearing and measures may be taken more promptly.

Alarming device is required for steam turbines and generators or coupled with other rotors which rated output exceeds 400MW, which is stipulated in technical guidelines (Steam Turbine) concerning Article 33.

(3) Stator temperature

In order to monitor overheat of a generator stator core and insulator of the winding, temperature is at such as a slot part of a stator winding, according to the capacity and type of generators.

In the case of the generator of a small capacity, temperature may be measured at the stator core.

In order to monitor the temperature of the stator winding, at least six embedded temperature detectors (ETD) should be supplied in accordance with IEC 60034-1.

Temperature detectors may be resistance thermometers, thermocouples or semi-conductor negative coefficient detectors and they are built into the machine during manufacturing or construction, at points which are inaccessible after the machine is completed.

For directly cooled generators, it is important to note that the temperature measured by ETD is no indication of the hot spot temperature of the stator winding.

Observance of maximum coolant temperatures will ensure that the temperature of the winding is not excessive. The limit of permissible temperature measured by ETD between the coil sides is intended to be a safeguard against excessive heating of the insulation from the core. The ETD temperature readings may be used to monitor the operation of the cooling system of the stator winding.

The number of temperature detectors measuring the coolant temperature where it enters the generator should be specified during designing.

(4) Amplitude of vibration

Vibration is measured according to the Article 33 of the technical standard of the steam turbine.

Considering moving rotor protection importance, in the case of generators driven by the turbine of a rated output exceeding 10,000kW, amplitude of vibrations should be measured automatically, and in the case of not less than 400MW, vibrations should be measured and recorded automatically. (Electronic media is included)

Furthermore, generators connected with the gas turbines and steam turbine rated below 400MW, are recommended to equip the unit which records the amplitude of vibration.

(5) Hydrogen pressure, hydrogen temperature

These items are measured in order to maintain safety.

Change of hydrogen pressure or temperature may be the signal or the result of hydrogen leak or ignition.

Alarm systems of hydrogen pressure should be equipped as stipulated guideline of Volume4 Article 264.

(6) Frequency

Frequency is recommended to be measured due to various reasons such as unit load control, or protection from over heat during low frequency.

In general, VT (Voltage transformer) output is used to measure frequency.

(7) Power factor

This item is recommended to be measured to operate the generator within its capability curve and also used for exciter control as stipulated guideline of Volume4 Article 251,262.

(8) Rotor winding temperature, field current or excitation voltage

Rotor winding temperature is recommended to be measured to prevent overheat which causes insulation deterioration. Generally, field temperature is measured as the resistance which is changed according to the temperature.

Field winding temperature can be found from the following formula:

$$T2 = \frac{R2\,(234.5+T1)}{R1} - 234.5$$

Where:

T2 = temperature (degree) corresponding to final resistance

T1 = temperature (degree) corresponding to initial resistance R1

The field resistance is induced from dividing excitation voltage by field current.

Field resistance R1 at temperature T1 is usually given on the generator manufacturer's test report and field voltage is measured at collector rings.

These recommendation items are not applied to generators with rotating rectifiers because field current and field voltage cannot be detected directly.

(9) Sealing oil pressure

As stipulated Volume 4 Article 257, hydrogen leak to outside of the generator should be prevented by maintaining seal oil pressure. For this reason, seal oil pressure is measured and monitored.

(10) Hydrogen purity or hydrogen density

As stipulated guideline of Volume4 Article 264, hydrogen purity is recommended to be measured in order to prevent explosion.

Gaseous hydrogen thermal conductivity is 712% of air.

If, the platinum line with fixed electric current generating heat beforehand is exposed to the detected gas, the heat diffusion percentage of this platinum line will change with the thermal conductivity of the gas. That is, since the thermal conductivity of air is smaller than hydrogen, when platinum line is exposed into the air, the temperature of a platinum line rises in proportion to it, and the electric resistance becomes large.

Therefore, applying this resistance alteration measurement, the concentration of hydrogen can be known.

Fig-43 is a principle-of-measurement figure of the gas analyzer by a heat-conduction method. A standard-gas room (S) and a detected gas chamber (R) are identically-shaped chambers prepared into the metal body, and the platinum resistance wires R and S coiled in the shape of a non-induction coil are stored into it, and they constitute the Wheatstone bridge, whose fixed resistances are P and Q. The platinum resistance wires R and S are always heated with the fixed electric current. The standard-gas room (S) is filled up with constant purity hydrogen gas, and it is introduced, a part of mainstream detected gas replacing by the gas chamber (R) one by once through a small hole. That is, hydrogen purity will be detected by measuring the output voltage.

Moreover, it applying hydrogen density is 7% of the air, the relationship between density and purity is as follows:

$$\text{Hydrogen purity} = (100-M)\frac{100}{93}\ (\%)$$

Where

M: density (%)

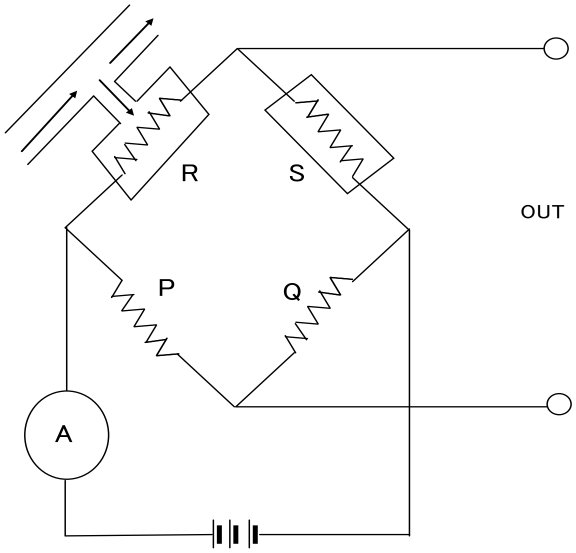


Fig- 43 Principle of hydrogen concentration detection

(11) Stator cooling water conductivity

Using ion exchange resin, stator cooling water conductivity is to be maintained below the value designated by the manufacture to prevent ground fault through cooling water. Therefore this item measurement is recommended so that measures are taken by an operator according to the conductivity situation immediately.

(12) Stator cooling water pressure

For generators with direct cooling of the stator winding, the pressure of the cooling medium at the inlet of this winding is recommended to be measured in order to monitor cooling water flow.

If the pressure decreases to the value designated by the manufacture, unit load is recommended to be decreased automatically (run back operation).

(13) Electric-energy, reactive-energy

These items are recommended to be measured for unit efficiency management or load dispatching management.

(14) Direct current controlling circuit voltage

Protecting circuit such as relay circuit or switch gear controlling circuit is required to work during emergency such as blackout. Direct current is used for these controlling circuits, therefore, its voltage is recommended to be measured.

(15) Synchronism detection

When the generator is paralleled in the electric system, the measure of controlling the over-current is taken by suppressing mutual voltage difference and phase difference within the designated value.

For this reason, the synchroscope for supervising a voltmeter, a frequency meter, and a mutual phase difference is used.

In addition, if an automatic synchronizer, which stops and arranges the voltage difference and the phase difference in parallel automatically within the rated value, is equipped, the synchroscope can be omitted when manual parallel is not performed.

(16) Zero phase voltage, or a neutral-point electric current

In order to detect the ground fault at the generator or the transformer, or the bus conductor connected to them, the zero phase voltage or a neutral point electric current is recommended to be measured.

In addition, when the protective device of ground fault is equipped, measurement of a zero phase voltage or a neutral-point electric current can be omitted.

Article 248-2. Automatic control systems for generator

1. Automatic control systems for generator

It is recommended to install following control systems.

Table- 39 Automatic control systems for generator (Recommendations)

№	Automatic control systems	Remarks
1	Voltage control	
2	Under excitation limiter	
3	Over excitation limiter	
4	Reactive power control	This is applied when the power system requires.
5	Power system stabilizing control	This is applied when the power system requires.
6	Sealing oil control	This is applied to hydrogen cooled generators.
7	Hydrogen cooling control	This is applied to hydrogen cooled generators.
8	Stator cooling water control	This is applied to generators whose stator is cooled by water.

Automatic control systems for generator shown in Table-39 are recommended due to followings.

(1) Voltage control

Generators should be capable of continuous rated output at the rated power factor over the ranges of ±5% in voltage.

Therefore, generator terminal voltage is to be controlled by Automatic Voltage Regulator (AVR). This control adjusts the generator terminal voltage to the rated value by adjusting and maintaining the field current of the generator.

Examples of AVR functions are referred to Article251 of operation and maintenance guideline.

(2) Under excitation limiter

This control restricts reactive power of a generator at leading power factor for the prevention from stator core-end over-heat and generator fall out of synchronism.

(3) Over excitation limiter

This control restricts reactive power of a generator at lagging power factor not to exceed the rotor thermal capacity.

(4) Reactive power control

This control adjusts reactive power at the value required from power-system by regulating terminal voltage of the generator

(5) Power system stabilizing control

The control adjusts the field voltage of a generator in order to secure larger dynamic-stability by improving the electromechanical fluctuation, with increasing damping torque, between a generator and power-system.

Though a generator output power is decided by the turbine mechanical torque, a generator output power also can be changed by changing excitation value transiently. This control detects the changing of generator output power, controls the excitation value, and reduces the fluctuation of power rapidly.

(6) Sealing oil control

This control maintains sealing oil pressure power at the rated value in order to prevent hydrogen leakage from a generator or air intrusion to a generator.

(7) Hydrogen cooling control

This control maintains the temperature of hydrogen at the rated value by adjusting a circulating water flow using the automatic controller the in order to secure the cooling capability of the generator.

(8) Stator cooling water control

This control maintains the temperature of the stator cooling water at the rated value by adjusting circulating water flow in order to secure the cooling capability of a generator with stator direct water cooling system.

Article 249. Measurement equipment for major transformer

1. General

In addition to the items required in Article 249 of the design technical regulation, following measurement items are recommended to be equipped.

Table- 40 Measurement Equipment for Transformers (Recommendations)

№	Operating condition	Remarks
1	Synchronism detection	
2	Electric-energy	Integration of power
3	Reactive-energy	Integration of reactive power
4	Direct current controlling circuit voltage	
5	Zero phase voltage, or a neutral-point electric current	

2. Details

What should be mentioned specially among the measuring devices shown in Article 249 of the design technical regulation and Table-40 are explained as follows:

(1) Voltage, current, power

These items are specified at the transformer rating, therefore these are essential for the transformer protection.

Moreover, when a transformer is paralleled in, inrush current may flow according to the condition, therefore, current is to be measured.

As described in Article 248, in designing, protection devices for the secondary circuit, protections are required for instrument transformers. It is necessary for the secondary circuit of CT to prevent open circuit, and for the secondary circuit of VT to prevent short circuit. Moreover, load of the secondary circuit is recommended to be considered carefully for accurate measurement.

These instrument transformers should be different from those for protections because operating voltages and current are different from the rated value during failure.

(2) Insulating oil temperature

Temperature rise of insulating oil may cause insulating oil deterioration or may be the sign of failure. Therefore, this item is a recommendation.

(3) Synchronism detection

When the transformer is paralleled in the electric system, the measure of controlling the over-current is taken by suppressing mutual voltage difference and phase difference within the designated value.

For this reason, the synchroscope for supervising a voltmeter, a frequency meter, and a mutual phase difference is used.

In addition, if an automatic synchronizer, which stops and arranges the voltage difference and the phase difference in parallel automatically within the rated value, is equipped, the synchroscope can be omitted when manual parallel is not performed.

(4) Electric-energy, reactive-energy

These items are recommended to be measured for unit efficiency management or load dispatching management.

(5) Direct current controlling circuit voltage

Protecting circuit such as relay circuit or switch gear controlling circuit is required to work during emergency such as blackout. Direct current is used for these controlling circuits, therefore, its voltage is recommended to be measured.

(6) Zero phase voltage, or a neutral-point electric current

In order to detect the ground fault at the generator or the transformer, or the bus conductor connected to them, the zero phase voltage or a neutral point electric current is recommended to be measured.

In addition, when the protective device of ground fault is equipped, measurement of a zero phase voltage or a neutral-point electric current can be omitted.

Section 5 Protection Equipment

Article 250. General provision

1. General

In the event of the failure, to minimize the risk is important in order to ensure the safety.

In the normal condition, a thermal plant is controlled by control devices and monitored by operators. When abnormal condition occurs, an operator may take measures for alarms. However, if the situation requires urgent measures for the plant, the plant should be protected automatically by protection equipment to minimize the risk, according to the idea of "fail-safe".

"Fail-safe" equipment is protection equipment which responds in a way that will cause no harm, or at least a minimum of harm, to other machinery or minimum of danger to personnel in the event of failure.

Thus, Article 250 of the design technical regulation is stipulated.

The objective of this section is to specify necessity or desirable protection list items for the safety of machinery and operators, not to specify detection or protection method, although some examples are shown in some cases.

In other words, automatic shutdown, automatic stop, and alarms may be generated either by the relays or the computer. Moreover, they may be detected by a single device or combination of some protection devices. In general, the protection device shut down the relevant equipment and other necessary equipment are shut down by the interlock as described in Article 256.

In addition, refer to "Article 258-1 SCADA/EMS system "for alarm units etc.

The principle of selecting items is as follows:

(1) What the technical regulations impose is taken as the mandatory list item.

(2) Following items are taken as recommendations.

- Items in relation to explosion or fire
- Items in relation to deterioration of the main machines
- Items in relation to other regulations

All items of protection equipment activation are recommended to be indicated on the panels or display, when operating, in order to determine the cause of the accident.

As for activation value, the manufactures should be responsible for the set values of protection equipment, considering the design conditions.

Moreover, the manufactures also should be responsible for the operation of the facility in accordance with Vietnamese standard decree, circular etc and international standard (ISO,IEC etc).

In addition, IEC60255-21-3 (Electrical relays) stipulates the class that corresponds to the severity class of seismic standards. Therefore, it is necessary to provide this information to the manufacturer at the designing stage by the user. Followings are classifications.

Class 0:No seismic request for measurement and protection relay

Class 1: Measurement and protection relays for normally use in industrial plants, power plants, substations

Class 2: Measurement and protection relays for very high seismic level which requires high level of security

Article 251. Protection for boiler

1. General

In thermal power plants, in order to protect a boiler and its facilities, when a abnormal condition occurs in the boiler or its attached facilities and a safe operation is impossible, fuel for the boiler is required to quickly cut off (MFT), and this activation is also required to be quickly and automatically.

2. Details

Protective items shown in Table-41 are mandatory, and protective items shown in Table-42 are recommended to be selected.

Moreover, in some cases, some items are added according to the requirement of installation or design.

Table- 41 Protection for boiler (Mandatory)

Emergency condition	Interpretation	Remarks
1 Loss of all forced draft fans	If all forced draft fans stop, the air-fuel ratios of the boiler becomes abnormal, therefore, the boiler cannot keep stable combustion. In order to prevent the furnace explosion, the boiler must be shut down.	
2 Loss of all induced draft fans	If all induced draft fans stop, all exhaust gas cannot be emitted from the chimney. In order to prevent the furnace explosion caused by residual fuel accumulation, the boiler installed induced draft fans must be shut down.	If used
3 Flame instability	In order to prevent the furnace explosion, the boiler must be shut down in cases shown below. a) Many burners flame-off	Not applied to bed combustion boiler cases

Emergency condition	Interpretation	Remarks
	b) All burners flame off c)All burner stop-valves closed d)Low pressure of burner fuel supply (in oil combustion cases) e) Low pressure of burner atomizing medium supply (in oil combustion cases) f) Low or high pressure of burner fuel supply(in gas combustion cases) g)Loss of all primary air fans (in pulverized coal combustion cases) h)Loss of all mills (in pulverized coal combustion cases) i)Others According to facility condition such as components, structures, or characteristics.	
4 High furnace draft	In order to prevent abnormal furnace draft rise cased by abnormal fuel combustion, the boiler must be shut down. Causes of high furnace draft is assumed to be as follows: ・Air or exhaust gas damper wrong activation ・Tube leak of super-heater , re-heater or economizer ・Explosive combustion in the furnace ・Abnormal control of air flow or circulating gas	
5 Low furnace draft	In order to prevent damage of furnace caused by abnormal draft decrease, the boiler must be shut down. Causes of low furnace draft low is assumed to be as follows: ・Air or exhaust gas damper wrong activation ・Close of Burner air damper or air resistor ・Abnormal control of air flow ・Abnormal combustion in the furnace	If induced draft fan used
6 Very low drum water level	In circulation boiler with combustion facility, very low drum water level is a risk of waterwall damages. On the other hand, because exhaust gas temperature is relatively low, heat recovery steam generator cases, risk of	In forced circulation boiler cases, “Low differential pressure of boiler circulation pump” is a choice.

Emergency condition	Interpretation	Remarks
	waterwall damage is less . But operation of the circulating pump and feed water pump is assumed to be influenced, alarm is recommended. If waterwall temperature endurance is not high enough to exhaust gas and risk of damage is assumed, trip may be chosen.	Not applied to once-through boilers
7 Low feed-water flow or low flow of water wall (Furnace wall)	In once-through boilers, because main steam temperature is maintained by keeping the ratio between feed-water and fuel quantity, heat absorption in each area changes according to feed water quantity. Therefore low feed-water flow or low flow of water wall result in water wall damage. In order to prevent this damage, the boiler should be shut down.	Applied to once-through boiler cases

Table- 42 Protection for boiler (Recommendation)

Emergency condition	Interpretation	Remarks
8 Loss of all feed water pumps	In once-through boiler cases, loss of all feed water pumps results in water wall damage. In order to prevent this damage, the boiler should be shut down.	Recommendation Applied to once-through boiler cases
9 High drum pressure or High main steam pressure	As Technical Guidelines (Boiler) Article 24, "set pressure of safety valves" stipulates, as follows: "In case of a boiler equipped with an automatic combustion control device and a device which cuts off fuel supply quickly with a pressure not higher than 1.06 times the maximum allowable working pressure at the outlet of the boiler, the capacity of a pressure relieve device or starting bypass device(applied only in once-through boiler cases), which is actuated automatically by a pressure not higher than the maximum allowable working pressure at the outlet of the boiler can be included in the capacity of the safety valves." According to this item, the boiler should be shut down with a pressure not higher than 1.06 times the maximum allowable working pressure.	Applied to the boiler equipped with an automatic combustion control device and a device which cuts off the fuel supply quickly with a pressure not higher than 1.06 times the maximum allowable working pressure at the outlet of the boiler, and a pressure relieve device or starting bypass device (applied only in once-through boiler cases), capacity is included in safety valve capacity.
10 Re-heater Protection	This protection is applied to re-heater steam no flow such as steam for turbine shutdown in re-heater installed boilers operation. The boiler should be shut down when fuel flow is over the value set for re-heater protection	Recommendation
11 High waterwall pressure	When the supercritical constant pressure once-through boiler unit, which is installed a stop valve for stating, starts or stops, with the valve is closed, the boiler cannot be shut down by high main steam pressure, because pressure after the stop valve is constant. Therefore, in this operating condition, the boiler must be shut down by high waterwall pressure.	Recommendation Applied to the boiler installed a stop valve for start-up
12 Low waterwall pressure	Supercritical constant pressure once-through boiler waterwall, which is installed a stop valve for start-up, is designed for single phase flow condition. In subcritical pressure, boiler waterwall becomes two phase flow. In this operating condition, the boiler should be shut down by low waterwall	Recommendation Applied to the boiler installed a stop valve for start-up

Emergency condition	Interpretation	Remarks
	pressure because heat transfer decreases.	
13 Low temperature of bed	In fluidized bed combustion boiler cases, when bed temperature is low, sable combustion is not maintained , therefore the boiler should be shut down.	Recommendation Applied to the bed combustion boiler cases

In the boiler star-up, in order to prevent the explosion of the furnace, it is necessary to carry out a furnace purge with the pure air from a forced draft fan etc.

Purging air flow is required to carry out purging time for more than at least 5 minutes not less than 25% of the boiler MCR air flow.

Ignition is required to be permitted after this furnace purge is completed.

Therefore, MFT is required to be reset by checking that there is no leak in the oil or gas fuel system and that the furnace purge is completed,

Moreover, for boilers using liquid and gaseous fuel, it is necessary to install the leak-check unit which can check that there is no fuel leak before opening a fuel stop valve, in the fuel systems.

In addition, the HRSG without combustion and its auxiliary or related machinery is required to be equipped with the functions to pre-purge to enable start up safely.

Article 252. Protection for steam turbine

1. General

The meaning of Article 252 of the design technical regulation is as follows:

When abnormal condition occurs in a steam turbine, or in its auxiliary facilities, and a safe operation cannot be continued, the steam turbine must be shut down safely. Therefore, a steam turbine and its auxiliary facilities are required to be equipped with the protection device shown in Table-43 so that the emergency stop (trip) of the turbine is carried out by intercepting steam inflow.

It is also recommended to install the protection devices shown in the recommendation list item of Table-44.

Moreover, a steam turbine is required to be equipped with the manual trip device so that a steam turbine can be shut down manually by operator’s decision.

2. Details and interpretation

From Table-43, protecting items which shut down the steam turbine should be selected, and from Table-44, protecting items which shut down the steam turbine are recommended to be selected.

Moreover, in some cases, some items are added according to the requirement of installation or design.

Table- 43 Protection for Steam Turbine (Mandatory)

Emergency condition	Interpretation	Remarks
1 Over-speed	The turbine must be shut down because over-speed causes damage to a rotor with an excessive centrifugal force. Considering reliability, trip system is made by the redundant system of an "over-speed" and a "back-up over-speed."	Speed meters are equipped for both "over-speed" and "back-up over-speed."
2 Thrust bearing wear or high thrust bearing temperature	The turbine must be shut down because a thrust bearing wear causes the collision of a rotating part and a stationary part.	This is applied to steam turbines of a rated output exceeding 10000kW and also gas turbines equipped with the common thrust bearing in a combined cycle plant.
3 Low condenser vacuum	The turbine must be shut down because low condenser vacuum causes excessive stress to last stage turbine blades.	This is applied to steam turbines of a rated output exceeding 10000kW.
4 Excessive vibration	The turbine must be shut down because excessive vibration causes mechanical damage to the turbine.	In consideration of the reliability of a shaft vibration meter, there is also a plant which uses a system, such as making a trip judgment in combination with other bearings.
5 Low bearing inlet oil pressure	The turbine must be shut down because low bearing inlet oil pressure causes bearing destruction by heat.	
6 Speed governor failure	When heavy fault of controlling devices such as speed governor fault occurs, the turbine must be shut down because important control such as speed governing is lost.	This is applied to steam turbines equipped with an electro-hydraulic governor. A power-source loss and a speed-signal loss are also included in the electro-hydraulic governor heavy fault.
7 Generator internal failure	The turbine must be shut down to prevent over-speed caused by the loss of the load.	This is applied to generators of a rated output of not less than 10000kVA.

Table- 44 Protection for Steam Turbine (Recommendations)

Emergency condition	Interpretation	Remarks
8 Low control oil pressure	The turbine should be shut down because main valves control function is lost, if control oil pressure decreases.	Recommendation
9 Low pressure of main oil pump outlet pressure	The turbine should be shut down because low outlet pressure of main oil pump shows main oil pump coupled with turbine broken.	Recommendation This item is not applied to motor- type main oil pump.
10 High exhaust room temperature	If exhaust room temperature becomes high, the turbine should be shut down because of an exhaust room distortion and the effect on rotor alignment	Recommendation There is also a plant in which this item is alarm only.
11 Low frequency	The turbine should be shut down to prevent fatigue failure by rotor blades resonance which occurs lower than the allowable frequency.	Recommendation This item is applied considering turbine rotor moving blade design condition such as rotating blade length or rotating blade material. However, the turbine should be able to operate, in the frequency range stipulated in the CIRCULAR (NO.12/2010/TT-BCT).

Article 253. Protection for gas turbine

1. General

When abnormal condition occurs in a gas turbine, or its auxiliary facilities, and safe operation cannot be continued, the gas turbine is required to shut down safely.

Therefore, gas turbine and its auxiliary facilities are required to be equipped with the protection device shown in Table-45 so that the emergency stop (trip) of the turbine is carried out by intercepting gas inflow.

It is recommended to install the protection shown in the recommendation list item of Table-46.

In addition to this, a gas turbine is required to be equipped with the manual trip device so that a gas turbine can be shut down manually by operator's decision.

2. Details and interpretation

What should be mentioned specially for trip items are explained as follows:

Protective items shown in Table-45 are mandatory, and protective items shown in Table-46, are recommended to be selected.

Moreover, in some cases, some items are added according to the requirement of installation or design.

Table- 45 Protection for Gas Turbine (Mandatory)

Emergency condition	Interpretation	Remarks
1 Over speed	This item is installed for a protection of a rotating machine, and the set point is 111% or less of the rated speed. There are two types, a mechanical type and an electric type.	
2 High temperature of exhaust gas	This item is installed since rising of exhaust gas temperature results in damage to the blades.	If direct measurement is impossible, temperature may be calculated from inlet gas temperature.
3 Excessive vibration	This item is installed to prevent damage by the high rotor vibration.	
4 All flame-off	This item is installed to prevent explosion in the combustor and blades damage when the fuel burns inside the gas turbine.	
5 Low bearing inlet oil pressure	This item is installed for the prevention of bearing damage due to the bearing oil pressure reduction.	
6 Speed governor failure	This item is installed because in the case of a gas turbine, it is impossible to operate a fuel control valve manually during control device trouble.	
7 Generator internal failure	This item is installed to prevent the turbine from accelerating due to the load loss associated with the generator trouble.	

In addition to Table-45, recommendation items are as follows:

Table- 46 Protection for Gas Turbine(Recommendation)

Emergency condition	Interpretation	Remarks
8 Low control oil pressure	This item is installed because if control oil pressure falls, speed-governor ability will be lost to close the fuel control valve, and because there is a risk of flame off.	Recommendation
9 Abnormal condition of compressor guide vane	This item is installed to prevent surging of the compressor.	Recommendation
10 Low pressure of supply fuel	This item is installed because when pressure decreases, fuel control becomes impossible and speed governing function is deteriorated.	Recommendation
11 Abnormal condition of compressor guide vane	This item is installed because there is a risk that too much fuel injection raises combustion temperature of the gas turbine in abnormal condition, such as full open of the fuel control valve at ignition.	Recommendation
12 Low frequency	This item is installed because there is a risk that the compressor of the gas turbine may causes surging in the condition that a rotational frequency is lower than a allowable value, and also because the resonance prevention of the blades is necessary.	Recommendation This item is applied considering turbine rotor moving blade design condition such as rotating blade length or rotating blade material. However, the turbine should be able to operate, in the frequency range stipulated in the CIRCULAR (NO.12/2010/TT-BCT).
13 Abnormal condition of starting equipment	This item is installed because if the starting equipment stops during start up, the proper rotational frequency cannot be maintained, poor ignition is caused, and after ignition, there is a risk of excessive fuel injection due to the speed up torque shortage.	Recommendation

Article 254. Protection for generator and major transformers

1. General

   When abnormal condition occurs, the generator and major transformers are required to disconnect from the electric power line and shut down safely, automatically and quickly by trip devices.

   Without these devices, electric facilities and its surroundings will be destructed, and there will be very high risk of fire.

   It is recommended to install the protection shown in the recommendation list item of Table-48.

2. Details and interpretation

   To maintain electric facilities security, trip items shown in Table-47 are mandatory, and items shown in Table-48 are recommended.

   Also, operating values of the devices should be carefully considered according to the installation circumstances and in some cases back-up protection is recommended.

Table- 47 Protection for Generator and Major Transformers (Mandatory)

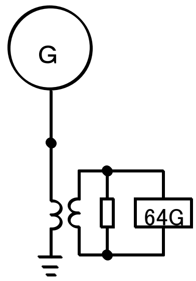
Emergency condition	Interpretation	Remarks
1 Generator internal failure	The Technical regulation stipulates that when generator internal failure occurs, the generator must be shut down to prevent failure expansion such as fire or generator destruction. In this case, differential relays are generally used, for quick and correct activation, but not limited to this type.	
2 Generator over-current	The Technical regulation stipulates that when failure occurs outside the generator, the generator must be shut down from the power line to prevent generator destruction and to stop the fault current supply. The over-current relay or the distance protection relay can be used as an over-current protecting device. If there is no circuit breaker between the generator and the major transformer, the protecting device can be common because individual protection is impossible.	
3 Generator excessive vibration	The generator must be shut down to prevent the abnormal operation with excessive vibration at the rotor shaft or at the bearing. Alarming device is required for steam turbines and generators or coupled	This is applied to generators driven by the turbine of a rated output exceeding 10,000kW.

Emergency condition	Interpretation	Remarks
	with other rotors which rated output exceeds 400MW, which is stipulated in technical guidelines (Steam Turbine) concerning Article 33. Considering moving rotor protection importance, generators driven by the turbine of a rated output exceeding 10,000kW are added to shut down item.	
4 Transformer over-current	When failure occurs outside or inside the transformer, the transformer must be shut down from the power line to prevent transformer destruction and to stop the fault current supply, because transformer failure results in electric outage in many cases and also has much influence on power system.	This is applied to the transformers whose voltages are not less than 11kV.
5 Transformer internal failure	The transformer rated output of less than 6.3MVA must be protected to prevent fires, to minimize the time of disconnection faults and to reduce the risk of catastrophic failure to simplify eventual repair. Causes of transformers internal faults are assumed as follows: ・ winding failures due to short circuits (turn-turn, phase-phase, phase-ground faults, open winding) ・ core faults caused by core insulation failure, shorted laminations ・ terminal failures (open leads, loose connections, short circuits ・ on-load tap changer failures (mechanical electrical short circuit , overheating) Transformers rated not less than5MVA and less than 6.3MVA should have alarm system at least. Since the transformers of larger capacity have large impact on security by the failure due to the large amount of oil inside, it is necessary to shut down the equipment prior to being damaged significantly by protections such as, differential relay, Buchholz relay, and shock relay. A sudden pressure relay is activated by detecting a rapid increase in the tank at the time of failure, mounted on the sidewall of the tank, and	This is applied to transformers of a rated output of not less than 6.3MVA.

Emergency condition	Interpretation	Remarks
	applicable to transformers without conservators.	

For security of facilities, recommendation items are as follows:

Table- 48 Protection for Generator and Major Transformers (Recommendations)

Emergency condition	Interpretation	Remarks
6 Generator ground	An alarm of the generator grounding is recommended to prevent stator short circuit, which results in severe damage to the generator. The generator circuit and its auxiliary circuit are protected together because separate failure detection is difficult. Fig 254-1 shows the preferred way to provide ground-fault protection for a generator that is operated as a unit with its power transformer. The generator neutral is grounded through a distribution transformer in the higher voltage winding side. A resistor and a relay are connected across the low voltage winding. In this case, the resistance is selected so that ground current is regulated below approximately 10A, therefore damage to the generator is assumed to be relatively low. Protecting all the windings near the generator neutral requires the method using third harmonic residual voltage, which appears generator neutral and terminal or the method using voltage injection to the neutral. Therefore, if 100% winding protection is required, specifying the protection of all stator windings is recommended.	Recommendation  Fig- 44 Preferred way to provide ground-fault protection

Emergency condition	Interpretation	Remarks
7 Field loss	Field loss protection is recommended to prevent stator and rotor burnout and power system insatiability caused by loss of synchronism. When a synchronous generator loses its excitation, it operates as an induction generator running above synchronous speed. Turbine generators are not suited to such operation because they do not have amortisseur (damper) windings to carry the induced rotor currents. Consequently, a generator's rotor will overheat very quickly by the induced currents flowing in the rotor, particularly at the ends of the rotor where the currents flow across the slots through the wedges and the retaining ring. The length of time to reach dangerous rotor overheating depends on the rate of slip. While the machine is running as an induction generator, the stator of synchronous generator may overheat, owing to over-current in the stator windings.	Recommendation When using this interlock, VT fuse should not be disconnected because correct impedance cannot be detected.

Emergency condition	Interpretation	Remarks
	The stator current may be high, depending on the slip. Such overheating does not tend to occur as quickly as rotor overheating. If the generator is not disconnected immediately after it loses excitation, widespread power system instability may develop very quickly, and shutdown may occur. When a generator loses excitation, higher than the generators rated load. Before it lost	

Emergency condition	Interpretation	Remarks
	excitation, the generator may have been delivering reactive power to the system. Thus, this large generator's reactive-power output reduction may cause widespread voltage reduction, and the other generators are subject to supply additional reactive load immediately. By using this impedance characteristic, loss of field is protected. Quick-acting equipment should be provided to shut down the generator's main and field breakers. An operator does not have sufficient time to act under such circumstances.	
8 Generator exciter failure	Generator exciter heavy failure protection such as exciter transformer internal failure, and all rectifier cooling fans stops are recommended to prevent exciter severe damage. Moreover, loss of exciter makes generator operation impossible, therefore, the generator shut down is recommended in this case.	Recommendation
9 Negative phase current	Negative phase current protection is recommended to prevent rotor burnout. When a generator is operated under unbalanced load, negative phase current flows in the stator coil, generating the revolving magnetic field which revolves in the opposite direction at the same speed of the rotor. This causes eddy current of double frequency flows on the surface of the rotor and the rotor wedge. This makes the rotor overheated especially in the part in which the eddy current concentrates. If the unbalance becomes serious, burning or strength deterioration may be caused by local overheating.	Recommendation In detail, Article 260 of operation and maintenance guideline is referred

Emergency condition	Interpretation	Remarks
10 Field ground	An alarm of field ground is recommended to protect rotor windings or its surroundings. The existence of a single ground fault increases the stress to ground at other points in the field winding, and the probability of a second ground occurring is increased. If a second ground occurs, part of the field windings will be by-passed, and the current through the remaining portion may be increased. By-passing part of the field grounding will unbalance the air gap fluxes, and this will unbalance the magnetic forces on opposite sides of the rotor. This unbalance of forces may be large enough to spring the rotor shaft. Resulting vibration may break bearing pedestals and this failure may cause extensive damage that is costly to repair and that keeps the machines out of service for a long time. Moreover, arcing at the fault may heat the rotor locally and the rotor distortion may be induced.	Recommendation
11 High temperature of the generator bearing or high temperature of outlet lubrication oil	An alarm of high temperature of the generator bearing or high temperature of outlet lubrication oil is recommended to prevent the risk of bearing burnout caused by continuous high temperature at the bearing.	Recommendation
12 Low stator cooling water purity	An alarm of low stator cooling water purity is recommended to prevent winding insulation deterioration.	Recommendation Article 153 of inspection guideline is referred.
13 Low inlet pressure of stator cooling water or High outlet temperature of stator cooling water	An alarm of low inlet pressure of stator cooling water or High outlet temperature of stator cooling water is recommended to prevent stator	Recommendation Article 153 of inspection guideline is referred.

Emergency condition	Interpretation	Remarks
	windings overheating.	
14 Low different pressure between the generator and seal oil or Low seal oil pressure	Alarms of different pressure between the generator and seal oil or low seal oil pressure are recommended to prevent hydrogen leakage by declining of sealing effect.	Recommendation Article 153 of inspection guideline is referred.
15 High hydrogen temperature	An alarm of high hydrogen temperature is recommended to prevent the generator cooling decrease, which causes insulation deterioration. Hydrogen cooling unit maintains hydrogen temperature to the constant value, therefore this alarm indicates cooling unit fault such as temperate control valve abnormal activation, decrease of cooling water, abnormal heat transfer by dead air, and so on.	Recommendation Article 152 of inspection guideline is referred.
16 Low hydrogen purity	Alarm of low hydrogen purity should be installed to prevent explosion by the decrease of hydrogen purity.	This is stipulated in Article 256,264 of operation and maintenance guideline. In addition, Article 152 of inspection guideline is referred.
17 High fluctuation of hydrogen pressure	High fluctuation of hydrogen pressure alarm is recommended to be installed because of the generator cooling decrease and over pressure induced as a result of the pressure fluctuation.	Recommendation Article 152 of inspection guideline is referred.
18 High major transformer temperature	High major transformer temperature Very high major transformer temperature causes insulation deterioration and burnout. To prevent these phenomena, an alarm should be installed for less than 5,000kVA and protecting device should be installed for not less than 5,000kVA.	Recommendation

Emergency condition	Interpretation	Remarks
19 Cooling facilities failures or high temperature in forced cooled major transformer	In forced cooled major transformers, the coolant is circulated by the pump, and in some cases the coolant is cooled by fans. Cooling facilities failures means the coolant circulation stop, which results in overheat or fires of the transformer.	Recommendation

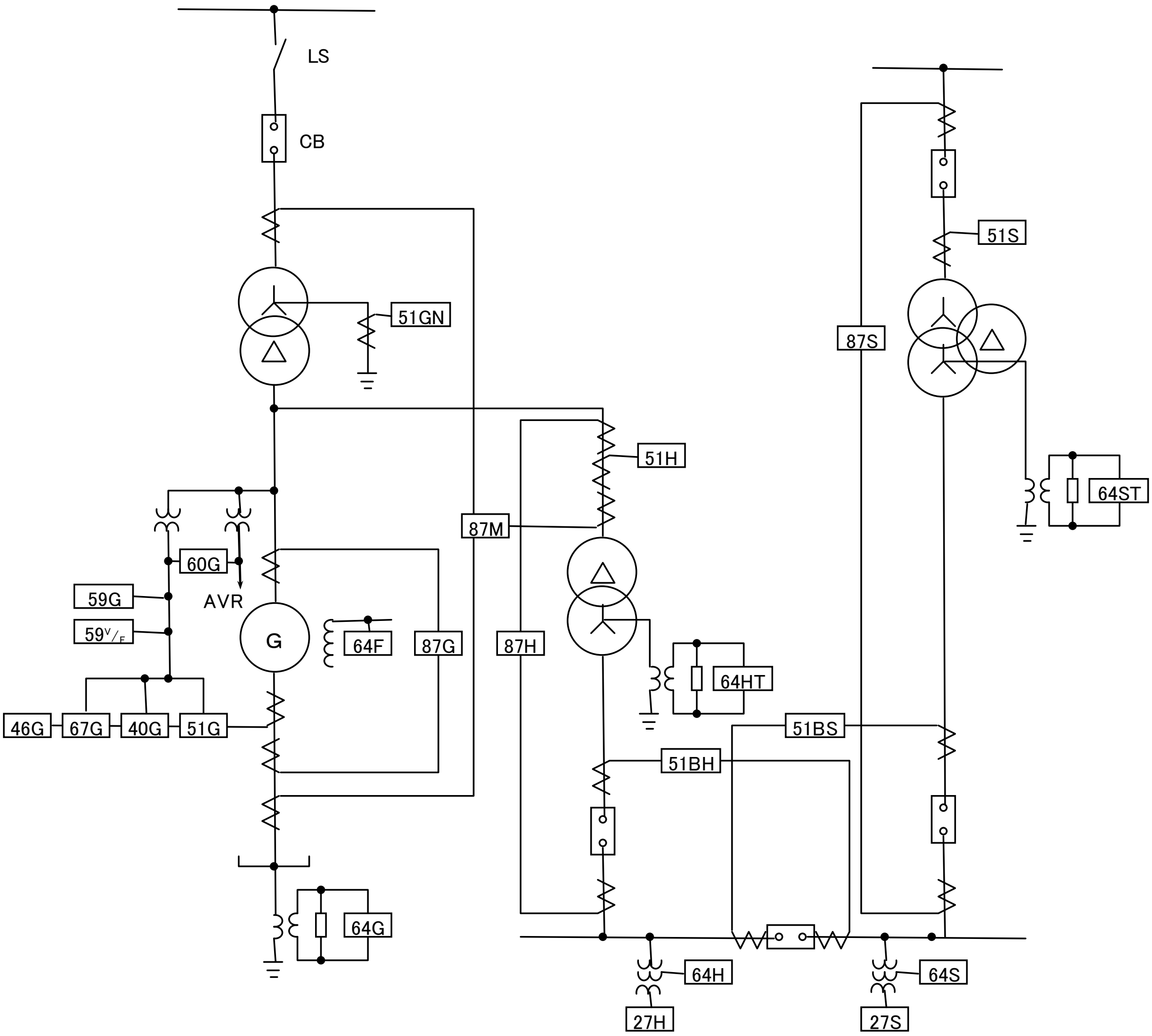


Fig- 45 An example of protecting relays in the electric power line for thermal power

87 Differential protective relay

64 Ground detector relay

51 Ac time over-current relay

67 Ac directional over-current relay

59 Over voltage relay

60 Voltage or current balance relay

46 Reverse-phase or phase-balance

27 Alternate current low voltage relay

Article 255. Protection for major auxiliary machinery

1. General

The major auxiliary machinery means auxiliary machines which restrict normal operation of the boiler, turbine and generator.

Their protections are shown as follows:

Table- 49 Protections of auxiliary machines (pump)

№	Category	Emergency condition	Shut down	Alarm	Remarks
1	Pump	Low bearing oil pressure	X		Motor feed water pump
2		Low inlet pressure	X		Fuel pump ,etc
3		Low level of inlet tank	X		Boiler circulation pump ,etc
4		High cooling water temperature		X	
5		Excessive vibration		X	
6		Electric failure	X		

Table- 50 Protections of auxiliary machines (Axial flow type fan)

№	Category	Emergency condition	Shut down	Alarm	Remarks
1	Axial flow type fan	Low bearing oil pressure	X		Fans with rotor blade control such as forced draft fans, or induced draft fans, or primary air fans
2		Low control oil pressure		X	
3		High bearing temperature		X	
4		Fan surging		X	
5		Excessive vibration		X	
6		Electric failure	X		

Table- 51 Protections of auxiliary machines (Centrifugal type fan)

№	Category	Emergency condition	Shut down	Alarm	Remarks
1	Centrifugal type fan	Low bearing oil pressure	X		Forced draft fans, or induced draft fans, or primary air fans, etc
2		High bearing temperature		X	
3		Excessive vibration		X	
4		Electric failure	X		

Table- 52 Protections of auxiliary machines (Axial flow type fan)

№	Category	Emergency condition	Shut down	Alarm	Remarks
1	Pulverizer	Lubricating oil pressure	X		
2		High bearing temperature		X	
3		Abnormal condition of pressurizing equipment		X	
4		Low seal air pressure		X	
5		Abnormal condition of pulverizer difference pressure		X	In the case of a vertical form mill
6		Abnormal level of pulverizer		X	In the case of the horizontal type mill
7		Excessive vibration		X	
8		Electric failure	X		

2. Details

Protective items from Table-49 to Table-52 are explained as follows:

(1) Low bearing oil pressure

If bearing oil pressure decreases, the pump is shut down automatically because oil film is not formed correctly, and this may cause bearing destruction by heat.

(2) Low inlet pressure

If the suction pressure of a pump declines, it is recommended to shut down automatically because there is a risk of starting cavitation.

(3) Low level of inlet tank

If the water level of an inlet tank water decreases, there is a risk that steam may flow into a pump, and the risk of cavitation increases, the pump is shut down automatically.

(4) High cooling water temperature

As for a flooded type pump like a boiler circulation pump, all the motor is cooled by the cooling water, and temperature rise of cooling water may result in damage to a motor, therefore, alarming is recommended.

(5) High bearing temperature

If a bearing metal temperature rise continues due to the cooling capacity degradation, the bearing may be damaged by high temperature, therefore, alarming is recommended.

(6) Low control oil pressure

As a result of control oil-pressure decrease, fan’s rotor blade operation which controls air flow, becomes impossible because control oil is used for operating a fan's rotor blade control. For this reason, alarming is recommended.

(7) Fan surging

Since there is a risk of causing damage to a fan, by the fan surging, alarming is recommended.

(8) Abnormal condition of pulverizer difference pressure, Abnormal level of pulverizer

These phenomena indicate increase of mill retaining coal. Excessive coal may interfere with the mill operation, therefore, alarming is recommended.

(9) Abnormal condition of pressurizing equipment, low seal air pressure

Abnormal conditions in a pressurizing equipment, or abnormal mill seal air pressure, causes the risk that pulverization of coal is not performed normally or a pulverized coal may infiltrate into a lubricous part or a rotation contact part, and may damage the equipment , therefore, alarming is recommended.

(10) Lubricating oil pressure

If lubricating oil pressure decreases, the pulverizer is shut down automatically because oil film is not formed correctly, and this may cause bearing destruction by heat.

(11) Excessive vibration

In order to prevent abnormal operation of auxiliary machines with excessive vibration at the shaft or bearing, alarming is recommended.

(12) Electric failure

Since there is a risk of causing damage to a motor, by the over-current of an electric failure, the motor is shut down automatically.

Article 256. Unit interlock for power plant

1. General

As the result of the activation of protection devices, other equipment among the boilers, the turbines and generators are required to be shut down automatically to protect the unit. This is called ”Unit interlock“. Various methods are taken depending on the configuration of the facility.

The purpose of Article 256 of the design technical regulation is to acquire safety operation of all thermal power plant facilities. This guideline is based on general technology and may not be applicable entirety to the design and installation of each power station. Accordingly, it is recommended that each power station reviews this guideline and adopts such features as appear applicable and reasonable for own facilities.

2. Principles

(1) 2 out of 3 logic

The Unit interlock should be designed to prevent nuisance shutdowns and to activate protection correctly. Considering instrument failure, not less than 3 instruments are to be equipped, and if 2 out of 3 signals from them reach the protection condition, unit interlock should activate automatically. This example of signal flow is shown in Fig-46.

(2) Power Sources

Firm power supply is required for the protection circuit in case of black out or voltage dips. Generally, DC from batteries is used for protection relay circuit, and also Constant Voltage Constant Frequency or AC-DC redundant system is used for control processors as described in Article 218 of operation and maintenance guideline. In designing protection circuit, movement to the safe state during black out should be considered to prevent serious failures, causing injury to persons or significant damage to the equipment.

If the power station has plural units, the control circuit should be divided into the relevant unit not to be affected by troubles by other units.

(3) Control circuit

In general, the circuit for unit interlock is designed by circuits using relays because speed and reliability are required. The relay circuit should be designed in accordance with IEC 60204-1, IEC 60947-5-1, and IEC 60947-5-5.

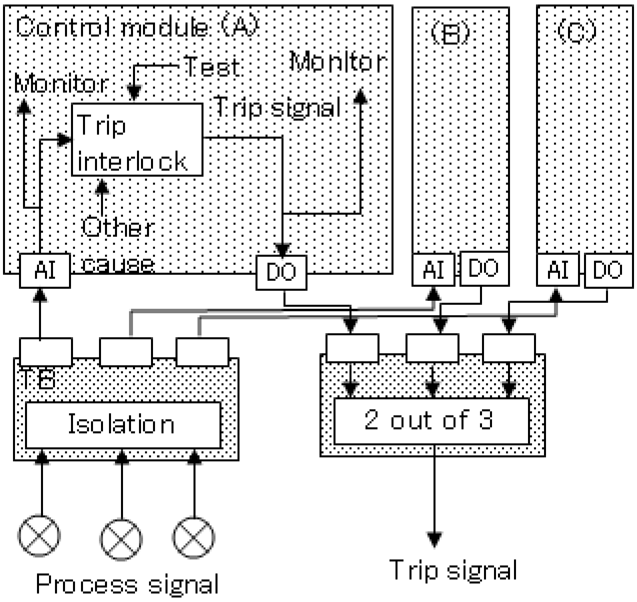


Fig- 46 An example of 2 out of 3 logic

3. Unit interlock of a conventional steam power plant

Followings are the explanation of Article256 for conventional plants.

(1) It is general to shut down the steam turbine automatically when the protection of generator is activated.

(2) When the protection instrument of boiler is actuated, one system is to shut down the boiler directly and automatically, and another system is to shut down the boiler automatically by the steam turbine shutdown.

(3) When the protection instrument of steam turbine is actuated, it is very general to shutdown the generator automatically and to open the main circuit breaker after confirming that each turbine valve is closed, in order to prevent the turbine from being overheated by motoring.

By Article252 of the technical regulation, it is very general to install the automatic cut-off equipment of steam turbine inlets, when failure occurs inside the generator whose capacity is over l0, 000kVA.

(4) When the protection instrument of steam turbine is actuated, one system is to shut down the boiler immediately after the steam turbine shutdown, and another system is to shut down the boiler only when required condition is satisfied.

The latter system is adopted in general, in case that the boiler can continue the independent operation after shutdown of the turbine (in case that there is no possibility of re-heater burnout, etc.); or that the steam of boiler is supplied to another facility.

(5) When the protection instrument of the boiler is actuated, one system is to shutdown the steam turbine automatically and immediately, another system is to shut down the steam turbine when required conditions are confirmed according to the conditions of facilities

In general, the former system is adopted when the retaining heat capacity is small as the once-through boiler, and the latter system is adopted when retaining heat capacity is large such as the circulation boiler or plural boilers are installed.

Block diagram of these activations are shown in Fig-47

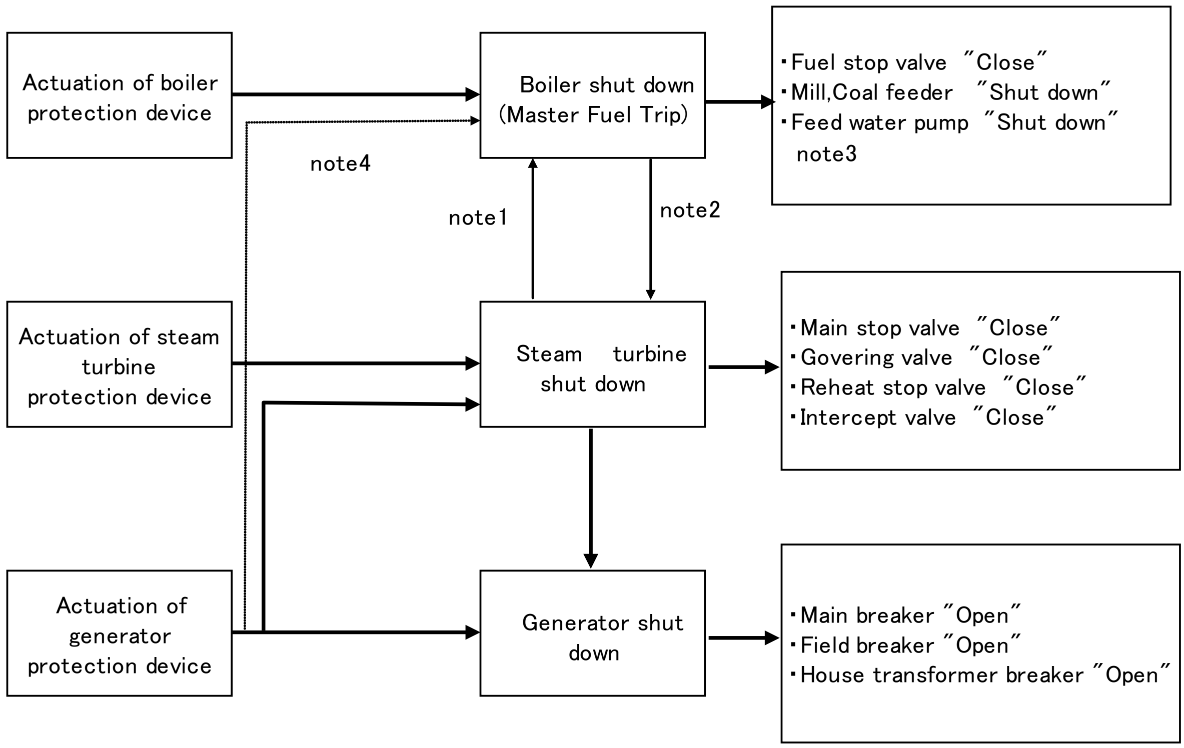


Fig- 47 An example of unit interlocks for conventional plants

Note1: When the protection instrument of steam turbine is actuated, the boiler is shut down automatically in the case of boilers without enough turbine-bypass system, or enough steam consumption. On the other hand, in case of isolated operation (fast cut back), or in the case there is enough steam consumption, this interlock is not applied.

Note2: When the protection instrument of boiler is actuated, the turbine is shut down because wet steam is harmful for turbine blades. If there is enough heat capacity in the boiler such as drum boiler, quick shut-down is not mandatory.

Note3: Rapid cooling of the boiler by feed water causes a risk of waterwall damage, therefore, quick shut-down of feed water pumps is recommended. But this interlock should not be applied to the boilers which require after-cooing by feed water.

Note4: There are two ways for the boiler shut down; the boiler is automatically shut down immediately or after automatic shutdown of the steam turbine.

4. Unit interlock of the gas turbine power plant

Followings are the meanings of the technical regulation of Article256 for gas turbine power plants.

(1) It is very general to shut down gas turbine automatically, when a generator protection instrument is actuated. In this case, one system is to shut down the gas turbine automatically and immediately according to the actuation items, and another system is to continue no-load operation by decreasing the fuel injection to gas turbine and to shutdown the gas turbine proper timing after cooling down.

By the technical regulation of Article253, it is very general to install the automatic cut-off equipment of gas turbine inlet fuel, when failure occurs inside the generator whose capacity is over l0, 000kVA.

(2) It is very general to shut down the generator automatically and to open main circuit breaker, after shut down the gas turbine, when the protection instrument of gas turbine is actuated.

Block diagram of these activations are described in Fig-48.

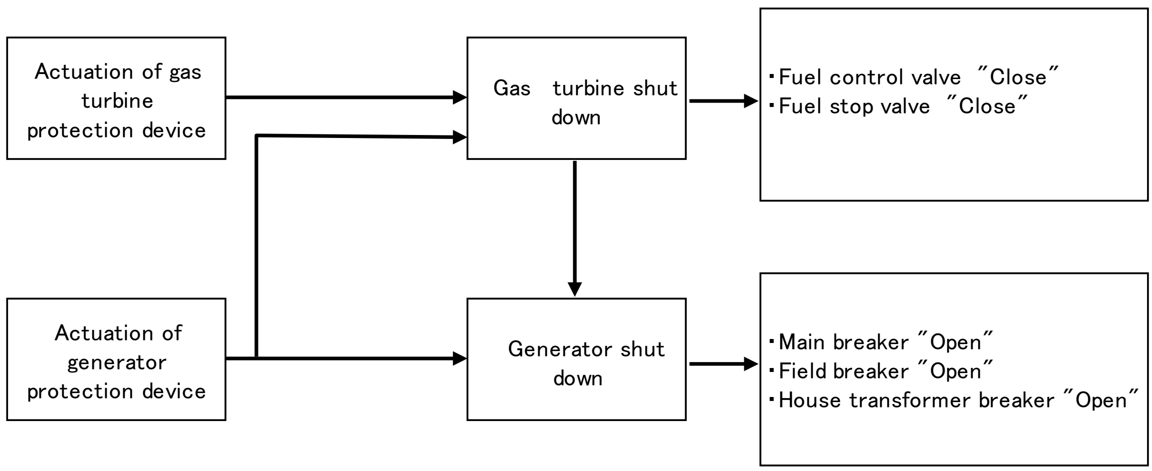


Fig- 48 An example of unit interlocks for gas turbine plants

Unit interlock of the single-shaft combined cycle power plant

Followings are the meanings of Article256 for single-shaft combined cycle power plants.

(1) Single-shaft combined cycle power plant facilities are composed by gas turbine, heat recovery steam generator using the gas turbine exhaust gas, steam turbine and generator, and are featured that gas turbine, steam turbine and generator are located on the same axis

It is general to shut down the gas turbine and the steam turbine as drivers automatically when the protection of generator is activated.

(2) When the protection instrument of gas turbine is actuated, it is general to shutdown the steam turbine on the same axis automatically and, also shutdown the generator automatically.

(3) When the protection instrument of steam turbine is actuated, it is general to shutdown the gas turbine on the same axis automatically and also shutdown the generator automatically.

(4) When the protection instrument of heat recovery steam generator is actuated, there are systems to shutdown the gas turbine automatically for interrupting the heat input to the heat recovery steam generator and also shutdown the steam turbine automatically for preventing the wet- steam flow to the steam turbine.

Block diagram of these activations are described in Fig-49

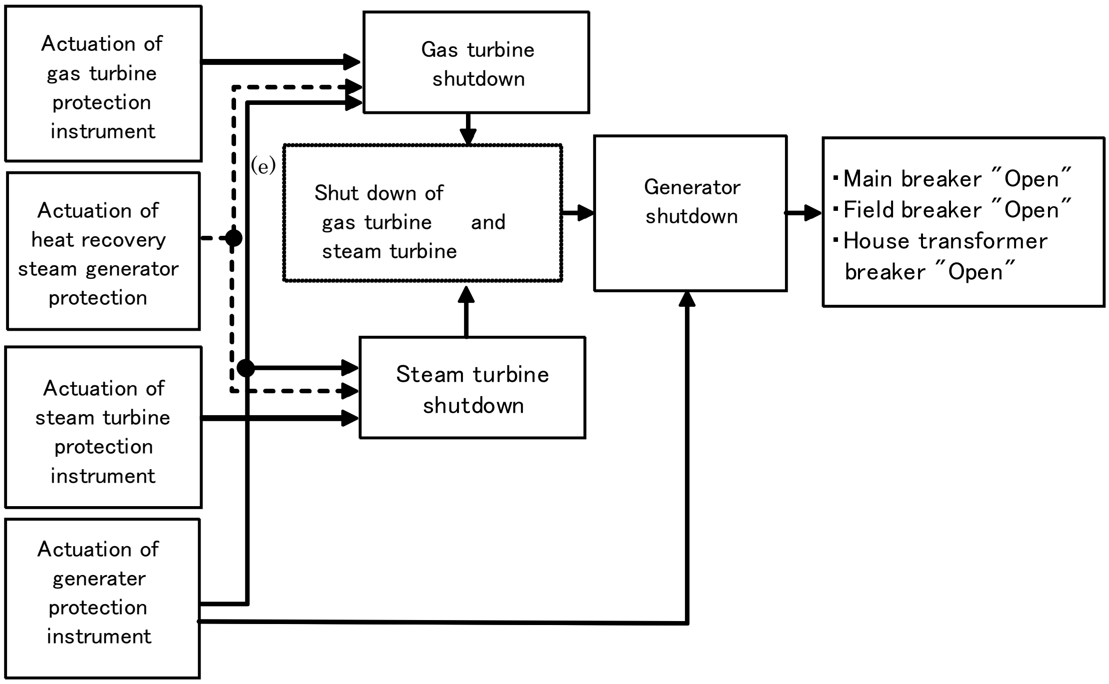


Fig- 49 An example of unit interlocks for single-shaft combined cycle power plant

5. Unit interlock of the multi-shaft combined cycle power plant

Followings are the meanings of Article256 for multi-shaft combined cycle power plants.

Multi-shaft combined power plant facilities are composed by gas turbine and its generator, heat recovery system generator using the gas turbine exhaust gas, and steam turbine and generator. In many cases, gas turbines and its generators and waste heat recovery boilers are installed plural.

(1) It is general to shutdown gas turbine automatically when gas turbine generator protection instrument is actuated. In this case, one system is to shutdown automatically the gas turbine immediately according to, the ,actuation items, and another system is to continue no-load

operation by decreasing the fuel injection to gas turbine and to shutdown the turbine at the proper timing after cooling down.

(2) It is general to shutdown gas turbine generator automatically and to open main circuit .breaker after shutdown of gas turbine, when the protection instrument of gas turbine is actuated.

(3) It is general to shutdown steam turbine automatically, when the protection instrument of steam turbine generator is activated.

(4) It is general to shutdown steam turbine generator and to open main circuit breaker, after shutdown of steam turbine when the protection instrument of steam turbine is actuated.

(5) When the protection instrument of heat recovery steam generator is actuated, there is a system to shutdown the gas turbine automatically for interrupting the heat input to the heat recovery steam generator. Besides, when the gas turbine exhaust gas can be emitted bypassing the heat recovery steam generator, it is not always necessary to shutdown the gas turbine automatically.

(6) When the protection instrument of heat, recovery steam generator is actuated, there is a system to shutdown steam turbine, immediately and automatically, and there is another system to shutdown it automatically after required conditions are confirmed as per the status of facilities. In general case of multi-shaft combined cycle power plant facilities, plural heat recovery steam generators are installed, so it is not necessary to shutdown the steam turbine automatically by the actuation of one heat recovery steam generator protection instrument. In other case of retaining heat capacity of heat recovery steam generator is large, it is not necessary to shutdown the steam turbine immediately and automatically by the actuation of one heat recovery steam generator protection instrument.

(7) When the protection instrument of gas turbine is actuated and the, shutdown of gas turbine occurs, there is one system to shutdown steam turbine immediately and automatically, and there is another system to shutdown it automatically after required conditions are confirmed as per the status of facilities. In general case of multi-shaft combined cycle power plant facilities plural gas turbines are installed, it is not necessary to shutdown the steam turbine immediately and automatically by shutdown of one gas turbine.

Block diagram of these activations are described in Fig-50.

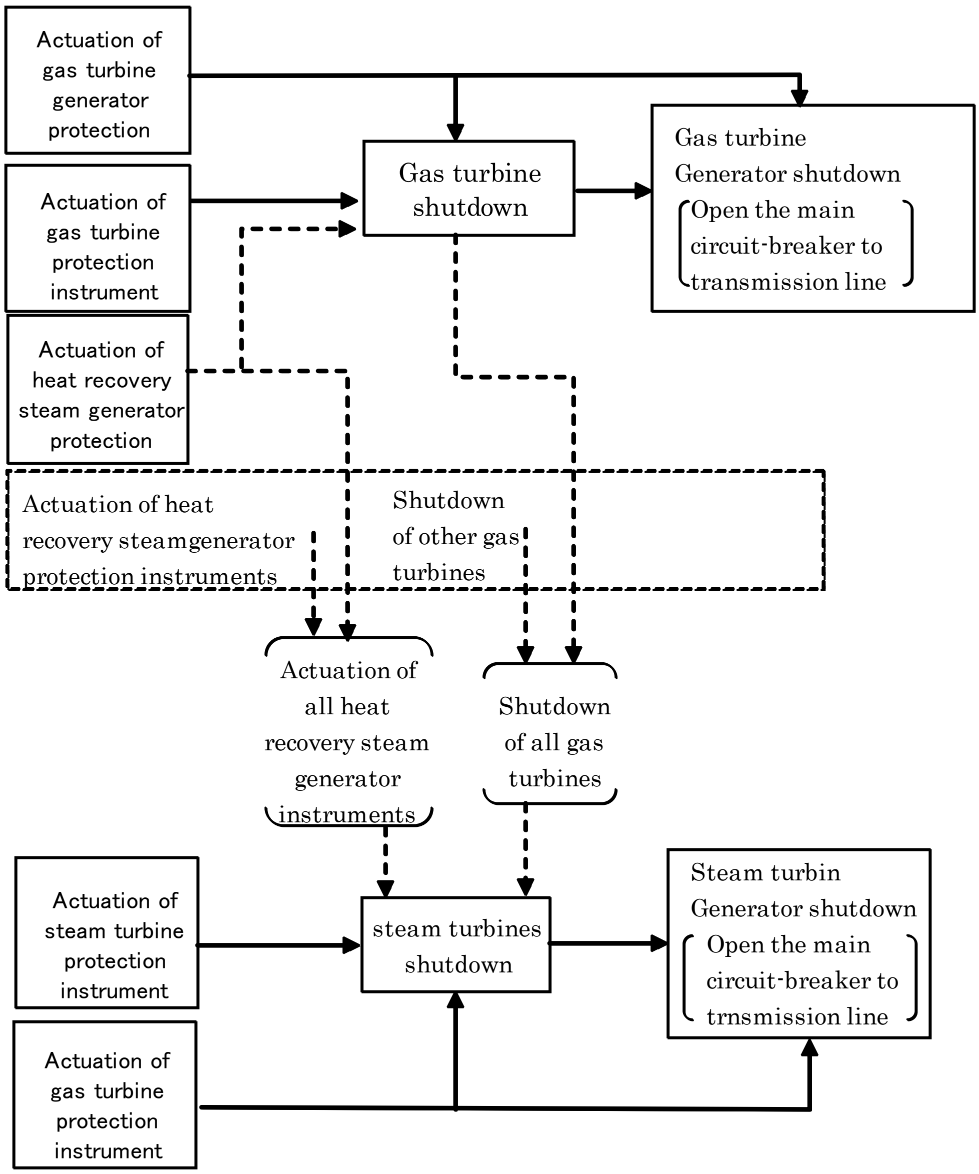


Fig- 50 An example of unit interlocks for multi-shaft combined cycle power plant

Section 6 SCADA/EMS System

Article 257. General provision

1. This guideline specifies necessity or desirable functions as supervisory, alarm, and an operating unit for the security to an operator and facilities, and for functional maintenance; however, it does not specify the method, unless it is specified in particular.

2. Even if supervisory, alarm and operating units are not based on the unit for exclusive use, the functions should just be achieved by a certain method.

   For example, when the function is synthetically achieved by a computer etc., it is not necessary to form a unit for exclusive use.

   Concerning the functions of the computer, examples are referred to Article 258-1 of this guideline.

   In addition, the functions of a supervisory, alarms, and operation are generally described here, and if they have the same meaning or functions, they do not have to be the same.

Article 258. SCADA/EMS system

Article 258-1. SCADA/EMS system

1. General

   Using SCADA/EMS system functions, stipulated in paragraph 5 or 7 in this article, help to achieve the purpose of the Decision provided in Article 258 of the design technical regulation.

2. Abstract of SCADA/EMS system

   The SCADA/EMS system usually refers to centralized systems which monitor and control entire sites, or systems spread out over large areas (from a plant to a nationwide). Most control actions are performed automatically by Distributed Control Systems etc. Host control functions are usually restricted to basic overriding or supervisory level intervention. For example, a DCS may control the flow of cooling water through part of an industrial process, but the SCADA system may allow operators to change the set points of the control, and enable alarm conditions, such as loss of flow and high temperature, to be displayed and recorded. The SCADA system monitors the overall performance of the control.

   For process automation, there are five levels in production.

   - Level 0: The physical level: sensors, actuators and process equipment;
   - Level 1: Sensor output, commands for actuators and computerized control and monitoring (PLC, DCS);
   - Level 2: Supervisory control level (SCADA) and Human-Machine Interface;
   - Level 3: Manufacturing Execution System: support of the best possible use of production resources, base materials and people for production (operations);
   - Level 4: Enterprise Resource Planning including business planning and logistics such as Enterprise Resource Management and Supply Chain Management

SCADA performs the following tasks:

(1) Visualization and operation of process components in various places
(Human-machine interaction)

(2) Controlled data exchange with the process control level, such as Distributed Control Systems (DCS) and Programmable Logic Controller (PLC)

(3) Alarm management, trend analysis and reports

(4) Logging and storage of historical data

(5) Handling batch operations - optional in a SCADA package.

(6) User management

(7) Data analysis and processing

(8) Controlled data exchange with the administrative domain.

SCADA specifies implementation of process control systems which is called Distributed Control Systems (DCS).This system monitors and control systems from the measuring instrument to the control console. Generally, process control systems are spread over large distances and have programmed control functions in the system. DCS are used in large stand-alone facilities. The difference between SCADA and DCS is becoming less and this is the reasons why the term SCADA is used generically.

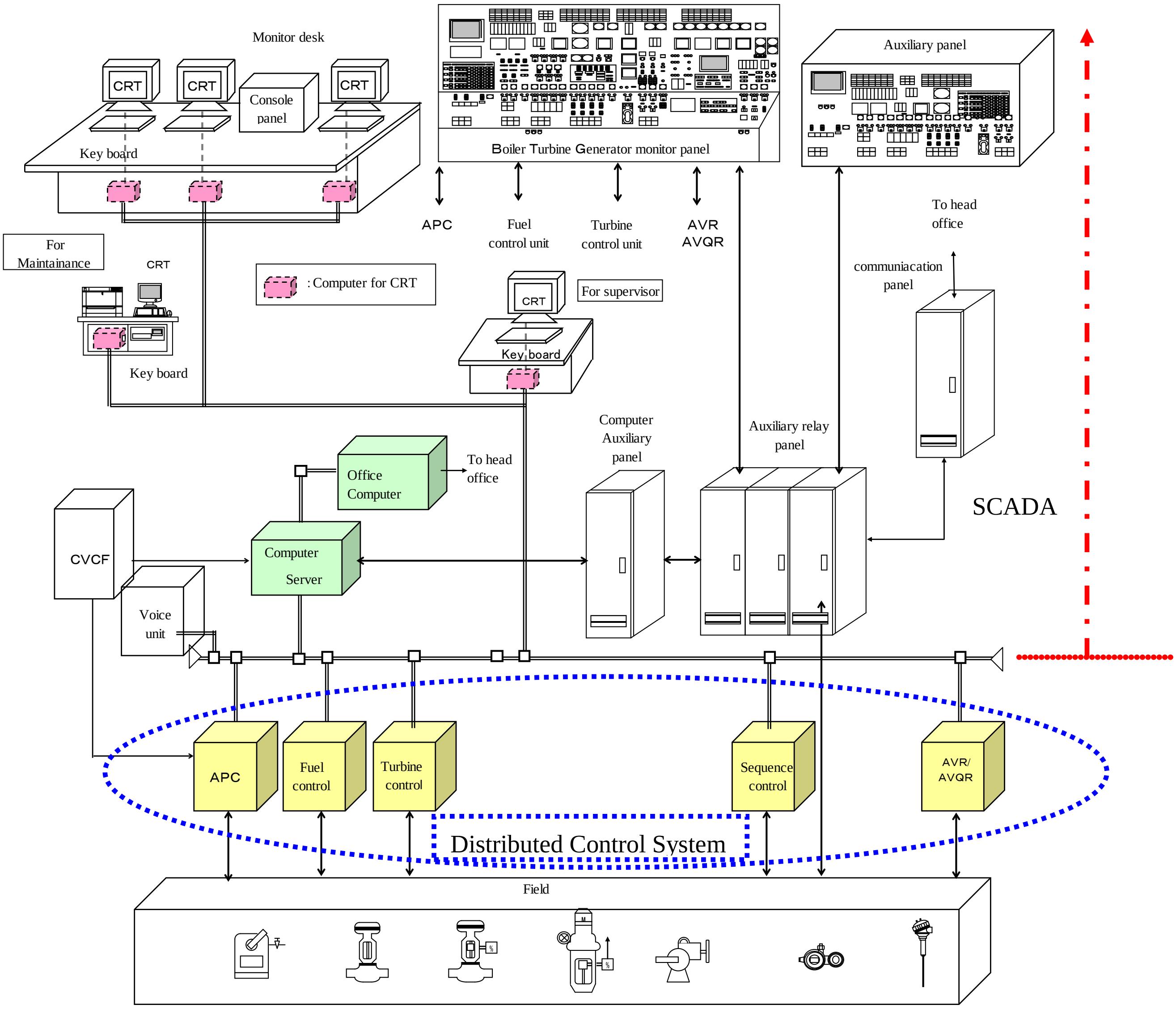
An example of SCADA/EMS system and control system is shown in Fig-51.

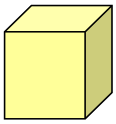
Data measured by instruments is transmitted to the DCS or PLC processor by analog or digital signal.

Most of collected data is transmitted to the computer server and monitored by operators through Cathode Ray Tube (CRT) .Alarms are also notified in the same way or by displaying on the control panel. Thus, installing by CRT operation system reduces numbers and area of control panels and enables better Human Machine Interface.

Data is also transmitted to the administrative section of the organization by way of the Office Automation (OA) computer.

In some cases, the computer sends set value of control or kick off signals to the DCS or PLC.





Distributed Control System

AVR: Automatic Voltage Regurator
CVCF:Constant Voltage Constant Frequncy
APC :Automatic Plant Control

Fig- 51 An example of SCADA/EMS system and control system

3. Security issues

SCADA systems are used to control and monitor physical process in thermal power stations. The security of these SCADA systems is important because compromise or destruction of these systems would impact multiple areas far from the original area. For example, a blackout caused by a compromised electrical SCADA system would cause financial losses to all the customers that received electricity from that source.

There are two distinct threats to a SCADA system. First is the threat of unauthorized access to the control software, whether it be human access or changes induced intentionally or accidentally by virus infections and other software threats residing on the control host machine. Second is the threat of packet access to the network segments hosting SCADA.

There are some examples of measures such as

- Protecting by the idea of “defense in depth”
- Separating SCADA from office automation environments
- Securing links to the SCADA environment using exclusive communication lines
- Securing SCADA systems and network components
- Securing protection of the SCADA environment
- Issuing password policy for the SCADA environment
- Managing media in the SCADA environment
- Prohibiting unauthorized access of both machines and personnel to SCADA
- Selecting protocols
- Providing anti-virus software of latest version

4. Requirements for SCADA

(1) Requirement for the supervisory units

Supervisory units are composed of indicating and recording units.

Following items are to be considered in the supervisory units in thermal power stations.

1) It is required to install the stable supervisory unit for the purpose of carrying out maintenance and operation of facilities efficiently.

2) It should be considered not to inform incorrect data as the indication of the measurement result.

3) It is desirable to consider so that lack of the measurement in the record may not occur due to the abnormal conditions, etc.

The purpose of the supervisory units is to record the measurement result, and to indicate the measurement result to an operator.

“To indicate” means to display measurement result at central control room, in this case.

As the methods of indication, there are various ways of using the indicator or recording instruments in the operator control panel or the operator display terminal, or using an indicator included in automatic/manual station, or displaying on a Visual Display Terminal in numerical or graphic form.

The indication of graphic panel at the operator control panel, or by the graphic representation of VDT, etc may be used in order to enable to grasp a measurement point immediately.

As a method of record, it may be a synchronous system or a multipoint recorder, or it may memorize to electronic media and display or print in a numerical or a graphic way, when required.

For thermal power stations, supervisory units' failure should be avoided for safety. To prevent lack of the measurement, hardware of SCADA is recommended to be installed in atmospheres for promoting long life of electronic components and be consistent with manufacturer's specifications such as temperature, humidity, vibration, voltage extremes, electromagnetic compatibility, altitude, contaminants, radiation, etc.

As for electromagnetic compatibility, IEC61298-3 and IEC61326-1 are referred in addition to IEC 61000 series. Both emission and immunity should be considered. Items of voltage dips, power interruption, frequency, disturbance induced by radio-frequency fields, surge, burst, electrostatic discharge etc are recommended to be checked according to IEC6100-4 during the test in the factory before installation as well as functional tests of software and hardware. According to IEC60038, hardware of SCADA should operate in the voltage of 10% deviation from the rated value.

Most hardware of the SCADA is recommended to be equipped in control rooms to satisfy the manufacturer's specification. However, for some field facilities, environment for some instruments should be considered by providing special instruments or installation of protection measures such as enclosures, heaters, coolers or seal air if needed.

Protection degrees of enclosures are specified by IP (International Protection) code shown in IEC 60529.

In the critical installations, reliability is enhanced by having redundant hardware and communications channels.

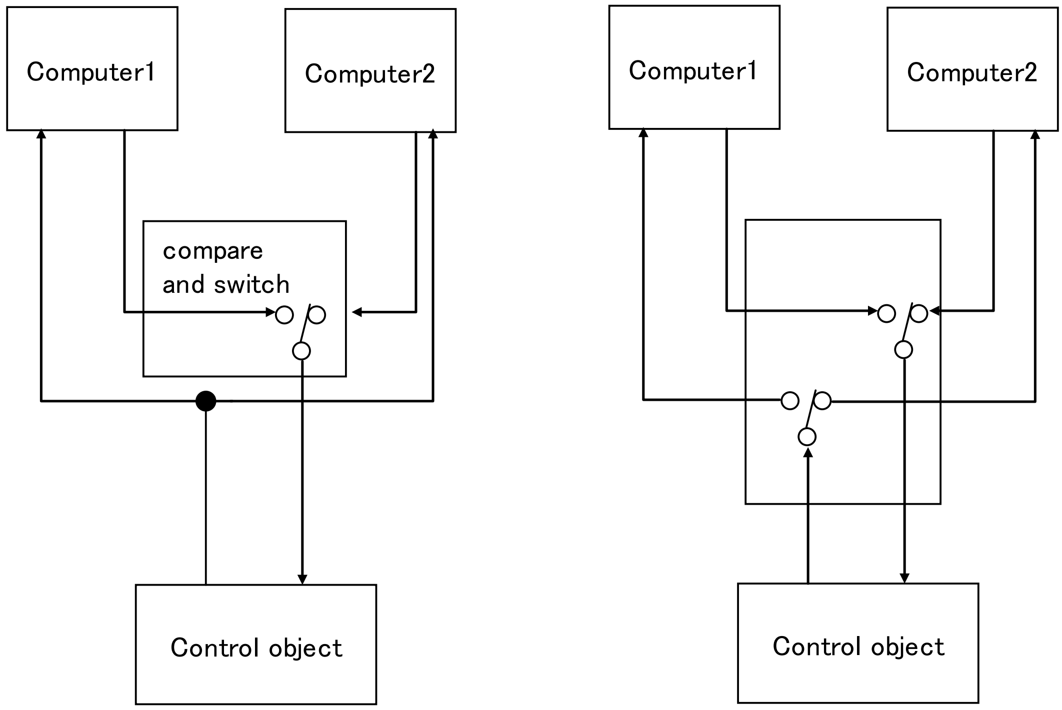
Moreover, power supply is recommended to be redundant for important process, as described in Article 218 of operation and maintenance guideline.

Redundant system may prevent lack of the measurement by identifying the failing part and by taking over to backup hardware, quickly, functionality and automatically without interrupting the process.

There are two kinds of redundant system, dual control system and duplex control system.

Dual control system is the system that two computers compare the results of both systems in parallel and when not in agreement, the fault location diagnosis of each system is performed, and the unusual system is separated from the normal system to continue the operation.

Duplex control system is the system which continues operation during system breakdown as a single system by switching to another computer which is processing the standby or another function. It takes a little time to switch. Examples of redundant system are shown in Fig-52.



Dual control system

Duplex control system

Fig- 52 Examples of redundant system

(2) Requirements for the alarm units

During abnormal conditions, alarm units notify it to an operator correctly and quickly. Operators perform the required measures corresponding to alarms for the purpose of carrying out maintenance and operation of facilities efficiently.

Followings are the requirements for the alarm units.

1) It is required for thermal power stations to install alarm equipment for the purpose of carrying out maintenance and operation of facilities efficiently.

2) Items of alarms recommended to be installed are stipulated in Article from 251 to 256 as emergency conditions.

3) In addition to these alarms, it is recommended to install the alarm equipment according to the necessity.

4) It is desirable to consider so that the alarm may operate, when required irrespective of the operational status of the main or auxiliary facilities.

5) It is desirable to consider so that personnel can recognize the content of the alarm correctly and immediately in notifying the alarms.

As for detecting alarms, there are methods by primary detection like sensors, such as a pressure switch, a thermostat, and by the secondary detection using the recording instrument or digital unit or a computer equipped in the operator control panel etc.

As for notifying alarms, there are methods by an alarm unit equipped in the operator control panel or methods notifying by devices equipped in the controller or, indicator, or recorder methods notifying by digital units or visual display terminal of the computer.

The content of an alarm should be considered so that an operator may not recognize incorrectly.

Therefore, the following methodologies may be taken.

- Alarms are indicated by according to the importance, dividing into various degrees ranging from what requires urgency to the slight thing which is only an attention.
- After common alarms are notified, individual information is indicated by the lamp display or Visual-Display-Terminal view in the equipment, or by a printing.

In the method of notifying with common alarms, when two or more factors generate alarms simultaneously or continuously, it is necessary to consider the operating instruction and the location of confirmation in order to prevent wrong recognition of alarm causes, and to avoid unnecessary confusion.

(3) Requirement for the operating units

1) It is required for thermal power stations to install operating equipment for the purpose of carrying out maintenance and operation of facilities efficiently.

2) It is desirable to consider so that they can be operated, when required irrespective of the operational status of the main or auxiliary facilities.

3) It should be considered not to make an operational mistake during the operation of operating units.

Operating units are devices for actuating or commanding to facilities or control devices in the thermal power stations, and these actions are performed by automatic/manual station equipped in the operator control panel or the operator display terminal or a signal set station, or a visual display terminal of a digital unit or a computer.

It is necessary to consider so that an operator may not make an operational mistake by considering man-machine interface.

As a category of operation, there are what operates the equipment individually, and what gives the set value of the control objectives, and startup or shutdown kick signals to the automatic controller.

5. Examples of SCADA functions

(1) Supervisory computer

1) Objectives and configuration

Supervisory computers have objectives such as supervisory, alarming, operation, and automation control, informing their status to an operator in the main control room using Visual-Display-Terminals, printers, or indicators equipped in the main control room.

The supervisory computer may consist of a single computer or distributed digital units, therefore, various configurations can be composed.

There are machines which have similar functions such as Cathode-Ray-Tube operation units or operator stations, data loggers, a SCADA.

Note 1: Visual-Display-Terminal is the equipment which displays the information output of computers in a letter, or graphics, etc.

Note 2: Cathode-Ray-Tube operation unit is the unit with which an operator performs operation of facilities through Visual Display Terminal etc.

Note 3: A SCADA (Supervisory Control And Data Acquisition) is a facility for supervisory control and data acquisition.

2) Functions

Table-53 shows examples of SCADA functions. Some may be omitted or added according to necessity.

Table- 53 Examples of SCADA functions

Objectives	Large category	Small category	Functions
Supervisory	Input or output	Analog signals input or output	The analog signals of the plant are inputted with the set-up period, and engineering unit translation, correction, etc. are processed. The analog signal is outputted with the set-up period.
		Contact signal input or output	Contact signals are inputted with the specified period and various kinds of processing are performed. Contact signals are outputted with the specified period.
		Pulse signals input	The pulse signals of the plant are inputted and various kinds of processing are performed.
		Transmission input or output	Analog signals and digital signals are transmitted to or received from other computers or digital units.
		Trial analog signals input	Calculations are performed to analog and contact input, and the data is processed as trial analog signals input.
		Trial digital signals input	Logic operations are performed to analog and contact input, and the data is processed as trial contacts input.
		Omit/restore	Specified signals are omitted from an input processing temporarily for the maintenance of a sensor etc. Moreover, the input processing of these omitted signals are restored.

(From previous Table)

Objectives	Large category	Small category	Functions
Supervisory	Trip sequence log		The contact signals which are directly or indirectly related to the trip of the plant are acquired outputted before and behind the trip and its result is displayed or printed.
	Historical data	Historical data printing	The data of the analog signal specified before and after the predetermined event is displayed and printed .
	Trend		The specified analog signals or specified digital signals are collected and memorized in a fixed period, and this result is displayed in a real-time or the trend historical graph.
	List displaying and printing	Data list	In the computer data, the setup data of signal names, current value, and the present status are displayed and printed as a list.
		Alarm list	The alarming items are displayed and printed as a list.
		Poor input list	Poor input items which are being generated are displayed and printed as a list.

Objectives	Large category	Small category	Functions
		Trial input signals list	Items of trial input signals are displayed and printed as a list.
		Excepting points of processing list	Excepting points of processing are displayed and printed as a list.
		Set points of alarm list	Set points of alarm list are displayed and printed as a list.
		Excepting points of alarms list	Excepting points of alarms are displayed and printed as a list.

(From previous Table)

Objectives	Large category	Small category	Functions
Supervisory	Displaying system diagrams		The system diagrams of the plant are displayed on visual display terminal (cathode ray tube), and plant data are displayed in real-time all over the diagram.
	Efficiency calculation		The plant operation efficiency etc. are calculated, displayed and printed.
	Snap shot		Data of set input points are collected and memorized and displayed and printed, if needed.
	Log	Printing	Log is printed.
		Correction	The data of log is corrected.
Alarm	Alarm	Alarm processing	Alarms generated from analog signals and a contact signals are supervised, and this result is displayed and printed or outputted to the alarm device equipped independently.
		Indication or change of alarm set points	View of the set points of alarms are indicated or changed.
		Omit/restore	Specified alarming items are omitted temporally. Moreover, omitted signals are restored.
		Setting valuable alarms	By computing the set value along with the formula defined in the computer according to the plant status, alarms are supervised, and the result is displayed and printed.
		Dead band processing	In order to prevent alarms from being generated frequently due to the input fluctuating around the set point, a dead band is prepared.

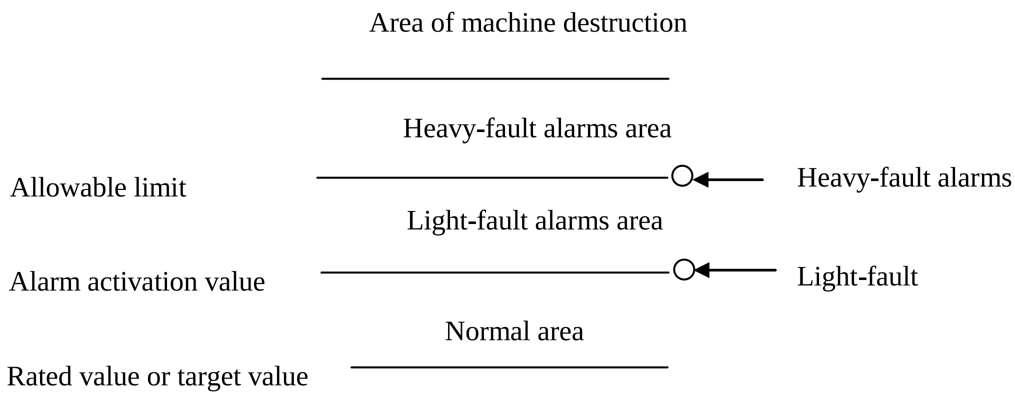
(From previous Table)

Objectives	Large category	Small category	Functions
Operation			The actuation frames similar to the conventional supervisory actuation machine are displayed on the video screen of Visual Display Terminal (Cathode Ray Tube), and the plant is operated by the analog signals.
Automation	Automation	Automation processing	According to the control logic set up before, start-up, shutdown, and normal operation of the plant are controlled. In some cases, the control for urgent failure may also be incorporated.
		Automation message processing	The status of the plant facilities corresponding to the automation control is supervised, and messages to the operation, such as conditions formation, or pending, completion of the actuation, or pending, are outputted.
			In the case of start-up/shutdown actuation in the plant, the schedule is calculated by predicting the conditions and time of main actuations. Moreover, the track record is displayed and recorded.

(2) Alarming

1) Classification of Alarms

Alarms items are classified by the following concepts according to importance.



a. Heavy-fault alarms

Heavy-fault alarm means that the alarm condition requires urgent and suitable measures by an operator.

(Examples)

(a) Trip of main machines

(b) Trip of main auxiliary machines

(c) Rapid control activation

(d) Load-run-back-operation

(e) Activation of plant protecting devices

(f) Important alarms concerning disaster prevention

b. Light-fault alarms

Light-fault alarm means that the alarm condition requires an operator confirmation, though it is not critical to the plant operation. However, if it is left with no measure, it may fall into a heavy-fault alarm level, thus an operator's suitable measure is required in this case.

(Examples)

(a) Preceding alarms which suggest trip of main machines

(b) Unusual result of measurement

(c) Control system failure at one system in the redundant control system

c. Status notification

Status notification means the status at the plant, machinery, devices which are monitored by an operator requires supervising or operation.

(Examples)

(a) What is similar to notifying the alteration of operation modes, or control modes.

(b) What is similar to the indication of operating or actuating.

2) Configuration of alarm unit

An example of the alarm equipment is shown below.

In addition, this figure is summarized so that the whole alarm equipment can be understood, and does not show the configuration of the unit.

In this case, an alarm device is installed on an operator console or an operator control panel, and individual alarms and common alarms are displayed.

As for common alarms, it is general to indicate their factors at a visual display terminal or a control unit or each local control panel.

Moreover, the common alarms may be notified again when alarms of other factors occur before the alarms of the same factors disappear.

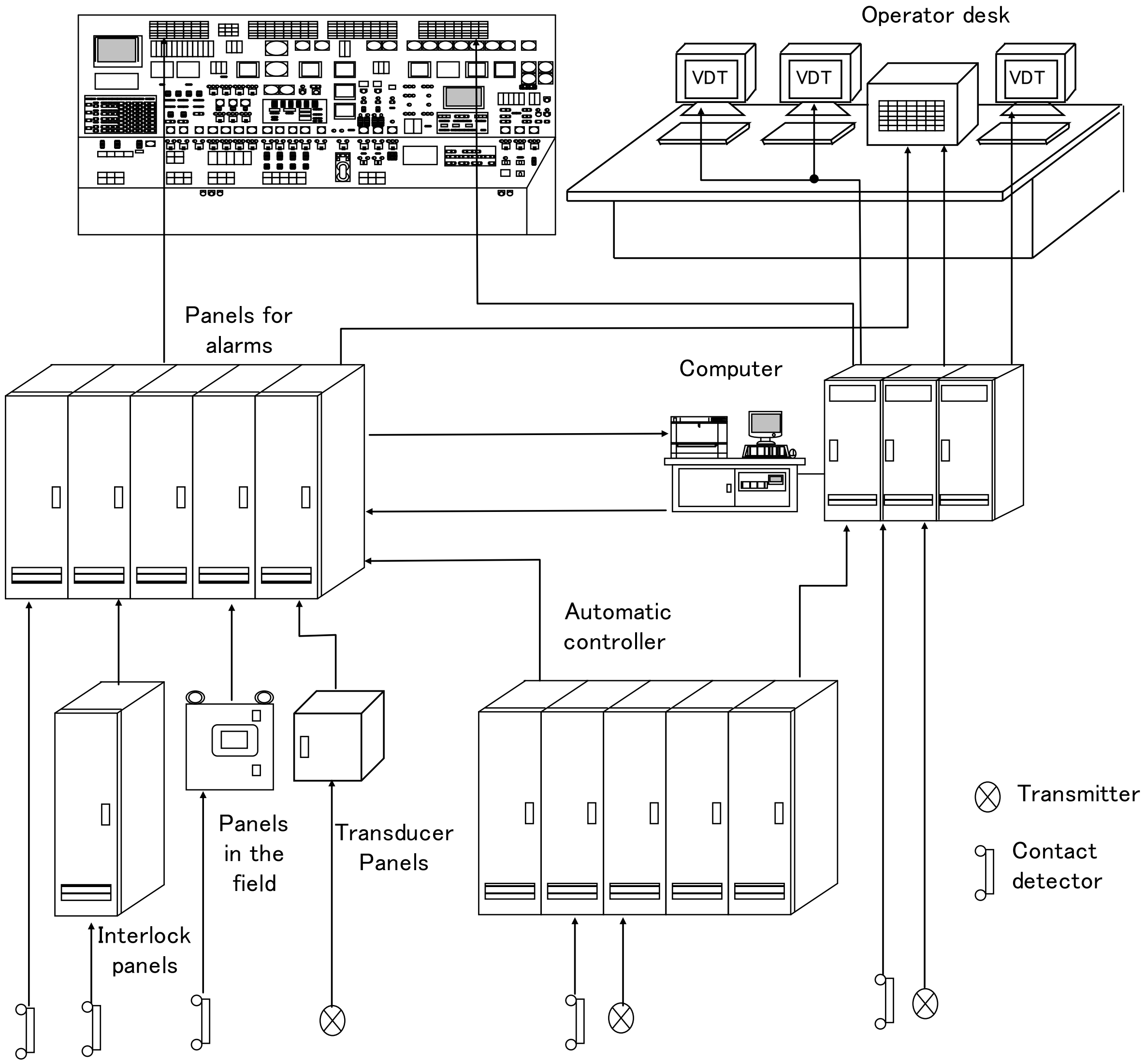


Fig- 53 Configuration of alarm unit

3) Detecting method of alarms

The alarm detection methodology includes the primary detection method and the secondary detection method.

a. Primary detection method is

The method by detecting with sensors, such as a pressure switch or a thermostat

The method of very simple and generally used system

b. Secondary detection method is

The method of alarm processing the signals from a sensor, or a transmitter, etc by the digital The method of alarm enabled by combination of transducers and alarm set station or by a digital unit or by a computer.

In following cases, secondary detection method is generally adopted

(a) In the case necessary accuracy is not acquired by the primary detection method

(b) In case of alarm processed by operation of addition, subtraction, a rate, etc.

(c) In case of setting an alarm point according to the plant status

(d) In case of a control, or automation alarm

(e) When the secondary detection method can attain rationalization compared with the primary detection method from the view of the total system.

4) Informing method of alarms

Following items are taken into alarm information so that an operator can recognize the content of the alarm correctly and immediately.

a. Alarm factors generate alarm sounds, and alarm messages are flickered or blinked on the visual display terminal.

b. Audible part of alarms stops by pushing an alarm identification button, and the alarm message of an alarm set station or visual display terminal continue lighting and indicating.

c. When an alarm factor is removed, the message of visual display terminal is eliminated after an automatic and fixed time period, and annunciator may switch off an alarm by pushing a reset button.

In addition, in order to distinguish the alarm importance easily, the following items may be taken into consideration.

d. The sounds of the alarms are divided in tone between the heavy-fault alarms and the light-failure alarms.

As examples, in the case of heavy-fault alarms or DC-power-supply loss, the bell is used, on the other hand, in the case of light-fault alarms, the chime or the buzzer is used.

e. Indication between the heavy-fault alarms and light-fault alarms is divided in colors.

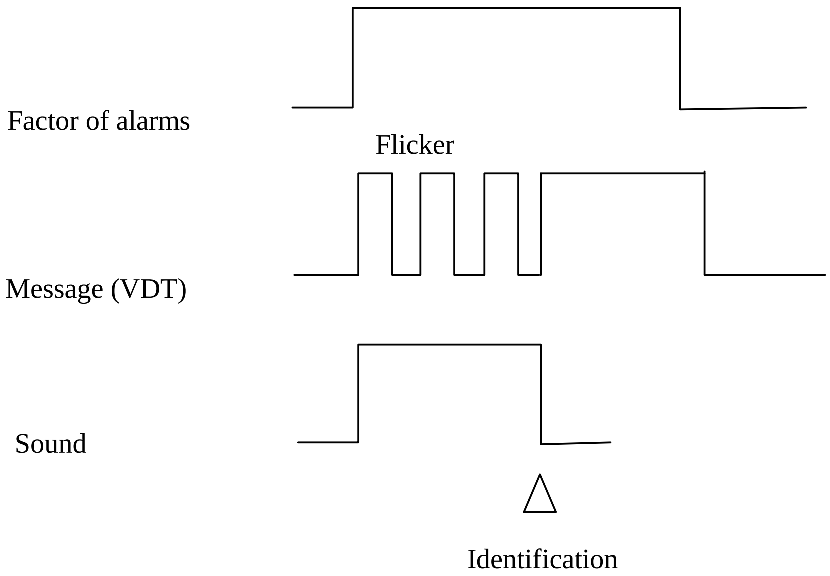


Fig- 54 An example of alarming

6. Automation

The objective of automation is improvement of control, operation, reliability, and security. The automation may be applied in following cases

(1) Start-up or shut-down control of the main machines, such as a boiler and a turbine, or auxiliary machines,

(2) The power control during normal operation and the number control of auxiliary machines

(3) Safe shutdown of the unit

(4) Conversion actuation to the special operation mode

7. Energy Management System

(1) General and objectives

It is required for electrical utilities to reduce costs and maximize use of existing facilities, while maintaining security. To achieve this requirement, effective energy management and energy conservation are important issues.

Moreover, a competitive power market increases the number of quick interchange transactions among power stations.

Under these circumstances, Energy Management System may be used to enhance energy efficiency by cutting energy consumption, with reducing emissions such as carbon dioxide.

EMS also enables to develop and implement a strategy or measures quickly, by identifying significant matters of energy consumption, such as areas or machines or fuels.

In order to improve the system performance, it is important not only to grasp and archive operation data, performance data, asset conditions and so on of all power plants, but also to integrate those individual systems into the total system.

EMS may help following management or tasks.

- Management of operation and maintenance
- Management of degradation of facilities
- Management of plant performance such as efficiency or cost
- Optimum plant operation using the data of generation, environment, fuel, efficiency etc
- Assistant management for accounting
- Total Energy management of all power stations

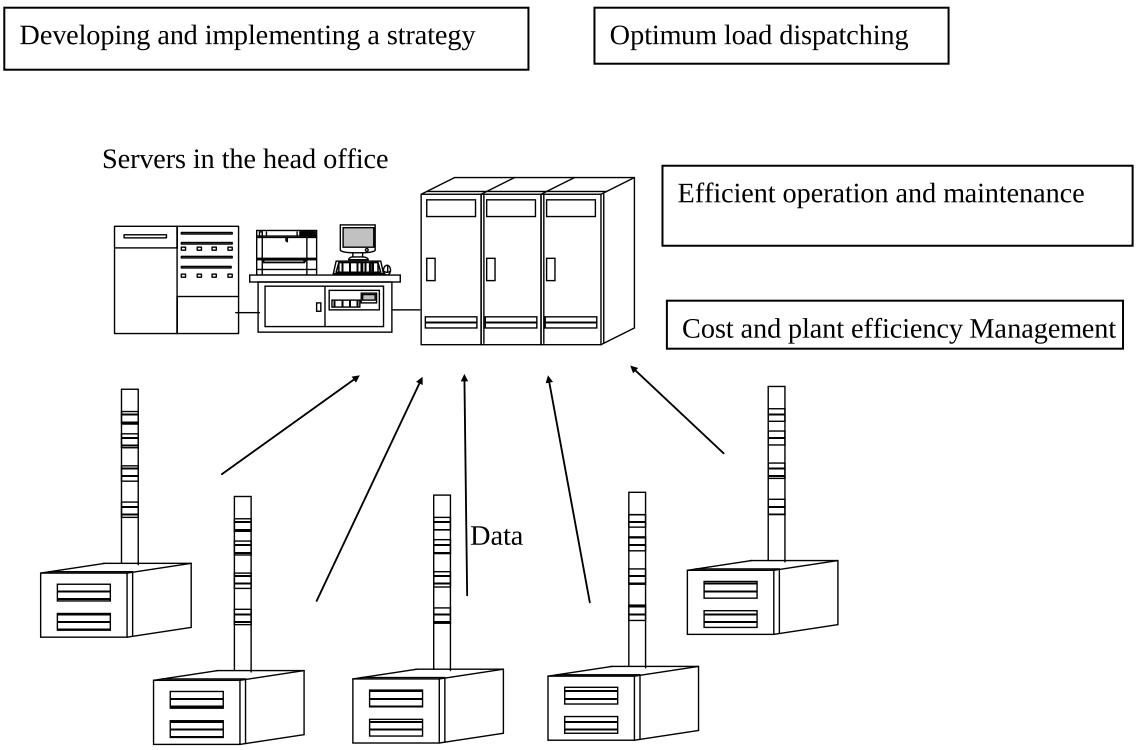


Fig- 55 Concept of EMS

In order to achieve these management or tasks, examples of functions may be as follows:

Some may be omitted or added according to the necessity.

1) Reading data from the process computer at specified intervals and saving data in the specified period.
2) Displaying with an analysis of measured data in a various forms and period according to the requirement such as optimum load dispatching or plant efficiency analysis.

3) Informing service-interruption supervisory of a power outage and power restoration to the customer or head office.

4) Remote measurement of various statuses

5) Automatic notification of the maintenance information

6) Acquiring or informing present electric power data to be utilized in both generation and consumption.

7) Cooperation with other systems such as cost accounting system.

8) Total energy management combining electric system, water system, vapor system, fuel system.

9) Searching present or past data according to the requirement.

10) Making daily, monthly, annual reports automatically

11) Recording the log of system maintenance

12) Restricting access to the system

13) Enabling end user computing

(2) System

An example of system configuration at a power station is shown in Fig-53 and its functions are shown in Fig-52.

1) Security

In order to protect the supervision and control system of the power station, firewall (FW) and multilayer defense of the transmission gateway (GW) are recommended to be installed between office-automation networks and monitor and control system in the power station.

Moreover, confidentiality can be raised by user's authentication management such as Single Sign On (SSO), and circumscription by the unit of a user, using the authenticator result to the facility

2) Data storage

Data storage enables long term analysis for operation and maintenance of thermal power stations.

For total energy management of many power stations, integrating storage area may help cost-cut by reduction of facilities and system maintenance.

Data storage area of EMS is not necessary located in the power station, therefore, can be integrated in the head office.

As stipulated before, to prevent data loss or data deficit in measurement caused by a single hardware error, database servers, application servers, and networking devices are recommended to have the redundancy configuration.

Considering disasters, the hysteresis data are recommended not only to back up each other periodically but also to be stored in distant site.

Moreover, installing transmission gateways (GW) which have backup buffer in the power station network may help to prevent data loss or deficit data in the trouble of the office automation network by resending deficit data at the time of necessity.

3) Data transmission

For correct and rapid data transmission, network performance is recommended to be estimated in advance and checked after installation. If office-automation network is used for data transmission, it is also recommended to confirm the fact that harmful effect on the regular work does not occur by real-time data transmission of EMS.

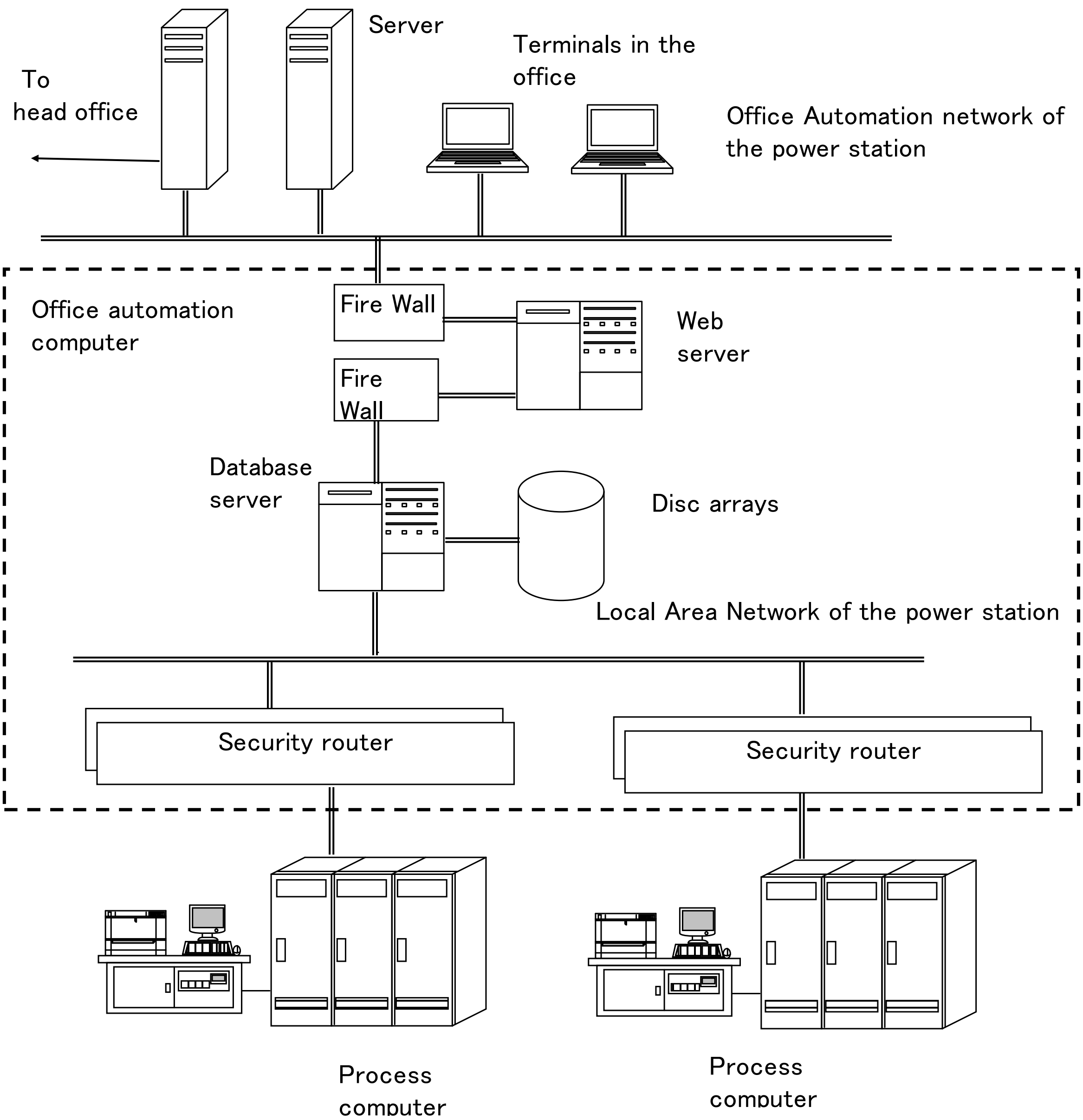


Fig- 56 An example of system configuration for EMS at the power station

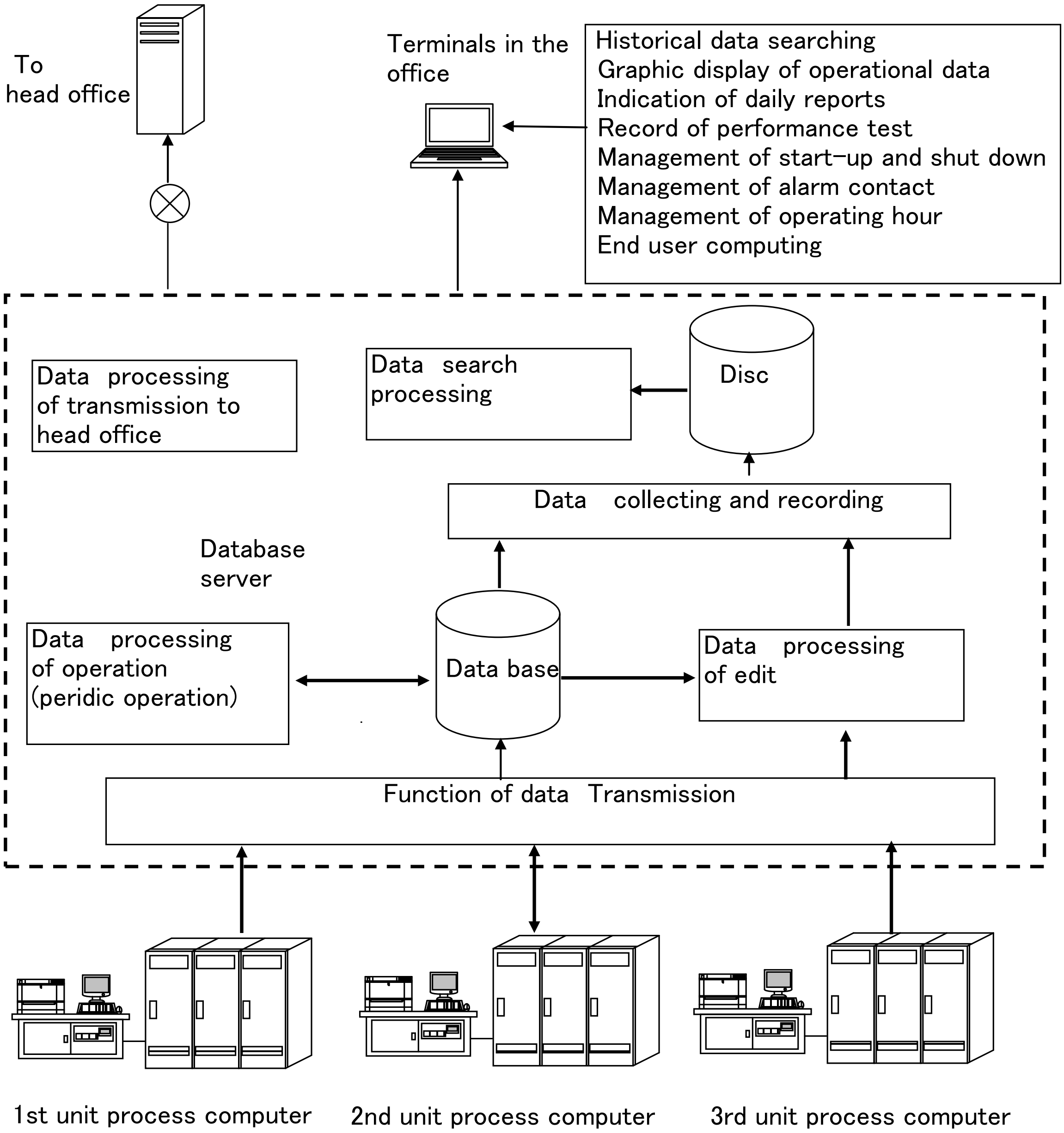


Fig- 57 An example of functions for EMS at the power station

Article 258-2. Distributed control system (DCS)

1. General

   A Distributed Control System (DCS) is a control system which the controller elements are not central in location but are distributed according to the each process to be controlled in order to improve reliability of power system and reduce impact caused by faults in power plants. The entire system of controllers is connected by networks for communication and monitoring.

The elements of a DCS may connect directly to physical equipment such as switches, transmitters and valves or they may work through an intermediate system such as a SCADA system, as described Level 1 in “2.Abstract of SCADA/EMS system”.

However, DCS may not be used in following cases.

-Protection circuits

- Safety equipment (such as emergency stop)

- When speed-control is required

-Alarm circuits (Contacts might be made by DCS)

2. Equipment of DCS

(1) Hardware features of DCS

Fig-58 shows an example of DCS configuration.

1) Processors or modules

A group of processors or modules are called various names such as Field Control Station (FCS), Process control unit (PCU) depending on the manufacture. If specified in the design, FCS or PCU can have the most of the SCADA functions of alarm, operation, supervision, automation, historical monitoring as described in Table-53.

FCS or PCU is responsible for the controlling and monitoring operation and generally designed to prevent the stop of processing due to hardware failure, as described in paragraph of “3 Functional feature of DCS”. Moreover, next item “(2) Modules of DCS” describes processors of DCS or PCU in detail.

In addition, FCS or PCU is also equipped with input output terminals, power units, connectors, alarm display, cooling fans as shown in Fig-60.

2) Input/Output (I/O) modules, Remote I/O modules

I/O modules or remote I/O modules are used to interface network with process signals.

After input, data is transmitted away from the central control room via network in order to monitor the operational condition.

3) Human Machine Interface (HMI)

Most of collected data is transmitted to the DCS and monitored by operators through Human Machine Interface (HMI) such as Cathode Ray Tube (CRT). Alarms are also notified in the same way or by displaying on the control panel. Thus, installing by CRT operation system reduces numbers and area of control panels and enables better Human Machine Interface.

HMI may include the following integrated functions depending on the owner’s specification:

- Intuitive contextual display navigation
- Faceplate control of any device in the plant
- Integrated alarm and event management with sequence-of-events

- Trend curves displaying current as well as historic values
- Comprehensive system status displays

4) Work station

Work station may include the following functions.

-Modification of the logic
-Setting or changing alarm points and items
-Setting a test value to the process value
-Adding or deleting items of signals
-Checking the signal condition inside the logic

Therefore, in addition to HMI, a work station may be installed in order to prevent the access by personnel who are not qualified. The work station may be an exclusive computer, or a personal computer. However, some manufacturers do not supply an exclusive work station because HMI has the relevant function. In this case, measures such as installing a lock on the HMI are to be taken in order to prevent access by personnel who are not qualified.

5) Type writer

The type writer is used to print out the reports, screen of HMI, log of alarms, etc.

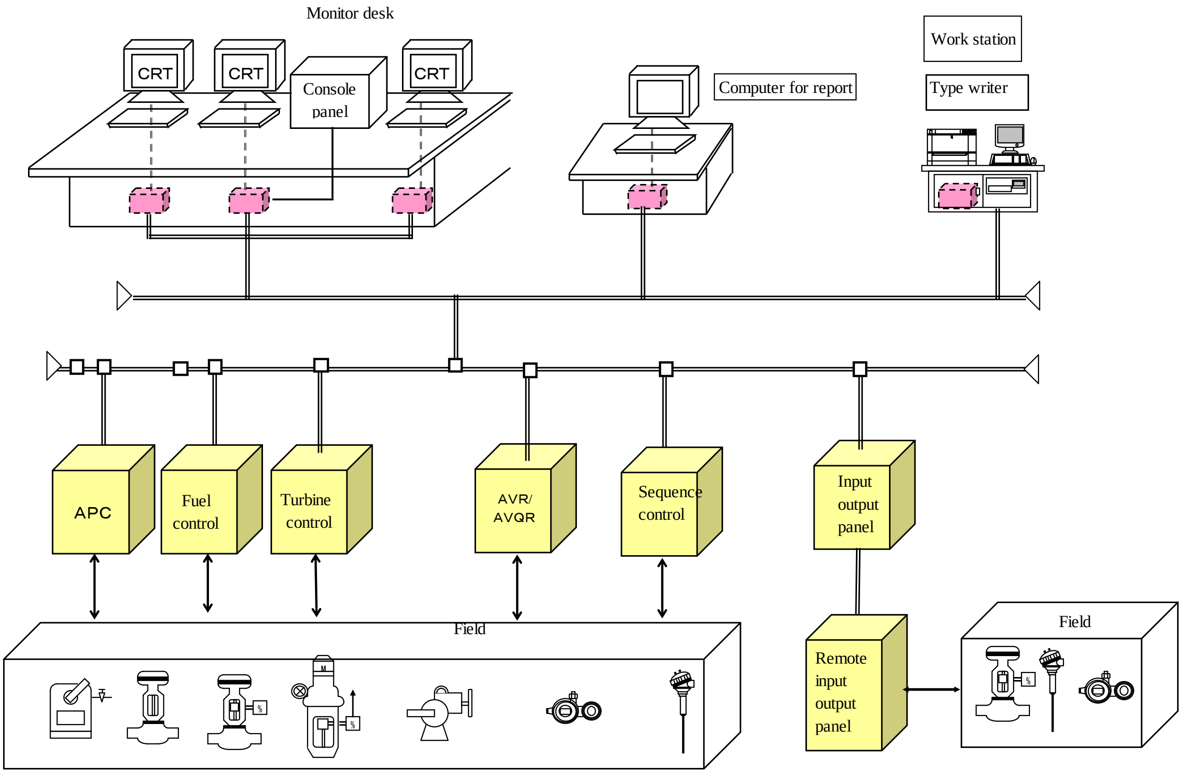


Fig- 58 An example of DCS system

(2) Modules of DCS

Modules of DCS consist of processing modules, communication modules, input-output modules and power modules. As for microprocessors, 16-bit or 32-bit microprocessors are available, and 32-bit types are common. Fig-59 shows an example of DCS module. (Processing module)
The range of operation time is approximately from 1 millisecond to 1sec, depending on the machine specifications and control process.
When speed-control is required, relay circuits or PLC or exclusive DCS are used generally.

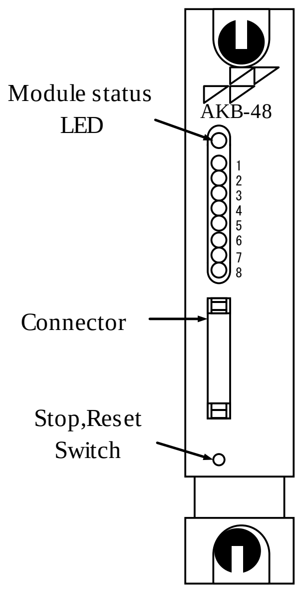


Fig- 59 An example of DCS module

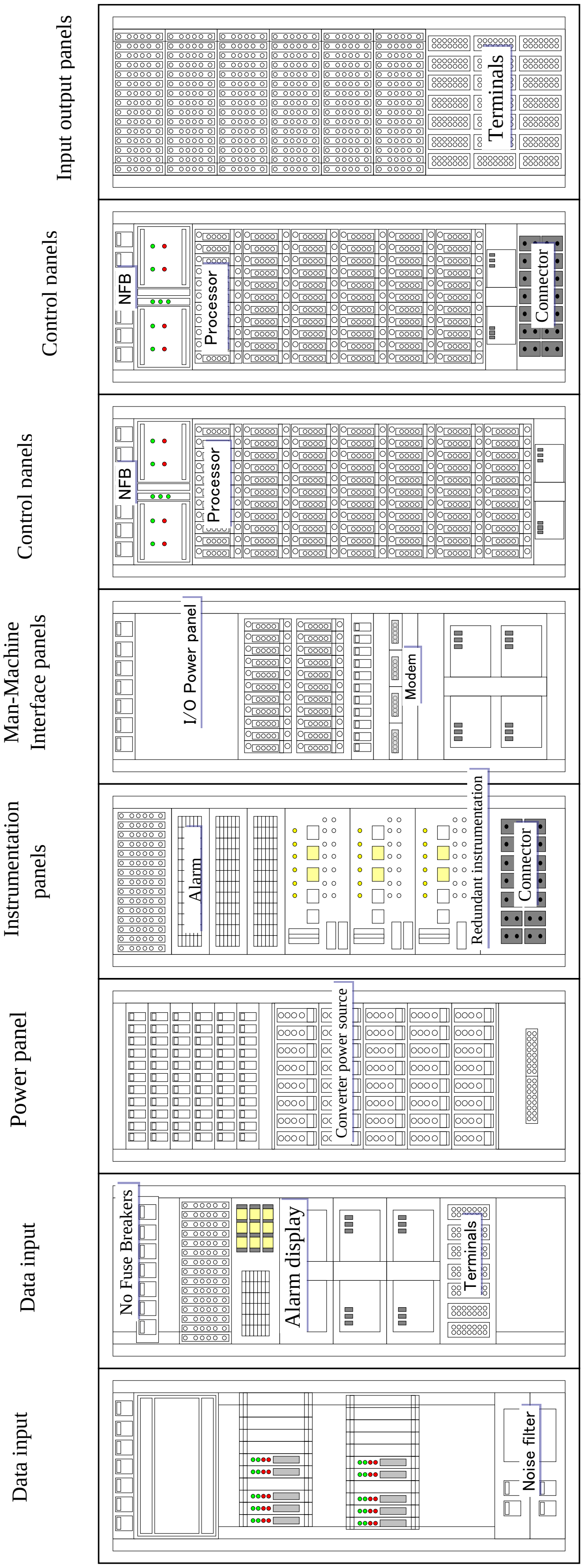


Fig- 60 An example of DCS configuration

3. Functional features of DCS

DCS is taking advantage of digital control devices, therefore DCS has following features.

(1) High reliability

Control can be processed in each processor independently; therefore, failure of one processor is limited in the relevant processor. For example, if the boiler control processors for fuel, feed-water and air-flow control are divided and the fuel control processor fails, feed-water and air-flow control can be controlled continuously and also the plant can be controlled by “turbine follow mode” by fixing fuel flow and relating demands such as feed-water or air-flow demands, as described in Article 245-2 of this guideline.

As for system failure or abnormal conditions of the control devices, self-diagnostic and system redundancy enhance reliability and shorten time for fault recovery.

Moreover, power supply is recommended to be redundant for important control process, as described in Article 218 of operation and maintenance guideline. Items of voltage dips, power interruption, frequency, disturbance induced by radio-frequency fields surge, burst, electrostatic discharge etc are recommended to be checked according to IEC6100-4 during the test in the factory before installation as well as function tests of software and hardware.

Thus, it is important not only to design or adopt hardware with high performance and reliability, but also to design system and software architecture of high independence and distribution, considering the diversifying risk.

(2) Easiness to transmit the data and easiness of operation

Making CRT monitoring screens by DCS makes “Human Machine Interface” very easy. In principle, all tags in the DCS network can be monitored.

Using CRT, DCS enables integration of monitoring and operating, while maintaining, separation of control functionality and also enables safe operation of a lot of facilities with little increasing personnel. In other words, DCS enables high level total multi unit’s control which reflects outputs or process values of other units, without increasing the control room.

For example, visualizing operating conditions makes an operator understand the plant condition very easily and very quick operation may be possible by CRT operation, with the help of voice notification, automatic sequence start-shutdown control, remote monitoring cameras, etc.

(3) Easiness to process data

It is easy for DCS to process data by using various functions equipped with. This feature enables various controls such as “main steam temperature control “applying optimum control or heat transfer calculation in the furnace.

Applying the central DCS of the identical machine among multi-units or between other units also enables unit total optimum control.

(4) System flexibility

It is relatively easy to modify hardware and software of DCS compared with PLC. However, exclusive knowledge for the relevant DCS is required for modification or improvement. Therefore, support from the manufacturer is necessary, in this case.

Moreover, transmission in one DCS system reduces number of cables, therefore; this contributes cost cut of cables, panels and installation of cables.

(5) Calculation period problem

A DCS performs time division control by dividing the time into operation period because it is a digital control device. Since a DCS has various functions, it requires a lot of processor resources. In other words, shorter operation period restricts the number of processing.

Thus, output of DCS has time delay depending on the operation period.

To utilize processor resources, longer operation period may be applied to temperature control whose response time is relatively late, if possible.

On the other hand, relay circuits or PLC or DCS for exclusive use are applied to electric control because required response time is short.

For example, shorter operation period is applied to AVR or EHC. (Approximately a few millisecond)

In general, operation period is selected from a few hundred milliseconds to 1 second, depending on the performance of the DCS and control object.

(6) Transmission problem between DCS

In designing DCS, transmission between two different DCS or other PLC becomes the issue because protocols in the network are different. Fig-61 shows an example of data transmission between two DCS. In this figure, control signals are transmitted by analog or contact signals, on the other hands, signals for monitor and alarms are transmitted by communication.

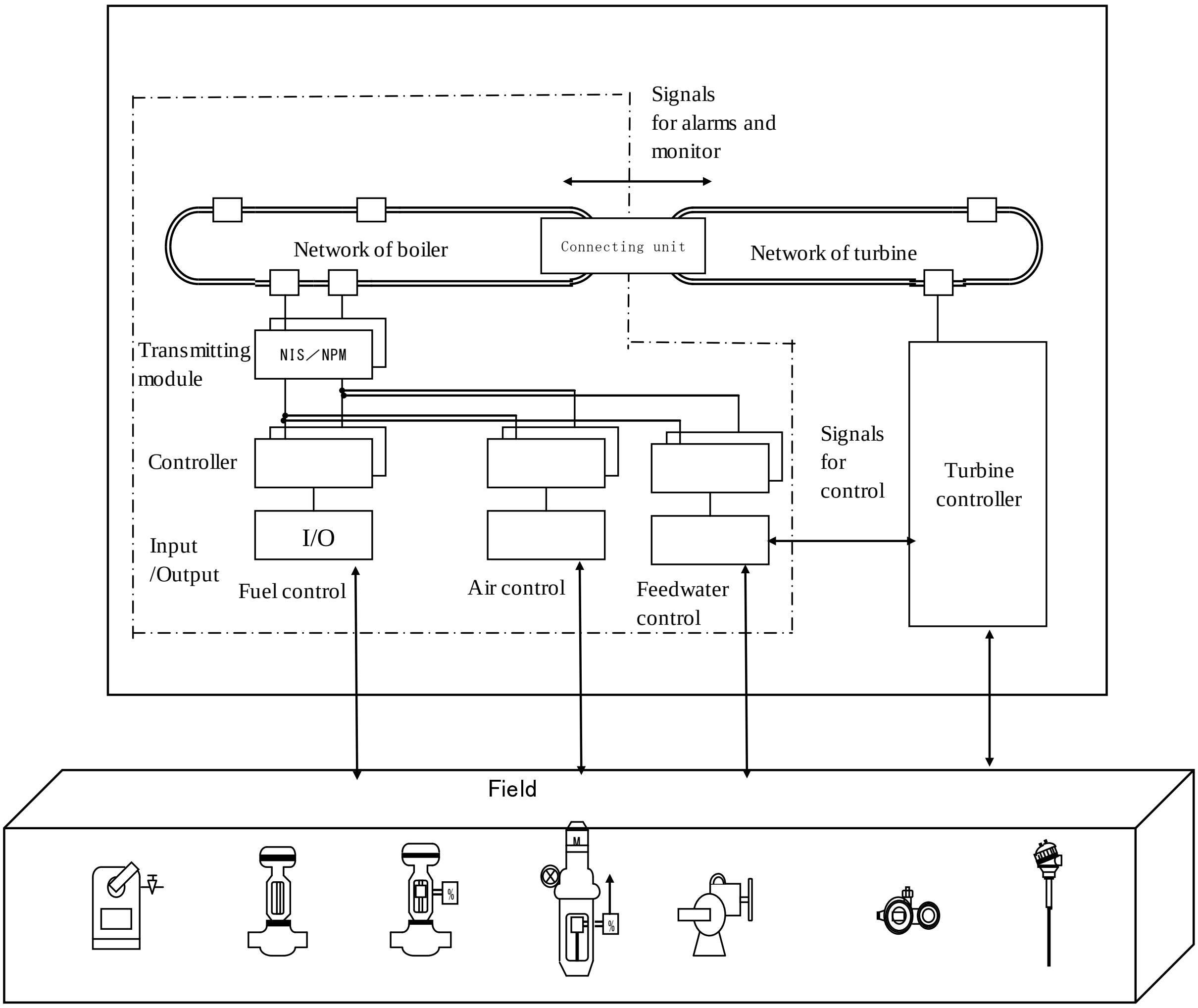


Fig- 61 An example of data transmission between DCS

Thus, data transmission between two different DCS or to other PLC or SCADA should be checked after installation. Therefore, protocols in the system are recommended to be minimized.

According to the OSI Seven Layer Model stipulated in ISO 7498, following seven layers are described

- Application layer
- Presentation layer
- Session layer
- Transport layer
- Network layer
- Data Link layer

- Physical layer

In general, gate ways may be used in connecting two different networks.

According to IEC61784-2, followings are examples of control network standards. (Real time Ethernet)

Table- 54 Examples of control network standards (Real time Ethernet)

Name	Organization
EtherNet/IP	Control Net International ODVA
PROFINET IO	PROFIBUS International
P-NET on IP	Denmark
INTERBUS PROFINET	GW INTERBUS Club
V-net/IP	JAPAN (Yokogawa)
TC-net	JAPAN (Toshiba)
Ether CAT	Ether CAT Technology Group
EPA	CHINA
MODBUS-RTPS	MODBUS-IDA
SERCOS III	Interests Group SERCOS interface e.V.

Moreover, protocols and services of real time Ethernet are described in IEC61158.

In addition, in the case of transmission between DCS and PLC, RS422 is used in general as well as analogue or contact signals.

4. Functions of DCS

DCS provides a wide variety of functional blocks of monitoring, control, operation, and sequence. Followings are examples of DCS functions.

(1) Continuous control block

For the purpose of monitoring and control of the process, the arithmetic processing is performed using process value. Blocks such as adjustable PID, input selections, manual operation, setting / signal selection etc may be available.

(2) Sequence control block

This function processes the sequence controls such as logic block sequence tables and charts, instrument switch, timer, counter, and input and output of code.

(3) Block operation

This function processes generic functions for analog and contact signals. This is an auxiliary function of a function block for continuous control, sequence control function.

5. Specification in design

(1) General

In designing DCS, IEC 61508 and 62061 are recommended to be taken into consideration.

For functional safety, these standards specify safety integrity level (SIL) considering the probability of failure on demand, severity of hazard to human, frequency and duration of hazard. Safety Integrity Level is recommended to be calculated and evaluated; combining sensors, DCS and actuators. This idea may help reducing the risk of a common cause failure.
In addition to quantity approach, quality approach used in each phase of the safety life-cycle is also specified in IEC61508. In designing process, risk and hazard should be analyzed and, overall safety requirements should be determined in each case, considering operation and maintenance conditions.

Following are examples hardware structures according to SIL. Most of control devices are classified into SIL1 or SIL2. SIL3 hardware structures are generally applied to protectors or shut down devices. In many cases, DCS may not be used directly in SIL3 system because it is difficult to attain the availability of SIL3. .In the case used in protection circuits, 2 out of 3 circuits is used as described in Article 256. In addition, SIL 4 is the highest risk that can be seen only in the nuclear industry.

Table- 55 An example of SIL and hardware structures

Safety Integrity Level	SIL1	SIL2	SIL3
Availability	0.9 to 0.99	0.99 to 0.999	0.999 to 0.9999
PFDavg (average probability of failure on demand)	10^{-2}<=PFDavg<10^{-1}	10^{-3}<=PFDavg<10^{-2}	10^{-4}<=PFDavg<10^{-3}
Logic structures that can be used	1 out of 1 ,1 out of 2 2 out of 2, 2 out of 3	1 out of 2 2 out of 2, 2 out of 3	1 out of 2 2 out of 3
Sensors and transmitters	Sensor may be binary. Redundancy is unnecessary in general.	Analog sensors may be preferable, however, binary sensors are allowed. Heterogeneous redundancy is recommended to be considered. Process is sampled by redundant system.	Analog sensors are used. Heterogeneous redundancy is recommended to be considered. Process is sampled by redundant system.
Input module	In the case of redundant sensors, the module is not necessary to be redundant in the single-channel. -Redundancy is usually unnecessary.	Input devices such as cards, I/O channels are redundant.	Input devices such as cards, I/O channels are redundant.

Safety Integrity Level	SIL1	SIL2	SIL3
Logic processor	Logic processor may be determined by users.	DCS, fail-safe solid state logic, relays, programmable electric system is used.	For protection, combination of fail-safe solid state logic, relays, programmable electric system (such as logic solver) may be used. External WDT is used in some cases.
Output module	Fail-safe diagnostic characteristics are recommended to be equipped.	Output devices such as cards, I/O channels are redundant. Diagnostic characteristics are equipped.	Output devices such as cards, I/O channels are redundant. Active diagnostic characteristics are equipped.
Control terminal (Final element such as emergency stop valve)	Feedback may be necessary in some cases.	Feedback by limit switches is necessary. Control valves cannot be used as stop valves.	Feedback by limit switches is necessary. Series type double solenoid valves are equipped.
Diagnostic function	Passive diagnostic is recommended. External WDT is recommended to be equipped.	External WDT is required to be equipped. Passive diagnostics is required. Active diagnostic is recommended to the logic solver and output	External WDT is required to be equipped.

(2) Examples to be taken into consideration in designing DCS

1) Function allocation

Optimum function allocation is necessary because there are some function similarities between DCS and SCADA. For example, DCS and SCADA have the function of data storage, therefore, some data may be transferred from DCS to SCADA after several time. In this case, data storage period and data storage capacity are the issues to be considered.

Moreover, in the case that alarms are processed by SCADA, data of alarms are also transferred from DCS to SCADA at the same time of generation. If alarms are processed in DCS, DCS should be equipped with functions described in Table-53.

Following features in Table-56 may be different between DCS and SCADA.

Table- 56 Difference between DCS and SCADA

	DCS	SCADA
Performance	Real time (Delay is not allowable)	Not real time in some cases (Delay is allowable in some cases)
Priority	Human safety	Data confidentiality
Way of operation	Continuous operation	Scheduled operation or batch operation(Continuous operation in some cases)
Measures for failures	Fail-safe (“Reboot” is not allowable.)	“Reboot” is allowable in some cases

Moreover, security measures should be taken in combination with SCADA.

2) The methods of Human Machine Interface

For good Human Machine Interface, optimum allocation of equipment is necessary among DCS (including CRT), SCADA (including CRT) and control panels.

Way of monitoring and operating should be considered totally.

For example, starting and stopping switches are classified into manual switches (emergency switches are included), or sequential starting and stopping switches of auxiliaries or the master switches or controllers.

Allocating these switches or controllers to the optimum equipment (SCADA each DCS and panels) and optimum area ensures operation safety and operation efficiency.

Switches or controllers which are important for security or required to be adjusted by an operator should be equipped in the central control room nearby the operator so that an operator can adjust, start, and stop quickly. (Processors of DCS or SCADA may be located in the relay room)

In the case of CRT operation, screens for operation and monitor should be able to be accessed quickly, and correctly by an operator, therefore, processing speed, screen configurations etc. should be considered.

In addition, some or all alarms are checked using DCS, depending on the design condition.

3) Measures for environment and electromagnetic compatibility

This item is referred to Article 258-1 of this guideline. Noise such as radio wave, static electricity, magnetic field or surge from power line may cause wrong activation of DCS. Therefore, electromagnetic conditions should be considered for installation of DCS. As for details of electromagnetic compatibility, IEC61298-3 and IEC61326-1 are referred in addition to IEC 61000 series. Both emission and immunity should be considered.
According to IEC60038, hardware of DCS should operate in the voltage of 10% deviation from the rated value.

As for environment of installation, equipment such as capacitors or cooling fans or filters of fans is recommended to be considered their lifetimes in addition to Article 258-1.

4) Design for test and calibration equipment or circuits in the DCS.

As described in Article 217 and 222 of operation and maintenance guideline, test and calibration equipment or circuits in the DCS are recommended to be equipped.

5) System redundancy

This item is referred to Article 258-1 of this guideline and Article 217 of operation and maintenance guideline. As for power supply, Article 218 of operation and maintenance guideline is referred.

Moreover, required probability of failure is recommended to be clarified. For example, critical controls such as the boiler, the turbine, and the generator controls are recommended to be redundant; however, local controls such as water treatment do not have to be redundant.

System network for signal transmission is also recommended to be redundant.

6) Operation (calculation) period

This item is referred to “3.Features of DCS”. .Proper period is recommended to be specified depending on the functions or process.

7) Measures for reliability and against failures

The basic concepts for reliability and against failures are “fault avoidance”, to enhance quality of components, and “fault tolerance” to prevent total failure by supposing that fault is unavoidable.

DCS should be designed not to output unnecessary control and alarm signals, by considering problems.

-Voltage dips

-Loss of power supply from batteries equipped in power module

-Unnecessary actions such as touching switches

-Intrusion of surge voltage

-Action for the control of the operation

-Failure of Integrated Circuit

Even when an operator select the wrong equipment, minimizing the influence is necessary by using methods such as interlock circuit which is separated from control circuit.

Methodologies ,which apply double operation using selection and control unnecessary for control and logical product using main failure and failure detection for protection ,are taken are as shown in Fig-62.

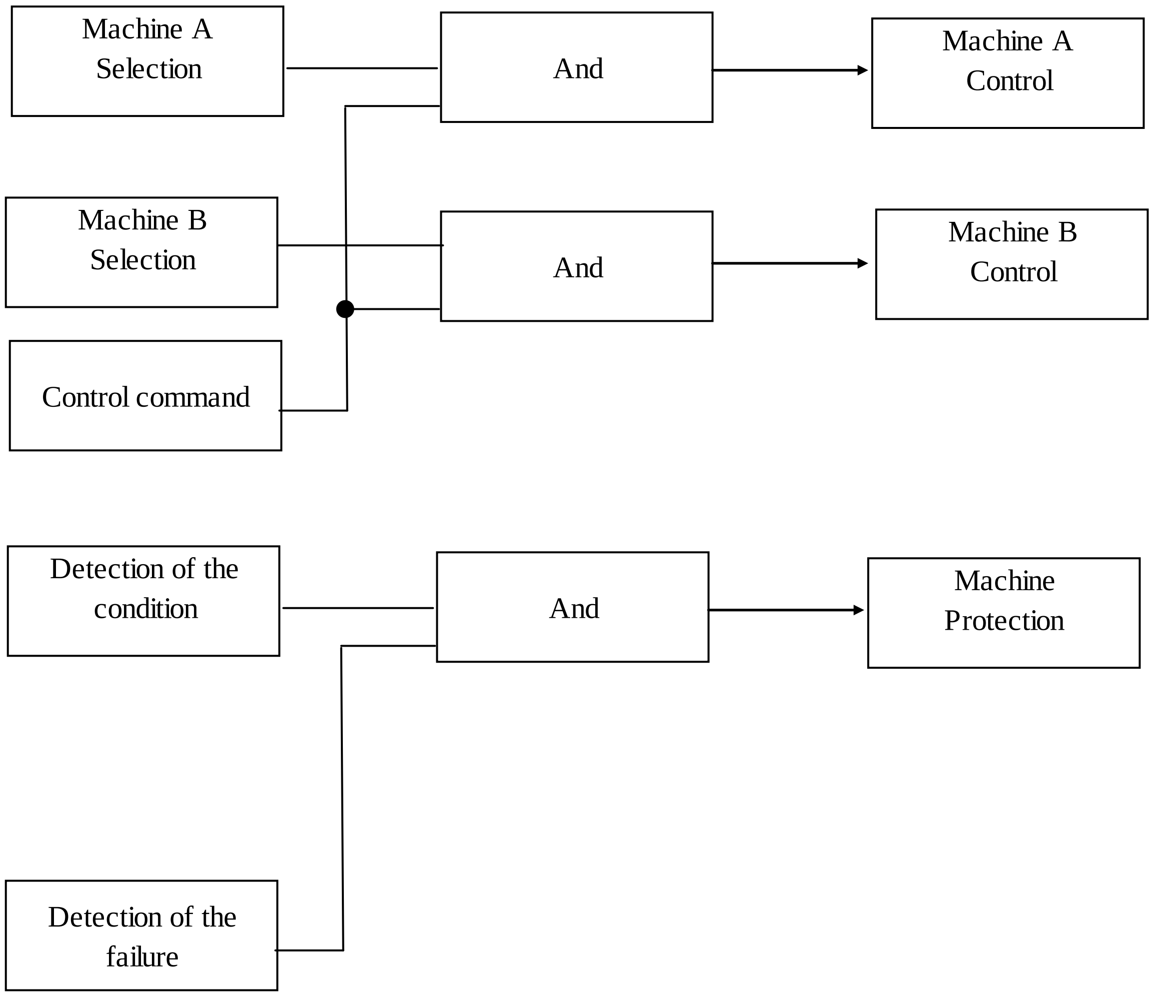


Fig- 62 An example of methodology for protection and control

Examples of detecting hardware failures are shown in IEC61508-7. Detection of system failures may be performed by contact signals, redundant CPU, watchdog timers, parity check, software for check etc.

The control logic in the DCS should be designated to provide both fail-safe and fault-tolerant operation. DCS reads signals from the sensors and executes pre-programmed actions to prevent a hazard by providing output signals to final control elements. Moreover, control circuits are recommended to be distributed to some processors according to the control function.

As for transmission failures, they may happen by collision of large amounts of communication frame simultaneously, or exceeding the limit of transmission capacity.The manufacture may take measures for this problem by allocating signals priority to control signals.

8) The methods of software management

The failure of the software (bugs) is the so-called deterministic failure. In general, bugs are incorporated at the time of production; and may be found to be bugs afterward; therefore, followings are specified to software in IEC 61508.

- The introduction of the safety lifecycle
- Adoption of software techniques that are specified according to the SIL
- Evaluation of the implementation of functional safety
- Safety management by the organization

Examples of software development are shown in IEC 61508-3 Annex A and B

Thus, the final revision of block and sequence diagrams should be available by documents.

In addition, the history of modification and its verifications and administrations are also recommended to be clarified.

Chapter 3 Reference International Technical Standards

Table- 57 Reference International Technical Standards (including national and industrial associations)

Number	Rev.	Title	Content
Cable and surroundings			
IEC 60227-5 ed3.0	2011	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V - Part 5: Flexible cables (cords)	IEC 60227-5:2011 details the particular specifications for polyvinyl chloride insulated flexible cables (cords), of rated voltages up to and including 300/500 V. All cables comply with the appropriate requirements given in IEC 60227-1 and each individual type of cable complies with the particular requirements of this part.
IEC 60227-7 ed1.2	2012	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V - Part 7: Flexible cables screened and unscreened with two or more conductors	IEC 60227-7:2011 details the particular specifications for polyvinyl chloride insulated, screened and unscreened control cables of rated voltages up to and including 300/500 V.
IEC 60245-4 ed3.0	2011	Rubber insulated cables - Rated voltages up to and including 450/750 V - Part 4: Cords and flexible cables	IEC 60245-4:2011 details the particular specifications for rubber insulated and braided cords and for rubber insulated and rubber or polychloroprene or other equivalent synthetic elastomer sheathed cords and flexible cables of rated voltages up to and including 450/750 V. All cables should comply with the appropriate requirements given in IEC 60245-1 and the individual types of cables should each comply with the particular requirements of this part.
IEC 60502-1 ed2.1	2009	Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV) - Part 1: Cables for rated voltages of 1 kV (Um = 1,2 kV) and 3 kV (Um = 3,6 kV)	IEC 60502-1:2009 specifies the construction, dimensions and test requirements of power cables with extruded solid insulation for rated voltages of 1 kV (Um = 1,2 kV) and 3 kV (Um = 3,6 kV) for fixed installations such as distribution networks or industrial installations. This standard includes cables which exhibit properties of reduced flame spread, low levels of smoke emission and halogen-free gas emission when exposed to fire. Cables for special installation and service conditions are not included, for example cables for overhead networks, the mining industry, nuclear power plants (in and around the containment area), submarine use or shipboard application.
IEC 60502-2 ed2.0	2005	Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV) - Part 2: Cables for rated voltages from 6 kV (Um = 7,2 kV) up to 30 kV (Um = 36 kV)	Specifies the construction, dimensions and test requirements of power cables with extruded solid insulation from 6 kV up to 30 kV for fixed installations such as distribution networks or industrial installations. When determining applications, it is recommended that the possible risk of radial water ingress is considered. Cable designs with barriers claimed to prevent longitudinal water penetration and an associated test are included in this part of IEC 60502. Cables for special installation and service conditions are not included, for example cables for overhead networks, the mining industry, nuclear power plants (in and around the containment area)

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			nor for submarine use or shipboard application.
IEC 60570 Ed. 4.0:	2003	Electrical supply track systems for luminaires.	This standard applies to track systems for ordinary interior use with two or more poles and with provision for earthing (Class 1), with a rated voltage not exceeding 440 V between poles (live conductors), rated frequency not exceeding 60 Hz and a rated current not exceeding 16 A per conductor for the connection of luminaires to the electrical supply
IEC 60584-3 ed2.0	2007	Thermocouples - Part 3: Extension and compensating cables - Tolerances and identification system	It specifies manufacturing tolerances for extension and compensating cables (other than mineral insulated cables) provided directly to users of industrial processes. These tolerances are determined with respect to the e.m.f.-temperature relationship of Part 1 of the standard. Furthermore, requirements for extension and compensating cables for use in industrial process control are specified.
IEC 60794 series	-	Optical fibre cables - Indoor cables - Outdoor cables - Aerial optical cables along electrical power lines	A series of IEC 60794 specifies applies to optical fibre cables for use with communication equipment and devices employing similar techniques and to cables having a combination of both optical fibres and electrical conductors. The object of this standard is to establish uniform generic requirements for the geometrical, transmission, material, mechanical, ageing (environmental exposure), climatic and electrical properties of optical fibre cables, where appropriate.
IEC 61386-1 Ed. 2.0:2008	2008	Conduit systems for cable management - Part 1: General requirements	This part of IEC 61386 specifies requirements and tests for conduit systems, including conduits and conduit fittings, for the protection and management of insulated conductors and/or cables in electrical installations or in communication systems up to 1 000 V a.c. and/or 1 500 V d.c. This second edition cancels and replaces the first edition published in 1996, and its Amendment 1 (2000), and it constitutes a technical revision. The changes to the first edition are as follows: - change to the length of the test specimen between fittings for the tensile test, - editorial and normative reference updates.
IEC 61386-21		Conduit systems for cable management - Part 21: Particular requirements - Rigid conduit systems	IEC 61386-21 specifies dimension ,structure etc., of rigid conduit systems.
IEC 61386-23		Conduit systems for cable management - Part 23: Particular requirements - Flexible conduit systems	IEC 61386-21 specifies dimension ,structure etc., of flexible conduit systems.
IEC 61515 ed1.0	1995	Mineral insulated thermocouple cables and thermocouples	Establishes the requirements for mineral insulated thermocouple cables and for mineral insulated thermocouples but does not specify cold end seals, terminations, connections and other accessories. Deals only with cables and thermocouples having one pair of base-metal

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			conductors and is intended for use in general industrial applications.
IEC 61534-1 Ed. 2.0:2011	2011	Powertrack systems - Part 1: General requirements	IEC 61534-1:2011 specifies general requirements and tests for powertrack (PT) systems with a rated voltage not exceeding 277 V a.c. single phase, or 480 V a.c. two or three phase 50 Hz/60 Hz with a rated current not exceeding 63 A. These systems are used for distributing electricity in household, commercial and industrial premises. This second edition cancels and replaces the first edition published in 2003 and constitutes a technical revision. The main changes from the previous edition are as follows: - updated normative references (Clause 2); - changes to the number of samples to be tested (Subclause 5.3); - inclusion of a short circuit test (New Clause 18); - changes to external influences (Clause 21).
Test for flame propagation for wire or cable			
IEC 60332-3-21 ed1.0	2000	Tests on electric cables under fire conditions - Part 3-21: Test for vertical flame spread of vertically-mounted bunched wires or cables - Category A F/R	IEC 60332-3-21 specifies method of test for the assessment of vertical flame spread of vertically-mounted bunched wires or cables, electrical or optical, under defined conditions. The test is intended for type approval testing. The requirements for the selection of cables for testing are given. The flame spread is measured as the extent of damage of the cable sample. This procedure may be used to demonstrate the cable's ability to limit flame spread. Covers category A F/R and relates only to power cables of conductor cross-sectional area greater than 35 mm2 installed on the test ladder in a spaced configuration on the front and rear to achieve a nominal total volume of non-metallic material of 7 l/m of test sample. The flame application time is 40 min. This method of mounting is intended for special cable designs used in particular installations when required in the cable specification. Category A F/R is not intended for general use. A recommended performance requirement is also given. Has the status of a group safety publication in accordance with IEC Guide 104
IEC 60332-3-22 ed1.1	2009	Tests on electric and optical fibre cables under fire conditions - Part 3-22: Test for vertical flame spread of vertically-mounted bunched wires or cables - Category A	IEC 60332-3-22 specifies method of test for the assessment of vertical flame spread of vertically-mounted bunched wires or cables, electrical or optical, under defined conditions. The test is intended for type approval testing. The requirements for the selection of cables for testing are given. The flame spread is measured as the extent of damage of the cable sample. This procedure may be used to demonstrate the cable's ability to limit flame spread. Covers category A and relates to cables installed on the test ladder to achieve a nominal total volume of non-metallic material of 7 l/m of test sample. The flame application time is 40 min. The method of mounting uses the front of the ladder, a standard or wide ladder being used for cables having a

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			conductor cross-section greater than 35 mm² according to the number of test pieces required, and a standard ladder for conductor cross-sections 35 mm² and smaller. The category is intended for general use where high volumes of non-metallic material are required to be evaluated. A recommended performance requirement is also given. Has the status of a group safety publication in accordance with IEC Guide 104.
IEC 60332-3-23 ed1.1	2009	Tests on electric cables under fire conditions - Part 3-23: Test for vertical flame spread of vertically-mounted bunched wires or cables - Category B	IEC 60332-3-23 specifies method of test for the assessment of vertical flame spread of vertically-mounted bunched wires or cables, electrical or optical, under defined conditions. The test is intended for type approval testing. The requirements for the selection of cables for testing are given. The flame spread is measured as the extent of damage of the cable sample. This procedure may be used to demonstrate the cable's ability to limit flame spread. Covers category B and relates to cables installed on the test ladder to achieve a nominal total volume of non-metallic material of 3,5 l/m of test sample. The flame application time is 40 min. The method of mounting uses the front of the standard ladder. The category is intended for general use where medium volumes of non-metallic material are required to be evaluated. A recommended performance requirement is also given. Has the status of a group safety publication in accordance with IEC Guide 104.
IEC 60695 series	-	Fire hazard testing	IEC 60695 series provides general guidance on how to reduce to acceptable levels the risk of fire and the potential effects of fires involving electrotechnical products. It also describes the hazard-based fire test methods
IEEE Std 1202	2006	IEEE Standard for Flame-Propagation Testing of Wire and Cable	Standardization of cable flame propagation testing is beneficial to cable manufacturers, distributors, and users. Uniform procedures; consistent, repeatable results; and measurable test acceptance criteria are required to allow comparisons among competing products and to allow selection of the correct product for the application.
Explosive atmospheres			
IEC 60079-0 ed6.0	2011	Explosive atmospheres - Part 0: Equipment – General requirements	IEC 60079-0:2011 specifies the general requirements for construction, testing and marking of electrical equipment and Ex Components intended for use in explosive atmospheres. Electrical equipment complying with this standard is intended for use in hazardous areas in which explosive gas atmospheres, caused by mixtures of air and gases, vapours or mists, exist under normal atmospheric conditions. The standard atmospheric conditions (relating to the explosion characteristics of the atmosphere) under which it may be assumed that electrical equipment can be operated are: - temperature -20 °C to +60 °C;

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			- pressure 80 kPa (0,8 bar) to 110 kPa (1,1 bar); and - air with normal oxygen content, typically 21 % v/v.
IEC 60079-10-1 ed1.0	2008	Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres	IEC 60079-10-1:2008 is concerned with the classification of areas where flammable gas or vapour or mist hazards may arise and may then be used as a basis to support the proper selection and installation of equipment for use in a hazardous area. It is intended to be applied where there may be an ignition hazard due to the presence of flammable gas or vapour, mixed with air under normal atmospheric conditions, but it does not apply to a) mines susceptible to firedamp; b) the processing and manufacture of explosives; c) areas where a hazard may arise due to the presence of combustible dusts or fibres; d) catastrophic failures which are beyond the concept of abnormality; e) rooms used for medical purposes; f) domestic premises.
IEC 60079-10-2 ed1.0	2009	Explosive atmospheres - Part 10-2: Classification of areas - Combustible dust atmospheres	IEC 60079-10-2:2009 is concerned with the identification and classification of areas where explosive dust atmospheres and combustible dust layers are present, in order to permit the proper assessment of ignition sources in such areas. The principles of this standard can also be followed when combustible fibres or flyings may cause a hazard. This standard is intended to be applied where there can be a risk due to the presence of explosive dust atmospheres or combustible dust layers under normal atmospheric conditions.
IEC 60079-14 ed4.0	2007	Explosive atmospheres - Part 14: Electrical installations design, selection and erection	This part of IEC 60079 contains the specific requirements for the design, selection and erection of electrical installations in hazardous areas associated with explosive atmospheres. Where the equipment is required to meet other environmental conditions, for example, protection against ingress of water and resistance to corrosion, additional methods of protection may be necessary. The method used should not adversely affect the integrity of the enclosure. The requirements of this standard apply only to the use of equipment under normal or near normal atmospheric conditions. The significant technical changes with respect to the previous edition are: Equipment Protection Levels (EPLs) have been introduced and are explained in the new Annex I and dust requirements included from IEC 61241 14, Ed. 1.0.
IEC 60529 Ed. 2.1:2001 (b)	2001	Degrees of protection provided by enclosures (IP Code)	IEC 60529 Ed. 2.1:2001 (b) applies to the classification of degrees of protection provided by enclosures for electrical equipment with a rated voltage not exceeding 72,5 kV has the status of a basic safety publication in accordance with IEC Guide

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			104.
IEC 61241-0 Ed. 1.0:2004 (b)	2004	Electrical apparatus for use in the presence of combustible dust - Part 0: General requirements	IEC 61241-0 specifies general requirements for the design, construction, testing and marking of electrical apparatus protected by any recognized safeguard technique for use in areas where combustible dust may be present in quantities that could lead to a fire or explosion hazard. The application of electrical apparatus in atmospheres which may contain explosive gas as well as combustible dust, whether simultaneously or separately, requires additional protective measures.
NFPA 497	2008	Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas	Chapter 1 Administration Chapter 2 Referenced Publications Chapter 3 Definitions Chapter 4 Classification of Combustible Materials Chapter 5 Classification of Class I (Combustible Material) Areas Annex A Explanatory Material Annex B Example of a Method for Determining NEC Group Classification for Mixtures Annex C Informational References
Instruments			
IEC 60051-1 Ed. 5.0:1997 (b)	1997	Direct acting indicating analogue electrical measuring instruments and their accessories - Part 1: Definitions and general requirements common to all parts	IEC 60051-1 Ed. 5.0:1997 (b) applies to direct indicating electrical measuring instruments having analogue display, such as: ammeters, voltmeters, wattmeters, varmeters, phasemeters, frequency meters, synchroscopes and ohmmeters. Also applies to certain accessories used with such apparatus, e.g., shunts, series resistors and impedance elements.
IEC 60051-2	1984	Direct acting indicating analogue electrical measuring instruments and their accessories. Part 2: Special requirements for ammeters and voltmeters	IEC 60051-2 is applied to direct acting indicating ammeters and voltmeters having an analogue display, and to non-interchangeable accessories used with ammeters and voltmeters.
IEC 60051-3	1984	Direct acting indicating analogue electrical measuring instruments and their accessories. Part 3: Special requirements for wattmeters and varmeters	IEC 60051-3 is applied to direct acting indicating wattmeters and varmeters having an analogue display, and to non-interchangeable accessories used with wattmeters and varmeters.
IEC 60051-4	1984	Direct acting indicating analogue electrical measuring instruments and their accessories. Part 4: Special requirements for frequency meters	IEC 60051-4 is applied to direct acting indicating frequency meters, and to non-interchangeable accessories used with frequency meters
IEC 60051-5	1985	Direct acting indicating analogue electrical measuring instruments and their accessories. Part 5: Special requirements for phase meters, power factor meters and synchroscopes	IEC 60051-5 is applied to direct acting indicating analogue phase meters, power factor meters and synchroscopes, and to non-interchangeable accessories used with phase meters, power factor meters and synchroscopes.
IEC 60073 Ed. 6.0:2002 (b)	2002	Basic and safety principles for man-machine interface, marking and identification - Coding principles for indication devices and actuators	IEC 60073 Ed. 6.0:2002establishes general rules for assigning particular meanings to certain visual, acoustic and tactile indications, and has the status of a basic safety publication in accordance with IEC Guide 104.

Number	Rev.	Title	Content
IEC 60359 Ed. 3.0:2001 (b)		Electrical and electronic measurement equipment - Expression of performance	IEC 60359 applies to the specification of performance, with primary reference to industrial applications, of the following kinds of electrical and electronic equipment: - indicating and recording instruments which measure electrical quantities; - material measures which supply electrical quantities; - instruments which measure non-electrical quantities using electrical means, for all parts of the measuring chain which present electrical output signals. It is based on the methods expounded in GUM for expressing and evaluating the uncertainty of measurement, and refers to GUM for the statistical procedures to be used in determining the intervals assigned to represent uncertainty (including the way to account for non-negligible uncertainties in the traceability chain). The object is to provide methods for ensuring uniformity in the specification and determination of uncertainties of equipment within its scope. All other necessary requirements have been reserved for dependent IEC product standards pertaining to particular types of equipment which fall within the scope of this standard.
IEC 60770-1 Ed. 2.0:2010 (b)	2019	Transmitters for use in industrial-process control systems - Part 1: Methods for performance evaluation	IEC 60770-1:2010 is intended to specify uniform methods of test for the evaluation of the performance of transmitters with pneumatic or electric output signals. It is applicable to transmitters which have either a standard analogue electric current output signal or a standard pneumatic output analogue signal in accordance with IEC 60381-1 or IEC 60382. The tests detailed herein may be applied to transmitters which have other output signals, provided that due allowance is made for such differences. This second edition cancels and replaces the first edition published in 1999 and constitutes a technical revision. The significant technical change with respect to the previous edition is as follows: 4.3 Load conditions, for pneumatic transmitters, load details have been added. This publication is to be read in conjunction with IEC 61298-1:2008, IEC 61298-2:2008, IEC 61298-3:2008 and IEC 61298-4:2008.
IEC 60382 Ed. 2.0:1991 (b)	1991	Analogue pneumatic signal for process control systems	IEC 60382 Ed. 2.0:1991 applies to analogue pneumatic signals used in process control systems to transmit information between the elements of systems and gives definitions, units and the recommended value of the range of the analogue pneumatic signal
IEC 60584-1 Ed. 2.0:1995 (b)	1995	Thermocouples - Part 1: Reference tables	IEC 60584-1 Ed. 2.0:1995 establishes a set of reference tables for the seven most commonly used types of commercially available thermocouples, giving both electromotive force as a function of temperature and temperature as a function of electromotive force. It also gives polynominal expressions from which the reference values can be computed. The reference tables are based on fundamental research and are consistent with the current edition of the International

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			Practical Temperature
IEC 60584-2 Ed. 1.0:1982 (b)	1982	Thermocouples. Part 2: Tolerances	IEC 60584-2 Ed. 1.0:1982 (b) Contains the manufacturing tolerances for both noble and base metal thermocouples manufactured in accordance with e.m.f. temperature relationships of Part 1 of the standard. The tolerance values are for a thermocouple manufactured from wires normally in the diameter range 0.25 mm to 3 mm, as delivered to the user and do not allow for calibration draft during use.
IEC 60688 Ed. 2.2:2002 (b)	2002	Electrical measuring transducers for converting a.c. electrical quantities to analogue or digital signals	IEC 60688 is applied to transducers with electrical inputs and outputs for making measurements of a.c. electrical quantities with a nominal frequency between 5 Hz and 1 500 Hz. The output signal may be in the form of an analogue direct current or in digital form.
IEC 60751 Ed. 2.0:2008 (b)	2008	Industrial platinum resistance thermometers and platinum temperature sensors	IEC 60751:2008 specifies the requirements and temperature/resistance relationship for industrial platinum resistance temperature sensors later referred to as ""platinum resistors"" or ""resistors"" and industrial platinum resistance thermometers later referred to as ""thermometers"" whose electrical resistance is a defined function of temperature. Values of temperature in this standard are in terms of the International Temperature Scale of 1990, ITS-90. Temperatures in degrees Celsius are denoted by the symbol t, except in Table 1 where the full nomenclature t90/ C is used. The standard covers resistors or thermometers for all or part of the temperature range 200 C to +850 C with different tolerance classes, which may cover restricted temperature ranges.
IEC 60947-5-1 Ed. 3.1:2009 (b)	2009	Low-voltage switchgear and controlgear - Part 5-1: Control circuit devices and switching elements - Electromechanical control circuit devices	IEC 60947-5-1 applies to control circuit devices and switching elements intended for controlling, signalling, interlocking, etc., of switchgear and controlgear. It applies to control circuit devices having a rated voltage not exceeding 1 000 V a.c. (at a frequency not exceeding 1 000 Hz) or 600 V d.c. The technical content is therefore identical to the base edition and its amendment and has been prepared for user convenience. It bears the edition number 3.1. This International Standard should be used in conjunction with IEC 60947-1.This consolidated version consists of the third edition (2003) and its amendment 1 (2009). Therefore, no need to order amendment in addition to this publication.
IEC 60947-5-5 Ed. 1.1:2005 (b)	2005	Low-voltage switchgear and controlgear - Part 5-5: Control circuit devices and switching elements - Electrical emergency stop device with mechanical latching function	IEC 60947-5-5 is applicable to electrical control circuit devices and switching elements which are used to provide an emergency stop signal. Such devices may be either provided with their own enclosure, or installed according to the manufacturer's instructions.
IEC 61010-1 Ed. 3.0:2010 (b)	2010	Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 1: General requirements	IEC 61010-1:2010 specifies general safety requirements for the following types of electrical equipment and their accessories, wherever they are intended to be used. a) Electrical test and measurement equipment b)

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			Electrical industrial process-control equipment c) Electrical laboratory equipment This third edition cancels and replaces the second edition published in 2001. It constitutes a technical revision. This edition includes the following significant changes from the second edition, as well as numerous other changes. - The scope of the standard has been expanded to include all locations where these products may be used, so that both professional and non-professional versions of these products are within the scope.- The requirements for testing and measuring circuits (in various subclauses and the entirety of Clause 16) have been removed and included in a particular standard IEC 61010-2-030.- Insulation requirements (6.7) have been completely rewritten.- Additional requirements for protection against mechanical HAZARDS (Clause 7) have been included.- Surface temperature limits (Clause 10) have been modified to conform to the limits of EN 563.- Radiation requirements (Clause 12) have been modified, and take into account a distinction between intended emission and unintended emission.- Requirements for reasonably foreseeable misuse and ergonomic aspects have been added (Clause 16).- A new clause (Clause 17) has been added to deal with HAZARDS and environments not covered by the standard, along with a new informative annex (Annex J) dealing with RISK assessment.- A new informative annex (Annex E) addresses methods of reducing the POLLUTION DEGREE of a micro-environment.- Requirements for the qualification of coatings for protection against POLLUTION have been added (Annex H).- A new informative annex (Annex I) has been added to further explain how to determine the WORKING VOLTAGE of a MAINS CIRCUIT.
IEC/TR 61158-1 Ed. 3.0:2010	2010	Industrial communication networks - Fieldbus specifications - Part 1: Overview and guidance for the IEC 61158 and IEC 61784 series	IEC 61158-1:2010(E) presents an overview and guidance for the IEC 61158 series by: - explaining the structure and content of the IEC 61158 series; - relating the structure of the IEC 61158 series to the ISO/IEC 7498 OSI Basic Reference Model; - showing the logical structure of the IEC 61784 series; - showing how to use parts of the IEC 61158 series in combination with the IEC 61784 series; - providing explanations of some aspects of the IEC 61158 series that are common to the parts of the IEC 61158-5 series. This third edition cancels and replaces the second edition published in 2007 and constitutes a technical revision. It includes the following significant changes with respect to the previous edition: - Updates of the references to the IEC 61158 series, IEC 61784-1, IEC 61784-3, IEC 61784-5 series and IEC 61918 throughout the document; - new Type 21 and the related profile family CPF 17; - new Type 22 and the related profile family CPF 18.

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IEC 61298-3	2008	Process measurement and control devices - General methods and procedures for evaluating performance - Part 3: Tests for the effects of influence quantities	IEC 61298-3:2008 specifies general methods and procedures for conducting tests and reporting on the functional and performance characteristics of process measurement and control devices. The tests are applicable to any such devices characterized by their own specific input and output variables, and by the specific relationship (transfer function) between the inputs and outputs, and include analogue and digital devices. For devices that require special tests, this standard should be used, together with any product-specific standard specifying special tests. It covers tests for the effects of influence quantities.
IEC 61326-1	2005	Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 1: General requirements	IEC 61326-1 specifies requirements for immunity and emissions regarding electromagnetic compatibility (EMC) for electrical equipment, operating from a supply or battery of less than 1 000 V a.c. or 1 500 V d.c. or from the circuit being measured, intended for professional, industrial-process, industrial-manufacturing and educational use, including equipment and computing devices
IEC 61508-1 Ed. 2.0:2010 (b)	2010	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 1: General requirements	IEC 61508-1:2010 covers those aspects to be considered when electrical/electronic/programmable electronic (E/E/PE) systems are used to carry out safety functions. A major objective of this standard is to facilitate the development of product and application sector international standards by the technical committees responsible for the product or application sector. This will allow all the relevant factors, associated with the product or application, to be fully taken into account and thereby meet the specific needs of users of the product and the application sector. A second objective of this standard is to enable the development of E/E/PE safety-related systems where product or application sector international standards do not exist. This second edition cancels and replaces the first edition published in 1998. This edition constitutes a technical revision. It has been subject to a thorough review and incorporates many comments received at the various revision stages.
IEC 61508-2 Ed. 2.0:2010 (b)	2010	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems	IEC 61508-2:2010 applies to any safety-related system, as defined by IEC 61508-1, that contains at least: - one electrical, electronic or programmable electronic element; - applies to all elements within an E/E/PE safety-related system; - specifies how to refine the E/E/PE system safety requirements specification, developed in accordance with IEC 61508-1, into the E/E/PE system design requirements specification; - specifies the requirements for activities that are to be applied during the design and manufacture of the E/E/PE safety-related systems except software, which is dealt with in IEC 61508-3. These requirements include the application of techniques and measures that: - are graded against the safety integrity level, for the

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			avoidance of, and control of, faults and failures; - specifies the information necessary for carrying out the installation, commissioning and final safety validation of the E/E/PE safety-related system; - provides requirements for the preparation of information and procedures needed by the user for the operation and maintenance of the E/E/PE safety-related systems; - specifies requirements to be met by the organisation carrying out any modification of the E/E/PE safety-related systems. This second edition cancels and replaces the first edition published in 1998. This edition constitutes a technical revision. It has been subject to a thorough review and incorporates many comments received at the various revision stages. It has the status of a basic safety publication according to IEC Guide 104.
IEC 61508-3 Ed. 2.0:2010 (b)	2010	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 3: Software requirements	IEC 61508-3:2010 applies to any software forming part of a safety-related system or used to develop a safety-related system within the scope of IEC 61508-1 and IEC 61508-2; provides specific requirements applicable to support tools used to develop and configure a safety-related system within the scope of IEC 61508-1 and IEC 61508-2; requires that the software safety functions and software systematic capability are specified; establishes requirements for safety lifecycle phases and activities which must be applied during the design and development of the safety-related software. These requirements include the application of measures and techniques, which are graded against the required systematic capability, for the avoidance of and control of faults and failures in the software; provides requirements for information relating to the software aspects of system safety validation to be passed to the organisation carrying out the E/E/PE system integration; provides requirements for the preparation of information and procedures concerning software needed by the user for the operation and maintenance of the E/E/PE safety-related system; provides requirements to be met by the organisation carrying out modifications to safety-related software; provides, in conjunction with IEC 61508-1 and IEC 61508-2, requirements for support tools such as development and design tools, language translators, testing and debugging tools, configuration management tools. This second edition cancels and replaces the first edition published in 1998. This edition constitutes a technical revision. It has been subject to a thorough review and incorporates many comments received at the various revision stages. It has the status of a basic safety publication according to IEC Guide 104.
IEC 61508-7:2010	2010	Functional safety of electrical/electronic/programmable electronic safety-related systems - Part 7: Overview of techniques and measures	IEC 61508-7:2010 contains an overview of various safety techniques and measures relevant to IEC 61508-2 and IEC 61508-3.The references should be considered as basic

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			references to methods and tools or as examples, and may not represent the state of the art. This edition constitutes a technical revision. It has been subject to a thorough review and incorporates many comments received at the various revision stages.
IEC 61784-2 Ed. 2.0:2010 (b)	2010	Industrial communication networks - Profiles - Part 2: Additional fieldbus profiles for real-time networks based on ISO/IEC 8802-3	IEC 61784-2:2010(E) specifies performance indicators supporting classification schemes for Real-Time Ethernet (RTE) requirements; profiles and related network components based on ISO/IEC 8802-3, IEC 61158 series, and IEC 61784-1; RTE solutions that are able to run in parallel with ISO/IEC 8802-3-based applications. These communication profiles are called Real-Time Ethernet communication profiles. This second edition cancels and replaces the first edition published in 2007. It constitutes a technical revision. The main changes with respect to the previous edition are listed below: - update of the dated references to the IEC 61158 series, to IEC 61784-1, to the IEC 61784-3 series, to the IEC 61784-5 series and to IEC 61918 throughout the document; - update of selection tables for CPF 2, CPF 3, CPF 11 and CPF 14; - addition of a new profile CP 11/2 in 12.3; - addition of a new profile CP 14/3 in subclause 15.5; - addition of a new Communication Profile Family - CPF 17; - new subclause 3.3.12 (CPF 17 symbols); - new Clause 18 for CPF 17 with one profile; - addition of a new Communication Profile Family - CPF 18; - new subclause 3.3.13 (CPF 18 symbols); - new Clause 19 for CPF 18 with one profile; - specification changes for CPF3; - update of the requirements for all conformance classes; - added precise timing requirements for IP; - updated timing requirements for IO devices; - added precise timing requirements for PTCP; - increasing the amount of synchronized devices in line; - integrating the fast startup as additional feature.
IEC 62382 Ed. 1.0:2006 (en)	2006	Electrical and instrumentation loop check	IEC 62382 Ed. 1.0:2006 describes the steps recommended to complete a loop check, which comprises the activities between the completion of the loop construction (including installation and point-to-point checks) and the start-up of cold commissioning. Is applicable for the construction of new plants and for expansion/retrofits (i.e. revamping) of E&I installations in existing plants (including PLC, BAS, DCS, panel-mounted and field instrumentation). It does not include a detailed checkout of power distribution systems, except as they relate to the loops being checked (i.e. a motor starter or a power supply to a four-wire transmitter).
IEC 61970-1 Ed. 1.0:2005 (b)	2005	Energy management system application program interface (EMS-API) - Part 1: Guidelines and general requirements	IEC 61970-1 provides a set of guidelines and general infrastructure capabilities required for the application of the EMS-API interface standards. It also describes typical integration scenarios where these standards are to be

Number	Rev.	Title	Content
			applied and the types of applications to be integrated. It also defines a reference model and provides a framework for the application of the other parts of these EMS-API standards.
IEC 61000-3-3 Ed. 3.2:2008 (b)	2008	Electromagnetic compatibility (EMC) - Part 3-3: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≦16 A per phase and not subject to conditional connection	IEC 61000-3-3:2008 is concerned with the limitation of voltage fluctuations and flicker impressed on the public low-voltage system. It specifies limits of voltage changes which may be produced by equipment tested under specified conditions and gives guidance on methods of assessment. This part of IEC 61000 is applicable to electrical and electronic equipment having an input current equal to or less than 16 A per phase, intended to be connected to public low-voltage distribution systems of between 220 V and 250 V line to neutral at 50 Hz, and not subject to conditional connection. The tests according to this part are type tests. Particular test conditions are given in annex A and the test circuit is shown in Figure 1. This second edition IEC 61000-3-3 cancels and replaces the first edition published in 1994, amendment 1 (2001) and amendment 2 (2005). This edition constitutes a revised edition. NEW! IEC 61000-3-3:2008 is also available as IEC Standards+ 61000-3-3:2008 which contains the International Standard and its Redline version, showing all changes of the technical content compared to the previous edition.
IEC 61000-4 Series	-	IEC 61000-4 Series	IEC 61000-4 Series describes electromagnetic compatibility.
IEC/TR 61000-5-1 Ed. 1.0:1996 (b)	1996	Electromagnetic compatibility (EMC) - Part 5: Installation and mitigation guidelines - Section 1: General considerations - Basic EMC publication	This technical report covers general considerations and guidelines on mitigation methods aimed at ensuring electromagnetic compatibility (EMC) among electrical and electronic apparatus or systems used in industrial, commercial, and residential installations. This technical report is intended for use by installers and users, and to some extent manufacturers, of sensitive electrical or electronic installations and systems, and equipment with high emission levels that could degrade the overall electromagnetic (EM) environment. It applies primarily to new installations, but where economically feasible, it may be applied to extensions or modifications to existing facilities.
ISO/IEC 7498-1:1994	1994	Information technology -- Open Systems Interconnection -- Basic Reference Model: The Basic Model	The purpose of this Reference Model of Open Systems Interconnection is to provide a common basis for the coordination of standards development for the purpose of systems interconnection. while allowing existing standards to be placed into perspective within the overall Reference Model. The term Open Systems Interconnection (OSI) qualifies standards for the exchange of information among systems that are “open” to one another for this purpose by virtue of their mutual use of the applicable standards.

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			The fact that a system is open does not imply any particular systems implementation, technology or means of interconnection, but refers to the mutual recognition and support of the applicable standards. It is also the purpose of this Reference Model to identify areas for developing or improving standards, and to provide a common reference for maintaining consistency of all related standards. It is not the intent of this Reference Model either to serve as an implementation specification, or to be a basis for appraising the conformance of actual implementations, or to provide a sufficient level of detail to define precisely the services and protocols of the interconnection architecture. Rather, this Reference Model provides a conceptual and functional framework which allows international teams of experts to work productively and independently on the development of standards for each layer of the Reference Model for OSI.
ISO 5167-1:2003	2003	Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full -- Part 1: General principles and requirements	ISO 5167-1:2003 specifies general requirements for pressure differential devices inserted in circular cross-section conduits running full.
Electrical equipment			
IEC 60034 series	-	Rotating electrical machines - synchronous generators driven by steam turbines or combustion gas turbines, etc.	A series of IEC 60034 specifies rotating electrical machines except those covered by other IEC standards, for example, IEC 60349. Machines within the scope of this standard may also be subject to superseding, modifying or additional requirements in other publications, for example, IEC 60079 and IEC 60092.
IEC 60038 Ed. 7.0:2009 (b)	2009	IEC standard voltages	IEC 60038:2009 specifies standard voltage values which are intended to serve as preferential values for the nominal voltage of electrical supply systems, and as reference values for equipment and system design. This seventh edition supersedes the sixth edition (1993), its Amendment 1 (1994) and its Amendment 2 (1997). It constitutes a technical revision. The significant technical changes are: - the addition of the values of 230 V (50 Hz) and 230/400 V (60 Hz) to Table 1; - the replacement of the utilization voltage range at LV by a reference to the relevant standard and an informative annex; - the addition of the value of 30 kV to Table 3; - the replacement of the value of 1 050 kV by 1 100 kV in Table 5. It has the status of a horizontal standard in accordance with IEC Guide 108.
IEC 60044 series	-	Instrument transformers - current transformers - voltage transformers	A series of IEC 60044 specifies instrument transformers for use with electrical measuring instruments and electrical protective devices at frequencies from 15

Number	Rev.	Title	Content
			Hz to 100 Hz.
IEC 60071-1 Ed. 8.1:2011 (b)	2011	Insulation co-ordination - Part 1: Definitions, principles and rules	IEC 60071-1: applies to three-phase a.c. systems having a highest voltage for equipment above 1 kV. It specifies the procedure for the selection of the rated withstand voltages for the phase-to-earth, phase-to-phase and longitudinal insulation of the equipment and the installations of these systems. It also gives the lists of the standard withstand voltages from which the rated withstand voltages should be selected. This standard recommends that the selected withstand voltages should be associated with the highest voltage for equipment. This association is for insulation co-ordination purposes only. The requirements for human safety are not covered by this standard. Although the principles of this standard also apply to transmission line insulation, the values of their withstand voltages may be different from the standard rated withstand voltages. The apparatus committees are responsible for specifying the rated withstand voltages and the test procedures suitable for the relevant equipment taking into consideration the recommendations of this standard. NOTE In IEC 60071-2, Application Guide, all rules for insulation co ordination given in this standard are justified in detail, in particular the association of the standard rated withstand voltages with the highest voltage for equipment. When more than one set of standard rated withstand voltages is associated with the same highest voltage for equipment, guidance is provided for the selection of the most suitable set. This publication has the status of a horizontal standard in accordance with IEC Guide 108.This consolidated version consists of the eight edition (2006) and its amendment 1 (2010).
IEC 60076 series	-	Power transformers - liquid-immersed transformers - dry-type transformers - gas-filled power transformers, etc.	A series of IEC 60076 specifies three-phase and single-phase power transformers (including auto-transformers) with the exception of certain categories of small and special transformers.
IEC 60085 Ed. 4.0:2007 (b)	2007	Electrical insulation - Thermal evaluation and designation	This International Standard now distinguishes between thermal classes for electrical insulation systems and electrical insulating materials. It establishes the criteria for evaluating the thermal endurance of either electrical insulating materials (EIM) or electrical insulation systems (EIS). It also establishes the procedure for assigning thermal classes. This standard is applicable where the thermal factor is the dominant ageing factor.
IEC 60099-1	1999	Surge arresters - Part 1: Non-linear resistor	IEC 60099-1 applies, in particular, to surge

Number	Rev.	Title	Content
		type gapped surge arresters for a.c. systems	arresters consisting of single or multiple spark gaps in series with one or more non-linear resistors
IEC 60099-4 ed2.2	2009	Surge arresters - Part 4: Metal-oxide surge arresters without gaps for a.c. systems	IEC 60099-4 applies to non-linear metal-oxide resistor type surge arresters without spark gaps designed to limit voltage surges on a.c. power circuits.
IEC 60099-5 Ed. 1.1:2000 (b)	2000	Surge arresters - Part 5: Selection and application recommendations	IEC 60099-5 Ed. 1.1:2000 (b) provides recommendations for the selection and application of surge arresters to be used in three-phase systems with nominal voltages above 1kV. It applies to non-linear resistor type gapped surge arresters as defined in IEC 60099-1 and to gapless metal-oxide surge arresters as defined in IEC 60099-4.
IEC 60204-1 Ed. 5.1:2009 (b)	2009	Safety of machinery - Electrical equipment of machines - Part 1: General requirements	IEC 60204-1 is applicable to the electrical equipment or parts of the electrical equipment that commences at the point of connection of the supply to the electrical equipment of the machine and operate with nominal supply voltages not exceeding 1 000 V for alternating current (a.c.) and not exceeding 1 500 V for direct current (d.c.), and with nominal supply frequencies not exceeding 200 Hz. The technical content is therefore identical to the base edition and its amendment and has been prepared for user convenience. A vertical line in the margin shows where the base publication has been modified by amendment 1.This consolidated version consists of the fifth edition (2008) and its amendment 1 (2008).
IEC 60204-11 Ed. 1.0:2000 (b)	2000	Safety of machinery - Electrical equipment of machines - Part 11: Requirements for HV equipment for voltages above 1 000 V a.c. or 1 500 V d.c. and not exceeding 36 kV	IEC 60204-11 is the requirements for HV equipment for voltages above 1 000 V a.c. or 1 500 V d.c. and not exceeding 36 kV.
IEC 60255 series	-	Measuring relays and protection equipment	A series of IEC 60255 specifies common rules and requirements applicable to measuring relays and protection equipment including any combination of devices to form schemes for power system protection such as control, monitoring and process interface equipment.
IEC 60364-1 Ed. 5.0:2005	2005	Low-voltage electrical installations - Part 1: Fundamental principles, assessment of general characteristics, definitions	IEC 60364-1 gives the rules for the design, erection, and verification of electrical installations. The rules are intended to provide for the safety of persons, livestock and property against dangers and damage which may arise in the reasonable use of electrical installations and to provide for the proper functioning of those installations. IEC 60364-1 applies to the design, erection and verification of electrical installations such as those of a) residential premises; b) commercial premises; c) public premises; d) industrial premises; e) agricultural and horticultural premises; f) prefabricated buildings; g) caravans, caravan sites and similar sites; h) construction sites, exhibitions, fairs and other installations for temporary purposes; i) marinas; j) external lighting and similar installations; k) medical locations; l) mobile or transportable units; m) photovoltaic

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			systems; n) low-voltage generating sets. IEC 60364-1 covers a) circuits supplied at nominal voltages up to and including 1 000 V a.c. or 1 500 V d.c.; b) circuits, other than the internal wiring of apparatus, operating at voltages exceeding 1 000 V and derived from an installation having a voltage not exceeding 1 000 V a.c., for example, discharge lighting, electrostatic precipitators; c) wiring systems and cables not specifically covered by the standards for appliances; d) all consumer installations external to buildings; e) fixed wiring for information and communication technology, signalling, control and the like (excluding internal wiring of apparatus); f) the extension or alteration of the installation and also parts of the existing installation affected by the extension or alteration
IEC 60364-4-41 Ed. 5.0:2005 (b)	2005	Low-voltage electrical installations - Part 4-41: Protection for safety - Protection against electric shock	IEC 60364-4 specifies essential requirements regarding protection against electric shock, including basic protection (protection against direct contact) and fault protection (protection against indirect contact) of persons and livestock. It deals also with the application and co-ordination of these requirements in relation to external influences. Requirements are also given for the application of additional protection in certain cases.
IEC/TS 60479-1	2005	Effects of current on human beings and livestock - Part 1: General aspects	For a given current path through the human body, the danger to persons depends mainly on the magnitude and duration of the current flow. However, the time/current zones specified in this publication are, in many cases, not directly applicable in practice for designing measures of protection against electrical shock. The necessary criterion is the admissible limit of touch voltage (i.e. the product of the current through the body called touch current and the body impedance) as a function of time. The relationship between current and voltage is not linear because the impedance of the human body varies with the touch voltage, and data on this relationship is therefore required. The different parts of the human body (such as the skin, blood, muscles, other tissues and joints) present to the electric current certain impedance composed of resistive and capacitive components. The values of body impedance depend on a number of factors and, in particular, on current path, on touch voltage, duration of current flow, frequency, degree of moisture of the skin, surface area of contact, pressure exerted and temperature. The impedance values indicated in this technical specification result from a close examination of the experimental results available from measurements carried out principally on corpses and on some living persons. This

Number	Rev.	Title	Content
			technical specification has the status of a basic safety publication in accordance with IEC Guide 104.
IEC 60896 series	-	Stationary lead-acid batteries	A series of IEC 60896 specify lead-acid cells and batteries which are designed for service in fixed locations (i.e. not habitually to be moved from place to place) and which are permanently connected to the load and to the d.c. power supply. Batteries operating in such applications are called "stationary batteries".
IEC 60947 series	-	Low-voltage switchgear and controlgear - Circuit-breakers - Switches, disconnectors - Contactors and motor-starters, etc.	A series of IEC 60947 specifies low-voltage switchgear and controlgear.
IEC/TS 61200-53 Ed. 1.0:1994 (b)	1994	Electrical installation guide - Part 53: Selection and erection of electrical equipment - Switchgear and controlgear	This technical report is for use as a guide for electrical installations. It explains the relationship between the time/current characteristic of protective devices and wiring, prospective short-circuit currents and maximum length of wiring and the thermal characteristics of conductors.
IEC 61800-3	2004	Adjustable speed electrical power drive systems - Part 3: EMC requirements and specific test methods	IEC 61800-3 specifies electromagnetic compatibility (EMC) requirements for power drive systems (PDSs). A PDS is defined in 3.1. These are adjustable speed a.c. or d.c. motor drives. Requirements are stated for PDSs with converter input and/or output voltages (line-to-line voltage), up to 35 kV a.c. r.m.s.
IEC 61936-1	2010	Power installations exceeding 1 kV a.c. - Part 1: Common rules	IEC 61936-1:2010 provides common rules for the design and the erection of electrical power installations in systems with nominal voltages above 1 kV a.c. and nominal frequency up to and including 60 Hz, so as to provide safety and proper functioning for the use intended. For the purpose of interpreting this standard, an electrical power installation is considered to be one of the following: a) Substation, including substation for railway power supply; b) Electrical installations on mast, pole and tower; Switchgear and/or transformers located outside a closed electrical operating area; c) One (or more) power station(s) located on a single site. The installation includes generators and transformers with all associated switchgear and all electrical auxiliary systems. Connections between generating stations located on different sites are excluded; d) The electrical system of a factory, industrial plant or other industrial, agricultural, commercial or public premises. The electrical power installation includes, among others, the following equipment: rotating electrical machines; switchgear; transformers and reactors; converters; cables; wiring systems;

Number	Rev.	Title	Content
			batteries; capacitors; earthing systems; buildings and fences which are part of a closed electrical operating area; associated protection, control and auxiliary systems; large air core reactor. NOTE: In general, a standard for an item of equipment takes precedence over this standard. This standard does not apply to the design and erection of any of the following: - overhead and underground lines between separate installations;- electric railways;- mining equipment and installations;- fluorescent lamp installations; - installations on ships and off-shore installations;- electrostatic equipment (e.g. electrostatic precipitators, spray-painting units);- test sites; - medical equipment, e.g. medical X-ray equipment.
IEC 62040-2	2005	Uninterruptible power systems (UPS) - Part 2: Electromagnetic compatibility (EMC) requirements	IEC 62040-2 is intended as a product standard allowing the EMC conformity assessment of products of categories C1, C2 and C3 as defined in this part of IEC 62040, before placing them on the market. The requirements have been selected so as to ensure an adequate level of electromagnetic compatibility (EMC) for UPS at public and industrial locations.
IEC 62271 series	-	High-voltage switchgear and controlgear	A series of IEC 62271 specifies a.c. switchgear and controlgear designed for indoor and outdoor installation and for operation at service frequencies up to and including 60 Hz on systems having voltages above 1 000 V.
IEEE Std 485-2010	2010	IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications	Methods for defining the direct current (dc) load and for sizing a lead-acid battery to supply that load for stationary battery applications in full-float operations are described in this recommended practice. Some factors relating to cell selection are provided for consideration. Installation, maintenance, qualification, testing procedures, and consideration of battery types other than lead-acid are beyond the scope of this recommended practice. Design of the dc system and sizing of the battery charger(s) are also beyond the scope of this recommended practice.
IEEE Std C50.13-2005	2005	IEEE Standard for Cylindrical-Rotor 50 Hz and 60 Hz Synchronous Generators Rated 10 MVA and Above	The requirements in this standard are applied to 50 Hz and 60 Hz, two-pole and four-pole, cylindrical-rotor synchronous generators driven by steam turbines and/or by combustion gas turbines. The drive may be direct or through a gearbox or other device that permits different speeds for the turbine and the generator. The generators covered by this standard are to have rated outputs of 10 MVA and above.
Grounding			
IEC/TR 61000-5-2 Ed. 1.0:1997 (b)	1997	Electromagnetic compatibility (EMC) - Part 5: Installation and mitigation guidelines - Section 2: Earthing and cabling	This technical report (type 3) covers guidelines for the earthing and cabling of electrical and electronic systems and installations aimed at ensuring

Number	Rev.	Title	Content
			electromagnetic compatibility among electrical and electronic apparatus or systems. More particularly, it is concerned with earthing practices and with cables used in industrial, commercial and residential installations. This technical report is intended for use by installers and users, and to some extent, manufacturers of sensitive electrical or electronic installations and systems, and equipment with high emission levels that could degrade the overall electromagnetic environment.
IEEE Std 665-1995	1995	IEEE Guide for Generating Station Grounding	A guide for the design of generating station grounding systems and for grounding practices applied to generating station indoor and outdoor structures and equipment, including the interconnection of the station and substation grounding systems, is provided.
IEEE Std 80-2000	2000	IEEE Guide for Safety in AC Substation Grounding	Outdoor ac substations, either conventional or gas-insulated, are covered in this guide. Distribution, transmission, and generating plant substations are also included. With proper caution, the methods described herein are also applicable to indoor portions of such substations, or to sub-stations that are wholly indoors.
Others			
ISO 4126-1	2004	Safety devices for protection against excessive pressure—Part 1: Safety valves	ISO 4126-1:2004 specifies general requirements for safety valves irrespective of the fluid for which they are designed. It is applicable to safety valves having a flow diameter of 6 mm and above which are for use at set pressures of 0,1 bar gauge and above. No limitation is placed on temperature. This is a product standard and is not concerned with applications for safety valves.

Table- 58 Reference Vietnamese Technical Regulations

Number	Rev.	Title	Content
QVCN22	2009	National Technical Regulation on Emission of Thermal Power industry	QVCN22 specifies allowable concentration of emissions from thermal power stations.

Table- 59 Reference Vietnamese Technical Standards

Number	Rev.	Title	Abstract
TCVN 1615	1975	Graphical symbols to be used electrical diagrams. Switching equipments	Switch Equipment specified in the schemes to perform in the cutting state, meaning that when non-electric current in the all of circuit of the diagrams and non-external force to effect on the closure point
TCVN 3725	1982	Electrical apparatus for voltages up to 1000 V. Test methods	This standard applies to electric instruments working at voltages up to 1000V, such as automatic breaker and non-automatic breakers, disconnect, switches, magnetic boot, relays, fuses, resistors, rheostat and the other instruments.
TCVN 5169	1993	Porcelain through insulators for voltages from 6 to 35 kV. Technical requirements	This standard applies to the type of through insulators used for 3-phase AC distribution equipment, frequency up to 100Hz and voltages from 6 to 35 kV
TCVN 6306-1	2006	Power transformers. Part 1: General	This standard applies to the power transformer with three-phase and single-phase Related Standard: IEC 60076-1:2000, TCVN ISO 9001
TCVN 6306-2	2006	Power transformers. Part 2: Temperature rise	This standard applies for identification of transformer cooling method, determine the temperature rise limits and detail specified the test methods to measure temperature rise. Related Standard: IEC 60076-2:1993, IEC 60279, IEC 60085
TCVN 6306-3	2006	Power transformers. Part 3: Insulation levels and dielectric tests and external clearances in air	This standard applies to three-phase, single-phase power (including of Auto-Connected Transformer) and the oil immersion transformers, except the special and small transformers which are defined in application area of TCVN 6306-1 Related Standard: IEC 60076-3:2000, IEC 60050, IEC 60060-1
TCVN 6306-5	2006	Power transformers. Part 5: Ability to withstand short circuit	This standard specifies requirements for power transformers to withstand without damage caused by the over-current effect is derived from external short circuit Related Standard: IEC 60076-5:2006, IEC 60076-11:2004, IEC 60076-8:1999
TCVN 6306-11	2009	Power transformers. Part 11: Dry-type transformers	This standard applies to dry type power transformer (including of Auto-Connected Transformer) with the highest voltage for equipment less than or equal to 36 kV and at least a working coil with voltage greater than 1.1 kV Related Standard: IEC 60076-11:2004
TCVN 6592-1	2009	Low-voltage switchgear and controlgear. Part 1: General rules	Related Standard: IEC 60947-1:2007
TCVN 6627-1	2008	Rotating electrical machines. Part 1:	This standard applies to all of rotating

Number	Rev.	Title	Abstract
		Rating and performance	electrical machines, except the rotating electrical machines which is mentioned in other IEC standards, e.g. IEC 60349 Related Standard: IEC 60034-1:2004
TCVN 6627-2-1	2010	Rotating electrical machines. Part 2-1:Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)	Related Standard: IEC 60034-2-1:2007
TCVN 6627-2A	2001	Rotating electrical machines. Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles). Measurement of losses by the calorimetric method	Methods for determining losses in this standard is designed to apply to large generators but the principles of using can also apply to other electrical machines Related Standard: IEC 34-2A:1974
TCVN 6627-3	2010	Rotating electrical machines. Part 3: Specific requirements for synchronous generators driven by steam turbines or combustion gas turbines	Related Standard: : IEC 60034-3:2007
TCVN 6627-5	2008	Rotating electrical machines. Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code). Classification	This standard applies to classify protection levels by external covers with the rotating electrical machines. This standard shows requirements of protection covers that all of other aspects are suitable for using external covers of anticipation on the basis of materials and processes, external covers also ensures that the characteristics mentioned in this standard are maintained in normal conditions of using Related Standard: IEC 60034-5:2000, IEC 60034-6
TCVN 6627-7	2008	Rotating electrical machines. Part 7: Classification of types of construction, mounting arrangements and terminal box position (IM Code)	This standard specifies IM code, classification of structure type, installation and position layout of rotating electrical machines connection box Related Standard: IEC 60034-7:2001
TCVN 6627-8	2010	Rotating electrical machines. Part 8: Terminal markings and direction of rotation	Related Standard: IEC 60034-8:2007
TCVN 6627-9	2000	Rotating electrical machines. Part 9: Noise limits	This standard specified sound power level of maximum A weight allows for rotating electrical machines accordance to TCVN 6627-1:2000 (IEC 34-1), cooling method according to IEC 34-6 and protection levels according to IEC 34-5 and has the following characteristics: criteria design , DC or AC, no special change of electrical, mechanical and sound to reduce noise levels; output nominal power from 1KW (or kVA) to 5500 kW (or kVA); the speed does not exceed of 3750 rpm Related Standard: IEC 34-9:1990, IEC 34-6:1969, IEC 34-5:1990

Number	Rev.	Title	Abstract
TCVN 6627-11	2008	Rotating electrical machines. Part 11: Thermal protection	This standard specifies the requirements related to the use of thermal protection device and thermal detectors installed in the stator coil or other appropriate position in the induction electrical machines to protect it from serious damage by the thermal overload Related Standard: IEC 60034-11:2004, IEC 60034-12
TCVN 6627-14	2008	Rotating electrical machines. Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher. Measurement, evaluation and limits of vibration severity	This standard specifies the acceptance testing process at the factory about vibration and vibration limits for some certain machines in specified conditions, when the machines disconnect to any load or the primary transmission parts This standard applies to one-dimensional and three-phase AC electric machines, with the height from the axis center of 56 mm or more and nominal power up to 50 MWs, working speed from 120 to 15,000 rpm Related Standard: IEC 60034-14:2003, ISO 7919-1, ISO 2954
TCVN 7697-1	2007	Instrument transformers. Part 1: Current transformers	This standard applies to the new manufacturing current transformers are used together with electric instrumentation and electrical protection device is in the range of frequencies from 15Hz to 100Hz. Related Standard: IEC 60044-1:2003, IEC 60028:1925, IEC 60038:1983
TCVN 7697-2	2007	Instrument transformers. Part 2 : Inductive voltage transformers	This standard applies to the new manufacturing inductive voltage transformers are used together with electric instrumentation and electrical protective devices are in the range of frequencies from 15Hz to 100Hz. Related Standard: IEC 60044-2:2003, IEC 60038:1983, IEC 60050:1986
TCVN 7994-1	2009	Low-voltage switchgear and controlgear assemblies. Part 1: Requirements for type-tested and partially type-tested assemblies	This standard applies to installation assembly for switching and control low-voltage circuit, nominal voltage not exceeding AC 1000 V and frequencies not exceeding 1000 Hz or 1500 V of DC. Related Standard: IEC 60439-1:2004
TCVN 8091-2	2007	Paper-insulated metal-sheathed cabled for rated voltages up to 18/30 kV (with copper or aluminum conductors and excluding gas-pressure and oil-filled cables). Part 2: General and construction requirements	Related Standard: IEC 60055-2:1981/ AMD 1:1989, AMD 2:2005

Table- 60 Reference Japanese Technical Standards

Number	Rev.	Title	Abstract/Equivalency
Instruments			
JISC1602	1995	Thermocouples	JISC 1602 specifies thermocouples used for temperature measurement. IEC 60584-1:1977 (MOD) IEC 60584-2:1982 (MOD)
JIS C 1604	1997	Resistance thermometer sensors	JISC 1604 specifies platinum resistance thermometer sensors for temperature measurement. IEC 60751:1985 (MOD)
JIS C1605	1995	Mineral insulated thermocouples	JISC 1605 specifies mineral insulated thermocouples used for thermometry. IEC 61515:1995 (MOD)
JISC1610	1995	Extension and compensating cables for thermocouples	JISC 1610 specifies extension and compensating cables for thermocouples used in combination with the thermoelectric couple and metal-sheathed thermocouple which are specified in JIS C 1602, and JIS C 1605. IEC 60584-3:1989 (MOD)
JIS B7551	1999	Variable area flowmeter	JIS B7551 specifies variable area flowmeter used for flow measurement of gas or liquid or steam.
JIS B7554	1997	Electromagnetic flowmeters	JIS B7554specifies the principle, construction and function, method of performance test and using method of the electromagnetic flowmeters for industrial use. This Standard does not apply to the fiowmeters for medical use, for measuring liquid metal and for measuring water flow in open conduits. ISO 6817:1992 (MOD) ISO 9104:1991 (MOD)
JIS B 7555	2003	Method of flow measurement by coriolis meters (mass flow, density and volume flow measurement)	JIS B 7555 gives guidelines for the selection, installation, calibration, performance and operation of Coriolis meters for the determination of mass flow, density, volume flow and other related parameters of fluids. It also gives appropriate considerations regarding the fluids to be measured. ISO 10790:1999 (MOD)
JIS Z8710	1993	Temperature measurement General requirement	JIS Z8710 specifies general methods for temperature measurement.
Cables			
JIS C1610	1995	Extension and compensating cables for thermocouples	IEC 60584-3:1989 (MOD)
JIS C3312	2000	600 V Grade polyvinyl chloride insulated and sheathed portable power cables	-
JIS C3327	2000	600V Rubber insulated flexible cables	JIS C3327 specifies rubber insulated which flexible cables which are used in power

Number	Rev.	Title	Abstract/Equivalency
			circuit of electrical machinery and apparatus for migration not more than 600V or used when flexibility is required. This should not be applied to the place where flexibility is not required IEC 60245-4:1994 (NEQ)
JIS C3342	2000	600V Polyvinyl chloride insulated and sheathed cables	JIS C3342 specifies vinyl chloride insulated and sheathed cables which are used in the circuit not more than 600Vand whose insulation and sheath are mainly made of vinyl chloride resin. IEC 60227-4:1997 (NEQ)
JIS C3361	2009	600 V Polyvinyl chloride insulated cables	JIS C3361specifies 600 V polyvinyl chloride insulated cables whose insulation and sheath are mainly made of vinyl chloride resin according to IEC specification. IEC 60502-1:2004 (MOD)
JIS C3362	2009	600 V Cross-linked polyethylene insulated cables	JIS C3362 specifies 600 V Cross-linked polyethylene insulated cables which are used in the circuit not more than 600V ,whose insulation are cross-linked polyethylene, and whose sheath are the compound made of mainly polyvinyl chloride resin, or the compound made of polyethylene resin according to IEC specification. IEC 60502-1:2004 (MOD)
JIS C3363	2009	600 V Ethylene-propylene rubber insulated cables	IEC 60502-1:2004 (MOD)
JIS C3364	2009	Control cables	JIS C3364 specifies control cables which are used in the circuit not more than 600V ,whose insulation are cross-linked polyethylene or the compound made of mainly vinyl chloride resin , and whose sheath are vinyl or polyethylene according to IEC specification. IEC 60502-1:2004 (MOD)
JIS C3401	2002	Control cables	JIS C3401 specifies control cables which are used in the circuit not more than 600V ,whose insulation are polyethylene or cross-linked polyethylene or the compound made of mainly vinyl chloride resin , and whose sheath are the fire- resistant compound made of mainly vinyl, or polyethylene, or polyethylene resin .
JIS C3605	2002	600V Polyethylene insulated cables	JIS C3605 specifies polyethylene insulated cables which are used in the circuit not more than 600V ,whose insulation are the compound made of polyethylene or cross-linked polyethylene, and whose sheath are the compound made of polyethylene or, the fire- resistant compound mainly made of polyethylene resin.
JIS C3606	2003	High-voltage cross-linked polyethylene	JIS C3605 specifies cross-linked polyethylene insulated cables which are

Number	Rev.	Title	Abstract/Equivalency
		insulated cables	used in the circuit not more than 600V ,whose insulation are cross-linked polyethylene , and whose sheath are the compound mainly made of vinyl chloride resin, and polyethylene or the fire-resistant compound mainly made of polyethylene resin. IEC 60502-2:1997 (MOD)
JIS C3621	2000	600V Grade ethylene-propylene rubber insulated cables	-
JIS C3662-4	2003	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750V - Part 4 : Sheathed cables for fixed wiring	JIS C3662-4 specifies sheathed cables for fixed wiring, not more than 450/750V of rated voltage, and also specifies detail specifications of light vinyl cables whose rated voltage is not more than 300/500V. IEC 60227-4:1992 (IDT)
JIS C3663-4	2007	Rubber insulated cables - Rated voltages up to and including 450/750V - Part 4: Cords and flexible cables	JIS C3663-4 specifies rubber insulated and braided cords and rubber insulated and rubber or polychloroprene or other equivalent synthetic elastomer sheathed cords and flexible cables of rated voltages up to and including 450/750. IEC 60245-4:1994 (MOD)
JIS C6870 series	-	Optical fibre cables - Indoor cables - Outdoor cables	A series of JIS C6870 specifies optical fiber cables for indoor and outdoor use. IEC 60794 series: (MOD)
Test for flame propagation for wire or cable			
JIS C 3665-1-2	2007	Tests on electric and optical fibre cables under fire conditions - Part 1-2: Test for vertical flame propagation for a single insulated wire or cable - Procedure for 1kW pre-mixed flame	JIS C 3665-1-2 specifies testing method of fire-retardancy when vertical flame propagates on a single insulated wire or cable or optical fibre cables under fire conditions. IEC 60332-1-2:2004 (IDT)
Explosive atmospheres			
JIS C60079-14	2008	Electrical apparatus for explosive gas atmospheres - Part 14: Electrical installations in hazardous areas (other than mines)	This part of JIS C60079 contains the specific requirements for the design, selection and erection of electrical installations in hazardous areas associated with explosive atmospheres. IEC 60079-14:2002 (IDT)
Electrical equipment			
JIS C 1731-1	1998	Instrument transformers for testing purpose and used with general instrument Part 1: Current transformers	JIS C1731-1 specifies instrument transformers manufactured newly for testing purpose and used with general instrument which serve within the power frequency range. IEC 60044-1:1996 (MOD)

Number	Rev.	Title	Abstract/Equivalency
JIS C1731-2	1998	Instrument transformers for testing purpose and used with general instrument Part 2: Voltage transformers	JIS C1731-2 specifies instrument transformers manufactured newly for testing purpose and used with general instrument in the commercial range. IEC 60044-2:1997 (MOD)
JIS C 4210	2001	Low-voltage three-phase squirrel-cage induction motors for general purpose	JIS C 4210 specifies low-voltage three-phase squirrel-cage induction motors for general purpose of continuous rating at a frequency 50 Hz or 60 Hz exclusively or 50 Hzl60 Hz in common, at a voltage not exceeding 600 V with a protection system IP2X (protected type) or IP4X (totally enclosed type) which are used in a place where the coolant temperature is not exceeding 40 'C. IEC 60034-12:1972 (MOD)
JIS C 4212	2000	Low-voltage three-phase squirrel-cage high-efficiency induction motors	JIS C 4212 specifies low-voltage three-phase squirrel-cage high-efficiency induction motors of continuous rating at a frequency 50 Hz or 60 Hz exclusively or 50 Hz/60 Hz in common, at a voltage not exceeding 600 V with a protection system IP2X (protected type) or IP4X (totally enclosed type) which are used in a place where the coolant temperature is not exceeding 40 C and of which efficiency is higher than that of low-voltage three-phase squirrel-cage induction motors for general purpose.
JIS C 8201-2-1	2011	Low-voltage switchgear and controlgear -- Part 2-1: Circuit-breakers	JIS C 8201-2-1 specifies circuit-breakers (specifying wiring breakers and other breakers) used in the circuit whose rated voltage is not more than 1000V AC or 1500V DC. IEC 60947-2:2006 (MOD)
JIS C 8201-2-2	2011	Low-voltage switchgear and controlgear -- Part 2-2: Circuit-breakers incorporating residual current protection	JIS C 8201-2-2 specifies circuit-breakers incorporating residual current protection, and rated voltage of the circuit which main contacts of the breakers are connected with is not more than 1000V AC of 50Hz or 60Hz., IEC 60947-2:2006 (MOD)
JIS C 8201-3	2009	Low-voltage switchgear and controlgear -- Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units	JIS C 4212 specifies switches, disconnectors, switch-disconnectors and fuse-combination units (except for equipped with uncovered fuse) used in the distribution or motor circuit whose rated voltage is not more than 1000V AC or 1500V DC. IEC 60947-3:1999 (MOD)
JIS C8201-4-1	2010	Low-voltage switchgear and controlgear—Part 4-1: Contactors and motor-starters: Electromechanical contactors and motor-starters	JIS C8201-4-1specifies electromechanical contactors and the motor-starters units in which has main contacts connected with the circuit whose rated voltage is not more than AC 1 000V, or not more than DC 1500V. IEC 60947-4-1:2000 (MOD)

Number	Rev.	Title	Abstract/Equivalency
JIS B8210	2009	Safety devices for protection against excessive pressure-Direct spring loaded safety valves for steam and gas service	JIS B8210 specifies cylindrical-coil direct spring loaded safety valves for steam and gas service. ISO 4126-1:2004 (MOD) ISO 4126-7:2004 (MOD)

Note: Explanation of Equivalency

1. IDT: "identical"

   JIS is identical to the International Standard if

(1) JIS is identical in technical content, structure and wording, or

(2) JIS is identical in technical content, although it may contain the minimal editorial changes specified in 4.2 of ISO/IEC GUIDE 21:1999.

   The "vice versa principle" is fulfilled.

2. MOD: "modified"

   JIS is modified in relation to the International Standard if technical deviations, which are permitted, are clearly identified and explained. JIS reflects the structure of the International Standard, but changes in structure are permitted provided that the altered structure permits easy comparison of the content of the two standards. Modified standards also include the changes permitted under identical correspondence.

3. NEQ: "not equivalent"

   JIS is not equivalent to the International Standard in technical content and structure and any changes have not been clearly identified. No clear correspondence is obvious between JIS and the International Standard.

   Note: This category of correspondence does not constitute an adoption.