

Initial Environmental Examination

Appendix I, Parts 1–3
March 2019

Cambodia: National Solar Park Project

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Appendix I – Part 1 Cambodia Environmental Quality Standards

(1) AMBIENT AIR QUALITY STANDARDS

Source: Sub-decree No. 42 ANRK.BK on Air Pollution Control and Noise Disturbance, MoE 2000.

Parameter	Averaging Period	Standard	
		Unit	Value
Nitrogen Dioxide (NO ₂)	24 hours	mg /m ³	0.1
Sulfur Dioxide (SO ₂)	24 hours	mg /m ³	0.3
Carbon Monoxide (CO)	24 hours	mg /m ³	20
PM 2.5	24 hours		-
PM 10	24 hours		-

(2) AMBIENT NOISE STANDARDS

Source: Sub-decree No. 42 ANRK.BK on Air Pollution Control and Noise Disturbance, MoE, 2000.

Areas	Time Period (24 hours)	Standard	
		Unit	Standard Value
Area is not identified	Day time (from 6:00am to 6:00pm)	Noise Level dB(A)	70.0
	Evening Time (from 6:00pm to 11:00pm)	Noise Level dB(A)	65.0
	Night time (from 11:00pm to 6:00am)	Noise Level dB(A)	50.0

(3) SURFACE WATER QUALITY STANDARD

Source: Sub-decree No. 27 ANRK.BK on Water Pollution Control, MoE, 1999; The standards of water quality are divided as follows:

Annex 2 of Sub-decree on Water Pollution Control

Effluent standard for pollution sources discharging wastewater to public water areas or sewer

No	Parameters	Unit	Allowable limits for pollutant substance discharging to	
			Protected public water area	Public water area and sewer

No	Parameters	Unit	Allowable limits for pollutant substance discharging to	
			Protected public water area	Public water area and sewer
1	Temperature	0C	< 45	< 45
2	pH		6 – 9	5 - 9
3	BOD5 (5 days at 200 C)	mg/l	< 30	< 80
4	COD	mg/l	< 50	< 100
5	Total Suspended Solids	mg/l	< 50	< 80
6	Total Dissolved Solids	mg/l	< 1000	< 2000
7	Grease and Oil	mg/l	< 5.0	< 15
8	Detergents	mg/l	< 5.0	< 15
9	Phenols	mg/l	< 0.1	< 1.2
10	Nitrate (NO ₃)	mg/l	< 10	< 20
11	Chlorine (free)	mg/l	< 1.0	< 2.0
12	Chloride (ion)	mg/l	< 500	< 700
13	Sulphate (as SO ₄)	mg/l	< 300	< 500
14	Sulphide (as Sulphur)	mg/l	< 0.2	< 1.0
15	Phosphate (PO ₄)	mg/l	< 3.0	< 6.0
16	Cyanide (CN)	mg/l	< 0.2	< 1.5
17	Barium (Ba)	mg/l	< 4.0	< 7.0
18	Arsenic (As)	mg/l	< 0.10	< 1.0
19	Tin (Sn)	mg/l	< 2.0	< 8.0
20	Iron (Fe)	mg/l	< 1.0	< 20
21	Boron (B)	mg/l	< 1.0	< 5.0
22	Manganese (Mn)	mg/l	< 1.0	< 5.0
23	Cadmium (Cd)	mg/l	< 0.1	< 0.5
24	Chromium (Cr)+3	mg/l	< 0.2	< 1.0
25	Chromium (Cr)+6	mg/l	< 0.05	< 0.5
26	Copper (Cu)	mg/l	< 0.2	< 1.0
27	Lead (Pb)	mg/l	< 0.1	< 1.0
28	Mercury (Hg)	mg/l	< 0.002	< 0.05
29	Nickel (Ni)	mg/l	< 0.2	< 1.0

No	Parameters	Unit	Allowable limits for pollutant substance discharging to	
			Protected public water area	Public water area and sewer
30	Selenium (Se)	mg/l	< 0.05	< 0.5
31	Silver (Ag)	mg/l	< 0.1	< 0.5
32	Zinc (Zn)	mg/l	< 1.0	< 3.0
33	Molybdenum (Mo)	mg/l	< 0.1	< 1.0
34	Ammonia (NH ₃)	mg/l	< 5.0	< 7.0
35	DO	mg/l	>2.0	>1.0
36	Polychlorinated Byphenyl	mg/l	<0.003	<0.003
37	Calcium	mg/l	<150	<200
38	Magnesium	mg/l	<150	<200
39	Carbon tetrachloride	mg/l	<3	<3
40	Hexachloro benzene	mg/l	<2	<2
41	DTT	mg/l	<1.3	<1.3
42	Endrin	mg/l	<0.01	<0.01
43	Dieldrin	mg/l	<0.01	<0.01
44	Aldrin	mg/l	<0.01	<0.01
45	Isodrin	mg/l	<0.01	<0.01
46	Perchloro ethylene	mg/l	<2.5	<2.5
47	Hexachloro butadiene	mg/l	<3	<3
48	Chloroform	mg/l	<1	<1
49	1,2 Dichloro ethylene	mg/l	<2.5	<2.5
50	Trichloro ethylene	mg/l	<1	<1
51	Trichloro benzene	mg/l	<2	<2
52	Hexachloro cyclohexene	mg/l	<2	<2

Remark: The Ministry of Environment and the Ministry of Agriculture, Forestry and Fishery shall collaborate to set up the standard of pesticides which discharged from pollution sources.

Annex 4 of Sub-decree on Water Pollution Control

Water quality standard in public water areas for bio-diversity conservation

a) River

Parameter	Standard	
	Unit	Value
pH	mg/l	6.5 – 8.5
BOD5	mg/l	1 – 10
Suspended Solid	mg/l	25 – 100
Dissolved Oxygen	mg/l	2.0 - 7.5
Coliform	MPN/100ml	< 5000

b) Lakes and Reservoirs

Parameter	Standard	
	Unit	Value
pH	mg/l	6.5 – 8.5
COD	mg/l	1 – 8
Suspended Solid	mg/l	1 – 15
Dissolved Oxygen	mg/l	2.0 - 7.5
Coliform	MPN/100ml	< 1000
Total Nitrogen	mg/l	1.0 – 0.6
Total Phosphorus	mg/l	0.005 – 0.05

Annex 5 of Sub-decree on Water Pollution Control

Water Quality Standard in public water areas for public health protection

No	Parameter	Unit	Standard Value
1	Carbon tetrachloride	µg/l	< 12
2	Hexachloro-benzene	µg/l	< 0.03
3	DDT	µg/l	< 10
4	Endrin	µg/l	< 0.01
5	Dieldrin	µg/l	< 0.01
6	Aldrin	µg/l	< 0.005
7	Isodrin	µg/l	< 0.005
8	Perchloroethylene	µg/l	< 10
9	Hexachlorobutadiene	µg/l	< 0.1
10	Chloroform	µg/l	< 12
11	1,2 Trichloroethylene	µg/l	< 10
12	Trichloroethylene	µg/l	< 10

No	Parameter	Unit	Standard Value
13	Trichlorobenzene	µg/l	< 0.4
14	Hexachloroethylene	µg/l	< 0.05
15	Benzene	µg/l	< 10
16	Tetrachloroethylene	µg/l	< 10
17	Cadmium	µg/l	< 1
18	Total mercury	µg/l	< 0.5
19	Organic mercury	µg/l	0
20	Lead	µg/l	< 10
21	Chromium, valent 6	µg/l	< 50
22	Arsenic	µg/l	< 10
23	Selenium	µg/l	< 10
24	Polychlorobiohenyl	µg/l	0
25	Cyanide	µg/l	< 0.005

(4) GROUNDWATER QUALITY STANDARD

Source: The Cambodian National Drinking Water Quality Standard (CNDWQS) is National Standard of the Ministry Industry and Handicraft.

No	Parameter	Standard	
		Unit	Value (CNDWQS Standard)
1	pH	-	6.5-8.5
2	Turbidity	NTU	5.0
3	Dissolved Oxygen (DO)	mg/l	NV
4	Total Suspended Solid (TSS)	mg/l	NV
5	Chloride (Cl-)	mg/l	250
6	Nitrate (NO3)	mg/l	50
7	Phosphate (PO4)	mg/l	NV
8	Sulphate (SO4)	mg/l	250
9	(BOD)5	mg/l	NV
10	(COD) Mn	mg/l	NV
11	Aluminum (Al)	mg/l	0.2
12	Arsenic (As)	mg/l	0.05
13	Copper (Cu)	mg/l	1.0
14	Iron (Fe)	mg/l	0.3
15	Lead (Pb)	mg/l	0.01

No	Parameter	Standard	
		Unit	Value (CNDWQS Standard)
16	Manganese (Mn)	mg/l	0.1
17	Mercury (Hg)	mg/l	0.001
18	Zinc (Zn)	mg/l	3.0
19	Total Coli form	MPN/100ml	0

(5) SOIL QUALITY STANDARD

Source: Cambodia National Quality Standards for Agriculture, Ministry of Agriculture, Forest, and Fishery (MAFF).

Parameter	Standard	
	Unit	Value
pH		
Salinity	ppt	6-8
Oil & Grease	mg/kg	-
Chloride	mg/kg	-
Petroleum Hydrocarbons		
Kerosene hydrocarbons (c10-c14)	mg/kg	-
Diesel hydrocarbons (c15-c28) (mg/L)	mg/kg	-
Heavy oil hydrocarbons (c29-c36) (mg/L)	mg/kg	-
BTEX		
Ethylbenzene	mg/kg	0.018
Benzene	mg/kg	0.0068
Toluene	mg/kg	0.08
Xylene	mg/kg	2.4
Metals		
Nickel	mg/kg	50
Copper	mg/kg	63
Zinc	mg/kg	200
Arsenic	mg/kg	12
Cadmium	mg/kg	1.4



KINGDOM OF CAMBODIA
NATION RELIGION KING

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**ELECTRIC POWER TECHNICAL
STANDARDS OF
THE KINGDOM OF CAMBODIA.**

- (1)- GENERAL REQUIREMENTS OF ELECTRIC POWER
TECHNICAL STANDARD OF THE KINGDOM OF
CAMBODIA.**
- (2)- SPECIFIC REQUIREMENTS OF ELECTRIC POWER
TECHNICAL STANDARD OF THE KINGDOM OF
CAMBODIA.**
- (3)- EXPLANATION SHEET FOR ELECTRIC POWER
TECHNICAL STANDARD.**
- (4)- GLOSSARY FOR ELECTRIC POWER TECHNICAL
STANDARD.**

Printed by Electricity Authority of Cambodia

General Requirements of Electric Power Technical Standard of the Kingdom of Cambodia

JULY 2004

**ISSUED BY MINISTRY OF INDUSTRY, MINES AND ENERGY IN ACCORDANCE
WITH THE ELECTRICITY LAW OF THE KINGDOM OF CAMBODI**

KINGDOM OF CAMBODIA
NATION KING RELIGION

Ministry of Industry, Mines and Energy

No. 470

July 16, 2004

PROKAS
ON ESTABLISHMENT OF GENERAL REQUIREMENT OF ELECTRIC
POWER TECHNICAL STANDARDS OF THE KINGDOM OF
CAMBODIA

MINISTER OF INDUSTRY, MINES AND ENERGY

- Seen the Constitution of the Kingdom of Cambodia;
- Seen the Royal KRET No. NS/RKT/1189/72 Dated December 30, 1998 on the appointment of the Royal Government;
- Seen the Royal KRAM No. NS/RKM/0196/05 Dated January 24, 1996 promulgating the law on establishment of the Ministry of Industry, Mines and Energy;
- Seen the urgent need and real situation at present;

DECIDES

Article 1

To establish the General Requirement of Electric Power Technical Standards of the Kingdom of Cambodia, for implementation, in 5 main parts as below:

- 1- Fuel Oil Generation Plant and Steam Power Plant
- 2- Hydro Power Plant
- 3- Transmission and Distribution System
- 4- Renewable Energy System
- 5- House and General Building Wiring System

Article 2

To issue the General Requirement of Electric Power Technical Standards of the Kingdom of Cambodia, full contents of which are attached here with.

Article 3

The Specific Requirement of each part shall be prepared and issued from time to time accordance with the priority.

Article 4

All electric suppliers and consumers shall fully follow this Standard.

Article 5

The electric suppliers are allowed to use their existing electric system for 2 years or any extension as decided by Electricity Authority of Cambodia from the date of signing of this Prokas, during which they are to improve their facilities to be in accordance with the electric power technical Standard. When the system is improved or changed, this standard shall be followed. The existing House and General Building Wiring System is allowed to remain in use except the unsafe system.

Article 6

Prokas or any decision in contradiction to this Prokas shall be null and void.

Article 7

This Prokas shall come into force from the date of signing.

Minister of Industry Mines and Energy

Sign and Seal

SUY SEM

KINGDOM OF CAMBODIA
NATION KING RELIGION

Ministry of Industry, Mines and Energy

No. 796

August 9, 2007

PROKAS
ON THE FIRST AMENDMENT ON THE PROKAS NO. 470, DATED
JULY 16, 2004 ON THE ESTABLISHMENT OF ELECTRIC POWER
TECHNICAL STANDARDS OF THE KINGDOM OF CAMBODIA

MINISTER OF INDUSTRY, MINES AND ENERGY

- Seen the Constitution of the Kingdom of Cambodia;
- Seen the Royal KRET No. NS/RKT/0704/124 Dated July 14, 2004 on the appointment of the Royal Government;
- Seen the Royal KRAM No. NS/RKM/0196/05 Dated January 24, 1996 promulgating the law on establishment of the Ministry of Industry, Mines and Energy;
- Seen the Royal KRAM No. NS/RKM/0201/ 03 Dated February 02, 2001 promulgating the Electricity Law of the Kingdom of Cambodia;
- Seen the Prokas No. 470, dated July 16, 2004 on the establishment of Electric Power Technical Standards of The Kingdom of Cambodia;
- Seen the urgent need and real situation at present;

DECIDES

Article 1

To amend the General Requirement of Electric Power Technical Standards of the Kingdom of Cambodia issued by Prokas No. 470, dated July 16, 2004 as follow:

- To add the definition of the word “Remote Areas” at paragraph 19 of clause 1 (“Remote Areas” means the areas whose electric demand is too small and whose grids are not connected to other grids).

- To add paragraph 4 in clause 3 (4.Electrical Power Facilities in Remote Areas).
- To revise the table in paragraph 6.2 (Variation of Voltages) of clause 6 as follow:

Nominal System Voltage	Value to be Maintained
230V	Between 207 to <i>253V</i>
400V	Between 360 to <i>440V</i>

Article 2

Other conditions and contents of General Requirement of Electric Power Technical Standards of the Kingdom of Cambodia issued by Prokas No. 470, dated July 16, 2004 besides the above amendment shall remain unaltered and in force.

Article 3

Prokas or any decision in contradiction to this Prokas shall be null and void.

Article 4

This Prokas shall come into force from the date of signing.

Minister of Industry Mines and Energy

Sign and Seal

SUY SEM

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CHAPTER 1

GENERAL PROVISIONS

PART 1

DEFINITIONS

Clause 1: Definitions

In this General Requirements of Electric Power Technical Standards, unless the context otherwise requires, the following terms shall have the meanings assigned against each term:

1. Dam

"Dam" means an artificial barrier across a stream including embankments, its foundations and affiliated facilities such as spillways, constructed to store flowing water or divert it to intakes for power generation.

2. Draw-in Conduit System

"Draw-in Conduit System" means an installation of underground lines, in which cables are installed in conduits.

3. EAC

EAC is abbreviation of Electricity Authority of Cambodia.

4. Electrical Line

"Electrical Line" means the part of electric power facilities used to transmit or supply electricity, which connects power stations, substations, switching stations and user's sites, and includes lines and associated protective devices and switchgears.

5. Electric Power Facility

"Electric Power Facility" means Generating Facilities, Substations, Switching Stations, Electrical Lines, and dispatching centers, including equipment, buildings, dam, waterways, fuel storageyards, ash disposal areas, etc.

6. Electrical Equipment

"Electrical Equipment" means electrically-charged facilities.

7. Generating Facilities

"Generating Facilities" means the electric power facilities used for generating electricity.

8. High-Voltage Line

"High-voltage Line" means an electrical line of voltage higher than 35kV

9. House Wiring

"House wiring" means the installation of user's electrical equipment like wiring or devices installed in houses or buildings etc for the purpose of using electricity. This installation doesn't include the

installation of electrical equipments which are not user's facilities, like power generating facilities or substation installed in that place.

10. IEC

IEC is abbreviation of International Electrotechnical Commission.

11. Indoor Electrical Appliances

“Indoor electrical appliances” means low-voltage incandescent lamps, discharge lamps, and household and business electrical appliances installed indoors.

12. Insulated Conductor

“Insulated Conductor” means a cross-linked polyethylene (XLPE) insulated conductor for the medium-voltage lines and XLPE insulated conductor or a polyvinyl chloride (PVC) insulated conductor for the low-voltage line, according to the substance of the covering insulator.

13. ISO

ISO is abbreviation of International Organization for Standardization.

14. Joint Use

“Joint Use” means a condition that electrical lines and/or communication lines belonging to two or more owners are installed on the same supporting structure.

15. Licensee

“Licensee” means an electric power service provider who has been issued a license by the EAC.

16. Low-Voltage Line

“Low-voltage Line” means an electrical line having voltage not more than 600V.

17. Medium-Voltage Line

“Medium-voltage Line” means an electrical line having voltage more than 600V but not more than 35kV.

18. National Grid

“National Grid” means the high voltage backbone system of interconnected transmission lines, substations and related facilities for the purpose of conveyance of bulk power.

19. Reservoir

“Reservoir” means stored water impounded by one or more dams or surrounding ground. It also means land on which water is impounded to the highest water storage level.

20. Remote area

“Remote area” means areas whose electric demand is too small and whose grids are not connected to other grids.

21. RTU

RTU is abbreviation of “Remote Terminal unit” for SCADA system, installed at the electric power facilities for monitoring the/fault status and control.

22. SCADA

SCADA is abbreviation of “Supervisory, control, and Data Acquisition” and means equipment used for monitoring and receiving data.

23. Service Connection

“Service Connection” means an electrical link between a consumer’s site and Low-voltage Line for supply electricity to that consumer.

24. Side by Side Use

“Side by Side Use” means a condition that electrical lines and/or communication lines of one owner are installed on the same supporting structure.

25. Substation

“Substation” means electric power facilities to transform the voltage, including transformers, lightning arresters, circuit breakers, disconnecting switches, potential devices, current transformers, bus bars, protective relay systems for electrical lines and equipment and devices, RTU for SCADA system, telecommunication facilities, etc.

26. Supporting Structure

“Supporting structure” means a structure to support electrical line, such as wooden poles, iron poles, reinforced concrete poles and steel towers.

27. Switching Station

“Switching Station” means electric power facilities to change-over the electrical lines which includes disconnecting switches, circuit breakers, bus-bars, protective relay system, RTU for SCADA system, etc.

28. The Technical Standards

“The Technical Standards” means The Electric Power Technical Standards in the Kingdom of Cambodia.

29. User’s Site

“User’s Site” means a place at which machines, apparatus and devices for using electricity are installed.

30. Waterway

“Waterway” means a general term of channels and auxiliaries including gates and valves that take flowing water, convey it to hydro-turbines, and discharge it into a river and so on for power generation. “Waterway” is generally composed of intakes, forebays (settling basins), headraces, head tanks or surge tanks, penstocks, tailraces, outlets, and other facilities.

PART 2

PURPOSE, AREA OF APPLICATION AND ENFORCEMENT

Clause 2: Purpose

This General Requirements of Technical Standards has the following main purposes:

1. To specify the technical, design, and operational criteria of Electrical Power Facility, House Wiring and Electrical Appliance,
2. To ensure that the basic rules for supply of electricity are fair and non-discriminatory for all Consumers of the same category, and
3. To maintain the technical standards (levels) of Electrical Power Facility, House Wiring and Electrical Appliance installed in the Kingdom of Cambodia

Clause 3: Area of Application

All electrical power facilities, house wiring and electrical appliances, except the following facilities, shall be in accordance with the Technical Standards.

1. Electrical equipment installed in airplanes, vessels, trains and vehicles
2. Electrical equipment operating at voltage lower than 30V AC/DC which has not been connected to the electric facilities of voltage 30V or more
3. Communication facilities other than the communication facilities for power system operation
4. Electric power facilities in remote areas.

Clause 4: Enforcement

4.1 Jurisdiction

All persons who are related to electric power supply, electrical works, use of electricity, manufacturing electric power facilities, trading in the facilities in the Kingdom of Cambodia shall strictly follow the Technical Standards. The Technical Standards will not exempt any concerned conditions stipulated in any other law or Regulations even though the matters not stipulated in the Technical Standards.

4.2 Attention to be paid for Power Project

1. In planning of electric power projects, the feasibility studies shall be made to examine the long term technical, economical and financial viability, and social acceptability.
2. The design, manufacturing, assembling and procurement of power facilities should be such that the facilities can be operated with the designated performance for a long time. Therefore, enough

attention shall be paid in selection of the materials, safety factors, and to easy operation, assembling/dismantling during operation and maintenance.

3. During installation of the electric power facilities and equipment and construction of the facilities, enough attention shall be paid in selection of the materials and construction management during the construction work.
 4. In operation and maintenance of the electric power facilities, enough attention for maintaining the required performance of the power facilities for long time and to protect the environment in the surrounding areas, shall be paid.
 5. In closing the electric power facilities, enough attention to the environmental and social issues after closure of the facilities, shall be paid.
- 4.3 Licensees of power utilities shall employ qualified electrical engineers or technicians as appropriated for supervision, operation and maintenance of the power facilities as provided in the Technical Standards and other regulations.
- 4.4 Electrical works, such as house wiring, cable connection, installation of electrical equipment, shall be carried out by qualified electricians. The works shall be carried out in accordance with the Technical Standards.

Clause 5: Transitional Provision

- 1 The existing electric power facilities not harmful to human beings, animals and trees could be operated till the time of its renewal or replacement.
- 2 The existing electrical power facilities harmful to human beings, animals and trees shall be modified within two years to be satisfactory with the requirement of the Technical Standards.

PART 3
QUALITY OF ELECTRIC POWER

Clause 6: Voltage

6.1 Standard Voltage

AC voltage shall be as follows below:

Classification of voltage	Range of Nominal Voltage	Nominal Voltage	Highest Voltage
Low Voltage	600V or less	230/400V	—
Medium Voltage	More than 600V to 35kV or less	22kV	24kV
High Voltage	More than 35kV	115kV	123kV
		230kV	245kV

If in the interest of development of the power sector in the Kingdom of Cambodia it becomes necessary to use a nominal voltage other than that given in the table above, the Ministry of Industry, Mines and Energy may allow the use of such nominal voltage as a standard voltage through issuing Prokas.

6.2 Variation of voltages

The AC voltage at low voltage power supply points shall be maintained to the value according to the nominal system voltage in accordance with the following table;

Nominal System Voltage	Value to be Maintained
230 V	Between 207 V and 253 V
400 V	Between 360 V and 440V

Clause 7: Frequency

The rating frequency is 50 Hz. The variation of the frequency shall be between 49.5 Hz and 50.5 Hz.

Clause 8: Continuity of Power Supply

- 1 Electric power supply shall be made continuously in accordance with the Regulations on General Conditions of Supply of Electricity in the Kingdom of Cambodia issued by EAC.

- 2 In case of interruption in power supply, power system failure or loss of power, all electric power licensees shall make all possible efforts to restore the normal conditions for continuous power supply.

PART 4

PREVENTION OF ELECTRIC POWER DISASTERS

Clause 9: Prevention of Electric Power Disasters

The electrical equipment shall be installed in such manner as not to cause electrical shock, fire and other accidents.

Clause 10: Prevention of Accidents Caused by Electric Power Facilities

The electric power facilities shall be installed with proper measures for operators not to touch their moving parts, hot parts and other dangerous parts, and not to fall from them, accidentally.

Clause 11: Safety of Third Persons

1. Appropriate measures shall be taken to prevent third persons from entering into compounds of power plants, substations and switching stations.
2. Appropriate measures shall be taken to prevent third persons from climbing supporting structures of overhead electrical lines.

Clause 12: Prevention of Failures of Electric Power Facilities from Natural Disasters

Proper measures shall be taken for preventing failures of electric power facilities from anticipated natural disasters such as floods, lightning, earthquakes, and strong winds.

PART 5
PREVENTION OF ELECTRIC POWER OUTAGE

Clause 13: Prevention of Electric Power Outage

1. When any generating facility is in serious fault, the generating facility shall be disconnected from the power system so that the effect of the fault on the system can be minimal and possibly the system could be operated, continuously.
2. When a power system fault occurs in system connected to generating facility, the generating facility shall be disconnected from the system immediately, so that the generator shall be continuously running with no-load to wait for the recovery of the system from fault.
3. When a power system fault occurs affecting electrical lines, the power cut areas shall be minimized as much as possible by disconnecting the faulty section or other suitable methods.

PART 6
PRESERVATION OF ENVIRONMENT

Clause 14: Compliance with the Environmental Standards

To prevent the Environmental pollution, the electric power facilities shall be in accordance with the environmental laws and regulations in the Kingdom of Cambodia.

CHAPTER 2

GENERAL REQUIREMENTS FOR ELECTRIC POWER FACILITIES

PART 1
GENERAL REQUIREMENTS FOR ALL FACILITIES

Clause 15: Applicable Standards

Electrical Power Facility, House Wiring and Electrical Appliance shall be as per the provision of the Technical Standards. In case a matter is not stipulated in the Technical Standards, then IEC Standards shall be applied. If it is not covered in IEC standards, then ISO Standards shall be applied. If it is not covered in ISO Standards, then internationally recognized standards shall be applied subject to the approval of EAC.

Clause 16: Life of Electrical Power Facility

1. Electrical power facilities shall be durable for a long time usage with efficient and stable operation.
2. Taking design of the electrical power facilities, selection of the materials, assembling and installation of the equipment into consideration, suitable safety factors against foreseeable stresses, such as thermal stress, mechanical stress, insulation strength, shall be considered.
3. To secure the power supply for a long time, necessary drawings, installation records, technical manuals, instruction manuals, operation records necessary for the proper maintenance works on the electrical equipment shall be provided.

Clause 17: Grounding

1. Grounding or other appropriate measures shall be provided for Electrical Equipment to prevent electric shock, danger to human beings, fire, and other impediments to objects.
2. Grounding for Electrical Equipment shall be installed to ensure that current can safely and securely flow to the ground.

Clause 18: Connection of Conductors

Conductors shall be connected as per following methods;

1. Conductors shall be connected firmly and the resistance of conductors shall not increase more than resistance of conductors without connection.
2. Conductors shall be connected so that the insulating capacity of cables and insulated conductors shall not decrease less than insulating capacity without connection.
3. The electrochemical corrosion shall not occur by connecting conductors of different kind of materials.

Clause 19: Communication System

To secure the power supply, necessary communication system shall be provided.

Clause 20: Accuracy of Power Meters

Power meters shall be accurate, fair and equitable power meters. The accuracy of Meter shall be generally as follows:

1. Electro-magnetic mechanical power meter

Type of Customer	*Class
High-voltage customers	0.5
Medium-voltage customers	1.0
Low-voltage customers	2.0

*In accordance with IEC

2. Electronic power meter

Type of Customer	*Class
High-voltage customers	0.5
Medium-voltage customers	1.0
Low-voltage customers	2.0

*In accordance with IEC

PART 2

GENERAL REQUIREMENTS FOR THERMAL GENERATING FACILITIES

Clause 21: Boiler and its Accessories

21.1 Materials for Boiler and its Accessories

Vessels and tubes of the boiler, dependent superheater and steam storage vessel and its accessories, the parts which are subject to an internal pressure higher than 0kg/cm² (hereinafter, referred to as pressure parts) shall be made of materials having enough mechanical strength and chemical stability under the maximum working pressure and temperature.

21.2 Structure of Boiler and its Accessories

The pressure parts of the vessels and tubes of the boiler shall have enough safety margins against the maximum stress under maximum working pressure or temperature condition. In this case, the stress shall not exceed the allowable stress of the material.

21.3 Safety Valves

Vessels and tubes of the boiler which may be subjected to overpressure shall be equipped with safety valve in order to release the pressure.

21.4 Feed Water System

1. The feed water system shall be able to avoid the thermal damage on the boiler during the maximum evaporating condition.
2. In order to avoid the abnormal condition on the boiler feed water system, the boiler shall be equipped with the standby feed water system.

21.5 Shutoff of Steam and Feed Water

1. The steam outlet of the boiler shall be able to be shutoff the steam.
2. The feed water inlet of the boiler shall be able to be shutoff automatically and firmly.

21.6 Drain off Device for Boiler

In case of circulation boiler, the drain-off device shall be equipped which protect deposit and to maintain the water level.

21.7 Monitor and Alarm System

Boiler and its accessories shall be equipped with the monitoring system to monitor the running condition and the alarm system to protect from the damage of the boiler and its accessories.

Clause 22: Steam Turbine and its Accessories

22.1 Materials for Steam Turbine and its Accessories

Cylinders, vessels and tubes of the steam turbine and its accessories and the pressure parts shall be made of materials having enough mechanical strength and chemical stability under the maximum working pressure and temperature.

22.2 Structure of Steam Turbine and Its Accessories

1. Structure of steam turbine shall have enough mechanical strength even when it is operated at a speed, which the steam turbine reaches when the emergency governor is actuated.
2. Structure of steam turbine shall have enough mechanical strength against the maximum amplitude value of vibration produced on the major bearings and shaft.
3. Bearings of steam turbine shall have the construction to be able to support the load stably during operation and without its abnormal wear and deformation, and overheat.
4. The critical speed of steam turbine and/or combined with generator or rotor on the same shaft shall not be in the speed between the minimum speed of governor and the maximum available speed of emergency governor. However, it will be exempted if it will be arranged to have enough countermeasure against the vibration at critical speed during operation of turbine.
5. The pressure parts and its accessories of the steam turbine shall have enough safety margin against the maximum stress under maximum working pressure and temperature. In this case, the stress shall not exceed the allowable stress of the material.

22.3 Governor

A steam turbine shall be equipped with a device to adjust automatically the steam entering into the steam turbine in order to prevent its speed and output from fluctuating continuously even in case of a change in load condition. The device to adjust the steam entering into the steam turbine automatically shall have an ability to keep the turbine speed after the interruption of the rated load below the speed at which the emergency governor is actuated.

22.4 Emergency Stop and Alarm Devices

1. A steam turbine shall be equipped with a device that functions to provide an alarm when the amplitude value of vibrations was detected to be beyond the allowable level during the turbine operation.
2. In order to avoid the occurrence of harm from overspeed or other abnormal conditions during steam turbine operation, steam turbine shall be equipped with a device which interrupts the inflow of steam automatically and a manual emergency stop device. When the above emergency stop device is actuated, the emergency stop alarm shall be energized.

22.5 Overpressure Protection Device

Steam turbine and its accessories which are likely to be subjected to overpressure shall be equipped with an overpressure protection device in order to release the pressure.

22.6 Monitor and Alarm System

A steam turbine and its accessories shall be equipped with the necessary monitoring system to monitor the operating condition and necessary alarm system to prevent any damages to the steam turbine and its accessories during the operation.

Clause 23: Gas Turbine and its Accessories

23.1 Materials for Gas Turbine and its Accessories

Cylinders, vessels and tubes of the gas turbine and its accessories and the pressure parts shall be made of materials which having enough mechanical strength and chemical stability under maximum working pressure and temperature.

23.2 Structure of Gas Turbine and its Accessories

1. A gas turbine shall have enough mechanical strength for the structure even when it is operated at a speed which the gas turbine reaches when the emergency governor is actuated.
2. A gas turbine shall have enough mechanical strength for the structure against the maximum amplitude value of vibration produced on the major bearings and shaft.
3. Bearings of gas turbine shall have the construction to be able to support the load stably during operation and without its abnormal wear and deformation, and overheat.
4. The critical speed of gas turbine and/or combined with generator or rotor on the same shaft shall not be in the speed between the minimum speed of governor and the maximum available speed of emergency governor. However, it will be exempted if it will be arranged to have enough countermeasure against the vibration at critical speed during operation of turbine.
5. The pressure parts and its accessories of the gas turbine shall have enough safety margin against the maximum stress under the maximum working pressure and temperature. In this case, the stress shall not exceed the allowable stress of the material

23.3 Governor

A gas turbine shall be equipped with a device to adjust automatically the energy entering into the gas turbine in order to prevent its speed and output from fluctuating continuously even in case of a change in load condition. The device to adjust the energy entering into the gas turbine automatically shall have an ability to keep the turbine speed after the interruption of the rated load below the speed at which the emergency governor is actuated.

23.4 Emergency Stop and Alarm Device

1. A gas turbine shall be equipped with a device that functions to provide an alarm when the amplitude value of vibrations was detected to be beyond the allowable level during the gas turbine operation.
2. In order to avoid the occurrence of harm from overspeed or other abnormal conditions during gas turbine operation, gas turbine shall be equipped with a device which interrupts the inflow of gas automatically and a manual emergency stop device. When the above emergency stop device is actuated, the emergency stop alarm shall be energized.

23.5 Overpressure Prevention Device

Gas turbine and its accessories which are likely to be subjected to overpressure shall be equipped with an overpressure protection device in order to release the pressure.

23.6 Monitor and Alarm System

A gas turbine and its accessories shall be equipped with the necessary monitoring system to monitor the operating condition and the necessary alarming system to prevent the damages of gas turbine and its accessories during the operation.

Clause 24: Internal Combustion Engine (reciprocating engine) and its Accessories

24.1 Material for Internal Combustion Engine and its Accessories

Cylinders, vessels and tubes of the internal combustion engine and its accessories, the pressure parts shall be made of the materials which have enough mechanical strength and chemical stability under the maximum working pressure and temperature.

24.2 Structure of Internal Combustion Engine and its Accessories

1. An internal combustion engine shall have enough mechanical strength even when it is operated at a speed which the internal combustion engine reaches when the emergency governor is actuated.
2. Bearings of the engine shall have the structure to be able to support the load stably during operation and without its abnormal wear and deformation, and overheat.
- 3 The pressure parts and its accessories which belong to the engine shall have enough safety margins against the maximum stress under the maximum working pressure and temperature. In this case, the stress shall not exceed the allowable stress of the material.

24.3 Governor

An engine shall be equipped with a device to adjust automatically the energy entering into an engine in order to prevent its speed and output from fluctuating continuously even in case of a change in load condition.

24.4 Emergency Stop Device

In order to avoid the occurrence of harm from overspeed or other abnormal conditions during the engine operation, the engine shall be equipped with a device which interrupts the inflow of fuel automatically and a manual emergency stop device. When the above emergency stop device is actuated, the emergency stop alarm shall be energized.

24.5 Overpressure prevention Device

An engine and its accessories which are likely to be subjected to overpressure shall be equipped with an overpressure protection device in order to release the pressure.

24.6 Monitoring and Alarming System

An engine shall be equipped with the necessary monitoring system to monitor the operating condition and the necessary system to provide an alarm to prevent the damages of the engine and its accessories during the operation.

Clause 25: Gas-Turbine Combined Cycle and its Accessories

Gas Turbine Combined Cycle and its Accessories shall be designed, manufactured, constructed and operated in accordance with the above Clause 21, 22 and 23.†

PART 3

GENERAL REQUIREMENTS FOR HYDRO POWER GENERATING FACILITIES

Clause 26: Dams, Waterways, Powerhouses and Other Facilities

26.1 Prevention of Overflow from Non-overflow Sections of Dams

Every dam shall be equipped on or near its body with a spillway capable of safe and secure discharge of an inflow design flood, and every dam body shall have an adequate freeboard, in order to prevent overflow of water from non-overflow sections of the dam for dam safety.

26.2 Dam Stability

1. Dam bodies shall be stable for sliding, overturning, and have required strength and durability for dam stability. Fill dam bodies shall be stable for sliding, and have required strength and durability for dam stability.
2. Dam foundations and the contact areas between the dam body and its foundations shall be stable for sliding, and have the required strength for dam stability.

26.3 Prevention of Seepage Failure of Dams

1. Dam foundations shall have required water-tightness and seepage failure shall not occur in dam foundations.
2. Dam bodies shall have required water-tightness. Excessive uplifts shall not occur under concrete dam bodies. Seepage failure shall not occur in fill dam bodies.
3. Seepage failure shall not occur at the contact areas between a dam body and its foundations.

26.4 Prevention of Serious Deformations and Cracks of Dams

1. Dam foundations shall have the required bearing capacity.
2. Serious cracks shall not occur in concrete dam bodies.
3. Fill dam bodies shall be embanked with adequate materials in order to prevent serious settlement and cracks.

26.5 Prevention of Failure of Waterways

1. Waterways shall be structurally stable for anticipated loads, and not be damaged by disasters such as a landslide and a flood.
2. Waterways shall be able to safely and securely discharge and control a design plant discharge, and be hydraulically stable.

26.6 Prevention of Failure and Damage of Powerhouses and Other Facilities

Structures related to hydroelectric power civil engineering facilities such as powerhouses, maintenance roads, and temporary facilities for construction works shall be stable for anticipated loads, and not suffer failure and damage due to a landslide and a flood.

Clause 27: Prevention of Damage caused by Hydroelectric Power Plant

27.1 Prevention of Damage to Reservoirs and Ground around Reservoirs

1. Reservoirs shall not cause harmful water leakage to the surrounding ground, seepage failure of the ground, and large-scale landslides.
2. Proper measures shall be taken if submergences of properties such as houses and buildings may occur at upstream areas of a reservoir due to rises in water level caused by the reservoir sedimentation.

27.2 Prevention of Damage to Downstream Areas of Dams and those of Outlets

1. Damage due to discharge from a dam to the downstream area under conditions of floods shall not increase in comparison with the damage of no dam existence.
2. Proper measures shall be taken if damage to humans or properties, and impacts on the surrounding environment and so on may occur at the downstream areas due to discharge from dams.
3. Proper measures shall be taken if a rapid change in water level at downstream area of an outlet due to discharge from a hydroelectric power plant may cause damage to the downstream area.

Clause 28: Hydraulic Turbines and Generators

28.1 Prevention of Damage to Hydraulic Turbines

1. Hydraulic turbines shall not be remarkably damaged by driftwood, floating debris, or sediment that flows into hydraulic turbines.
2. Vibrations that may damage hydraulic turbines shall not occur.
3. Cavitation erosion that may damage hydraulic turbines shall not occur.

28.2 Equipment to Quickly Shut off the Inflow of Water

Hydraulic turbines or waterways shall be equipped in principle with facilities that can quickly shut off the inflow of water into the turbines.

28.3 Mechanical Strength of Hydraulic Turbines and Generators

1. Hydraulic turbines shall withstand the maximum water pressure in case the load is rejected.
2. Hydraulic turbines and generators shall withstand the maximum speed in case the load is rejected.
3. Generators shall withstand the mechanical shock caused by short-circuit current.

28.4 Thermal Strength of Hydraulic Turbines and Generators

Hydraulic turbines and generators shall withstand the heat generated by hydraulic turbines and generators under normal operations.

28.5 Protective Devices for Hydraulic Turbines and Generators

Hydraulic turbines and generators shall be equipped with devices to disconnect the generators from the electrical circuits and to stop the hydraulic turbines automatically in case any abnormality that may cause significant damage and/or make serious trouble to the supply of electricity occurs.

PART 4
GENERAL REQUIREMENTS FOR OTHER GENERATING FACILITIES

Clause 29: Renewable Energy, Portable Generators and Small Hydro Generations

In General, the Technical Standards shall also applicable to renewable energy generating facilities including photovoltaic generation, wind power, bio-mass or bio-gas generation, portable generators and small hydropower generation including micro-hydro generation. However, some of the conditions of the clauses stipulated in the Technical Standards which may be difficult to be applied to such generating facilities because of special features of the facilities and/or the circumstances. Relaxation from these conditions may be allowed on application from the prospective owner with the reasons if it is judged reasonable.

Clause 30: Pumped Storage Generating Facilities

The Technical Standards shall be applicable to the generating facilities. Since the Technical Standards are not enough for the generating facilities, an additional version of the Technical Standards on the generating facilities will be issued and promulgated by the time when it is needed.!

PART 5
GENERAL REQUIREMENTS COMMON FOR TRANSMISSION AND DISTRIBUTION
FACILITIES

Clause 31: Property of Conductors

1. The conductor of transmission and distribution facilities shall be cables, insulated conductors or bare conductors. Bare conductors shall not be used for low-voltage lines.
2. Cables and insulated conductors shall have sufficient insulation capacity appropriate for the conditions of the applied voltage.!!

Clause 32: Prevention of Climbing on Supporting Structures

As for supporting structures of electrical lines, following measures shall be taken to prevent danger to third persons.

1. Any metal steps of supporting structures shall not be installed at the height of 1.8m or less from the ground.
2. Warning signs to make third persons recognize danger shall be installed at each supporting structure.
3. As for high-voltage lines, appropriate devices shall be installed at all legs of supporting structures to prevent third persons from climbing the supporting structures. However, in case that the supporting structures are located at places where third persons hardly approach such as in the mountains or the supporting structures are surrounded by fences or walls with appropriate height, this article shall not be applicable.

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Clause 33: Safety Factor of Bare Conductors and Ground Wires of Overhead Electrical Lines

As for tensile strength of conductors and ground wires for overhead electrical lines except for cables, the safety factor shall be not less than 2.5.

Clause 34: Side by Side Use and Joint Use of Electrical Lines or Communication Lines

34.1 High-Voltage Lines, Medium-Voltage Lines and Low-Voltage Lines

Side by side use and joint use of electrical lines shall be done by following methods.

1. When a high-voltage line and a medium-voltage line are installed at the same supporting structure, the medium-voltage line shall be installed under the high-voltage line and on separate cross arms.
2. When a medium-voltage line and a low-voltage line are installed at the same supporting structure, the low-voltage line shall be installed under the medium-voltage line and on separate cross arms.

3. No low-voltage line shall be installed at the same supporting structure where a high-voltage line is installed.

34.2 Electrical Lines and Communication Lines

Side by side use and joint use of electrical lines and communication lines shall be done by following methods. If communication lines are optical fibers and they are tied to electrical lines or ground wires, this may not be applicable.

1. When a medium-voltage or a low-voltage line and a communication line are installed on the same supporting structure, the medium-voltage or the low-voltage line shall be installed above the communication line and on separate cross arms.
2. No communication line shall be installed at the same supporting structure where a high-voltage line is installed.

Clause 35: Underground Lines

35.1 Cables shall be used for underground electrical lines.

35.2 In case that underground lines are installed with draw-in conduit system, tubes shall withstand the pressure of vehicles and other heavy objects.

35.3 In case that underground lines are installed with a direct burial system, they shall be installed in accordance with following methods.

1. Installation of proper plates above the underground lines or other proper measures shall be taken to protect the underground lines against mechanical shocks.
2. The installed position of underground facilities shall be no less than 1.2 m in depth at a place where there is a danger of receiving pressure from vehicles or other objects, and no less than 0.6 m at other place.

Clause 36: Protection against Over-current

Protection equipment against over-current shall be installed at the appropriate places of electrical circuits to prevent electrical equipment from over-heating due to excessive current and not to cause fire.

Clause 37: Protection against Ground Faults

Protection equipment against ground faults or other appropriate measures shall be provided to prevent damage of electrical equipment, electrical shock and fire.

Clause 38: SCADA System for Load Dispatching Center

1. RTU for SCADA System shall be installed in electric power facilities so that the state of the National Grid could be monitored and control of the Power Facilities could be made at the Dispatching Center.
2. Necessary telecommunication system shall be installed among Dispatching Center and electric power facilities. As the redundancy, at least two different telecommunication systems shall be required for the National Grid.

Clause 39: Classification of Grounding for Electrical Lines.

The types of grounding, the places to be applied, installation conditions, resistance value to earth of distribution line shall be as given in the following table;

Kinds of groundings

Grounding type	Application	Installation conditions	Resistance to earth (Ω)
System grounding	MV/LV transformer	Low-voltage neutral conductor of TT or TN grounding type	Value prescribed for Class B grounding work
Safety grounding	Exposed conductive parts(*1)	For high-voltage lines(*2)	Value prescribed for Class A grounding work
		For medium-voltage	
		For low-voltage exceeding 300 V	Value prescribed for Class C grounding work
		For low-voltage not exceeding 300 V	Value prescribed for Class D grounding work
Arrester grounding	Surge arrester	For medium-voltage	Value prescribed for Class A grounding work

Remarks

- (*1) “Exposed conductive parts” refers to parts such as steel stands, metal case or the like of apparatus installed in the electrical circuit.
- (*2) Groundings for high-voltage substations and switching stations shall be individually designed, depending on the short-circuit capacity.

Class A - Class D resistance value to earth shall be equal to or less than the value given in the following table.

Classification of grounding work	Resistance to earth	Conditions for easement of resistance value
Class A	10Ω or less	
Class B	10Ω or less (When $\frac{230}{I^{*1}}$ is less than 10, resistance to earth shall be the value of $\frac{230}{I^{*1}}$ or less.)	In cases where voltage to earth of a low-voltage electrical circuit exceeds 230V due to power contact between the medium-voltage electrical circuit and the low-voltage electrical circuit of the transformer, when an earth leakage breaker that cuts off the electrical circuit within 1 second is installed, $\frac{600}{I^{*1}}$ Ω or less. When $\frac{230}{I^{*1}}$ becomes less than 5Ω, it shall not be necessary to obtain resistance less than 5Ω.
Class C	10Ω or less	In the case where grounding arises in a low-voltage electrical circuit, when an earth leakage breaker that acts within 0.5 seconds is installed, the resistance value shall be 500Ω or less.
Class D	100Ω or less	In the case where grounding arises in a low-voltage electrical circuit, when an earth leakage breaker that acts within 0.5 seconds is installed, the resistance value shall be 500Ω or less.

*1 Single-line earth fault current

PART 6
GENERAL REQUIREMENTS FOR HIGH VOLTAGE TRANSMISSION FACILITIES

Clause 40: Design of Supporting Structures of Overhead High-voltage Lines

- Supporting structures of overhead lines shall be designed, taking into account the following loads.

Kinds of Loads

Type of Load	Components of Load
Vertical loads	Weight of the supporting structure
	Weight of the conductors and the ground wires and the accessories supported by the supporting structure
	Weight of the insulator strings and the fittings supported by the supporting structure
	A vertical component of the maximum tension of the guy wires supporting the supporting structure, if any
Horizontal transverse loads	Wind pressure of the supporting structure under the maximum wind velocity
	Wind pressure of the conductors and the ground wires supported by the supporting structure under the maximum wind velocity
	Wind pressure of the insulator strings and the fittings supported by the supporting structure
	A horizontal transverse component of the maximum tension of the conductors and the ground wires supported by the supporting structure and the guy wires supporting the supporting structure, if any
Horizontal longitudinal loads	Wind pressure of the supporting structure under the maximum wind velocity
	A horizontal longitudinal component of the unbalanced maximum tension of the conductors and the ground wires supported by the supporting structure and the maximum tension of the guy wires supporting the supporting structure, if any

- Supporting structures and foundations of overhead high-voltage lines shall be designed in consideration of the value of wind pressure based on the assumed maximum wind velocity in Cambodia.
- Supporting structures and foundations of overhead high-voltage lines shall be designed so that those withstand the maximum loads, in consideration of appropriate safety factors.
- In cases that overhead high-voltage lines are installed at places on the worst conditions such as inside river areas, windy areas, and so on, the supporting structures and the foundations shall be designed to withstand such the severe conditions.

Clause 41: Safety Factor of Fittings for Conductors and/or Ground Wires of Overhead High-voltage Lines

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

Clause 42: Protection against Lightning for Overhead High-voltage Lines

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

1. Installation of ground wires for overhead high-voltage lines
2. Installation of arcing horns for both ends of insulator assemblies of overhead high-voltage lines
3. Installation of armor rods to wrap conductors by a clamp of suspension insulator assemblies of overhead high-voltage lines

Clause 43: Bare Conductors of Overhead High-voltage Lines

1. Vibration Dampers

An appropriate type and number of dampers shall be installed to prevent fatigue of bare conductors and ground wires for overhead high-voltage lines due to their aeolian vibration.

2. Connection

In case that bare conductors and ground wires are jointed with each other or with insulated conductors or cables, the connection shall conform to the following requirements in addition to the Clause 18.

- (1) Bare conductors and ground wires shall be connected with compression type sleeves or compression type devices.
- (2) Tensile strength of connection of bare conductors and ground wires shall be 95 % or more of the tensile strength of the connected bare conductors and ground wires. However, this requirement shall not be applied to cases where the maximum tension to be designed is substantially smaller than the ultimate strength of the bare conductors and ground wires such as jumper conductors, the end span to substations and others.

Clause 44: Clearance among Bare Conductors and Supporting Structures of Overhead High-voltage Lines

1. Clearance among bare conductors and supporting structures, arms, guy wires and/or pole braces of overhead high-voltage lines shall be as follows. The clearances shall be secured, in any cases of the maximum swing of conductors under the maximum wind velocity to be designed, as follows;

Nominal Voltage	Clearance
115kV	No less than 0.70m
230kV	No less than 1.45m

2. Clearance among ground wires and the nearest conductor in the same span shall be larger at any points in the span than the clearance of the supporting point~~s~~ at the both sides of the span.

Clause 45: Height of Overhead High-voltage Lines

Height of conductors of overhead high-voltage lines shall be as follows.

1. Height in urban areas

Height of conductors of overhead high-voltage lines in urban areas shall be no less than the value by adding 0.06 m for every 10kV over 35kV to 6.5m,

2. Height in areas where third persons hardly approach

Height of conductors of overhead high-voltage lines in areas where third persons hardly approach shall be no less than the value by adding 0.06 m for every 10kV over 35kV to 5.5m.

3. Height over roads and/or railways

Height of conductors of overhead high-voltage lines crossing over roads and/or railways shall be no less than the value by adding 0.06 m for every 10kV over 35kV to 13m.

4. Height over rivers and/or seas

Height of conductors of overhead high-voltage lines crossing rivers and/or seas shall be as follows.

At places with no vessel passage	At places with vessel passage
From the highest water level	From the highest point of vessels on the highest water level(*1)
No less than the value by adding 0.06 m for every 10kV over 35kV to 5.5m;	No less than the value by adding 0.06 m for every 10kV over 35kV to 3m;

(*1) The highest point of vessels shall be decided taking into account the future possibility.

5. All the heights described above shall be secured in any cases of the maximum sagging of conductors in the maximum temperature to be designed.

Clause 46: Clearance among Overhead High-voltage Lines and Other Facilities or Trees

Clearance among each conductor of overhead high-voltage lines and other facilities or trees shall be as follows;

1. Clearance to other facilities

Clearance among each conductor of overhead high-voltage lines and other facilities shall be no less than the value by adding 0.06 m for every 10kV over 35kV to 3m.

2. Clearance to trees

Clearance among each conductor of overhead high-voltage lines and trees shall be no less than the value by adding 0.06 m for every 10kV over 35kV to 2m.

3. The clearances described above shall be secured in any cases of the maximum sagging of conductors in the maximum temperature and/or the maximum swing of conductors under the maximum wind velocity to be designed.

Clause 47: Prevention of Danger and Interference due to Electrostatic Induction and Electromagnetic Induction

47.1 Electrostatic Induction

High-voltage lines shall be installed to prevent danger to human bodies and/or interference on communication lines installed near the high-voltage lines caused by electrostatic induction, taking appropriate measures including following items 1, 2 and Clause 34 into consideration.

1. The electrical field, which is caused by overhead high-voltage lines, at 1 m above the ground surface shall be 3kV/m or less, except for overhead high-voltage lines in the places where third persons seem to hardly approach such as in the mountains, in farming land and so on.
2. Conductive materials on the surface of the buildings under overhead high-voltage lines shall be grounded with the Class D in accordance with Clause 39.

47.2 Electromagnetic Induction

High-voltage lines shall be installed to prevent danger to human bodies and/or interference on communication lines caused by electromagnetic induction on the low voltage lines and/or communication lines installed near the high-voltage lines, taking appropriate measures including Clause 39.

Clause 48: Surge Arresters

Surge arresters shall be installed at the appropriate places of Electrical Lines.

PART 7

TRANSMISSION AND DISTRIBUTION FACILITIES (MEDIUM AND LOW VOLTAGE)

Clause 49: Supporting Structures

49.1 Safety Factor of Foundation of Supporting Structures

1. The safety factor of foundation of supporting structure for low-voltage lines shall be 2 or more to the wind load.
2. The safety factor of foundation of supporting structure for medium-voltage lines shall be 2 or more to the load prescribed in Clause 40.
3. If wooden poles, iron-poles and iron-reinforced concrete poles are installed at other than soft ground in accordance with the following table, this clause may not be applicable.

	Design load of supporting structure	Length of Poles	Setting depth	Span
Wooden pole		15m or less	1/6 of overall length or more	Medium-voltage lines in urban area: No more than 75m
		More than 15m, and 16m or less	2.5m or more	
Iron pole		15m or less	1/6 of overall length or more	Low-voltage lines in urban area: No more than 40m Other: No more than 150m
		More than 15m, and 16m or less	2.5m or more	
Iron-reinforced concrete pole	6.5kN or less	15m or less	1/6 of overall length or more	
		More than 15m, and 16m or less	2.5m or more	
		More than 16m, and 20m or less	2.8m or more	

49.2 Strength of Iron-reinforced Concrete Pole

1. Iron-reinforced concrete pole for low-voltage lines shall have the strength to withstand the wind load.
2. Iron-reinforced concrete pole for medium-voltage lines shall have the strength to withstand the load prescribed in Clause 40.
3. Iron-reinforced concrete pole shall withstand 2 times the strength of design load.

Clause 50: Overhead Lines

50.1 Cables for Overhead Lines

1. When cables are used for overhead lines, the cables shall be installed not to be inflicted the tensile strength using messenger wires or other appropriate measures. The messenger wires shall be installed in accordance with the provision of Clause 41.
2. When cables are installed along a building or another object, the cables shall be supported not to be damaged by contacting the building or the object.

50.2 Connecting Methods of Overhead Conductors

The tensile strength of the conductors shall not be reduced by 20% or more, when electric conductors are connected. If the tension working on the conductors is distinctly smaller than the general tensile strength of conductors this may not apply.

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Branching of Overhead Lines

Branching of overhead lines shall be made at the supporting point of the lines. If branching shall be done not to inflict tension to conductor at the branch point, this may not be applicable.

Clause 51: Mechanical Strength of Insulators

The insulator to support medium-voltage line shall be installed in such a manner that it has sufficient strength to attain a safety factor of 2.5 or more based on the assumption that the following loads are exerted to the insulators.

1. For the insulators to anchor lines, the load is the assumed maximum tension of the lines.
2. For the insulators to support lines, the load is the horizontal lateral load or vertical load exerted perpendicular to the axis of the insulators.

Clause 52: MV/LV Transformers

MV/LV transformers including medium-voltage conductors other than cables, shall be installed not to be in danger of electrical shock in either manner of following method.

1. MV/LV transformers shall be installed in an exclusive cabin that is locked.
2. MV/LV transformers shall be installed at the height of 5.0m or more above the ground in order that persons do not touch them easily.!
3. Appropriate fences shall be installed around the MV/LV transformers in order that persons do not touch them easily and warning signs to indicate the danger are displayed. Otherwise MV/LV transformers of which charged parts are not exposed shall be installed for persons not to touch them easily.

Clause 53: Protective Devices

53.1 Installation of Medium-Voltage Over Current Circuit Breakers

1. On a Medium-voltage Lines, an over current circuit breaker shall be installed at the outgoing point of a substation or similar location and on the primary side of a transformer.
2. Over current breakers for a short circuit protection shall have the ability to break the short circuit current that pass the breakers.

53.2 Installation of Medium-Voltage Ground Fault Circuit Breakers

A ground fault breaker that breaks circuit automatically when an earth fault happens in the lines shall be installed at an outgoing point of substation or similar locations.

53.3 Installation of Surge Arresters

To prevent electrical equipment from being damaged by lightning, surge arresters shall be installed at the places of lines stated below or their surrounding areas. If electric power facilities will not be damaged by lightning, this may not be applicable.

1. A lead-out of overhead line from power station, substation, and equivalent places.
2. The connecting point of overhead medium-voltage lines with a main transformer.

Clause 54: Height of Overhead Lines

The height of overhead lines shall be no less than the values in the following table;

(Unit: meter)

	Low-voltage	Medium-voltage		
		Urban area		Other area
		Cable	Others	
Crossing a road	6.5	8.0	8.0	6.5
Others	5.5	5.5	6.5	5.5

Clause 55: Clearance between Overhead Lines and Other Objects

Minimum clearance between a line and another object shall be the values in the following table;

(Unit: meter)

				Low-voltage	Medium-voltage
Structures of buildings	Up side adjacency	With the possibility for persons to climb on	Bare conductor	-	3.0
			Insulated conductor	2.0	2.5
			Cable	1.0	1.2
		Others	Bare conductor	-	3.0
			Insulated conductor	1.2	1.5
			Cable	0.4	0.5
	Lateral and downside adjacency		Bare conductor	-	3.0
			Insulated conductor	1.2	1.5
			Cable	0.4	0.5
Plants			Bare conductor	-	2.0
			Insulated conductor	Shall not contact directly	
			Cable	Shall not contact directly	

Low voltage cable including ABC (Ariel Bundle Conductor) type cable may be installed directly on a wall of a building by using clip and clamp in such a way that normally a person cannot reach the cable.

Clause 56: Adjacency and Crossing of Overhead Lines

56.1 Plural Medium-Voltage Lines

When a medium-voltage line is installed adjoining or crossing another medium-voltage line, the clearance between the two medium-voltage lines shall be 2.0m or more. If one is a cable and the other is a cable or an insulated conductor, the clearance shall be 0.5m or more.

56.2 Medium-Voltage Lines and Low-Voltage Lines

When a medium-voltage line and a low-voltage line are installed with adjoining or crossing each other, they shall be installed in the manner of following method.

1. The medium-voltage line shall not be installed under the low-voltage lines. If the medium-voltage line keeps the horizontal clearance of 3.0m or more with the low-voltage line, and the low-voltage line does not come in contact with the medium-voltage line when the support structure of the low-voltage line collapses, this may not be applicable.
2. The clearance between the medium-voltage line and the low-voltage line shall be 0.5m or more when the medium-voltage line is a cable, 1.0m or more when it is an insulated conductor, and 2.0m or more when it is a bare conductor.
3. The medium-voltage line shall not cross under the low-voltage line. If the medium-voltage line is a cable and the clearance between the medium-voltage line and the low-voltage line is 0.5m or more, this may not be applicable.

56.3 Plural Low-Voltage Lines

When a low-voltage line is installed adjoining or crossing other low-voltage lines, the clearance between the two low-voltage lines shall be 0.6m or more. When one is a cable and the other is a cable or an insulated conductor, the clearance shall be 0.3m or more.

56.4 Medium-Voltage Lines and Communication Lines

When a medium-voltage line is installed adjoining or crossing a communication line, the medium-voltage line shall be installed in the manner of following methods.

1. The medium-voltage line shall not be installed under the communication line. If the medium-voltage line keeps the horizontal clearance of 3.0m or more with the communication line, and the communication line does not come in contact with the medium-voltage line when the support structure of the low-voltage line collapses, this may not be applicable.
2. The clearance between the medium-voltage line and the communication line shall be 0.5m or more when the medium-voltage is a cable, 1.0m or more when it is an insulated conductor, and 2.0m or more when it is a bare conductor.
3. The medium-voltage line shall not cross under the communication line. If the medium-voltage line is a cable and the clearance between the medium-voltage line and the communication line is 0.5m or more, this may not be applicable.

56.5 Low-Voltage Lines and Communication Lines

When a low-voltage line is installed adjoining or crossing a communication line, the low-voltage line shall be installed in the manner of following method.

1. The low-voltage line shall not cross under the communication line. If other methods are not technically realistic, this may not be applicable.
2. The clearance between the low-voltage line and the communication line shall be 0.3m or more when the low-voltage is a cable, and 0.6m or more when it is insulated conductor.

PART 8
GENERAL REQUIREMENTS FOR HOUSE WIRING

Clause 57: Insulation

The insulation resistance between conductors of low-voltage wiring and between the electrical circuit and ground shall be no less than the value given in the following table with respect to the nominal circuit voltage for each section into which the electrical circuit can be divided by switching devices or over-current circuit breakers.

If insulation resistance measurement is difficult, it is sufficient to keep the leakage current 1 mA or less.

Nominal circuit voltage [V]	Test voltage d.c. [V]	Minimum of Insulation resistance [MΩ]
500 V or less	500	More than 0.5
Over 500 V	1,000	More than 1.0

Clause 58: Grounding

Grounding shall be installed according to Clause 39.

Clause 59: Protection against Overcurrent

Devices to protect against Overcurrent shall be installed according to Clause 36.

Clause 60: Protection against Ground Fault

On an electrical circuit to supply electricity to low-voltage equipment and devices enclosed with a metal case and installed at a place where there is the danger of persons easily touching it, a device shall be installed to interrupt the circuit automatically when a ground fault occurs in the electrical circuit. However, such a device need not be installed if the situation is under one of the following:

1. If the equipment and devices are installed in a dry place.
2. If the equipment and devices are covered with rubber, synthetic resin or other insulating material.
3. In the case of supplying electricity to emergency lighting equipment etc of which could impair ensured public safety.

Clause 61: Indoor Wiring

61.1 Restriction of bare conductor

Bare conductor shall not be used for indoor wiring.

61.2 Sign of indoor wiring

The color sign for neutral conductor shall be black or blue. And the color sign for protective conductor shall be green or green with white or yellow.

Clause 62: Indoor Wiring Utensil

Indoor wiring utensils attached to the indoor electrical circuits shall be installed as follows:

1. No live parts shall be exposed.

The above shall not apply to a place prepared to block out any person other than the operator.

2. The utensil shall be connected fast and electrically safely by screw fastening or the like. In addition, no mechanical tension shall act on the connection point.
3. The indoor wiring shall contain protective grounding conductors beforehand to ensure the grounding of electric equipment.

Clause 63: Installation Methods of Indoor Electrical Appliances

Indoor electrical appliances shall be installed as follows:

1. No live parts of electrical household appliances shall be exposed.
2. No live parts of low-voltage business electrical appliances shall be exposed. However the above shall not apply to appliances that are used with some live part inevitably exposed and the case that these are installed in a place made inaccessible for any person other than the operator.
3. If the indoor electric appliance is connected to an electrical conductor, the electrical conductor shall be connected fast and electrically perfect. In addition, no mechanical tension shall act on the connection point.

Clause 64: Indoor Wiring for Adjacency and Crossing

The low-voltage indoor wiring shall be installed in such a manner so as not to contact a telecommunication conductor, water supply pipe, gas pipe or other similar object.

Clause 65: Outdoor Installation at user's site

65.1 Overhead low-voltage service drop lines

1. Height from ground

The height from the ground surface shall be not less than 4 m, and no less than 6.5 m for road crossing.

2. Clearance to other objects

A low-voltage overhead service drop line shall be installed according to Clause 55. For a building in which a low-voltage overhead service drop line is directly installed, or if it is technically difficult to install such facilities according Clause 55, A low-voltage overhead service drop line shall be installed in such a manner that a person cannot reach it even if he or she stretches out his/her hand from a window, corridor, or a passage where person can ordinarily access.

65.2 Other outdoor Installation at user's site

The wire or cable shall be in a conduit if people have possibility of touching them.

Outlets shall be waterproof type if they have possibility of taking rainwater.

A protective device shall be installed if it is considered danger.

Specific Requirements of Electric Power Technical Standard of the Kingdom of Cambodia

- (1)- SPECIFIC REQUIREMENTS FOR TRANSMISSION AND
DISTRIBUTION FACILITIES**
- (2)- SPECIFIC REQUIREMENTS FOR THERMAL POWER
GENERATING FACILITIES**

JULY 2007

**ISSUED BY MINISTRY OF INDUSTRY, MINES AND ENERGY IN ACCORDANCE
WITH THE ELECTRICITY LAW OF THE KINGDOM OF CAMBODI**

KINGDOM OF CAMBODIA
NATION KING RELIGION

Ministry of Industry, Mines and Energy

No. 701

July 17, 2007

PROKAS
ON ESTABLISHMENT OF SPECIFIC REQUIREMENT
OF ELECTRIC POWER TECHNICAL STANDARDS
OF THE KINGDOM OF CAMBODIA

MINISTER OF INDUSTRY, MINES AND ENERGY

- Seen the Constitution of the Kingdom of Cambodia;
- Seen the Royal KRET No. NS/RKT/0704/124 Dated July 15, 2004 on the appointment of the Royal Government;
- Seen the Royal KRAM No. NS/RKM/0196/05 Dated January 24, 1996 promulgating the law on establishment of the Ministry of Industry, Mines and Energy;
- Seen the Royal KRAM No. NS/RKM/0201/ 03 Dated February 02, 2001 promulgating the Electricity Law of the Kingdom of Cambodia;
- Seen the Prokas No. 470, dated July 16, 2004 on the establishment of Electric Power Technical Standards of The Kingdom of Cambodia;
- Seen the urgent need and real situation at present;

DECIDES

Article 1

To establish the Specific Requirement of Electric Power Technical Standards of the Kingdom of Cambodia, for implementation, in 2 main parts as below:

- 1- Specific Requirement of Electric Power Technical Standards for Thermal Generating Facilities.
- 2- Specific Requirement of Electric Power Technical Standards for Transmission and Distribution Facilities.

Article 2

To issue the Specific Requirement of Electric Power Technical Standards in above 2 parts full contents of which are attached here with.

Article 3

All electric suppliers and consumers shall fully follow this specific requirement of the Standards.

Article 4

The electric suppliers are allowed to use their existing electric system for 2 years or any extension as decided by Electricity Authority of Cambodia from the date of signing of this Prokas, during which they are to improve their facilities to be in accordance with the electric power technical Standard. When the system is improved or changed or new installed, this standard shall be followed.

Article 5

Prokas or any decision in contradiction to this Prokas shall be null and void.

Article 6

This Prokas shall come into force from the date of signing.

Minister of Industry Mines and Energy

Sign and Seal

SUY SEM

Specific Requirements for Transmission and Distribution Facilities

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CHAPTER 1

INTRODUCTION

Article 1: Definitions

In this Specific Requirements of Electric Power Technical Standards, unless the context otherwise requires, the terms below shall have the following meanings assigned to them:

1. EAC

“EAC” is the acronym for the Electricity Authority of Cambodia.

2. Electrical Line

“Electrical Line” means the part of electric power facilities used to transmit or supply electricity.

“Electrical Line” connects power stations, substations, switching stations and user’s sites. The "Electrical Line " also includes lines in associated protective devices and switchgears.

3. Electric Power Facility

“Electric Power Facility” means all facilities for generation, transmission and supply of electric power such as power stations, substations, switching stations, electrical lines, dispatching centers etc... in this also including equipment, buildings, dams, waterways, fuel storage yards, ash disposal areas, etc.

4. Electrical Equipment

“Electrical Equipment” means electrically-charged facilities.

5. GREPTS

“GREPTS” is the acronym for the General Requirements of Electric Power Technical Standards of the Kingdom of Cambodia.

6. Guy

“Guy” means a wire to reinforce the foundation of a supporting structure. It is usually installed between the ground and the upper part of the supporting structure.

7. High-voltage Line

“High-voltage Line” means an electrical line of voltage higher than 35kV.

8. IEC

“IEC” is the acronym for the International Electro technical Commission.

9. Insulated Conductor

“Insulated Conductor” means a cross-linked polyethylene (XLPE) insulated conductor for the medium-voltage lines and a XLPE insulated conductor or a polyvinyl chloride (PVC) insulated conductor for the low-voltage line.

10. ISO

“ISO” is the acronym for the International Organization for Standardization.

11. Joint Use

“Joint Use” means a condition that electrical lines and/or communication lines belonging to two or more owners are installed on the same supporting structure.

12. Low-Voltage Line

“Low-voltage Line” means an electrical line having voltage of not more than 600V.

13. Medium-Voltage Line

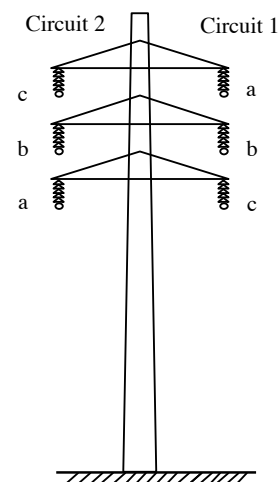
“Medium-voltage Line” means an electrical line having voltage of between 600V and 35kV.

14. National Grid

“National Grid” is the high voltage backbone system of interconnected transmission lines, substations and related facilities for the purpose of conveying bulk power.

15. Reversed phase-formation

“Reversed phase-formation” means a formation of double-circuit overhead-lines where three phase order of one side circuit is different from that of the other circuit as given in the right drawing.



16. RTU

“RTU” is the acronym for “Remote Terminal unit” for the SCADA system, installed at electric power facilities for monitoring and controlling those facilities.

17. SCADA

“SCADA” is the acronym for “Supervisory, Control, and Data Acquisition” and refers to the equipment used for monitoring and receiving data.

18. Side by Side Use

“Side by Side Use” means a condition that electrical lines and/or communication lines of one owner are installed on the same supporting structure.

19. SREPTS

“SREPTS” is the acronym for the Specific Requirements of Electric Power Technical Standards of the Kingdom of Cambodia.

20. Substation

“Substation” means the electric power facilities where voltage of electrical power is transformed and including transformers, lightning arresters, circuit breakers, disconnecting switches, voltage transformers, current transformers, bus bars, protective relay systems, RTU for SCADA system, telecommunication facilities, etc.

21. Supporting Structure

“Supporting structure” means a structure that supports electrical lines, such as wooden poles, iron poles, reinforced concrete poles and steel towers.

22. SWER

“SWER” is the acronym for the Single Wire Earth Return system. “SWER” is an electricity distribution method using one conductor with the return path through the earth.

23. Switching Station

“Switching Station” means the electric power facilities used to change-over the electrical lines, which include disconnecting switches, circuit breakers, bus-bars, protective relay system, the RTU for the SCADA system, etc.

24. The Technical Standards

“The Technical Standards” means the Electric Power Technical Standards in the Kingdom of Cambodia.

25. User’s Site

“User’s Site” means any place at which machines, apparatus and devices for using electricity are installed.

Article 2: Purpose

This Specific Requirements of Electric Power Technical Standards for Transmission and Distribution Facilities prescribes the basic requirements necessary to regulate the existing and the planned transmission and distribution facilities in the Kingdom of Cambodia. The requirements in this standard document are mainly for facility security and safety operation of the most important parts for facilities.

Article 3: Area of Application

All transmission and distribution facilities in the Kingdom of Cambodia shall be in accordance with the requirements prescribed in this Technical Standard.

All persons including licensees, consultants, contractors and consumers who are related to the study, design, construction and operation of transmission and distribution facilities shall follow these Specific Requirements of electric Power Technical Transmission and Distribution Standards.

Article 4: Applicable Standards

Power transmission and distribution facilities planned to construct and operate in the Kingdom of Cambodia shall be as per the provision of this Technical Standards. In case a matter is not stipulated in the Technical Standards, IEC Standards shall be applied. If it is not covered in the IEC standards, ISO Standards shall be applied. If it is not covered in the ISO Standards, internationally recognized standards shall be applied, subject to the approval by MIME.

Article 5: Types of Power Transmission and Distribution Facilities

Power transmission and distribution facilities regulated in this Specific Requirements of Electric Power Technical Standards has been divided into 2 types:

- High Voltage Facilities
- Medium and Low Voltage Facilities.

Article 6: Voltage

1. Standard Voltage

AC voltage shall be as follows below:

Table 1 Voltage Classification

Classification of Voltage	Range of Nominal Voltage	Nominal Voltage	Highest Voltage
Low Voltage	600V or less	230/400V	
Medium Voltage	More than 600V 35kV or less	22kV	24kV
High Voltage	More than 35kV	115kV	123kV
		230kV	245kV

If in the interest of development of the power sector in the Kingdom of Cambodia it becomes necessary to use a nominal voltage other than that given in the table above, the Ministry of Industry, Mines and Energy may allow the use of such nominal voltage as a standard voltage through issuing Prokas.

6.2 Variation of voltage

The AC voltage at low voltage power supply points shall be maintained to the value according to the nominal system voltage in accordance with the following table:

Table 2 Voltage Variation

Nominal System Voltage	Value to be Maintained
230V	Between 207V to 253V
400V	Between 360V to 440V

Notwithstanding the table above, variation of voltages can be extended only in the following cases:

- The licensee owns only low-voltage distribution line(s);
- The supply point where the voltage is out of the range of the table above is almost at the end of the feeder;
- The voltage does not affect the consumer's appliances;
- The licensee has obtained the consumer's consent.

CHAPTER 2
GENERALS FOR TRANSMISSION AND DISTRIBUTION

PART 1
General Provisions

Article 7: Prevention of Electric Power Disasters

The electrical equipment shall be installed in such a manner that does not cause electric shock, fire and other accidents.

Article 8: Prevention of Accidents Caused by Electric Power Facilities

The electric power facilities shall be installed with proper measures for operators not to touch their moving parts, hot parts and other dangerous parts, and to prevent them from falling accidentally.

Article 9: Safety of Third Persons

1. Safety of Third Persons at Power Stations, Substations and Switching Stations

Appropriate measures shall be taken to prevent third persons from entering compounds containing power stations, substations and switching stations. These measures shall include:

- a. External fences or walls to separate outside from inside compound. The height of external fences or walls shall not be lower than 1,800 mm. Boundary Clearance from these fences or walls to electrical equipment shall not be less than the values described in the following table:

Table 3 Boundary Clearance from Walls or Fences to Electrical Equipment

Nominal voltage [kV]	A : Height of a wall or a fence [mm]	Boundary clearance [mm]	
		B : Wall	C : Fence
(22)	not less than 1,800	not less than 2,100	not less than 2,600
115	not less than 1,800	not less than 2,100	not less than 2,600
230	not less than 1,800	not less than 2,900	not less than 3,400

- b. Signs to alert third persons to danger shall be installed at the entrances/exits. Moreover, where necessary, signs shall also be displayed on walls and fences.
- c. Locking devices or other appropriate devices shall be installed at the entrances/exits.

2. Safety of Third Persons at Electric Supporting Structures

Appropriate measures shall be taken to prevent third persons from climbing supporting structures of overhead electrical lines. To prevent danger to third persons related the supporting structures of electrical lines the following measures shall be taken:

- Any metal steps on supporting structures shall be installed more than 1.8m from the ground.
- Warning signs to alert the third persons to danger shall be installed at each supporting structure.
- As for high-voltage lines, appropriate devices shall be installed at all legs of supporting structures to prevent third persons from climbing the supporting structures. However, in case the supporting structures are located at places where third persons seldom approach such as in the mountains or where the supporting structures are surrounded by fences or walls with of an appropriate height, this article shall not be applicable.

Article 10: Prevention of Failures of Electric Power Facilities from Natural Disasters

Proper measures shall be taken to prevent failures of electric power facilities from anticipated natural disasters such as floods, lightning, earthquakes and strong winds

Article 11: Prevention of Electric Power Outage

- When any generating facilities have a serious fault, these facilities shall be disconnected from the power system so that the effect of the fault on the system can be minimized and the system could be operated continuously.
- When a power system fault occurs in a system connected to a generating facility, the generating facility shall immediately be disconnected from the system, so that the generator runs continuously with no-load while waiting for the recovery of the system from fault.
- When a power system fault affecting electrical lines occurs, the power cut areas shall be minimized as much as possible by disconnecting the faulty section or by other appropriate methods.

Article 12: Protection against Over-current

1. General provision

Protection equipment against over-current shall be installed at the appropriate places of electrical circuits to prevent electrical equipment from over-heating due to excessive current and not to cause fire.

2. Properties of Over-current Protection Equipment for High-Voltage Lines and Medium Voltage Lines

- a. Properties of fuses used for protection of over-current on a medium-voltage electrical circuit shall conform to related IEC 60282 (2002-01) [High-voltage fuses].

- b. Properties of circuit breakers used for protection against over-current on a medium-voltage electrical circuit shall conform to related IEC 62271[High-voltage switchgear and control gear].
- c. An over-current breaker shall have a device to indicate its switching status according to its operation. However, if its switching status can be easily confirmed, it need not have such a device.

Article 13: Protection against Ground Faults

Protection equipment against ground faults or other appropriate measures shall be provided to prevent damage of electrical equipment, electrical shock and fire.

Article 14: Environmental Protection

1. Compliance with Environmental Standards

To prevent environmental pollution, the electric power facilities shall be constructed in accordance with the environmental laws and regulations of the Kingdom of Cambodia.

2. Prohibition of Installation of Electrical Machines or Equipment Containing Polychlorinated Biphenyls (PCBs)

- a. The installation of new electrical equipment using insulating oil that contains greater than 0.005 percent (50ppm) polychlorinated biphenyls (PCBs) shall be prohibited.
- b. The use of existing electrical equipment using material containing PCBs, if it was installed before the Specific Requirements of Electric Power Technical Standards came into force, and effective and sufficient measures shall be taken in order to prevent the material containing PCBs from escaping from the oil container, shall be permitted.
- c. Once removed from the electrical equipment, the material containing PCBs greater than 0.005 percent (50ppm) PCBs shall not be reinstalled in another electrical facility and shall be safely scrapped as noxious industrial wastes.

Article 15: Life of Electrical Power Facilities

Electrical power facilities shall be durable for long term usage with efficient and stable operation.

Article 16: Requirements related to the Design of Electrical Power Facilities

With regard to the design of electrical power facilities, selection of the materials, assembling and installation of the equipment, suitable safety factors against foreseeable stresses, such as insulation strength, thermal stress and mechanical stress shall be considered.

1. Insulation Co-ordination

Taking everything into consideration technically, economically and operationally, the insulation strength of electrical equipment and facilities of an electric power system, including power stations, substations, switching stations, transmission lines and distribution lines, shall be coordinated so that it may be in the most rational conditions. In co-ordination of insulation the following important items shall be considered:

a. Standard Withstand Voltage of Insulation

In selection of electrical equipment, its insulation shall be suitable with the “Standard lightning impulse withstand voltage” and “Standard short-duration power-frequency withstand voltage” given in the table of standard withstand voltage of insulation below.

Table 4 Standard Withstand Voltage of Insulation

Nominal Voltage	22kV	115kV	230kV
Standard lightning impulse withstand voltage	95, 125, 145kV	550kV	950kV
Standard short-duration power-frequency withstand voltage	50kV	230kV	360, 395kV

b. Installation of Surge Arresters

“Lightning impulse” and “Switching impulse” shall be controlled by installing surge arresters to coordinate them correctly.

c. Insulation Co-ordination of Power Stations, Substations, Switching Stations and Transmission Lines

In order to prevent the lightning impulse invasion to power stations, substations and switching stations from transmission lines as much as possible, the arcing horn gaps of the steel tower near the power stations, substations and switching stations shall coordinate with the standard withstand voltage of electrical equipment in the power stations, substations and switching stations.

2. Dielectric Strength of Electrical Circuits

The dielectric strength of electrical circuits shall be examined by dielectric strength test, insulation resistance measurement and so on, to ensure that their performance corresponds to their nominal voltage.

Moreover, before starting operation, the dielectric strength shall be confirmed by charging nominal-voltage to the circuit continuously for 10 minutes.

However, if the nominal voltage of the electrical circuit is low-voltage, it can be tested by insulation resistance measurement or leakage current measurement. In case of the leakage measurement, it is sufficient to keep 1mA or less.

3. Thermal Strength of Electrical Equipment

Electrical equipment to be installed in the substations, switching stations and high-voltage and medium-voltage users' sites shall be able to withstand the heat generated by electrical equipment in normal operations.

4. Mechanical Strength of Electrical Equipment against Short-circuit Current

Generators, transformers, reactive power compensators, switching devices, bus bars and insulators for supporting bus bars to be installed in the substations and high-voltage and medium-voltage users' sites shall be able to withstand the mechanical shock caused by short-circuit current.

5. Prevention of Damage of Pressure Tanks

Gas insulated equipment installed in the substations, switching stations and high-voltage and medium-voltage users' sites shall be designed as the following in order to avoid any risk of damage:

- a. Materials and structure of the parts receiving pressure shall be able to withstand the maximum operating pressure and shall also be safe.
- b. Parts receiving pressure shall be corrosion-resistant.
- c. Insulation gas shall not be inflammable, corrosive or hazardous.
- d. Tanks shall withstand the gas pressure rising during fault continuous time at internal failure of gas insulated equipment.

Article 17: Technical Documents of Electrical Power Facilities

To secure long term power supply, each facility shall have its drawings, installation records, technical manuals, instruction manuals and operation records necessary for its proper maintenance works. These documents shall be safekept well.

Article 18: Communication System

To secure the power supply, suitable communication facilities consisted of SCADA systems and voice communication systems shall be provided.

1. SCADA System

SCADA systems are used to monitor and control electric power facilities and consist of RTUs, telecommunication lines and a master station.

- a. The RTU for the SCADA System shall be installed in electric power facilities so that the state of the National Grid can be monitored and the power facilities can be controlled at the Dispatching Center.

- b. Necessary SCADA system shall be installed between the Dispatching Center and electric power facilities.

2. Telecommunication Line

Necessary telecommunication lines for SCADA systems and voice communication systems shall be installed as follows.

2.1 Installation Sites

- a. Between the NCC and the Load Dispatching Center;
- b. Between the Load Dispatching Center and the power facilities that compose the National Grid.
- c. Between the NCC and neighboring countries' NCCs when the power system is connected to a neighboring country. If there are any agreements on these systems with neighboring countries, this may not be applicable.

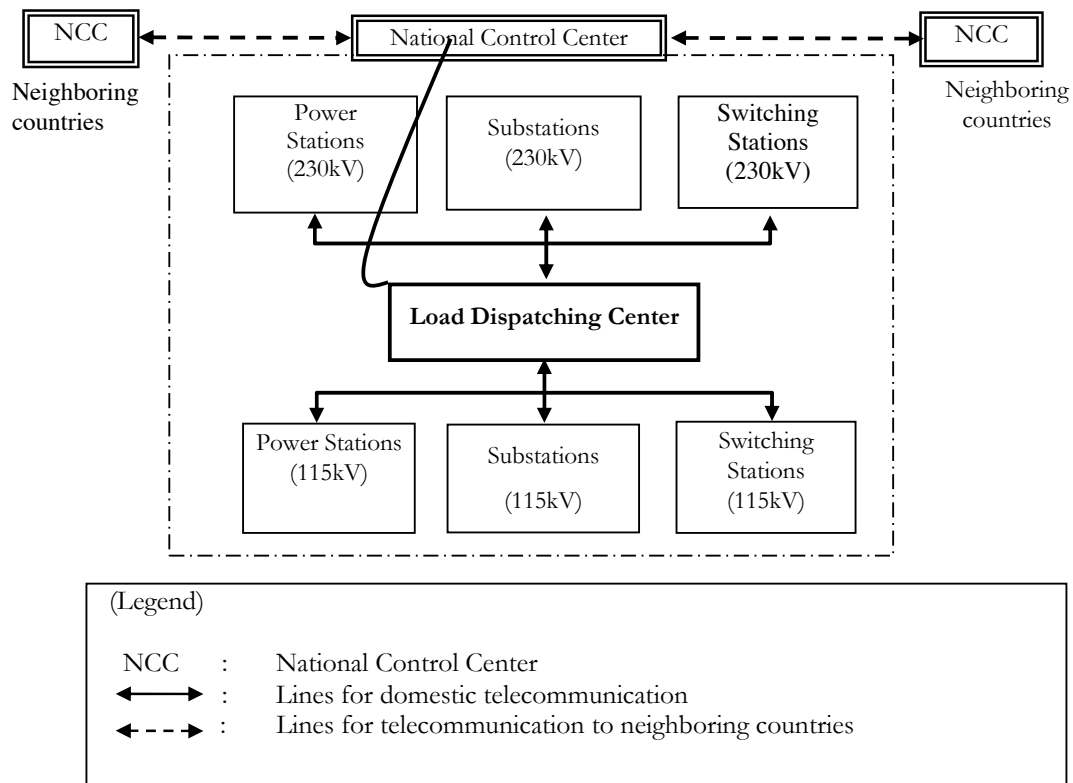


Figure 1: Installation Sites

2.2 Kinds of Lines and Condition of Lines for Domestic Telecommunication line

- At least two different telecommunication lines shall be required for the National Grid.
- Lines for domestic telecommunication systems for the power system shall be provided in accordance with Table 5.

Table 5: Type of Lines for Facilities Connected to the National Grid

		Between National Control Center and Load Dispatching Center		Between Load Dispatching Center and Power Facilities	
		Data	Voice	Data	Voice
Type of Line	Optical fiber	1 line	1 line	1 line	1 line
	Optical fiber	1 line (selected from 5 types)	1 line (selected from 5 types)	1 line (selected from 5 types)	1 line (selected from 5 types)
	Metal cable				
	Radio				
	Power line carrier				
	Microwave				
Condition of lines		Exclusive line for Power System			

3. Securing means of communication in an emergency

Communication facilities, which are essential to recover the power system when unexpected disasters occur, shall be sufficiently reliable to be secure in an emergency.

Article 19: Accuracy of Power Meters

Power meters shall be accurate, fair and equitable. The accuracy of a meter shall be generally as follows:

Table 6: Accuracy of Electro-magnetic Mechanical Power Meters and Electric Power Meters

Type of Customer	*Class
High-voltage customers	0.5
Medium-voltage customers	1.0
Low-voltage customers	2.0

* In accordance with the IEC

PART 2

Grounding

Article 20: General Requirements for Grounding

Grounding or other appropriate measures shall be provided for electrical equipment to prevent electric shock, danger to human beings, fire, and other trouble to objects.

Grounding for electrical equipment shall be installed to ensure that current can safely and securely flow to the ground.

Article 21: Classification of Grounding

Grounding for electrical equipment of all electric power facilities can be classified in 4 classes as shown in the following table:

Table 7: Classification of Grounding Work

Classification of grounding work	Resistance to earth	Conditions for easement of resistance value
Class A	10Ω or less	
Class B	10Ω or less (When $\frac{230}{I^{*1}}$ is less than 10, resistance to earth shall be the value of $\frac{230}{I^{*1}}$ or less.)	In the case where voltage to earth of a low-voltage electrical circuit exceeds 230V due to power contact between the medium-voltage electrical circuit and the low-voltage electrical circuit of the transformer, when an earth leakage breaker that cuts off the electrical circuit within 1 second is installed, $\frac{600}{I^{*1}}$ Ω or less. When $\frac{230}{I^{*1}}$ becomes less than 5Ω, it shall not be necessary to obtain resistance less than 5Ω.
Class C	10Ω or less	In the case where grounding arises in a low-voltage electrical circuit, when an earth leakage breaker that acts within 0.5 seconds is installed, the resistance value shall be 500Ω or less.
Class D	100Ω or less	In the case where grounding arises in a low-voltage electrical circuit, when an earth leakage breaker that acts within 0.5 seconds is installed, the resistance value shall be 500Ω or less.

Remarks:

*1 - I is Single-line ground fault current (A)

Article 22: Grounding for Electrical Lines

The types of grounding, the places to be applied, installation conditions, and the resistance value to earth of electrical lines shall be as given in the following table.

Table 8: Kinds of Groundings for Electrical Lines

Grounding	Application	Installation conditions	Resistance to earth (Ω)
System grounding	MV/LV transformer	Low-voltage neutral conductor of 'TT' or TN grounding type	Value prescribed for Class B grounding work
Safety grounding	Exposed conductive parts (*1)	For high-voltage line (*2)	Value prescribed for Class A grounding work
		For medium-voltage	
		For low -voltage exceeding 300V	Value prescribed for Class C grounding work
		For low-voltage not exceeding 300V	Value prescribed for Class D grounding work
Arrester grounding	Surge arrester	For medium-voltage	Value prescribed for Class A grounding work

Remarks:

- (*1) "Exposed conductive parts" refers to parts such as steel stands, metal case or similar, of apparatus installed in the electrical circuit.
- (*2) Groundings for high-voltage substations and switching stations shall be individually designed, depending on the short-circuit capacity.

Article 23: Grounding for Power Stations, Substations, Switching Stations and High-voltage and Medium-voltage Users' Sites**1. Grounding for Electrical Facilities****1.1 Safety Grounding**

Electrical equipment to be installed in power stations, substations, switching stations and high-voltage and medium-voltage users' sites shall be equipped with the protective groundings listed below so that there is no risk of rise of potential under abnormal conditions, no harm to human bodies and no damage to other objects due to electric shocks and fires caused by high voltage invasion.

1.1.1 Grounding for Exposed Conductive Parts of Electrical Equipment

Exposed conductive parts of electrical equipment such as metal stands and metal case shall be connected with the ground by grounding. Grounding for exposed conductive parts of electrical equipment of different voltage is provided in the table below:

Table 9: Grounding for Exposed Conductive Parts of Electrical Equipment

Voltage of electrical equipment	Kind of grounding work
High-voltage electrical equipment	Class A
Medium-voltage electrical equipment	Class A
Low-voltage electrical equipment (Over 300V)	Class C
Low-voltage electrical equipment (300V or lower)	Class D

1.1.2 Grounding for other facilities

Other facilities such as outdoor metal structures, external metal fences, protective metal fences and metal stands for operation shall be provided also with grounding work according to the voltage of the electrical facilities or equipment listed in table above.

1.1.3 Grounding for Conductive Parts in Electrical Equipment

At necessary points in electrical circuits, the grounding listed below shall be provided:

a. Grounding of Instrument Transformers (Current or Voltage Transformers)

Class A grounding work shall be provided at an arbitrarily chosen point in the electrical circuit on the secondary side of a high-voltage or medium-voltage instrument transformer.

In case where grounding work is provided for the electrical circuit on the primary side of a high-voltage or medium-voltage instrument transformer, Class A grounding work shall be provided.

b. Grounding for Station Service Transformers

In case where grounding is provided for the electrical circuit on the secondary side of transformers connecting a medium-voltage electrical circuit and a low-voltage electrical circuit, Class B grounding work shall be provided.

A “low-voltage electrical circuit” means an electrical circuit that supplies electricity to automatic control circuits, remote control circuits, signal circuits for remote monitoring devices, and the like.

c. Grounding for the Stabilizing Windings in Transformers

In case where the star-star winding high-voltage and medium-voltage transformers have a stabilizing winding for reducing the zero phase impedance which is not connected with outgoing electrical circuit, this winding shall be grounded with Class A grounding.

1.2 Grounding for Neutral Points in High-voltage and Medium-voltage Electrical Circuits

In case where grounding is provided for the neutral point of high-voltage and medium-voltage electrical circuits in power stations, substations, switching stations and high-voltage and medium-voltage users' sites in order to secure reliable operation, to suppress abnormal voltage and to reduce the voltage to ground for protective devices of electrical circuits, the grounding electrode shall be installed to prevent risks of danger to people, domestic animals and other facilities due to the potential difference generated between the pole and the nearby ground when any failure occurs.

1.3 Grounding for Electrical Equipment for SWER

In case where electrical equipment for SWER are installed in power stations and substations, grounding for electrical equipment for SWER shall be provided to prevent risks of danger to people, domestic animals and other facilities due to the potential difference between the electrical equipment and the nearby ground caused by load current and when any failure occurs.

1.4 Grounding for Lightning Guards

The grounding resistance provided for lightning guards such as overhead ground wires and lightning rods to be installed in power stations, substations, switching stations and high-voltage and medium-voltage users' sites shall be not greater than 10 Ω .

However, in case where overhead ground wires are used as SWER, the grounding work shall apply as grounding on earth-return side of SWER provided above.

1.5 Grounding for Surge Arresters

The grounding resistance provided for surge arresters for high-voltage and medium-voltage electrical circuits in power stations, substations, switching stations and high-voltage and medium-voltage users' sites shall be less than 10 Ω as much as possible to prevent hindrance to the functions of the surge arrester

2. Particularities of Grounding Arrangement

2.1 Properties of Grounding Conductors

Grounding conductors to be installed in electrical circuits in power stations, substations, switching stations and high-voltage and medium-voltage users' sites shall be constructed of corrosion-resistant metallic wire and shall be able to carry the current safely during failures.

a. Mechanical Strength of Grounding Conductors

In order to secure necessary mechanical strength, the grounding conductors listed in Table 9 shall be used, depending on the kind of grounding work for which the grounding conductor is used.

Table 10: Grounding Conductors to be used for Grounding Work

Kind of grounding conductors Kind of grounding work		Metal wire	Annealed copper wire	Annealed copper twisted wire
		Tensile strength	Diameter	Sectional Area
Class A	Grounding conductors for neutral points of high-voltage and medium-voltage electrical circuits in generators and transformers	not less than 3 kN	not less than 4 mm	not less than 14 mm ²
	Others	not less than 2 kN	not less than 3 mm	not less than 6 mm ²
Class B	Low-voltage side neutral points of transformers transforming medium-voltage into low voltage	not less than 2 kN	not less than 3 mm	not less than 6 mm ²
Class C		not less than 1kN	not less than 2 mm	not less than 4 mm ²
Class D		not less than 1kN	not less than 2 mm	not less than 4 mm ²

b. Thermal Strength of Grounding Conductors

Grounding conductors in which grounding current flows when any abnormality occurs, such as those for neutral points of electrical equipment and high-voltage and medium-voltage electrical circuits, shall have also enough thermal strength against the heat from grounding current during the occurrence of such abnormality or failures in addition to mechanical strength.

2.2 Installation of Grounding Conductors

Grounding conductors for instrument transformers, neutral points, surge arresters and SWER to be installed in power stations, substations, switching stations and high-voltage and medium-voltage users' sites shall be grounded directly to the ground without being connected to stands of equipment. Bare live parts of grounding conductors shall be installed so that there is no risk of operators easily coming into contact with them.

2.3 Neutral Grounding Devices

Resistors and reactors to be connected to grounding conductors in power stations, substations, switching stations and high-voltage and medium-voltage users' sites shall be suitable and safe for the flows of electric current when any failure occurs.

Bare live parts of resistors, reactors and other neutral grounding devices shall be installed so that there is no risk of operators easily coming into contact with them.

2.4 Prohibition against Installation of Switching Devices on Grounding Conductors for Neutral

No switching device and power fuse, excluding switching devices to be installed to switch neutral resistors and neutral reactors, shall be installed on grounding conductors for neutral in power stations, substations, switching stations and high-voltage and medium-voltage users' sites.

2.5 Connection between Grounding Conductors

Grounding conductors of earth-return side of SWER to be installed in power stations and substations shall not be connected to the grounding conductors of other electrical equipment.

Article 24: Grounding for Distribution Lines and Low-Voltage Users' Sites

1. Particularities of Grounding Arrangement

Grounding for distribution lines and low-voltage users' sites shall be installed according to the following.

1.1 Grounding Electrodes

1.1.1 Materials and dimensions of the grounding electrodes shall be selected for corrosion resistance and adequate mechanical strength.

1.1.2 The following are examples of grounding electrodes which may be used:

- a. Metal plates
- b. Metal rods or pipes
- c. Metal tapes or wires
- d. Underground structural networks embedded in foundations (foundation grounding)
- e. Other suitable underground metalwork approved by MIME

1.2 Grounding Conductors and Protective Conductors

Protective conductors in this provision mean the conductors used for connecting electrical equipment to the grounding system.

- a. Grounding conductors and protective conductors shall be constructed of corrosion-resistant metallic wire and shall be able to carry the current safely at failures.
- b. Grounding conductors shall comply with paragraph c and, where buried in the soil, their cross-sectional areas shall be in accordance with Table 11A.

Table 11A: Minimum Cross-sectional Areas of Grounding Conductors Buried in the Soil

Conditions	Mechanically protected	Mechanically unprotected
Protected against corrosion	2.5 mm ² Cu (Copper) 10mm ² Fe (Iron)	16mm ² Cu (Copper) 16mm ² Fe (Iron)
Not protected against corrosion	25mm ² Cu 50mm ² Fe	

- c. The cross-sectional area of protective conductors shall be selected in accordance with Table 11B or paragraph d.

Table 11B: Minimum Cross-sectional Area of Protective Conductors

Cross-sectional area of lineconductor, S (mm ²)	Minimum cross-sectional area of the corresponding protective conductor (mm ²)	
	If the protective conductor is the same material as the line conductor	If the protective conductor is not the same material as the line conductor
$S \leq 16$	S	$k \times S$
$16 < S \leq 35$	16	$k \times 16$
$S > 35$	$S/2$	$k \times S/2$

*k is selected from Table 11C.

Table 11C: Factor k, for Table 11B

Materials of line conductors	Conductor insulation	Materials of protective conductors					
		Aluminum		Copper		Steel	
		PVC	Rubber	PVC	Rubber	PVC	Rubber
Aluminum	PVC <300mm ²	-	-	0.58	0.48	1.56	1.32
	PVC >300mm ²	-	-	0.52	0.43	1.39	1.18
	EPR / XLPE	-	-	0.71	0.60	1.92	1.92
Copper	PVC <300mm ²	1.31	0.73	-	-	2.45	1.99
	PVC >300mm ²	1.18	0.65	-	-	2.11	1.78
	EPR/ XLPE	1.63	0.90	-	-	2.92	2.47

*Note: Factor k provided here is used only for insulated protective conductors not incorporated in cables and not bunched with other cables. In case of other protective conductors, the factor shall follow IEC60364-5-54.

- d. The cross-sectional area of every protective conductor which does not form part of the cable or which is not in a common enclosure with the line conductor shall be not less than the size given in Table 11D.

Table 11D: Cross-sectional Area of Protective Conductors (IEC60364-5-54)

Mechanically protected	Mechanically unprotected
2.5mm ² Cu	4mm ² Cu
16mm ² Al	16mm ² Al

1.3 Installation of Grounding Electrodes and Conductors

In case there is any danger of persons touching grounding conductors, electrodes and conductors for Class A and Class B shall be installed as described below:

- Grounding electrodes shall be installed at depths of not less than 75cm underground.
- Grounding conductors shall be covered in the section from 75cm underground to 2.0 m above ground by a synthetic resin pipe or another shield of equivalent or higher insulating effect and strength.
- If the grounding electrode is installed along iron poles or other metallic objects, insulated conductor or cable shall be used for the full length of the grounding conductor.
- If the grounding electrode is installed along iron poles or other metallic objects, the grounding electrode shall be buried with a clearance of not less than 1m from those metallic objects.

In case where the grounding electrode is installed along iron poles or other metallic objects, the clearance between the top of the electrode and the bottom of iron poles or other metallic objects shall be not less than 30 cm.

2. Class B Grounding Resistance

Single-line ground fault current (I) of an electrical circuit in the medium-voltage side used for calculation of resistance of Class B grounding provided in Article 21 of these SREPTS shall conform to an actual value, or the following:

2.1 Medium-voltage Electrical Circuit of Isolated Neutral System

Class B grounding resistance for isolated neutral systems shall be determined by the following:

- Electrical circuits using an electric conductor other than a cable
For electrical circuits using an electric conductor other than a cable, Class B grounding resistance shall be not more than ten 10 Ω .
- Electrical circuits using a cable for an electrical conductor

For electrical circuits using a cable for an electrical conductor, Class B grounding resistance shall be determined by Table 11E and Table 11F according to the total length of medium-voltage circuit (limited to that using a cable for an electrical conductor) connected to the same bus.

Table 11E: In Case Class B is Decided by 230/I

L	<3km	3km≤
Class B grounding resistance (Ω)	10	5

Table 11F: In Case Class B is Decided by 600/I*

L	<4.5km	4.5km≤
Class B grounding resistance (Ω)	10	5

* In case of an earth leakage breaker that cuts off the electrical circuit within 1 second

Where:

- L: the total length of medium-voltage circuit (limited to that using a cable for an electrical conductor) connected to the same bus.
- c. Electrical circuits using an electrical conductor other than cable and also a cable for an electrical conductor

In this case, Class B grounding resistance shall be determined by Table 11E and Table 11F according to the total length of medium-voltage feeders (limited to that using a cable for an electrical conductor) connected to the same bus.

2.2 Medium-voltage Electrical Circuit of Solidly Grounded Neutral System

Single-line ground fault current (I_2) of an electrical circuit in the medium-voltage side used for calculation of grounding resistance in Class B grounding provided in Article 21 of these SREPTS shall conform to an actual value, or the following formula.

$$I_2 = \sqrt{I_1^2 + \frac{V^2}{3R^2}} \times 10^6$$

* Any fraction less than the decimal point shall be rounded up.

Where:

I_2 : Single-line ground fault current (A);

I_1 : Single-line ground fault current of the electrical circuit in case of no solidly system grounding which is calculated by a theoretical formula (A);

V: Nominal system voltage of the electrical circuit (kV);

R: Electric resistance value of the resistance used in the neutral point (including the resistance to ground value of the neutral point) (Ω);

3. Grounding Systems for Low-voltage Lines

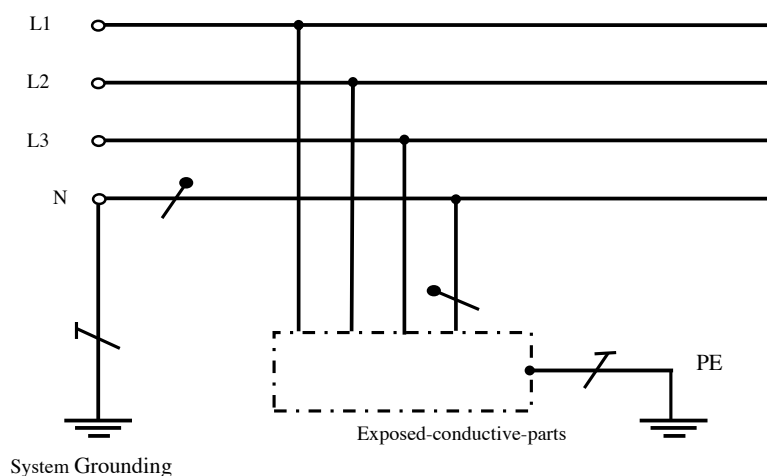
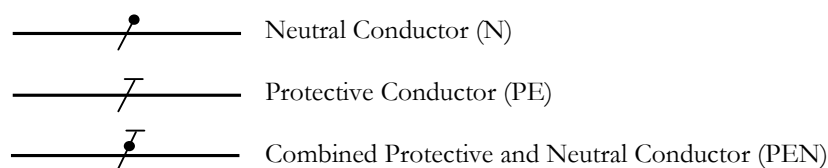
Grounding systems for low-voltage lines have 2 types: TT and TN. These grounding works shall comply with IEC 60364-1.

- a. The TT system has one point directly grounded and the exposed-conductive parts of the installation are connected to ground that are electrodes electrically independent of the ground electrodes of the power system.
- b. The TN system has one point directly grounded and the exposed-conductive parts are connected to the point by protective conductors. Two types of TN system are considered according to the arrangement of neutral and protective conductors, as follows:
 - TN-S system: in which, throughout the system, a separate protective conductor is used;
 - TN-C system: in which neutral and protective functions are combined.

- c. Low-voltage electrical equipment to be installed at users' sites shall be installed according to the IEC 60364 series. If it is directly connected to a power supplier, the grounding system shall be the same as that of the supplier's equipment involved in the supply of low-voltage electricity.

Low-voltage electrical equipment shall not be installed in such a manner that the grounding systems are different from those used at the same user's site.

(LEGEND)



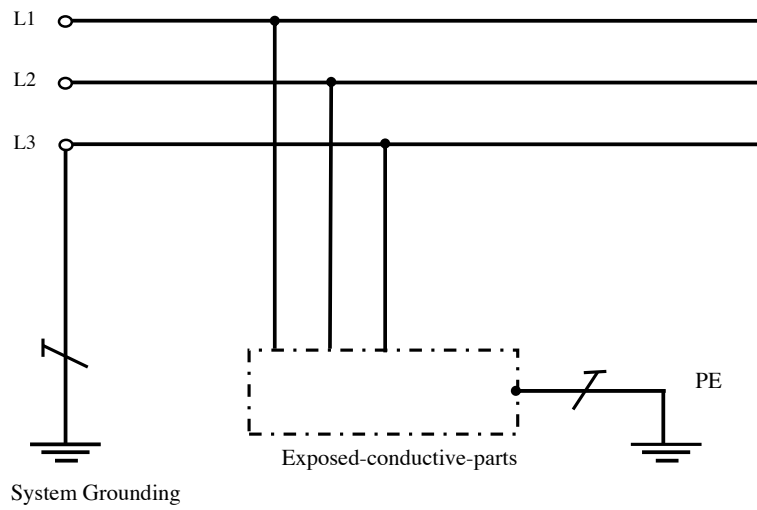


Figure 2: TT System

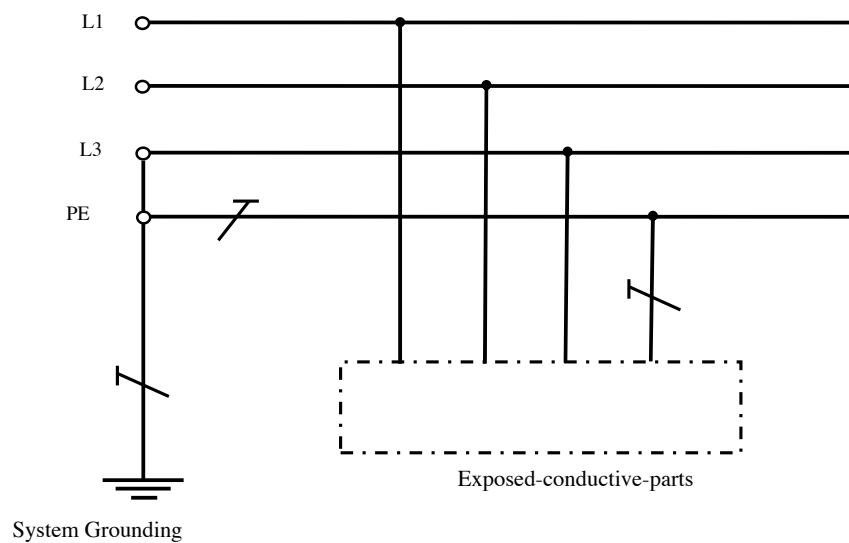
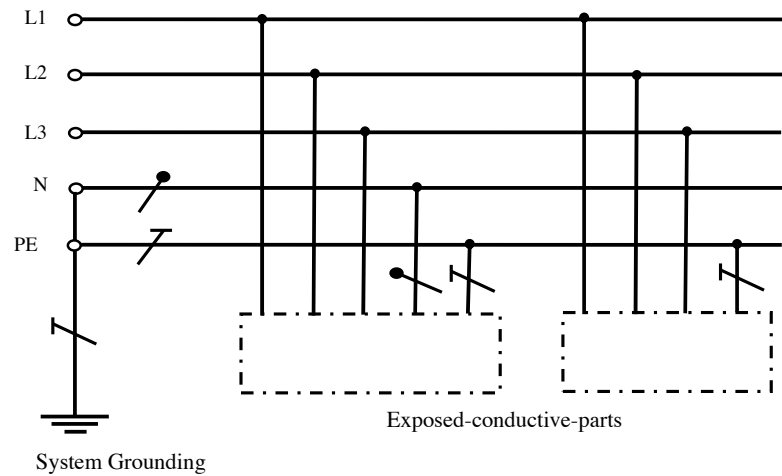


Figure 3: TN-S System

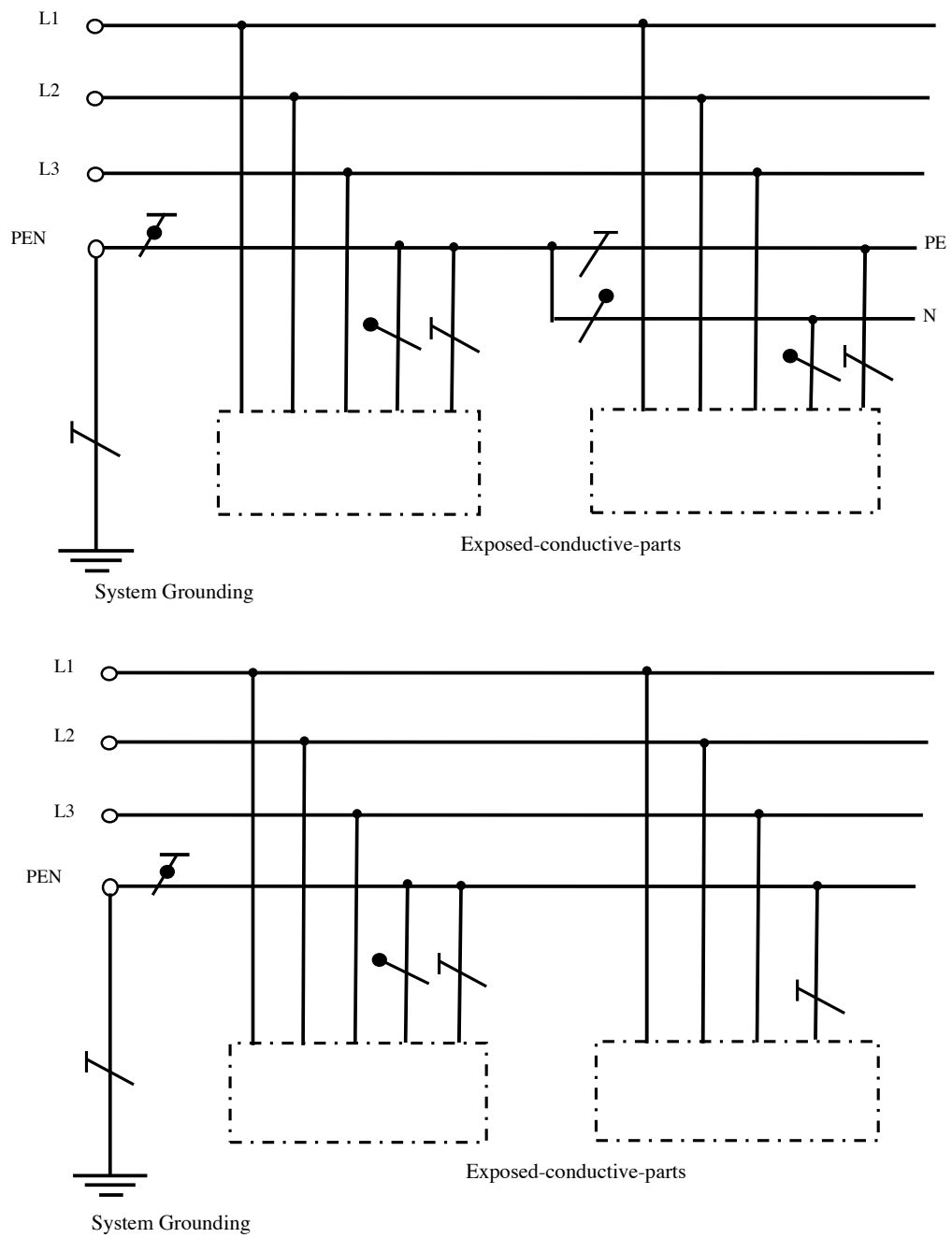


Figure 4: TN-C System

PART 3

Conductor

Article 25: Conductors for Transmission and Distribution Facilities

1. Generals

The conductors for transmission and distribution facilities shall be cables, insulated conductors or bare conductors. Bare conductors shall not be used for low-voltage lines.

Cables and insulated conductors shall have sufficient insulation capacity appropriate for the conditions of the applied voltage.

2. Property of Conductors

2.1 The conductors shall withstand temperatures under ordinary use.

2.2 The structure of the conductors

a. Insulated Conductors

The structure shall be an electric conductor covered with insulating material.

b. Cables used in Low-voltage Line

The structure shall be such that an electric conductor is covered with insulating material that is protected with armor.

c. Cables used in Medium-voltage Line

The structure shall be such that an electric conductor is covered with insulating material that is protected with armor, and that has a metal electric shielding layer made of metal provided on the cable core in a single-core cable, and on the cable cores bundled together, or on each cable core in a multi-core cable.

2.3 The conductors, the completed product to be used in a transmission line, or in a distribution line shall pass an appropriate AC withstand voltage test.

2.4 The tensile strength per unit area (MPa) of hard-drawn aluminum wires used for single conductors in an overhead line shall be not less the value given in Table 12 conforming to the related IEC standards.

Table 12: Tensile Strength of Hard-drawn Aluminum Wires (IEC 60889)

Nominal diameter		Minimum tensile strength (MPa)
Over (mm)	Up to and including (mm)	
-	1.25	200
1.25	1.50	195
1.50	1.75	190
1.75	2.00	185
2.00	2.25	180
2.25	2.50	175
2.50	3.00	170
3.00	3.50	165
3.50	5.00	160

Article 26: Connection of Conductors

Conductors shall be connected as per following methods:

- a. Conductors shall be connected firmly and the resistance of conductors shall not increase more than the resistance of conductors without connection.
- b. Conductors shall be connected so that the insulating capacity of cables and insulated conductors shall not decrease less than the insulating capacity without connection.
- c. With regard to connecting conductors of different kind of materials, electrochemical corrosion shall be prevented.

Article 27: Safety Factor of Bare Conductors and Ground Wires of Overhead Electrical Lines

1. Generals

As for tensile strength of conductors and ground wires for overhead electrical lines except for cables, the safety factor shall be 2.5 or more.

2. Loads on Conductors for Overhead Transmission Lines

2.1 Assumed Load and Safety Factor

Overhead transmission conductors and overhead ground wires (excluding cables, the same applies hereafter in this clause) shall be installed with the tension to allow a safety factor specified in the

following Item 2.1.2 when they are subject to the assumed load specified in the following Item 2.1.1 below at the average temperature in the area.

2.1.1 Assumed Load

The assumed load for the calculation of tension of overhead transmission conductors and overhead ground wires shall be the composite load of the vertical loads specified in the following item a and the horizontal loads specified in the following item b.

- a. The vertical load shall be the weight of the electrical conductor.
- b. The horizontal load shall be the horizontal maximum wind pressure load of the electrical conductor's vertical projected area.

2.1.2 Safety Factor

A safety factor of 2.5 or more shall be applied to the tensile strength (ultimate tensile strength; breaking strength) of overhead transmission conductors and overhead ground wires.

2.1.3 Reference Wind Velocity

Reference wind velocity to design overhead lines shall be as given in Table 13.

Table 13: Reference Wind Velocity

Yearly maximum of 10-minute average wind velocity (50 year return period)	32 m/sec
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In the following circumstances, the above reference wind velocity can be changed.

- a. When sufficient observed data have been accumulated.
- b. When greater reliability is especially needed.
- c. When the design is needed to cooperate with the designs of neighboring countries.

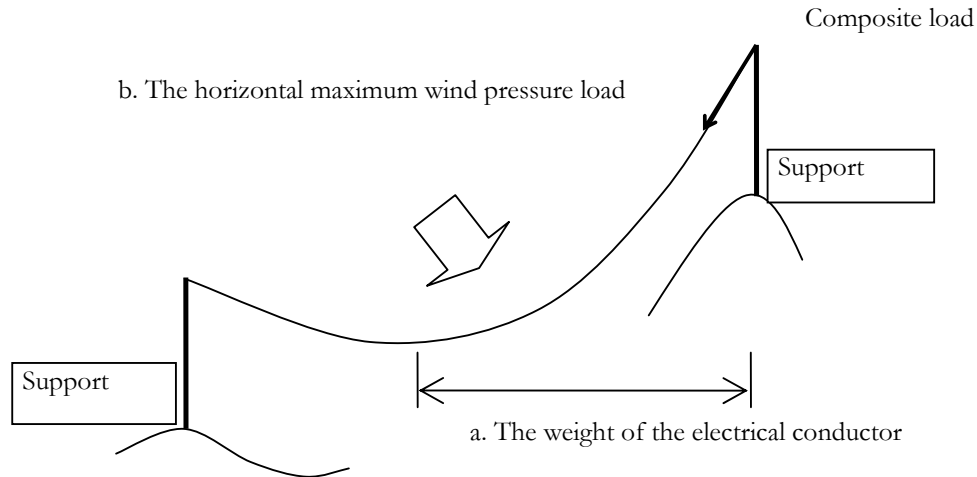


Figure 5: Assumed Load

2.2 Every Day Stress of conductors

EDS* (Every Day Stress) of conductors shall be considered to avoid conductor's fatigue in overhead lines due to aeolian vibration.

* EDS is expressed as the percentage of ultimate tensile strength (UTS) under windless condition.

Article 28: Side-by-Side Use and Joint Use of Electrical Lines or Communication Lines

1. High-Voltage Lines, Medium-Voltage Lines and Low-Voltage Lines

Side-by-side use and joint use of electrical lines shall be done by the following methods.

1.1 High-voltage Lines and Medium-voltage Lines

- When a high-voltage line and a medium-voltage line are installed at the same supporting structure, the medium-voltage line shall be installed under the high-voltage line and on separate crossarms.
- The clearance between any overhead high-voltage line conductors and any overhead medium-voltage line conductors shall under no circumstances be less than the values specified in Article 37 of these SREPTS at any point in the span.
- The overhead high-voltage line conductor shall be stranded wire with a tensile strength of at least 30kN, unless they are cables.
- The nominal voltage of the high-voltage electrical lines in side-by-side use or joint use shall be not more than 115kV.

1.2 Medium-voltage Lines and Low-voltage Lines

- 1.2.1 When a medium-voltage line and a low-voltage line are installed at the same supporting structure, the low-voltage line shall be installed under the medium-voltage line and on separate cross arms.
- 1.2.2 The conductor of the low-voltage line shall be conformed with following provisions, except in cases where cables are used:
 - a- In case the span of the low-voltage line is shorter than 50m, the tensile strength shall be not less than 5kN.
 - b- In case the span of the low-voltage line is 50m or over, the tensile strength shall be not less than 8kN.
- 1.2.3 The low-voltage line in a part installed on the same supporting structure of an overhead medium-voltage line shall be grounded with class B grounding and its resistance shall be not more than 10Ω.
- 1.2.4 The clearance between any overhead medium-voltage line conductors and any overhead low-voltage line conductors shall under no circumstances be less than the values specified in Article 48 of the SREPTS at any point in the span.

1.3 High-voltage Lines and Low-voltage Lines

- 1.3.1 No low-voltage line shall be installed at the same supporting structure where a high-voltage line is installed.
- 1.3.2 Exception of Side-by-side Use of High-voltage Lines and Low-voltage Lines

Side-by-side use of high-voltage lines and low-voltage lines is permitted only if all following measures are taken to intensify the facilities.

- (1) The conductor of the low-voltage line shall be conformed with following provisions, except in cases where cables are used:
 - a. In case the span of the low-voltage line is shorter than 50m, the tensile strength shall be not less than 5kN.
 - b. In case the span of the low-voltage line is longer than 50m, the tensile strength shall be not less than 8kN.
- (2) The low-voltage line in a part installed on the same supporting structure of an overhead high-voltage line shall be grounded with Class B grounding and its resistance shall be not more than 10Ω.

- (3) The clearance between any overhead high-voltage line conductors and any overhead low-voltage line conductors shall under no circumstance be less than 4.5m at any point in the span.
- (4) The overhead high-voltage line conductor shall be stranded wire with a tensile strength of at least 30kN unless they are cables.
- (5) The nominal voltage of the high-voltage line shall be not more than 115kV. In case the high-voltage line has double circuits, reversed phase-formation shall be adopted.
- (6) The distance of side-by-side use of high-voltage lines and low-voltage lines shall be decided taking the assumed induction voltage into consideration.
- (7) Exception can be allowed in the following unavoidable circumstances:
 - a. There is no suitable space to install a low-voltage line in urban areas, because houses stand close together and the only appropriate low-voltage line route is along a road but a high-voltage transmission line has been already installed there.
 - b. Other special circumstances approved by the EAC.

2. Electrical Lines and Communication Lines

Side-by-side use and joint use of electrical lines and communication lines shall be done by the following methods. If communication lines consist of optical fibers and they are tied to electrical lines or ground wires, this may not be applicable.

- a. When a medium-voltage or a low-voltage line and a communication line are installed on the same supporting structure, the medium-voltage or the low-voltage line shall be installed above the communication line and on separate cross arms.
- b. No communication line shall be installed at the same supporting structure where a high-voltage line is installed.

Article 29: Underground Lines

1. Conductors of Underground Lines

Cables shall be used for underground electrical lines.

2. Draw-in Conduit System and Culvert System

- a. In case underground lines are installed with a draw-in conduit system, tubes of the draw-in conduit system shall have sufficient strength to withstand the pressure of vehicles and other heavy objects.
- b. In case the strength of the tubes cannot be verified, they shall be installed not less than 1.2 m in depth to prevent a danger due to the pressure from vehicles and other heavy objects.

- c. In case underground lines are installed with a draw-in culvert system as shown in Figure 6 B, culverts shall be capable of withstanding the pressure of vehicles and other heavy objects.

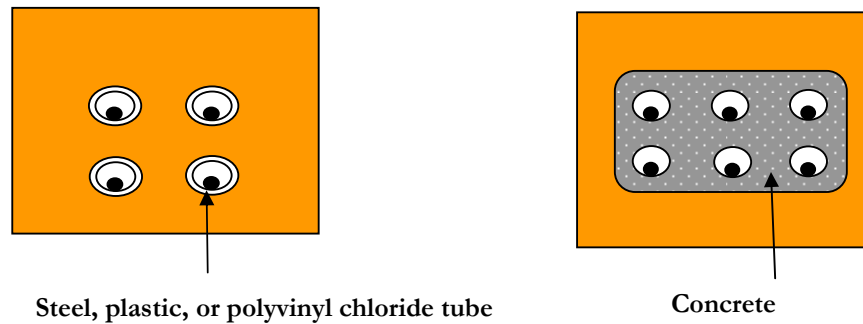


Figure 6A: Example of Draw-in Conduit System

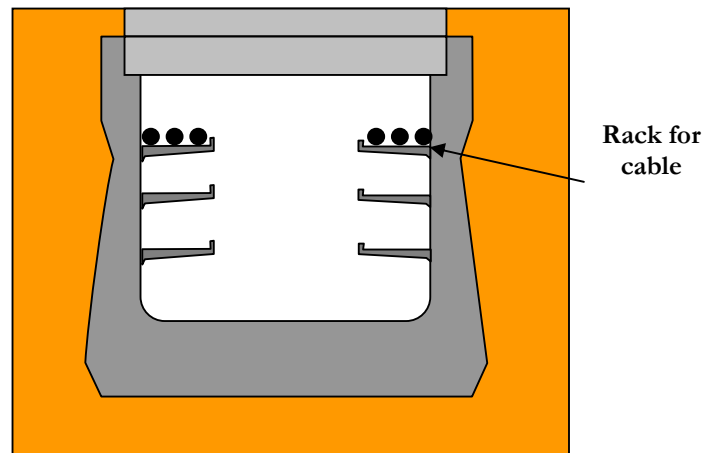


Figure 6B: Example of Draw-in Culvert System

3. Direct Burial System

- 3.1 In case underground lines are installed with a direct burial system, they shall be installed in accordance with the following methods.
- Installation of proper plates above the underground lines or other proper measures shall be taken to protect the underground lines against mechanical shocks.
 - The installed position of underground facilities shall be not less than 1.2 m in depth at a place where there is a danger of receiving pressure from vehicles or other objects, and not less than 0.6 m at any other place.

3.2 The depth of underground facilities described in 3.1.b above signifies the depth of such facility measured from the plate to protect cables.

3.3 The following places shall be included among the 'any other place' of 3.1.b above.

- a. The sidewalk of a road.
- b. A road where no cars pass.

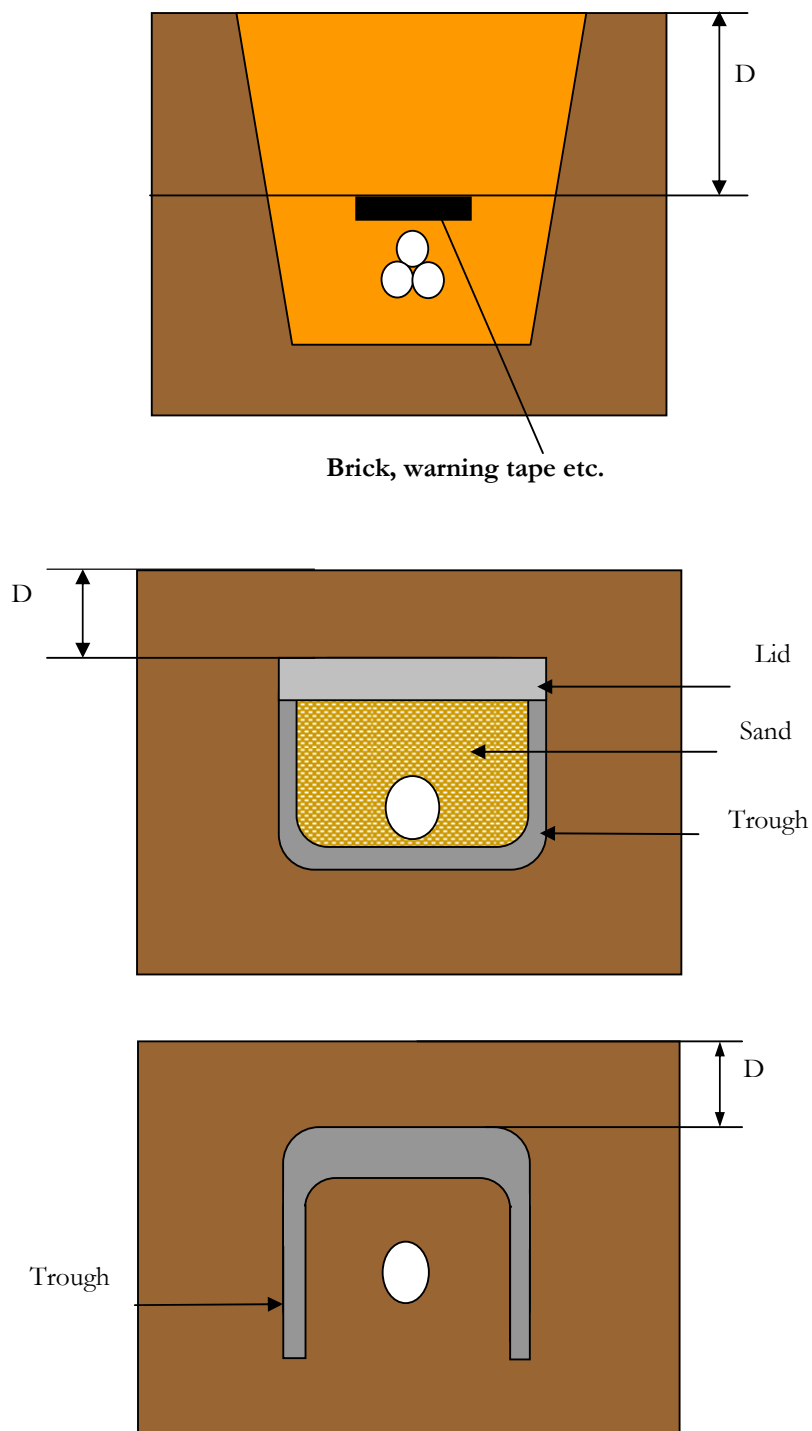


Figure 6C: Explanation of the Depth of the Direct Burial System

Table 14A: Depth in case of Direct Burial System

At a place where there is a danger of receiving pressure from vehicles or other objects	D = Not less than 1.2 m
Other place	D = Not less than 0.6 m

4. Clearance between Multiple Underground Lines

- 4.1 Minimum clearance between a new underground line and other electrical lines shall be as shown in the following table:

Table 14B: Clearance between Multiple Underground Lines**(Unit: m)**

New line	Other electrical lines		
	Low voltage	Medium voltage	High voltage
Low-voltage	0.15	0.3	0.3
Medium-voltage	0.3	0.3	0.3
High-voltage	0.3	0.3	0.3

- 4.2 In case one of two electrical lines is installed in an incombustible stout tube, the minimum clearance shall not be required.

5. Clearance between Underground Lines and Other Facilities

- a. Minimum clearance between a new underground line and other facilities shall be as shown in the following table:

Table 14C: Clearance between Underground Lines and Other Facilities**(Unit: m)**

New line	Other facilities			
	Communication line	Gas	Water	Sewerage
Low voltage	(*0.1) 0.3	Shall not make direct contact		
Medium voltage	(*0.1) 0.6	1.0	0.3	0.3
High voltage	0.6	1.0	0.3	0.3

* The approval of the owner of the communication line shall be required.

- b. In case the electrical line is installed in an incombustible stout tube and the tube does not come into direct contact with other facilities, the minimum clearance shall not be required.
- c. In case communication lines are united with electrical lines, the minimum clearance shall not be required.

6. Connection of Underground Cables

The connection of underground cables shall be implemented with the following methods, in addition to Article 26 of these SREPTS.

- a. The connecting device shall be able to withstand the external forces that will be extended under the expected conditions.
- b. The connected cables shall be in good order for the permissive current of the original cables.
- c. The connected cables shall have same waterproof performance.

7. Structure of Underground Boxes

In case underground boxes are installed, their structure shall be as follows:

- a. The underground boxes shall be able to withstand the pressure of vehicles and other heavy objects.
- b. When there is some possibility that explosive gases or combustible gases are filled in the box and the capacity of the box is 1m³ or more, a device such as a ventilator to exhaust the gases shall be installed.
- c. The lids of underground boxes shall be so installed that third persons are unable to open them easily.

8. Grounding for Underground Facilities

Safety grounding of Class D shall be installed at the metallic part of such facilities as the tube, culvert and joint box, and the metallic shield tape of a cable.

CHAPTER 3

**HIGH-VOLTAGE TRANSMISSION
FACILITIES**

Article 30: Protective Devices for Electrical Equipment

1. Measures for protecting Conductors and Electrical Equipment against Over-current

At necessary points in electrical circuits, over-current circuit breakers that protect against heating damage by over-current and prevent outbreaks of a fire shall be installed.

2. Protection and Alarm Devices for Transformers and Reactive Power Compensators

Transformers and reactive power compensators to be installed in stations and high-voltage and medium-voltage users' sites shall be equipped with devices to automatically cut off the transformer and the reactive power compensator from the electrical circuit when any abnormality that might cause significant damage and serious trouble to the supply of electric power occurs, in addition to other appropriate protection systems, as shown in Table 15.

Table 15: Protection Systems for Transformers and Reactive Power Compensators

Classification		Abnormality	Protection and alarm device	
			Automatic shutdown device	Alarm device
Main transformer	Common	Over current	○	---
		Internal fault	○	---
		Significantly rise in temperature	---	○
	Transformer with cooling system (A cooling system in which the coolant is sealed-in to directly cool the windings and iron core of the transformers, and is forcibly circulated)	When the cooling system fails or when there is a significant rise in the temperature of the transformer	---	○
Power capacitor	Common	Over current or over voltage or internal fault	○	---
Shunt reactor	Common	Over current	○	---
		Internal fault	○	---
		Significant rise in temperature	---	○
	Shunt reactor with cooling system (A cooling system in which the coolant is sealed-in to directly cool the winding and iron core of the shunt reactor, and is forcibly circulated)	When the cooling system fails or when there is a significant rise in the temperature of the Shunt reactor	---	○

Notes- ○ : Equips

-- : No need

Article 31: Design of Supporting Structures of Overhead High-voltage Lines

1. Basic Conditions

- a. Supporting structures of overhead lines shall be designed, taking into account the following loads.

Table 16A: Type of Loads

Type of Load	Components of Load
Vertical loads	Weight of the supporting structure
	Weight of the conductors and the ground wires and the accessories supported by the supporting structure
	Weight of the insulator strings and the fittings supported by the supporting structure
	A vertical component of the maximum tension of the guy wires supporting the supporting structure, if any
Horizontal transverse loads	Wind pressure on the supporting structure under the maximum wind velocity
	Wind pressure on the conductors and the ground wires supported by the supporting structure under the maximum wind velocity
	Wind pressure on the insulator strings and the fittings supported by the supporting structure
	A horizontal transverse component of the maximum tension of the conductors and the ground wires supported by the supporting structure and the guy wires supporting the supporting structure, if any
Horizontal longitudinal loads	Wind pressure on the supporting structure under the maximum wind velocity
	A horizontal longitudinal component of the unbalanced maximum tension of the conductors and the ground wires supported by the supporting structure and the maximum tension of the guy wires supporting the supporting structure, if any

- b. Supporting structures and foundations of overhead high-voltage lines shall be designed, taking the value of wind pressure based on the reference wind velocity prescribed in Article 27 of these SREPTS into consideration.
- c. Supporting structures and foundations of overhead high-voltage lines shall be designed to withstand the maximum loads, taking appropriate safety factors into consideration.
- d. In case overhead high-voltage lines are installed at places with the worst conditions, such as inside river areas, windy areas, and so on, the supporting structures and the foundations shall be designed to withstand such severe conditions.

2. Components of Supporting Structures

Components of supporting structures shall satisfy the following or shall have an equivalent strength to these items.

2.1 Fundamental Properties of Components of Supporting Structures

Flat steel, shaped steel, steel pipes, steel plates, steel bars and bolts which compose a steel tower or an iron pole used for overhead transmission lines shall be appropriate ones as specified in the ISO (International Organization for Standardization) standards or other standards equivalent to these standards.

2.2 Thickness of Steel Members etc.

Shaped steel, steel pipes and steel plates to be used for a steel tower or an iron pole for overhead transmission lines shall have the thickness and other dimensions specified below.

2.2.1 Minimum Thickness of Shaped Steel

- a. Those to be used as a main post member of an iron pole (in which a main member of a cross arm is included. The same shall apply hereafter in this article) shall have a thickness of 4 mm.
- b. Those to be used as a main post member of a steel tower shall have a thickness of 5 mm.
- c. Those to be used as other structural members shall have a thickness of 3 mm.

2.2.2 Minimum Thickness of Steel Pipes

- a. Those to be used as a main post member of an iron pole shall have a thickness of 2 mm.
- b. Those to be used as a main post member of a steel tower shall have a thickness of 2.4 mm.
- c. Those to be used as other structural members shall have a thickness of 1.6 mm.

2.2.3 Slenderness Ratio of Steel Members

The slenderness ratio of a steel member is an indicator showing the state of tallness of its form. Slenderness Ratio of steel member is a division of its length to its section turning radius. More slenderness ratio means longer length or smaller section, so the form of steel member is more slim and weaker. Lesser slenderness ratio means shorter length or bigger section, so the form of steel member is more rotund and stronger.

The slenderness ratio of a compression member shall be not more than 200 for those to be used as the main post members, not more than 220 for compression members other than main post members (excluding those used as auxiliary members) and not more than 250 for those used as auxiliary members.

2.2.4 Minimum Thickness of Steel Plates

The thickness shall be not less than 1 mm.

2.3 Strength of Steel Members and Bolts

Steel members and bolts to be used for a steel tower or an iron pole of overhead transmission lines shall have the strength as specified in Table 16B.

Table 16B: Strength of Steel Members and Bolts

Classification of strength		Strength
Tensile strength	When $\sigma Y \leq 0.7\sigma B$	σY
	When $\sigma Y > 0.7\sigma B$	$0.7\sigma B$
Compression strength		σY
Flexural strength		σY
Shearing strength	When $\sigma Y \leq 0.7\sigma B$	$\sigma Y / \sqrt{3}$
	When $\sigma Y > 0.7\sigma B$	$0.7\sigma B / \sqrt{3}$
Bearing strength		$1.65\sigma Y$
Buckling strength	$0 < \lambda_k < \Lambda$	$\sigma Y \left[K_0 - K_1 \left\{ \lambda_k / \left(\pi / \sqrt{E / \sigma Y} \right) \right\} - K_2 \left\{ \lambda_k / \left(\pi / \sqrt{E / \sigma Y} \right) \right\}^2 \right]$
	$\Lambda \leq \lambda_k$	$1.5\pi^2 E / 2.2\lambda_k^2$

Where:

σY : Yield point strength of steel members and bolts

σB : Tensile strength of steel members and bolts

λ_k : Effective slenderness ratio ($= L_k / r$)

L_k : Effective buckling length of steel members

r : Turning radius of a steel member cross section

E : Elastic modulus ($20.6 \times 10^2 \text{ N/m}^2$)

$$\Lambda: \pi \sqrt{(15E / 2.2K\sigma Y)}$$

K, K_0, K_1, K_2 : Refer to Table 16C.

Table 16C K, K₀, K₁, K₂, for Table 16B

	K	K ₀	K ₁	K ₂
Structural members with little decentering (steel pipe, cruciform section steel, etc.)	0.6	1	0	0.352
Structural members with some decentering (angle steel used for a main post member, etc.)	0.5	0.945	0.0123	0.316
Structural members with significant decentering (angle steel used for a web member with one side flange joint, etc.) (*)	0.3	0.939	0.424	0

(*) Note that the buckling strength shall be not more than $0.6\sigma Y$ for structural members with significant decentering.

2.4 Strength of Foundation Components used for Steel Poles or Steel Towers

Foundation components of a steel pole or steel tower for overhead transmission lines shall have the strength specified below:

a. Strength of Concrete

The strength of concrete at yield point shall be based on the design standard strength (4-week strength; F_c) of concrete and conform to Table 16D.

Table 16D: Strength of Concrete

Kind of strength	Strength of concrete [$\times 10^6 \text{N/m}^2$]
Compression strength	$F_c/2$
Tensile strength	$F_c/20$
Shearing strength	$F_c/20$ and $0.74+1.5F_c/100$

b. Bond Strength of Concrete

The bond strength of concrete at yield point shall be based on the design standard strength (4-week strength; F_c) and conform to Table 16E.

Table 16E: Bond Strength of Concrete

[$\times 10^6 \text{N/m}^2$]

	Member		Fixative joint
	Upper edge round bar	Normal round bar	
Round bar	$6F_c/100$ and not more than 1.32	$9F_c/100$ and not more than 1.99	$6F_c/100$ and not more than 1.32
Deformed round bar	$F_c/10$ and not more than $1.32+3F_c/75$	$3F_c/20$ and not more than $1.99+3F_c/50$	$F_c/10$ and not more than $1.32+3F_c/75$
Shaped steel			$3F_c/100$ and not more than 0.66

c. Strength of Shaped Steel, Flat Steel and Steel Bars

The strength of shaped steel, flat steel and steel bars at yield point shall conform to Table 16F.

Table 16F: Strength of Shaped Steel, Flat Steel and Steel Bars

		Yield tensile strength (N/mm ²)	Yield compression strength (N/mm ²)
Round bar		σ_Y and not more than 234	σ_Y and not more than 234
Deformed round bar	Diameter ≥ 29 mm	σ_Y and not more than 294	σ_Y and not more than 294
	29 mm > Diameter > 25 mm	σ_Y	σ_Y
	25 mm \geq Diameter	σ_Y and not more than 322	σ_Y and not more than 322
Others		σ_Y and not more than $0.7\sigma_B$	σ_Y

σ_Y : Strength of material at yield point

σ_B : Tensile strength of material

d. Strength of Bolts

The strength of bolts shall conform to Table 16B.

3. Wind Pressure Load

3.1 Wind Pressure Values

The wind pressure load shall be the value obtained by calculation based on the wind pressure specified in the following Table 16G.

This shall not apply when calculation is made based on values obtained by a wind pressure (wind duct) test using a wind at a velocity of not less than 32 m/s.

The wind receiving area shall be the vertical projected area of the structural member. For crossarms of a concrete pole, an iron pole except a columnar pole, and a steel tower, the wind receiving area shall be the vertical projected area of the front structures that receive the wind.

Table 16G: Wind Pressure to calculate the Wind Pressure Load

Subject to the wind pressure				Wind pressure to 1 m ² of the vertical projected area of the structural member (N)		
Supporting structure	Iron pole	Columnar pole		520		
		Triangle or rhombic pole		1,220		
		Square pole consisting of steel pipes		970		
		Others		1,540		
	Reinforced concrete pole	Columnar pole		520		
		Square pole		1,290		
	Steel tower	Shaped steel tower		2,350 *		
		Steel pipe tower		1,340 *		
		Single pole	Columnar pole		520	
			Hexagonal or octagonal pole		970	
Electrical conductors and other wires	Electrical wires forming multiple conductors (limited to those in which two compositional conductors are arranged horizontally and the distance between such electrical conductors is not more than 20 times their outer diameter)			610		
	Others			680		
Insulator device				900		
Crossarms for an iron pole (limited to a columnar pole) and a reinforced concrete pole				1,030 when it is used as a single member		
				1,410 in other cases		

* This value shall be applied to 115kV high-voltage towers which are less than 40m high.

3.2 Wind Pressure Load at an Oblique Wind

When the wind blows to the electrical line at an angle of 60°, the wind pressure load in an assumed normal load of a common type steel tower shall be that calculated by the wind pressure load multiplier (in case of a square tower) in Table 16H.

Table 16H: Multiplier to Wind Pressure Load

Classification of wind pressure load			The multiplier to the wind pressure load when the wind blows perpendicular to the electrical line (in case of a square tower)
Wind pressure load to steel tower	Wind pressure load to body	Shaped steel tower	1.6
		Steel pipe tower	1.4
	Wind pressure load to cross arm		0.5 (for the wind pressure in the direction of the electrical line)
Wind pressure load to wire			0.75

4. Loads on Supporting Structures and Safety Factors

Loads on supporting structures and safety factors shall satisfy the following items or shall have an equivalent performance to these items.

4.1 Types and Combinations of Assumed Loads

The types and combinations of assumed loads to be used for calculating the strength of supporting structures for overhead transmission lines shall conform to the following provisions.

The assumed loads on supporting structures shall be classified as the loads specified in Table 16I. The combination of these loads on the supporting structures shall be in accordance with Table 16J depending on the classification and type of supporting structures.

Table 16I: Classification of Assumed Loads on Supporting Structures

Type of Load	Contents	Symbol
Vertical loads	Weight of the supporting structure	W_t
	Weight of the conductors and the ground wires and the accessories supported by the supporting structure	W_c
	Weight of the insulator strings and the fittings supported by the supporting structure	W_i
	A vertical component of the maximum tension of the conductors and the ground wires	V_a
	A vertical component of the maximum tension of the guy wires supporting the supporting structure, if any	W_s
Horizontal transverse loads	Wind pressure on the supporting structure under maximum wind velocity	H_t
	Wind pressure on the conductors and the ground wires supported by the supporting structure under the maximum wind velocity	H_c
	Wind pressure on the insulator strings and the fittings supported by the supporting structure	H_i

	A horizontal transverse component of the maximum tension of the conductors and the ground wires supported by the supporting structure and the guy wires supporting the supporting structure, if any	Ha Hs
	A torsional load due to the unbalance of the maximum tension of conductors of any phase	q
Horizontal longitudinal loads	Wind pressure on the supporting structure under the maximum wind velocity	Ht'
	A horizontal longitudinal component of the maximum tension of the guy wires supporting the supporting structure, if any	Ws'
	The unbalance of the maximum tension of the conductors of all phases and the ground wires	P1
	The unbalance of the maximum tension of the conductors of any phase	P2
	A torsional load due to the unbalance of the maximum tension of the conductors of any phase	q1

Table 16J: Combination of Loads on the Supporting Structures

Classification of supporting structure	Type	Design cases		Combination of assumed loads															
		Load condition	Wind direction	Vertical load					Horizontal transverse load					Horizontal longitudinal load					
				W _t	W _c , W _i	V _a	W _s	H _t	H _c , H _i	H _a	H _s	q	H _t	P1	P2	q1	W _s		
Concrete pole	Tension & Suspension Type Tower	Normal	Horizontal transverse	○	○	○	○	○	○	○	○	○							
			Horizontal longitudinal	○	○	○	○				○			○				○	
Steel pole	Dead-end Type Tower	Normal	Horizontal transverse	○	○	○	○	○	○			○			○				
			Horizontal longitudinal	○	○	○	○						○	○				○	
Steel tower	Tension & Suspension Type Tower	Normal	Horizontal transverse/60°	○	○	○	○	○	○	○	○	○							
			Horizontal longitudinal	○	○	○	○				○			○				○	
		Abnormal	Horizontal transverse	○	○	○	○	○	○	○	○	○				○	○		
			Horizontal longitudinal	○	○	○	○				○		○	○		○	○	○	
Single steel pole	Dead-end Type Tower	Normal	Horizontal transverse	○	○	○	○	○	○			○			○				
			Horizontal longitudinal	○	○	○	○						○	○				○	
		Abnormal	Horizontal transverse	○	○	○	○	○	○			○	○		○		○		
			Horizontal longitudinal	○	○	○	○						○	○	○		○	○	

Where:

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

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

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

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

Where strung wires are arranged asymmetrically on the supporting structure, the assumed vertical eccentric load shall be added to the load in Table 16J and the load by normal torsional load shall also be added for the dead-end type.

4.2 Unbalanced Maximum Tension and so on

Unbalanced maximum tension and so on used in 4.1 shall conform to the following requirements:

4.2.1 The unbalanced maximum tension and torsional force shall conform to Table 16K.

Table 16K: Unbalanced Tension and Torsional Force

Classification of supporting structure	Type of supporting structure	Unbalanced tension and torsional force	
		Assumed normal load	Assumed abnormal load
Steel tower	Tension & Suspension Type Tower	No specification	Horizontal longitudinal component of force of the unbalanced tension and torsional force generated by cutting strung wires
	Dead-end Type Tower	Horizontal longitudinal component of force of the unbalanced tension equal to the assumed maximum tension for each strung wire	
Iron reinforced concrete pole and iron pole	Tension & Suspension Type Tower	No specification	No specification
	Dead-end Type Tower	Horizontal longitudinal component of force of the unbalanced tension equal to the assumed maximum tension for each strung wire	

4.2.2 For steel towers, the strung wires shall be cut according to the following requirements, depending on the total number of phases of electrical conductors (which mean phases for each circuit. The same shall apply hereafter).

- a. The overhead ground wire shall not be cut at the same time as the electrical conductors and only one wire shall be cut;
- b. Where the total number of phases of electrical conductors is not more than twelve (12), one phase that maximizes the stress generated in each structural member (two electrical conductors from one phase in case of multiple conductors for steel towers other than dead-end type);
- c. Where the total number of phases of electrical conductors is over twelve (12) (excluding the case specified in the following Item d.), two phases in different circuits that maximize the stress generated in each structural member (two electrical conductors from one phase in case of multiple conductors for steel towers other than dead-end type);
- d. Where electrical conductors are arranged so that nine or more phases are in a longitudinal row and two phases are in a transverse row, one of the top six phases in the longitudinal row (two electrical conductors from one phase in case of multiple conductors for steel towers other than dead-end type) and one phase from the other phases (two electrical conductors from one phase in case of multiple conductors for steel towers other than dead-end type) that maximize the stress generated in each structural member.

4.2.3 The unbalanced tension generated by cutting the strung wire shall be equal to the assumed maximum tension.

Provided, however, that the unbalanced tension may be 0.6 times the assumed maximum tension if, depending on the mounting method of the strung wire, the supporting point of the strung wire shifts when the wire is cut or the strung wire slides at the supporting point.

4.3 Safety Factor of Supporting Structure

The yield strength of the structural members of reinforced concrete poles, iron poles and steel towers used for overhead transmission lines shall satisfy the safety factor listed in Table 16L for the assumed loads specified in 4.1 to 4.2.

Table 16L: Safely Factors of Supporting Structures

Classification of supporting structure	Load condition	Safety factor
Reinforced concrete pole Iron pole	Assumed normal load	2.0
Steel tower	Assumed normal load	1.5
	Assumed abnormal load	1.0 (1.5 for crossarms)

5 Loads on Foundations of Supporting Structures and Safety Factors

5.1 Loads on the Foundation of a Supporting Structure

The loads applied to the foundation of a supporting structure for overhead transmission lines shall be calculated from combinations of the assumed loads of the supporting structure specified in paragraph 4 and the resulting maximum values shall be the assumed normal and abnormal loads for the foundation.

5.2 Safety Factor of the Foundation

The safety factor of the foundation of a supporting structure for overhead transmission lines shall satisfy the value listed in Table 16M for its yield strength.

Table 16M: Safety Factors of the Foundations

Classification of supporting structure	Safety factor	
	Assumed normal load	Assumed abnormal load
Reinforced concrete pole and iron pole	2.0	-
Steel tower	2.0	1.33

5.3 Treatment of the Weight of the Foundation

The weight of the foundation used for calculating the safety factor shall be treated in accordance with the following provisions:

- a. For a foundation that is subject to a lifting load, not more than two-thirds of the weight of the foundation (or the weight of the foundation of a steel tower to an abnormal load) may be included in the lift bearing power.
- b. For a foundation that is subject to a compressive load, the weight of the foundation shall be included in the compressive load.

Article 32: Design of Fittings for Conductors and/or Ground Wires of Overhead High-voltage Lines

1. Safety Factor of Fittings for Conductors and/or Ground Wires of Overhead High-voltage Lines

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

1.2 The safety factor mentioned in 1.1 shall be obtained as follows:

- a. Tension insulator device (insulator device that anchors electrical conductors)
$$[\text{Safety factor}] = [\text{Tensile break strength}] / [\text{Assumed maximum tension at a support point}];$$

- b. Suspension insulator device (Insulator device from which electrical conductors are hung)

$$[\text{Safety factor}] = [\text{Tensile break strength}] / [\text{Composite load of vertical load and horizontal transverse load}];$$
- c. Supporting insulator device

$$[\text{Safety factor}] = [\text{Bending break strength}] / [\text{Horizontal transverse load or vertical load applied perpendicular to the axis of the insulator device}].$$

2 Mechanical Strength of Insulators for Overhead Transmission Lines

2.1 Assumed Load

The assumed loads to be used for calculating the strength of insulator devices for overhead transmission lines shall conform to the following requirements.

a. Vertical Load

The vertical load shall be the sum of the weight of electrical conductors, the weight of insulator devices and the vertical component of the force generated by the assumed maximum tension of the electrical conductors.

b. Horizontal Transverse Load

The horizontal transverse load shall be the sum of the wind pressure loads of electrical conductors and insulator devices and the horizontal component of load generated by the assumed maximum tension of the electrical conductors. The wind pressure loads shall be calculated based on the values listed in Table 16G.

c. Assumed Maximum Tension of Conductors

The assumed maximum tension of conductors shall be the tension of the transmission conductor under the composite load of the vertical load generated by the weight of the electrical conductor, and the horizontal load generated by the horizontal wind pressure stipulated in Table 16G at the average temperature in the area.

Article 33: Protection against Lightning for Overhead High-voltage Lines

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

- a. Installation of ground wires for overhead high-voltage lines;
- b. Installation of arcing horns for both ends of insulator assemblies of overhead high-voltage lines;
- c. Installation of armor rods to wrap conductors in a clamp of suspension insulator assemblies of overhead high-voltage lines.

Article 34: Bare Conductors of Overhead High-voltage Lines

1. Vibration Dampers

An appropriate type and number of dampers shall be installed to prevent fatigue of bare conductors and ground wires for overhead high-voltage lines due to their aeolian vibration.

2. Connection

In case bare conductors and ground wires are jointed with each other or with insulated conductors or cables, the connection shall conform to the following requirements in addition to Article 26 of these SREPTS.

- a. Bare conductors and ground wires shall be connected with compression type sleeves or compression type devices.
- b. The tensile strength of connection of bare conductors and ground wires shall be not less than 95 % of the tensile strength of the connected bare conductors and ground wires. This requirement, however, shall not be applied to cases where the maximum tension to be designed is substantially less than the ultimate strength of the bare conductors and ground wires such as jumper conductors, the end span to substations and others.

Article 35: Clearance between Bare Conductors and Supporting Structures of Overhead High-voltage Lines

Clearance between bare conductors and supporting structures, arms, guy wires and/or pole braces of overhead high-voltage lines shall be as follows. The clearances shall be secured, in any cases where the maximum swing of conductors under the maximum wind velocity to be designed.

Table 17: Clearance between Bare Conductors and Supporting Structures

Nominal Voltage	Clearance
115kV	Not less than 0.70m
230kV	Not less than 1.45m

Clearance between ground wires and the nearest conductor in the same span shall be larger at any point in the span than the clearance of the supporting point at both sides of the span.

Article 36: Height of Overhead High-voltage Lines

The height of conductors of overhead high-voltage lines shall be as follows:

1. Height in Urban Areas

Height of conductors of overhead high-voltage lines in urban areas shall be not less than the value calculating by adding 0.060 m to a base height 6.5m for every 10kV over 35kV.

Table 18A: Height in Urban Areas

Nominal Voltage	Height
115kV	Not less than 7.0m
230kV	Not less than 7.7m

2. Height in Areas Where Third Persons Hardly Approach

The height of conductors of overhead high-voltage lines in areas where third persons hardly approach shall be not less than the value calculated by adding 0.06 m to a base height of 5.5m for every 10kV over 35kV.

Table 18B: Height in Areas Where Third Persons Hardly Approach

Nominal Voltage	Height
115kV	Not less than 6.0m
230kV	Not less than 6.7m

3. Height over Roads and/or Railways

The height of conductors of overhead high-voltage lines crossing over roads and/or railways shall be not less than the value calculated by adding 0.060 m to a base height of 13m for every 10kV over 35kV.

Table 18C: Height over Roads and/or Railways

Nominal Voltage	Height
115kV	Not less than 13.5m
230kV	Not less than 14.2m

4. Height over Rivers and/or Seas

The height of conductors of overhead high-voltage lines crossing rivers and/or seas shall be as follows:

Table 18D: Height over Rivers and/or Seas

At places with no vessel passage		At places with vessel passage	
From the highest water level		From the highest point of vessels on the highest water level(*1)	
Not less than the value calculated by adding 0.06 m to a base height of 5.5m for every 10kV over 35kV		Not less than the value calculated by adding 0.06 m to a base height of 3m for every 10kV over 35kV	
Nominal Voltage	Height	Nominal Voltage	Clearance
115kV	Not less than 6.0m	115kV	Not less than 3.5m
230kV	Not less than 6.7m	230kV	Not less than 4.2m

(*1) The highest point of vessels shall be decided taking into account any future possible changes.

5. Note

All the heights described above shall be secured in any cases of the maximum sagging of conductors in the maximum temperature to be designed.

Article 37: Clearance between Overhead High-voltage Lines and Other Facilities or Trees

1 Generals

The clearance between each conductor of overhead high-voltage lines and other facilities or trees shall be as follows:

a. Clearance to Other Facilities

The clearance between each conductor of overhead high-voltage lines and other facilities shall be not less than the value calculated by adding 0.06 to a base height of 3m for every 10kV over 35kV.

Table 19A: Clearance to Other Facilities

Nominal Voltage	Height
115kV	Not less than 3.5m
230kV	Not less than 4.2m

b. Clearance to Trees

The clearance between each conductor of overhead high-voltage lines and trees shall be not less than the value calculated by adding 0.06 m to a base height of 2m for every 10kV over 35kV.

Table 19B: Clearance to Trees

Nominal Voltage	Height
115kV	Not less than 2.5m
230kV	Not less than 3.2m

c. Note

The clearances described above shall be secured in any cases of the maximum sagging of conductors in the maximum temperature and/or the maximum swing of conductors under the maximum wind velocity to be designed.

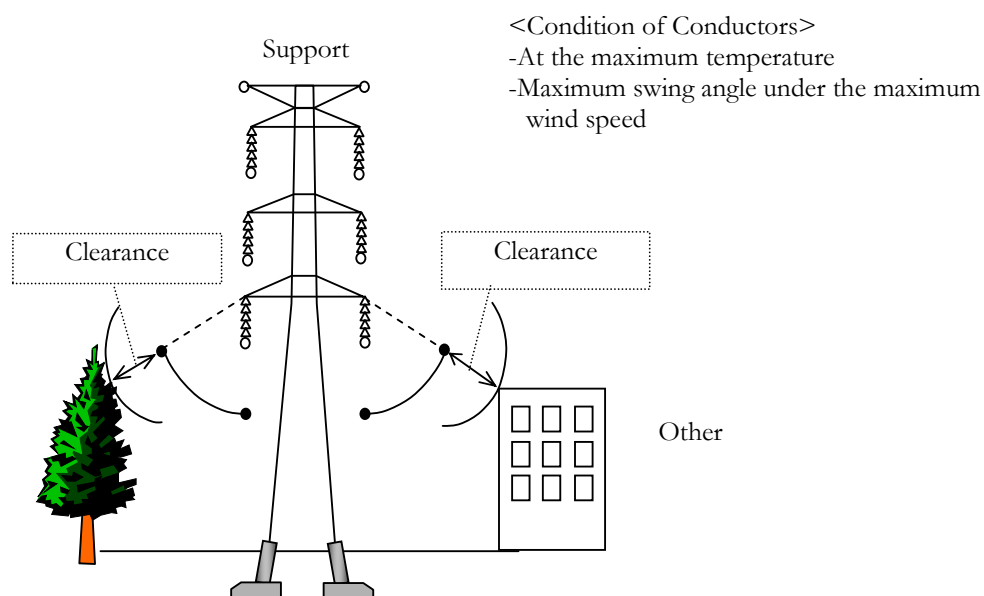


Figure 7: Direct Proximity

2 Proximity to and Crossing with Buildings

2.1 230kV Overhead High-voltage Line

Overhead transmission conductors with a nominal voltage 230kV shall be installed not less than 3 meters away in a horizontal distance above or to the side of buildings.

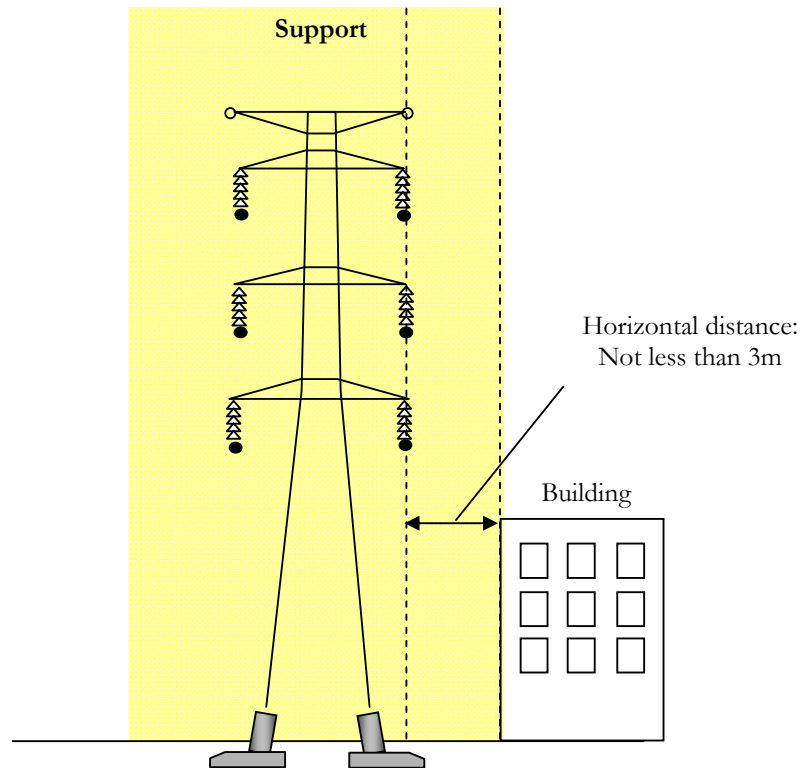


Figure 8: Proximity to Buildings (230kV)

2.2 115kV Overhead High-voltage Line

Overhead transmission conductors with a nominal voltage of 115kV shall be installed not less than 6 meters from the top of buildings when the 115kV overhead high-voltage line is adjacent laterally within 3m or crossing with buildings.

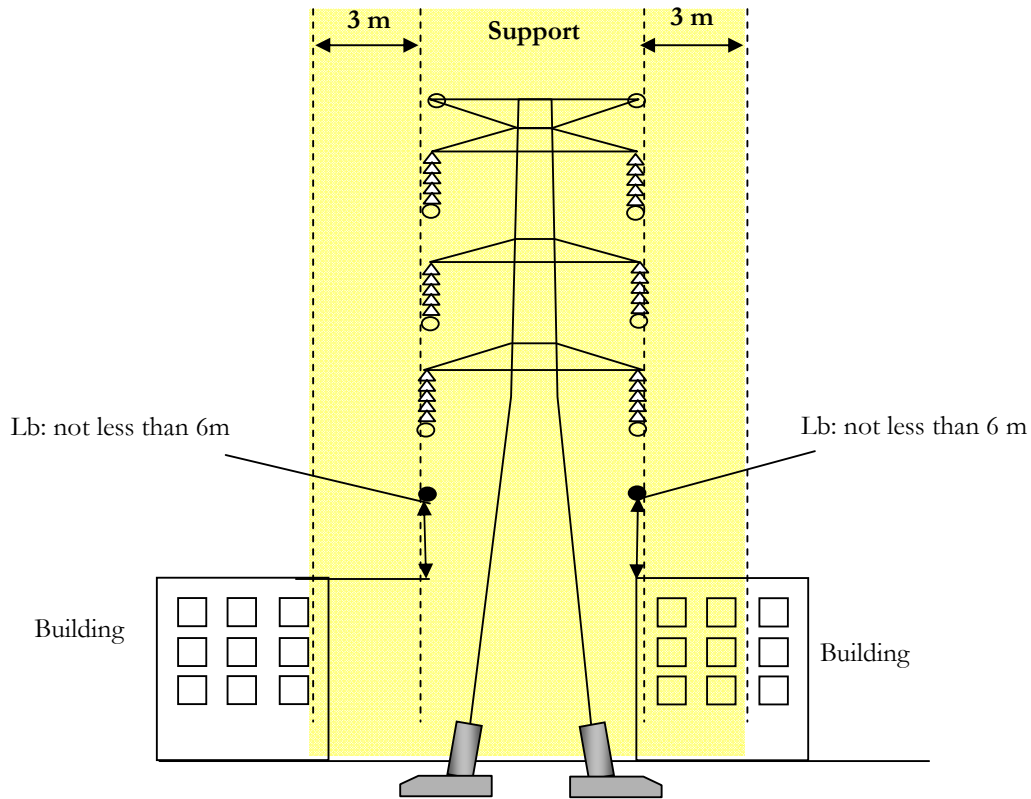


Figure 9: Crossing with Buildings (115kV)

3. Proximity to and Crossing with Medium-voltage Lines and High-voltage Lines

The clearance between each conductor of overhead high-voltage lines and other medium-voltage lines or high-voltage lines shall be not less than the value calculated by adding 0.06m to a base height of 2m for every 10kV over 35kV.

Table 20: Clearance between Conductors

	Nominal Voltage[kV]	Clearance[m]
Clearance (Ll*)	115	Not less than 2.5
	230	Not less than 3.2

* Refer to Figure 10.

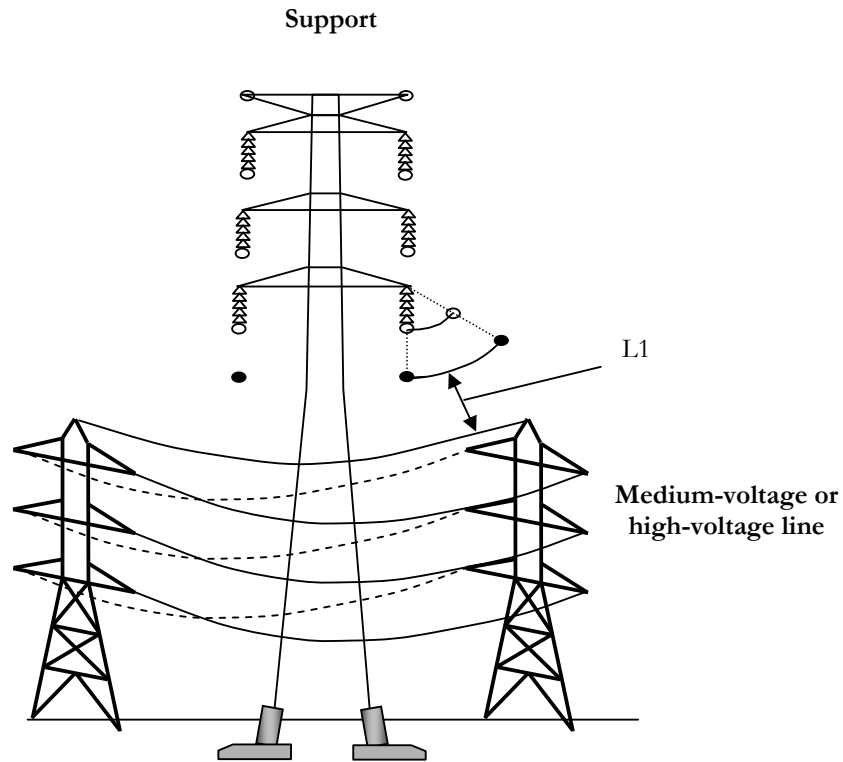


Figure 10: Proximity and Crossing with Medium-voltage Lines and High-voltage Lines

Article 38: Prevention of Danger and Interference due to Electrostatic Induction and Electromagnetic Induction

1. Electrostatic Induction

High-voltage lines shall be installed to prevent danger to persons and/or interference on communication lines installed near the high-voltage lines caused by electrostatic induction, taking appropriate measures including the following items a, b and Article 28 of these SREPTS into consideration.

- a. The electrical field caused by overhead high-voltage lines shall be 3kV/m or less at 1 m above the ground surface, except for overhead high-voltage lines in places where third persons hardly approach, such as in mountains, on farming land and so on.
- b. Conductive materials on the surface of the buildings under overhead high-voltage lines shall be grounded with the Class D grounding in accordance with Article 22 of these SREPTS.

2. Electromagnetic Induction

High-voltage lines shall be installed to prevent danger to persons and/or interference on communication lines caused by electromagnetic induction on the low voltage lines and/or communication lines installed near the high-voltage lines, taking appropriate measures including Article 28 of these SREPTS.

Article 39: Surge Arresters

1. Generals

Surge arresters shall be installed at the appropriate places on electrical lines.

2. Installation of surge arresters

2.1 Installation Points for Surge Arresters

In high-voltage and medium-voltage electrical circuits surge arresters shall be installed at the points listed below or at locations close to such points, in order to prevent damage to be electrical equipment installed in electrical circuits in the power stations, substations and switching stations and high-voltage and medium-voltage users' sites, by over-voltage.

However, the same shall not apply in cases where there is no risk of damage to such electrical equipment.

- a. Receiving and outgoing points on overhead electrical lines in the power stations, substations and switching stations;
- b. Receiving points on the high-voltage and medium-voltage users' sites to which power is supplied from high-voltage and medium voltage overhead electrical lines;
- c. Locations where there is a risk that the protective effects of surge arresters installed in accordance with the above provisions may not be achieved.

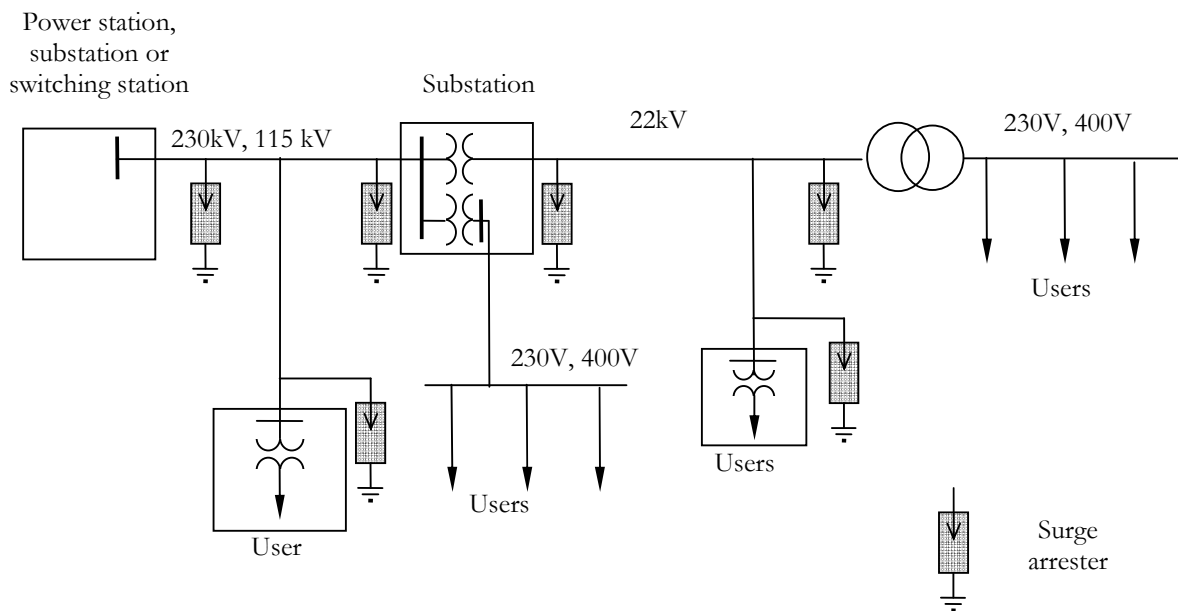


Figure 11: Installation Points for Surge Arresters

2.2 Grounding of Surge Arresters

Grounding of surge arresters shall be installed in accordance with Article 22 and 23 of these SREPTS.

The grounding resistance provided for surge arresters in high-voltage and medium-voltage electrical circuits in power stations, substations, switching stations and high-voltage and medium-voltage users' sites shall be as much lower than $10\ \Omega$ as possible in order to prevent hinder to the functions of the surge arrester.

CHAPTER 4

**MEDIUM AND LOW-VOLTAGE
DISTRIBUTION FACILITIES**

Article 40: Supporting Structures

1. Loads on Overhead Distribution Lines

Supporting structures of overhead medium-voltage and low-voltage lines shall be designed taking into account the loads shown in Table 21A.

Table 21A: Kinds of Loads

Type of Load	Contents
Vertical loads	Weight of supporting structures
	Weight of the conductors and the ground wires and the accessories supported by the supporting structure
	Weight of the insulating devices, the crossarms and the distribution equipment supported by the supporting structure
	A vertical component of the maximum tension of the guy wires supporting the supporting structure, if any
Horizontal transverse loads	Wind pressure on the supporting structure under the maximum wind velocity
	Wind pressure on the conductors and the ground wires supported by the supporting structure under the maximum wind velocity
	Wind pressure on the insulator, the crossarms and the distribution equipment supported by the supporting structure under the maximum wind velocity
	A horizontal transverse component of the maximum tension of the conductors and the ground wires supported by the supporting structure and the guy wires supporting the supporting structure, if any
Horizontal longitudinal loads	Wind pressure on the supporting structure under the maximum wind velocity
	A horizontal longitudinal component of the unbalanced maximum tension of the conductors and the ground wires supported by the supporting structure and the maximum tension of the guy wires supporting the supporting structure, if any

By calculating, firstly, the load when wind pressure is applied in a horizontal transverse direction to the distribution line, and secondly, the load when wind pressure is applied in the horizontal longitudinal direction of the distribution line, the one of these two loads which generates greater stress on the structural member shall be adopted for the assumed normal load.

2. Safety Factor of Foundations of Supporting Structures

- The safety factor of the foundations of supporting structures for low-voltage lines shall be 2 or more to the wind pressure.

- The safety factor of the foundations of supporting structures for medium-voltage lines shall be 2 or more to the load prescribed in Table 21A.
- If wooden poles, iron-poles and iron-reinforced concrete poles are installed at other than soft ground in accordance with Table 21B, this article may not be applicable.

Table 21B

	Design load of poles	Length of poles	Setting depth	Span
Wooden pole	----	15m or less	1/6 of overall length or more	Medium-voltage lines in an urban area: Not more than 75m
		More than 15m, and 16m or less	2.5m or more	
Iron pole	----	15m or less	1/6 of overall length or more	Low-voltage lines in an urban area: Not more than 40m
		More than 15m, and 16m or less	2.5m or more	
Iron-reinforced concrete pole	6.5kN or less	15m or less	1/6 of overall length or more	Other: Not more than 150m
		More than 15m, and 16m or less	2.5m or more	
		More than 16m, and 20m or less	2.8m or more	

3. Strength of Iron-reinforced Concrete Pole

- Iron-reinforced concrete poles for low-voltage lines shall have the strength to withstand wind pressure.
- Iron-reinforced concrete pole for medium-voltage lines shall have the strength to withstand the load prescribed in Article 31 of these SREPTS.
- Iron-reinforced concrete pole shall have the strength to withstand two times of the design load.

4. Safety Factor of conductors and supporting structures

4.1 Conductor

A safety factor of 2.5 or more shall be applied to the tensile strength (ultimate tensile strength; breaking strength) of overhead distribution conductors and overhead ground wires.

4.2 Supporting Structure

- (1) Supporting structures for overhead low-voltage lines shall have the strength to withstand a load of 1.2 times the wind pressure for wooden poles, and a load equal to the wind pressure for others.
- (2) Wooden poles to be used as the supporting structures for overhead medium-voltage lines shall be installed in accordance with the following items:
 - a. The safety factor against a wind pressure shall be 1.5 or more; and
 - b. The thickness shall be not less than 12 cm in diameter at the top end.
- (3) Iron-reinforced concrete poles and iron poles to be used as supporting structures for overhead medium-voltage lines shall have the strength to withstand the assumed normal load.

5. Reference Wind Velocity

Reference wind velocity used in the calculation of wind loads on overhead distribution lines shall be as follows:

Table 21C: Reference Wind Velocity

Yearly maximum of 10-minute average wind velocity (50 year return period)	32m/sec
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In the following circumstances, the above reference wind velocity shall be changed:

- a. When sufficient observed wind velocity data have been accumulated.
- b. When greater reliability is particularly needed.
- c. When a terrain has the effect to decrease the wind velocity.

6. Reinforcement for Supporting Structures by Guys

Supporting structures shall be guyed to share strength with the guys according to Table 21D. In such case, the strength of the supporting structure itself shall be such that it bears at least half of the wind load.

6.1 Installation and Safety Factor of Guys

- a. Installation of Guys

Guys shall be installed in order to reinforce the foundation of a supporting structure if the calculated result of the safety factor of supporting structure's foundation is less than 2.0 under the following conditions.

Table 21D: Conditions of Installation of Guys

Conditions	Installation method	Safety factor of the guy
a. Supporting structures lacking strength against wind pressure	Guys that withstand wind pressure shall be installed at right angle to the lines.	2.5 or more
b. Supporting structure of which spans on both sides are too different	Guys that withstand the force caused by unbalanced tension shall be installed on both sides in the direction of the line.	1.5 or more
c. Supporting structure of which lines on both sides make an angle of more than 5 degrees	Guys that withstand the force caused by the assumed maximum tension of each line shall be installed at the opposite side of the line.	1.5 or more
d. Supporting structure which supports the end of a line	Guys that withstand the assumed maximum tension of the line shall be installed at the opposite side of the line.	

b. Section near the Ground of the Guy

For the section near the ground, that is, from the underground portion of the guy to 30cm above the ground, a galvanized iron rod or similar rod equal or superior to it in strength and corrosion resistance shall be used.

c. Foundation of the Guy

The guy anchor shall be installed firmly so that it can adequately bear the tensile load from the guy. A guy anchor installed with a supporting structure shall be of such a material that it hardly corrodes.

d. Globe Insulator

If a guy is installed on an overhead distribution line that is in danger of touching an electrical conductor, a globe insulator shall be inserted in the upper part of the guy.

A globe insulator, however, need not be inserted if the guy is installed on a low-voltage overhead distribution line in a place other than a rice field or other swamp area.

e. Height of Guy

A guy crossing a road shall have a height of not less than 6.5 m from the road surface. If this is impossible for technical reasons, a height of not less than 4.5m (not less than 2.5m, if a sidewalk) is allowed if there is no danger of interfering with traffic.

f. Strut

A strut that has equivalent or higher effect than a guy can be substituted for a guy.

Article 41: Overhead Medium-voltage and Low-voltage Lines

1. Cables for Overhead Lines

- a. When cables are used for overhead lines, the cables shall be installed using messenger wires or other appropriate measures so that they bear no tensile strength. The messenger wires shall be installed in accordance with the provision of Article 32 of these SREPTS.
- b. When cables are installed along a building or another object, the cables shall be supported so that they are not damaged by contacting the building or the object.

2. Connecting Methods of Overhead Conductors

The tensile strength of the conductors shall not be reduced by 20% or more, when electric conductors are connected. If the tension on the conductors is distinctly less than the general tensile strength of conductors, this may not apply.

3. Branching of Overhead Lines

Branching of overhead lines shall be made at the supporting point of the lines. If branching can be done in a way that does not to inflict tension on the conductor at the branch point, this may not be applicable.

Article 42: Mechanical Strength of Insulators

1. Generals of Mechanical Strength of Insulators

The insulator to support medium-voltage lines shall be installed in such a manner that it has sufficient strength to attain the safety factor of at least 2.5 based on the assumption that the following loads are exerted on the insulators.

- a. For the insulators to anchor lines, the load is the assumed maximum tension of the lines.
- b. For the insulators to support lines, the load is the horizontal lateral load or vertical load exerted perpendicular to the axis of the insulators.

2. Safety factor of Insulators

The safety factor of insulators for medium-voltage lines shall be calculated using the following equations.

- a. Tension insulator (Insulator that anchors electrical conductors)

$$[\text{Safety factor}] = \frac{[\text{Tensile break strength}]}{[\text{Assumed maximum tension of the lines}]}$$

- b. Supporting insulator

$$[\text{Safety factor}] = \frac{[\text{Tensile break strength}]}{[\text{Horizontal transverse load or vertical load applied perpendicular to the axis of the insulator device}]}$$

3. Assumed Load

The assumed loads to be used for calculating the strength of insulator for medium-voltage lines shall conform to the following requirements.

- a. Vertical load

The vertical load shall be the sum of the weight of electrical conductors and the weight of insulator devices.

- b. Horizontal transverse load

The horizontal transverse load shall be the sum of the wind pressure loads of electrical conductors and insulator devices and the horizontal component of a load generated by the assumed maximum tension of the electrical conductors. The wind pressure loads shall be calculated based on the values listed in Table 22.

Table 22: Wind Pressure Loads

Segment of an object receiving wind pressure	Wind pressure to 1m ² of the vertical projected area (Pa)
Electrical conductor and other strung conductor	680
Insulation device	900

*The wind pressures are obtained from 32m/s wind velocity as same as Table 21C.

4. Assumed Maximum Tension of the Lines

The assumed maximum tension of the lines shall be the tension of the medium-voltage line conductor under the composite load of:

- a. The load generated by the weight of the electrical conductor, and
- b. The horizontal load generated by the horizontal wind pressure stipulated in Table 22.

Article 43: Medium-voltage/Low-voltage (MV/LV) Transformers

MV/LV transformers, including medium-voltage conductors other than cables, shall be installed so that they are not in danger of electrical shock using either of the following methods.

1. MV/LV transformers shall be installed in an exclusive cabin that is locked.
2. MV/LV transformers shall be installed at a height of not less than 5.0m above the ground in order that persons can not touch them easily.
3. Appropriate fences shall be installed around the MV/LV transformers in order that persons can not touch them easily and warning signs to indicate the danger shall be displayed. Otherwise MV/LV transformers, the charged parts of which are not exposed shall be installed so that persons can not touch them easily.

Article 44: Installation of Distribution Transformers for Single Wire Earth Return (SWER) Systems

1. Grounding Arrangement for SWER

Grounding on the primary side of distribution transformers for SWER shall be installed by the following methods, in order to avoid risk of danger to persons, domestic animals and other facilities due to the potential difference between the grounding conductor and the ground caused by load current, when any failure occurs.

- a. The grounding resistance shall be not more than 5ohms.
- b. The cross-sectional areas of grounding conductors shall be not less than 16mm².
- c. The grounding conductors placed up to a depth of 75cm underground or up to a height of 2.0 m above ground shall be covered by a synthetic resin pipe or another shield of equivalent or higher insulating effect and strength.
- d. The grounding for SWER installed on the primary side of a distribution transformer and the Class B grounding for it shall be completely separated to keep the safety of low voltage line system.

2. Load Current of Distribution Transformers

The load current in any earth-return circuits shall be not more than 8 amperes.

3. Isolating Transformer

SWER circuits shall be supplied from double-wound transformers (isolating transformers).

4. Safety of Third Persons

Warning signs to alert third persons' attention shall be installed near the grounding point.

Article 45: Protective Devices

1. Installation of Medium-Voltage Over-current Circuit Breakers

- a. On medium-voltage lines, an over current circuit breaker shall be installed at the outgoing point of a substation or similar location and on the primary side of a transformer.
- b. Over current breakers for short circuit protection shall have the ability to break the short circuit current that passes the breakers.

2. Installation of Medium-Voltage Ground Fault Circuit Breakers

A ground fault breaker that breaks circuit automatically when an earth fault happens in the lines shall be installed at an outgoing point of substation or similar locations.

3. Installation of Surge Arresters

To prevent electrical equipment from being damaged by lightning, surge arresters shall be installed at the places of lines stated below or their surrounding areas. If electric power facilities are not damaged by lightning, this may not be applicable.

- a. A lead-out of overhead line from power station, substation, and equivalent places.
- b. The connecting point of overhead medium-voltage lines with a main transformer.

4. Exceptions to Installation of an Over Current Breaker for Medium-voltage and Low-voltage Lines

No over current circuit breaker shall be installed at the following places:

- a. Grounding conductor of grounding work.
- b. Neutral conductor of an electrical conductor. An over-current circuit breaker, however, may be installed if all the poles are shut off simultaneously.
- c. Grounding conductor of a low-voltage overhead electrical conductor whose circuit is provided with class B grounding work in part.

Article 46: Height of Overhead Medium-voltage and Low-voltage Lines

1. Regulations for Medium and Low-voltage Overhead Distribution Conductors

The height of medium and low-voltage overhead lines shall be no less than the values in the following table:

Table 23: Height of Medium and Low-Voltage Overhead Lines

(Unit: meter)

	Low-voltage	Medium-voltage		
		Urban area		Other area
		Cable	Others	
Crossing a road	6.5	8.0	8.0	6.5
Others	5.5	5.5	6.5	5.5

2. Urban Areas to be Included

The following areas shall be included in the urban area.

- a. Area
 - Phnom Penh city and other cities
 - Provincial towns
- b. Road
 - The National Road
 - The Provincial Roads

3. Exclusions for Road Crossings

The conductor is not regarded as crossing a road in the followings:

- The road is so narrow that cars can not pass through it.
- The road is on private land.

4. Mitigation of Height for Low-voltage Conductors

The minimum height of the low-voltage conductor is mitigated up to 4.0 m on the place other than a road. Furthermore, the minimum height of the low-voltage conductor is mitigated up to 3.0 m on the following conditions:

- The licensee owning the distribution line is a small licensee in the area other than urban areas;
- The insulation of the conductor(s) must be always kept in good condition;
- Vehicles including carts never pass under the line.

Article 47: Clearance between Overhead Medium-voltage and Low-voltage Lines and Other Objects

1. Clearance between Overhead Lines and Buildings/Plants

The minimum clearance between a line and another object shall be the values shown in the Table 24A.

Table 24A: Clearance between Overhead Lines and Other Objects

(Unit: meter)

				Low-voltage	Medium-voltage	
Structures of buildings	Up side proximity	With the possibility for persons to climb on	Bare conductor	-	3.0	
			Insulated conductor	2.0	2.5	
			Cable	1.0	1.2	
		Others	Bare conductor	-	3.0	
			Insulated conductor	1.2	1.5	
			Cable	0.4	0.5	
	Lateral and downside proximity			Bare conductor	-	3.0
				Insulated conductor	1.2	1.5
				Cable	0.4	0.5
Plants			Bare conductor	-	2.0	
			Insulated conductor	Shall not contact directly		
			Cable	Shall not contact directly		

Low-voltage cable including ABC (Aerial Bundle Conductor) type cable may be installed directly on a wall of a building by using a clip and clamp in such a way that in normal circumstances a person cannot reach the cable.

2. Clearance between Overhead Distribution Lines and a Road

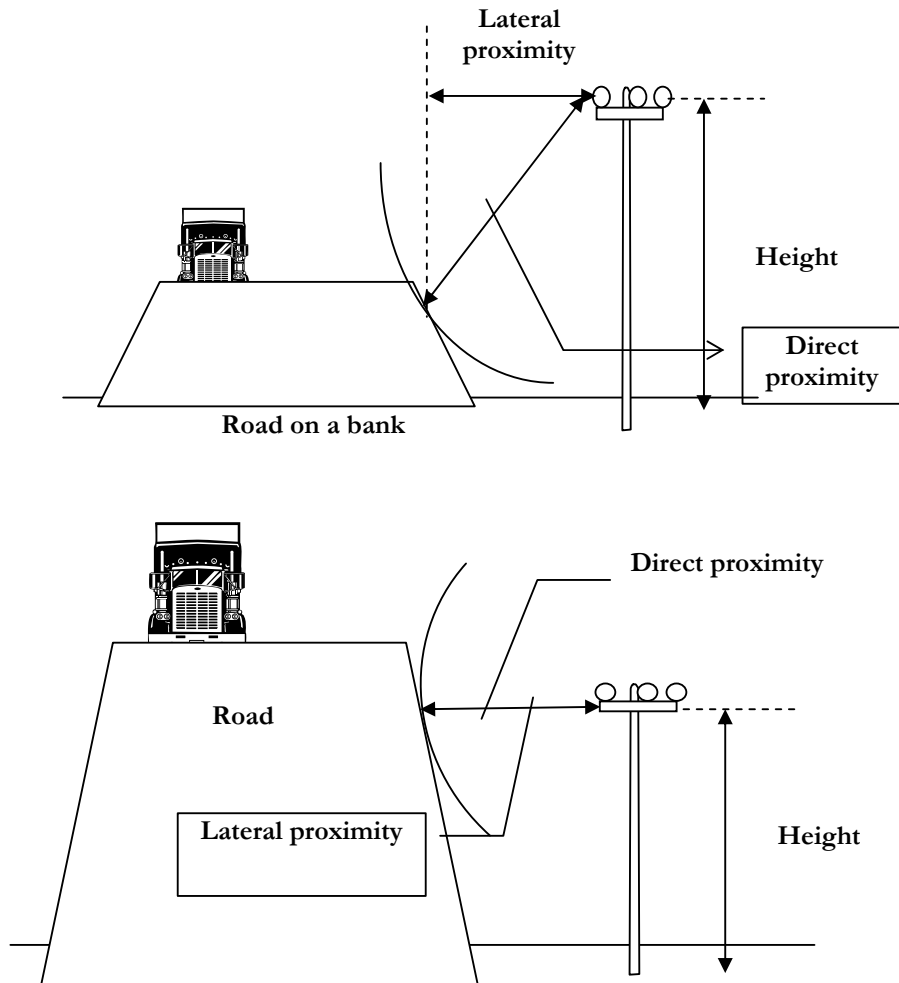
When a supporting structure is installed below a road, the minimum clearance between a line and a road shall be the values shown in Tables 24B and 24C.

Table 24B: Clearance between a Line and a Road on a Bank

(Unit: m)

Direct proximity	Type of wire	Low-voltage	Medium-voltage
	Bare conductor	Do not install	3.0
	Insulated conductor	3.0	3.0
	Cable	3.0	3.0
Lateral proximity	Bare conductor	Do not install	3.0
	Insulated conductor	1.0	1.5
	Cable	1.0	1.2

* If the lateral proximity is equal to the direct proximity, the lateral proximity required the same value as the direct adjacency.



* If the lateral proximity is equal to the direct proximity, the lateral proximity required the same value as the direct proximity.

Figure 12: Explanation of Direct Proximity and Lateral Proximity (Road on a Bank)

Table 24C: Minimum Clearance between a Line and an Overpass

(Unit: m)

	Type of wire	Low-voltage	Medium-voltage
Upper access	Bare conductor	Do not install	Direct proximity:3.0
	Insulated conductor	Direct proximity:3.0 or Lateral proximity:1.0	Direct proximity:3.0 or Lateral proximity:1.5
	Cable	Direct proximity:3.0 or Lateral proximity:1.0	Direct proximity:3.0 or Lateral proximity:1.2
Lower access	Bare conductor	Do not install	Lateral proximity:3.0
	Insulated conductor	Direct proximity:0.6	Direct proximity:1.5
	Cable	Direct proximity:0.3	Direct proximity:0.5

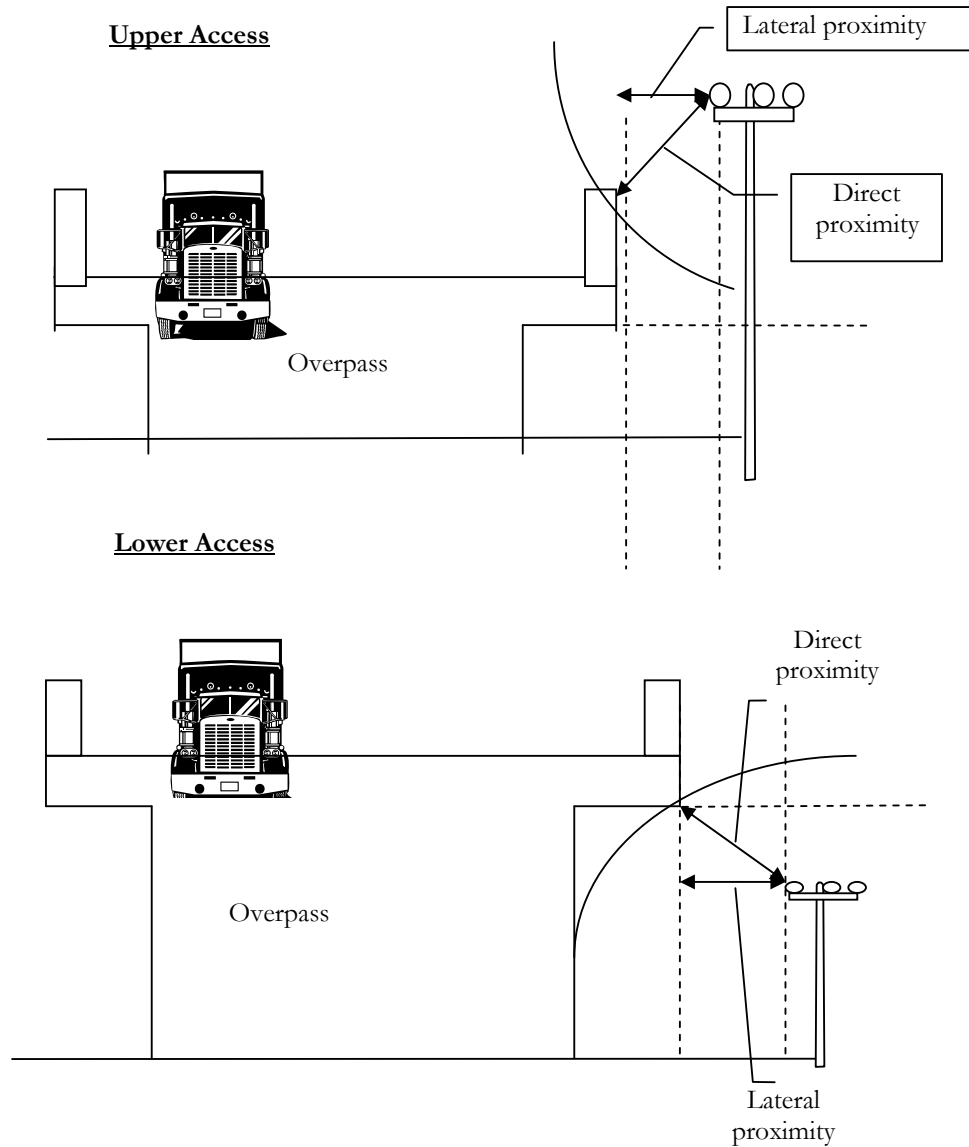


Figure 13: Explanation of Direct Proximity and Lateral Proximity (Overpass)

Article 48: Proximity and Crossing of Overhead Medium-voltage and Low-voltage Lines

1. Multiple Medium-voltage Line

When a medium-voltage line is installed adjoining or crossing other medium-voltage lines, the clearance between the two medium-voltage lines shall be not less than 2.0m. If one is a cable and the other is a cable or an insulated conductor, the clearance shall be not less than 0.5m.

Above requirements shall be also applied, when two or more medium-voltage lines are installed at the same supporting structure.

2. Medium-voltage Lines and Low-Voltage Lines

When a medium-voltage line and a low-voltage line are installed so that they adjoin or cross each other, they shall be installed in the following manners.

- The medium-voltage line shall not be installed under the low-voltage lines. If the medium-voltage line maintains a horizontal clearance of not less than 3.0m from the low-voltage line, and the low-voltage line does not come in contact with the medium-voltage line when the support structure of the low-voltage line collapses, this may not be applicable.
- The clearance between the medium-voltage line and the low-voltage line shall be not less than 0.5m when the medium-voltage line is a cable, not less than 1.0m when it is an insulated conductor, and not less than 2.0m when it is a bare conductor.
- The medium-voltage line shall not cross under the low-voltage line. If the medium-voltage line is a cable and the clearance between the medium-voltage line and the low-voltage line is not less than 0.5m, this may not be applicable.

3. Multiple Low voltage Lines

When a low-voltage line is installed adjoining or crossing other low-voltage lines, the clearance between the two low-voltage lines shall be not less than 0.6m. When one is a cable and the other is a cable or an insulated conductor, the clearance shall be not less than 0.3m.

Above requirements shall be also applied, when two or more low-voltage lines are installed at the same supporting structure.

4. Medium-voltage Lines and Communication Lines

When a medium-voltage line is installed adjoining or crossing a communication line, the medium-voltage line shall be installed in the following manners.

- The medium-voltage line shall not be installed under the communication line. If the medium-voltage line maintains a horizontal clearance of not less than 3.0m from the communication line, and the communication line does not come in contact with the medium-voltage line when the support structure of the communication line collapses, this may not be applicable.

- The clearance between the medium-voltage line and the communication line shall be not less than 0.5m when the medium-voltage is a cable, not less than 1.0m when it is an insulated conductor, and not less than 2.0m when it is a bare conductor.
- The medium-voltage line shall not cross under the communication line. If the medium-voltage line is a cable and the clearance between the medium-voltage line and the communication line is not less than 0.5m, this may not be applicable.

5. Low-voltage Lines and Communication Lines

When a low-voltage line is installed adjoining or crossing a communication line, the low-voltage line shall be installed in the following manners.

- The low-voltage line shall not cross under the communication line. If other methods are not technically realistic, this may not be applicable.
- The clearance between the low-voltage line and the communication line shall be not less than 0.3m when the low-voltage line is a cable, and not less than 0.6m when conductor is insulated.

Specific Requirements for Thermal Power Generating Facilities

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Specific Requirements for Thermal Power Generating Facilities

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CHAPTER 1

Introduction

CHAPTER 1

Introduction

Article 1: Definitions

In this Specific Requirements of Electric Power Technical Standards, unless the context otherwise requires, the following terms shall have the meanings assigned to each term:

1. EAC

“EAC” is the acronym for the Electricity Authority of Cambodia.

2. Electrical Line

“Electrical Line” means the part of electric power facilities used to transmit or supply electricity, which connects power stations, substations, switching stations and user’s sites, and includes lines and associated protective devices and switchgears.

3. Electric Power Facility

“Electric Power Facility” means generating facilities, substations, switching stations, electrical lines, and dispatching centers, including equipment, buildings, dam, waterways, fuel storage yards, ash disposal areas, etc.

4. Electrical Equipment

“Electrical Equipment” means electrically-charged facilities.

5. GREPTS

“GREPTS” is the acronym for the General Requirements of Electric Power Technical Standards of the Kingdom of Cambodia.

6. IEC

“IEC” is the acronym for the International Electrotechnical Commission.

7. ISO

“ISO” is acronym of International Organization for Standardization.

8. Licensee

“Licensee” means an electric power service provider who has been issued a license by the EAC.

9. SREPTS

“SREPTS” is the acronym for the Specific Requirements of Electric Power Technical Standards of the Kingdom of Cambodia.

10. The Technical Standards

“The Technical Standards” means The Electric Power Technical Standards in the Kingdom of Cambodia.

Article 2: Purpose

This Specific Requirements of Electric Power Technical Standards for Thermal Power Generating Facilities prescribes the basic requirements necessary to regulate the existing and the planned thermal power generating facilities in the Kingdom of Cambodia. The requirements in this standard document are mainly for facility security and safety operation of the most important parts for thermal generating facilities.

Article 3: Area of Application

All thermal power generating facilities in the Kingdom of Cambodia shall be in accordance with the requirements prescribed in this Technical Standard.

All persons including licensees, consultants, contractors and consumers who are related to the study, design, construction and operation of thermal power generating facilities shall follow this Specific Requirements of Electric Power Technical Standards for Thermal Power Generating Facilities.

Article 4: Applicable Standards

Thermal Power Generating Facilities planned to construct and operate in the Kingdom of Cambodia shall be as per the provision of this Technical Standards. In case a matter is not stipulated in the Technical Standards, IEC Standards shall be applied. If it is not covered in the IEC standards, ISO Standards shall be applied. If it is not covered in the ISO Standards, internationally recognized standards shall be applied, subject to the approval by MIME.

Article 5: Facilities regulated in this Specific Requirements

A thermal power plant consists of three main components, a turbine/engine, a generator and a substation. This Specific Requirements provides the requirements to regulate the generating facilities such as turbine/engine and its accessories, and the generator including control systems, except the substation.

The requirements for the substation shall be in accordance with the Specific Requirements of Electric Power Technical Standards for Transmission and Distribution.

Thermal power generating facilities regulated in this Specific Requirements of Electric Power Technical Standards for Thermal Power Generating Facilities are following:

- 1- Steam Turbine Generating Facility
- 2- Gas Turbine Generating Facility
- 3- Internal Combustion Engine
- 4-Generator

CHAPTER 2

Requirements for all types of Thermal Generating Facility

CHAPTER 2

Requirements for all types of Thermal Generating Facility

Article 6: Prevention of Electric Power Disasters from the Facility

The facilities shall be installed in such a manner that does not cause electrical shock, fire and other accidents.

The power facilities shall be installed with proper measures to protect operators from touching their moving parts, hot parts and other dangerous parts, and to prevent them from falling accidentally.

Article 7: Safety of Third Persons

Appropriate measures shall be taken to prevent third persons from entering compounds containing a power plant. These measures shall include:

- a. External fences or walls separated outside from inside compound. The height of external fences or walls shall not be lower than 1,800 mm. Boundary clearance from the fences or the walls to the electrical equipment shall not be less than the values described in the following table:

Table 1: Boundary Clearance from Walls or Fences to Electrical Equipment

Nominal voltage [kV]	A : Height of a wall or a fence [mm]	Boundary clearance [mm]	
		B : Wall	C : Fence
(22)	not less than 1,800	not less than 2,100	not less than 2,600
115	not less than 1,800	not less than 2,100	not less than 2,600
230	not less than 1,800	not less than 2,900	not less than 3,400

- b. Signs to alert third persons to danger to be installed at the entrances/exits. Moreover, where necessary, signs shall also be displayed on walls and fences.
- c. Locking devices or other appropriate devices to be installed at the entrances / exits.

Article 8: Requirements related to the Fuel

1. Requirements related to Fuel Handling

- a. Fuel handling shall be in accordance with the related laws.
- b. Maintenance and safety checks of fuel facilities shall be implemented every day.
- c. A responsible person for fuel facilities shall be designated.
- d. The responsible person shall receive education and training regarding fuel handling every year.

2. Requirements related to Fuel Storage

- a. Fuel storage tanks and fuel storage yards shall be in accordance with the related laws.
- b. An appropriate vessel shall be used for the storage tank.
- c. The storage yard shall be kept clean and appropriate signs shall be indicated in front of the storage tank.
- d. Necessary fire extinguishers or fire fighting systems shall be installed around the fuel storage area.

3. Requirements related to Fuel Transportation

- a. Specifications of fuel transportation facilities or vehicles shall be in accordance with the related laws.
- b. Working areas for fuel unloading shall be kept clean and appropriate lighting systems shall be installed around the working area.
- c. Working procedures for fuel transportation shall be prepared and be followed by the persons concerned.

Article 9: Requirements related to the Handling of Chemical Materials

Handling of chemical materials at power plants shall follow the provisions of environment law and regulations of the Kingdom of Cambodia.

Taking the characteristics of chemical materials to be used into consideration, appropriate measures against those chemical materials shall be implemented and tools to protect against potential danger shall be installed.

Article 10: Requirements related to the Natural Disasters

Proper measures shall be taken to prevent failures of electric power facilities from anticipated natural disasters such as floods, lightning, earthquakes and strong winds

Article 11: Requirements related to the Operation of Generating Facilities with Power System

When any generating facility has a serious fault, this facility shall be disconnected from the power system so that the effect of the fault on the system can be minimized and the system could be operated continuously.

When a power system fault occurs in a system connected to a generating facility, the generating facility shall be immediately disconnected from the system, so that the generator runs continuously with no-load while waiting for the recovery of the system from fault. The next action shall be in accordance with procedures of Grid Code and/or Distribution Code of the system.

Article 12 : Requirements related to the Environment

1. Compliance with Environmental Standards

To prevent environmental pollution, the electric power facilities shall be constructed in accordance with the environmental laws and regulations of the Kingdom of Cambodia.

2. Prohibition of Installation of Electrical Machines or Equipment Containing Polychlorinated Biphenyls (PCBs)

- a. The installation of new electrical equipment using insulating oil that contains greater than 0.005 percent (50ppm) polychlorinated biphenyls (PCBs) shall be prohibited.
- b. The use of existing electrical equipment using material containing PCBs, if it was installed before the Specific Requirements of Electric Power Technical Standards came into force, and effective and sufficient measures shall be taken in order to prevent the material containing PCBs from escaping from the oil container, shall be permitted.
- c. Once removed from the electrical equipment, the material containing PCBs greater than 0.005 percent (50ppm) PCBs shall not be reinstalled in another electrical facility and shall be safely scrapped as noxious industrial wastes.

Article 13: The Life of Electric Power Facilities

Electric power facilities shall be durable for long term usage with efficient and stable operation.

Article 14: Requirements related to the Design of Electric Power Facilities

With regard to the design of electric power facilities, selection of the materials, assembling and installation of the equipment, suitable safety factors against foreseeable stresses, such as thermal stress, mechanical stress and insulation strength shall be considered.

1. Insulation Co-ordination

Taking everything into consideration technically, economically and operationally, the insulation strength of electrical equipment in the power plant shall be coordinated with the insulation of electrical equipment in substations, transmission lines and distribution lines so that it may be in the most rational conditions.

2. Dielectric Strength of Electrical Circuits

The dielectric strength of electrical circuits in the power plant shall be examined by dielectric strength test, insulation resistance measurement and so on, to ensure that their performance corresponds to their nominal voltage.

Moreover, before starting operation, the dielectric strength shall be confirmed by charging nominal-voltage to the circuit continuously for 10 minutes.

However, if the nominal voltage of the electrical circuit is low-voltage, it can be tested by insulation resistance measurement or leakage current measurement. In case of the leakage measurement, it is sufficient to keep 1mA or less.

3. Mechanical Strength of Electrical Equipment against Short-circuit Current

All electrical equipment to be installed in the power plant shall be able to withstand the mechanical shock caused by short-circuit current.

4. Thermal Strength of Electrical Equipment

Electrical equipment to be installed in the power plant shall be able to withstand the heat generated by electrical equipment in normal operations.

5. Prevention of Damage of Pressure Tanks

Gas insulated equipment placed in the power plant shall be designed as following in order to avoid any risk of damage:

- a. Materials and structure of the parts receiving pressure shall be able to withstand the maximum operating pressure and shall also be safe.
- b. Parts receiving pressure shall be corrosion-resistant.
- c. Insulation gas shall not be inflammable, corrosive or hazardous.
- d. Tanks shall withstand the gas pressure rising during fault continuous time at internal failure of gas insulated equipment.

Article 15: Requirements related to the Technical Document of Electric Power Facilities

To secure long term operation, each facility shall have its drawings, installation records, technical manuals, instruction manuals and operation records necessary for its proper maintenance works. These documents shall be safekept well.

Article 16: Requirements related to the Grounding

Grounding or other appropriate measures shall be provided for electrical equipment of thermal generating facilities to prevent electrical shock, danger to human beings, fire, and other trouble to objects.

Grounding for electrical equipment shall be installed to ensure that current can safely and securely flow to the ground. This grounding shall be in accordance with the types, the method and the resistance value of grounding of each equipment provided in the Specific Requirements of Technical Standard for Transmission and Distribution.

CHAPTER 3

Requirements for Steam Turbine Generating Facility

CHAPTER 3

Requirements for Steam Turbine Generating Facility

Article 17: Steam Turbine Generating Facility

A steam turbine generating facility is a facility which generates electric power from the rotation of steam turbine which rotates by the power of pressurized steam spouted out from the boiler. Two main components of the steam turbine generating facility are the boiler and the steam turbine.

A boiler is a closed vessel in which water is heated under pressure. Then the steam from the boiler is used for turbine rotation and preheating feed water.

A steam turbine is a mechanical device that can extract thermal energy from pressurized steam, which is supplied from a boiler, and converts it into useful mechanical work to rotate the turbine. The steam turbine consists of a rotor supported on bearings and enclosed in a cylindrical casing. The rotor is turned by steam, which expands through nozzles and spouts out at a high speed against the moving blades to turn the impellers.

PART 1

Boiler

Article 18: Requirements for Materials of Boiler and its Accessories

Vessels and tubes of the boiler, independent superheater and steam storage vessel and its accessories, and the parts which are subject to an internal pressure higher than 0MPa (hereinafter, referred to as pressure parts) shall be made of materials having sufficient mechanical strength and chemical stability under the maximum working pressure and temperature.

“Sufficient mechanical strength” shall mean having good weldability, tensile strength, ductility, toughness, hardness and other mechanical properties.

“Sufficient chemical stability” shall mean having character like good corrosion resistance, good heating resistance and other chemical properties.

Article 19: Requirements for Structure of Boiler and its Accessories

1. Safety margins against the maximum stress

Structure of pressure parts of the vessels and tubes of the boiler shall have adequate safety margins against the maximum stress under maximum working pressure or temperature condition. In this case, to prevent the danger the stress shall keep the level not exceeding the allowable stress of the material. The allowable tensile stress for each material shall be determined in accordance with its material temperature condition.

To ensure adequate safety margins against the maximum stress, the structure of pressure parts of the boiler and its accessories shall be able to withstand a water pressure test with a water pressure 1.5 times as high as their respective maximum allowable working pressures without the occurrence of leakage.

The design pressure of economizers shall be not less than the maximum working pressure of the economizer determined based on the maximum working pressure of the feed pump.

2. Prevention against Overheat

To prevent overheat of the water tubes in the furnace the following conditions shall be provided:

- a. Boiler water shall be sufficiently circulated to the water tubes.
- b. Boiler water shall be sufficiently purified. For this, proper measures such as a water softener, a demineralizer, etc. shall be provided.

3. Protections against Flame

In case part of the boiler drum and tube heater are so constructed that they are exposed to flames or high temperature gas, proper thermal protection, such as installation of a heat resisting tube material and/or installation of a heat protection, or other suitable means shall be provided.

4. Considerations for Structural Strength

Where the effects of additional stresses such as spot concentration stress, repeated loads and thermal stress are significant, suitable measurements such as increasing thickness shall be taken if necessary.

Article 20: Safety Valve for Vessels and Tubes of the Boiler

Vessels and tubes of the boiler which may be subjected to overpressure shall be equipped with safety valves in order to release the pressure. In case of overpressure such as when the steam pressure of the boiler goes up beyond regulation limits, safety valves shall be operated to release the pressure in order to prevent danger.

The safety valves for the boiler and its accessories shall have the following conditions:

- a. The safety valves shall be installed in position that can be easily inspected.
- b. At least, one safety valve shall be installed on the drum and one on the super-heater outlet.
- c. The total capacity of the safety valves shall be not smaller than the maximum designed steam capacity of the boiler.
- d. At least one set pressure of the safety valves shall be not higher than the maximum allowable pressure of any parts of the boiler (including superheaters and reheaters).
- e. The safety valves shall be spring loaded safety valves or safety valves with a spring loaded pilot valve.

Article 21: Feed Water System of Boiler

A feed water system is the system of equipment for feeding water to a boiler. The requirements for the feed water system for boiler are the following:

- The feed water system shall be able to prevent thermal damage to the boiler during the maximum evaporating condition.
- In order to prevent the thermal damage to the boiler caused by the feed water system's trouble, the feed water system of the boiler shall be equipped with two or more means of water supply equipment.
- The feed water system shall be able to independently supply a quantity of water not less than the maximum designed steaming capacity of the boiler at any time and independently.

Article 22: Water Feeding and Steam Outpouring of Boiler

Water feeding and steam outpouring of boiler shall be required as follows:

- The steam outlet of the boiler shall be able to shut off the steam;
- The feed water inlet of the boiler shall be able to automatically and firmly shut off;
- A circulation boiler shall be equipped with a drain-off device which protects deposit and regulates the water level.

Article 23: Monitoring the Running Condition of Boiler and Safety and Alarm System

The boiler and its accessories shall be equipped with the systems to monitor the running condition and the alarm systems to prevent from the damage to the boiler and its accessories. The monitoring and alarm systems as described above shall be equipped with devices as defining below:

1. For monitoring Circulation Boilers

- a. Water level indicator in the boiler drum
- b. Pressure indicator in the boiler drum
- c. Temperature indicator at superheater and reheater outlet steam

2. For monitoring Once-through Boilers

- a. Pressure indicator at superheater outlet steam
- b. Temperature indicator at superheater and reheater outlet steam

3. For Safety and Alarm

The boiler shall be fitted with safety devices, which are capable of shutting off automatically the fuel supply to all burners, and alarm devices which are capable to alarm when:

- a. The flame vanishes
- b. The water level falls (for circulation boiler drums)
- c. The combustion air supply stops

4. For monitoring Boiler Water

The boilers shall be provided with means such as a water analyzer or other suitable devices to supervise and control the quality of the feed water and boiler water.

* All above monitoring devices shall be installed in position that allows easy observation.

PART 2

Steam Turbine

Article 24: Requirements for Materials of Steam Turbine and its Accessories

Cylinders, vessels and tubes of the steam turbine and its accessories, and the pressure parts shall be made of materials having sufficient mechanical strength such as good weldability, tensile strength, ductility, toughness, hardness, and other mechanical properties and chemical stability such as having character like corrosion resistance, abrasion resistance and other chemical properties under the maximum working pressure and temperature.

Article 25: Mechanical Strength of Structure of Steam Turbine and its Accessories

Structure of steam turbines shall have sufficient mechanical strength such as having good weldability, tensile strength, ductility, toughness, hardness and other mechanical properties, even when they are operated at the speed, that the steam turbine reaches when the emergency governor is actuated. "Speed that the steam turbine reaches when the emergency governor is actuated" shall include not only the actuated point of the emergency governor but also the accelerated speed from the actuated point.

Structure of steam turbines shall have sufficient mechanical strength against the maximum amplitude value of vibration produced on the major bearings and shafts. "Maximum amplitude value of vibration" shall mean the maximum vibration reached during turbine operation including turbine start and stop operation.

The pressure parts and its accessories of the steam turbine shall have a sufficient safety margin against the maximum stress under the maximum working pressure and shall not exceed the allowable stress of the material.

A steam turbine and its accessories which are likely to be subjected to overpressure shall be equipped with an overpressure protection device in order to release the pressure.

Article 26: Bearings of Steam Turbine

Bearings of steam turbines shall be constructed to be able to stably support the load during operation and without the occurrence of abnormal wear and deformation and overheat. To prevent the bearings from "its abnormal wear and deformation and overheat" the following measures shall be provided:

- a. Steam turbines shall be equipped with main lubricating oil feed pumps, auxiliary oil pumps and an emergency oil pump.
- b. Quantity of lubricating oil for steam turbines shall be sufficient in all times.
- c. Auxiliary oil pumps shall start automatically when the main oil pump out-put pressure becomes abnormally low

- d. An emergency oil pump or manual operation auxiliary oil pumps, which are installed for safety stop of the main turbine when the main and/or auxiliary oil pumps have broken down.
- e. The lubricating oil tank shall have necessary lubricating oil for the turbine.
- f. Devices to clean lubricating oil shall be equipped
- g. Device to control temperature of lubricating oil shall be equipped.

Article 27: Governance of Turbine Speed

1. Speed Governor

A steam turbine shall be equipped with a system capable to adjust automatically the steam entering the steam turbine in accordance with the actual speed of the turbine in order to prevent its speed and output from fluctuating continuously even in case of a change in load condition. This system is called speed governor. The speed governor consists of a speed monitoring device used for monitoring the actual speed of steam turbine and then providing the order to a steam adjusting valve to adjust the quantity of steam flow entering the steam turbine for the purpose to maintain speed of the turbine at the constant level. This speed governor shall regulate the turbine speed not to reach the tripping speed even if the rated turbine output is shut down instantaneously.

2. Emergency Speed Governor

In addition to a speed governor, a main turbine shall be equipped with an independent emergency speed governor in order to prevent the speed from being increased abnormally. The emergency speed governor shall be activated to interrupt the flow of steam to the turbine when the speed of turbine reaches the tripping speed. The tripping speed of the turbine shall be at 110% ($\pm 1\%$) of the rated speed.

3. Normal Speed, Over Speed and Critical Speed of Turbine

Normal Speed of a steam turbine is the operational speed of the turbine when it normally loaded and when the governor is in normal operation. The turbine shall be capable to operate at normal speed without any restrictions upon the time and output. This normal speed shall be in between 98 to 101% of the rated speed of the turbine. The normal speed of the turbine shall not be the speed remarkably less or more than the rated speed.

Over-speed is the speed over than the normal speed which could do harm to the turbine.

Critical speed of a turbine is the speed which creates the resonance on the turbine. To avoid the damage of the turbine caused by this resonance, the critical speed of the turbine combined with the generator on the same shaft shall not be in the speed between the minimum speed controlled by the governor and the maximum available speed of emergency stop device. However, it will be exempted if it will be arranged to have enough countermeasure against the vibration at critical speed during operation of the turbine.

“Speed between the minimum speed controlled by the governor and the maximum available speed of the emergency governor” is the speed can be operated by the steam turbine.

4. Limits of Turbine Speed

A turbine shall be capable to maintain the speed within the following limits:

- a. Momentary variations shall be not more than 10% of the maximum rated speed when the rated output of the generator is suddenly thrown off;
- b. At all loads in a range between no load and the rated load, the permanent speed variation shall be within $\pm 5\%$ of the maximum rated speed.

5. Protection against Over-speed

- a. All main and auxiliary turbines (in case of turbine-driven boiler feed pumps) shall be equipped with over-speed protective devices to prevent the turbine speed from being exceeded by more than 10% of the normal speed of turbine.
- b. In addition to the over-speed protective device, the main steam turbine shall be equipped with a device capable to control the speed of the unloaded turbine without activating the over-speed protective device into action.

Article 28: Requirements to Alarm and to Stop the Turbine in Emergency Case

In order to avoid the occurrence of damage from abnormal conditions (emergency case) during steam turbine operation, the steam turbine shall be equipped with two systems: 1-protection system and 2-alarm system.

1. Emergency Protection System or Tripping System

In order to avoid the occurrence of damage from abnormal conditions, a main turbine shall be equipped with a protection system which is capable to automatically shut off the steam supply to the turbine (automatic emergency stop device) in the following cases:

- a. Low lubricating oil pressure
- b. High exhaust steam pressure
- c. Low condenser vacuum
- d. Over-speed
- e. Emergency stop button is locally or remotely operated.

In addition to the automatic emergency stop device, the protection system shall have also a manual emergency stop device.

When the above emergency stop device is actuated, the emergency stop alarm shall be energized.

2. Emergency Alarm System

The steam turbine shall be provided with alarm systems which give visual and audible alarm in the event of abnormal conditions before steam shut off devices are activated. The abnormal conditions of steam turbine operation can be indicated by the level of vibrations of the steam turbine.

When the maximum double amplitude value of vibrations of the major bearings or the shaft close to it is detected to be beyond the allowable level during the turbine operation, the steam turbine operation is considered as in abnormal condition.

The steam turbine shall be equipped with an alarm system, which gives an alarm when the maximum double amplitude of vibrations of the major bearing or the shaft close to it exceeds the value shown in the table below:

Table2: Allowable Level of Maximum Double Amplitude of Vibrations

Measurement point	Rated speed	Allowable level of the maximum double amplitude of vibrations	
		In case of speed less than rated speed	In case of speed not less than rated speed
Bearing pedestal	3000 r/min	0.075 mm	0.062 mm
	1500 r/min	0.105 mm	0.087 mm
Shaft	3000 r/min	0.15 mm	0.125 mm
	1500 r/min	0.21 mm	0.175 mm

3. Reviewing of Emergency Protection and Alarm System

For insuring the safety of steam turbine operation, before commercial operation of steam turbines, Licensee shall submit to EAC for reviewing the following documents related to emergency protection and alarm system:

- a. Turbine protection system diagram
- b. Explanation sheet for alarming and tripping set-points figure

Article 29: Monitoring the Condition of Turbine Operation

A steam turbine and its accessories shall be equipped with systems necessary to monitor the operating condition and necessary alarm system to prevent any damages to the steam turbine and its accessories during the operation.

Monitoring and alarm systems of steam turbines shall be capable to monitor the following data:

- a. Rotational speed of the turbine
- b. Main steam temperature and pressure (before main stop valve position)
- c. Reheated steam temperature and pressure (before reheat stop valve position)
- d. Steam turbine exhaust steam pressure

- e. Lubricating oil inlet pressure of steam turbine bearings
- f. Lubricating oil outlet temperature of steam turbine bearings or bearing metal temperature
- g. Steam flow control valve position
- h. Steam turbine vibration amplitude (with automatic recorder - media record is acceptable.)

Article 30: Reviewing the Safety of Steam Turbine and its Accessories

To ensure the safety of steam turbine operation, Licensees who plan to install a steam turbine in the Kingdom of Cambodia shall submit the drawings and data related to the steam turbine on the items as follows to EAC for reviewing the adoption of the requirements in this standard:

- a. Turbine casings
- b. Turbine rotors
- c. Critical speed of turbine rotor
- d. Technical data for strength calculations specified above
- e. Material specifications of principal components
- f. Assembly drawings
- g. Control system diagram
- h. Drawings and data which are deemed necessary by the Government

CHAPTER 4

Requirements for Gas Turbine Generating Facility

CHAPTER 4

Requirements for Gas Turbine Generating Facility

Article 31: Gas Turbine Generating Facility

A gas turbine generating facility is a facility which generates electric power from the rotation of the gas turbine which rotates by the power of the flow of combustion gas spouted out from the combustor. In the combustor, fuel is mixed with air and ignited, this combustion increases the temperature, velocity and volume of the gas which expands through nozzles and spouts out at a high speed against the moving blades to turn the impellers.

Main components of the gas turbine which are regulated by the requirements in this chapter are the following:

- Turbine itself
- Bearings
- Governor
- Emergency stop and alarm device
- Overpressure protection device
- Monitoring and alarm system

Article 32: Requirements for Materials of Gas Turbine and its Accessories

Principal components of gas turbines which are subject to an internal pressure higher than 0MPa shall be made of materials having enough mechanical strength such as having good weldability, tensile strength, ductility, toughness, hardness and other mechanical properties and chemical stability such as good corrosion resistance, good heating resistance and other chemical properties under the maximum working pressure and temperature.

These principal components of gas turbines are following:

- a. Rotors, stationary blades and moving blades of turbines
- b. Rotors, stationary blades and moving blades of compressors
- c. Turbines and compressor casings
- d. Combustion chambers
- e. Turbine output shafts
- f. Connecting bolts for main components of turbines
- g. Shaft coupling and bolts
- h. Pipes, valves and fittings attached to turbines

The principal components of gas turbines excluding bolts, pipes, valves and fittings shall have been subjected to the non-destructive tests.

The materials used in high temperature parts shall possess properties suitable for the design performance and service life against corruptions, thermal stresses, creeps and relaxations.

In case where the base material coated with corrosion-resistant surfacing, the coating material shall be firmly attached to the base material and shall not impair the strength of the base material.

The mechanical strength of all materials of gas turbines shall be confirmed to be sufficient through strength calculation or other methods.

Article 33: Mechanical Strength of Structure of Gas Turbine and its Accessories

Structure of gas turbines shall have sufficient mechanical strength such as having good weldability, tensile strength, ductility, toughness, hardness and other mechanical properties even when it is operated at the speed that the gas turbine reaches when the emergency speed governor is actuated. Even if the rotational speed of the gas turbine exceeds the rated rotational speed for any reasons and an emergency speed governor is actuated, the turbine shall not be damaged.

Structure of gas turbines shall have sufficient mechanical strength against the maximum amplitude value of vibration produced on the major bearings and shaft. "Maximum amplitude value of vibration" shall mean the maximum vibration reached during turbine operation including turbine start and stop operation.

The pressure parts and their accessories of the steam turbine shall have a sufficient safety margin against the maximum stress under maximum working pressure and temperature. In this case, the stress shall not exceed the allowable stress of the material. To ensure the sufficient safety margin against the maximum stress, the structure of pressure parts of the gas turbine and its accessories shall be able to withstand a water pressure test with a water pressure 1.5 times as high as their respective maximum allowable working pressures without leakage.

Gas turbine and its accessories which are likely to be subjected to overpressure shall be equipped with an overpressure protection device in order to release the pressure.

Article 34: Bearings of Gas Turbine

Bearings of gas turbines shall be constructed to be able to stably support the load during operation and without the occurrence of abnormal wear and deformation, and overheat. To prevent the "abnormal wear and deformation and overheat" of bearings, the gas turbine shall be equipped with the following lubricating oil feed pumps to provide the satisfactory lubricating oil to the bearings:

- a. Main lubricating oil feed pumps

While the turbine is operating, the main lubricating oil feed pumps shall be operated to provide a satisfactory lubricating oil to the bearing of the gas turbine.

b. Auxiliary oil pumps

Auxiliary oil pumps shall automatically start when the main oil pump out-put pressure becomes abnormally low

However, if a gas turbine is equipped with a device to automatically shut off the inflow of fuel and safety stop when the outlet pressure of a main oil pump decreases, it is not required to equip an auxiliary oil pump.

c. Emergency oil pump

An emergency oil pump or manual operation auxiliary oil pumps shall be installed for safety stop of the main turbine when main and/or auxiliary oil pumps have broken down.

Article 35: Governance of Turbine Speed

1. Speed Governor

A gas turbine shall be equipped with a device capable to automatically adjust the flow of fuel entering the gas turbine in order to prevent its speed and output from fluctuating continuously even in case of a change in load condition. The device to automatically adjust the flow of fuel entering into the gas turbine automatically is called Speed Governor. This Speed Governor shall have an ability to hold the turbine speed after the interruption of the rated load below the speed at which the emergency governor is actuated.

Even the gas turbines without direct fuel burning shall be equipped with a device to control the maximum rotational speed.

2. Normal Speed, Over-Speed and Critical Speed of Gas Turbine

Normal Speed of a gas turbine is the operational speed of the turbine when it normally loaded and when the governor is in normal operation. The turbine shall be capable to operate at normal speed without any restrictions upon the time and output. This Normal Speed shall be in between 98 to 101% of the rated speed of the turbine. The normal speed of the turbine shall not be the speed remarkably less or more than the rated speed.

Over-speed is the speed over than the normal speed which could do harm to the turbine.

Critical speed of a turbine is the speed which creates the resonance on the turbine. To avoid the damage of the turbine caused by this resonance, the critical speed of the turbine combined with the generator on the same shaft shall not be in the speed between the minimum speed of governor and the maximum available speed of emergency stop device. However, it will be exempted if it will be arranged to have enough countermeasure against the vibration at critical speed during operation of the turbine.

“Speed between the minimum speed of governor and the maximum available speed of emergency stop device” is the speed can be operated by the steam turbine.

“The minimum speed of governor” shall mean the following;

- a. The minimum speed in speed variation when the turbine is not combined with a generator or a rotor.
- b. The minimum speed of grid frequency when the turbine is combined with a generator or a rotor.

Article 36: Emergency Alarm and Stop Devices

In order to avoid the occurrence of damage from over-speed and abnormal conditions (emergency case) during operation, the gas turbine shall be equipped with two devices: 1-Emergency Stop Device and 2-Emergency Alarm Device.

1. Emergency Stop Device

In order to avoid the occurrence of damage from over-speed or other abnormal conditions during gas turbine operation, the gas turbine shall be equipped with a device which automatically interrupts the inflow of fuel or gas called Automatic Emergency Stop Device. In addition to the Automatic Emergency Stop Device, the gas turbine shall be also equipped with a manual emergency stop device. When the above emergency stop device is actuated, the emergency stop alarm shall be activated.

In case of over-speeds or speeds exceeded the rated speed of the gas turbine, the automatic emergency stop device shall be actuated to stop the turbine when the speed reaches the tripping speed. The tripping speed of the turbine shall be at 110% ($\pm 1\%$) of the rated speed.

“Other abnormal conditions” are the following cases:

- a. The case where an internal failure occurs in a generator.
- b. The case where the gas temperature significantly increases.
- c. The case where the lubricating oil temperature significantly increases.
- d. The case where the lubricating oil pressure significantly decreases.

2. Emergency Alarm Device

A gas turbine shall be equipped with a device that functions to provide an alarm when the amplitude value of vibrations is detected to be beyond the allowable level during the gas turbine operation.

Article 37: Monitoring and Alarm Systems

A gas turbine and its accessories shall be equipped with systems necessary to monitor the operating condition and alarm system to prevent any damages of the gas turbine and its accessories during the operation.

Monitoring systems of gas turbines shall be capable to monitor the following data:

- a. Rotational speed of the turbine (Gas turbine tachometer)
- b. Outlet pressure of an air compressor of gas turbine
- c. Gas temperature at the inlet of a gas turbine (The calculation method to determine the inlet temperature of gas based on the measured outlet temperature of the gas is applicable.)
- d. Lubricating oil inlet pressure of gas turbine bearings
- e. Lubricating oil outlet temperature of gas turbine bearings or bearing metal temperature

Alarm systems of gas turbines shall provide an alarm when the following situations occur:

- a. Temperature of inlet or outlet gas of gas turbine is high
- b. Lubricating oil pressure is low (shall alarm before the function of the emergency stopping device.)
- c. Fuel oil supply pressure is low.

Article 38: Reviewing the Safety of Gas Turbine

To ensure the safety of gas turbine operation, Licensees who plans to install gas turbine in The Kingdom of Cambodia shall submit the drawings and data related to the gas turbine on the items as follows to EAC for reviewing the adoption of safety requirements in this standard:

- a. Combustion chambers
- b. Piping arrangements fitted to turbines (including fuel, lubricating oil and cooling water system)
- c. Particulars (type of turbine, power and rotation speed of turbine, gas pressure and temperatures at turbine inlet and outlet, ambient condition, service fuel and lubricating oil)
- d. Material specifications of principal components
- e. General arrangement
- f. Control system diagram
- g. Calculation sheets for vibration of turbine blades

Article 39: Requirements for Gas-Turbine Combined Cycle and its Accessories

Gas turbine combined cycle plants and their accessories shall be designed, manufactured, constructed and operated in accordance with the requirements in this chapter and chapter 3.

CHAPTER 4

Requirements for Gas Turbine Generating Facility

CHAPTER 5

Requirements for Internal Combustion Engine

Article 40: Internal Combustion Engine

A generating facility by an internal combustion engine is a facility where the generator is rotated by the internal combustion engine to generate the electric power. The internal combustion engine is a engine in which the fuel is mixed with air and burnt in confined space called a combustion chamber. The combustion of mixed fuel and air in the combustion chamber creates gases of high temperature and pressure which moves the moving parts of the engine such as pistons, rotors.

Main components of the internal combustion engine which are regulated by the requirements in this chapter are the following:

- Engine itself
- Bearings
- Governor
- Emergency stop and alarm device
- Overpressure protection device
- Monitoring and alarm system

Article 41: Requirements for Materials of Internal Combustion Engine

Cylinders, vessels and tubes of the internal combustion engine and its accessories and the pressure parts shall be made of the materials which have sufficient mechanical strength such as having good weldability, tensile strength, ductility, toughness, hardness and other mechanical properties and chemical stability such as good corrosion resistance, good heating resistance, and other chemical properties under the maximum working pressure and temperature.

The scope of properties of materials shall be chosen according to the specific conditions of use.

Article 42: Mechanical Strength of Structure of Internal Combustion Engine

Structure of an internal combustion engine shall have sufficient mechanical strength such as having good weldability, tensile strength, ductility, toughness, hardness and other mechanical properties even when it is operated at the speed that the engine reaches when the emergency speed governor is actuated. Even if the rotational speed of the engine exceeds the rated rotational speed for any reasons and the emergency speed governor is activated, the machine shall not be damaged.

Pressure parts and their accessories of the internal combustion shall have a sufficient safety margin against the maximum stress under the maximum working pressure and temperature. In this case, the stress shall not exceed the allowable stress of the material.

To provide “sufficient safety margins” to the pressure parts and their accessories, the following conditions shall be fulfilled:

- a. Combustion chamber and pipes of the ancillary equipment for internal combustion engines shall meet the requirement of good weldability, tensile strength, ductility, toughness, hardness and other properties.
- b. Internal combustion engines and ancillary equipment shall meet the requirement of corrosion resistance and abrasion resistance, if it's necessary.
- c. The pressure parts of internal combustion engines and their accessories shall be able to withstand a water pressure test using a water pressure 1.5 times their respective maximum allowable working pressures without leakage.
- d. However, the water pressure test is not required for;
 - (i) Internal combustion engine's casing which has the result of a water pressure test that was conducted under the same structure and same material conditions.
 - (ii) Internal combustion engines, the strength of which has been proven theoretically by calculation to have the mechanical strength to resist a water-pressure of 1.5 times of the maximum allowable pressure.

Article 43: Bearings of Internal Combustion Engine

Bearings of the internal combustion engine shall be structurally able to stably support the load during operation and without the occurrence of abnormal wear, deformation and overheat.

For the bearings with lubricating oil system to prevent the abnormal wear and deformation and overheat of bearings the following conditions shall be provided:

- a. The main lubricating oil pump shall be capable to feed sufficient lubricating oil to the engine during normal conditions
- b. The lubricating oil tank shall be capable to store the quantity of lubricating oil required for the engine.
- c. Devices capable to clean the lubricating oil (An oil filter which has the capacity to clean the lubricating oil can be one of them.) shall be equipped.
- d. Devices capable to regulate the temperature of the lubricating oil (An oil cooler for controlling the oil temperature, which may be automatic or manual, can be one of them.) shall be equipped.

Bearings without lubricating oil system shall also be regarded as satisfactory if their technical mechanism is proved to be sufficient for the required level of safety.

Article 44: Governance of Internal Combustion Engine Speed

An internal combustion engine shall be equipped with a device to automatically adjust the fuel entering the engine in order to prevent its speed and output from fluctuating continuously even in case of a change in load condition. This device is called a speed governor. Speed governors shall be capable of preventing the rotational speed and output of the engine from hunting in case of any changes. The maximum rotational speed shall be controlled in the range lower than the speed at which the emergency speed governor is actuated, even when the rated load is cut off.

Article 45: Emergency Stop and Alarm Devices

In order to avoid the occurrence of damage from over-speed or other abnormal conditions during the engine operation, the internal combustion engine shall be equipped with an automatic emergency stop device, a manual emergency stop device and emergency alarm device. Emergency stop device automatically interrupts the inflow of fuel. When the above emergency stop device is actuated, the emergency stop alarm shall be activated. “Over-speed” in this article is the state which an internal combustion engine speed exceeds its rated rotational speed. “Other abnormal conditions” in this article is the state with an excessive rise of the cooling water temperature, the accidental stoppage of the cooling water feed and so on.

All internal combustion engines except those with a rated output less than 3000kW shall be equipped with an emergency governor which is actuated to stop the engine at a speed higher than engine rated speed but not higher than 1.16 times of this rated speed.

All internal combustion engines except those with a rated output less than 3000kW shall be equipped with a device which stops the fuel flow automatically in case the cooling water temperature rises abnormally or the cooling water feeding stops.

Article 46: Overpressure Protection Devices

An engine and its accessories which are likely to be subjected to overpressure shall be equipped with an overpressure protection device in order to release the pressure such as relief valve which shall have a sufficient capacity for preventing overpressure, and shall activate at a pressure lower than the maximum pressure.

“An engine and its accessories are likely to be subjected to overpressure” means the following parts:

- a. Cylinders with a diameter of more than 230mm and the maximum allowable pressure of more than 3.4 MPa (excluding gas fuel engines).
- b. Sealed crankcases in the cylinders with a diameter of more than 250mm.

Article 47: Monitoring and Alarm Systems

An engine shall be equipped with systems necessary to monitor the operating condition and systems necessary to provide an alarm to prevent damages to the engine and its accessories during the operation.

Monitoring systems of internal combustion engines shall be capable to monitor the following data:

- a. The rotation speed of the internal combustion engine
- b. The temperature of the cooling water at the outlet of the internal combustion engine
- c. The pressure of the lubricating oil at the inlet of the internal combustion engine
- d. The temperature of the lubricating oil at the outlet of the internal combustion engine

CHAPTER 6

Requirements for Generators

CHAPTER 6

Requirements for Generators

Article 48: Protection of Generators

Thermal power generators shall be equipped with a protection device against any over-current accident.

The thermal power generators shall be also equipped with devices to automatically cut off the generator from the electrical line when:

- a. Over-current occurs.
- b. Internal failures, such as grounding or short-circuit of stator windings, of the generator with a capacity of 3000kVA or more occurs.
- c. The thrust bearings of the turbine with a rated capacity of 3000kW or more are significantly worn down and there is a significant rise in the temperature of the bearings.

Article 49: Electrical Equipment

Electrical equipment installed in thermal power plants shall be designed and constructed so that it structurally allows easy operation, inspection, overhauls and repairs.

Article 50: Cables in Thermal Power Plants

Cables used in thermal power plants shall be installed so that the original properties of non-flammability are not impaired.

In case cables are installed in such hazardous areas that there is a risk of fire or explosion in the event of an electrical fault, proper protections against such risks shall be provided.

Cables and wires shall be installed and supported so that they will not be damaged by any mechanical stress.

Article 51: Installation of Hydrogen Cooling Type Generators

The hydrogen cooling system is usually adopted in a large capacity generator. Such generators are filled with hydrogen to cool all windings of generator. Because hydrogen explodes if it is mixed with air, the following measures against the explosion shall be taken for the generator with the hydrogen cooling system:

1. The generator shall be structurally constructed so that the hydrogen will not leak to the outside and the air will not go into the inside.

2. The structure of the generator shall have sufficient mechanical strength (explosion-proof construction) to withstand pressure generated by hydrogen explosion.
3. The generator shall be equipped with an alarm device to be activated when purity of hydrogen decreases to 85% or less. Moreover, the device shall raise an alarm when pressure and/or temperature of the hydrogen change remarkably.
4. Tubes and valves filled with hydrogen shall have the structure to prevent hydrogen leakage. The tubes shall be a copper pipe or a seamless steel pipe.
5. When the hydrogen leaks from the shaft seal part of the generator, the gas leakage shall be stopped and the gas shall be safely discharged outside.

Article 52: Control Systems

The control system for generators shall have the integrated interlocking system to properly and safely control the generator.

Annunciators shall be provided for detection of abnormal operating conditions and shall be equipped with emergency trip functions necessary to assure equipment integrity and overall plant safety. The annunciator and trip functions shall be implemented through each independent device.

The control system shall have a function to start up and shut down the generator. The thermal power plant including the generator shall be started up and shut down manually from the control panel and automatically through the individual sequence programs.

CHAPTER 7

Transitional Provisions

CHAPTER 7

Transitional Provisions

Article 53: Transitional Provisions for Small and Medium Licensees

Requirements in this chapter are the minimum requirements and temporarily applicable to generation facilities of small and medium licensees when their generation facilities are in the transitional stage taking into consideration present level of existing generation facilities in Cambodia. Therefore these requirements will be cancelled in the future by Ministry of Industry, Mines and Energy when the generation facilities of Licensees in Cambodia passed the transitional stage.

“Small licensee” means the licensees with an installed capacity of less than 500 kW.

“Medium licensee” means the licensees with an installed capacity from 500kW up to 3000kW.

The minimum requirements to temporary apply to generation facilities of small and medium licensees are described in the following articles in this chapter.

Article 54: Prevention of Electric Power Disasters

For prevention of electric power disasters, all power generating facilities of small and medium licensees which are in the transitional stage at present shall be at least in accordance with the following minimum requirements:

- A generator circuit breaker shall be equipped to each generator.
- A bare conductor is allowed only when it is installed inside of the panel or box.
- A naked knife-switch is allowed only when it is installed inside of the panel or box.
- Each cable shall have the cable number attached.
- Electrical facilities shall be grounded appropriately.
- All power cables and control cables shall be installed inside the cable tray or conduit pipe in the facility area.

Article 55: Safety of Third Persons

For prevention of danger to third persons, all power generating facilities of small and medium licensees which are in the transitional stage at present shall be at least in accordance with the following minimum requirements:

- Fences and/or walls shall be installed around the generating facilities to prevent third persons' accidents.
- The entrances/exits of above fences or walls needs appropriate key lock systems.
- "Keep out" signs shall be indicated at the entrance of generating facilities.
- Generating facility area shall be kept clean.
- All rotating and working parts shall be covered and protected from workers' accidents.
- Any belt drive power transmission systems shall be not approvable.

Article 56: Safety Measures for Fuel and Chemical Materials

For safety in using fuel and chemical materials, all power generating facilities of small and medium licensees which are in the transitional stage at present shall be provided with the following measures:

- Fire fighting systems and/or extinguishers shall be equipped near the fuel storage area.
- Fuel tanks shall be equipped at least 1 (one) meter away from electrical facilities.
- Fuel tanks shall be equipped solidly and combustible materials shall not be left within 1 (one) meter.
- Exhaust gas shall be discharged at least 2(two) meters high outside of the building.
- Exhaust pipes and/or hot parts of engines shall be protected.

Article 57: Environmental Protection

- Noise of generating facilities shall be prevented in residential areas. (Refer to related laws).

Table 3: Countermeasures for Preventing Noise of Generating Facilities

Operation case	Countermeasures
Interval operations (except night time)	-----
24 hours operation (including night time)	Generation facilities shall be enclosed by walls or installed in a specific building.

- Waste oil shall not be discharged directly to the ground in order to prevent soil pollution and protecting well water.

Article 58: Requirements for Operation

1. Monitoring Devices

Generators and generating facilities shall be equipped with the following monitoring devices:

- Generator volt meter

- b. Generator ammeter
- c. Generator frequency meter
- d. Energy meter (kWh)
- e. Generator out put (kW) meter
- g. Fuel tank level (or fuel flow meter)
- h. Engine oil pressure meter
- i. Engine oil temperature meter (if any)
- j. Cooling water temperature (if any)

2. Record Requirements and Maintenance of Generating Facilities

- Daily operational data, such as generated energy (kWh), Voltage, frequency, operation time and all instrument data, shall be recorded.
- Considering the operational period, overhaul of the engines shall be scheduled and implemented.
- Maintenance records including replacement parts and checking points shall be established.

3. Report Requirement

The following reports shall be submitted to EAC and copied to MIME every year:

- a. Operation records
- b. Maintenance records
- c. Trouble records

If any trouble or accidents in relation to the generating facilities occurs, the licensee shall report to EAC without delay.

Article 59: Safety and Technical Training

“Small and Medium Licensee” and/or technical staff who operate and maintain their facilities shall pass a training school program or course recognized by MIME or EAC. The technical training shall be provided to refresh their memory within three years or less.

Explanation Sheet of Electric Power Technical Standards

- (1)- EXPLANATION SHEET FOR DISTRIBUTION AND
TRANSMISSION FACILITIES.**
- (2)- EXPLANATION SHEET FOR THERMAL POWER
GENERATING FACILITIES.**

**Explanation Sheet for
Transmission and Distribution Facilities**

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CHAPTER 1

INTRODUCTION

Article 1: Definitions**Article 2: Purpose****Article 3: Area of Application****Article 4: Applicable Standards**

<IEC>

The International Electrotechnical Commission (IEC) is an international standards organization dealing with electrical, electronic and related technologies. Some of its standards are developed jointly with ISO.

The IEC charter embraces all electrotechnologies including energy production and distribution, electronics, magnetism and electromagnetics, electroacoustics, multimedia and telecommunication, as well as associated general disciplines such as terminology and symbols, electromagnetic compatibility, measurement and performance, dependability, design and development, safety and the environment.

Today, the IEC is the world's leading international organization in its field, and its standards are adopted as national standards by its members. The work is done by some 10 000 electrical and electronics experts from industry, government, academia, test labs and others with an interest in the subject.

<ISO>

The International Organization for Standardization (ISO) is an international standard-setting body composed of representatives from national standards bodies. Founded on February 23, 1947, the organization produces world-wide industrial and commercial standards, the so-called ISO standards.

While the ISO defines itself as a non-governmental organization (NGO), its ability to set standards which often become law through treaties or national standards makes it more powerful than most NGOs, and in practice it acts as a consortium with strong links to governments. Participants include several major corporations and at least one standards body from each member country.

ISO cooperates closely with the International Electrotechnical Commission (IEC), which is responsible for standardization of electrical equipment.



Figure ES4A Authorized Logo of ISO

Article 5: Types of Power Transmission and Distribution Facilities**Article 6: Voltage**

CHAPTER 2

**GENERALS FOR TRANSMISSION AND
DISTRIBUTION**

PART 1

General Provisions

Article 7: Prevention of Electric Power Disasters

< Installing Restrictions for Switches with Oil >

If an internal short-circuit accident occurs inside a switch, a disconnecter, or a circuit breaker installed on the supporting structure of an overhead electrical line due to a lightning attack and so on, there is a fear that erupting insulation oil causes a serious damage to third persons or buildings.

Therefore, switches, disconnectors, or circuit breakers with insulation oil shall not be installed on the supporting structure of an overhead electrical line.

As for a switching device installed on the supporting structure of an overhead electrical line, a vacuum switch, air switch or gas switch (SF₆) is mostly adopted.

Article 8: Prevention of Accidents Caused by Electric Power Facilities

Licensees have an obligation to supply electricity to their consumers stably. Moreover, careful and special consideration should be paid for safety of the employees as well as third persons. In this article, safety measures for prevention of accidents for their employees are required.

There are various hazards in electric power facilities such as generating facilities, substations, switching stations. For example;

- Turbines and engines have rotational and moving parts
- Generators, transformers, switches, etc. have charged parts with dangerous voltage to human beings.
- Hydro power stations have some big civil structures which should be protected for their employees not to fall down.
- There may be some holes on the floor during maintenance and construction.

As mentioned above, licensees have to pay attention to safety for their employees. It is very important not only to install a fence, a cover and other protection facilities but also to provide safety training to their employees and establish working procedures for safety.

<Prevention of Fires caused by an Arc>

A switch, a breaker, an arrester, and other similar equipment (hereafter “switch etc.” in this Article) for high-voltage or medium-voltage that generates arcs during operation shall be separated from a wooden wall or ceiling or other flammable material by 1 m or further for medium-voltage and by 2 m or further for high-voltage.

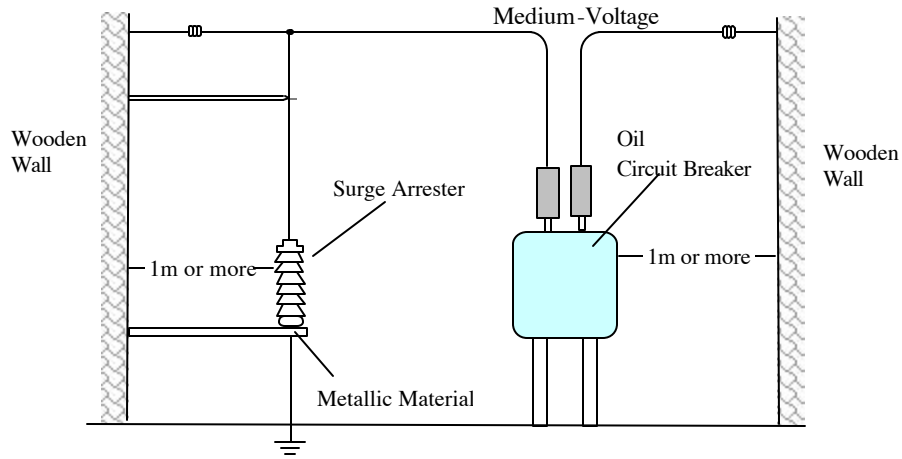


Figure ES8A Installation of a Switch for Medium-voltage (Example)

Article 9: Safety of Third Persons

1 Safety of Third Persons at Power Stations, Substations and Switching Stations

It is provided in Clause 11 of GREPTS that a suitable measure is taken so that a third person may not come into a power station, a substation, and a switching station.

Also when people enter a power station, a substation, a switching station, etc. where live parts are exposed, an electric shock accident may occur and it may cause accident influencing an electric power system. Fences or walls, therefore, shall be installed so that people don't enter within the enclosure. This paragraph shows the height of the fence and the level clearance between the fence and the live part. These values are based on IEC 61936-1.

Moreover, signs warning that the high-voltage and medium-voltage facilities are dangerous to any person other than operators shall be provided and appropriate locking mechanism shall be taken so that no person other than operators can easily enter the closed electrical operating area.

However, in case people can't enter the station because it is surrounded by the cliff, a ditch, etc., there is no necessity for a fence or a wall.

Table ES9A Boundary Clearance

Nominal voltage [kV]		Boundary clearance [mm]	Minimum line to ground insulating clearance N [mm]
160kV or less	22	Wall: N+1,000	1,100
	115		
Over 160kV	230	Fence: N+1,500	1,900

Source: IEC61936-1

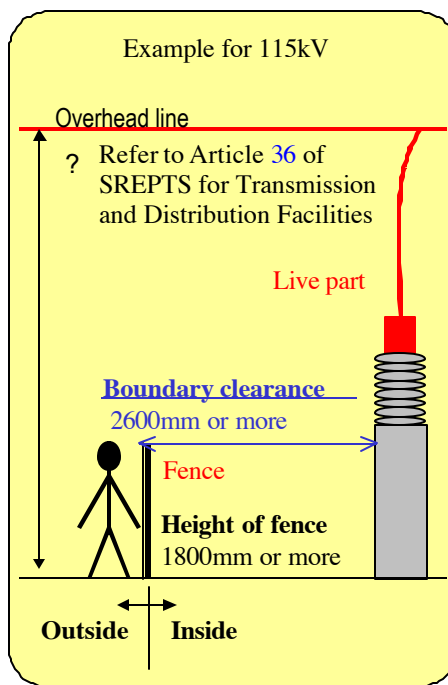


Figure ES9A Boundary Clearance (Example for 115kV)

2 Safety of Third Persons at Electric Supporting Structures

An example of arrangement of "a warning sign", "anti-climbing devices" and "steps" is as shown in the following figures.

Points to be considered are as follows:

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

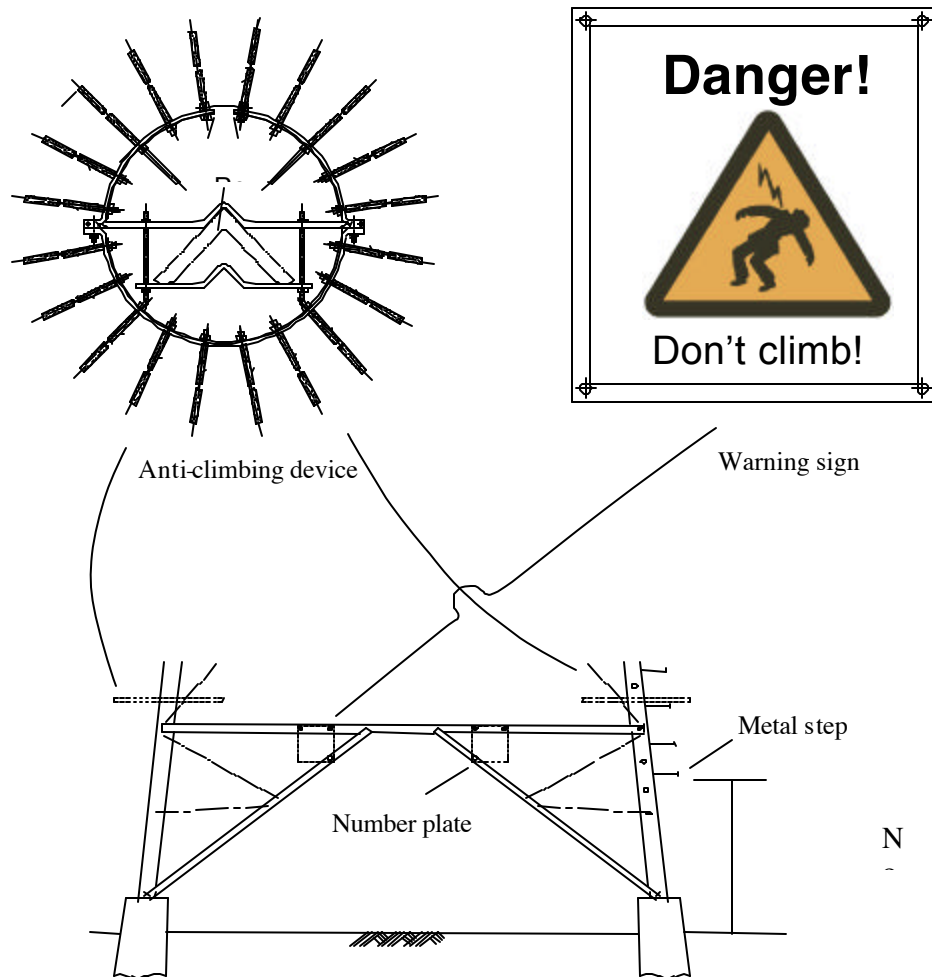


Figure ES9B Example of Measures for Anti-climbing

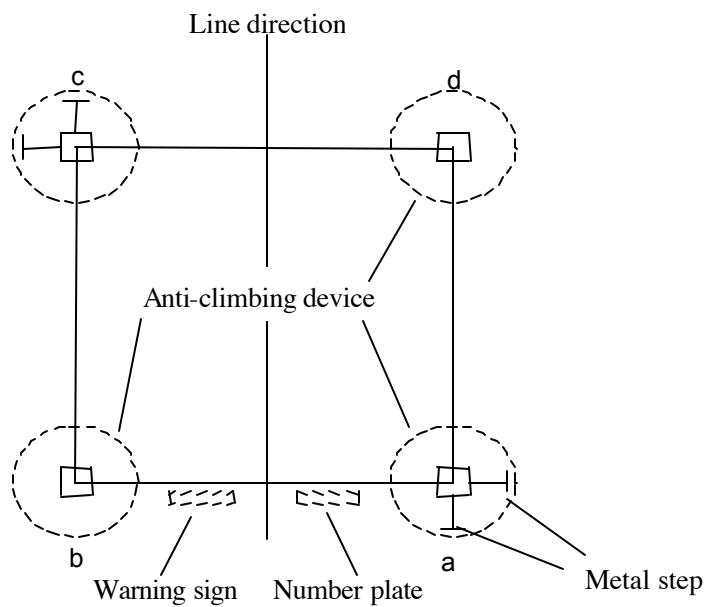


Figure ES 9C Plane View of a Tower

(*)In case of a supporting structure for overhead distribution lines, it is important to prevent third people from climbing it and getting an electric shock by making it hard to climb.

On the other hand, it is necessary to climb a supporting structure safely and rapidly when a worker begins a maintenance work for overhead distribution lines.

Therefore, with regard to above two conflicting conditions, any metal steps on supporting structures may be installed at heights of more than 1.8m from the ground.

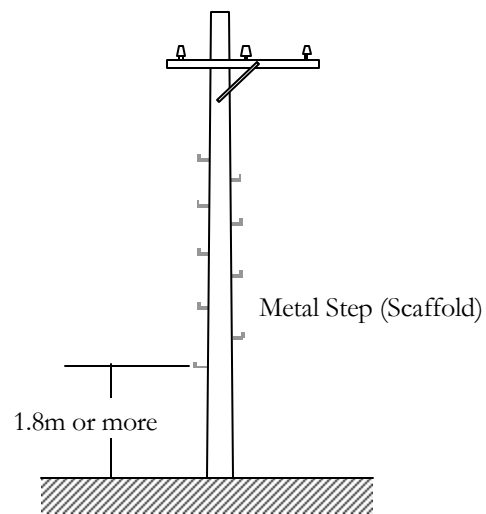


Figure ES9D Prevention of Climbing a Pole (Example)

Article 10: Prevention of Failures of Electric Power Facilities from Natural Disasters

Article 11: Prevention of Electric Power Outage

Article 12: Protection against Over-current

1 Properties of Over-current Protection Equipment for High-voltage Lines and Medium-voltage Lines

1.1 Over-current Breakers for Medium-voltage Lines

Over-current breakers for medium-voltage lines can be classified in “fuses” and “switchgears”.

(1) Transformer MV fuses

Every distribution transformer shall be protected on the primary side with suitably rated cutout fuses. The time-current characteristic of the fuse link is carefully controlled to enable correct discrimination with other fuses and devices.

A distribution fuse-cutout is defined in IEC 60282 as a current-limiting fuse.

The outline of IEC 60282 (2002-01) [High-voltage fuses-Current-limiting fuses] is as follows;

a. Definitions

Fuse-base

Fixed part of a fuse provided with contacts and terminals

Fuse-link

Part of a fuse (including the fuse element(s)) intended to be replaced after the fuse has operated.

Rated voltage

A voltage is equal to the highest voltage for the equipment

Rated current of the fuse-base

The current assigned to a fuse-base that a new clean fuse-base will carry continuously without exceeding specified temperature rises, when equipped with a fuse-link of the same current rating designed to be used in the particular fuse-base connected to the circuit with certain specified conductor sizes and lengths, at an ambient air temperature of not more than 40 °C.

Rated current of the fuse-link

The current assigned to the fuse-link that a new clean fuse-link will carry continuously without exceeding specified temperature rises when mounted on a fuse-base specified by the manufacturer and connected to the circuit with certain specified conductor sizes and lengths, at an ambient air temperature of not more than 40 °C.

Rated maximum breaking current

The maximum current that a fuse is capable of breaking at a stated voltage under prescribed conditions of use.

b. Rated voltage

The rated voltage of a fuse should be selected from the voltages given in below table.

Table ES12A Example of Rated Voltages

Series I (kV)	Series II (kV)
3.6	2.75
7.2	5.5
12	8.25
17.5	15
24	15.5
36	25.8
40.5	38
52	48.3
72.5	72.5

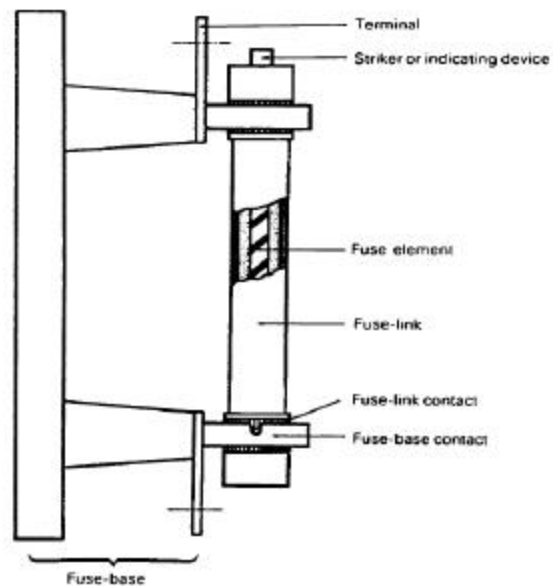


Figure ES12A Terminology of Current-limiting Fuse

c. Rated current of the fuse-base

The rated current of the fuse-base should be selected from the following values.

10 A, 25 A, 63 A, 100 A, 200 A, 400 A, 630 A, 1 000 A

d. Rated current of the fuse-link

The rated current in amperes of the fuse-link should be selected from the following values.

10 A, 12 A, 12.5 A, 14 A, 16 A, 18 A, 20 A, 22.4 A, 25 A, 28 A, 31.5 A, 35.5 A, 40 A, 45 A, 50 A, 56A, 63 A, 71 A, 80 A, 90 A

e. Rated maximum breaking current

The rated maximum breaking current of the fuse-link should be selected from the following values.

10 kA, 12.5 kA, 16 kA, 20 kA, 25 kA, 31.5 kA, 40 kA, 50 kA, 63 kA, 80 kA

(2) Switchgears installed at the outgoing point of a substation

Switchgears installed at the outgoing point of a substation is so called “circuit breaker for distribution feeder”.

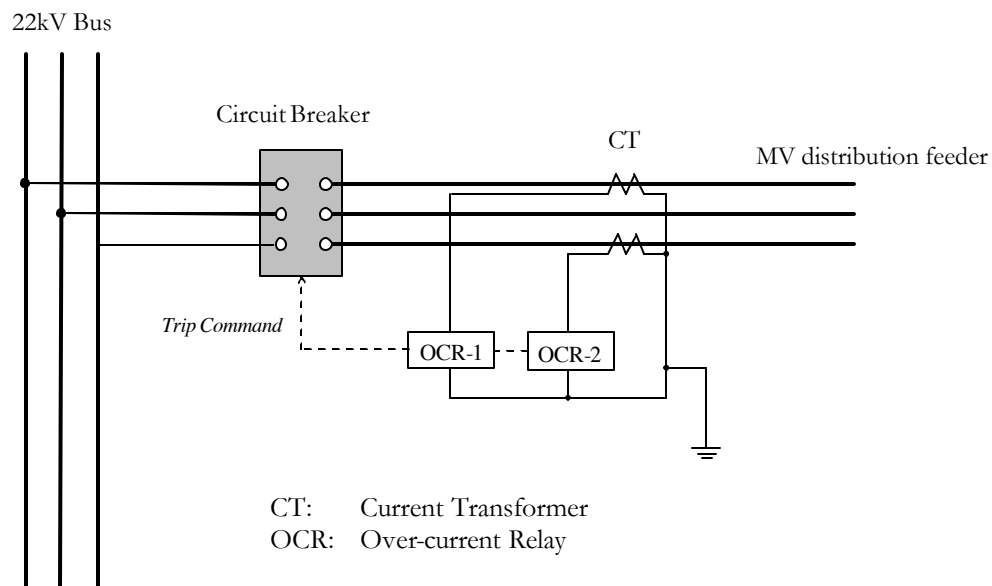


Figure ES12B Example of Overcurrent Relay Method

Though there are no requirements for properties of switchgears installed at the outgoing point of a substation in SREPTS, it is desirable to conform to related IEC 62271-100 (2003-05) [High-voltage switchgear and controlgear - Part 100: High-voltage alternating-current circuit-breakers].

(There are no standards for properties of switchgears for a distribution feeder in Japan.)

Article 13: Protection against Ground Faults

1 Installation of Ground Fault Circuit Breakers

In addition to GREPTS 53-2, it is desirable to install a ground fault circuit breaker at the receiving point where the medium-voltage power supply is received from others.

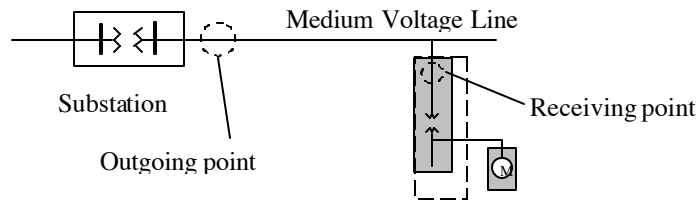
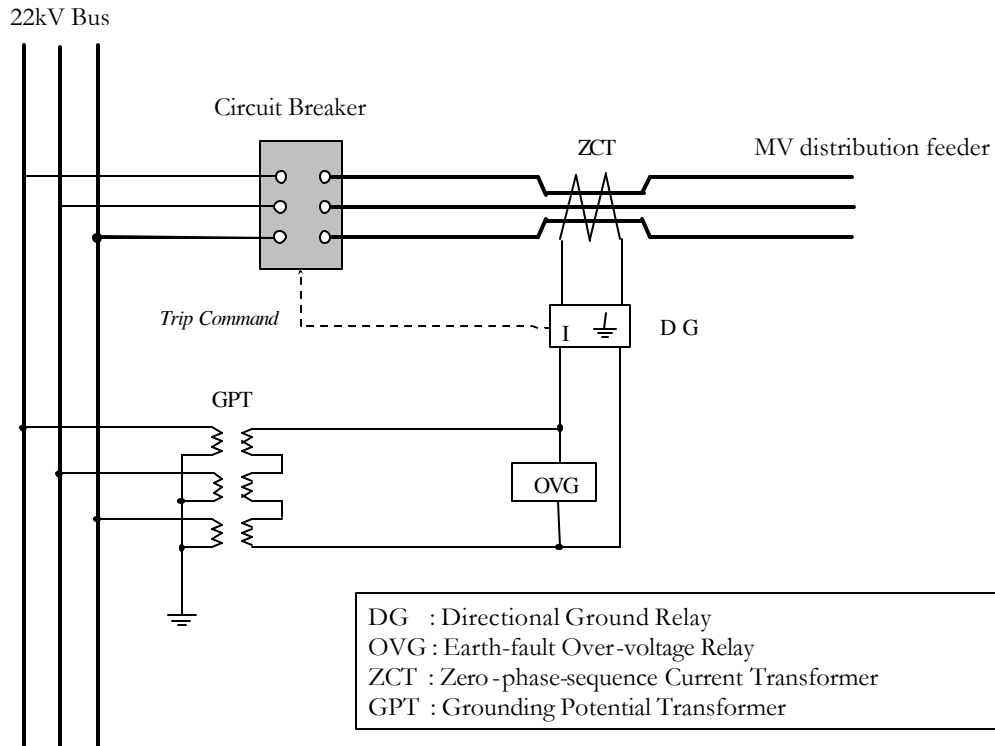


Figure ES13A Example of Installation of Ground Fault Current Breakers



**Figure ES13B Example of the Ground Fault Directional Relay System
(Outgoing point of Substation)**

2 Ground Fault Breakers for Low-voltage Circuits

A ground fault breaker is not always necessary to be installed at the secondary side of a distribution transformer (22kV/0.4kV), because over-current breaker is substitutable for it and protects the circuit against a ground fault. (If the value of a ground fault current is much more than that of the breaking current, an over-current breaker can work and interrupt the low-voltage fault circuit.)

3 Properties of Ground Fault Breakers

Properties of ground fault breakers shall conform to related IEC 60947-2(1998-03) [Low-voltage switchgear and controlgear – Part 2: Circuit-breakers].

Article 14: Environmental Protection

1 Compliance with the Environmental Standards

A lot of special terms are used in environmental issues. To make the discussion for environmental protection easy, the important terms are picked out and provided as follows;

1.1 Atmosphere

Down wash

A phenomenon that flue gas diffusion is extremely disturbed by the wind whirled by a barometric pressure different at the back of a building or funnel.

NO_x (nitrogen oxides)

Generic term of nitrogen oxides generated in combustion processes. NO and NO₂ occupy most of the NO_x. In general, it is divided into “thermal NO_x” generated when nitrogen in the air is combined with oxygen during combustion and “fuel NO_x” generated when nitrogen oxides in fuel are oxidized.

SO_x (sulphur oxides)

Generic term of sulfur oxides, which are generated as fuel with much amount of sulfur is burnt.

Suspended particulate matter

Refers to the floating dust with a diameter of 10 μm or less.

Soot and dust

Solid grains contained in combustion gases, such as soot, ash, etc. generated in combustion processes.

Sulfuric-acid mist

Foggy sulfuric acid, which is one of the harmful air pollution substance. It is said that this mist is generated when sulfurous acid gas is mixed with water content in the air to form sulfurous acid, then oxidization by oxidant and change in sulfuric acid mist.

Acid rain

A phenomenon that sulfurous oxides (mainly SO₂) discharged by high sulfuric fuel combustion, etc, and oxidized gradually in the air into dilute sulfuric acid mist and it is solved in raindrops in a distant area.

Dust

Substance generated or scattered as a result of mechanical treatment, such as crushing and selection of material or heaping material.

1.2 Water Quality

pH (Potential of hydrogen)

A symbol used to indicate the concentration of hydrogen ion (hydrogen ion gram quantity existing in 1,000 ml). It is represented by a common logarithm of the inverse number of the hydrogen concentration in water.

$$pH = \log \frac{1}{(H)^+} = -\log(H^+)$$

Pure water pH is 7.

BOD (biochemical oxygen demand)

This BOD indicates the amount of oxygen consumed when organic substances in water are decomposed by breeding or breathing of aerobic bacteria. This value is desirable 5ppm or less in rivers.

COD (Chemical oxygen demand)

Indicated the amount of oxygen consumed by oxidized substances in water, which is analyzed by a chemical method. This value is desirable 5ppm or less.

DO (dissolved oxygen)

This DO in clean water is 7 to 14ppm. At least, 5ppm is needed for fishes.

Activated sludge

Flocked deposit generated by rapid breeding of aerobic micro organism in sewage and waste water it can decompose sludge significantly.

SS (suspended solids)

Substances floating in water. It is harmful, since it sticks on living organism in water and is precipitated on river beds. The SS value is desirable 10ppm or less.

1.3 Noise

Sound pressure level (dB)

20 times of the common logarithm of the ratio between sound pressure P and reference sound pressure P_0 . In other words, it means $20 \log_{10} (P/P_0)$. In this case, $P_0 = 0.0002 \mu b$. In the case of parallel progressive waves, it can be assumed to be the same sound strength level for practical use.

Volume level of sound

The sound pressure level of 1,000Hz pure sound it judges that the volume that a listening person was the same as could hear it. For example, it is 60 phon when the volume that is the same as 1,000Hz pure sound of 60dB can hear it.

Noise level (phon or dB value)

Value measured using a noise level meter.

Background noise

When a specific noise is measured at a place, if no sound is detected there, then the noise heard at that place is referred to as the background noise at that place.

Low frequency air vibration

How to call sounds below 20 Hz or special low sounds is not defined in Japan. They are referred to as low frequency sound, low frequency micro barometric pressure change, low frequency noise, etc.

1.4 Waste

Industrial waste

Combustion residue, sludge, waste oil, waste acid, waste alkalis, waste plastic, etc., generated from business activities.

Municipal waste

Waste other than industrial one.

PCB (polychlorinated biphenyl)

One of organic chlorine compound. Since it is excellent in heat resistance and insulation properties, it has been used widely for insulator of the electric equipment, as well as additives such as paint, ink, etc. However, it was found to be harmful to human bodies and its manufacture and use was prohibited.

1.5 Others

Environmental standard

Defined by the government for the atmospheric air, water quality, so noise, etc. in order to protect the human health and preservation of the living environment.

ppm (parts per million)

In the case of gas, this value indicates the ml quantity of the substance existing in 1 m³. In case of solid or liquid, it indicates the mg quantity of the substance existing in 1 kg.

ppb (parts per billion)

Indicates the concentration of 1/1,000 of 1ppm.

pphm (parts per hundred million)

Indicates the concentration of 1/100 of 1ppm.

Global warming problem

It has been found through climate data analysis that the temperatures on the earth are getting steady higher and higher in these 100 years, although there are some exceptions in some years. If this phenomenon is continued on, then, it will affect many things including agriculture, sea level, etc. Increasing of the concentration of greenhouse gases such as CO₂, methane, freon, N₂O etc. in the air is pointed out as the main factor.

Depletion of ozone layer:(Greenhouse Gas)

When CFC (chlorofluorocarbon, a kind of the so-called freon) and Halon which are widely used for the refrigerant, the cleaning agent, the foaming agent, etc. are released into the environment, it reaches the stratosphere, and so it is exposed to the strong ultraviolet radiation there, chlorine is emitted, and an ozone layer is destroyed by these disrupters.

As a result, the amount of the irradiation of harmful ultraviolet rays, which reach on the ground, increases, and there is a possibility that the increase in skin cancer, a bad influence to the ecosystem, etc. might be caused.

<Sulfur hexafluoride Gas (SF₆ gas)>

SF₆ gas is used by the electric power industry as an insulation material and is contained in gas blast circuit breakers, gas insulated switchgears (GIS) and other electrical equipment, because SF₆ gas has a much higher dielectric strength than air or dry nitrogen and this property makes it possible to significantly reduce size of electrical gear and to develop its reliability in long-term operation.

At the same time, SF₆ gas is said to be the most potent greenhouse gas that it has evaluated, with a global warming potential of about 23,000 times that of CO₂ (carbon dioxide) over a 100 year period. When electric equipment that contains SF₆ gas is removed and scrapped, the SF₆ gas shall be collected appropriately so as not to scatter into air for the purpose of reduction of greenhouse gas emissions.

Dioxin

Although it is originally the name of a specific molecule (2, 3, 7, 8-tetrachlorodioxine benzopara-dioxin, TCDD for short), polychlorodibenzo-dioxin (PCDD for short), generally, the general term of varieties indicate. It was presumed that the all are poisonous and they had carcinogenic, TCDD slightly contained in 2, 4, 5-T of a herbicide especially had the strongest toxicity as tetratogen, and after the U.S Forces use it for defoliation operation by the Vietnam War, malformed children occurred frequently. Generating dioxin in large quantities by incineration of the organic chlorine compounds including vinyl chloride is pointed out, and the immediate measurement needed.

2 Prohibition of Installation of Electrical Machines or Equipment Containing Polychlorinated Biphenyls (PCBs)

PCB oils were initially proposed as dielectric fluids for use in electrical equipment such as transformers, capacitors, circuit-breakers, voltage regulators, etc. because of their excellent dielectric properties and also because of their very low flammability.

However, when PCBs do burn, for example if a transformer or capacitor is present in a factory or domestic fire, very toxic chemicals are formed. These have the deleterious effects on health. PCBs also are dangerous substances because of their great stability, and their oleophilic nature, meaning that they are easily absorbed by the fatty tissues of humans and animals. PCB concentrations can then build up in the body, for example in the fat, the liver etc., and molecules are very difficult to eliminate.

Therefore newly installation of electric equipment with PCB should be prohibited.

2.1 Properties of Polychlorinated Biphenyls (PCBs)

PCBs are a family of organic chemicals consisting of two benzene rings linked by a carbon-carbon bond. Chlorine atoms displace any or all of the ten remaining available sites (Hydrogen atoms).

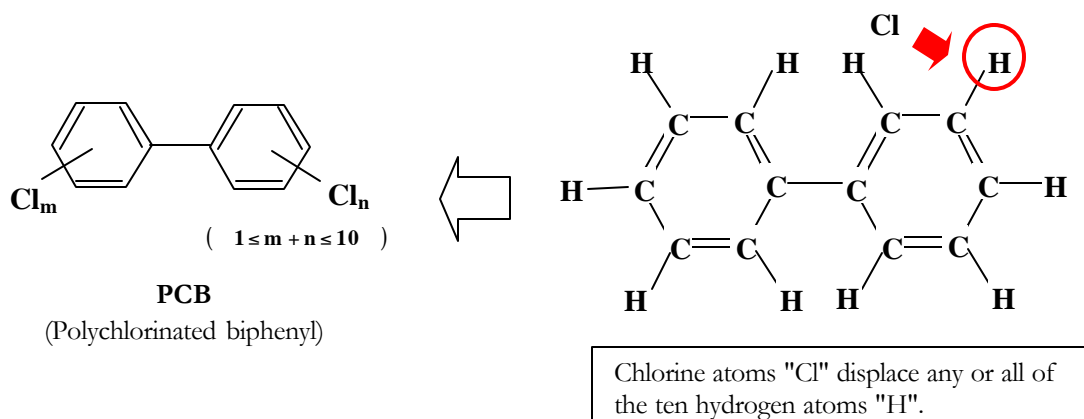


Figure ES14A Structure of PCB

PCBs are among the most stable organic chemicals known. Their low dielectric constant and high boiling point make them ideal for use as dielectric fluids in electrical capacitors and transformers. In summary, PCBs have:

- Low dielectric constant;
- Low volatility;
- Good fire resistance;
- Low water solubility;
- High solubility in organic solvents; and
- Good ageing properties, with no deterioration in service.

However, the disadvantages of PCBs fluids are now seen as considerable, since they are:

- Non-biodegradable;
- Persistent in the environment;
- Able to accumulate in fatty tissues in the body; and
- Suspected of being carcinogenic

The effects of PCBs on humans can be serious:

- Leading to failure of kidneys and other human organs;
- Producing headaches, sickness, etc., if inhaled; and
- Causing chlor-acne if absorbed through the skin.

2.2 Reference

This paragraph is based on "The Stockholm Convention" which is a global treaty to protect human health and the environment from persistent organic pollutants (POPs). "The Stockholm Convention" is the first of a series of world environmental conferences in relation to United Nations Environment Programme (UNEP) Chemicals.

The Cambodian Government has not ratified "The Stockholm Convention" yet, but many other countries have already ratified it. Therefore "The Stockholm Convention" can be regarded as a world-widely unified view.

"The Stockholm Convention" suggests the elimination of the use of PCBs in equipment (e.g. transformers, capacitors or other receptacles containing liquid stocks) by 2025 and for its realization, there are some regulations with respect to the treatments of PCBs.

Article 15: Life of Electric Power Facilities

Article 16: Requirements related to the Design of Electric Power Facilities

1 Insulation Co-ordination

1.1 Concept of insulation co-ordination

The concept of insulation co-ordination for stations and HV and MV users' sites shall conform to IEC60071-1 and other relevant IEC standards. The insulation co-ordination means choices of dielectric strength level of electrical equipment in consideration of normal or abnormal voltage on the power system and the characteristic of protective devices on the power system.

When the insulation co-ordination is considered, the following should be cared.

- Arrange arresters appropriately
- Control surge voltage with improvement of power system composition, circuit-breakers, control devices, protective devices and so on
- Design the insulation rationally
- Carry out a rational examination for proving the design

1.2 Standard Withstand Voltage

Standard withstand voltage conforms to IEC60071-1. The IEC standard shows that the standard insulation level of equipment is determined by the following two kinds of standard withstand voltages.

For equipment in the range of above 1kV to 245kV

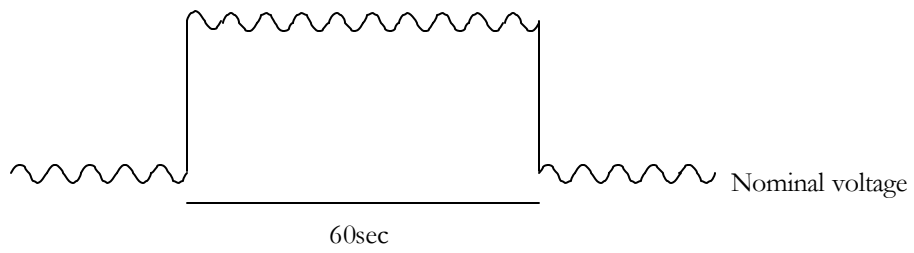
- a) the standard lightning impulse withstand voltage
- b) the standard short-duration power frequency withstand voltage.

For equipment in the range of above 245kV

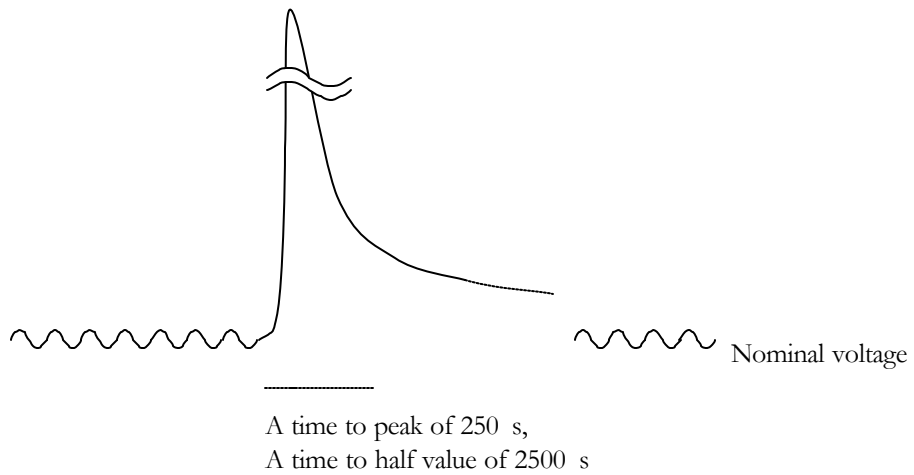
- a) the standard switching impulse withstand voltage
- b) the standard lightning impulse withstand voltage

(Standard voltage shapes)

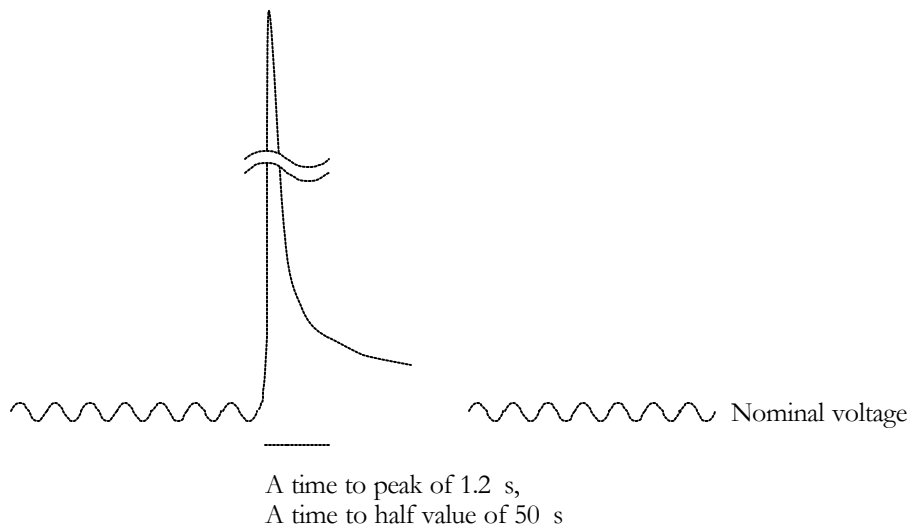
- The standard short-duration power-frequency voltage
 - a sinusoidal voltage with frequency between 48Hz and 62Hz, and duration of 60s
- The standard switching impulse
 - an impulse voltage having a time to peak of 250 μ s and a time to half-value of 2500 μ s.
- The standard lightning impulse
 - an impulse voltage having a front time of 1.2 μ s and a time to half-value of 50 μ s.



a. The standard short-duration power frequency



b. The standard switching impulse



c. The standard lightning impulse

Figure ES16A Image of Standard Withstand Voltage

1.3 Insulation Co-ordination by Surge Arresters

Insulation co-ordination of stations is basically performed by suitable arrangement of metal oxide surge arresters.

However, in case a detailed examination of composition of equipment or arrangement of surge arresters is needed, it is desirable for the co-ordination to be analyzed with EMTP and so on.

(Note) EMTP: Electromagnetic Transient Program, which is a digital simulation program of transient phenomena for the power system. This program is widely used in the world.

2 Dielectric Strength of Electrical Circuits

(The need for insulation)

In case electrical circuits are not insulated sufficiently, it might cause an electric shock, a fire by leakage current and some trouble such as power loss increasing. Then all of electrical circuits must be sufficiently insulated according to the classification of voltage.

(Check of insulation)

As understood from the reasons mentioned above, the insulation needs to be judged before using it. As a judgment method, the insulation resistance measurement and the dielectric strength charge examination are generally adopted.

In order to judge the level of insulation, it is the most ideal method to check the insulation with the dielectric strength charge examination. Its impressed voltage and time is a good indicator to confirm the level.

As for low voltage electrical circuits, however, the insulation resistance measurement is generally adopted because it is very easy to measure and it is available to judge the possibility of preventing a fire.

In case it is difficult to carry out the insulation resistance measurement with outage, leakage current measurement can be adopted for checking insulation of electrical circuits instead of the insulation resistance measurement.

(High and Medium voltage lines)

As for high and medium voltage lines, temporary over-voltage occurred by a single phase grounding fault and switching surge shall be considered when the dielectric strength charge examination are carried out.

However, in case it is assumed that the insulation performance, which was checked and confirmed according to IEC, JIS and other equivalent standards, is kept at the construction site, the dielectric strength may be checked by impressing nominal voltage continuously for 10 minutes.

(Electric Power Technical Standards of Japan)

The dielectric strength test of high voltage lines on Japanese Electric Power Technical Standards is as follows.

The insulation of high voltage lines shall withstand the test voltage given in Table ES16A which is impressed between the ground and the line continuously for 10 minutes. (In case the conductor of the line is cable, DC voltage is used for the test and the voltage 2.0 times of the test voltage shall be adopted.)

Table ES16A Test Voltage of Dielectric Strength Test in Japan

The type of electrical circuit	Test voltage
Lines with the highest voltage over 7kV but not higher than 60kV	The voltage 1.25 times of the highest voltage (10.5kV when it is lower than 10.5kV) is impressed
Lines with the highest voltage over 60kV to be connected to the electrical circuit of the isolated neutral system	The voltage 1.25 times of the highest voltage is impressed
Lines with the highest voltage over 60kV to be connected to the electrical circuit of the solidly earthed neutral system	The voltage 1.1 times of the highest voltage (75kV when it is lower than 75kV) is impressed
Lines with the highest voltage over 170kV to be connected to the electrical circuit of the directly earthed neutral system	The voltage 0.72 times of the highest voltage is impressed

3 Thermal Strength of Electrical Equipment

It shall be confirmed that the temperature rise of the electrical equipment does not exceed the allowable maximum temperature of the electrical equipment or the maximum temperature under which there is no risk of damage to the electrical equipment, when the temperature rise test based on the following items and the standard concerning the electrical equipment is carried out.

3.1 Generators

The temperature rise of generators when operated with the rated load shall not exceed the allowable maximum temperature corresponding to its thermal strength class, and the thermal strength of generators shall be such that there is no risk of damage within the range of the allowable maximum temperature.

3.2 Bearings of hydraulic turbines and generators

The thermal strength of bearings of hydraulic turbines and generators shall be such that there is no risk of damage due to the maximum temperature to be generated in the bearing with the rated load.

3.3 Transformers

The temperature rise of transformers when operated with the rated load shall not exceed the allowable maximum temperature corresponding to its thermal strength class, and the thermal strength of transformers shall be such that there is no risk of damage within the range of the allowable maximum temperature.

3.4 Machines

This item shall apply to electrical circuits in switching devices, circuit breakers, reactors, power capacitors, instrument transformers, surge arresters, other machines, bus bars, and connection conductors for machines.

The temperature rise of machines when operated with the rated load shall not exceed the allowable maximum temperature corresponding to its thermal strength class, and the thermal strength of machines shall be such that there is no risk of damage within the range of the allowable maximum temperature.

4 Prevention of Damage to Pressure Tanks

- (1) The maximum operation pressure of pressure tanks has to be designed in consideration of the pressure rise by the operation pressure range and the maximum operation temperature.
- (2) “To withstand the gas pressure rising during fault continuous time at internal failure” means that there is not leakage of gas during failures and after failure removal in case the tank does not have devices for controlling the pressure rises.
- (3) Although standards such as sorts of material, allowable stress, and structure are not specified, the pressured part has to withstand the maximum operation pressure and it must be safe.

Article 17: Technical Documents of Electric Power Facilities

Article 18: Communication System

1 Conformity to International Standards

Installation of a communication system should be based on relevant standards of IEC, ITU(*), etc.

*ITU: International Telecommunication Union, which was established as an impartial, international organization within which governments and the private sector could work together to coordinate the operation of telecommunication networks and services and advance the development of communications technology.

2 Selection of Equipment for Telecommunication

In case of installation of the equipment, it is desirable to select the system in consideration of the importance, line length, amount of information, installation conditions, economical efficiency, etc.

Lines for telecommunication are very important as the nervous system to maintain the power system stably, safely and economically, because nowadays our daily life is supported by electricity which is treated as the same as air and water. Therefore high reliability and stability are requested for them.

In case of installation of facilities belonging to main electric power systems, it is desirable to apply reliable lines as shown in Table 5 of SREPTS.

3 Installation of Power Supply Equipment

It is desirable to install uninterruptible power supply systems as the service power source of communication facilities.

The power supply equipment should have high electric power supply reliability so that lines for communication and telecommunication can always work well even in case of electric system failures reliable lines as shown in Table 5 of SREPTS.

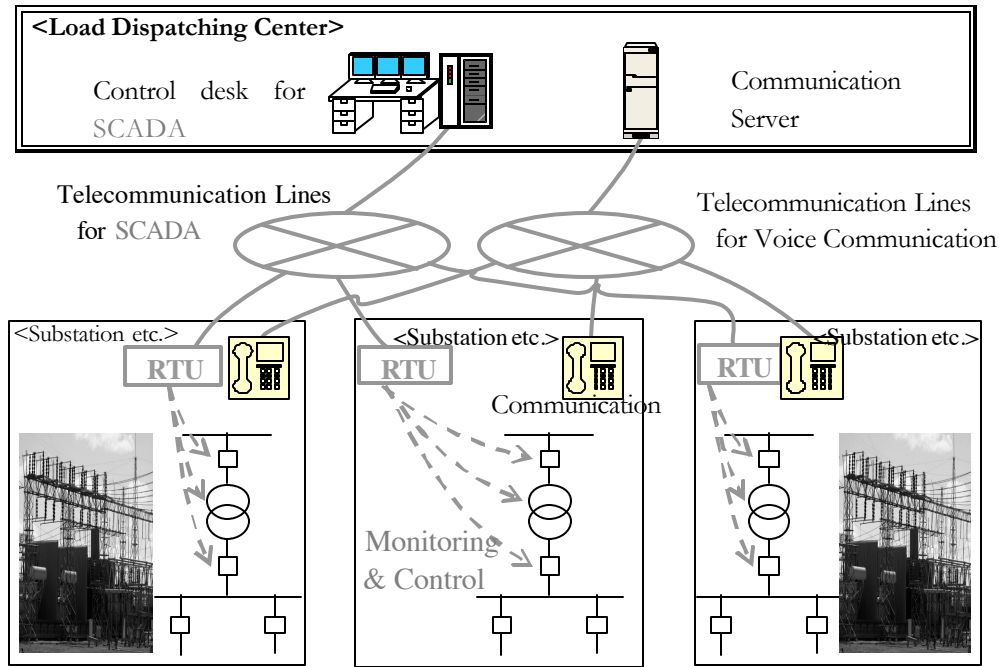


Figure ES18A Communication System

Article 19: Accuracy of Power Meters

The error of power meters is given by the equation below:

$$\varepsilon = M - T, \quad \varepsilon_0 = \frac{M - T}{T} \times 100(\%)$$

Where:

ε : Error

ε_0 : Percent Error (%)

M : True Value

T : Measurement Value

Power meters are classified by degree of allowable margin of error.

The classification of power meters is shown in ES 19A.

Table ES19A Class of Power Meters

Type of Customer	Class	Allowable Margin of Error for Rated Power (%)
High-voltage customer	Class 0.5	± 0.5
Medium-voltage customer	Class 1.0	± 1.0
Low-voltage customer	Class 2.0	± 2.0

Power Meters the accuracy of which has been tested shall be used for power energy measurement.

PART 2

Grounding

Article 20: General Requirements for Grounding

1 Danger to Human Beings

When human beings get in touch with a charged part, the link between the current and the influence to human beings is reported as follows:

Table ES20A Influence to Human Beings of Electrical Currents

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

Article 21: Classification of Grounding

Article 22: Grounding for Electrical Lines

1 Type of Grounding

1.1 System Grounding

System grounding is installed to protect a low-voltage line system against the faults that occur due to an accidental contact between medium-voltage and low-voltage inside a distribution transformer. It is stipulated as Class B grounding in GREPTS and SREPTS.

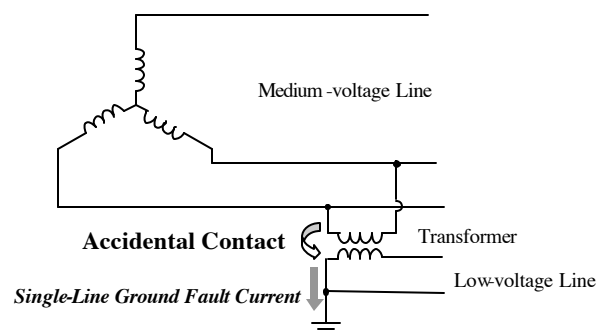


Figure ES22A: Accidental Contact between MV and LV

1.2 Safety Grounding

When the insulation for electrical equipment becomes deteriorated for some reasons, there is a danger of an electric shock due to the occurrence of abnormal voltage on exposed conductive parts such as steel stands, metal cabinets, metal tube, metal ducts, etc. outside the equipment. Safety grounding is installed to restrict excessive voltage to ground.

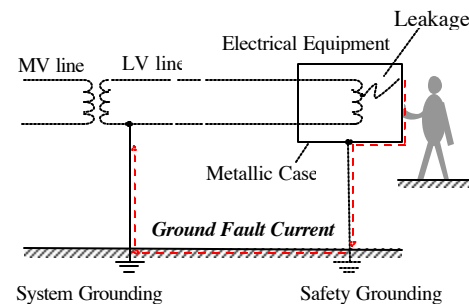


Figure ES22B: Protection against electric shock

1.3 Arrester Grounding

Arrester grounding is installed such that current of the lightning that attacked an arrester, or surge current can easily flow toward the earth.

1.4 Grounding for Measures against Electrostatic Hazard

This grounding is installed to discharge static electricity through the earth as soon as it is generated in order that static electricity should not be charged and lead to hazard.

1.5 Grounding for Measures against Noise

This grounding is installed to prevent electronic machine malfunction or degradation of telecommunication quality due to invasion of noise. Also it is installed to protect other machines against high-frequency energy that is produced inside the machine and leaks outside.

2 Class B Grounding

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

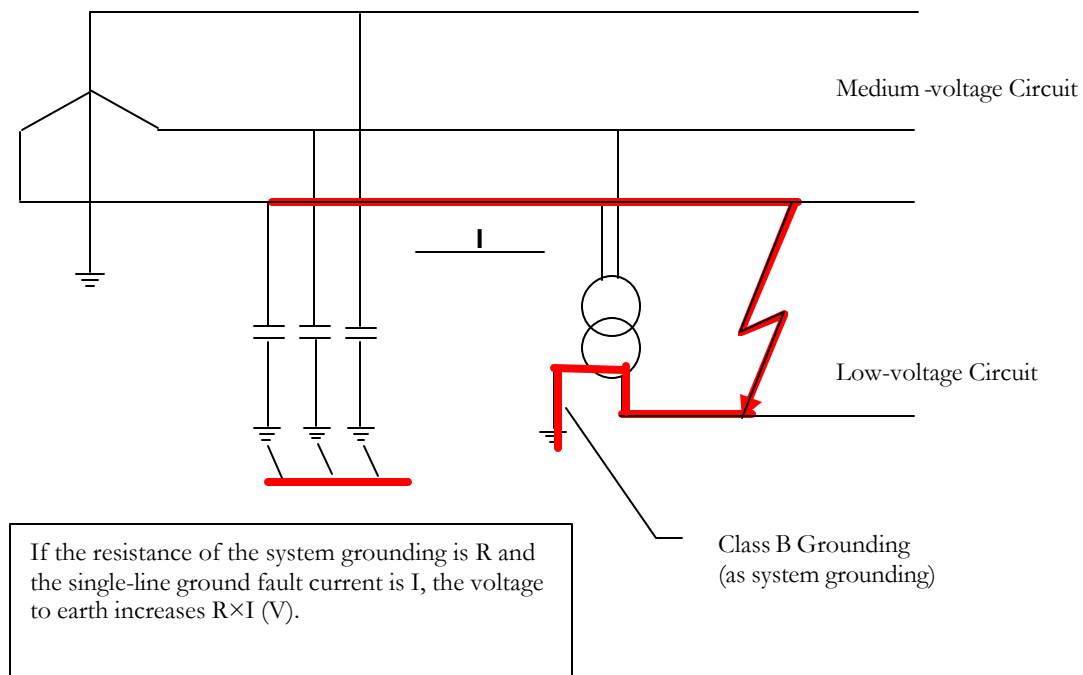


Figure ES22C: Class B Grounding and Single-line Ground Fault Current

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

When a medium-voltage line contacts a low-voltage line, the voltage of the low-voltage line will increase. Therefore if human beings get in touch with the low-voltage line, it is more dangerous compared with the normal situation.

Article 23: Grounding for Power Stations, Substations, Switching Stations and High-voltage and Medium-voltage User's Sites

1 Grounding for Electrical Facilities

1.1 Safety Grounding

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

It is said that allowable current to the human body is given in the following formula (Dr. C.F.Dalazial).

$$I_K = \frac{0.116}{\sqrt{t}} \text{ (A)}$$

where I_K : Allowable current to the human body (Arms)

t : Fault continuous time (sec)

Step-voltage (E_{STEP}) and touch-voltage (E_{TOUCH}) are calculated by the following. (Refer to Figure ES23A.)

$$E_{STEP} = (R_K + 2R_F)I_K$$

$$E_{Touch} = (R_K + \frac{R_F}{2})I_K$$

where I_K : Allowable current to the human body (Arms)

R_K : Resistance of the human body (O), 500 - 1000 O

R_F : Underfoot ground resistance (O), about 3ρ

ρ : Ground resistivity (O-m)

(Soil: 100 O-m, Concrete: 200 O-m, Gravel:3000 O-m, Asphalt:5000 O-m)

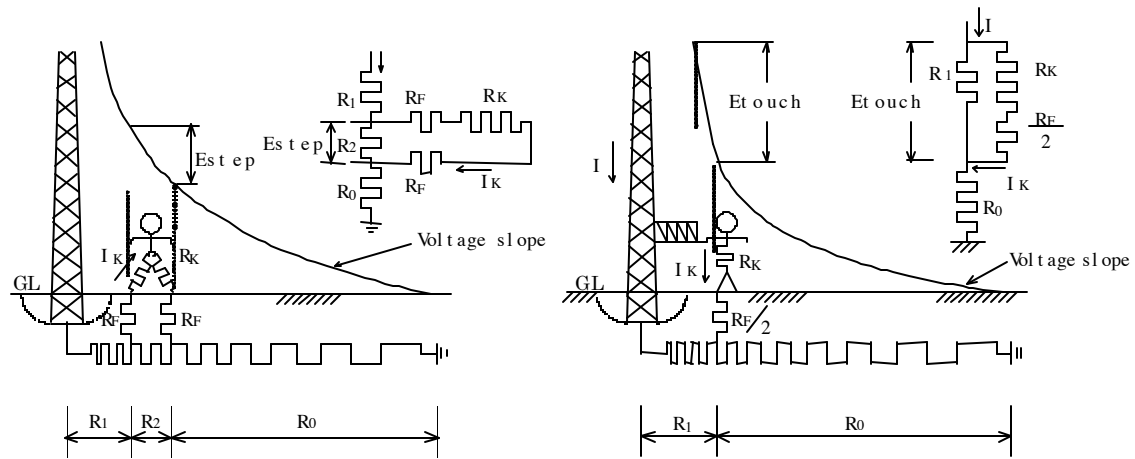


Figure ES23A: Step-voltage and Touch-voltage

(1) Grounding for Other Facilities

This paragraph regulates the safety grounding in order to prevent danger caused by the leak current or ground fault. It is easy to gain lower value of resistance to earth than regulated value in Clause 39 of GREPTS as long as it connects with the earth mesh in stations where the solidly earthed neutral system is applied.

Table ES23A: Examples of Grounding Work

Kind of Electrical Equipment	Kind of Grounding Work	Examples	
High-voltage electrical equipment	Class A	HV or MV electrical equipment	Metal fence for HV or MV electrical equipment
Medium-voltage electrical equipment			
Low-voltage electrical equipment (Over 300V)	Class C	400V 3φ motor	400V Control panel
Low-voltage electrical equipment (300V or lower)	Class D	230V motor	

(2) Grounding for Conductive Parts in Electrical Equipment

a. Grounding of Instrument Transformers

Class A grounding work is applied to the high-voltage and medium-voltage instrument transformers in order to protect the low-voltage electrical circuits in their secondary side, because the potential rise in secondary side is very big in an accident that breaks out the insulation of winding.

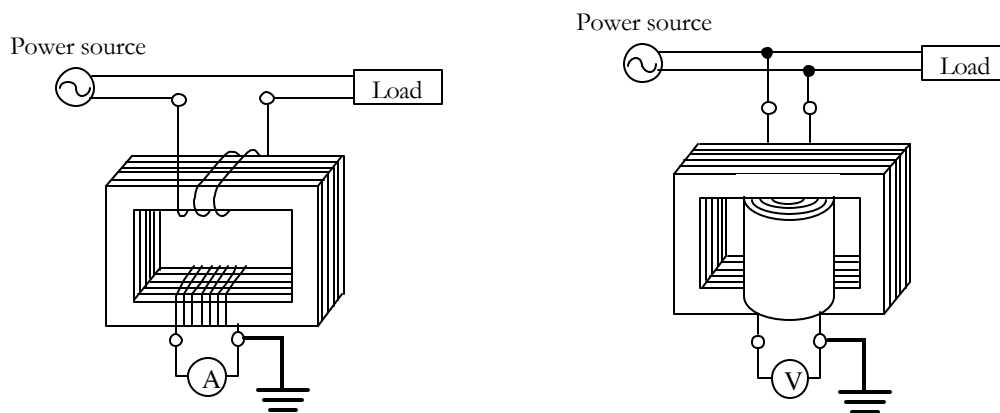


Figure ES23B: Examples of Grounding of Instrument T transformers

b. Grounding for Station Service Transformers

This paragraph is based on the same concept in Clause 39 of GREPTS, that is to say, Class B grounding shall be installed on the neutral of low-voltage side of MV/LV transformers.

c. Grounding for Stabilizing Windings in Transformers

In cases where grounding is provided for stabilizing windings and idle windings in high-voltage and medium-voltage transformers, Class A grounding work shall be provided.

Stabilizing windings are provided to reduce the zero phase impedance of star-star winding transformers. The winding connecting with the outgoing electrical circuit such as distribution lines shall not be grounded.

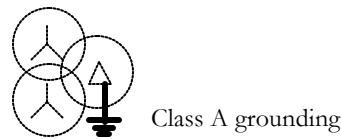


Figure ES23C: Grounding for Stabilizing Windings

<Y-Y-? connection (Star-Star-Delta Connection)>

Y-Y-? connection (Star-star-delta connection) consists of Y-Y connection (star-star connection) windings and a stabilizing winding (*) the shape of which is a ? connection.

The characteristics of Y-Y-? connection are as follows:

- Both the primary winding and the secondary winding can have the grounding for neutral point, and it is possible to reduce an abnormal voltage when a ground fault occurs,
- There is no phase angle difference between the each phase of the primary winding and that of the secondary winding, and generated third harmonic can flow through the stabilizing winding. This is why the third harmonic generated on each phase can be reduced.
- The zero phase impedance of the transformer can be reduced, because zero phase current that occurs in case of a single-line ground fault can flow through the stabilizing winding.
- Low-voltage electric power can be provided for power source for the substation and so on.

1.2 Grounding on Earth-return Side of SWER

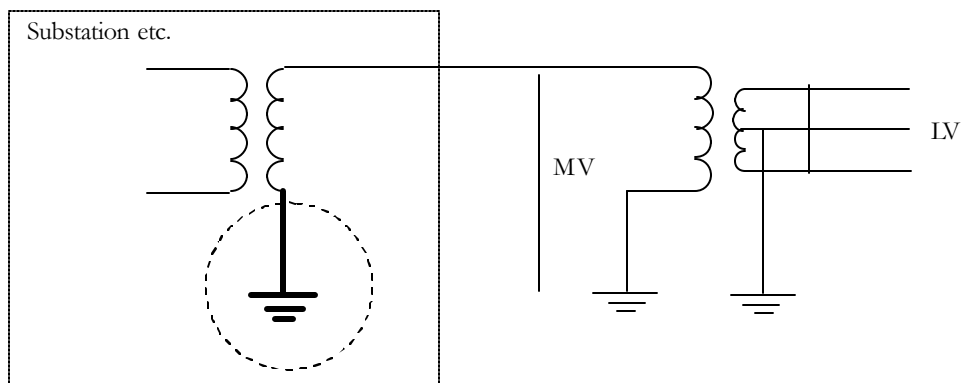


Figure ES23D: Grounding on Earth-return Side of SWER

1.3 Grounding for Lightning Guards

This paragraph provides the recommended grounding resistance for lightning guards. Lightning guards such as ground wires and lightning rods are installed in outdoor stations so as to protect against the direct-stroke lightning. The value of 10 ohm corresponding to Class A grounding work is applied as minimum grounding resistance. It should be reduced as low as possible so that the lightning guard can take effect sufficiently.



Figure ES23E: Ground Wire

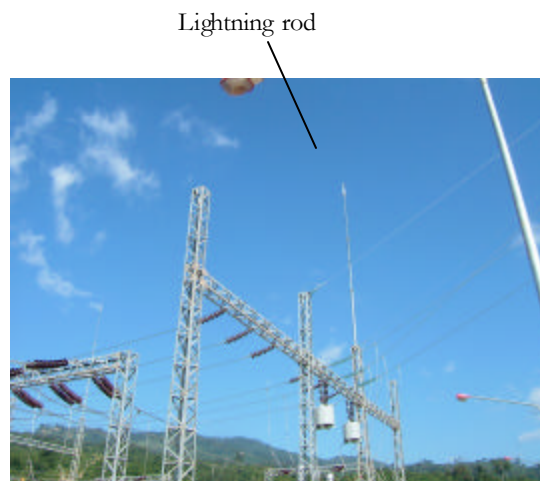


Figure ES23F: Lightning Rod

1.4 Grounding for Surge Arresters

This paragraph provides the recommended grounding resistance for surge arresters. The value of 10 ohm corresponding to Class A grounding work is applied as minimum grounding resistance. It should be reduced as low as possible so that the surge arrester can get take effect sufficiently.

It is no problem for the stations where the solidly neutral grounding is applied, because the resistance to earth may be 0.5 ohms or less necessarily.

2 Particularities of Grounding Arrangement

2.1 Properties of Grounding Conductors

(1) Mechanical Strength of Grounding Conductors

This paragraph provides the way to select the thickness of grounding conductors. The minimum thickness is decided according to mechanical strength.

This thickness may be applied to the grounding conductor without the ground current flowing in an accident. Therefore the metal fence and protective fence in facilities listed in Article 23-1.1.2 of SREPTS are applicable.

(2) Thermal Strength of Grounding Conductors

The following formula is used for calculating instant current rating of copper wires. (ANSI/IEEE Standard 80, 1986)

$$A = I \sqrt{\frac{TCAP \times 10^{-4}}{t_c \times \alpha_r \times \rho_r} \log_e \left(\frac{K_0 + T_m}{K_0 + T_a} \right)} \quad \text{----- formula 1}$$

where I : Current (kArms)

A : Cross sectional area of a wire (mm²)

T_m : Maximum allowable temperature (°C)

T_a : Ambient temperature (°C)

$K_0 = 1/\alpha_0$ or $(1/\alpha_r) - T_r$

T_r : Datum temperature of a constant (°C)

α_r : Coefficient of temperature at T_r

ρ_r : Resistivity of a wire at T_r ($\mu\Omega cm$)

α_0 : Coefficient of temperature at 0°C

t_c : Fault continuous time (sec.)

$TCAP$: Coefficient of thermal capacity ($J / cm^3 / ^\circ C$)

Table ES23B: Physical Constant of Copper Wires

Item	Conductivity (%)	α_r (20°C)	K_0	Melting Temp. (°C)	ρ_r (20°C) ($\mu\Omega cm$)	$TCAP$ ($J / cm^3 / ^\circ C$)
Annealed Copper wire	100.0	0.00393	234	1083	1.7241	3.422
Hard-drawn copper wire	97.0	0.00381	242	1084	1.7774	3.422

In case of $T_a = 40^\circ\text{C}$, formula 1 is transformed to the following by using the data of above annealed copper wire.

$$A = I \sqrt{\frac{8.5 \times 10^{-6} \times t}{\log_{10}\left(\frac{T}{274} + 1\right)}} \text{ ----- formula 2}$$

Where A : Necessary cross sectional area (mm^2)

I : Fault current (Three-phase short circuit) (Arms)

T : Maximum allowable temperature rise of grounding conductors ($^\circ\text{C}$)

t : Fault continuous time (sec)

A calculation example for necessary sectional area of grounding conductors according to formula 2 is given as Table ES23C.

Table ES23C: Example of Necessary Cross Sectional Area of Grounding Conductors Considered Thermal Strength

Nominal voltage (kV)	Fault current (kA)	Fault continuous time (sec)	Necessary sectional area (mm^2)
230	50	1	179
115	40	1	143
	31.5	1	113
22	25	2	127

Note: Maximum allowable temperature rise of grounding conductors is regarded 1000 ($^\circ\text{C}$)

2.2 Neutral Grounding Devices

<Neutral Grounding System>

Neutral resistors and neutral reactors are used in neutral grounding systems. The purposes of neutral grounding system are as follows:

- Prevention of the occurrence of abnormal voltage on electric lines due to the ground fault by arc of lightning attack
- Reduction of insulation for electrical lines or electrical equipment by control of rise of sound phase voltage in case of a ground fault
- Security of voltage or current that can operate protective equipment or relays reliably in order to break the failed part as soon as possible, by making current flow to the neutral point in case of a ground fault.

The types of neutral grounding system are as follows:

(1) Direct-grounding system

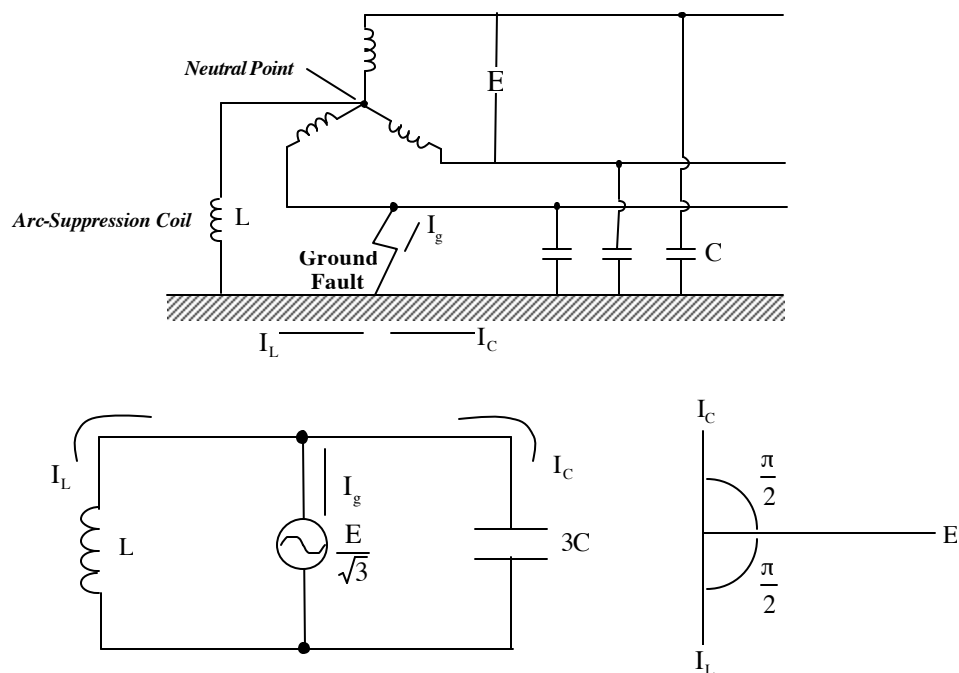
- A neutral point is directly connected to the ground.
- Abnormal voltage rarely occurs.
- It is possible to reduce insulation of electrical equipment because voltage of sound phase to ground does not rise very much in case of a ground fault.
- Measurements need to be taken because inductive interference to communication lines is remarkable when any accident occurs.
- Protective equipment or relays act reliably because a ground fault current is comparatively large.
- High speed breaking and re-close system is required so that the effect on other transmission lines can be as small as possible.

(2) Resistance grounding system

- A neutral point is connected to the ground through a resistance.
- When the resistance value is determined, both reliable acts of protective equipment or relays and severity of inductive interference to communication lines are taken into consideration.
- The sound phase voltage to ground rises in accordance with the resistance value.
- Inductive interference to communication lines can be small, if the resistance is set to a high value.

(3) Reactance grounding system by arc-suppression coil

- A neutral point is connected to the ground through an arc-suppression coil with the iron that has reactance resonating with the capacitance of the electric line to the ground, so that the single-line ground fault current should be 0 ampere.



$$\dot{I}_g = \dot{I}_C + \dot{I}_L = j3\omega CE + \frac{E}{j\omega L} = jE \left(3\omega C - \frac{1}{\omega L} \right)$$

$$\text{If the value of } L \text{ is set as } L \cong \frac{1}{3\omega^2 C}, \quad \dot{I}_g \cong 0$$

Figure ES23G: Resonance with the circuit capacitance

- There is a possibility of occurrence of abnormal voltage.
- In most cases when a temporary ground fault such as a lightning surge occurs, the arc is extinguished promptly and the operation can be continued without an outage.
- The damage to conductors, supporting structures such as insulators on an electrical line can be reduced in case of a ground fault.
- The inductive interference to communication lines can be reduced in case of a fault.
- An operation for this system becomes very complicated.
- The construction cost of this system is comparatively high.

(4) Isolated neutral system

- A neutral point is not connected to the ground.
- There is a possibility of occurrence of abnormal voltage.
- There is a fear that sound phase to the ground rises to $\sqrt{3}$ times (it equals to phase voltage) in case of a ground fault, therefore it is necessary to reinforce the insulating strength.
- The inductive interference to communication lines can be reduced in case of a fault.
- It is necessary to use more sensitive protective equipment or relays, because a ground fault current is comparatively small.

Article 24: Grounding for Distribution Lines and Low-voltage Users' Sites

1 Particularities of Grounding Arrangement

1.1 Grounding Electrodes

Materials and size for grounding electrodes are recommended in IEC60364-5-54 as Table ES24A.

Table ES24A: Common Minimum Sizes for Grounding Electrodes of Commonly Used Material from the Point of View of Corrosion and Mechanical Strength Where Embedded in the Soil

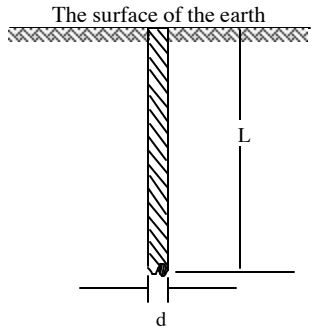
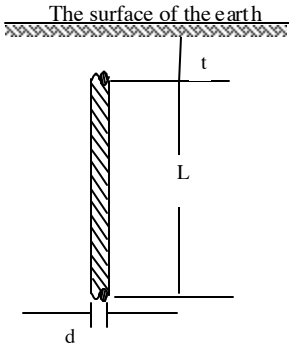
Material	Surface	Shape	Minimum size				
			Diameter mm	Cross- sectional area mm ²	Thick -ness mm	Thickness of coating/sheathing	
						Individual value, m	Average value, m
Steel	Hot-dip galvanized ^a or Stainless ^{a, b}	Strip ^c		90	3	63	70
		Round rod for deep earth electrodes	16			63	70
		Round wire for surface electrode ^g	10				50 ^e
		Pipe	25		2	47	55
	Copper- sheathed	Round rod for deep earth electrode	15			2 000	
	With electro- deposited copper coating	Round rod for deep earth electrode	14			90	100
	Copper	Bare ^a	Strip		50	2	
Round wire for surface electrode ^g				25 ^f			
Rope			1,8 for individual strands of wire	25			
Pipe			20 1,8 for individual strands of wire		2		
Tin-coated		Rope		25		1	5
Zinc-coated		Strip ^d		50	2	20	20

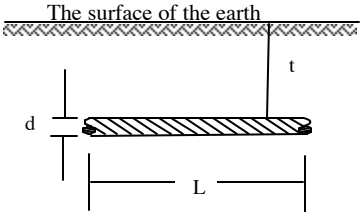
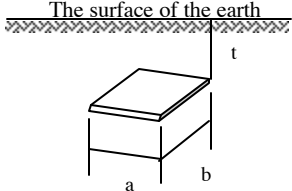
- a Can also be used for electrodes to be embedded in concrete.
- b No coating applied.
- c As rolled strip or slit strip with rounded edges.
- d Strip with rounded edges.
- e In the case of continuous bath coating, only 50 μ m thickness is technically feasible at present.
- f Where experience shows that the risk of corrosion and mechanical damage is extremely low, 16 mm² can be used.
- g An earth electrode is considered to be as a surface electrode when installed at a depth not exceeding 0,5 m.

[Reference]

The grounding resistance of a few grounding electrodes that have simple shapes is calculated as the following Table ES24B, on the supposition that there is an equipotential surface under the ground and that its current flows vertically into the electrode.

Table ES24B: Theoretical Formulas for the Calculation of the Grounding Resistance

Shape of a grounding electrode	Theoretical formulas for the calculation
<p>Round Rod</p> 	<p>If $L \gg d$,</p> $R = \frac{\rho \ln \frac{2L + d}{d}}{2\pi L} = \frac{\rho \ln \frac{2L}{d}}{2\pi L}$
<p>Round Rod</p> 	$R = \frac{\rho}{2\pi} \left\{ \frac{1}{L} \ln \frac{2t(L + d)}{d(L + 2t)} + \frac{1}{L + t} \ln \frac{L + 2t}{t} \right\}$

<p>Round Rod</p> 	$R = \rho \left\{ \frac{1}{2\pi L} \ln \frac{2t(L+d)}{d(L+2t)} + \frac{1}{\sqrt{-q}} \ln \frac{\pi(L+6t) + \sqrt{-q}}{\pi(L+6t) - \sqrt{-q}} \right\}$ <p>where $q = 16\pi tL - \pi^2(L+2t)^2$</p>
<p>Flat rectangle plate</p> 	$R = \frac{\rho}{2\pi} \left\{ \frac{1}{2} \left(\sqrt{\frac{2\pi}{ab}} - \frac{1}{t} \right) + \frac{1}{t} \ln 2 \right\}$

Where:

ρ : Resistivity of the soil

\ln : Natural logarithm

1.2 Grounding Conductors and Protective Conductors

IEC 60364-5-54 "Electrical installations of buildings- Selection and erection of electrical equipment Earthing arrangements, protective conductors and protective bonding conductors" provides subjects on grounding conductors and protective conductors.

Tables in Article 24 of SREPTS are given according to the IEC standard. Factor k in Table 11C, however, is simplified for easy calculation. On different conditions from the note of Table 11C, the following Tables are helpful.

Table E S24C: Minimum Cross-sectional Area of Protective Conductors

Cross-sectional area of line conductor S (mm ²)	Minimum cross-sectional area of the corresponding protective conductor (mm ²)	
	If the protective conductor is the same material as the line conductor	If the protective conductor is not the same material as the line conductor
$S \leq 16$	S	$k_1/k_2 \times S$
$16 < S \leq 35$	16	$k_1/k_2 \times 16$
$S > 35$	$S/2$	$k_1/k_2 \times S/2$

* k_1 is the value of k for the line conductor and selected from Table ES24D.

* k_2 is the value of k for the protective conductor and selected from tables ES24E to 24I.

Table ES24D: Value of k_1 for the Line Conductors

Conductor insulation	Material of conductor	
	Copper	Aluminum
	Values for k	
PVC $\leq 300\text{mm}^2$	115	76
PVC $>300\text{mm}^2$	103	68
EPR / XLPE	143	94
60°C rubber	141	93

* k_1 for various types of conductor insulation are given in IEC 30364-4-43

Table ES24E: Value of k_2 for Insulated Protective Conductors Not Incorporated in Cables and Not Bunched with Other Cables

Conductor insulation	Temperature °C ^b		Material of conductor		
			Copper	Aluminum	Steel
	Initial	Final	Values for k		
70 °C PVC	30	160/140 ^a	143/133 ^a	95/88 ^a	52/49 ^a
90 °C PVC	30	160/140 ^a	143/133 ^a	95/88 ^a	52/49 ^a
60 °C thermosetting*	30	250	176	116	64
60 °C rubber	30	200	159	105	58
85 °C rubber	30	220	166	110	60
Silicone rubber	30	350	201	133	73
^a The lower value applies to PVC insulated conductors of cross-sectional area greater than 300mm ²					
^b Temperature limits for various types of insulation are given in IEC 60724					

*Thermosetting: Phenol resin

Table ES24F: Value of k_2 for Bare Protective Conductors in Contact with Cable Covering but Not Bunched with Other Cables

Cable covering	Temperature °C ^a		Material of conductor		
			Copper	Aluminum	Steel
	Initial	Final	Value for k		
PVC	30	200	159	105	58
Polyethylene	30	150	138	91	50
CSP*	30	220	166	110	60
^a Temperature limits for various types of insulation are given in IEC 60724					

* CSP: Chlorosulfone PE

Table ES24G: Value of k_2 for Protective Conductors as a Core Incorporated in a Cable or Bunched with Other Cables or Insulated Conductors

Cable covering	Temperature		Material of conductor		
	°C ^b		Copper	Aluminum	Steel
	Initial	Final	Values for k_2		
70 °C PVC	70	160/140 ^a	115/103 ^a	76/68 ^a	42/37 ^a
90 °C PVC	90	160/140 ^a	100/86 ^a	66/57 ^a	36/31 ^a
90 °C thermosetting	90	250	143	94	52
60 °C rubber	60	200	141	93	51
85 °C rubber	85	220	134	89	48
Silicone rubber	180	350	132	87	47
^a The lower value applies to PVC insulated conductor of cross-sectional area greater than 300mm ²					
^b Temperature limits for various types of insulation are given in IEC 60724					

Table ES24H: Value of k_2 for Protective Conductors as a Metallic Layer of a Cable e.g. Armor, Metallic Sheath, Concentric Conductor, etc.

Cable insulation	Temperature		Material of conductor			
	°C ^a		Copper	Aluminum	Lead	Steel
	Initial	Final	Values for k_2			
70 °C PVC	60	200	141	93	26	51
90 °C PVC	80	200	128	85	23	46
90 °C thermosetting	80	200	128	85	23	46
60 °C rubber	55	200	144	95	26	52
85 °C rubber	75	220	140	93	26	51
Mineral PVC covered ^b	70	200	135	-	-	-
Mineral bare sheath	105	250	135	-	-	-
^a Temperature limits for various types of insulation are given in IEC 60724.						
^b This value shall also be used for bare conductors exposed to touch or in contact with combustible material.						

Table ES24I: Value of k for Bare Conductors Where There Is No Risk of Damage to Any Neighboring Material by the Temperature Indicated

		Material of conductor					
		Copper		Aluminum		Steel	
Condition	Initial temperature °C	k value	Maximum temperature °C	k value	Maximum temperature °C	k value	Maximum temperature °C
Visible and in restricted area	30	228	500	125	300	82	500
Normal conditions	30	159	200	105	200	58	200
Fire risk	30	138	150	91	150	50	150

The relationship between grounding conductors and protective conductors is as Figure ES24A.

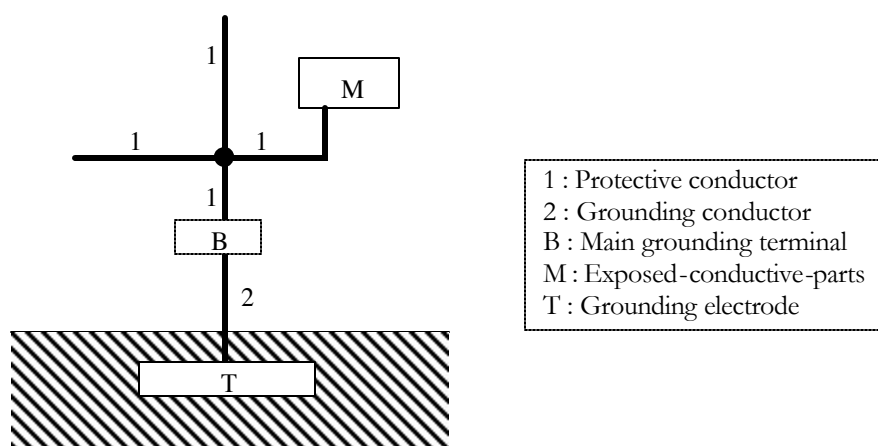


Figure ES24A: Grounding Conductors and Protective Conductors

1.3 Installation of Grounding Electrodes and Conductors

When a fault current flows into a grounding conductor and electrode, voltage is generated between the ground and the grounding electrode due to resistance of the grounding electrode and the voltage gradient appears on the surface of the ground around the grounding electrode. Therefore where the Class A or Class B grounding is installed, grounding electrodes shall be embedded with appropriate depths and grounding conductors placed up to a depth of 75cm underground or up to a height of 2.0 m aboveground shall be covered by a synthetic resin pipe or another shield of equivalent or higher insulating effect and strength. (Refer to Figure ES24B)

When voltage generated by a fault current flowing into a grounding conductor is transmitted directly to the iron pole or the voltage is transmitted to the iron pole near the electrode in the soil, the voltage gradient will be very high on the surface of the ground.

These paragraphs are provided to avoid electric shock to human beings and livestock because of such voltage gradient.

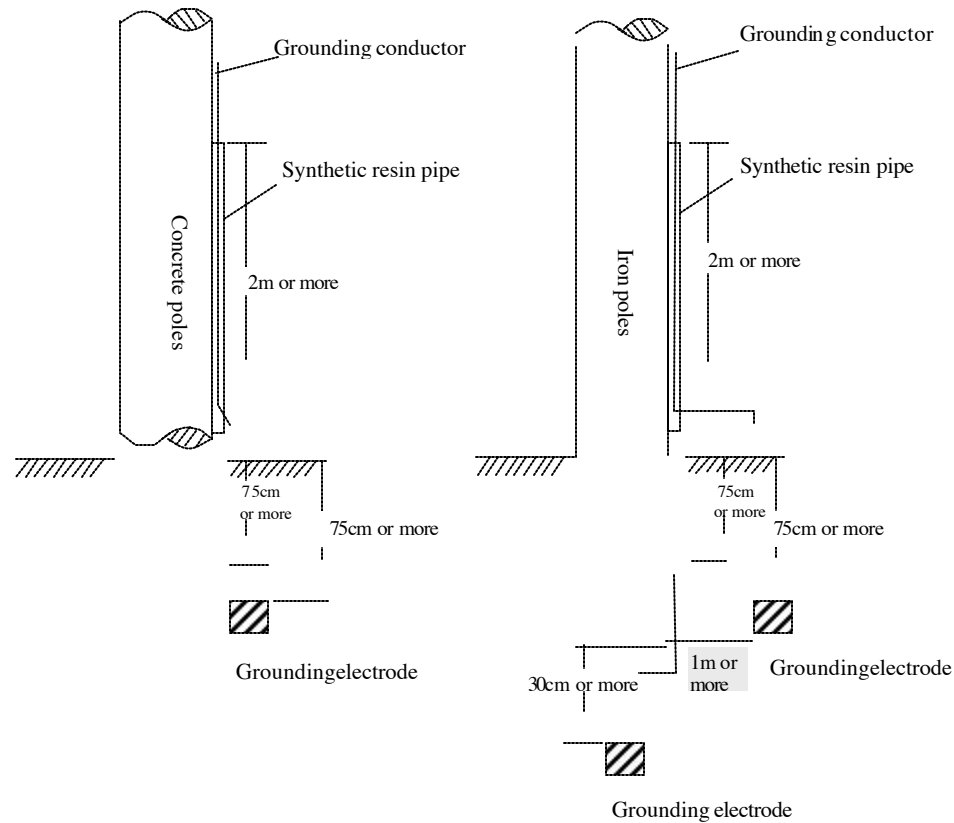


Figure ES24B: Installation of Grounding Electrodes and Conductors for Class A and B Grounding

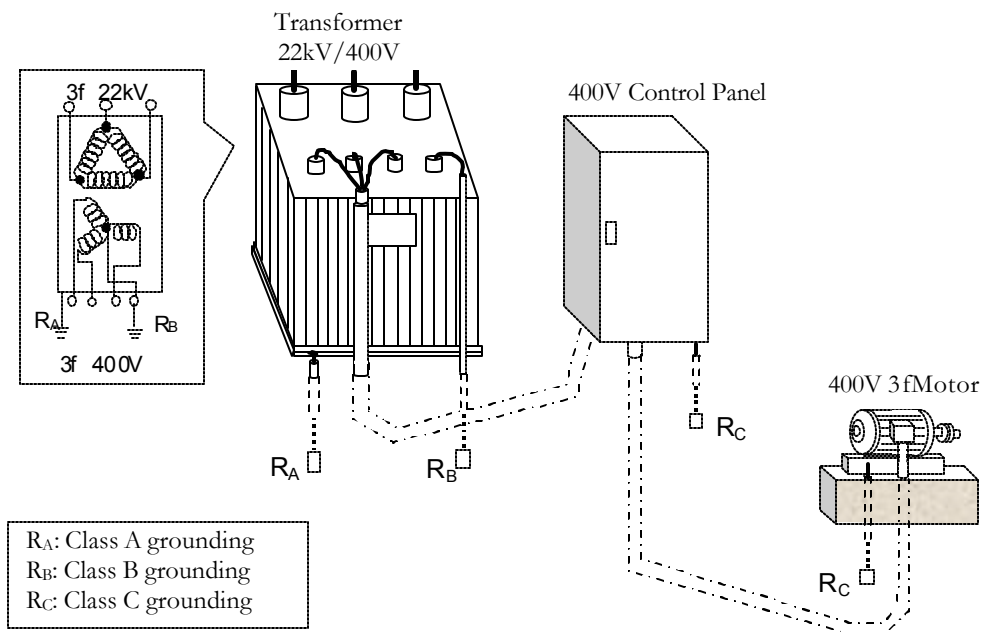


Figure ES24C: Examples of Grounding

2 Class B Grounding Resistance

2.1 Medium-voltage Electrical Circuit of Isolated Neutral System

(1) Electrical Circuits Using an Electric Conductor Other Than a Cable

Single-line ground fault current (I_g) is calculated by the formula given in Figure ES24D.

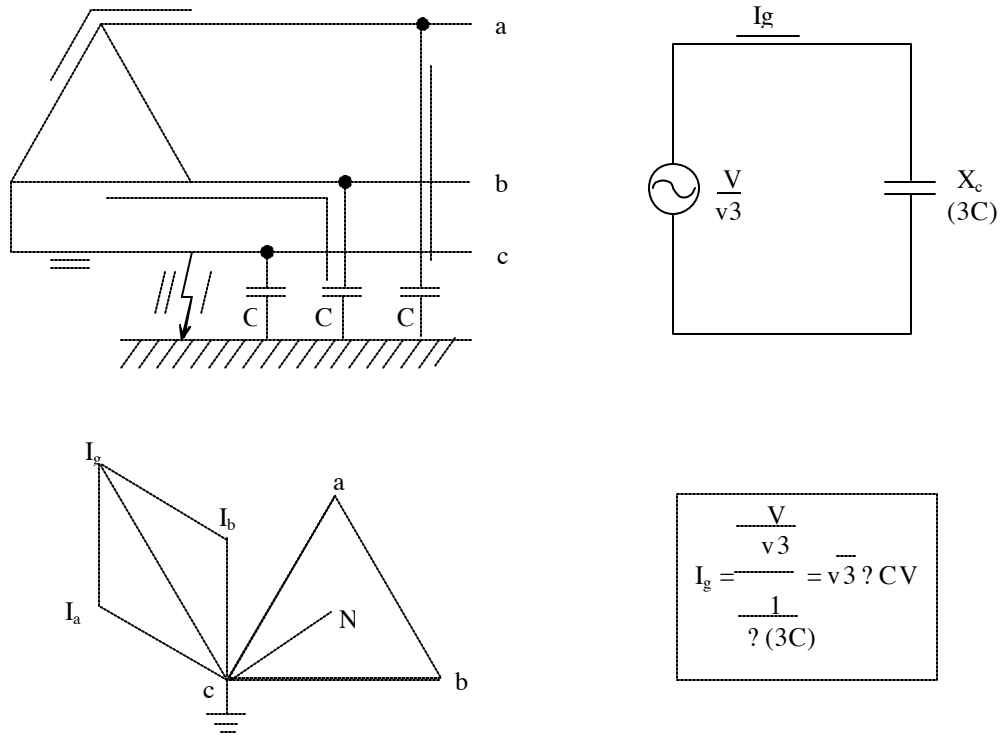
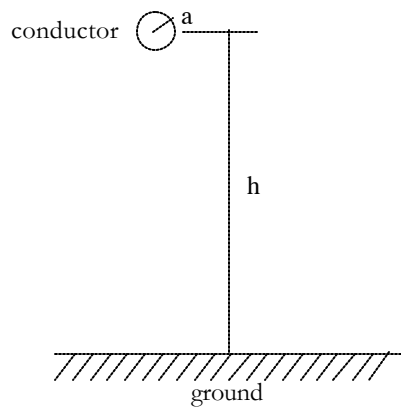


Figure ES24D: Calculation of Single-line Ground Fault Current



a : radius of a conductor
h : height of a conductor from the ground

$$C = \frac{0.02413 \times 10^{-9}}{\log_{10} \frac{2h}{a}} \quad (\text{F/m})$$

Figure ES24E: Calculation of Capacitance between a Conductor and the Ground

Single-line ground fault current (I_g) for electrical circuits using an electric conductor other than a cable is calculated as follows:

(Calculation conditions)

Item	Value	Selection reason
Height of the overhead line	5.5m	The value is given in Clause 54 of GREPTS. “The height of MV lines shall be not less than 5.5m.”
Type of the conductor	150mm ² AAC	The maximum size of MV lines conductor used by EDC
Radius of the conductor	8.04mm	From the above conductor

Capacitance (C) is calculated by using the formula given in Figure ES24E.

$$\begin{aligned}
 C &= \frac{0.02413 \times 10^{-9}}{\log_{10} \frac{2h}{a}} \\
 &= \frac{0.02413 \times 10^{-9}}{\log_{10}(2 \times 5.5 / 0.008)} \\
 &= 7.689 \times 10^{-12} \quad (\text{F/m})
 \end{aligned}$$

Hence, using the formula in Figure ES24D,

$$\begin{aligned}
 I_g &= \sqrt{3} \omega C V \\
 &= \sqrt{3} \times 2\pi \times 50 \times 7.689 \times 10^{-12} \times 22 \times 10^3 \\
 &= 0.092 \quad (\text{A/km})
 \end{aligned}$$

According to Clause 39 of GREPTS, Class B grounding resistance (R_B) shall be 10Ω or less, and when $\frac{230}{I_g}$

is less than 10, the resistance shall be the value of $\frac{230}{I_g}$ or less.

In other words, when I_g is more than 23A (the conductor distance is more than 250km ($\frac{23}{0.092} = 250\text{km}$)), the value of $\frac{230}{I_g}$ shall be used for deciding R_B .

250km of conductor length means 83.3km of line length. This value is too high for a MV line. Therefore it is understood that $\frac{230}{I_g}$ shall not be considered for electrical circuits using an electric conductor other than a cable.

- (2) Electrical Circuits Using a Cable for an Electrical Conductor or Electrical Circuits Using an Cable and Electrical Conductor Other Than a Cable for an Electrical Conductor

Single-line ground fault current (I_g) for electrical circuits using a cable for an electrical conductor is calculated as follows:

(Calculation conditions)

Item	Value	Selection reason
Type of the cable	3×240mm ² Al 3×300mm ² Al	The maximum size of MV line conductor used by EDC is 3×240mm ² Al. Taking into consideration a safety margin, the upper size was also considered.
Capacitance of the conductor	350nF/km	The value depends on the manufacturer. Since the capacitance is between 300 and 350nF/km, the maximum value was selected.

$$\begin{aligned}
 I_g &= \sqrt{3}\omega CV \\
 &= \sqrt{3} \times 2\pi \times 50 \times 350 \times 10^{-9} \times 22 \times 10^3 \\
 &= 4.19 \text{ (A/km)}
 \end{aligned}$$

(i) When 230/I is applied for Class B grounding resistance calculation;

$$R_B = \frac{230}{4.19 \times 3 \times l} = \frac{18.3}{l} (\Omega) \quad \text{Where: } l \text{ line length (km)}$$

(ii) When 600/I is applied for Class B grounding resistance calculation;

$$R_B = \frac{600}{4.19 \times 3 \times l} = \frac{47.7}{l} (\Omega) \quad \text{Where: } l \text{ line length (km)}$$

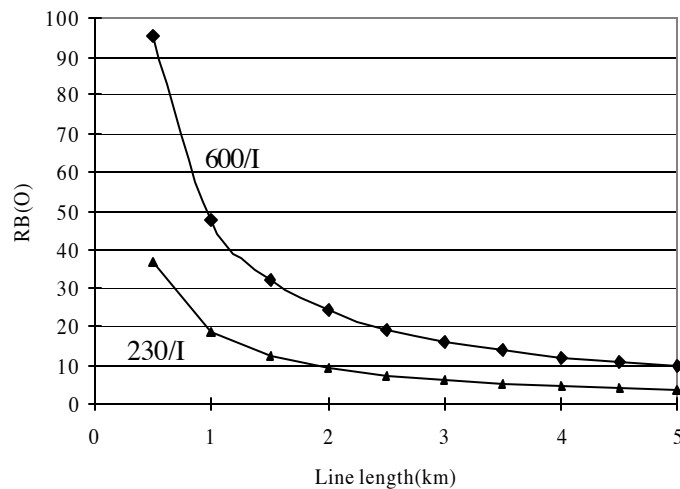


Figure ES24F: Relationship between the Class B Grounding Resistance and the Line Length

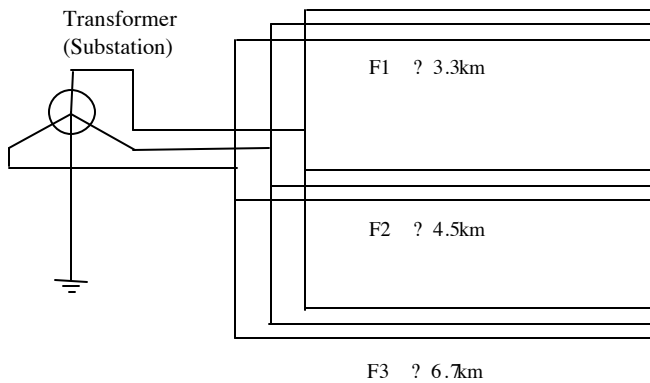
Table11E and Table11F in Article 24 of SREPTS were decided according to the above consideration.

[Example]

(LEGEND)

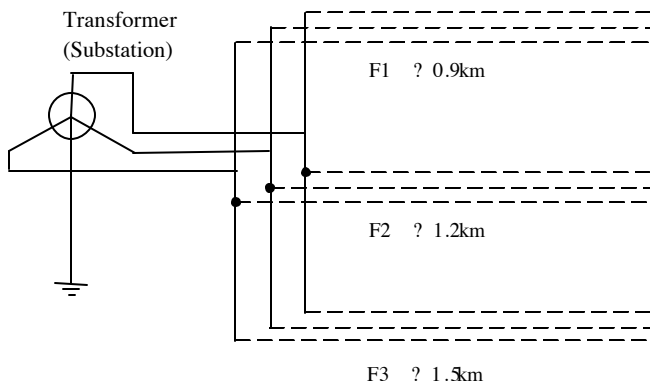
- An electrical conductor other than a cable
 - - - - - A cable for an electrical conductor

[Case 1]



According to Article 24-2.1 (1), Class B grounding resistance shall be not more than 10.

[Case 2]



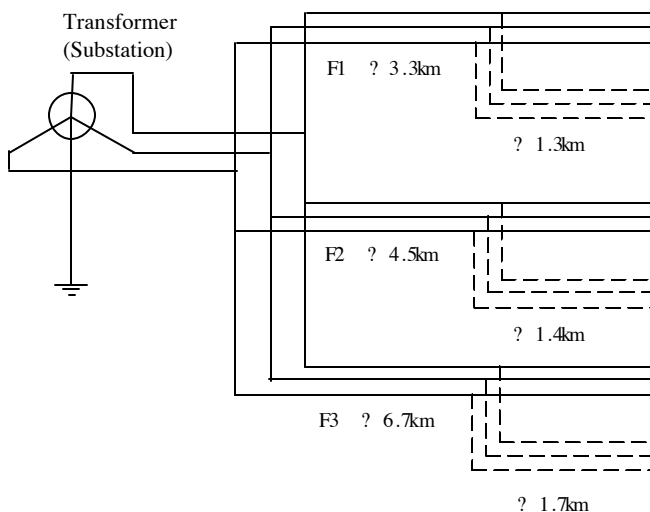
$$L = 0.9 + 1.2 + 1.5 = 3.6(\text{km})$$

According to Article 24-2.1 (2), Class B grounding resistance R_B shall be as follows;

$$R_B \leq 50 \quad (\text{if it is decided by '230/I'})$$

$$R_B \leq 100 \quad (\text{if it is decided by '600/I'})$$

[Case 3]



$$L = 1.3 + 1.4 + 1.7 = 4.4(\text{km})$$

According to Article 24-2.1 (2), Class B grounding resistance R_B shall be as follows;

$$R_B \leq 50 \quad (\text{if it is decided by '230/I'})$$

$$R_B \leq 100 \quad (\text{if it is decided by '600/I'})$$

2.2 Medium-voltage Electrical Circuit of Solidly Grounded Neutral System

$$I_2 = \sqrt{I_1^2 + \frac{V^2}{3R^2} \times 10^6}$$

* Any fraction less than the decimal point shall be rounded up.

Where:

I_2 : Single-line ground fault current, in A;

I_1 : Single-line ground fault current of the electrical circuit in case of no solidly system grounding which is calculated by a theoretical formula, in A;

V : Nominal system voltage of the electrical circuit, in kV;

R : Electric resistance value of the resistance used in the neutral point (including the resistance to ground value of the neutral point), in Ω .

The phase relationship of I_1 and I_2 is shown in Figure ES24G.

The single-line ground fault is regarded as charging current according to the capacitance between conductors and the ground. Therefore, i_a and i_b lead V_{ca} and V_{cb} respectively by 90 degree. I_1 leads E_{cn} by 90 degree.

On the other hand, the phase of I_R is the same as that of E_{cn} and is given by

$$I_R = \frac{E_{cn}}{R} = \frac{V/\sqrt{3}}{R} = \frac{V}{\sqrt{3}R}$$

Hence, the single-line ground fault current I_2 is given by

$$I_2 = \sqrt{I_1^2 + I_R^2} = \sqrt{I_1^2 + \frac{V^2}{3R^2} \times 10^6}$$

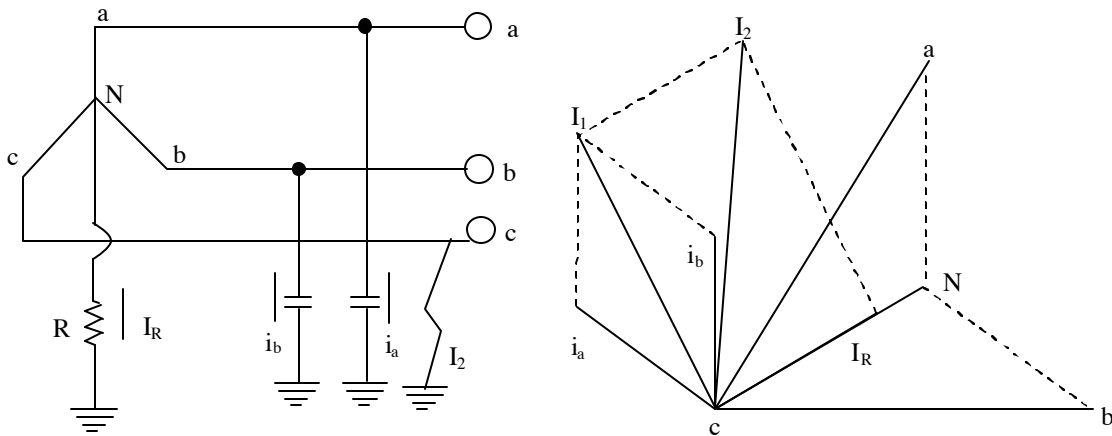
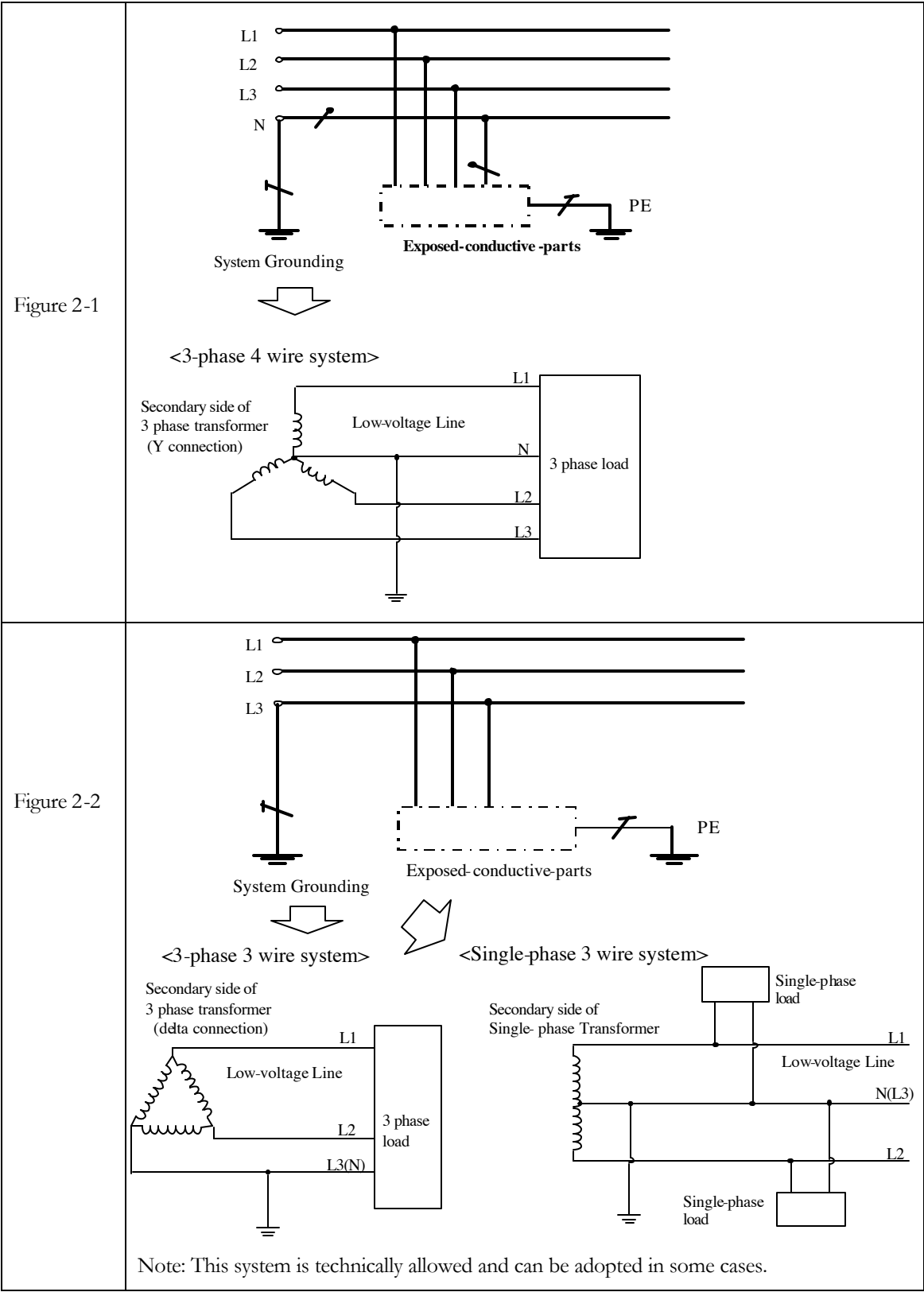


Figure ES24G: Single-line Ground Fault Current in Medium-voltage Electrical Circuits of Solidly Grounded Neutral System

3 Grounding Systems for Low-voltage Lines

<Explanation about “Figure 2 TT system” on SREPTS>

The difference between Figure 2-1 and Figure 2-2 is the difference of low-voltage supply system.



<IT system>

Besides TT system and TN system, IT system is provided in IEC60364-1. The IT system has all parts isolated from ground or one point connected to ground through an impedance, the exposed-conductive-parts of the electrical installation being grounded independently or collectively or to the grounding of the system. Because this system is not used in this country and there is little possibility of being used, it is not provided in Article 24 of SREPTS.

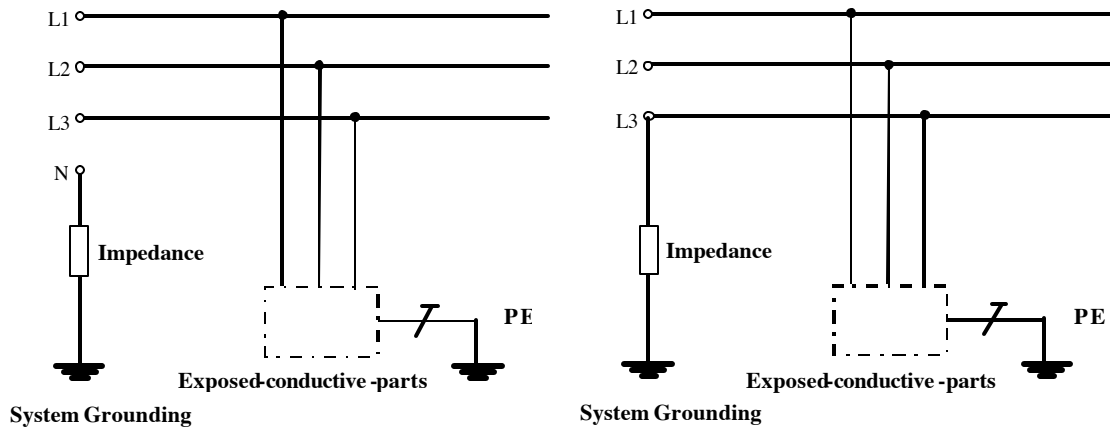


Figure ES24H: IT System

<IEC Nomenclature>

IEC 60364 series distinguish three families of grounding systems using the two-letter codes TN, TT and IT.

The first letter indicates the connection between earth and power-supply equipment (generator or transformer);

T: direct connection of a point with earth (“T” derives from French word ”Terre”).

I: no point is connected with earth (isolation), except perhaps via a high impedance.

(“I” derives from “Isolation”).

The second letter indicates the connection between earth and an exposed conductive part of electrical equipment.

T: direct connection with earth, an exposed conductive part of electrical equipment;

N: connection to earth via the neutral point of supply network. (“N” derives from “Neutral”).

If there are three letters, the third letter indicates the treatment of N conductor and PE conductor.

S: N conductor and PE conductor are separated.

C: N conductor and PE conductor are combined into one conductor.

<Properties of each grounding system>

3.1 TT system

(1) Characteristic

The system has one point directly earthed, the exposed-conductive parts of the installation being connected to earth electrodes electrically independent of the earth electrodes of the system.

(2) Protection against Ground Fault

An earth leakage circuit breaker can be used for the protection against ground fault.

3.2 TN system

In a TN system, the system grounding and the safety grounding for electric equipment are combined, one of the points in the system is connected directly with earth, and an exposed conductive part of an electric equipment is connected with this system grounding point by means of a PE conductor. There are three methods in TN system.

(1) TN-S system

a. Characteristic

Throughout a TN-S system, N conductor and PE conductor are separated, and the exposed conductive part is connected to the PE conductor.

b. Protection against Ground Fault

An earth leakage circuit breaker or an over current breaker can be used.

(2) TN-C system

a. Characteristic

Throughout a TN-C system, neutral and protective functions are combined in a single conductor (PEN conductor), and the exposed conductive part is connected to the PEN conductor.

b. Protection against Ground Fault

It is impossible to detect zero-phase current because PEN conductor is used as both as PE and N. Therefore, an earth leakage circuit breaker cannot be used. Only an overcurrent breaker can be used.

However considering safety in case of practical use, it is better to protect end parts against ground fault by an earth leakage circuit breaker, on the condition that the end part is converted TN-C system into TN-S system. (That is to say, TN-S-C system is adopted as total system.)

(3) TN-C-S system

a. Characteristic

Throughout a TN-C-S system, neutral and protective functions are combined in a single conductor in a part of the system. (Part of the system uses a combined PEN conductor, which is at some point split up into separate PE and N conductors. It is possible to have both TN-S and TN-C-S supplies from the same transformer.

b. Protection against Ground Fault

An over current breaker can be used in all part of the system, and an earth leakage circuit breaker can be adopted in the part where TN-S system is partly adopted.

3.3 IT system

(1) Characteristic

As a system grounding, an isolated grounding system or a high-resistance grounding system is adopted. And as a safety grounding of electrical equipment, an exposed conductive part is combined to the earth severally or all together.

(*) Isolated Grounding System: The grounding system that all charged parts of the system is isolated from the earth.

High-resistance Grounding System: One of the points in the system is combined with the earth by means of a high impedance resistance.

(2) Protection against Ground Fault

It is impossible to detect zero-phase current, therefore, a supervisory instrument for insulation is usually used for detecting ground fault.

Table ES24J: Explanation of TT System, TN System (IEC 60364-1)

Systems	Explanation
TT system	The TT system has one point directly earthed, the exposed-conductive-parts of the installation being connected to earth electrodes electrically independent of the earth electrodes of the power system.
TN system	TN power systems have one point directly earthed, the exposed-conductive-parts of the installation being connected to that point by protecting conductors. Three types of TN system are considered according to the arrangement of neutral and protective conductors, as follows; (TN-S system) in which throughout the system, a separate protective conductor is used; (TN-C-S system)

	<p>in which neutral and protective functions are combined in a single conductor in a part of the system; (TN-C system)</p> <p>in which neutral and protective functions are combined in a single conductor throughout the system.</p>
IT system	The IT power system has all live parts isolated from earth or one point connected to earth through an impedance, the exposed-conductive parts of the electrical installation being earthed independently or collectively or to the grounding of the system.

The neutral conductor is intended to carry current in the circuit under normal conditions. An earthing (or bonding or grounding) conductor is intended to carry current only when a fault has developed in the circuit insulation.

As described in Article 13.3, low-voltage electrical equipment to be installed at user's sites shall be installed according to IEC's 60364 series. The IEC's 60364 series has many items and mentions various contents. These may be simplified and provided in SREPTS. However these parts should be considered after regulation policy for house wiring is issued by MIME.

Relevant IEC standards are shown in Table ES24K.

Table ES24K: IEC60364 Series

IEC Standards	Document name
60364-1	Electrical installations of buildings - Part 1: Fundamental principles, assessment of general characteristics, definitions
60364-4-41	Electrical installations of buildings - Part 4-41: Protection for safety -Protection against electric shock
60364-4-42	Electrical installations of buildings - Part 4-42: Protection for safety -Protection against thermal effects
60364-4-43	Electrical installations of buildings - Part 4-43: Protection for safety -Protection against over-current
60364-4-44	Electrical installations of buildings - Part 4-44: Protection for safety -Protection against voltage disturbances and electromagnetic disturbances
60364-5-51	Electrical installations of buildings - Part 5-51: Selection and erection of electrical equipment - Common rules
60364-5-52	Electrical installations of buildings - Part 5-52: Selection and erection of electrical equipment - Wiring systems
60364-5-53	Electrical installations of buildings - Part 5-53: Selection and erection of electrical equipment - Isolation, switching and control
60364-5-54	Electrical installations of buildings - Part 5-54: Selection and erection of electrical

	equipment - Earthing arrangements, protective conductors and protective bonding conductors
60364-5-55	Electrical installations of buildings - Part 5-55: Selection and erection of electrical equipment - Other equipment
60364-5-61	Electrical installations of buildings - Part 6-61: Verification - Initial verification
630364-7-701 to 715,717,740	Electrical installations of buildings. Part 7: Requirements for special installations or locations

PART 3

Conductor

Article 25: Conductors for Transmission and Distribution Facilities

1 Property of Conductors

1.1 Example (Structure of a Cable Used in Medium-voltage Line)

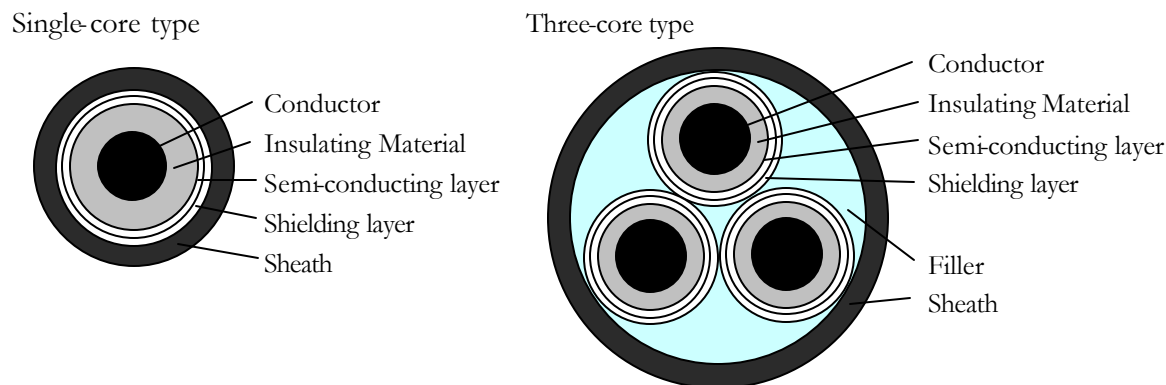


Figure ES25A: Structure of Cables

- IEC standards related to property of cables used in overhead distribution lines

- (1) IEC 61089 (1997-05) [Round wire concentric lay overhead electrical stranded conductors]

- IEC standards related to property of conductors

- (2) IEC 60028 (1925-01) [International standard of resistance for copper]
- (3) IEC 60889 (1987-11) [Hard-drawn aluminum wire for overhead line conductors]
- (4) IEC 60888 (1987-12) [Zinc-coated steel wires for stranded conductors]
- (5) IEC 61232 (1993-06) [Aluminums-clad steel wires for electrical purposes]

1.2 Example of Test Methods of AC Withstand Test and Insulation Resistance Test

(1) Cables Used in Medium-voltage Lines

The completed product shall, depending on the type of cable as indicated in the left-hand column of Table ES25A, withstand the test made by impressing AC voltage of 25,000 V in a cable continuously for 10 minutes under the test method prescribed in the right-hand column of the Table ES25A. Furthermore, the insulation resistance of the insulator shall have the value R(MO-km) or higher when measured after impressing DC voltage of 100 V for 1 minute between the conductor and the armor in a metal armored cable and between the conductor and the shield in a cable with other than metal armor.

$$R = 3.665 \times 10^{-12} \cdot \rho \log_{10} \frac{D}{d}$$

Where:

R: Insulation resistance at 20°C (MO-km)

ρ: Specific volume resistance at 20°C (O-cm) ($= 1 \times 10^{14}$)

D: Outer diameter of an insulator (mm)

d: Inner diameter of an insulator (mm)

When $\frac{D}{d} \geq 1.8$, assume $\frac{D}{d} = 1.8$ for calculation

Table ES25A: Test Method of AC Withstand Test in Medium-voltage Cables

Types of Cables		Test Method
Cable with metal armor	With a solid cored	Test voltage is impressed between the conductor and metal armor.
	With a multicore	Test voltage is impressed between conductors and between the conductor and metal sheath.
Cable with other than metal armor	With a solid cored	Test voltage is impressed between the conductor and shield.
	With a multicore	Test voltage is impressed between conductors and between the conductor and shield.

(2) Cables Used in Low-voltage Lines

The completed product shall, depending on the type of cable as indicated in the left-hand column of Table ES25B, withstand the test made by impressing AC voltage prescribed in Table ES25C continuously for 10 minutes under the test method prescribed in the right-hand column of the Table ES25B. Furthermore, the insulation resistance of the insulator shall have the value R(MO-km) or higher when measured after impressing DC voltage of 100 V for 1 minute between the conductor and the armor in a metal armored cable and between the conductor and the shielding in a cable with other than metal armor.

$$R = 3.665 \times 10^{-12} \cdot \rho \log_{10} \frac{D}{d}$$

Where:

R: Insulation resistance at 20°C (MO-km)

ρ: Specific volume resistance at 20°C (O-cm) ($= 5 \times 10^{13}$)

D: Outer diameter of an insulator (mm)

d: Inner diameter of an insulator (mm)

When $\frac{D}{d} \geq 1.8$, assume $\frac{D}{d} = 1.8$ for calculation

Table ES25B: Test Method of AC Withstand Test in Low-voltage Cables

Types of Cables		Test Method
Cable with metal armor	With a solid core	The test voltage is impressed between the conductor and metal armor.
	With a multicore	The test voltage is impressed between conductors and between a conductor and metal armor.
Cable with other than metal armor	With a solid core	After immersion in fresh water for 1 hour, the test voltage is impressed between the conductor and the ground.
	With a multicore	After immersion in fresh water for 1 hour, the test voltage is impressed between the conductors and between the conductor and the ground.

Table ES25C: Test Voltage of Low-voltage Cables

Conductors		Test voltage (AC V)
Formed single wires and twisted wires (a nominal cross-sectional area mm ²)	Single wires (diameter mm)	
8 or less	3.2 or less	1,500
More than 8 and 30 or less	More than 3.2 and 5 or less	2,000
More than 30 and 80 or less	—	2,500
More than 80 and 400 or less	—	3,000
More than 400	—	3,500

(3) Insulated Conductors

The completed product shall withstand a test made by impressing the respective test voltage shown in the right-hand column of Table ES25D continuously for one (1) minute, depending on the type of insulated conductor indicated in the left-hand column of the Table ES25D after the product has been immersed in fresh water for 1 hour, between the conductor and the ground.

Table ES25D: Test Voltage of Insulated Conductors

Types of Insulated Conductor	Test voltage (AC V)
Insulated conductor used in MV lines	25,000
Insulated conductor used in LV lines	3,500
	(For a wire with a cross sectional area of 300 mm ² or smaller: 3,000)

Furthermore, the insulating resistance of the insulating material measured after DC voltage of 100 V is impressed between the conductor and the ground for one (1) minute, shall be the value R(MO-km) or higher.

$$R = 3.665 \times 10^{-12} \cdot \rho \cdot \log_{10} \frac{D}{d}$$

Where:

R: Insulation resistance at 20°C (MO-km)

ρ : Specific volume resistance at 20°C (O-cm) $(= 1 \times 10^{14}$ when used in MV lines)
 $(= 5 \times 10^{13}$ when used in LV lines)

D: Outer diameter of an insulator (mm)

d: Inner diameter of an insulator (mm)

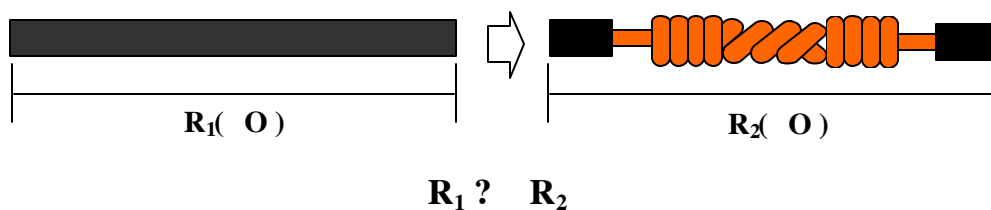
When $\frac{D}{d} \geq 1.8$, assume $\frac{D}{d} = 1.8$ for calculation

Article 26: Connection of Conductors

Conductors shall be connected as per following methods:

1 Resistance of Connected Conductors

Conductors shall be connected firmly and the resistance of conductors shall not increase.



- If necessary, the connected conductor shall undergo a resistance test.

2 Insulating Capacity of Cables and Insulating Conductors

The insulating capacity of cables and insulated conductors shall not decrease.

- If necessary, the connected conductor shall undergo a dielectric strength test and an insulation resistance test.

3 Electrochemical Corrosion

The electrochemical corrosion shall not occur by connecting conductors of different kinds of materials.

[Example (connection of aluminum and copper)]

The ionization tendency of aluminum is higher than that of copper. Therefore, if there is electrolyte at contact surface of two metals, aluminum ions are melted into electrolyte and move toward the copper.

As a result, the surface of aluminum turns corroded.

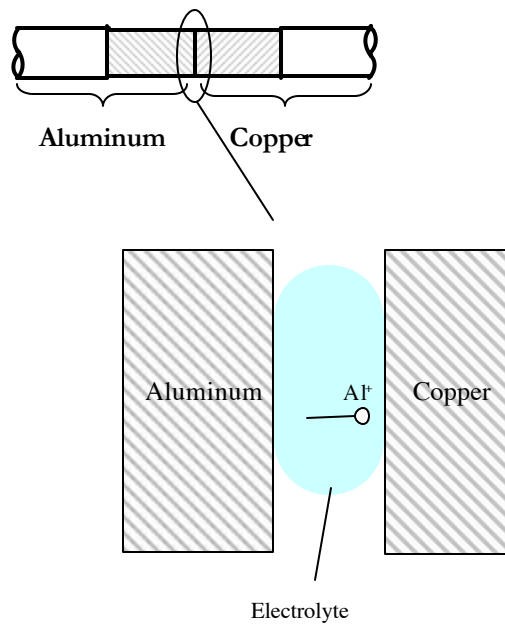


Figure ES26A: Example of Electrochemical Corrosion

Article 27: Safety Factor of Bare Conductors and Ground Wires of Overhead Electrical Lines

1 Loads on Conductors for Overhead Transmission Lines

As for tensile strength of conductors and ground wires for overhead electrical lines except for cables, Clause 33 of GREPTS provides that the safety factor shall be not less than 2.5.

Article 27-2 of SREPTS “Loads on Overhead Transmission Lines” specifies the assumed load and the strength for considering the safety factor.

This explanation sheet shows the parameters when the assumed load and the safety factor are considered.

1.1 The Safety Factor Applied in Other Standards

Standards	Safety factor based on U.T.S.
General Requirements of Electric Power Technical Standards : Cambodia	2.5 or more
Technical Standard: Japan	2.5 or more
National Electrical Safety Code (NESC): U.S.A	1.67 or more
The Electricity (Overhead Lines) Regulations: U.K.	2.0 - 2.5 or more
VDE0210: Germany	2.3 - 2.5 or more

*U.T.S.: Ultimate tensile strength

1.2 The Weather Conditions in Cambodia (temperature, wind velocity)

(1) Temperature

Station	Temperature Max (°C)	Temperature Min (°C)	Temperature Average (°C)
Banteaymean Chey	37.0	21.5	29.3
Battambang	37.4	17.6	27.5
Kampong Cham	37.1	17.7	27.4
Kampot	34.4	19.7	27.1
Kratie	37.6	14.0	25.8
Pochentong	36.8	19.7	28.3
Prey Veng	37.6	21.0	29.3
Pursat	39.5	19.9	29.7
Siem Reap	40.1	17.9	29.0
Sihanoukville	34.0	21.3	27.7
Stung Treng	36.4	17.5	27.0
Svay Rieng	36.4	18.8	27.6
Average	37.0	18.9	28.0

*Source: Department of Meteorology, Ministry of Water Resources and Meteorology

*Observation duration: 1985 to 2001

(2) Wind Velocity (annual maximum value of 10-minute average wind velocity)

Observation place: Pochentong, Phnom Penh

Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
wind(m/s)	12	16	16	16	14	14	10	6	16	16	14

1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
17	18	18	17	11	14	13	11	11	10	12	12

Observation place: Siem Reap

Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
wind(m/s)	-	-	-	-	-	-	-	20	20	25	21

1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
24	24	40	20	28	24	26	24	16	24	14	16

1.3 Design Wind Velocity Applied for Transmission Lines in Cambodia

Transmission line name	Voltage	Design wind velocity (application temperature)
GS1-L01-GS3	115kV	24m/sec (20°C)
GS2-L02-GS3	115kV	24m/sec (20°C)
GS1-L03-Kpongspoe	115kV	30m/sec (15°C)
Kpongsp-L04-Kirirom	115kV	30m/sec (15°C)

1.4 Design Wind Velocity of Neighboring Countries

Name of a country	Design wind velocity [wind pressure(application temperature)]	Note
Laos	35.0 m/sec [790Ns/sq m] (normal temperature)	
Thailand	33.8 m/sec	The design value of 500kV transmission lines
Vietnam	32.6 m/sec – 54.9 m/sec	3-second average wind 20year return period 'Load and Actions-Design Code'

1.5 Reference Wind Velocity (the yearly maximum of 10-minute average wind velocity by 50year return period)

Here the yearly maximum of 10-minute average wind velocity (50year return period) in Cambodia is calculated from observation data at two places in Cambodia provided by Department of Meteorology, Ministry of Water Resources and Meteorology.

Before that, all of data are confirmed whether they are significant or not according to Annex “Observation data of wind velocity and Gumbel distribution”.

*Gumbel distribution: A special case of the generalized extreme value distribution. It is used in the environmental sciences to model extreme values associated with flooding, rainfall, wind, etc.

(1) Pochentong in Phnom Penh

The extremum of wind is usually adjusted to Gumbel distribution. This case is assumed to be adjusted to Gumbel distribution according to Annex, therefore the yearly maximum of 10-minute average wind velocity (50year return Period) in Pochentong is calculated by the following formula.

$$P(V) = 1 - \exp \left[- \exp \left\{ - \frac{p}{\sqrt{6} s_v} \left(V - \bar{V} + 0.45 s_v \right) \right\} \right] \dots\dots\dots \text{(formula 1)}$$

Where $P(v)$: probability that wind velocity will exceed V ($= \frac{1}{T}$, T : Recurrence interval)

\bar{V} : Average value of the yearly maximum wind velocity

s_v : Standard deviation of the yearly maximum wind velocity

Formula 1 can be transformed to formula 2.

$$V = \frac{\sqrt{6}s_v}{p} \left[-\ln \left\{ -\ln \left(1 - \frac{1}{T} \right) \right\} \right] + \bar{V} - 0.45s_v \quad \text{..... (formula 2)}$$

Moreover, \bar{V} , s_v are calculated from the wind velocity data of Cambodia shown in Annex(1).

$$\bar{V} = 13.65 \text{ (m/s)}$$

$$s_v = 2.97$$

These values are substituted to formula 2 and the yearly maximum of 10-minute average wind velocity (50year return Period) in Pochentong is finally given as follows:

$$\boxed{V = 21.36 \text{ (m/s)} \quad \text{----- (Pochentong)}}$$

(2) Siem Reap

As same as Pochentong, the yearly maximum of 10-minute average wind velocity (50year return Period) in Siem Reap is calculated from the wind velocity data of Cambodia shown in Annex (2) except for 40m/s (1994) which is considered not to be significant based on Annex “Observation data of wind velocity and Gumbel distribution”

\bar{V} : Average value of the yearly maximum wind velocity

s_v : Standard deviation of the yearly maximum wind velocity

$$\bar{V} = 21.73 \text{ (m/s)}$$

$$s_v = 3.91$$

These values are substituted to formula 2 and the yearly maximum of 10-minute average wind velocity (50year return Period) in Siem Reap is finally given as follows;

$$\boxed{V = 31.86 \text{ (m/s)} \quad \text{----- (Siem Reap)}}$$

1.6 Maximum Instantaneous Wind Speed

Maximum instantaneous wind speed is given by multiplying the above value and Gust Factor. On condition that Gust Factor is 1.3-1.5, the maximum instantaneous wind velocity is given as formula 3.

$$G = V_t / V_{600} \quad \text{..... (formula 3)}$$

Where: G : Gust Factor

V_t : Gust wind velocity (m/s) for average-number-of-hours t seconds

V_{600} : 10-minute average wind velocity (m/s)

(1) Pochentong

$$\begin{aligned} \text{Maximum instantaneous wind velocity (50year return Period)} &= 21.36 \times G \text{ (1.3 to 1.5)} \\ &= 27.8 \text{ to } 32.0 \end{aligned}$$

(2) Siem Reap

$$\begin{aligned} \text{Maximum instantaneous wind velocity (50year return Period)} &= 31.86 \times G \text{ (1.3 to 1.5)} \\ &= 41.4 \text{ to } 47.8 \end{aligned}$$

1.7 Consideration and attention in case of actual design

We have to decide the wind pressure load to conductors, ground wires, supporting structures and so on when designing a transmission line. Using the reference wind velocity given in Article 27 of SREPTS, the wind pressure load can be calculated and decided. Refer to Explanation Sheet of Article 31, 40 of SREPTS.

It might be premature to fix the reference wind velocity from insufficient observed data at this moment. Because transmission lines need to be secured adequate reliability to send bulk power, it is efficient to show a standard value in SREPTS. Minimum reliability has to be secured.

This paragraph requests the designer of a transmission line to consider the wind pressure load very carefully on a case-by-case basis according to the required reliability of the transmission line, the conditions and circumstances of the route, wind observation data of the area.

In case of designing a transmission line connected to neighboring countries, it is necessary to consider and coordinate the design conditions of the country.

“Observation data of wind velocity and Gumbel distribution”

(1) Pochentong

The data is assumed to be adjusted to Gumbel distribution as the graph27A.

Observation data

Year	Wind (m/s)
1981	12
1982	16
1983	16
1984	16
1985	14
1986	14
1987	10
1988	6
1989	16
1990	16
1991	14
1992	17
1993	18
1994	18
1995	17
1996	11
1997	14
1998	13
1999	11
2000	11
2001	10
2002	12
2003	12

arrange

Thomas Plot

number (i)	Year	Wind (m/s)	Excess probability $W=i/(n+1)$	Return period $1/w$ (year)
1	1993	18	0.04	23.81
2	1994	18	0.08	12.05
3	1992	17	0.13	8.00
4	1995	17	0.17	5.99
5	1982	16	0.21	4.81
6	1983	16	0.25	4.00
7	1984	16	0.29	3.42
8	1989	16	0.33	3.00
9	1990	16	0.38	2.67
10	1985	14	0.42	2.40
11	1986	14	0.46	2.18
12	1991	14	0.50	2.00
13	1997	14	0.54	1.85
14	1998	13	0.58	1.72
15	1981	12	0.63	1.60
16	2002	12	0.67	1.50
17	2003	12	0.71	1.41
18	1996	11	0.75	1.33
19	1999	11	0.79	1.26
20	2000	11	0.83	1.20
21	1987	10	0.88	1.14
22	2001	10	0.92	1.09
23=n	1988	6	0.96	1.04

Frequency distribution

Wind(m/s)	Number
18	2
17	2
16	5
15	0
14	4

$$V = \frac{\sqrt{s_v}}{p} \left[-\ln \left\{ -\ln \left(1 - \frac{1}{T} \right) \right\} \right] + \bar{V} - 0.4 \bar{s}_v$$

\bar{V} : Average value of
the yearly maximum wind velocity
= 13.65 m/s

Gumbel distribution

Return period(year)	Wind(m/s)
90.00	22.73
80.00	22.46
70.00	22.14
60.00	21.78
<u>50.00</u>	<u>21.36</u>

13	1
12	3
11	3
10	2
9	0
8	0
7	0
6	

s_v : Standard deviation of
the yearly maximum wind velocity
= 2.97

40.00	20.83
30.00	20.16
20.00	19.20
10.00	17.53
8.00	16.98
6.00	16.26
4.00	15.20
2.00	13.16
1.80	12.80
1.60	12.36
1.40	11.79
1.20	10.96
1.10	10.29

(2) Siem Reap

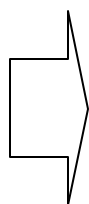
- Case 1

As the following frequency distribution, 40m/s (1994) is far from other data.

According to Graph 27B, 40m/s (1994) shows a marked different tendency from other data. Therefore an analysis excluding 40m/s (1994) is tried as (3).

Observation data

Year	Wind(m/s)
1988	20
1989	20
1990	25
1991	21
1992	24
1993	24
1994	40
1995	20
1996	28
1997	24
1998	26
1999	24
2000	16
2001	24
2002	14
2003	16



arrange

Thomas Plot

Number (i)	Year	Wind(m/s)	Excess probability $W=i/(n+1)$	Return period $1/w$ (year)
1	1994	40	0.06	16.95
2	1996	28	0.12	8.47
3	1998	26	0.18	5.68
4	1990	25	0.24	4.26
5	1992	24	0.29	3.40
6	1993	24	0.35	2.83
7	1997	24	0.41	2.43
8	1999	24	0.47	2.12
9	2001	24	0.53	1.89
10	1991	21	0.59	1.70
11	1988	20	0.65	1.55
12	1989	20	0.71	1.42
13	1995	20	0.77	1.31
14	2000	16	0.82	1.21
15	2003	16	0.88	1.13
16=n	2002	14	0.94	1.06



Frequency distribution

Wind(m/s)	Number
40	1
39	0
38	0
37	0
36	0
35	0
34	0
33	0
32	0
31	0
30	0
29	0
28	1
27	0
26	1
25	1
24	5
23	0
22	0
21	1
20	3
19	0
18	0
17	0
16	2
15	0
14	1

Gumbel distribution

$$V = \frac{\sqrt{6}s_v}{p} \left[-\ln \left\{ -\ln \left(1 - \frac{1}{T} \right) \right\} \right] + \bar{V} - 0.45s_v$$

\bar{V} : Average value of
the yearly maximum wind velocity
= 22.88 m/s

s_v : Standard deviation of
the yearly maximum wind velocity
= 5.82

Return period(year)	Wind(m/s)
90.00	40.65
80.00	40.11
70.00	39.50
60.00	38.79
50.00	37.96
40.00	36.94
30.00	35.61
20.00	33.73
10.00	30.47
8.00	29.39
6.00	27.98
4.00	25.91
2.00	21.92
1.80	21.21
1.60	20.34
1.40	19.23
1.20	17.61
1.10	16.29

As a result, this data is not adopted.

- Case 2

The data is assumed to be adjusted to Gumbel distribution as the graph 27C. The value 40m/s (1994) in case1 is quite larger than neighboring countries in which it is supposed that the wind is stronger than that in Cambodia. In this case, the yearly maximum of 10-minute average wind velocity (50year return Period) is calculated from the data excluding 40m/s (1994) because it is doubtful whether this data was observed in a proper manner.

Observation data

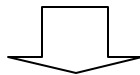
Year	Wind (m/s)
1988	20
1989	20
1990	25
1991	21
1992	24
1993	24
1995	20
1996	28
1997	24
1998	26
1999	24
2000	16
2001	24
2002	14
2003	16



arrange

Thomas Plot

Number (i)	Year	Wind (m/s)	Excess probability $W=i/(n+1)$	Return period $1/w$ (year)
1	1996	28	0.06	15.87
2	1998	26	0.13	8.00
3	1990	25	0.19	5.32
4	1992	24	0.25	4.00
5	1993	24	0.31	3.19
6	1997	24	0.38	2.67
7	1999	24	0.44	2.28
8	2001	24	0.50	2.00
9	1991	21	0.56	1.78
10	1988	20	0.63	1.60
11	1989	20	0.69	1.45
12	1995	20	0.75	1.33
13	2000	16	0.81	1.23
14	2003	16	0.88	1.14
15=n	2002	14	0.94	1.07



Frequency distribution

Wind (m/s)	Number
28	1
27	0
26	1
25	1
24	5
23	0
22	0
21	1
20	3
19	0
18	0
17	0
16	2
15	0
14	1

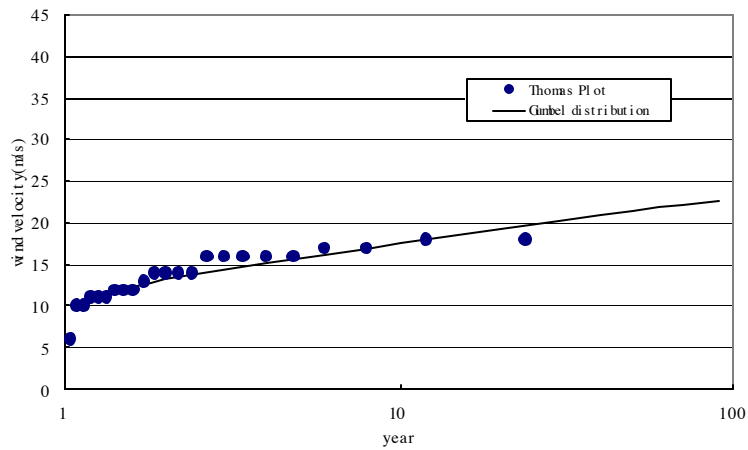
Gumbel distribution

$$V = \frac{\sqrt{6}s_v}{p} \left[-\ln \left\{ -\ln \left(1 - \frac{1}{T} \right) \right\} \right] + \bar{V} - 0.45s_v$$

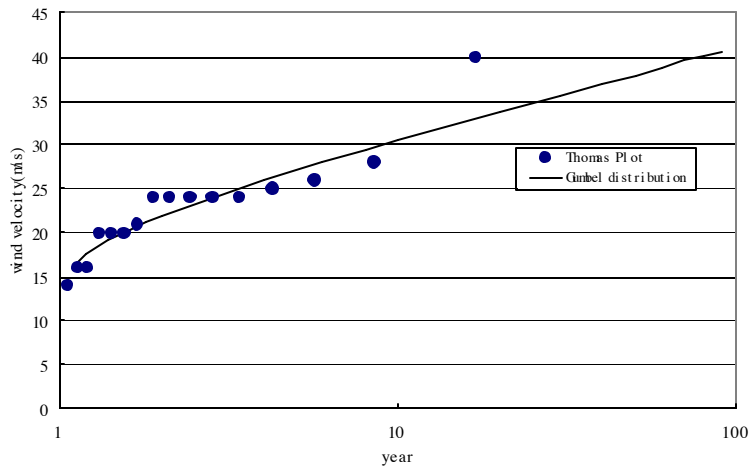
\bar{V} : Average value of
the yearly maximum wind velocity
= 21.73 m/s

s_v : Standard deviation of
the yearly maximum wind velocity
= 3.91

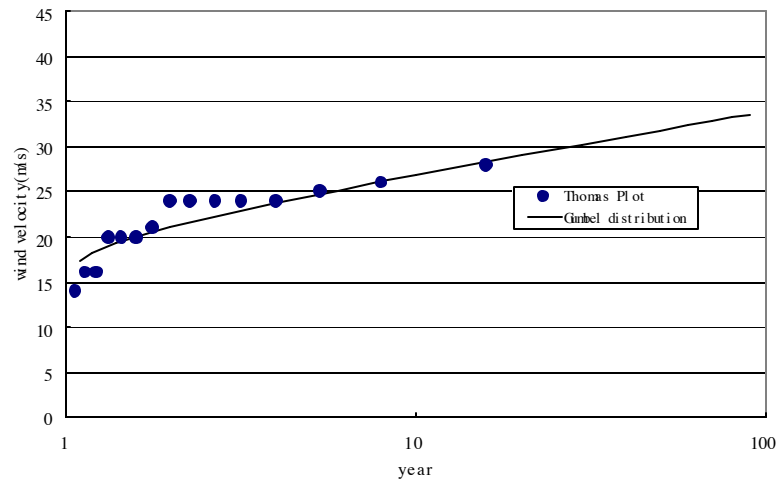
Return period(year)	Wind(m/s)
90.00	33.66
80.00	33.30
70.00	32.89
60.00	32.42
50.00	31.86
40.00	31.17
30.00	30.28
20.00	29.02
10.00	26.83
8.00	26.11
6.00	25.16
4.00	23.77
2.00	21.09
1.80	20.61
1.60	20.03
1.40	19.29
1.20	18.20
1.10	17.31



Graph 27A: Modeling of Observation Data (Pochentong)



Graph 27B: Modeling of Observation Data (Siem Reap)



Graph 27C: Modeling of Observation Data (Siem Reap, where 40m/s (1994) is excluded)

2 The Maximum Working Tension of Overhead Conductors(for High-voltage lines)

2.1 Concept

The limiting conditions for conductor tensions may be governed by either the worst condition (Strong wind) or Normal condition (Every Day Stress).

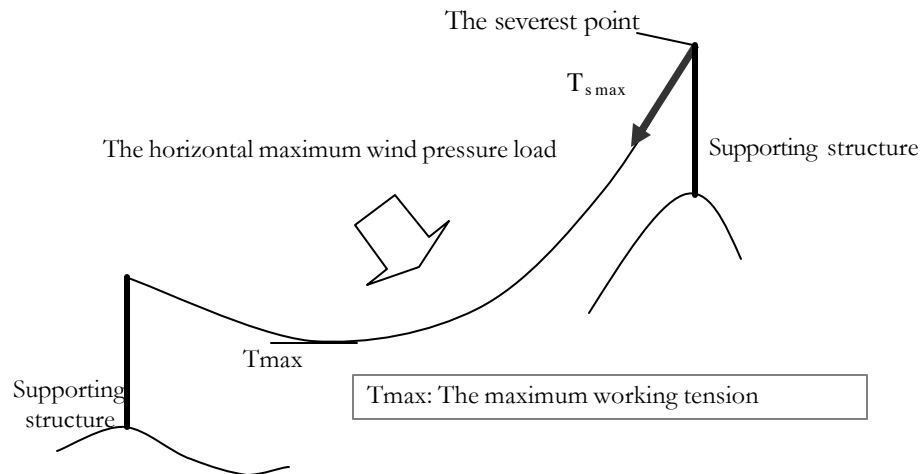
Lower one between these two tensions calculated by following two conditions should be adopted.

(1) The Worst Condition (Strong Wind)

The maximum working tension means the maximum value of horizontal tension in case of the worst condition which means a condition under strong wind.

The real maximum tension loaded on the conductor is the maximum tension $T_{s\max}$ on high-side supporting point and is larger than the maximum working tension T_{\max} .

Figure ES27A : The Maximum Working Tension



Therefore Safety factor of conductors needs some margin when the maximum tension is calculated.

$$T_{UTS}^{*1} / \text{Safety Factor (2.5)} \geq \text{Tension of the conductor (under the severest condition)}$$

*1 Ultimate Tensile Strength of the Conductor

(2) Usual condition (Windless)

Because the fatigue of conductors by aeolian vibration has close relationship to EDS, the windless tension should be not more than EDS.

*EDS: abbreviation of Every Day Stress which is the value of percentage of everyday load tension under windless conditions to the ultimate tensile strength of the conductor)

The windless tension can be calculated by the maximum working tension mentioned above content (1).

In case the calculated windless tension is over EDS, the windless tension should be decreased under EDS and the maximum working tension should be recalculated by the windless tension.

$$T_{UTS} \times 24\% \geq \text{Windless tension}$$

2.2 Example of Actual Calculation

Here the maximum (working) tension is examined about WOLF (an conductor of British Standard) as a case.

(1) Properties of the Conductor

Table ES27A: Properties of a Conductor [WOLF (British Standard)]

Particular		Input data	Unit
Weight of conductor	$W_c =$	0.727	Kg/m
Cross-sectional area	$A =$	194.94	mm ²
Conductor diameter	$D =$	18.13	mm
Modulus of elasticity	$E =$	8510	kg/mm ²
Coefficient of linear expansion	$a =$	0.0000184	/ °C
Ultimate tensile strength (\cong Breaking load)	$T_{UTS} =$	7050	kg

(2) Temporary Value of the Maximum Working Tension

At first temporary value of the maximum working tension is gotten by the ultimate tensile strength and safety factor 2.5. And the maximum working tension needs some margin that is described in 2.1. In this case, 10% margin is applied as the tension on the high side of supporting point meets the 2.5 of safety factor.

Therefore temporary T_{max} is calculated by the following.

$$T_{max} = \{T_{UTS} / \text{Safety Factor} (\geq 2.5)\} \times 90\% = (7050\text{kg} / 2.5) \times 0.9 \cong 2530\text{kg}$$

(3) Conditions of the Conductor

a. Worst condition (Strong wind)

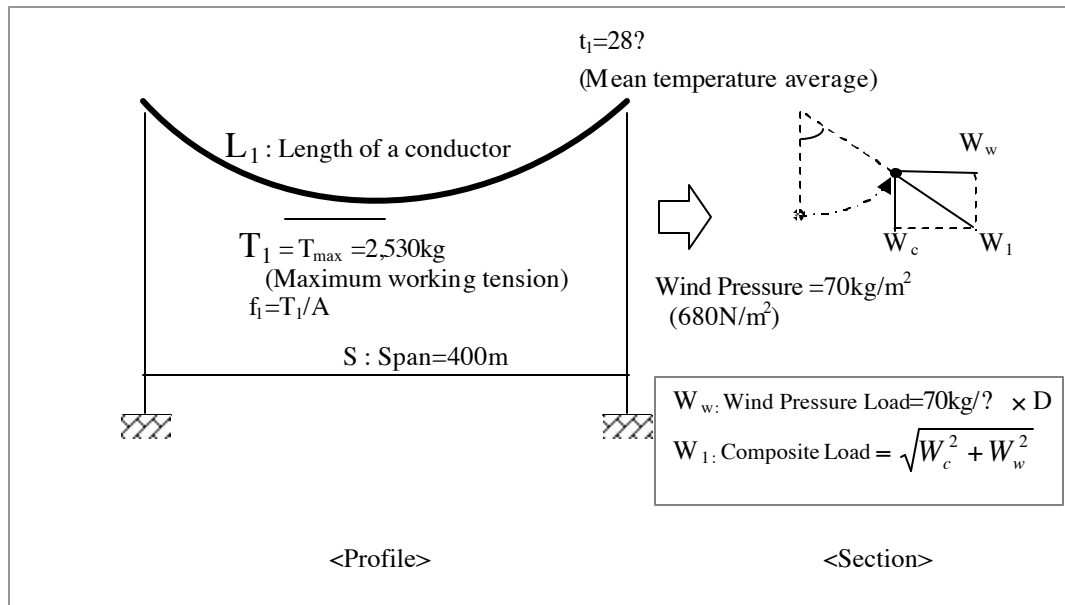


Figure ES27B: The Worst Condition

b. Usual condition (Windless)

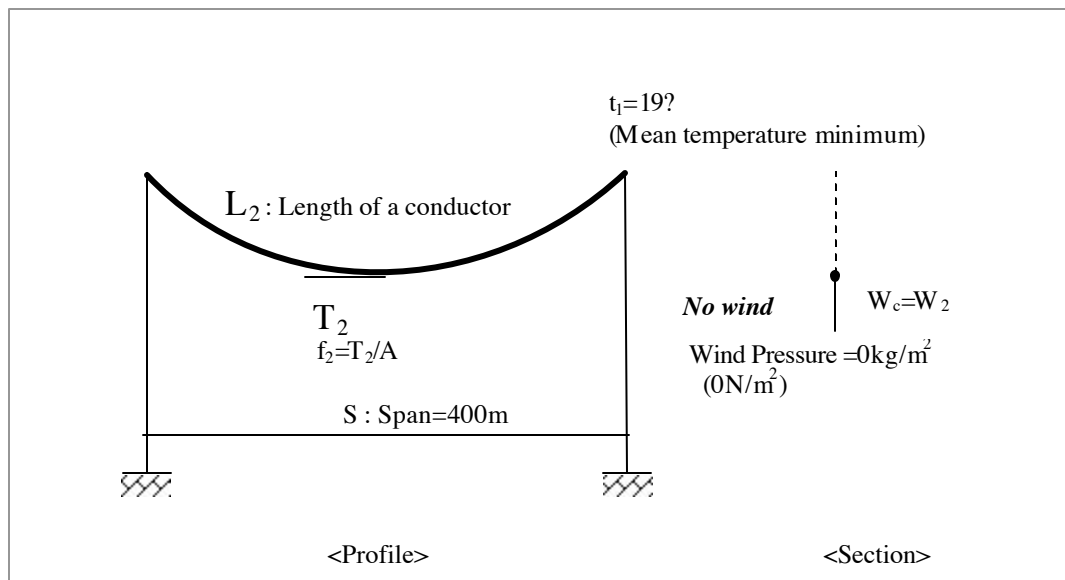


Figure ES27C: Usual Condition

(4) Calculation of Normal Tension

Here, because a relationship between 2.2 (3) a. the worst condition and 2.2 (3) b. usual condition is made of characteristic of elasticity and characteristic of linear expansion, the relationship is described as the following formula.

Usual tension T_2 is calculated using this formula.

$$L_2 - L_1 = \left\{ \frac{f_2 - f_1}{E} + \alpha (t_2 - t_1) \right\} L_1$$

Above formula is transformed to the following.

$$f_2^2 \{ f_2 - (K - \alpha t E) \} = M$$

Where:

$$t = t_2 - t_1$$

$$K - \alpha t E = \frac{T_1}{A} - \frac{(S^2 \times W_1^2 \times E)}{24 T_1^2} - \alpha t E$$

$$M = \frac{W_2^2 S^2 E}{24 A^2}$$

$K - \alpha t E$, M are calculated as the following.

$$K - \alpha t E = \frac{2,530}{194.94} - \frac{(400^2 \times (0.727^2 + (70 \times 18.13 \times 10^{-3})^2) \times 8,510)}{24 \times 2,530^2}$$

$$-1.84 \times 10^{-5} \times (-9) \times 8,510 = -4.583$$

$$M = \frac{0.727^2 \times 400^2 \times 8,510}{24 \times 194.94^2} = 789.1$$

$$f_2^2 (f_2 + 4.583) = 789.1$$

$$\therefore f_2 = 7.938 \text{ kg/mm}^2$$

As a result, $T_2 = f_2 \times A = 7.938 \text{ kg/m}^2 \times 194.94 \text{ m}^2 = 1,547 \text{ kg}$

(5) Examination on EDS

EDS=24% (refer to 2.3 EDS)

$$T_{\text{EDS}(24\%)} = T_{\text{UTS}} \times 24\% = 7050 \text{ kg} \times 24\% = 1,692 \text{ kg}$$

Now, Comparing the $T_{\text{EDS}(24\%)}$ to T_2 (Usual tension of the conductor),

$$T_2 \leq T_{\text{EDS}(24\%)}$$

The usual tension meets the requirement that the usual tension is not more than EDS.

As the result, the maximum working tension is confirmed.

$$T_1 = T_{\text{max}} = 2,530 \text{ kg}$$

In this connection, when the span $S=300\text{m}$, the calculation is $T_2 = 1,772\text{kg}$? $T_2 \geq T_{\text{EDS}(24\%)}$.

In this case, the maximum working tension should be decreased and reexamined because the usual tension is more than EDS.

Consequently, when the maximum working tension is calculated, the span should be considered.

2.3 EDS

(Explanation sheet Article34 Bare Conductors of Overhead High-voltage Lines)

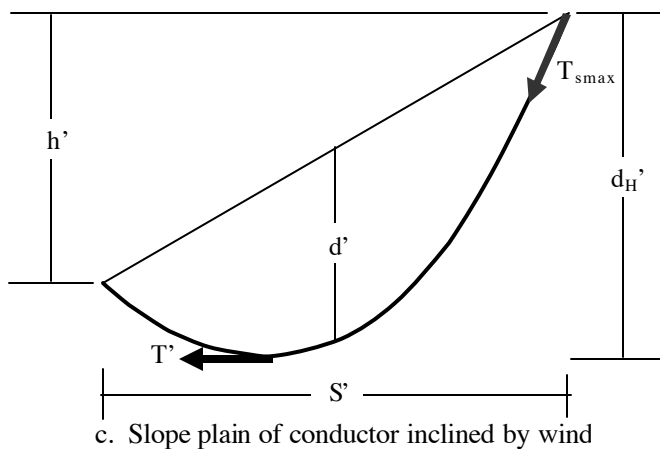
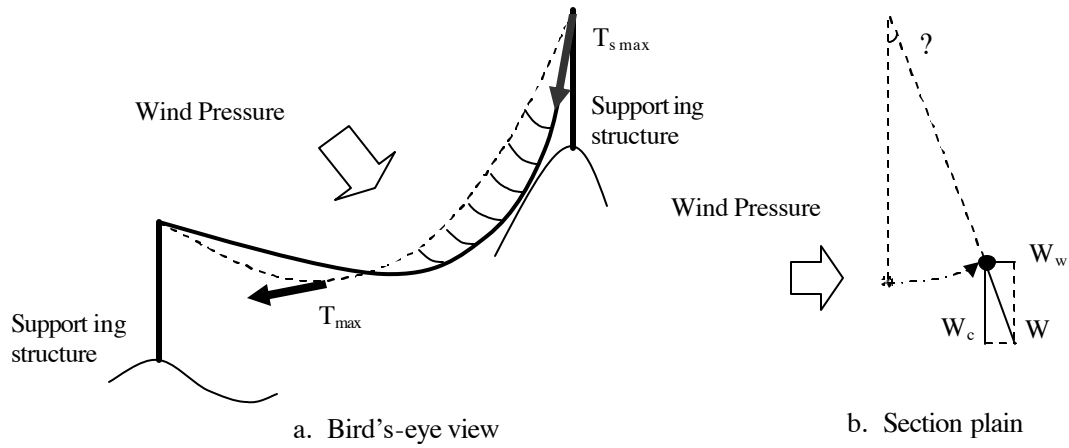
EDS: abbreviation of Every Day Stress which is the value of percentage of everyday load tension under windless conditions to the ultimate tensile strength

EDS: CIGRE takes into consideration investigation results of exiting facilities and recommends that EDS should be less than the values shown in following Table.

- * CIGRE: Conseil International des Grands Reseaux Electriques (International Council on Large Electric Systems), which is one of the leading worldwide Organizations on Electric Power Systems, covering their technical, economic, environmental, organisational and regulatory aspects.

Table ES27B: Recommended Value of EDS by CIGRE CSC6-58-3

Conductor	No attachment	With dampers	With armor rods	With dampers and armor rods
ACSR	18%	24%	22%	24%



W_c : Weight of conductor

W_w : Wind Pressure Load

$$W = \sqrt{W_c^2 + W_w^2}$$

$$q = W / W_c$$

$$T_{s \max} = T' + W_c \times q \times d'_{H'}$$

$$d'_{H'} = d' \left(1 + \frac{h'}{4d'} \right)^2$$

$$d' = \frac{W_c \times q \times S'^2}{8T'}$$

$$h' = h \times \cos \gamma$$

$$S' = \sqrt{S^2 + h^2 \sin^2 \gamma}$$

$$\cos \gamma = \frac{W_c}{\sqrt{W_c^2 + W_w^2}}$$

$$T' = T_{\max} \sqrt{1 + \left(\frac{h}{S} \right)^2 \sin^2 \gamma}$$

$T_{s \max}$: support point tension

T_{\max} : maximum working tension

T' : Horizontal component force of the force actually applied to the tower support point

q : Load coefficient under worst case conditions

$d'_{H'}$: Sag from the high support point side on a slope surface (m)

d' : Slope sag from the high support point side on a slope surface (m)

h' : Height difference from the high support point side on a slope surface (m)

S' : Span length from the high support point side on a slope surface (m)

h : Support point height difference (m)

S : Span length (m)

(Example C calculation)

Kind of conductor: WOLF (British Standard)

$$W_c = 0.727 \text{ kg/m}$$

$$W_w = 70 \text{ kg/?} \times 18.13 \times 10^{-3} \text{ m} = 1.2691 \text{ kg/m}$$

$$T_{\max} = 2,530 \text{ kg}$$

$$h : 50 \text{ m}$$

$$S : 400 \text{ m}$$

$$W = \sqrt{W_c^2 + W_w^2} = \sqrt{0.727^2 + 1.2691^2} = 1.4626$$

$$\sin \lambda = \frac{W_w}{W} = \frac{1.2691}{1.4626} = 0.8677$$

$$\cos \lambda = \frac{W_c}{W} = \frac{0.727}{1.4626} = 0.4971$$

$$q = \frac{W}{W_c} = \frac{1.4626}{0.727} = 2.0118$$

$$S' = \sqrt{S^2 + h^2 \sin^2 \gamma} = \sqrt{400^2 + 50^2 \times 0.8677^2} = 402.35$$

$$h' = h \times \cos \gamma = 50 \times 0.4971 = 24.855$$

$$T' = T_{\max} \sqrt{1 + \left(\frac{h}{S}\right)^2 \sin^2 \gamma} = 2,530 \sqrt{1 + \left(\frac{50}{400}\right)^2 0.8677^2} = 2,544.84 \text{ kg}$$

$$d' = \frac{W_c \times q \times S'^2}{8T'} = \frac{0.727 \times 2.0118 \times 402.35^2}{8 \times 2,544.84} = 11.63 \text{ m}$$

$$d_H' = d' \left(1 + \frac{h'}{4d'}\right)^2 = 11.63 \times \left(1 + \frac{24.855}{4 \times 11.63}\right)^2 = 27.38 \text{ m}$$

$$T_{s \max} = T' + W_c \times q \times d_H' = 2,544.84 + 0.727 \times 2.0118 \times 27.38 = 2,584.89 \text{ kg}$$

Article 28: Side-by-Side Use and Joint Use of Electrical Lines or Communication Lines

1 High-Voltage Lines, Medium-Voltage Lines and Low-Voltage Lines

This paragraph provides the installation method for side-by-side use of high-voltage lines, medium-voltage lines and low-voltage lines.

1.1 Side-by-Side Use of High-voltage Lines and Medium-voltage Lines

It is decided in this paragraph that the tensile strength of high-voltage line conductors shall be 30kN or over. We can judge which conductors follow the SREPTS or not by checking Table ES28A.

Table ES28A: Examples of Tensile Strength for High-voltage Conductors

Name	Wire			Tensile strength, (kN)
	Area (mm ²)	No. of wires	Diameter (mm)	
AAC 100	100	19/2.59	12.90	17.00
AAC 125	125	19/2.89	14.50	21.25
AAC 160	160	19/3.27	16.40	26.40
AAC 200	200	19/3.66	18.30	32.00
AAC 250	250	19/4.09	20.50	40.00
AAC 400	400	37/3.71	26.00	64.00
AAAC 63	72.5	7/3.63	10.90	21.39
AAAC 100	115	19/2.78	13.90	33.96
AAAC 125	144	19/3.10	15.50	42.44
ACSR 63	Al 63/ St 10.5	Al 6/ St 1	11.00	21.63
ACSR 100	Al 100/ St 16.7	Al 6/ St 1	13.80	34.33
ACSR 125	Al 125/ St 6.94	Al 18/ St 1	14.9	29.17
ACSR 125	Al 125/ St 20.4	Al 26/ St 7	15.7	45.69
ACSR 160	Al 160/ St 8.89	Al 18/ St 1	16.8	36.18
ACSR 160	Al 160/ St 26.1	Al 26/ St 7	17.7	57.69

*Source: IEC1089

1.2 Side-by-Side Use of Medium -voltage Lines and Low-voltage Lines

It is decided in this paragraph that the minimum tensile strength of low-voltage line conductors shall be not less than 5kN or not less than 8kN according to the span. We can judge which conductors follow the SREPTS or not by checking Table ES28B.

Table ES28B: Examples of Tensile Strength for Low-voltage Conductors

Name	Conductor			Tensile strength, (kN)
	Area (mm ²)	No. of wires	Diameter (mm)	
ABC2x25	25	2	6.08	7.0
ABC2x35	35	2	6.90	9.8
ABC2x50	50	2	8.00	14.0
ABC2x95	95	2	11.3	26.6
ABC4x25	25	4	6.08	14.0
ABC4x35	35	4	6.90	19.6
ABC4x50	50	4	8.00	28.0
ABC4x70	70	4	9.60	39.2
ABC4x95	95	4	11.3	53.2
ABC4x120	120	4	12.9	67.2
ABC4x150	150	4	14.3	84.0
PVC-Al 25	25	6	5.85	4.1
PVC-Al 35	35	6	6.88	5.6
PVC-Al 50	50	6	8.01	7.3
PVC-Al 70	70	12	9.63	10.4
PVC-Al 95	95	15	11.33	14.1
PVC-Al 120	120	15	12.75	18.5

Sources: (1) Data for ABC: Pirelli technical document

(2) Data for PVC-Al (THWA-C): Thai-YAZAKI

1.3 Side-by-Side Use of High -voltage Lines and Low-voltage Lines

Installing an overhead low-voltage line on the same supporting structure of an overhead high-voltage line should be avoided as much as possible because it causes danger of electrical contact, invasion of abnormal voltage into overhead distribution conductor at the fault of overhead high-voltage transmission lines and electrostatic inductive and electromagnetic inductive interference.

Therefore Clause 34 of GREPTS prohibits low-voltage line installation on the same supporting structure where a high-voltage line is installed.

This paragraph permits such installation only on condition that the facilities are intensified as prescribed in Article 28-1.3 of SREPTS to avoid above mentioned danger, in case it is inevitable, for example: there is no suitable space to install a low-voltage line in the urban area such as Phnom Penh, because houses stand close together and the appropriate low-voltage line route is only along a road but a high-voltage transmission line has been already installed along the road.

However, installing an overhead low-voltage line on the supporting structure of overhead high-voltage transmission lines with over 115kV nominal voltage is prohibited.

“Under no circumstances” in Article 28-1.1, 1.2, 1.3 means that the worst condition shall be considered, such as:

- When the high-voltage conductor's sag is long at full load, but the low-voltage conductor's sag is short at no load.

Taking into consideration safety for workers, space for maintenance shall be kept as much as possible and the clearance shall be as long as possible.

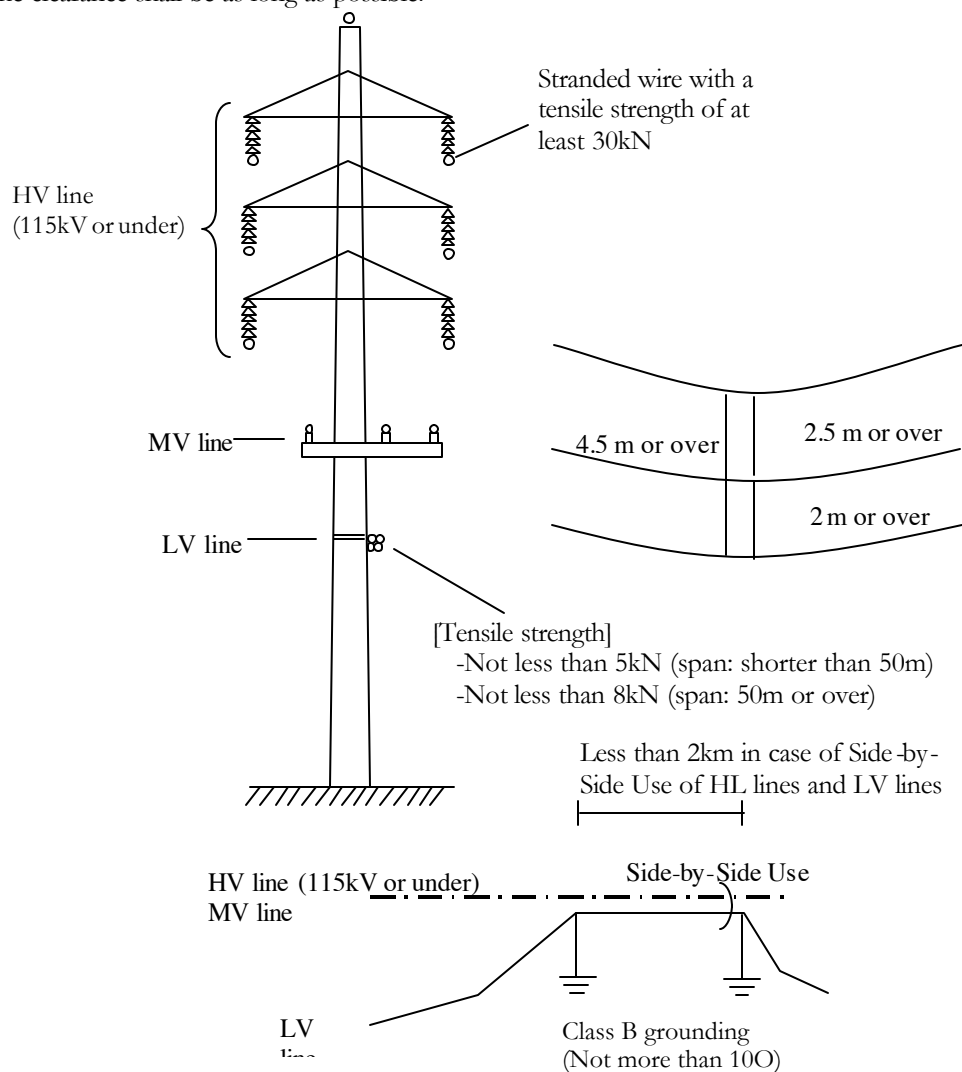


Figure ES28A: Way of Side-by-Side Use of High-voltage Lines, Medium-voltage Lines and Low-voltage Lines

(1) Electrostatic Induction Voltage and Electromagnetic Induction Voltage

The electromagnetic field from an AC line causes two kinds of induction, electrostatic (electric field) induction and electromagnetic (magnetic field) induction.

As shown in Figure ES28B, as the distance between a HV line and a LV line gets longer, the electrostatic induction voltage decreases extremely. On the contrary, the electromagnetic induction voltage does not decrease very much.

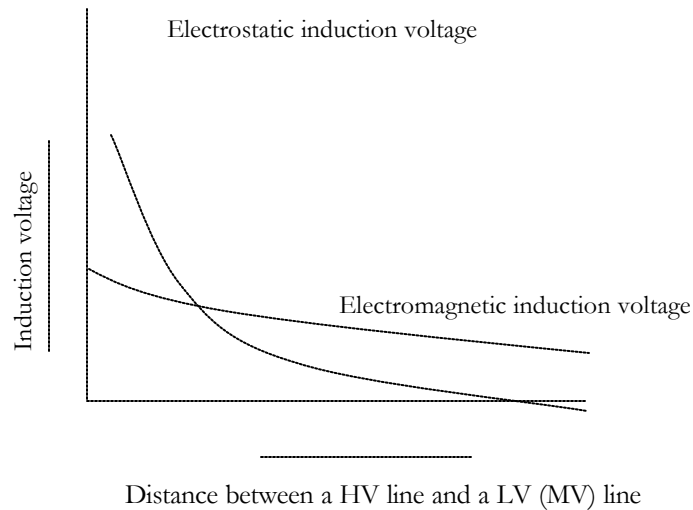


Figure ES28B: Comparison Between Two Kinds of Induction Voltages

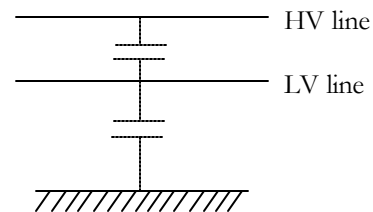
a. Electrostatic Induction Voltage

An isolated and ungrounded conductor (for example: LV line) strung near a live conductor (for example: HV line) has an induced voltage on it, because each conductor acts as a plate of a capacitor. This is called electrostatic induction voltage.

So a medium-voltage line or a low-voltage line near a high-voltage line has a voltage induced from the high-voltage line.

The magnitude of the induced voltage is higher when:

- The voltage of the high-voltage line is high.
- The distance between the two lines is decreased.



Electrostatic induction voltage is calculated from formula 1.

$$\dot{E}_s = \frac{C_a \dot{E}_a + C_b \dot{E}_b + C_c \dot{E}_c}{C_a + C_b + C_c + C_s} \text{ ----- (formula 1)}$$

Where: E_s : Voltage induced to a LV conductor (V)

E_a, E_b, E_c : Phase voltage to the ground (V)

C_a, C_b, C_c : Capacitance between HV conductors and a LV conductor (F)

C_s : Capacitance between a LV conductor and the ground (F)

To reduce the electrostatic induction voltage, C_a , C_b and C_c should be smaller and C_s should be bigger. As shown in Figure ES28C, ES28D and ES28E, the distance between a HV conductor and a LV conductor and the distance between a LV conductor and the ground are very important to decide the capacitance.

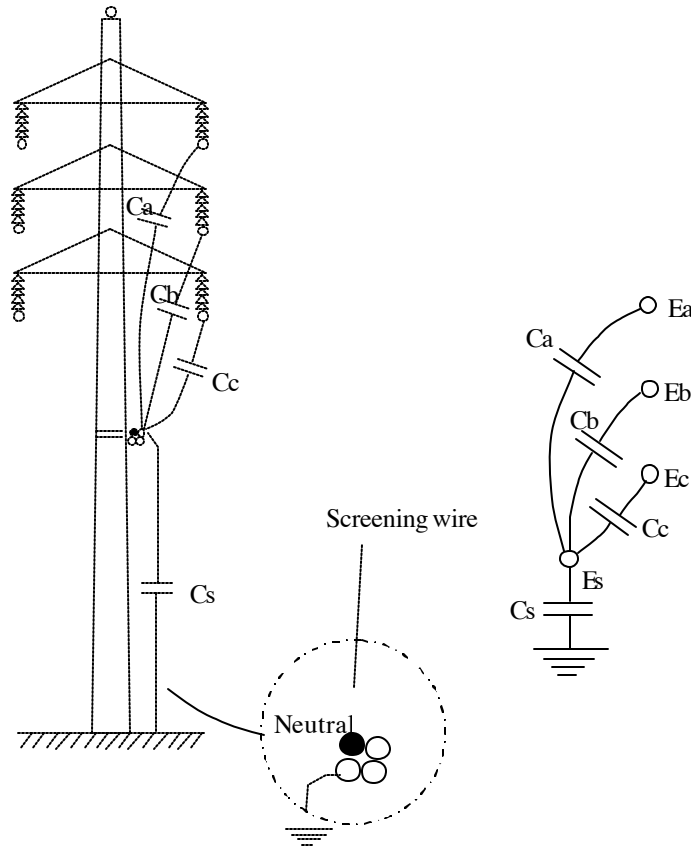


Figure ES28C: Electrostatic Inductive Voltage

Conductor A a

d

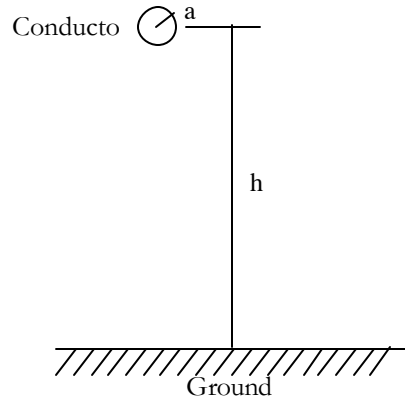
Conductor B b

$$C = \frac{2\pi\epsilon}{\ln \frac{d^2}{ab}} \quad (F / m)$$

$$= \frac{0.02413 \times 10^{-9}}{\log_{10} \frac{d^2}{ab}} \quad (F / m) \text{ ----- (formula 2)}$$

ϵ : permittivity= $8.855 \times 10^{-12} (F/m)$
 a : radius of conductor A (m)
 b : radius of conductor B (m)
 d : distance between conductor A and conductor B (m)

Figure ES28D: Calculation of Capacitance between Conductors



$$C = \frac{2\pi\epsilon}{\ln \frac{2h}{a}} \quad (F / m)$$

$$= \frac{0.02413 \times 10^{-9}}{\log_{10} \frac{2h}{a}} \quad (F / m) \text{ ----- (formula 3)}$$

a : radius of the conductor (m)
 h : height of the conductor from the ground (m)

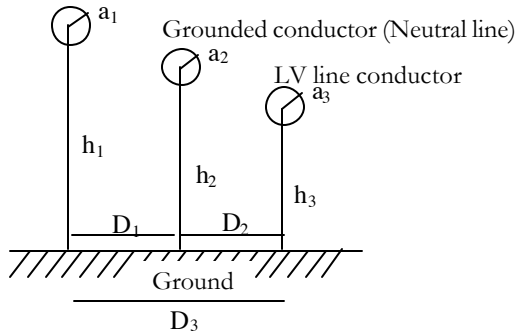
Figure ES28E: Calculation of Capacitance between a Conductor and the Ground

(Screening effect by a grounded conductor)

As shown in Figure ES28F, a grounded conductor, the neutral line of the LV line, acts as a screening wire which has an effect on reducing the induction voltage. The screening factor, K , is calculated from the formula in Figure ES28F.

When K is 0.6, the induction voltage will be reduced by 40%. For example: the induction voltage without the screening wire is 200V, but it will be 120V with the screening wire.

HV line conductor



$$K = 1 - \frac{\frac{2.3}{2\pi\epsilon_0} \log_{10} \frac{\sqrt{(h_3 + h_2)^2 + D_2^2}}{\sqrt{(h_3 - h_2)^2 + D_2^2}}}{\frac{2.3}{2\pi\epsilon_0} \log_{10} \frac{2h_3}{a_3}}$$

$$= 1 - \frac{\log_{10} \frac{\sqrt{(h_3 + h_2)^2 + D_2^2}}{\sqrt{(h_3 - h_2)^2 + D_2^2}}}{\log_{10} \frac{2h_3}{a_3}} \text{ -- (formula 4)}$$

K : screening factor

Figure ES28F: Screening Factor for Electrostatic Induction Voltage

b. Electromagnetic Induction Voltage

Electromagnetic induction voltage is calculated from formula 5. (Refer to Figure ES28G.)

Each HV line conductor acts like a coil in a transformer and the air acts like the core of a transformer.

The LV line conductor acts as the secondary coil.

$$\dot{V} = j\omega l(M_a \dot{I}_a + M_b \dot{I}_b + M_c \dot{I}_c) \text{ ----- (formula 5)}$$

Where: \dot{V} : voltage induced on LV line (V)

$\dot{I}_a, \dot{I}_b, \dot{I}_c$: current of each phase (A)

M_a, M_b, M_c : mutual inductance between HV conductors and a LV conductor (H/km)

l : length of side by side use (km)

ω : 2 πf (rad/s)

f : frequency (Hz)

When M_a, M_b and M_c are almost equal, formula 5 is transformed to:

$$\begin{aligned} \dot{V} &= j\omega l M (\dot{I}_a + \dot{I}_b + \dot{I}_c) \\ &= j\omega l M I_0 \text{ ----- (formula 6)} \end{aligned}$$

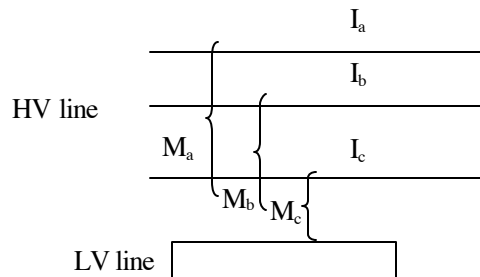


Figure ES28G: Electrostatic Inductive Voltage

As understood from formula 6, when a transmission line is operated normally and the load is balanced, the electromagnetic induction voltage is not much generated because I_0 does not flow. When the single-line ground fault occurs, electromagnetic voltage is much generated because I_0 flows. Single-line ground fault current, therefore, should be used for considering the electromagnetic induction voltage.

The magnitude of the induced voltage is higher when:

- The single-line ground fault current is increased.
- The length of parallel between the two conductors is increased.
- The distance between the two conductors is decreased. (not so much influence compared to electrostatic induction)

Mutual inductance (M) is calculated by Karson-Porachek equation as follows:

$$M = \left[4.6 \log_{10} \frac{2}{kd} - 0.1544 + \frac{2\sqrt{2}}{3} k(h+y) - j \left\{ \frac{\pi}{2} - \frac{2\sqrt{2}}{3} k(h+y) \right\} \right] \times 10^{-4} \quad (H / km)$$

Where:

$d = \sqrt{x^2 + (h-y)^2}$: Distance between a HV line and a LV line (m)

x : horizontal distance between HV line and LV line (m)

h : distance to the ground of HV line (m)

y : distance to the ground of LV line (m)

$$k = \sqrt{4\pi\omega\sigma} \times 10^{-7}$$

$\omega = 2\pi f$ f : frequency (Hz)

σ : ground conductivity (s/m),

(Screening effect by a grounded conductor)

As shown in Figure ES28H, a grounded conductor acts as a screening wire which has an effect on reducing the induction voltage. The screening factor, K, is calculated from the formula in Figure ES28H.

When K is 0.6, the induction voltage will be reduced by 40%. For example: the induction voltage without the screening wire is 200V, but it will be 120V with the screening wire.

$$K = 1 - \frac{\omega \left(\frac{\pi}{2} + j 4.6 \log_{10} \frac{2}{k d_1} \right) \times 10^{-4}}{r_s + \omega \left\{ \frac{\pi}{2} + j \left(4.6 \log_{10} \frac{2}{k a} + \frac{\mu_s}{2} \right) \right\} \times 10^{-4}}$$

Where:

d_1 : equivalent distance between each LV conductor to the grounded conductor (m), $d_1 = \sqrt[3]{D_1 \times D_2 \times D_3}$

a : radius of the conductor (m)

r_s : resistance of the conductor (O/km)

μ_s : permeability of the conductor

$$k = \sqrt{4\pi\omega\sigma} \times 10^{-7}$$

$\omega = 2\pi f$ f : frequency (Hz)

σ : ground conductivity (s/m),

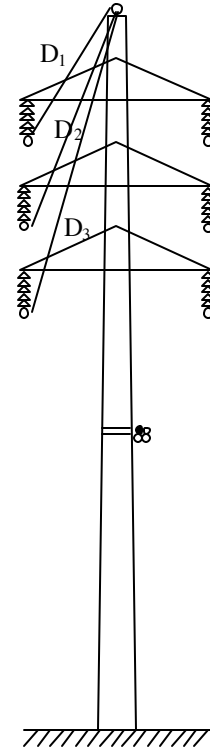


Figure ES28H: Screening Factor for Electromagnetic Induction Voltage

(2) How to Decide the Regulation for Clearance between HV lines and LV lines

When permissible induction voltages are adopted as described in Table ES28C, necessary clearance between HV lines and LV lines can be decided by calculating the induction voltages for the existing HV line of EDC.

Table ES28C: Permissible Induction Voltage

HV line conditions	Permissible induction voltage of LV lines	Reason
At normal operation	Electrostatic induction voltage<230V	The same concept of Clause 39 of GREPTS was adopted.
At single phase ground fault	Electromagnetic induction voltage<650V	The regulation for communication lines applied in some countries, such as UK, USA, France and Japan, was adopted.

a. Electrostatic Induction Voltage

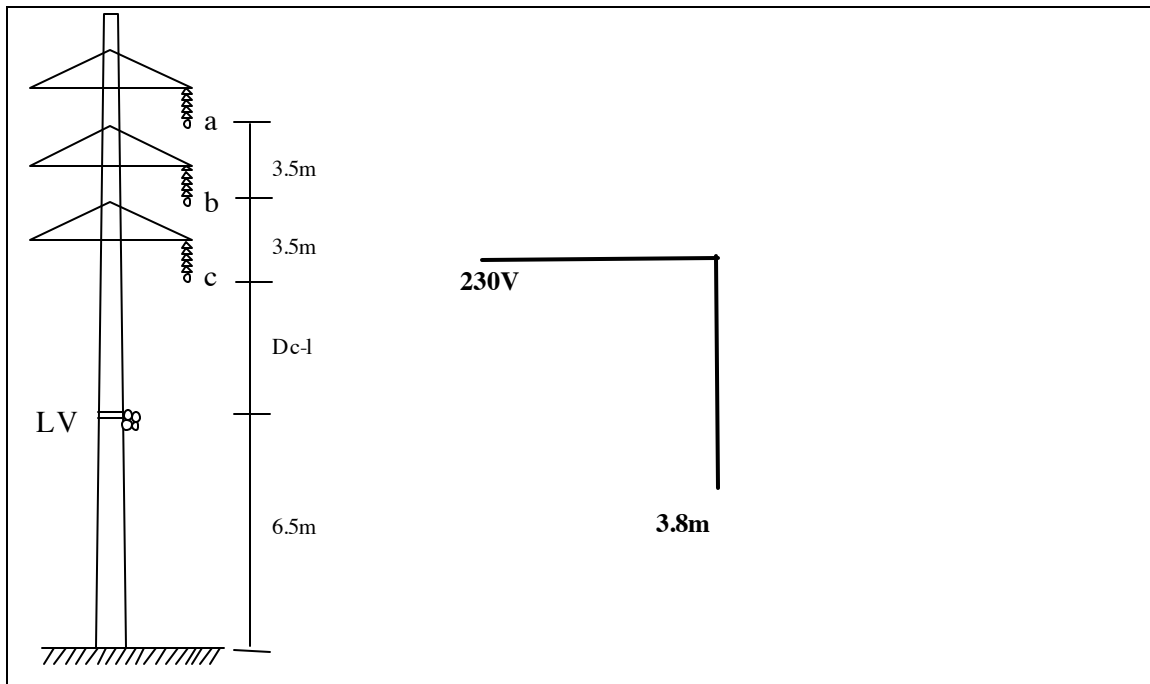
(Calculation conditions)

Items	Unit	Value
Radius of a HV line conductor	mm	10.55
Equivalent radius of 2 bundle conductor	mm	46.51
Radius of a LV line conductor	mm	7.25
Radius of a Neutral line conductor	mm	5.00
Distance of side by side use	m	500
Length of LV line	m	500

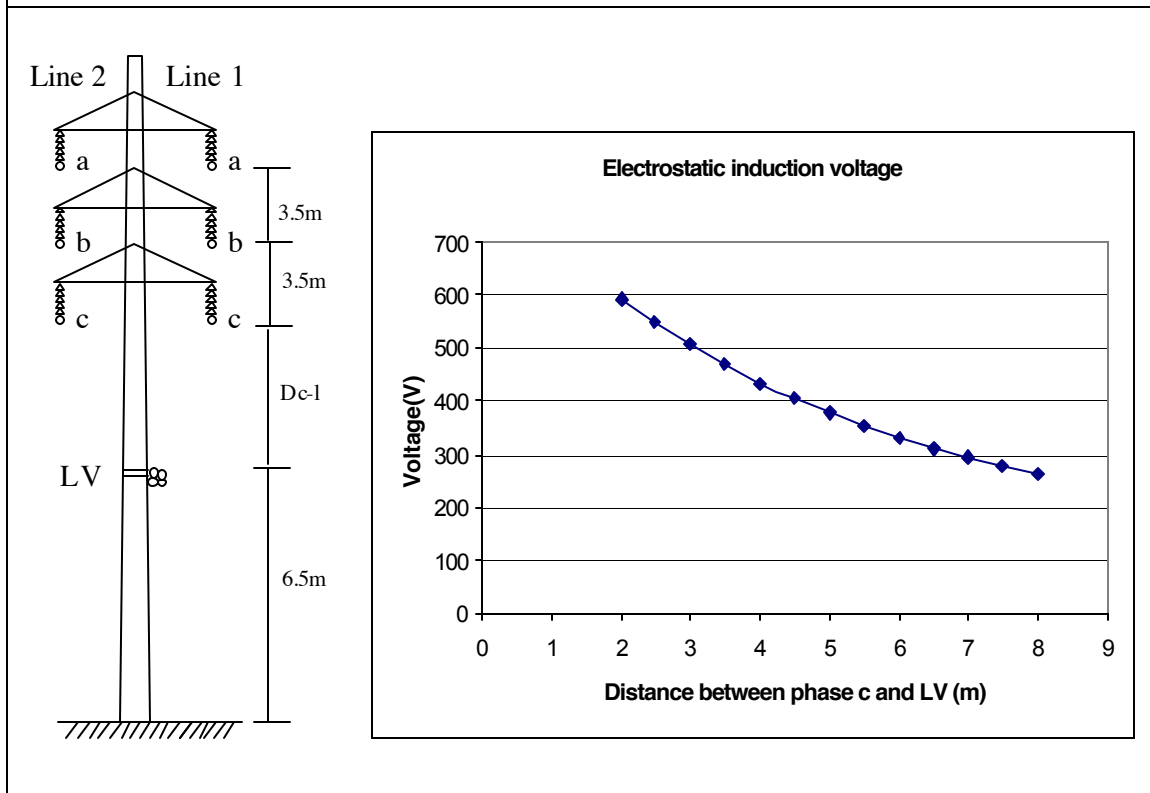
The calculation results of the following three cases are given below.

- In case of a single-circuit HV line
- In case of a double-circuit HV line with same phase-formation
- In case of a double-circuit HV line with reversed phase-formation

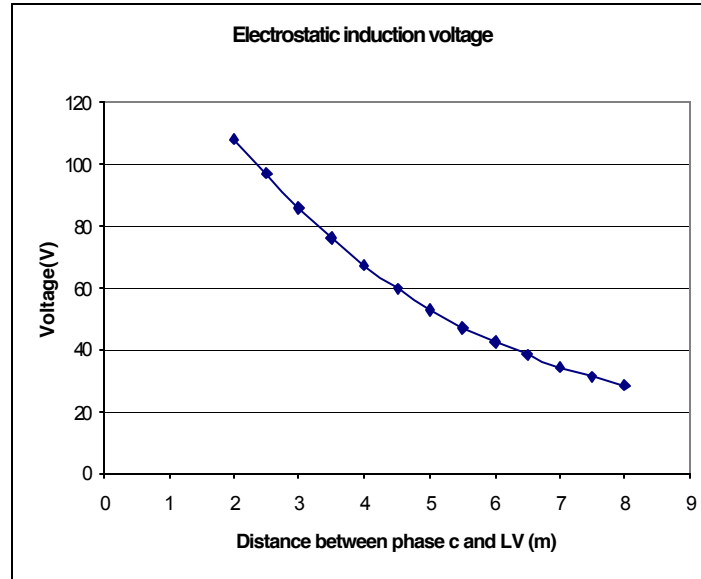
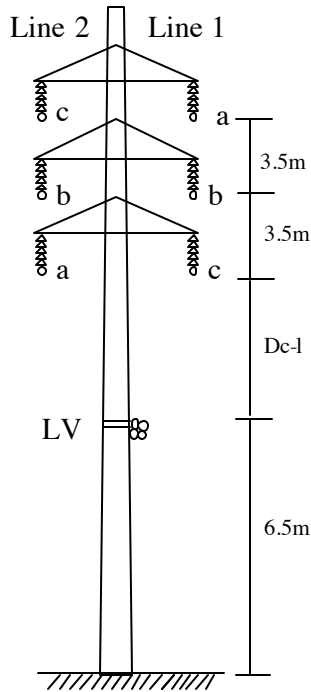
a. In case of a single-circuit HV line (Where the neutral conductor is grounded)



b. In case of a double-circuit HV line with same phase-formation
(Where the neutral conductor is grounded)



c. In case of a double-circuit HV line with reversed phase-formation
(Where the neutral conductor is grounded)



As understood from the above calculation results, in case of double-circuit HV line with same phase-formation, the induction voltage can not be reduced to less than 230V, even if the neutral conductor of the LV lines is grounded. When the HV line has double circuits, therefore, reversed phase-formation shall be adopted. The necessary clearance between high-voltage line conductors and low-voltage line conductors should be at least 3.6m. Taking into account the calculation error, 20% margin was added and finally 4.5m was decided as the minimum clearance.

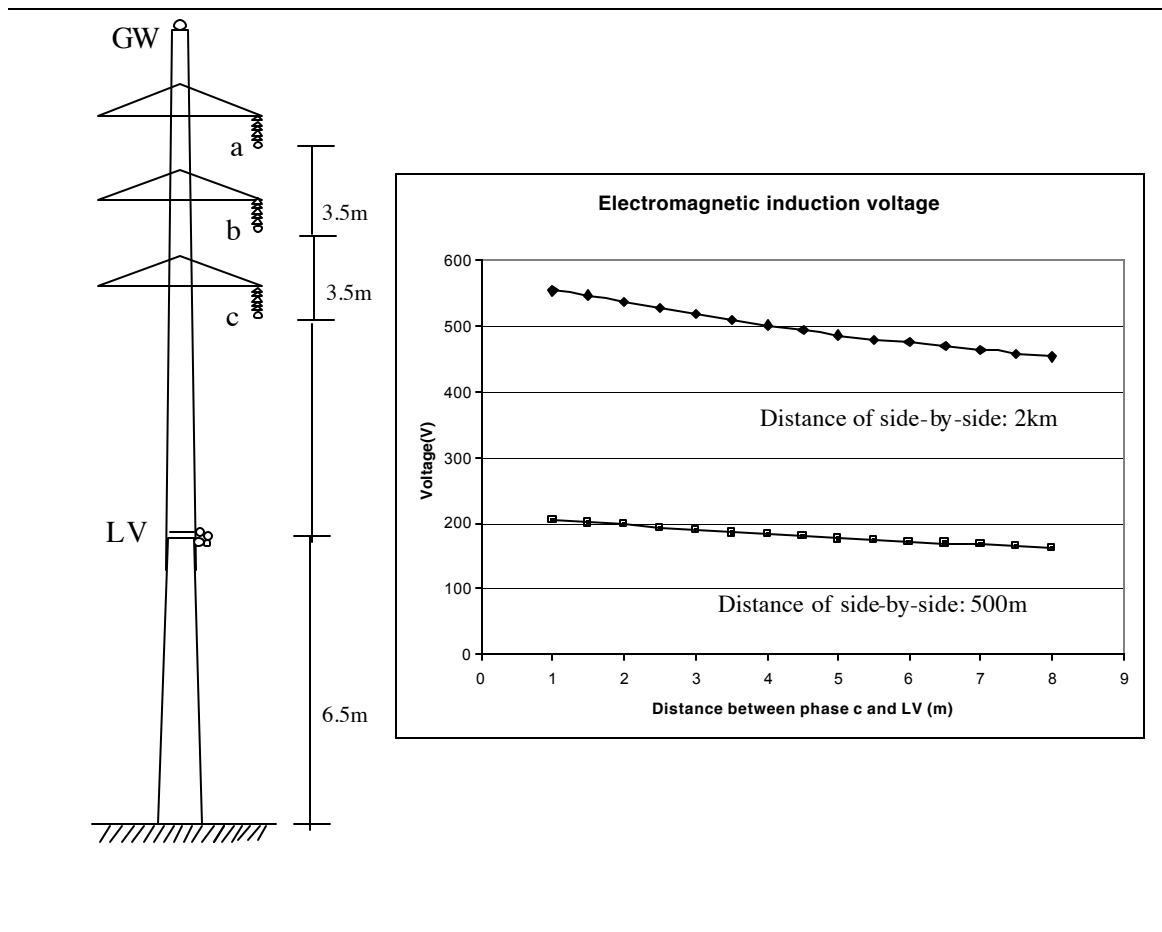
In case of a double-circuit HV line with reversed phase-formation, the induction voltage is fairly low compared to the same phase-formation.

In the above calculations, the neutral conductor of the LV line is grounded. In case of no grounding, the induction voltage can not be reduced to less than 230V. When ABC cable is used for a LV line, therefore, class B grounding of the neutral conductor is necessary for reducing the induction voltage.

b. Electromagnetic Induction Voltage

(Calculation conditions)

Items	Unit	Value
Radius of a HV line conductor	mm	10.55
Radius of a LV line conductor	mm	7.25
Radius of a Neutral line conductor	mm	5.00
Single-phase ground fault current	A	1,000



In case of above calculation, the electromagnetic induction voltage does not exceed 650V. The necessary clearance, 4.5m, decided by the calculation result of electrostatic induction voltage can be applied.

However, when the distance of side-by-side becomes longer, the electromagnetic induction voltage will exceed 650V. Therefore the distance of side-by-side should be decided carefully in consideration of the assumed induction voltage.

Article 29: Underground Lines

1 Draw-in Conduit System and Culvert System

As for the installation of underground facilities, the most important thing is:

- To install facility to withstand such external forces as the weight of vehicles.
- To manage the location of the facilities so that they can be easily identified.

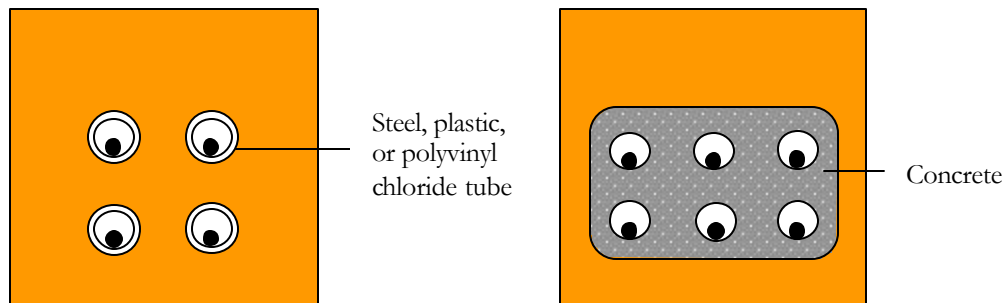
Generally, a cable is installed with some protective tubes or a culvert that withstand the pressure (the draw-in conduit system). This system has another advantage that the change of the cable is relatively easy compared with the direct burial system.

When underground lines are installed with a draw-in conduit system, the depth of a line is not regulated. However the tubes of the draw-in conduit system shall have sufficient strength to withstand pressure of vehicles and other heavy objects.

Clause 35.2 of GREPTS shall be applied to systems similar to the culvert system.

In case the strength of the tubes cannot be verified, they shall be installed in accordance with the Clause 35.3.2 of GREPTS.

Draw-in conduit system



* This system is relatively reasonable and effective for maintenance works.

Culvert system

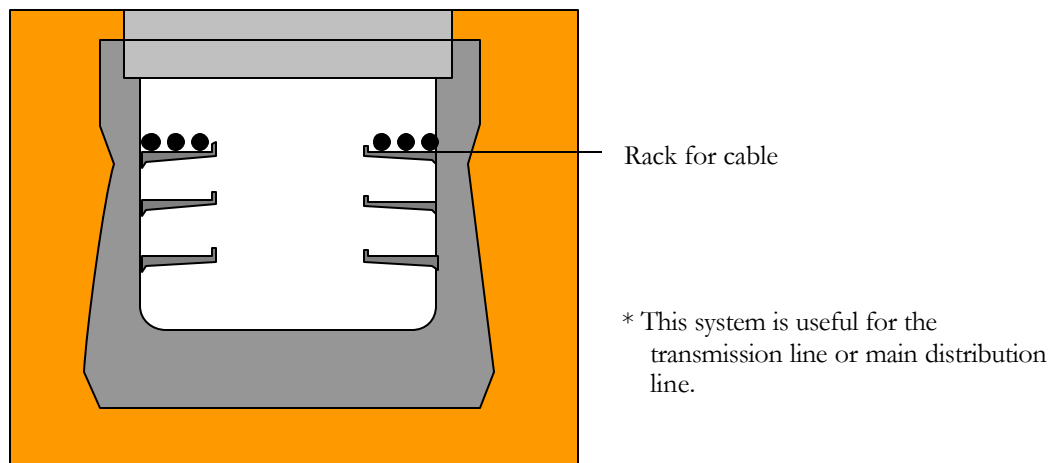


Figure ES29A: Examples of Draw-in Conduit System and Culvert System

2 Direct Burial System

The underground lines shall be installed to withstand the pressure of vehicles and other heavy objects.

When a cable is laid directly under the ground, proper measures shall be taken in order to protect the cable from the pressure and the mechanical shock of a pickax. One of the measures is to install a plate above the cable. Another measure is to use the trough. In these cases the position of the underground facilities is lower than the values that are decided in the GREPT. The depth shall be explained in Figure ES29B.

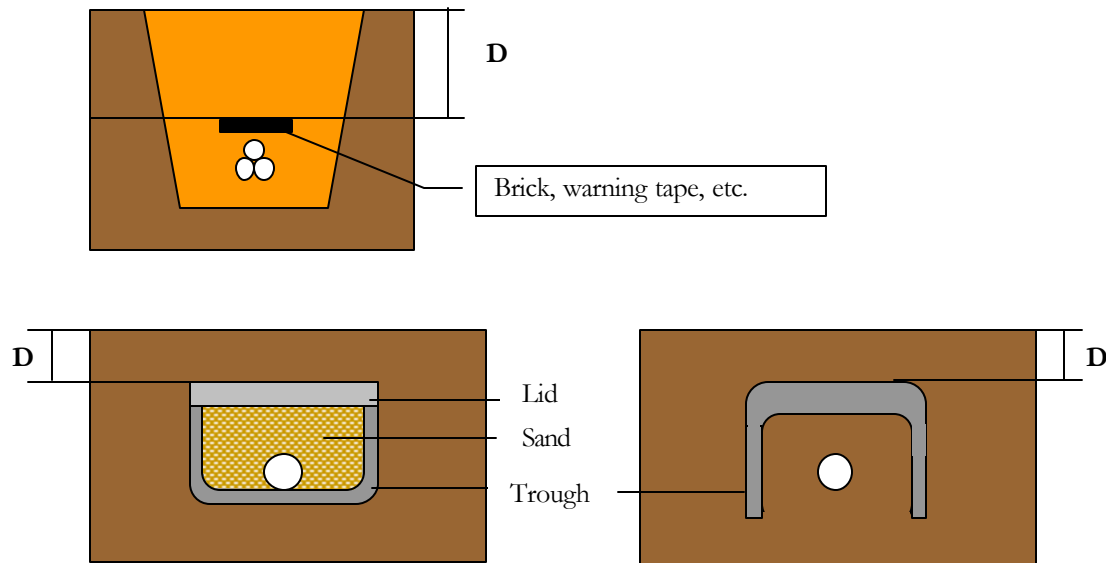


Figure ES29B: Explanation of the Depth of Direct Burial System

- 2.1 The depth of underground facilities described in clause 35.3.2 of GREPTS signifies the depth of such facility as a plate to protect cables.

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

Though the received pressure is different depending on the structure of a road, the values are decided based on the present situation of underground lines in Cambodia and the standards of other countries. Besides the standards, the depth of the lines shall be approved by such road administrator as the local government.

- 2.2 The following places shall be included among the ‘any other place’.

- The sidewalk of a road.
- A road where no vehicles pass.

Still more, considering the facts that a road may be blocked due to the underground works for the expansion of network and the restoration of troubled facilities, it is desirable that the underground lines are installed under a sidewalk at the main street.

3 Clearance between Multiple Underground Lines

When a new electrical line is installed, the adequate clearance from other existing lines shall be ensured in order to prevent other lines from the damage caused by the trouble of one line.

Minimum clearance between a new underground line and other electrical lines shall be the values in Table 14B of SREPTS.

However, in case that one of two electrical lines is installed in an incombustible stout tube, the minimum clearance shall not be required.

4 Clearance between Underground Lines and Other facilities

The underground facilities are not usually visible. And 'Underground' is shared with such utilities as the telecommunication company, the water bureau and the gas company. Therefore when a new electrical line is installed, the adequate clearance from other existing facilities shall be ensured in order to prevent the facilities from the damage caused by the troubles of the line.

Minimum clearance between a new underground line and other facilities shall be the values in Table 14C of SREPTS.

However, in case the electrical line is installed in an incombustible stout tube and the tube does not come into direct contact with other facilities, the minimum clearance shall not be required and also in case communication lines are united with electrical lines, the minimum clearance shall not be required.

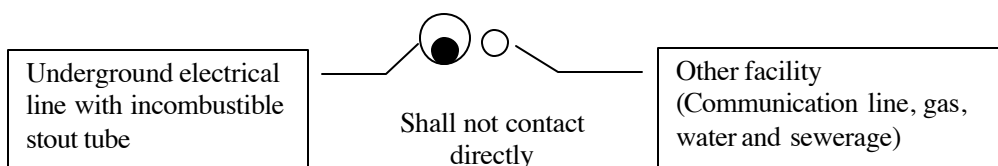
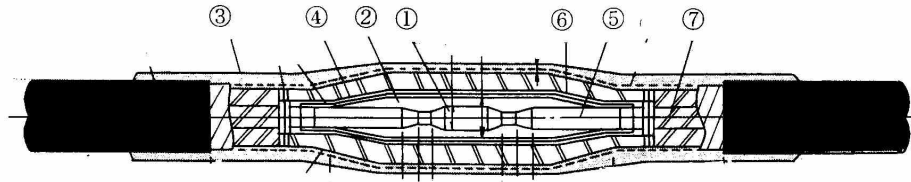


Figure ES29C: Explanation between Underground Lines and Other Facilities

Still more, the underground facilities shall be managed their location, by GIS (Geographic Information System), drawings or other proper measures. Especially when such important lines as the high-voltage line and the medium-voltage trunk line are installed, the signs that show the location of facilities shall be installed at a site, in order not to be damaged the facilities by accident.

5 Connection of Underground Cables

For the underground line, the cable, manufactured under such international standards, shall be used in order to prevent the electric disasters and the ground faults. The regulation regarding the connection of conductors is described in Clause 18 of GREPTS. In addition to the regulation, when underground cables are connected, connection shall be implemented using appropriate devices in order to maintain the equivalent physical and electrical performance to the original cables, because the number of troubles at the connecting point is relatively large. The requirements are prescribed in this paragraph.



- ? Connecting pipe
- ? Waterproof tape
- ? Cross linked polyethylene
- ? Shield metallic tape
- ? Adhesive polyethylene tape
- ? Lead tape
- ? Semi-conductive fusion bonding tape

Figure ES29D: Example of Connecting Method for Medium-voltage Line

6 Structure of Underground Boxes

When such underground boxes as a manhole and a hand hole are installed for the connection and branching of cables, the regulation regarding its structure is required. In this paragraph, the fundamental requirements for the underground boxes are described.

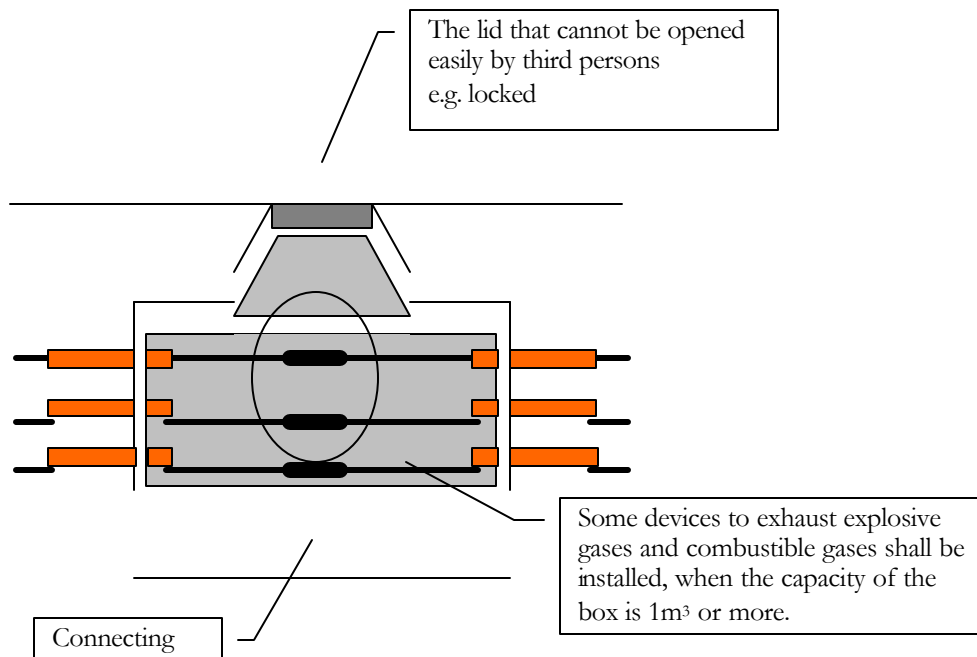


Figure ES29E: Example of an Underground Box

7 Grounding for Underground Facilities

The necessity of grounding is described in Clause 39 of GREPTS. In this Article, the required grounding for the underground facilities is regulated.

In order to prevent from the electrical shock caused by the cable troubles, the safety grounding of Class D described in Clause 39 of GREPTS shall be required for the metallic part of underground facilities.

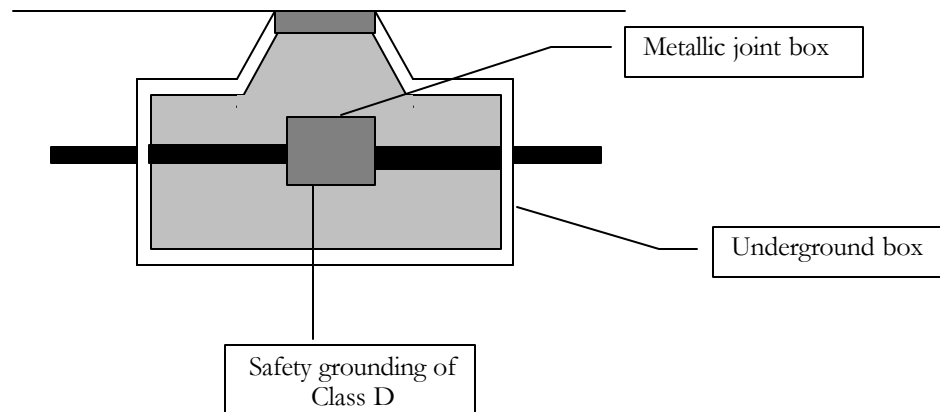


Figure ES29F: Example of an Underground Box

8 Others

- A caution sign such as 'Warning ??kV Underground Cable under this sign' should be laid underground between an underground line and surface of the earth so that any constructor may not damage a cable accidentally at the time of digging.
- A lid of a manhole shall be such that people other than operators cannot open it easily especially for High-voltage underground lines.

CHAPTER 3

HIGH-VOLTAGE TRANSMISSION

FACILITIES

Article 30: Protective Devices for Electrical Equipment

1 Protection and Alarm Devices for Transformers and Reactive Power Compensators

- 1.1 Over-current relays shall be installed in essential places to protect conductors and electrical equipment from over-current and to prevent a fire caused by over-current.

In case over-current occurs in a circuit, this device breaks the circuit.

In case of Low-voltage, an over-current relay means a fuse or a circuit breaker for distribution lines. In case of High and Medium voltage, the over-current relay means a circuit breaker.

The over-current relay is installed on high-voltage lines and equipment to prevent accidents and protect themselves because lines or equipment might be damaged by a short-circuit fault, etc. and the accident might cause a fire or an outage.

- 1.2 In case of a large capacity transformer, the transformer has a lot of insulating oil, and if an accident happens on the transformer, the accident causes a great influence on environmental pollution and disaster protection. Therefore, the circuit has to be disconnected before damage of the transformer becomes serious.

Differential relay, Oil flow relay, Pressure relay and so on are used for internal failures in a transformer.

Power capacitors and shunt reactors are devices to control reactive power on power system. In case an internal failure happens in these devices, these devices have to be cut off from the circuit not to influence the power system. And these devices should never cause a fire.

1.3 Function of Relays

(1) Over-current Relay (OC)

OC Relay monitors the current value and detects the over current in case of short circuit faults or grounding faults.

(2) Pressure Relay (Pr), Oil flow Relay (Oil)

These relays work mechanically and monitor the gas pressure or oil flow in the transformer.

In case of the internal fault of the transformer, they detect the increase of the gas pressure or the oil flow.

(3) Differential Relay (Df)

In the normal conditions, the current value of I_0 which flows through Df relay is zero because I_1 and I_2 are balanced and canceled each other.

However in case of the internal fault of the transformer, both are unbalanced and I_0 appears through the Df relay. The Df relay detects this I_0 and separate this transformer from the electrical circuit by tripping each side of CBs.

1.2 Strength of Steel Members and Bolts

(1) Relation between Stress and Strain

Strain of a material will increase gradually if the external force of the materials increases.

In case the stress of the material increases on O-E line, if the external force is removed, the strain disappears and the material is restored to the original form immediately. It works as a perfect elastic material. Between this OE is called the elastic region. E-point is called the elastic limit.

If the stress increases over E-point, it amounts to Y-point. The strain after Y-point is longer than that between O-point and Y-point. Y-point is called the yield point.

If the strain exceeds U-point, the stress decreases. The stress intensity of U-point is called the ultimate strength. The stress intensity in case the material fractures (B points) is called the destructive strength.

The yield point is the most important to examine a property of steel.

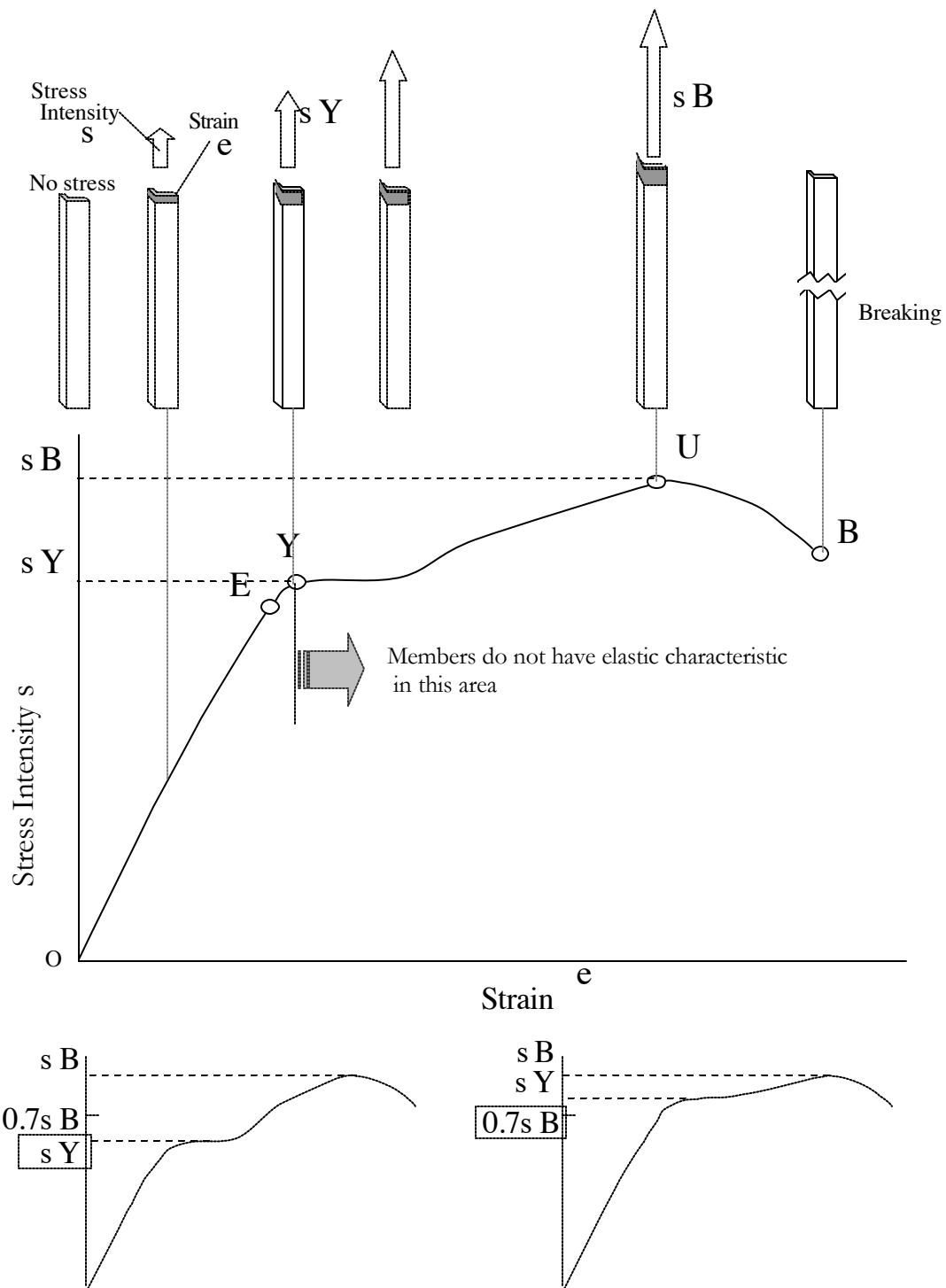
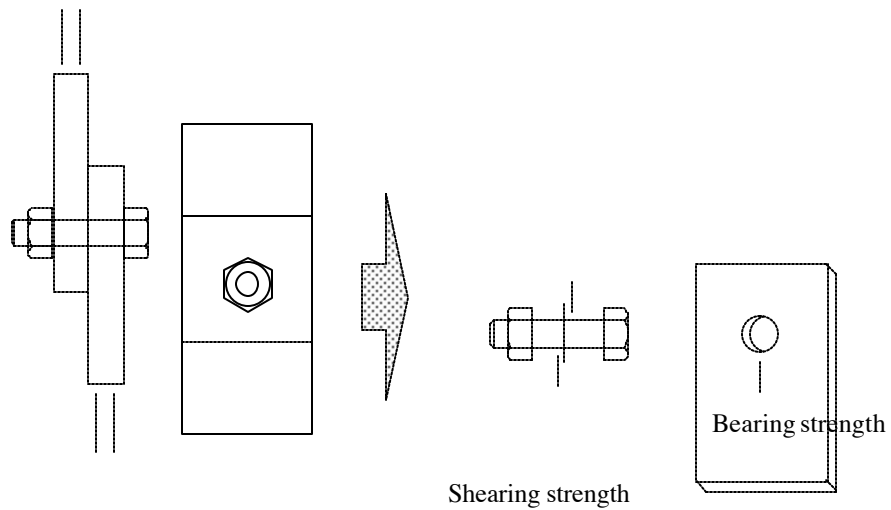
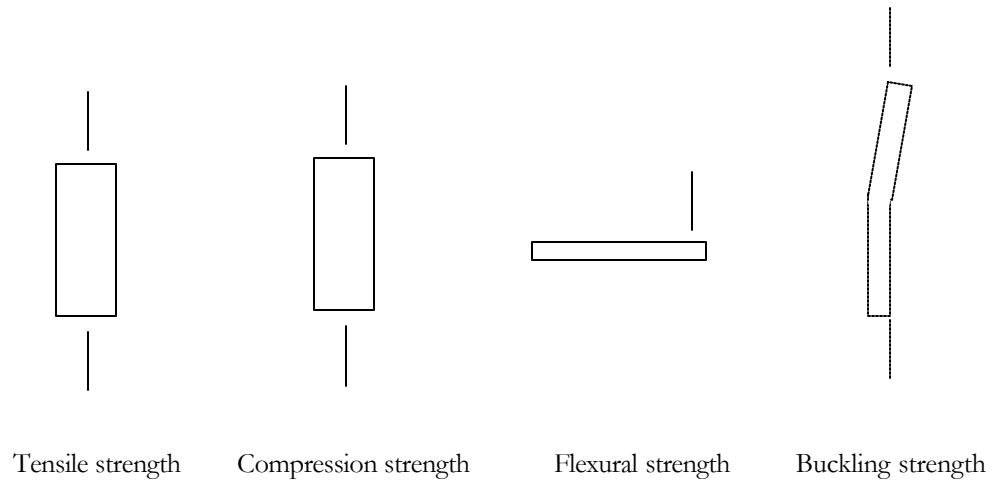


Figure ES31B: Relation between Stress and Strain

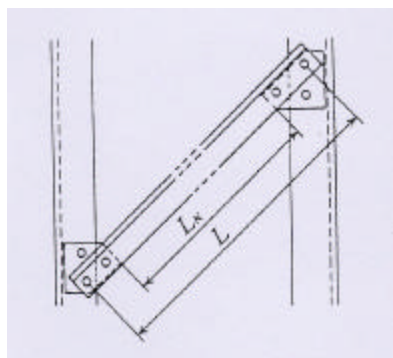
(2) Classification of Strength



In case two members are bolted on, these members withstand against external force with shearing strength and bearing strength.

Figure ES31C: Shearing Strength and Bearing Strength

(3) Relation between L and L_k



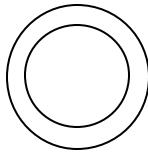
L : Length of supporting points
 L_k : Effective buckling length of a steel member

Generally $L_k = 0.9L$

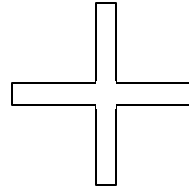
Figure ES31D: Relation between L and L_k

(4) Strength of Steel Members and Bolts

- Structural members with little decentering

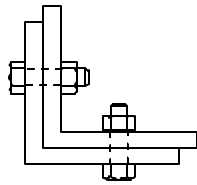


Steel pipe (section)



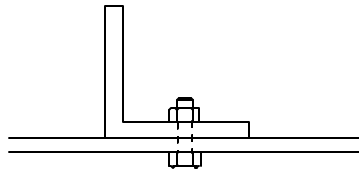
Cruciform section steel (section)

- Structural members with some decentering



Angle steels used for a main post member (section)

- Structural members with significant decentering



Angle steels used for a web member with one side flange joint (section)

Figure ES31E: Relation between Structural Members and Decentering

(5) Bond Strength of Concrete

Bond strength of concrete means strength between a round bar or a shaped steel etc. and a concrete of a foundation as the following figure.

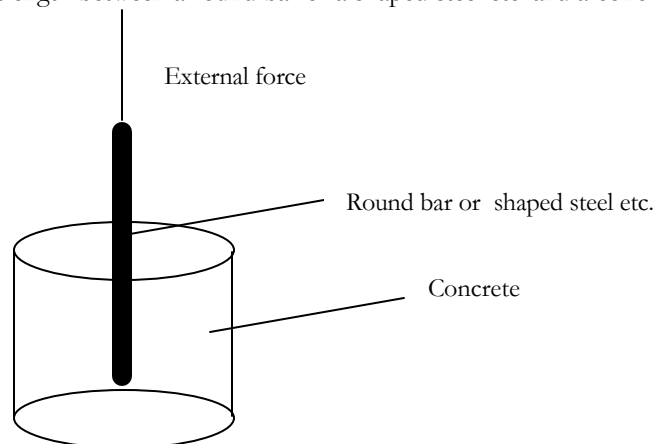


Figure ES31F : Bond Strength of Concrete

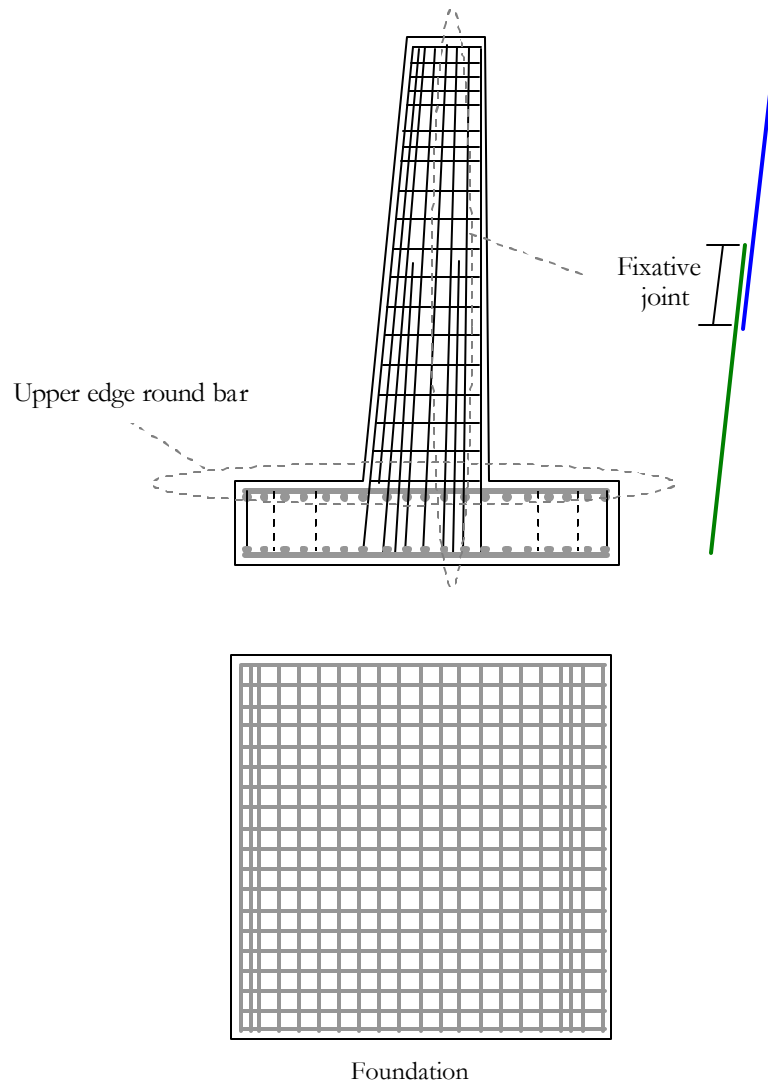


Figure ES31G: Upper Edge Round Bar and Fixative Joint

2 Wind Pressure Load

2.1 Wind Pressure Value

The wind pressures calculated by the formula in this paragraph are shown in Table ES31A. The results are taken a 10% margin into consideration because there are few data of wind velocity and a value '32m/s' does not have complete reliability.

Table ES31A: Wind Pressure

Subject to the wind pressure				Resistance Coefficient	Wind pressure to 1m ² of the vertical projected area (Pa)
Supporting structure	Iron pole	Columnar pole		0.8	520
		Triangle or rhombic pole		1.9	1,220
		Square pole consisting of steel pipes		1.5	970
		Others		2.4	1,540
	Reinforced concrete pole	Columnar pole		0.8	520
		Square pole		2.0	1290
	Steel tower	Shaped steel tower		Refer to EX31-2.3	2,350 *
		Steel pipe tower		Refer to EX31-2.3	1,340 *
Single pole		Columnar pole	0.8	520	
		Hexagonal or octagonal pole	1.5	970	
Electrical conductors and other strung wires	Electrical wires forming multiple conductors (Limited to those in which two compositional conductors are arranged horizontally and the distance between such electrical conductors is not more than 20 times their outer diameter)			1.05*0.9	610
	Others			1.05	680
Insulator device				1.4	900
Cross arms for an iron pole (limited to a columnar pole) and a reinforced concrete pole				1.6	1,030 when it is used as a single member
				2.2	1,410 in other cases

* This value shall be applied to 115kV high-voltage towers which are less than 40 m high.

Conditions:

- The wind velocity 32m/s
- Density of air 1.137kg/m³ (28°C, 80%, 1,013×10⁵Pa)
- Average temperature 28 °C
- Average humidity 80%

The following formula should be applied to calculate the wind pressure load to 1m² of the vertical projected area. (IEC60826 is referred)

$$P = C \left(\frac{1}{2} \delta K_R^2 V^2 \right) \quad [\text{Pa}]$$

Where: C = Resistance coefficient

d = Density of air (kg/m³)

V = Wind velocity (= 32m/s)

K_R = Roughness factor (= 1.00)

2.2 Examination Regarding Oblique Winds

In case wind pressure on a steel tower accounts for a significant percentage of the overall loads acting on it, winds blowing in the tower's oblique directions may endanger the tower. In case of high-voltage transmission towers which are high and have long cross arms, or towers similar in construction to them, the strength of the corner posts and foundations against oblique winds must be studied.

A wind angle necessitation maximum design stress varies with individual steel towers. It is sufficient, however, to study an oblique wind coming from 60°, at which the corner posts develop the maximum stress under wind pressure.

In case of dead-end towers which are assumed to develop a great unbalanced tension, it seems unlikely that exposure to an oblique wind will generate a still greater uneven tension in them. Even if wind pressure on the steel towers increases, it will be sufficiently compensated by decrease of the wind pressure on conductors and the conductor tension so that oblique winds need not be taken into consideration as far as these steel towers are concerned.

(1) Wind Pressure on Tower Bodies

a. Shaped Steel Towers

Wind pressure on steel tower bodies increases when they are exposed to oblique winds. The load on a square-section tower increases to the maximum when exposed to a wind coming from 60° to it. The maximum load is about 1.2 times the load by a wind blowing at 90°. In this case, member stress, particularly, web member stress does not pose problems as compared with the case where the tower is exposed to a 90° wind. The post members 'a' and 'c' shown in Figure ES31H will develop a stress of 1.64 times (=1.2{sin60°+cos60°}) according to calculation results.

Actually, however, wind and wind pressure directions may be a little different from each other. The wind tunnel test results give a post stress increase of about 1.56 times.

Therefore, the post stress of a square-section tower

generated by the wind pressure on the tower bodies exposed to a 60° wind may be regarded as 1.6 times that to a 90° wind.

b. Steel Pipe Towers

In case of steel pipe towers, wind pressure on tower bodies will also increase due to oblique winds, but not so much as that in the case of shape steel towers.

According to the test results, the post stress of a square-section tower generated by the wind pressure on the tower bodies exposed to a 60° wind is considered to be about 1.4 times that to a 90° wind.

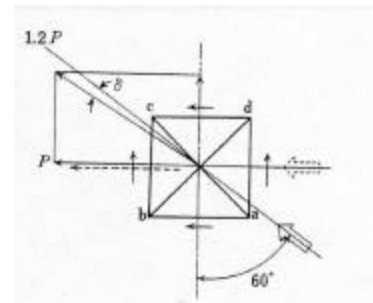


Figure ES31H

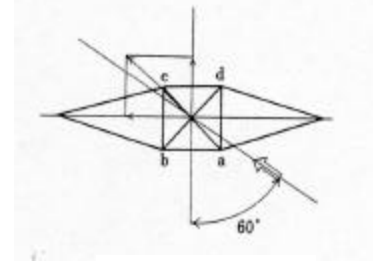


Figure ES31I

(2) Wind Pressure on Cross Arms

Wind pressure on cross arms by oblique winds has components of forces on the front and sides as shown in Figure ES31I. A wind tunnel test using a cross arm model has shown that when the model is exposed to a wind blowing from an angle of 60° , the posts 'a' and 'c' develop a stress 0.55 times that when they are exposed to a 0° wind.

The wind pressure for the tower bodies is used as wind pressure for the cross arms. This value, however, is a little safe figure for the cross arms so that the post stress of a tower generated by wind pressure on the cross arms exposed to a 60° wind may be 0.5 times the stress calculated on the assumption that a wind pressure obtained by multiplying the front cross arm projected area by the standard wind pressure will act in the longitudinal directions of the line.

(3) Wind Pressure on Conductors

A wind tunnel test has confirmed that a wind pressure force on conductors by an oblique wind which is from right angles to the conductors decreases nearly in direct proportion to \sin^2 of the wind receiving angle ϕ , and that the wind pressure component in the directions of the conductors is almost negligible. Therefore, the post stress caused by wind pressure to conductors by a 60° wind will be 0.75 times ($= \sin^2 60^\circ / \sin^2 90^\circ$) of that for a 90° wind.

2.3 Increasing of Wind Pressure Depending on Height

(1) Calculation of Wind Pressure Value for Towers

Equivalent wind pressure of a tower body is calculated by the following equation with Aerodynamic Coefficient depending on the shape and the wind pressure calculated with the design wind pressure considering the gradual increasing coefficient.

$$P = \frac{\int_0^H C_h q_h h dh}{\int_0^H h dh}$$

a. Wind Pressure of Towers

P : Wind pressure of towers (Pa)

C_h : Aerodynamic Coefficient $h(m)$ aboveground $C_h = C_a + b(H - h)$

C_a : Aerodynamic Coefficient on the tower top

b : Increasing rate of Aerodynamic Coefficient

H : Height from ground to the top(m)

h : Height aboveground (m)

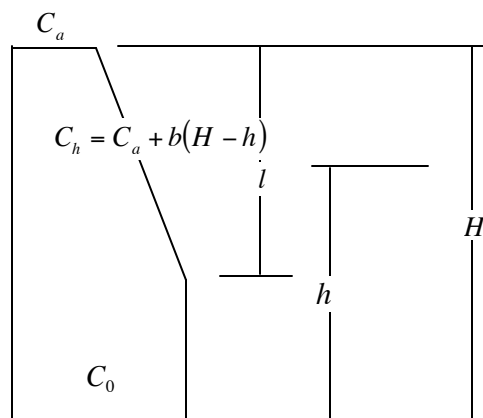
q_h : Design velocity pressure $h(m)$ aboveground (Pa)

b. Aerodynamic Coefficient

Aerodynamic Coefficient examples about existing tower bodies in Japan are shown in Table ES31B.

Table ES31B: Aerodynamic Coefficient of Tower Body

	Shaped steel tower		Steel pipe tower	
	110-154kV	185-275kV	110-154kV	185-275kV
C_0	3.4	3.4	1.8	1.8
C_a	2.7	2.8	1.6	1.7
b	0.0175	0.012	0.005	0.002
l	40	50	40	50



$$H - l < h \quad C_h = C_a + b(H - h)$$

$$H - l > h \quad C_h = C_0$$

l : Height for calculation

Figure ES31J: Aerodynamic Coefficient

(2) Calculation of Design Wind Pressure

The design wind pressure at h (m) above the ground is calculated with standard velocity q_0 and

$$q_h = \alpha \cdot q_0$$

$$\alpha = \left(\frac{h}{h_0} \right)^{1/4}$$

Gradual increasing coefficient α as follows.

α : Gradual increasing Coefficient

q_h : Design wind pressure(Pa)

q_0 : Standard wind pressure(Pa)

h : Height above the ground(m)

h_0 : Standard Height 10m

The standard wind pressure is calculated based on the standard velocity 10m above the ground as follows:

$$q_0 = \frac{1}{2} \delta V_{G10}^2$$

δ = Density of air (kg/m³), 1.137kg/m³ (28 °C, 1,013×10⁵Pa)

V_{G10} : Wind velocity 10m above the ground (m/sec)

g : Gravity(9.80665m/sec²)

(3) Equivalent Wind Pressure of Tower Body

Equivalent wind pressure of a tower body in Cambodia is calculated according to (1) and (2)

a. Standard Wind Pressure and Standard Height above the Ground

Standard wind pressure based on design wind velocity 32m/sec in Cambodia is shown as follows.

Table ES31C: Standard wind pressure

q_0	680 N
h_0	10 m

b. Equivalent Wind Pressure of Tower Body

Equivalent wind pressure of a tower body in Cambodia is shown as follows.

Table ES31D: Equivalent Wind Pressure of Tower Body in Cambodia

Height of tower H(m)	Shaped steel tower		Steel pipe tower	
	110-154kV	185-275kV	110-154kV	185-275kV
40 or less	2350	2380	1340	1390
50 or less	2530	2540	1430	1480
60 or less	2690	2690	1510	1550
70 or less	-	2830	-	1620
80 or less	-	2950	-	1680

3 Loads on Supporting Structures and Safety Factors

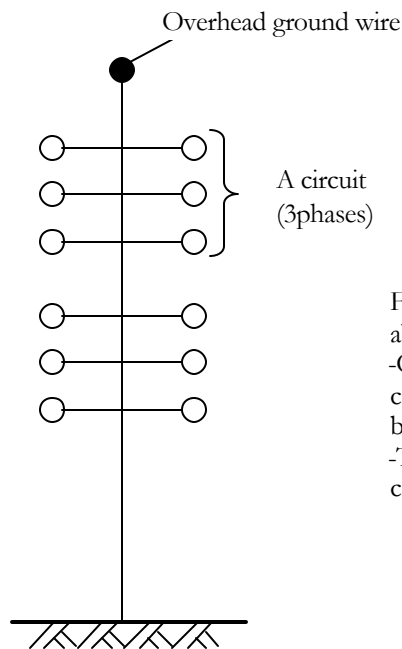
3.1 Types and Combinations of Assumed Loads

Stress calculations are executed separately in the cases of a normal condition or an abnormal condition.

Calculation in the case of an abnormal condition is executed only about steel towers.

Moreover the external force is considered separately in a direction of vertical against ground, a direction of a transmission line (Horizontal longitudinal) and a direction of a right angle with a transmission line (Horizontal transverse).

3.2 Pattern of Cutting Wire in Abnormal Case



Following strung wire shall be assumed to be cut for abnormal condition.

-One phase or one overhead ground wire which makes worst condition for the supporting structure when the wire is broken

-Two conductors from one phase in case of multiple conductors

a. In the case of not more than 12 phases

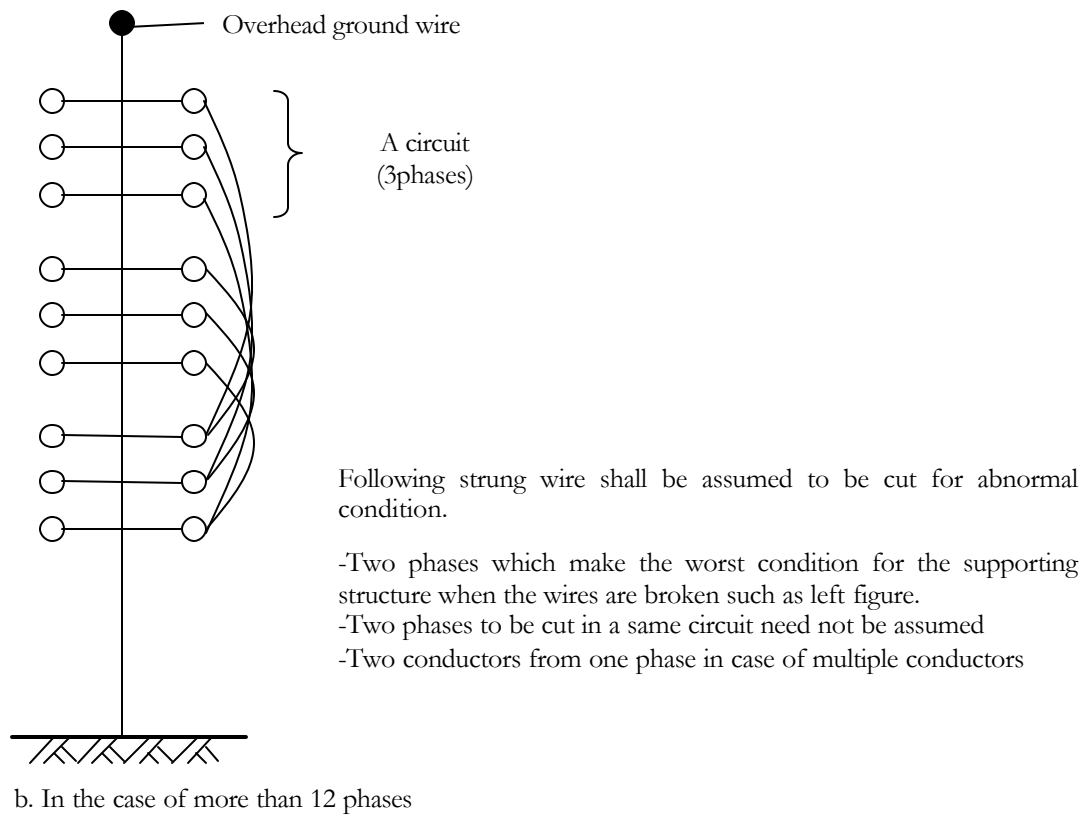


Figure ES31K: Pattern of Cutting Wire in Abnormal Case

- Type of Assumed Loads

Table ES31E: Load on Support Structures

Symbol	Vertical loads
W_t Weight of steel tower	
W_c Weight of conductors and ground wire	
W_i Weight of insulators	
V_a Tension of conductors and ground wires	
W_s Tension of guy wires	
	Horizontal transverse loads
H_t Wind pressure of support	
H_c Wind pressure of conductors and ground wires	
H_i Wind pressure of insulators	
H_a, H_s Tension of conductors, ground wires and guy wires	
q Torsional load due to unbalanced tension	
	Horizontal longitudinal loads
H_t' Wind pressure of support	
W_s' Tension of guy wires	
$P1$ Unbalanced tension of all phases	
$P2$ Unbalanced tension of any phase	
q_l Torsional load due to unbalanced tension	

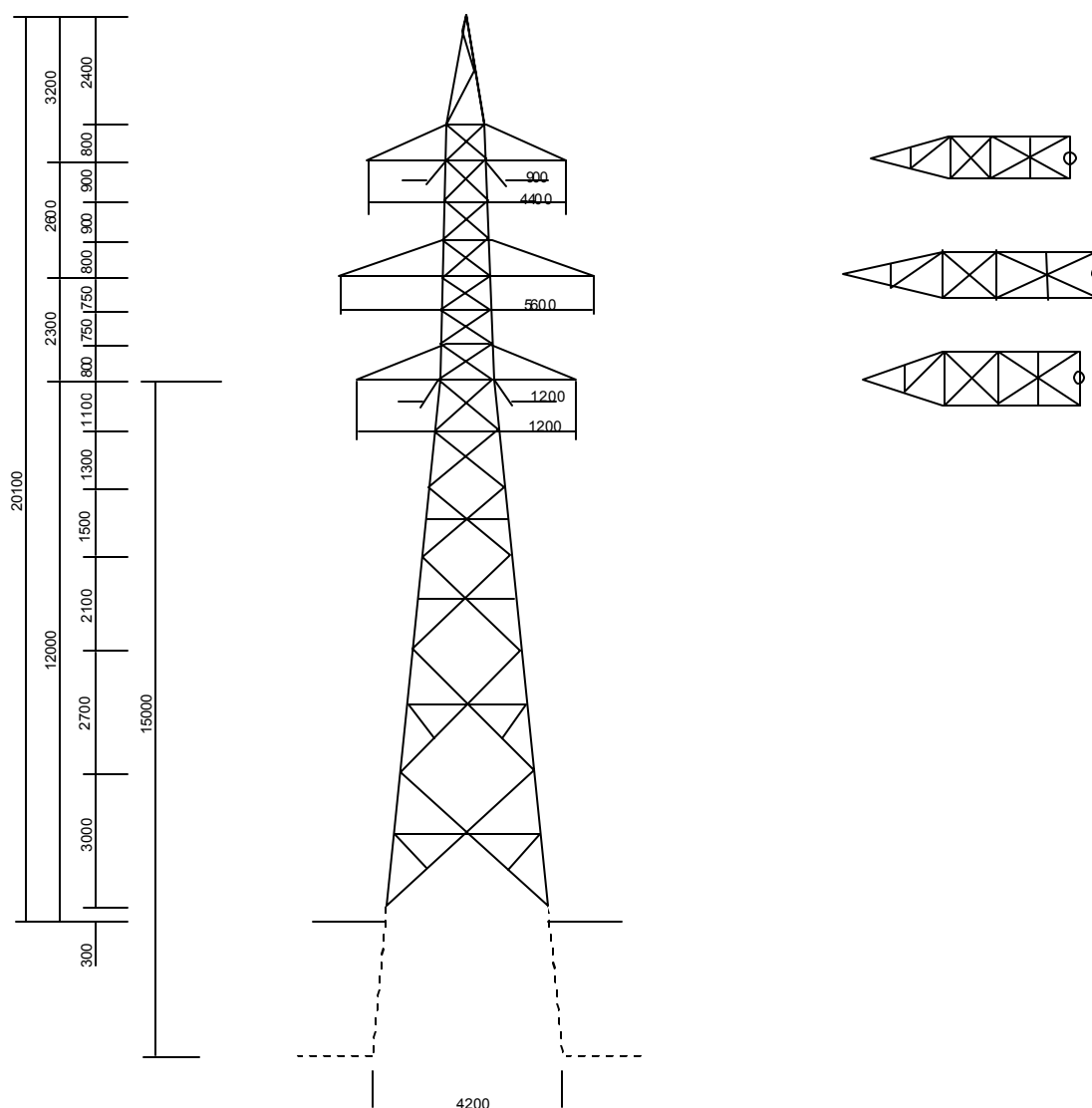


Figure ES31L: Skeleton of Support

Table ES31F : Condition of Design (example)

Condition of Design				
Item		unit	Value	
Nominal voltage		kV	66	
Number of circuits		cct	2	
Loading span		m	150	200
Line angle		degree	20	
Rate of vertical angle		————	+ 0.1 0.1	
Conductor	Kind		————	ACSR/ AC 410mm ² × 1
	Diameter		mm	28.5
	Unit mass		kg/ m	1.569
	Maximum tension	High temp	N	43800
		Low temp	N	44000
Ground wire	Kind		————	AC 70 mm ²
	Diameter		mm	10.5
	Unit mass		kg/ m	0.4265
	Maximum tension	High temp	N	8430
		Low temp	N	-
Insulator	Kind		————	250mm disk type insulator
	Diameter		piece/ string	7
	Unit mass		kg/ support	130
Post Insulator	Kind		————	Long rod post insulator
	Number		piece/ string	1
	Unit mass		kg/ string	35
Design wind pressure	Support		P a	2840
	Conductor		P a	980
	Ground wire		P a	980
	Insulator		N support	590
	Post insulator		N string	200
Note				

Table ES31G: Assumed load calculation (example)

Example Calculation

Table of assumed load calculation

Assumed load calculation(kN support point)				
Item		Calculation		Result
Weight of conductors & ground wire		G	$\{ 0.4265 \times (150 + 200) \times g \times 10^{-3}$	1.47
		C1~ 3	$(1.569 \times (150 + 200)) + 130 + 35 / 2) \times g \times 10^{-3}$	6.84
		C4~ 6		
Vertical component of tension	Pull down	G	$(8430 \times 0.1) \times 10^{-3}$	0.85
		C1~ 3	$43800 \times 0.1 \times 1 \times 10^{-3}$	4.38
		C4~ 6		
	Pull up	G	$(8430 \times 0.1) \times 10^{-3}$	0.85
		C1~ 3	$43800 \times 0.1 \times 1 \times 10^{-3}$	4.38
		C4~ 6		
Wind pressure of conductor & ground wire	Horizontal transvers	G	$\{ 980 \times 10.5 \times 10^{-3} \times (150 + 200) \times \} \times 10^{-3}$	3.61
		C1~ 3	$\{ 980 \times 28.5 \times 10^{-3} \times (150 + 200) + 590 + 200 / 2 \} \times 10^{-3}$	10.47
		C4~ 6		
	Horizontal Longitudinal	G		
		C1~ 3		
		C4~ 6		
Horizontal transverse component of tension		G	$2 \times 8430 \times 20 \times 10^{-3}$	337.2
		C1~ 3	$2 \times 43800 \times 1 \times 20 \times 10^{-3}$	1752
		C4~ 6		
P1 Unbalanced tension of conductor of all phases		G		
		C1~ 3		
		C4~ 6		
P2 Unbalanced tension of conductors of any phase		G	0×10^{-3}	0
		C1~ 3	$43800 \times 10^{-3} \times 10^{-3}$	43.8
		C4~ 6		
q ₁ Torsional load due to unbalanced tension		G		
		C1	$\{ 43800 \times 2.2 \times / (2 \times 0.900) \} \times 10^{-3}$	53.54
		C2	$\{ 43800 \times 2.8 \times / (2 \times 1.059) \} \times 10^{-3}$	57.91
		C3	$\{ 43800 \times 2.4 \times / (2 \times 1.200) \} \times 10^{-3}$	43.8
		C4		
		C5		
		C6		
(Nt e)				
$\sin 20^{\circ} / 2= 0.1736$ $g \Rightarrow 9.80665$ (Gravitational acceleration)				

Article 32: Design of Fittings for Conductors and/or Ground Wires of Overhead High-voltage Lines

1 Safety Factor of Fittings for Conductors and/or Ground Wires of Overhead High-voltage Lines

1.1 The Safety Factor Applied in Other Standards

The safety factor of insulators is not less than 2.5 against their destruction strength. Safety Factor 2.5 is the most appropriate value judged from that of foreign countries' standards.

Table ES32A: Safety Factor in other Countries

Standards	Safety factor
General Requirement of Electric Power Technical Standard : Cambodia	2.5 or more
Technical Standard : Japan	2.5 or more
National Electrical Safety Code(NESC) : United State	2.0 or more against tensile 2.5 or more against bend
The Electricity (Overhead Lines) Regulations : England	No regulation
VDE0210 : Germany	3.3 or more

1.2 The Calculation of the Strength for Insulator Devices

The vertical load and the horizontal transverse load are calculated as follows:

$$\text{Vertical Load} = (W_i + W_c \times S) \times g + T_1 \tan \alpha_1 + T_2 \tan \alpha_2 \quad (\text{N})$$

$$\text{Horizontal Transverse Load} = H_i + H_c \times D \times S + T_1 \sin \alpha_1 + T_2 \sin \alpha_2 \quad (\text{N})$$

Where: W_i : Weight of insulator device (kg)

W_c : Weight of conductor (a length unit) (kg/m)

D : Diameter of conductor (m)

S : Weight span (m)

g : 9.80665 (m/s²)

T_1, T_2 : Horizontal component of maximum assumed tension of transmission conductors (N)

α_1, α_2 : Elevation angle of supporting point

H_i : Wind pressure load of insulator device (N)

H_c : Wind pressure load of conductor (N/m²)

α_1, α_2 : Horizontal angle

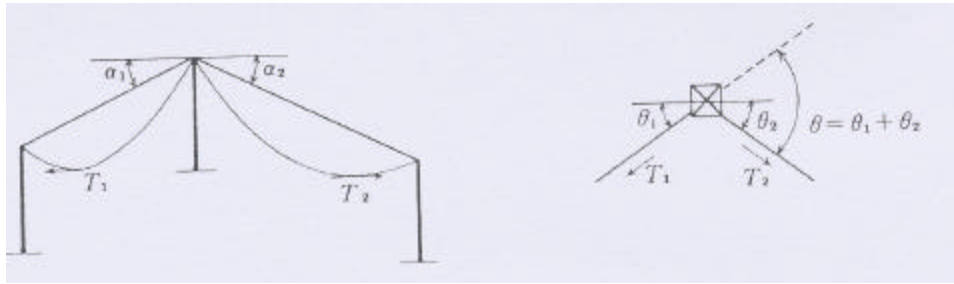


Figure ES32A

2 Mechanical Strength of Insulators for Overhead Transmission Lines

(Wind pressure load to be used for calculating the strength of insulator devices)

The wind pressure load which is shown in Article 31.3 of SREPTS is calculated by values shown in Table ES32B. The calculation method of wind pressure load is explained in detail on the explanation sheet Article 40.5 of SREPTS.

Table ES32B (reinsert)

Subject to wind pressure		Wind pressure per 1 m ² of vertical projected area (N)
Electrical conductor	Multiple conductors *1	610
	Single conductors	680
Insulator device		900

*1: This applies only to cases where two compositional conductors are arranged horizontally and the distance between such electrical conductors is not more than twenty times their outer diameter.

Table ES32C: Values to Be Used for Calculating the Wind Pressure

	C	d(kg/m ³)	K _R	V(m/s)	Margin	Wind Pressure (N/m ²)
Multiple conductors	0.9	1.172	1.05	32.0	1.1	610
Single conductors	1.0	1.172	1.05	32.0	1.1	680
Insulator device	1.4	1.172	1.0	32.0	1.1	900

$$P = C \left(\frac{1}{2} \rho K_R V^2 \right) [\text{Pa}]$$

Where

C = Resistance coefficient

ρ = Density of air (kg/m^3) [28°C, humidity: 80%]

V = Wind Speed

K_R = Roughness factor

In case where multiple conductors are strung parallel to wind direction, the wind pressure is 90% of single conductors considering a decrease by mutual interference of conductors. ($680 \times 0.9 = 610$).



Article 33: Protection against Lightning for Overhead High-voltage Lines

Clause 42 of GREPTS provides three measures to reduce electric faults caused by lightning and prevent the facilities from being damaged by electric faults caused by lightning.

This explanation sheet shows these three measures in detail.

1 Overhead ground wire

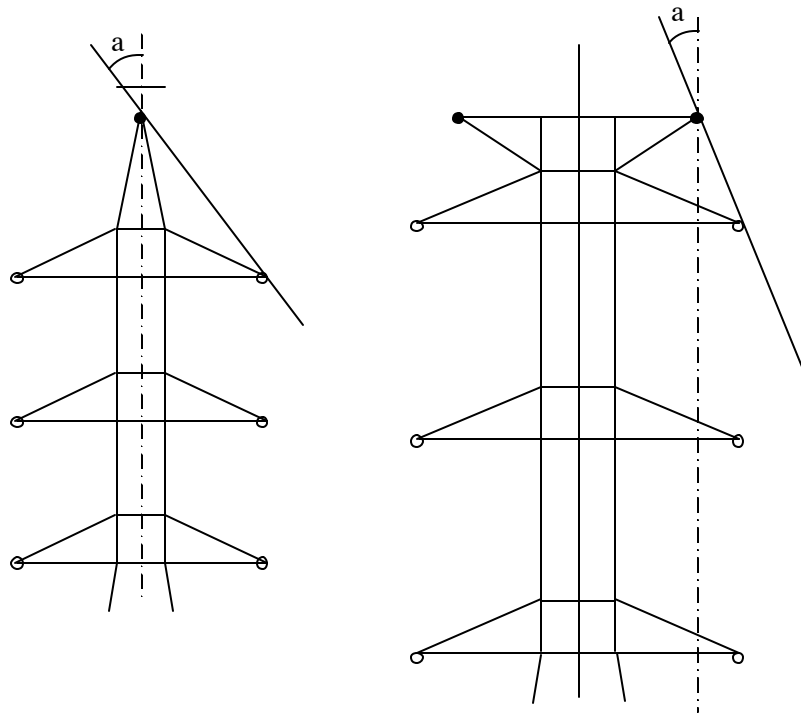
Overhead ground wires have an effect on protecting conductors against direct lightning stroke and on reducing an electric potential rise of supporting structure and an electromagnetic induction voltage. Installing overhead ground wires is one of measures to reduce flashover by lightning.

Overhead ground wires have an effect on protecting conductors against lightning striking because the lightning is guided to the overhead ground wire by a shielding effect.

As for 115kV high voltage lines which have comparatively low supporting structures, one overhead ground wire should be installed and it is desirable to set a shielding angle less than 35 degrees to keep shielding efficiency 90%.

However, as for 230kV high voltage lines which have comparatively high supporting structures, it is desirable to secure enough shielding efficiency by installing two overhead ground wires because these lines should have high reliability.

In areas where lightning occurs frequently, it is needed to consider the size of an overhead ground wire to prevent the overhead ground wire itself from being damaged.



a: shield angle

The smaller a shield angle becomes, the larger a shield effect becomes.

A shield angle is desirable to be smaller than 35 degrees.

Figure ES33A: Overhead Ground Wire and Shield Angle

2 Arcing horn

Arcing horns are used to reduce damage as much as possible when flashover occurs on an insulator assembly. They have an effect to make flashover occur between arcing horns to prevent insulator assemblies from being damaged as much as possible.

If an insulator assembly is installed with arcing horns, the arcs of lightning surge move from the surface of an insulator assembly to the end of the arcing horns, therefore, the arcing horns can protect insulators against lightning.

The horn gap is normally 70% to 80% as long as the length of an insulator assembly.

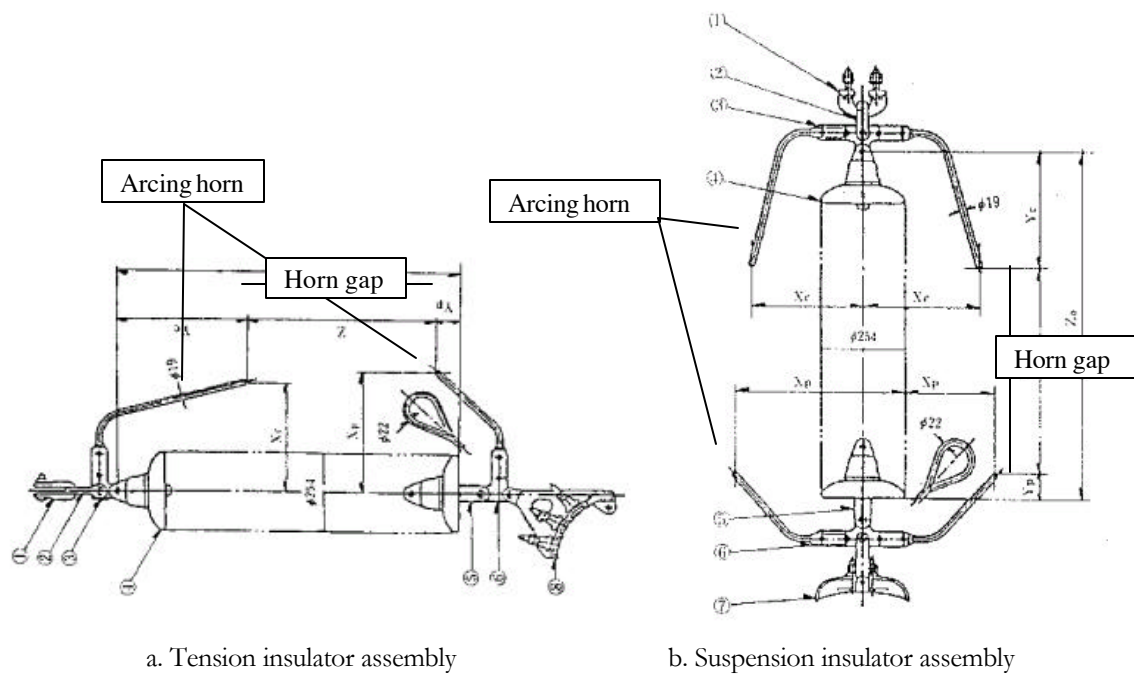


Figure ES33B: Arcing horn

3 Armor rods

A armor rods are used to reduce damage as much as possible when flashover occurs on a suspension insulator assembly. The armor rods are twisted by dozens of strands, which diameter is about 1 to 3 mm, along the outside of a conductor.

Installing armor rods has an effect on preventing the conductor from being melted by arcs which occur in a suspension clamp because the armor rods substantially increase the cross section.

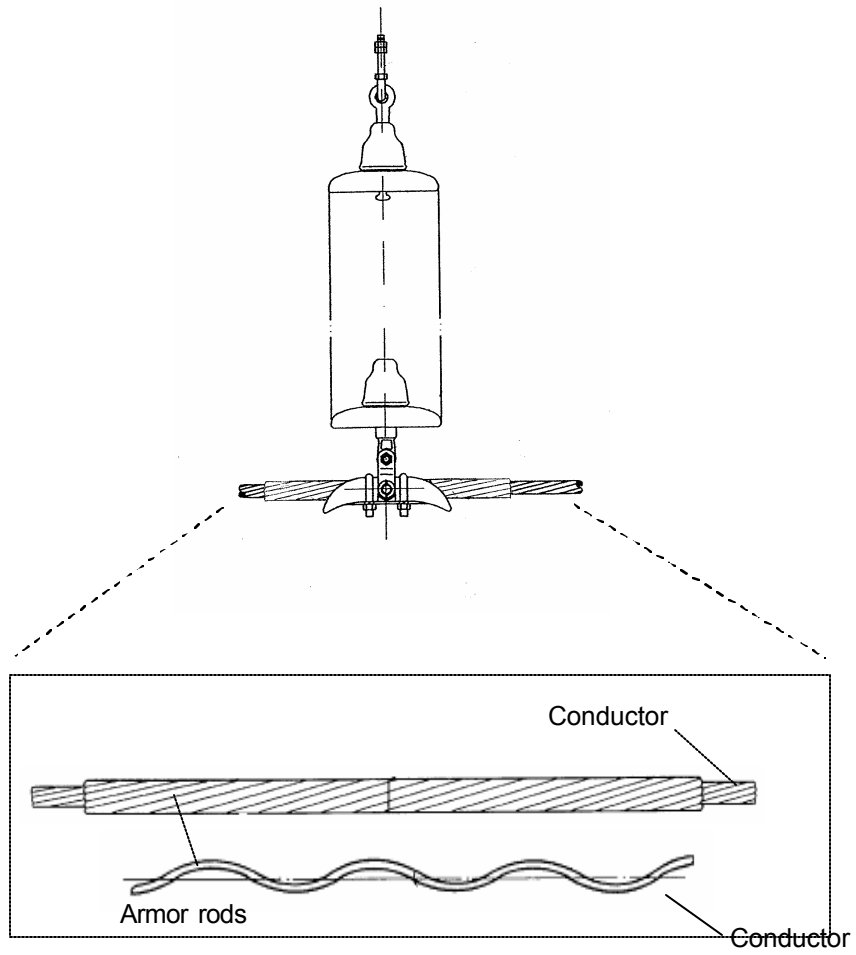


Figure ES33C: Armor Rods

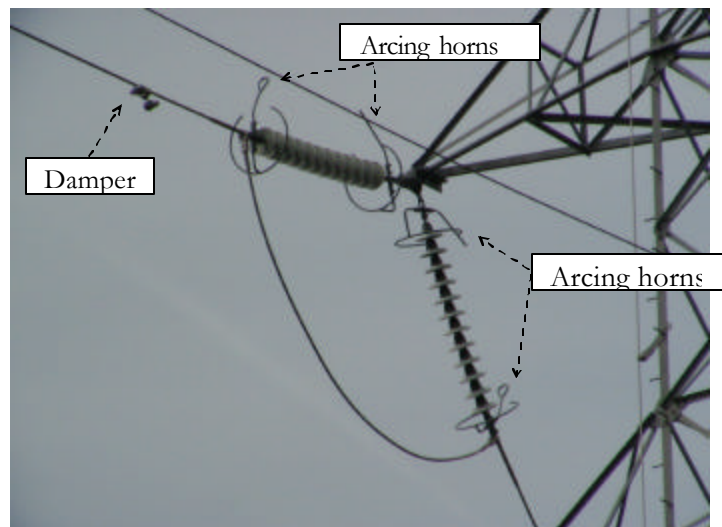


Figure ES33D: Arcing Horns (Tension Type Insulator Device)

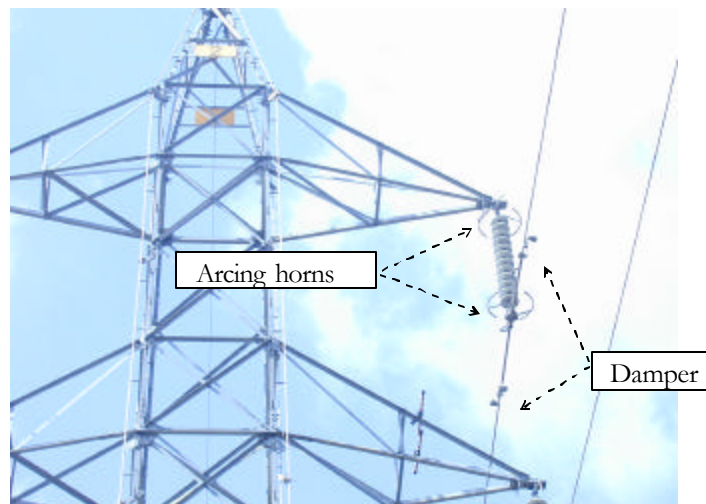


Figure ES33E: Arcing Horns (Suspension Type Insulator Device)

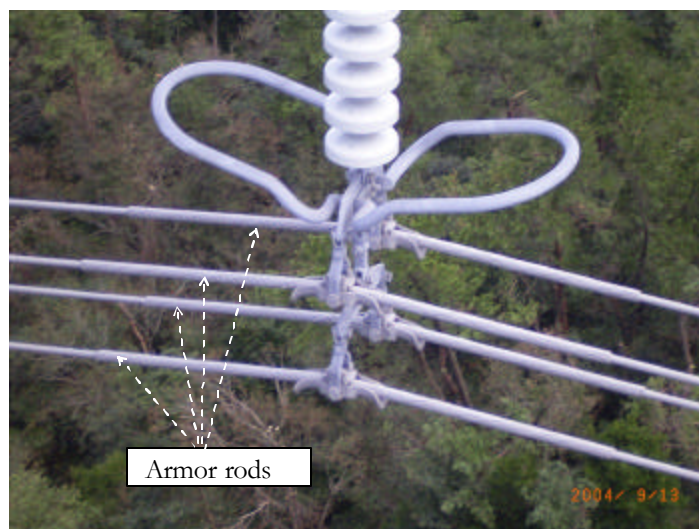


Figure ES33F: Armor rods

Article 34: Bare Conductors of Overhead High-voltage Lines

1 Vibration Dampers

The following measures shall be taken to prevent aeolian vibration for overhead high-voltage lines.
Examples of dampers are shown as follows:

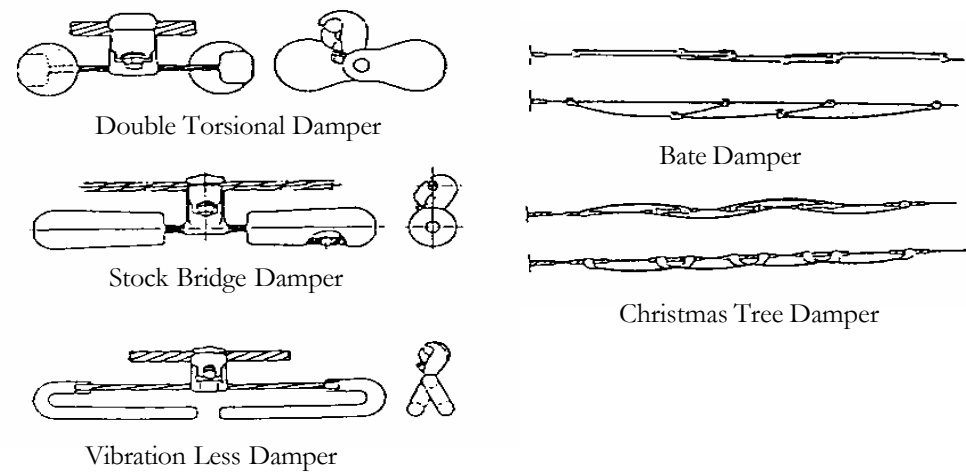


Figure ES34A: Examples of Dampers

There is a close relationship between fatigue of bare conductors and EDS (abbreviation of Every Day Stress which is the value of percentage of everyday load tension under windless conditions to the ultimate tensile strength). CIGRE takes into consideration investigation results of exiting facilities and recommends that EDS should be less than the values shown in Table ES34A.

* CIGRE: Conseil International des Grands Reseaux Electriques (International Council on Large Electric Systems), which is one of the leading worldwide Organizations on Electric Power Systems, covering their technical, economic, environmental, organizational and regulatory aspects.



Table ES34A: Recommended Value of EDS by CIGRE CSC6-58-3

Conductor	No attachment	With dampers	With armor rods	With dampers and armor rods
ACSR	18%	24%	22%	24%

Article 35: Clearance between Bare Conductors and Supporting Structures of Overhead High-voltage Lines

1 Minimum Insulation Clearance

Clearance between a conductor and a supporting structure should be decided in accordance with the switching surge voltage, taking into account the swing of the conductors. Normally, the switching surge voltages are decided as Table ES35A.

Table ES35A: Clearance between a Conductor and a Supporting Structure

(1) Nominal voltage :V[kV]	115	230
(2) Highest equipment voltage :Vm[kV]	123	245
(3) Peak value of line to ground voltage :Vm×v(2/3)[kV]	100.4	200.0
(4) Switching surge multiple n	2.8	2.8
(5) Switching surge voltage[kV] (3)×(4)	281.2	560.1
(6) Insulating drop coefficient	1.1	1.1
(7) Required withstand voltage[kV] (5)×(6)	309.3	616.1
(8) Clearance[m]	0.64	1.40

- Clearance is found from the switching impulse wet flashover voltage characteristic and the withstanding voltage characteristic between conductor-tower body.
(Institute of Electrical Engineers of Japan Technical Report No.220)

- Highest equipment voltage is based on Clause 6 of GREPTS which is referred from IEC 60038.

- Insulating drop coefficient

It is generally known that the higher the altitude becomes, the lower the flashover voltage becomes. For that reason, insulating drop coefficient is used for revision. Its value is 1.1 by altitude 1000m.
(Institute of Electrical Engineers of Japan Technical Report No.220)

- Switching surge multiple n

Table ES35B: Switching Surge Multiple

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

(Report by Institute of Electrical Engineers of Japan)

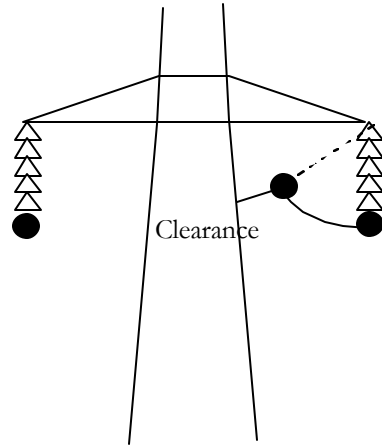
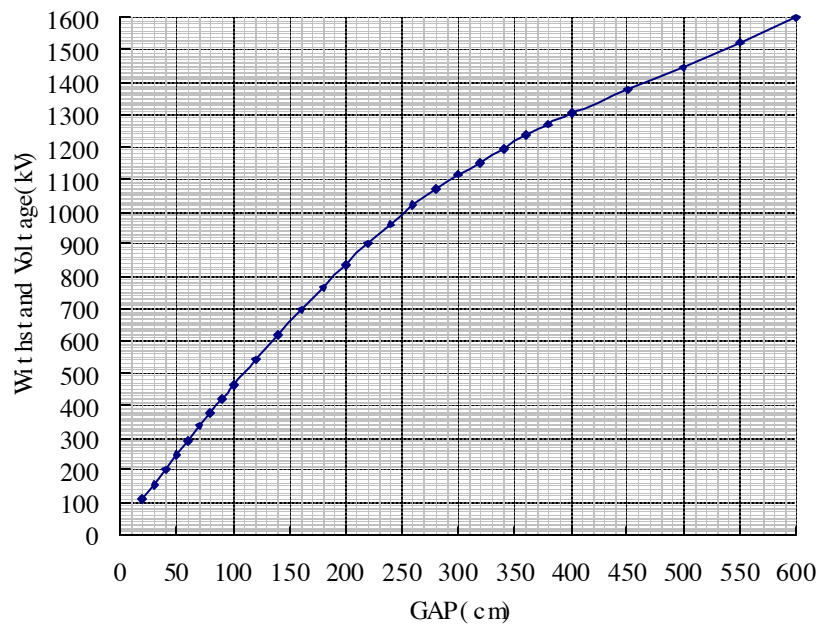


Figure ES35A: Relationship of Clearance between a Conductor and a Supporting Structure



Graph ES35A: Characteristics of switching surge wet flashover voltage between a conductor and a steel member from the experience in Japan

2 Clearance among Ground Wires and the Nearest Conductor

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

Overhead ground wires are installed to prevent back flashover of high voltage lines from occurring. The clearance between a ground wire and a high-voltage conductor on spans shall be more than that on supports to avoid the conductor breaking.

Generally sags of overhead ground wires are 80% as long as those of high-voltage overhead conductors on a condition of average temperature and no wind.

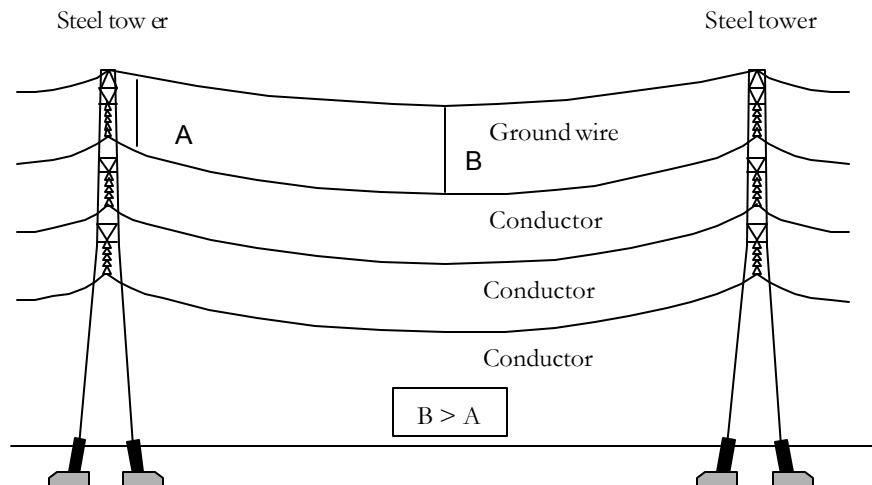


Figure ES35B: Relationship of Clearance between a Ground Wire and a Conductor

In the case of the end span to substations as shown in Figure ES35C, the clearance should be designed as $A > B > C$.

Although it becomes $A > B$ in the case of the end span to substations etc. and it is not satisfied with Clause 44 of GRPTS, what is necessary is just $B > C$.

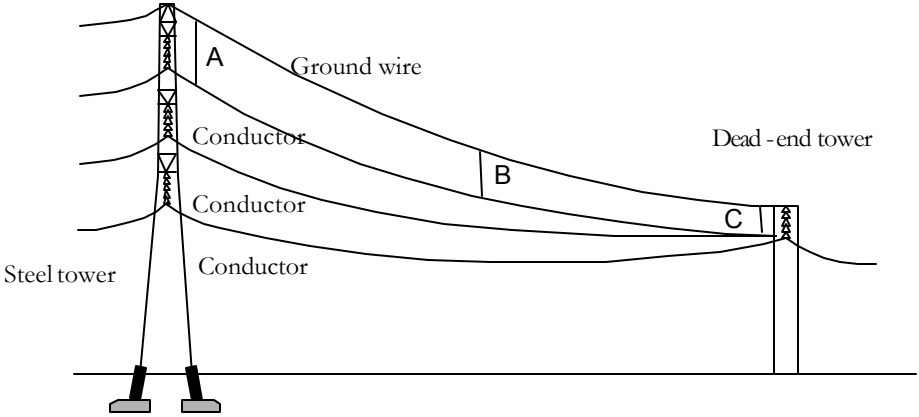


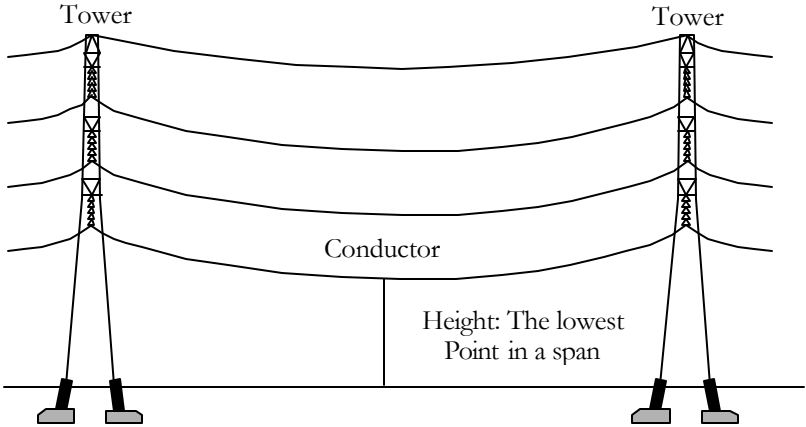
Figure ES35C: Clearance in the End Span to a Substation

Article 36: Height of Overhead High-voltage Lines

The technical standard "Clause45 Height of high-voltage lines" provides height of overhead high-voltage line conductors above the ground surface, over roads, over railways and over rivers or seas.

1 Height in Urban Areas

An example of height of overhead high-voltage line conductors in and around urban areas is as follows:



Voltage [kV]	Height [m]
115	Not less than 7.0
230	Not less than 7.7

[Example of height calculation for 115kV Transmission conductor]
 $6.5\text{m} + (115-35)/10 \times 0.06 = 6.98\text{m}$

Figure ES36A: Example of Height in Urban Areas

2 Height in Areas Where Third Persons hardly Approach

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

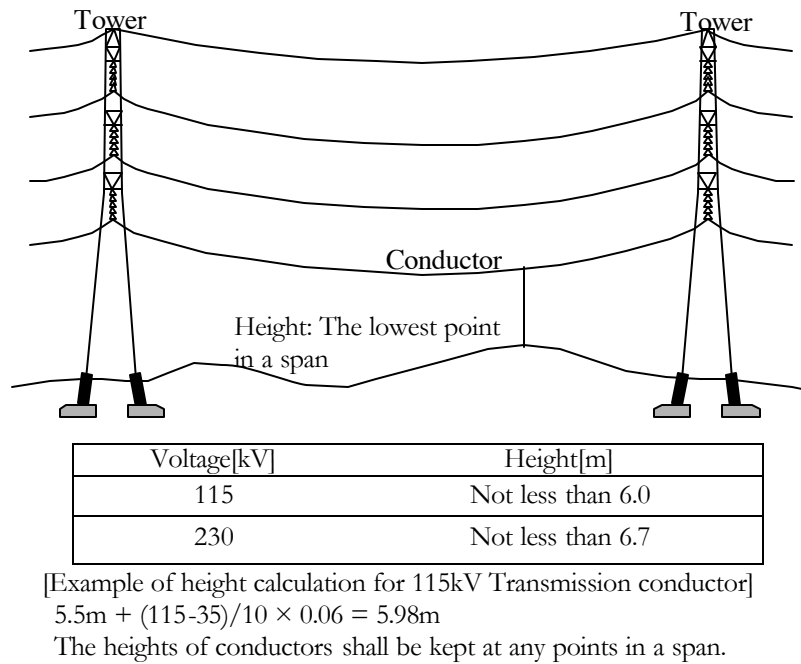
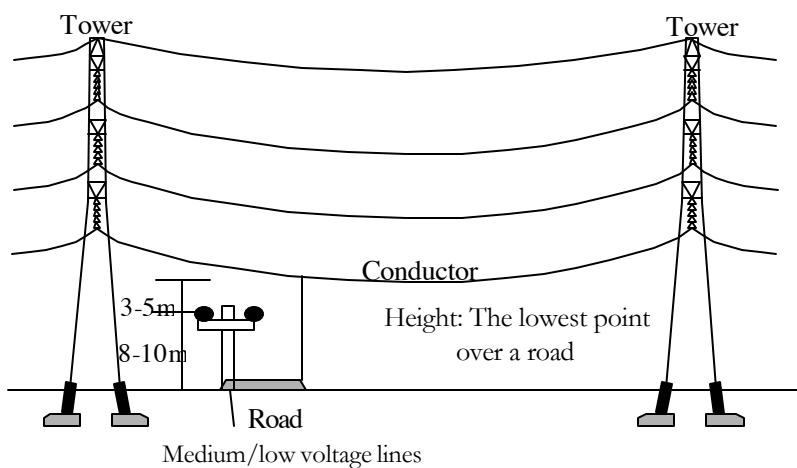


Figure ES36B: Example of Height in Areas where Third Persons Hardly Approach

3 Height over Roads and/or Railways

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



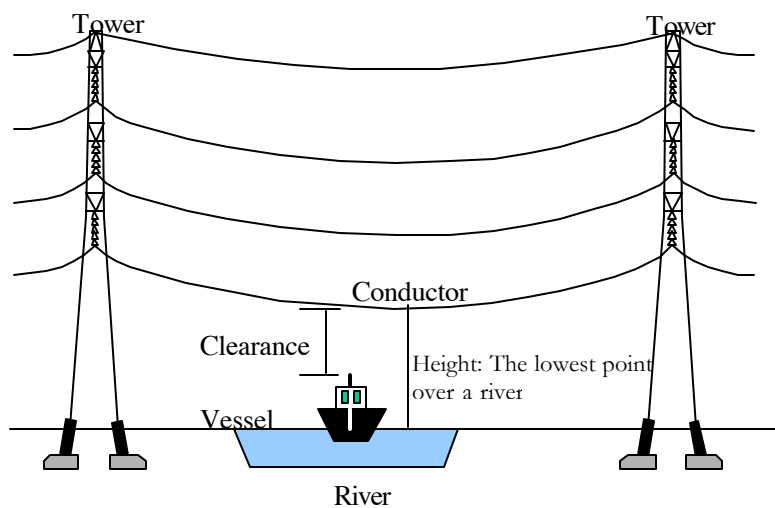
Voltage [kV]	Height [m]
115	Not less than 13.5
230	Not less than 14.2

[Example of height calculation for 115kV Transmission conductor]
 $13.0\text{m} + (115-35)/10 \times 0.06 = 13.48\text{m}$

Figure ES36C: Example of Height over Roads and/or Railways

4 Height over rivers and/or Seas

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



Voltage[kV]	Height or Clearance [m]
115	Height: Not less than 6.0
	Clearance: Not less than 3.5
230	Height: Not less than 6.7
	Clearance: Not less than 4.2

[Example of height calculation for 115kV Transmission conductor] $5.5\text{m} + (115-35)/10 \times 0.06 = 5.98\text{m}$

[Example of Clearance calculation for 115kV Transmission conductor]

$3.0\text{m} + (115-35)/10 \times 0.06 = 3.48\text{m}$

Figure ES36D : Example of Height over Rivers and/or Seas

The height above the water surface shall be based on the highest water level.

When a transmission line crossing a river is constructed, the highest water level at the point should be set up after investigating the records of water level. In case where it is difficult to investigate the record, the highest water level may be set up by referring to the experiential highest water level or the height of nearby existing transmission lines.

Article 37: Clearance between Overhead High-voltage Lines and Other Facilities or Trees

1 Generals

The image of clearance among overhead high-voltage lines and other facilities or trees is as follows:

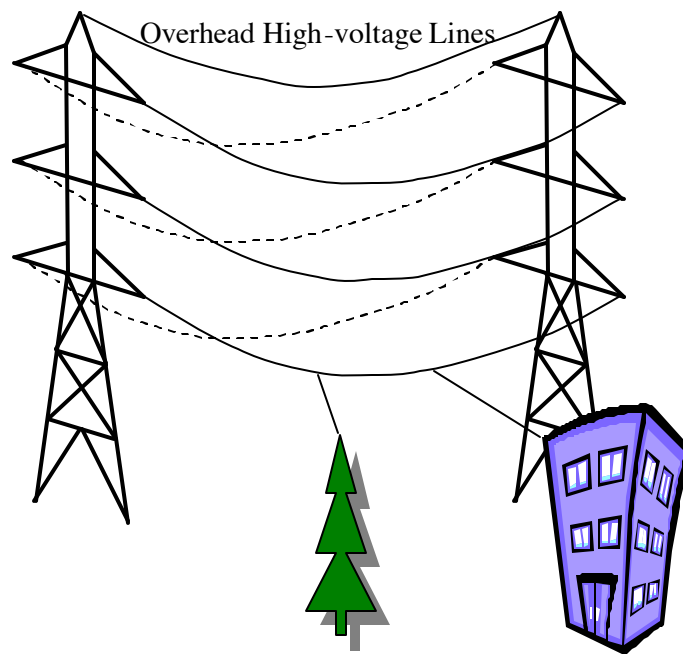


Figure ES37A: Image of Clearance

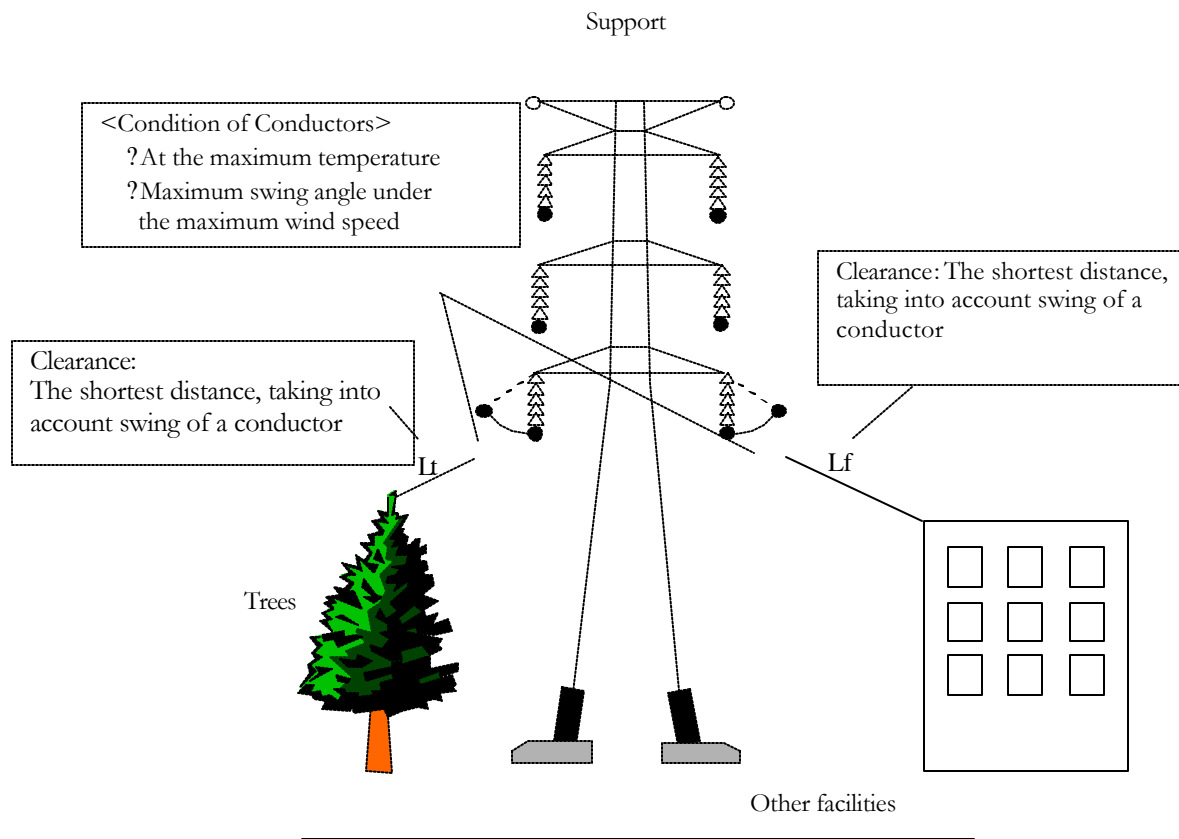


Figure ES37B: Clearance at a Support

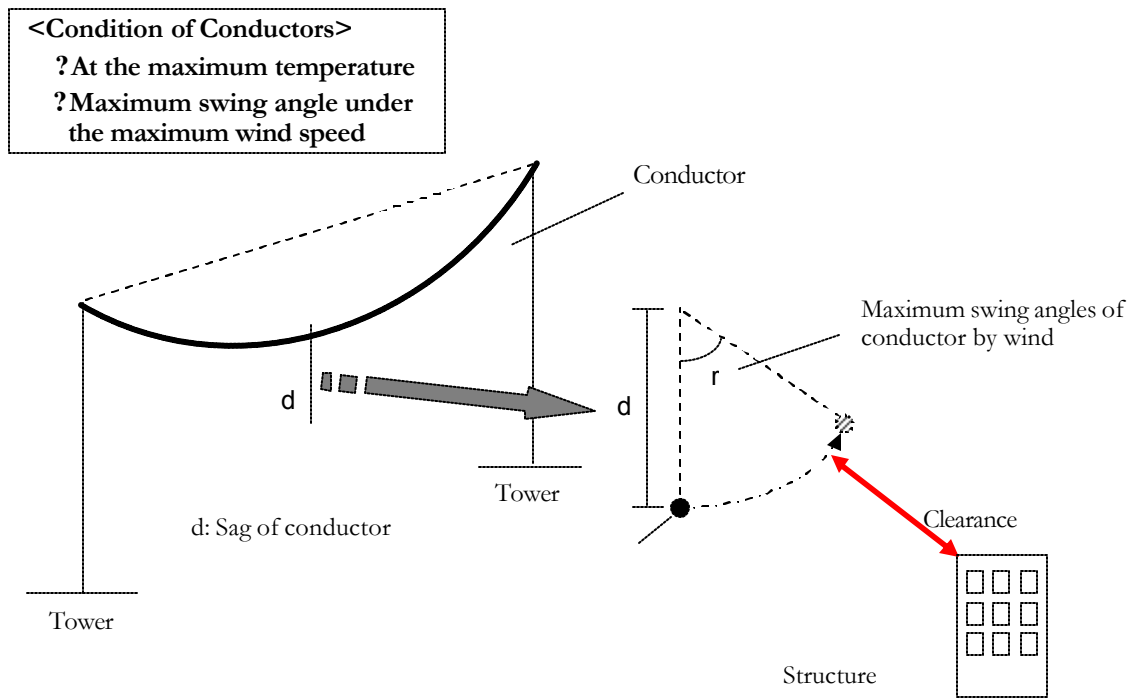


Figure ES37C: Clearance in the Span

1.1 Clearance to Other Facilities

Structures such as a pedestrian overpass through which people pass frequently are included in other facilities. Then, in order to ensure this safety, 3.0m is secured in 35kV or less. Moreover, when exceeding 35kV, the value calculating by adding 0.06m to a base height of 3m for every 10kV over 35kV shall be followed.

1.2 Clearance to Trees

The clearance between overhead high-voltage lines and trees is secured 2.0m in 35kV or less in consideration of swing of the trees by a wind etc. When exceeding 35kV, the value calculating by adding 0.06m to a base height of 3m for every 10kV over 35kV shall be followed.

But Clause 46 of GREPTS excludes the following case:

- Overhead transmission conductors with 115kV voltage, for which cables are used, shall be installed so as not to contact plants.

The concrete values according to voltage are as shown in Table ES37A.

Table ES37A: Values of necessary clearances

	Object	Voltage [kV]	Clearance[m]	Calculation
Lf	Other facilities	115	3.5	$3.0+0.06 \times (115-35)/10$ =3.48
		230	4.2	$3.0+0.06 \times (230-35)/10$ =4.17
Lt	Trees	115	2.5	$2.0+0.06 \times (115-35)/10$ =2.48
		230	3.2	$2.0+0.06 \times (230-35)/10$ =3.17

Below the decimal point has rounded up to the first place.

[Standards of other Countries (Reference)]

The clearances have been decided, taking into account foreign countries' standards and technical standards for distribution lines and current conditions in Cambodia. Values in foreign countries' standards are describes below for reference.

Table ES37B: Clearance between Overhead High-voltage Lines and Other Facilities

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

Remark: () is the clearance when conductors are swinging.

Table ES37C: Clearance between Overhead High-voltage Lines and Trees

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

Remark: () is the clearance when conductors are swinging.

2 Proximity to and Crossing with Buildings

It is not desirable for high voltage transmission lines to be installed immediately near a building or above a building because it has security risks such as breaking of conductors by the fire of a building, extension of a building, installation of a television antenna and so on.

(230kV Overhead Line)

We decided not to accept that over 230kV high voltage lines are installed above the building because there is a possibility that a fire of buildings below the over 230kV high-voltage lines causes serious damage of electric supply.

(115kV Overhead Line)

Since it is unavoidable to be installed near buildings or above buildings for the electric power supply to urban areas, we decided to accept that 115kV high voltage lines which are necessary facilities in urban areas are installed near buildings or above buildings under the strict condition as follows:

The clearance between overhead 115kV lines and other facilities shall be 3.5m as shown in Table ES37A. There is some fear that a human being stands on the building and near the charged conductors. Taking this case into consideration, a safety margin was added to 3.5m and as a result 6.0 m was decided as the regulation value. (3.5 m + Safety margin = 6.0 m)

Article 38: Prevention of Danger and Interference due to Electrostatic Induction and Electromagnetic Induction

1 Prevention of Electrostatic Inductive Interference in Overhead Telephone Lines

In the construction of transmission lines, it is necessary to thoroughly investigate the proximity of pre-existing overhead telephone lines, examine the extent to which such telephone lines may suffer interference, and take measures such as ensuring an appropriate separation distance from them.

Regarding overhead telephone lines that are erected after transmission lines have been constructed, thoroughgoing consultations must be conducted with the erector so that erection of the telephone lines within the areas where they would suffer inductive interference will be avoided, or, if such is unavoidable, so that measures will be devised to eliminate inductive interference.

Unlike electromagnetic induction effects, electrostatic induction effects pose problems of interference with telephone conversations, rather than security problems, during power transmission. Accordingly the principle is to prevent interference with routine telecommunication and momentary interference is not regarded as a problem.

There will be no electrostatic induction effects on telecommunication lines in the case of a high-voltage overhead transmission line that consists of cables with a shielding layer. Neither will there be any electrostatic induction effects on an overhead telephone line that consists of telecommunication cables with grounded messenger wires. Such cases are therefore excluded from the consideration.

Where according to calculations the lines are separated by a distance that will prevent interference, but there is still danger that inductive interference will occur when use of the lines actually begins, interference should be eliminated by carrying out thorough transposition of the high-voltage overhead transmission line, or erecting a metal cable with class D grounding between the two lines to serve as shielding, or by some similar measures.

In some cases of this kind it may be more economical and effective to perform transposition or some other measures on the telephone line, instead of transposition of the high voltage overhead transmission line or erection of a shielding cable. The managers of both of the lines must thoroughly deliberate and reach an agreement on the appropriate measures.

2 Prevention of Harm to Humans from Electrostatic Induction

Electrostatic induction is a phenomenon where an insulated conductive object is present in the electric field beneath a transmission line, so that an electric potential difference arises between it and the ground. A person who comes into contact with such object will experience irritation and discharged current will flow through that person's body.

Surveys conducted in Japan concerning the degree to which people perceive the transient discharge at the moment when they contact an umbrella etc., in such an environment found that they hardly perceive it if the strength of the electric field at 1 meter above the ground surface is less than 3 kV/m. Accordingly this value is taken as the level for regulation.

Such electric shock phenomena will occur only under very limited conditions such as when a person walking with an umbrella below a transmission line touches a metal part of the umbrella. Accordingly

the electric field strength regulation in the present item does not apply to paddies, arable fields and mountain woodland, nor to mountain paths and farm tracks used by only a limited number of people for work access to mountain woodland and agricultural land, nor to any other places where people pass infrequently. It does however apply to those woodland paths and farm tracks that are in general use, as well as to riverbeds used as parks, and similar places.

From similar considerations, the regulation in the present item applies to the strength of electric fields under the normal operating state of a transmission line. For a line consisting of two circuits parallel transmission lines, “normal operating state” refers to when both transmission lines are in operation. The operating temperature of a conductor under the normal state is taken as the target temperature level.

There are the following methods of reducing electrostatic induction:

2.1 Raising of the Transmission Lines’ Elevation above the Ground

Raising the transmission line height to a higher level above the ground will weaken the electric field strength close to the ground surface. Figure ES38A shows sample calculations of maximum field strengths at 1 m above the ground surface with various transmission line heights.

2.2 Employment of a Reverse-phase Formation for the Transmission Lines

If each of two transmission circuits arranged in a vertical formation has a phase sequence reverse to the other, the electric fields from the various phases will cancel each other out and the composite electric field strength will be reduced. Figure ES38B shows Phase-formation and Figure ES38C shows sample calculations of the field strength distribution at 1 m above the ground surface beneath 500 kV transmission lines.

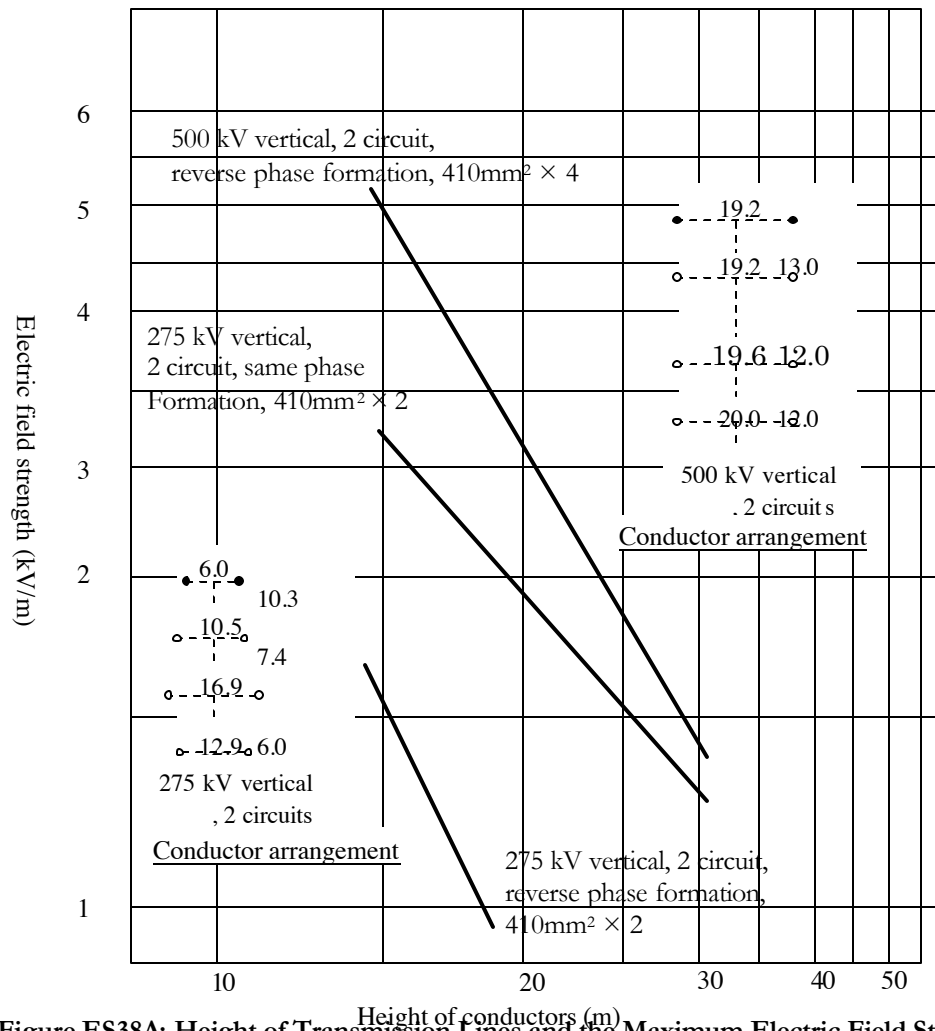
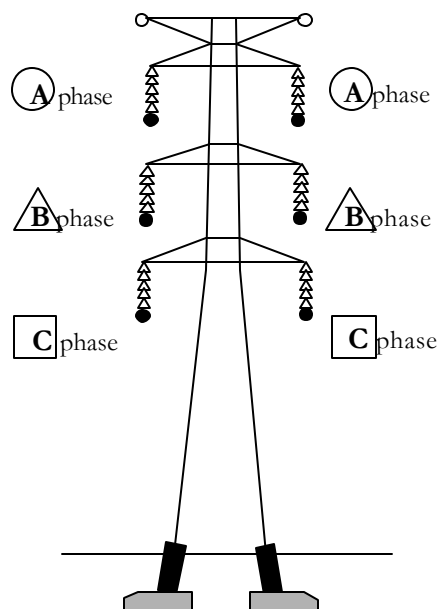
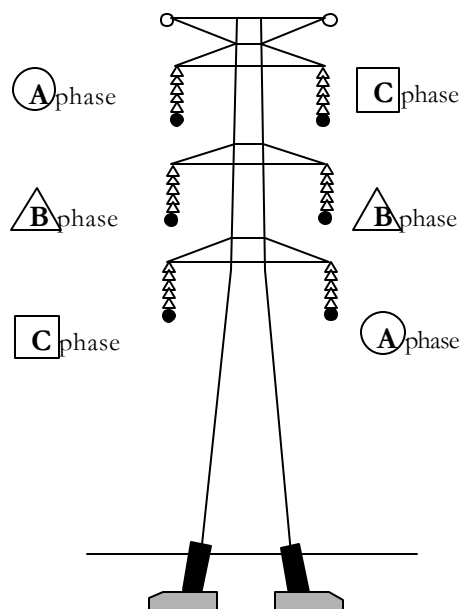


Figure ES38A: Height of Transmission Lines and the Maximum Electric Field Strength at 1 m above the Ground Surface



An example of same phase-formation



An example of reversed phase-formation

Figure ES38B: Phase-formation

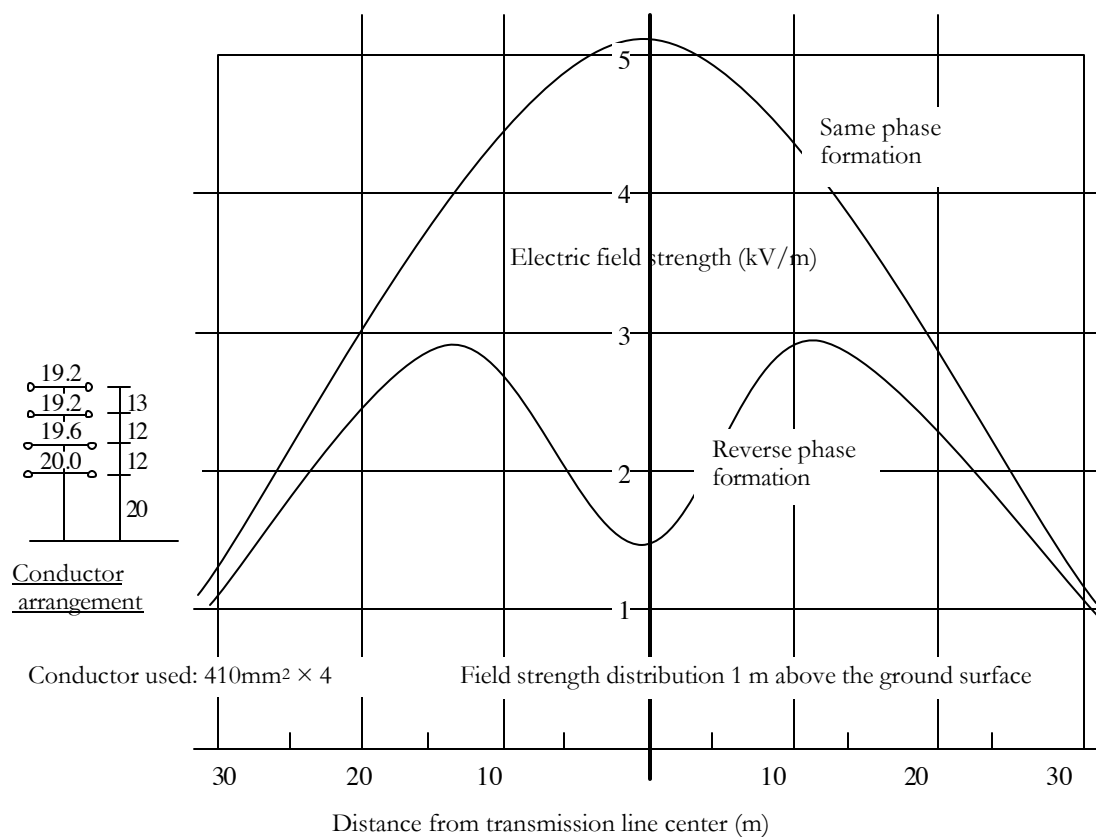


Figure ES38C: Electric Field Strength Distribution beneath 500 kV transmission Lines

2.3 Installation of Shielding Equipment

Shielding equipment includes shielding wires, shielding fences, tree-planting and metal poles. The effectiveness of each will depend on its structure and its positional relationship with the transmission lines and the induction-affected body, but generally speaking the denser the shielding equipment, the greater its effectiveness will be. Taking into account the field strength distribution and related factors, shielding wires should be installed not only in the area directly below the conductors but also to several meters outside of it.

2.4 Grounding of Affected Objects

Grounding should be taken for metallic roofs and fences, etc., that are close to the transmission lines. The grounding applied to the metal parts of such structures will be amply effective if it provides a grounding resistance of around 500Ω . Other details of the grounding work, apart from the resistance level, should preferably be based on class D grounding.

When such measures are implemented, account should be taken of the fact that induction irritations are perceived to varying degrees depending on a variety of conditions, and consideration should be given to the local environment and so forth, so that the measures applied match the actual circumstances of the locality.

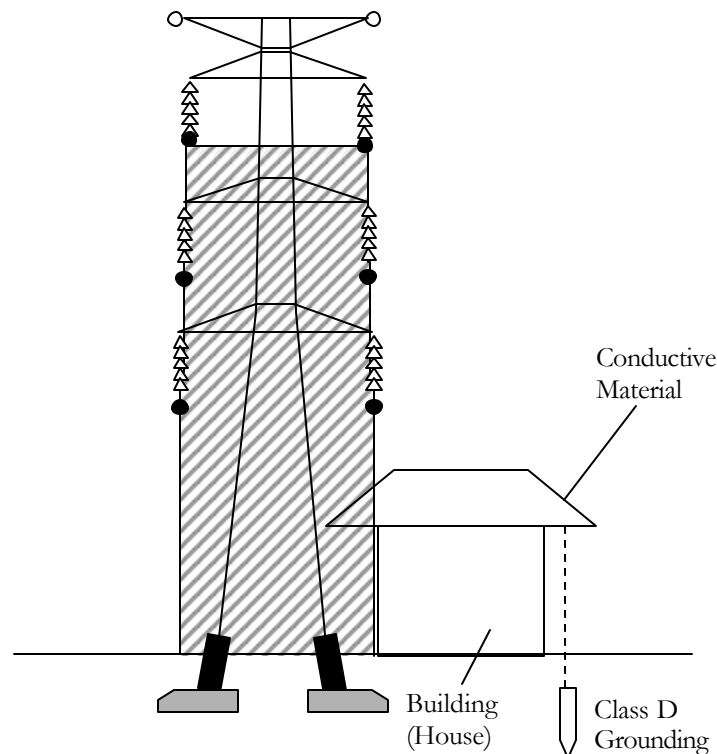


Figure ES38D: Grounding for Conductive Materials

3 Prevention of Telecommunication Interference due to Electromagnetic Induction Effects on Weak-current Electric Cables

Interference with telecommunication due to electromagnetic induction effects is most likely to happen in transmission lines with a neutral grounding.

Grounding of neutral points curbs the occurrence of abnormal voltage and has the additional advantage that when a grounding accident occurs, the affected circuit(s) can be selectively shut off so as to maintain power transmission stability. However, this system also has the drawback that accidents occurring in it produce ground fault current, whose electromagnetic induction effects will generate induction voltage in adjacent weak-current electric cables. Such voltage could cause harm to people or equipment and bring about telecommunication interference.

There are the following methods to eliminate such harm/interference:

- (1) Increase the separation distance between the two lines.
- (2) Replace the weak-current electric cables with optic fiber cables.
- (3) Use an electromagnetic shielding cable for the weak-current electric cables.
- (4) Change the weak-current electric cables from overhead to underground.
- (5) Install an appropriate safety device, such as a lightning arrester, to the weak-current electric cables.
- (6) Change to a different telecommunication mode such as carrier or wireless.
- (7) Use high-speed circuit breakers.
- (8) Raise the value of the neutral points' resistors to a level that will keep the ground fault current at the minimum level necessary from the viewpoint of the protective relay's sensitivity.

In some cases, installing protective equipment to the weak-current electric cables will be more economical and effective as an interference prevention method. Accordingly the various methods above must all be thoroughly researched so as to find the optimal measures to implement.

4 Prevention of Harm to People from Electromagnetic Induction Effects Passed Along Weak-current Electric Cables

The harm from electromagnetic induction effects is not limited to interference with telecommunication. During transmission line accidents, these effects generate induced voltage in weak-current electric cables and such voltage could potentially give shocks to people working on or having telephone conversations through such cables. Measures must be devised to prevent such shocks from occurring.

Article 39: Surge Arresters

1 Generals

Surge arresters to be installed in electrical circuits in the stations, medium-voltage distribution lines and high-voltage and medium-voltage users' sites shall be installed as shown below.

Surge arresters, here, mean devices that protect insulation of electrical equipment by restricting over-voltage through discharge when the crest value of over-voltage caused by lightning and switching of the circuit exceeds a certain value, and have an ability to restore the normal conditions without disturbing the normal status of the power system.

Devices with low self-restoring ability, such as devices with air-gaps, are not suitable as surge arresters.

(Reference)

Definition of surge arrester (IEC60099-1)

= a device designed to protect electrical apparatus from high transient voltage and to limit the duration and frequently the amplitude of follow-current. The term "surge arrester" includes any external series gap which is essential for the proper functioning of the device as installed for service, regardless of whether or not it is supplied as an integral part of the device.

1.1 Structure of Surge Arresters

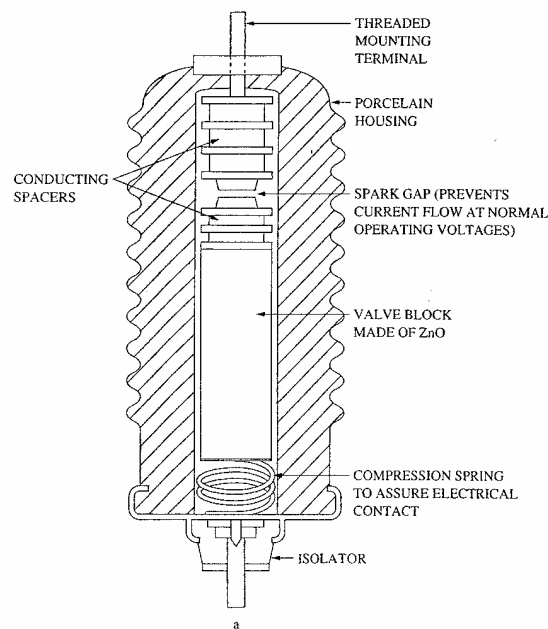


Figure ES39A: Structure of a Surge Arrester (Example)

1.2 Characteristics of Surge Arrestors

Surge arrestors have a non-linear resistance characteristic as shown in Figure ES39B. For normal operating voltages, they have extremely high resistance and the operating current cannot flow through surge arresters. On the contrary, for extraordinary voltages such as switching surge or lightning surge, they have extremely low resistance and the surge current can easily flow through surge arresters toward the grounding conductor.

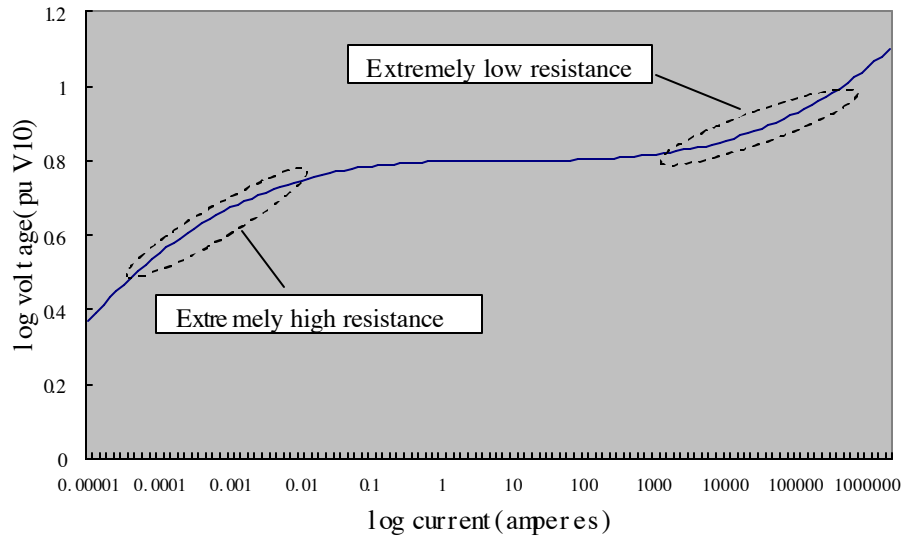


Figure ES39B: Non-linear Voltage versus Current Characteristic of Surge Arresters

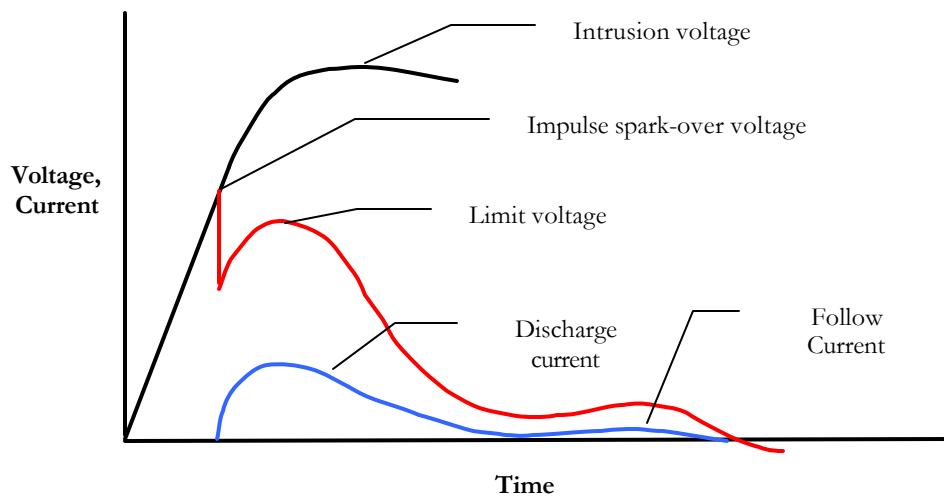


Figure ES39C: Operation Principle of a Surge Arrester

(1) Impulse spark-over voltage

The highest instantaneous value of terminal voltage which can be attained prior to initiation of terminal voltage drop due to sufficient formation of discharge current, at the first stage of the lightning arrester discharge by the application of impulse voltage across the terminal.

(2) Limit voltage

The impulse voltage that remains across both terminals when the over-voltage is limited during discharge of a lightning arrester

(3) Discharge current

The impulse current that flows through a lightning arrester during discharge

(4) Follow current

The current that flows through a lightning arrester being supplied from a power-frequency supply circuit successively after a discharge phenomenon has substantially finished.

1.3 Performances of Surge Arresters

The performances of surge arresters to be installed in the Stations, MV distribution lines and HV and MV user's sites shall conform to the following provisions, IEC60099 and other relevant IEC standards.

- IEC 60099-1 (1999-12) [Surge arresters – Part 1: Non-linear resistor type gapped surge arrester for a.c. Systems],
- IEC 60099-3 (1990-09) [Surge arresters – Part 3: Artificial pollution testing of surge arresters],
- IEC 60099-4 (1998-08) [Surge arresters – Part 4: metal oxide surge arresters without gaps for a.c. systems],
- IEC 60099-5 (2000-03) [Surge arresters – Part 5: Selection and application recommendations] and related IEC standards.

(1) Rated voltage

The rated voltage of surge arresters shall be chosen based on the principle that the surge arrester can perform the prescribed operating duties under the condition of temporary over-voltage to occur in the Stations and HV and MV user's sites due to a single-line ground fault and load rejection.

(2) Nominal discharge current

The nominal discharge current is selected according to the lightning discharge current through the arrester, for which protection of equipment is desired. As a general rule, the following values are suitable depending on the expected lightning discharge current.

(Above 1kV to 245kV):5kA or 10kA

In systems of IEC60071-1 where the line distances between arresters are small (below 5km), surge arresters at distribution transformers with nominal discharge current of 5kA have proven sufficiently reliable.

In systems with highest voltages of 72.5kV and below, surge arresters with a nominal discharge current of 5kA may be sufficient for areas with low ground flash density and effectively shielded incoming overhead-lines with low tower footing impedances. Arresters with a nominal discharge current of 10kA may be preferable for important installations (need for the best protection) particularly in areas with high lightning flash density or high earth resistances.

In systems with highest voltages above 72.5kV, surge arresters with a nominal discharge current of 10kA are generally recommended.

2 Installation of Surge Arresters

In addition to Clause 53-1 of GPEPTS and Article 39 of SREPTS, it is desirable to install a surge arrester at the following places as need arises to prevent distribution line accidents.

- Installed place of switching devices
- Installed place of voltage regulators, power capacitors or other similar equipment and devices
(On the both sides if it is series equipment)

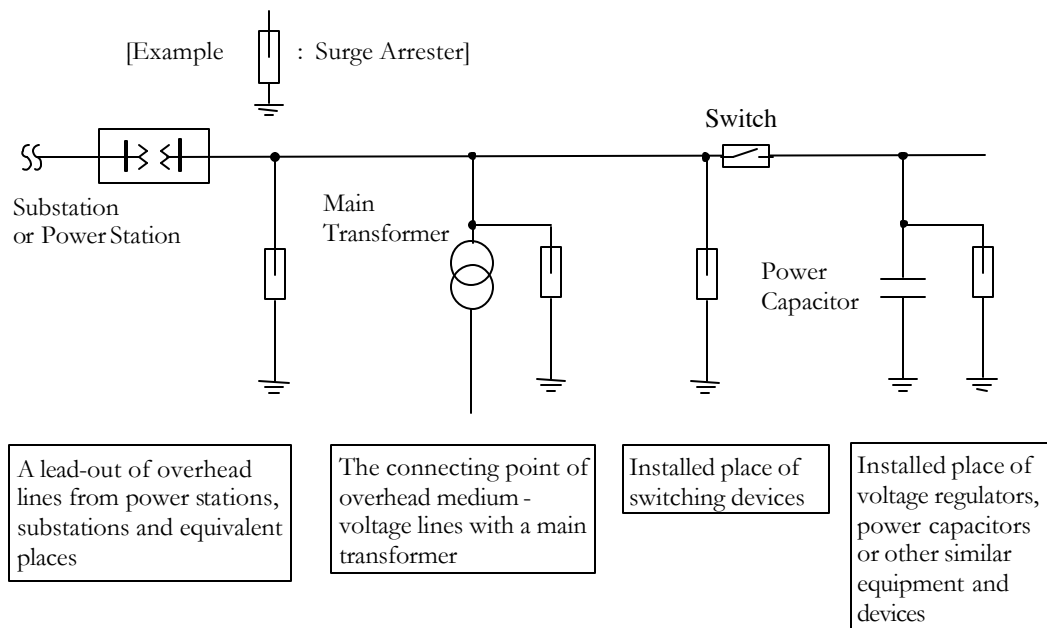


Figure ES39D: Recommended Installation Places of Surge Arresters

CHAPTER 4

**MEDIUM AND LOW-VOLTAGE
DISTRIBUTION FACILITIES**

Article 40: Supporting Structures

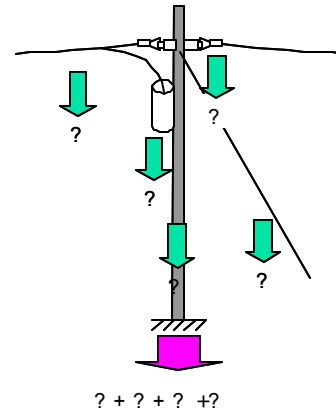
In order to construct supporting structures that conform to Clause 49 of GREPTS and Article 40 of SREPTS, it is necessary to understand the meanings of their descriptions to some extent. But the numerical formulas used in this explanation sheets are extremely difficult to understand. Therefore the examples of calculation method of these formulas have been prepared in order to make them more understandable and to prevent defective supporting structures.

1 Loads on Overhead Distribution Lines

1.1 Kinds of Load

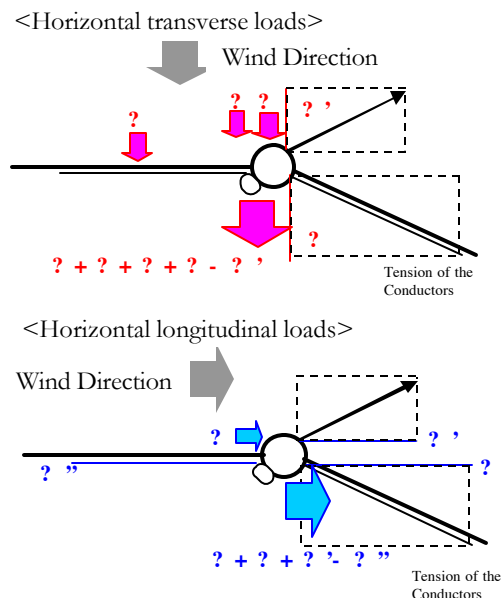
(1) Vertical Load

- ① : Weight of Supporting Structure
- ② : Weight of the Conductors and the Ground
Wires and Accessories
- ③ : Weight of the Insulating Devices, the Crossarms
and the Distribution Equipment
- ④ : A Vertical Component of the Maximum Tension
of the Guy Wires Supporting the Supporting
Structure



(2) Horizontal Transverse Loads

- ① : Wind Pressure on the Supporting Structure
- ② : Wind Pressure on the Conductors and
the Ground Wire
- ③ : Wind Pressure on the Insulator, the Crossarms
and the Distribution Equipment
- ④, ④' : A Horizontal Transverse Component
of the Maximum Tension of the Conductor,
the Ground Wire and the Guy Wires

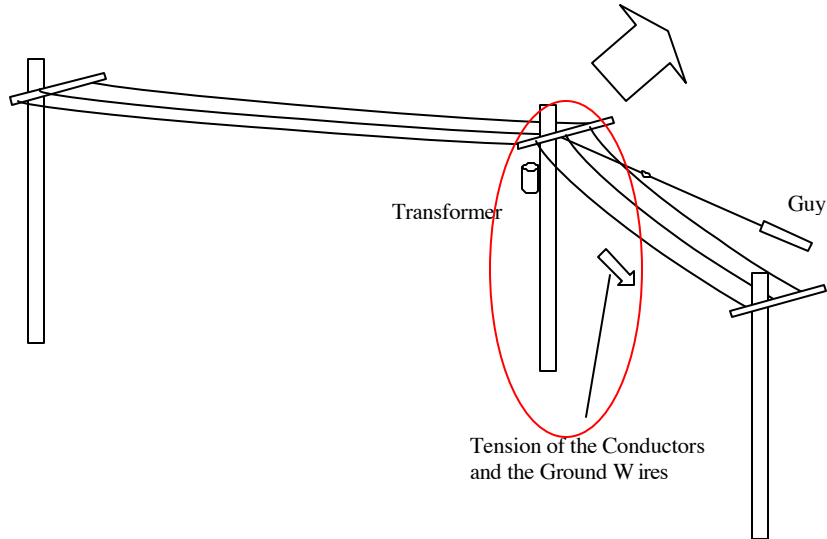


(3) Horizontal Longitudinal Loads

① : Wind Pressure on the Supporting Structures

②, ②', ②'' : A Horizontal Longitudinal Component

of the Maximum Tension of the Conductor, the Ground Wire and the Guy Wires.



1.2 Tension of Conductors

The tension of overhead distribution conductors supported by the supporting structure is calculated by the following formula.

(1) Sag for span which height of support point is not different

$$T = \frac{WgS^2}{8D} \quad [N] \quad \text{-----}(\text{ex 40-1})$$

Where:

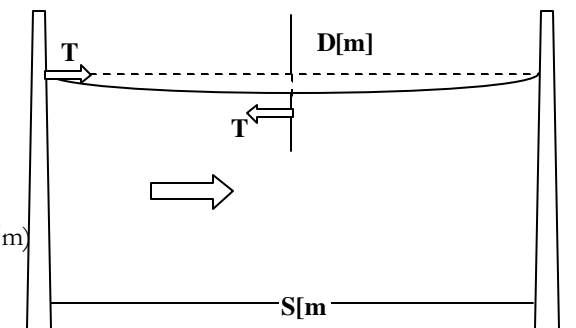
D = Sag for overhead conductor (m)

W = Weight per unit conductor length (kg/m)

g = Gravity acceleration (m/s²)

S = Span between two poles (m)

T = Tension in the horizontal direction in the lowest point of the overhead conductor (N)



[Example Calculation for a Horizontal Longitudinal Component of the Maximum Tension of the Conductors]

(Condition)

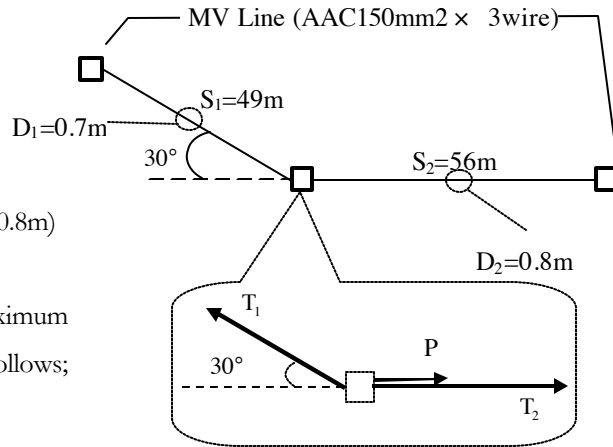
? MV Line (AAC150mm²×3wire,

Weight W=0.434kg/m)

② Span (S₁=49m, S₂=56m)

③ Sag for overhead MV line (D₁=0.7m, D₂=0.8m)

Horizontal longitudinal component of the maximum tension of the conductors (P) is calculated as follows;



$$T_1 = \frac{WgS_1^2}{8D_1} \times 3 = \frac{0.434 \times 9.8 \times 49^2}{8 \times 0.7} \times 3 = 5,471 \text{ (N)}$$

$$T_2 = \frac{WgS_2^2}{8D_2} \times 3 = \frac{0.434 \times 9.8 \times 56^2}{8 \times 0.8} \times 3 = 6,252 \text{ (N)}$$

$$\Rightarrow P = T_2 - T_1 \cos 30^\circ = 6,252 - \frac{\sqrt{3}}{2} \times 5,471 = 1,514 \text{ (N)}$$

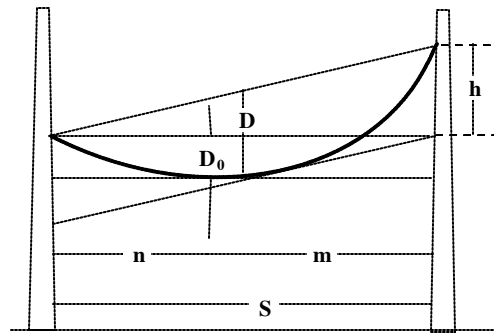
(2) Sag for span which height of support point is different

$$D_0 = D \left(1 - \frac{h}{4D} \right)^2 \text{ [m]} \quad \text{----- (ex40-2)}$$

Where:

D₀ = Sag of the lowest point of the span from the lower supporting point [m]

D = Slanted sag at the middle of the span [m]



$$\left(D = \frac{WgS^2}{8T} = \frac{S^2}{8C}, \quad C = \frac{T}{Wg} \text{ [m]} \right)$$

h = The difference between the heights of both supporting points [m]

$$m = \frac{S}{2} + \frac{Ch}{S}$$

$$n = \frac{S}{2} - \frac{Ch}{S}$$

[Example Calculation]

(Condition)

? MV Line (AAC150mm²×3wire

Weight W=0.434kg/m)

② Span(S=56m)

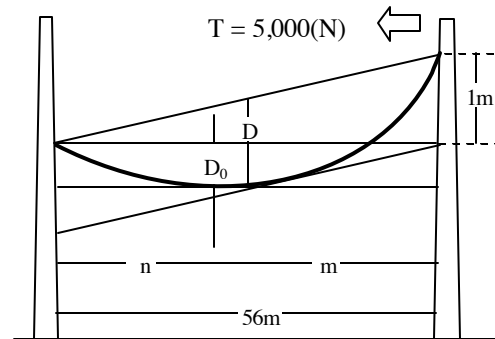
③ Sag for overhead MV line (D₁=0.7m, D₂=0.8m)

④ Tension in the horizontal direction in the lowest point of the overhead conductor

T = 5,000(N)

⑤ The difference between the heights of both supporting points, h = 1(m)

MV Line (AAC150mm² × 3wire)



$$D = \frac{WgS^2}{8T} = \frac{0.434 \times 9.8 \times 56^2}{8 \times 5,000} = 0.417(\text{m})$$

$$D_0 = D \left(1 - \frac{h}{4D} \right)^2 = 0.417 \times \left(1 - \frac{1}{4 \times 0.417} \right)^2 = 0.067(\text{m})$$

$$m = \frac{S}{2} + \frac{Ch}{S} = \frac{S}{2} + \frac{Th}{WgS} = \frac{56}{2} + \frac{5,000 \times 1}{0.434 \times 9.8 \times 56} = 49(\text{m})$$

$$n = \frac{S}{2} - \frac{Ch}{S} = \frac{S}{2} - \frac{Th}{WgS} = \frac{56}{2} - \frac{5,000 \times 1}{0.434 \times 9.8 \times 56} = 7(\text{m})$$

2 Test Method for an Iron-reinforced Concrete pole and a Steel Pole

2.1 Strength Test

- (1) The iron-reinforced concrete pole is fixed by the method like the following figure.
- (2) The force equivalent to the strength of the design load is inflicted at the load point vertically to the pole at the same velocity. In the same way, the force is inflicted to the opposite direction.
- (3) Then the pole is examined if there are no cracks of more than 0.25 mm width.

2.2 Breakage Test (in succession the Strength Test)

- (1) The force is inflicted until the pole is broken down.
- (2) Then the maximum strength measured by a load meter is examined to be equal 2 times of design load or more.
- (3) The pole is fixed from the bottom to $1/6$ of the total length of the pole.
- (4) If the force 2 times of design load is inflicted and the pole is not broken down, this test may be completed.
- (5) Figure ES40A shows an example of the breakage test equipment.

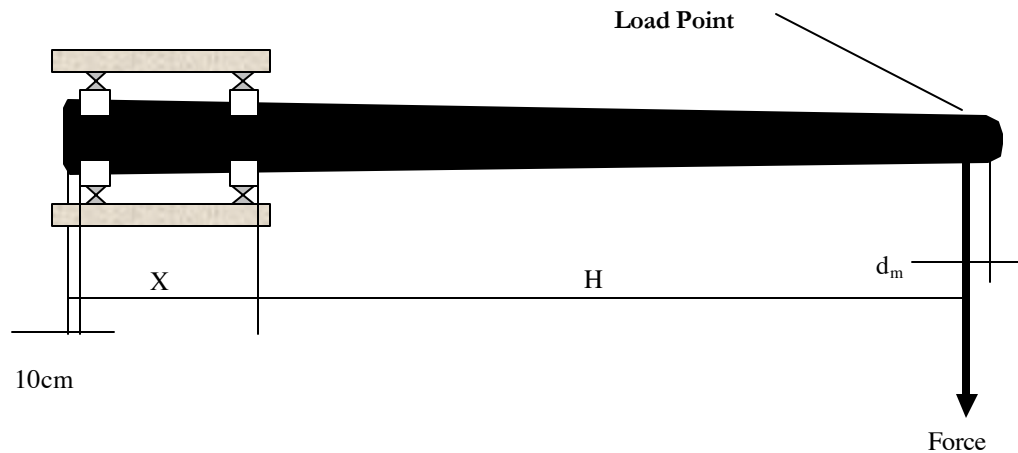


Figure ES40A: Example of Breaking Test Equipment

Table ES40A: The Breakage Test (Unit: m)

Length of Pole	Setting depth (X)	H
7	1.2	5.55
8	1.4	6.35
9	1.5	7.25
10	1.7	8.05
11	1.9	8.85
12	2.0	9.75
13	2.2	10.55
14	2.4	11.35
15	2.5	12.25
16	2.5	13.25

3 Safety Factor (Supporting Structures)

3.1 Iron Pole and Iron-reinforced Concrete Pole

Iron poles and iron-reinforced concrete poles used for overhead lines shall have the strength to withstand the load as below.

Table ES40B: Load of Iron Pole and Iron -reinforced Concrete Pole

Type of Supporting Structure	Voltage	Low-Voltage	Medium-Voltage
Iron Pole		Wind Pressure	Assumed Normal Load
Iron-reinforced Concrete Pole		Wind Pressure	Assumed Normal Load

3.2 Wooden poles used for overhead lines shall be maintained so that the safety factor against a wind pressure should be not less than following value;

Table ES40C: Safety Factor for Wooden Pole

Voltage	Safety Factor to maintain
Low-Voltage	1.2
Medium-Voltage	1.5

A wooden pole gradually deteriorates year by year due to the progress of decay. Therefore, it is necessary to adopt much larger value as the safety factor for a wooden pole when it is newly constructed.

And it is also necessary to inspect the condition of wooden poles periodically and to maintain them, including the chemical treatment to retard the progress of decay. Off course, at the same time, the safety factor needs to be checked by measurement of the diameter and calculation.

4 Reference Wind Velocity

4.1 Calculation of Wind Pressure

In order to evaluate the strength of supporting structures, the wind pressure will be assumed.

Generally the wind pressures are assumed by calculation based on experiments.

The following formula is one example to calculate the wind pressure to 1m² of the vertical projected area.

$$\mathbf{P = C \left(\frac{1}{2} \delta V^2 \right) \quad [Pa] \quad \text{----- (ex40-3)}}$$

Where:

P = Wind pressure load

C = Resistance coefficient given in the following table ES40D

(The values are decided based on experiments in Japan.)

d= Density of air (kg/m³)

V = Wind velocity (m/s)

Table ES40D : Resistance Coefficient

Segment of an object receiving wind pressure			Resistance Coefficient
Supporting structure	Wooden pole	Columnar pole	0.8($V > 30\text{m/s}$) ^(*) 1.2($V \leq 30\text{m/s}$)
	Iron pole	Columnar pole	0.8($V > 30\text{m/s}$) 1.2($V \leq 30\text{m/s}$)
		Triangle or rhombic pole	1.9
		Square pole consisting of steel pipes	1.5
		Others	2.4
	Iron-reinforced concrete pole	Columnar pole	0.8($V > 30\text{m/s}$) 1.2($V \leq 30\text{m/s}$)
		Square pole	2.0
	Electrical conductor and other strung conductor		
Insulation device			1.4
Cross arm for medium-voltage lines		Used as single material	1.6
		Others	2.2

* 1 The value of resistance coefficient changes due to Reynolds number which effects fluid mechanism. (IEC 60826 is referred.)

The wind velocity gives an important influence on the decision of the wind pressure, because it affects the wind pressure by its square.

Density of Air

$$\delta = \delta_0 \left(1 - 0.378 \cdot \frac{p}{H} \right) \quad [\text{kg} / \text{m}^3]$$

$$\delta_0 = \frac{1.293}{1 + 0.00367 \cdot T} \cdot \frac{H}{760} \quad [\text{kg} / \text{m}^3]$$

$$p = \frac{760}{1,013} \cdot \frac{m}{100} \cdot \left(6.11 \times 10^{\frac{7.5 \cdot T}{T+237.3}} \right) \quad [\text{torr}] \quad \text{----- (ex40-4)}$$

(based on Tetens formula)

Where:

ρ = Density of air with vapor [kg/m³]

ρ_0 = Density of dry air [kg/m³]

T = Average temperature[°C]

H = Air pressure [torr] (1[torr]=1.33322[hPa])

p = Vapor pressure [torr]

m = Average humidity [%]

In Cambodia the decision of the wind velocity is a difficult problem, because the accumulated wind velocity data is poor in Cambodia. If we use the faster wind velocity for the calculation of the wind pressure, it will be better for safety but not for cost, and vice versa.

According to explanation sheet of Article 27, there are only 2 points where wind velocity data have been observed, Pochentong and SiemReap. The statistical analysis results of observation data are shown in Table ES40E.

Table ES40E: The Statistical Analysis Result of Wind Velocity (Pochentong, SiemReap)

Item Observation point	Yearly maximum of 10-minute average wind velocity (50 year return period)
Pochentong	21.36(m/s)
SiemReap	31.86(m/s)

Therefore, the wind velocity of 32m/s is adopted as the wind velocity value 'V'. But in the circumference of Pochentong, it will cause excess investment of distribution lines. To avoid excess investment, it is possible to set a lesser maximum wind velocity regionally when sufficient observed data have been accumulated and analyzed.

For example, 25m/s may be applied in Phnom Penh area on the basis of wind velocity data in Pochentong.

The wind pressures calculated by the above formula are shown in Table ES40F. The results are taken a 10% margin into consideration, because there are few data of wind velocity and a value '32m/s' does not have complete reliability.

Table ES40F: Wind Pressure

Segment of an object receiving wind pressure			Wind pressure to 1m ² of the vertical projected area (Pa)
Supporting structure	Wooden pole	Columnnar pole	520
	Iron pole	Columnnar pole	520
		Triangle or rhombic pole	1,220
		Square pole consisting of steel pipes	970
		Others	1,540
	Iron -reinforced concrete pole	Columnnar pole	520
		Square pole	1,290
Electrical conductor and other strung conductor			680
Insulation device			900
Cross arm for medium-voltage lines	Used as single material		1,030
		Others	1,410

* The values are rounded up.

Condition:

The wind velocity 32m/s
Density of air 1.137kg/m³ (28°C, 1,013×10⁵Pa)
Average temperature 28°C
Average humidity 80%

When there is no wind velocity data, the following formula may be applied to calculate the wind pressure to 1m² of the vertical projected area in terrains with numerous small obstacles of low height, such as hedges, trees and buildings, because wind velocity decreases near ground level with numerous small obstacles. (IEC 60826 is referred.)

$$P = C \left(\frac{1}{2} \rho K_R^2 V^2 \right) \quad [\text{Pa}] \quad \text{----- (ex40-5)}$$

Where:

C = Resistance coefficient
d= Density of air (kg/m³)
V = Wind velocity (= 32m/s)
K_R = Roughness factor (= 0.85)

4.2 Calculation of Strength of an Iron-reinforced Concrete Pole and a Steel Pole

The strength of iron-reinforced a concrete pole and a steel pole against wind pressure load perpendicular to the distribution line is calculated as follows:

(1) Wind pressure for a Pole

The wind pressure for a pole is calculated by the integration of the wind pressure load of minuscule areas. The wind pressure of a minuscule area is shown as a following formula:

$$\begin{aligned} dW_L &= K_1 D(x) dx \\ &= K_1 \left\{ D_0 - \left(\frac{D_0 - D_1}{H} \right) x \right\} dx \end{aligned}$$

Where:

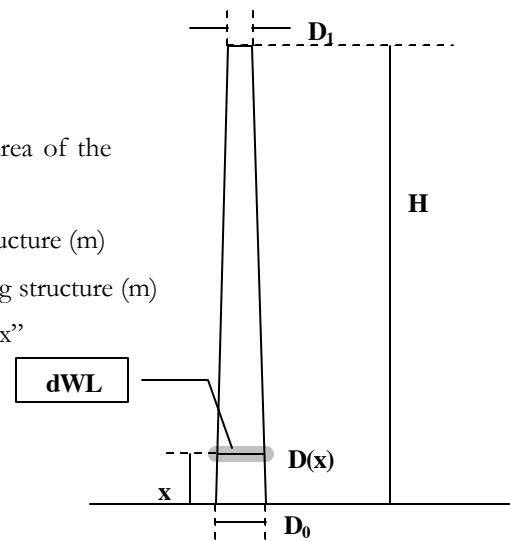
K_1 : Wind pressure per 1 m² of vertically projected area of the supporting structure (N/ m²)

D_1 : Top end diameter or breadth of the supporting structure (m)

D_0 : Ground-level diameter or breadth of the supporting structure (m)

$D(x)$: The diameter or breadth of the point of height, "x"

$$\left[D(x) = D_0 - \left(\frac{D_0 - D_1}{H} \right) x \right]$$



Therefore the bending moment due to the wind pressure load for a pole converted into the top position of the pole (M_p) is given by the following formula;

$$\begin{aligned} M_p &= \int_0^H x \cdot dW_L = K_1 \int_0^H \left\{ D_0 - \left(\frac{D_0 - D_1}{H} \right) x \right\} x dx \\ &= \frac{K_1 (2D_1 + D_0) H^2}{6} \end{aligned}$$

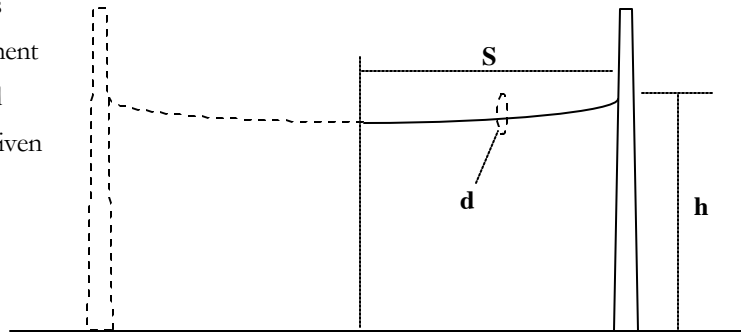
----- (ex40-6)

Where:

H: Height of the supporting structure above the ground (m)

(2) Wind Pressure for Conductors

The sum of the bending moment due to the wind pressure load for each conductor (M_w) is given by the following formula:



$$M_w = K_2 S \left(\sum dh \right) \quad \text{????????? (ex40-7)}$$

Where:

K_2 : Wind pressure per 1 m² of vertically projected area of the distribution conductors (N/ m²)

S: A half of the sum of the spans on the both sides (m)

d: Diameter of the distribution conductor (m)

h: Height of the supported position of a conductor (m)

When considerable wind pressure load are only those for a pole and conductors, the pole shall have sufficient strength to withstand the total bending moment multiplied by the safety factor.

$$(H - d_m)P \geq f(M_p + M_w)$$

$$\frac{(H - d_m)P}{f} \geq K_1 \frac{(2D_1 + D_0)H^2}{6} + K_2 S \left(\sum dh \right) \quad \text{----- (ex40-8)}$$

Where:

P: Breaking load of the supporting structure (standard design load \times 2) (N)

d_m : Length from the top of the structure to the design top load (m)

[Example (Calculation of Strength of Reinforced Concrete Pole)]

(Condition)

(1) MV Line (AAC150mm² × 3wire, Height $h_1=11.4\text{m}$,

Diameter $d_1=0.0168\text{m}$)

(2) LV Line (PVC75mm² × 3wire, Height $h_2=10.4\text{m}$, $h_3=10.1\text{m}$,

$h_4=9.8\text{m}$, Diameter $d_k=0.0170\text{m}$)

(3) Weight Span ($S_1=60\text{m}$, $S_2=40\text{m}$; $S=(S_1+S_2)/2=50\text{m}$)

(4) Breaking load of the supporting structure $P=10\text{kN}$

(5) Supporting Structure (Square pole)

Top end breadth $D_1=0.15\text{m}$,

Ground-level breadth $D_0=0.30\text{m}$

Height above the ground $H=11.7\text{m}$

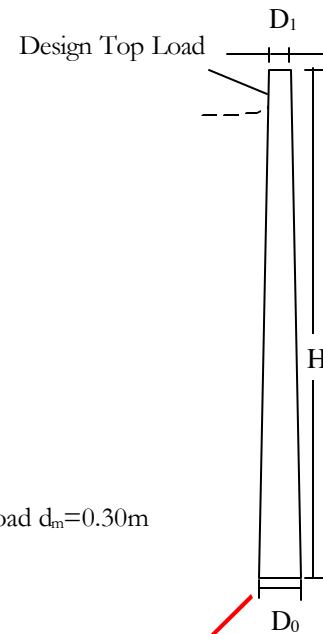
Length from the top of the structure to the design top load $d_m=0.30\text{m}$

(6) Wind pressure to 1m² of the vertical projected area

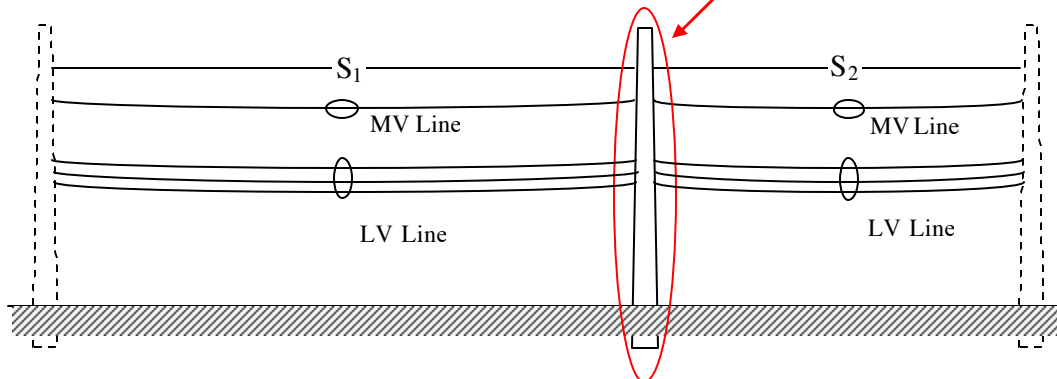
Iron-reinforced concrete pole (square pole) : $K_1=1,290\text{Pa}$

Conductor : $K_2= 680\text{Pa}$

(7) Safety Factor $f = 2$



[Figure]



$$\frac{(H-d_m)P}{f} = \frac{(11.7-0.3) \times 10 \times 10^3}{2} = 57,000 \text{ (N} \cdot \text{m)}$$

$$M_p = K_1 \frac{(2D_1+D_0)H^2}{6} = 1,290 \times \frac{(2 \times 0.15+0.30) \times 11.7^2}{6} = 17,659 \text{ (N} \cdot \text{m)}$$

$$M_w = K_2 S (? \text{ dh})$$

$$= 680 \times 50 \times (0.0168 \times 11.4 \times 3 + 0.0170 \times 10.4 + 0.0170 \times 10.1 + 0.0170 \times 9.8)$$

$$= 37,048 \text{ (N} \cdot \text{m)}$$

$$57,000 \approx 54,707 (=17,659+37,048)$$

Therefore

$$\frac{(H - d_m)P}{f} \approx K_1 \frac{(2D_r + D_0)H^2}{6} + K_2 S(\sum dh)$$

4.3 Calculation of Strength of Wooden Poles

The wooden pole shall have the strength to withstand the wind pressure. The safety factor for LV lines shall be not less than 1.2, and that for MV lines shall be not less than 1.5.

The calculation of strength LV wooden poles against the wind pressure in a direction at the right angle to the direction of overhead lines is made by the following formulas.

(1) Single Pole without Guys

$$\frac{P}{F} \geq \frac{32K}{\pi} \left\{ \frac{K_1}{100} \left(\frac{D_0 H^2}{2} - \frac{k H^3}{3} \right) + K_2 \frac{S(\sum dh)}{1000} \right\} / (D'_0)^3 \quad \text{----- (ex40-9)}$$

In the case of $K_1=520(\text{N/m}^2)$, $K_2=680(\text{N/m}^2)$, $k=0.9(\text{cm/m})$;

$$\frac{P}{F} \geq K \frac{265D_0 H^2 - 158H^3 + S(\sum 69dh)}{10(D'_0)^3} \quad \text{----- (ex40-10)}$$

(2) Single Pole with Guys

$$\frac{P}{F} \geq \frac{16K}{\pi} \left\{ \frac{K_1}{100} \left(\frac{D_0 H^2}{2} - \frac{k H^3}{3} \right) + K_2 \frac{S(\sum dh)}{1000} \right\} / (D'_0)^3 \quad \text{----- (ex40-11)}$$

In the case of $K_1=520(\text{N/m}^2)$, $K_2=680(\text{N/m}^2)$, $k=0.9(\text{cm/m})$;

$$\frac{P}{F} \geq K \frac{133D_0 H^2 - 79H^3 + 0.5S(\sum 69dh)}{10(D'_0)^3} \quad \text{----- (ex40-12)}$$

Where:

K: constant (=1 ;under normal condition)

K_1 : Wind pressure per 1 m² of vertically projected area of the wooden pole (N/ m²)

K_2 : Wind pressure per 1 m² of vertically projected area of the distribution conductors (N/ m²)

S: The half of the sum of the span on both sides of the pole (m)

d: The outer diameter of each wire (mm)

h: The height of the supporting point of each wire above the ground (m)

H: The height of the pole above the ground (m)

D_0 : $D+0.9H$ (The diameter of the pole at the surface of the ground) (cm)

D : The diameter of the pole at the tip of the pole (cm)

D_0' : The diameter of the round of which area is equal to the section area of the pole at the surface of the ground that is excluded the corrosion part.

(If there are no corrosion, D_0' equal to D_0)

k : The increase rate of the diameter of the wooden pole(cm/m)

P : The breaking strength to the bend of the pole given in the following table;

Table ES40G: Breaking Strength of Wood

Type of wood <i>Common name / (Botanical name)</i>	P (Breaking strength)
Phchok (Shorea obtusa)	11 N/mm ²
Koki Khsach (Hopea pierrei)	17 N/mm ²
Thbaeng (Dipterocarpus obtusifolius)	20 N/mm ²
Khlong (Dipterocarpus tuberculatus)	13 N/mm ²

F: Safety factor of wooden pole

The calculation of strength for medium-voltage wooden pole is done by the same method. However the wind pressure loads of insulation devices and cross arms will be taken into consideration.

[Calculation of the equation ex40-9, 10, 11 and 12]

The diameter or breadth of the point of height "x" (D(x)) is given by the following formula;

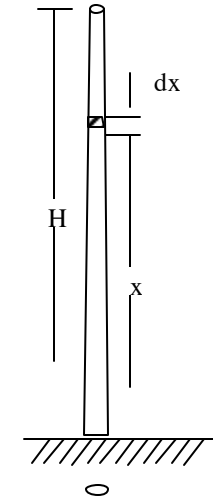
$$D(x) = D_0 - kx$$

The wind pressure of a minuscule area is shown as the following formula:

$$\begin{aligned} dW_L &= K_1 D(x) dx \\ &= K_1 (D_0 - kx) dx \end{aligned}$$

Therefore the bending moment due to the wind pressure for a pole converted into the top position of the pole (Mp) is given by the following formula:

$$\begin{aligned} M_p &= \int_0^H \frac{x \cdot dW_L}{100} = \frac{K_1}{100} \int_0^H (D_0 - kx) x dx \\ &= \frac{K_1}{100} \left(\frac{D_0 H^2}{2} - \frac{k H^3}{3} \right) \end{aligned}$$



----- (ex40-13)

The sum of the bending moment due to the wind pressure for each conductor (Mw) is given by the following formula:

$$M_w = K_2 \frac{S(\sum dh)}{1000} \quad \text{----- (ex40-14)}$$

The allowable stress of wooden pole against its bending (f) is given the following formula:

$$f = \frac{P(1000)^2}{F} \text{ (N/m}^2\text{)}$$

The modulus of the cross section of the wooden pole (Z) is given the following formula:

$$Z = \frac{\pi}{32} (D'_0)^3 \text{ (cm}^3\text{)} = \frac{\pi}{32} \left(\frac{D'_0}{100} \right)^3 \text{ (m}^3\text{)}$$

Therefore the resistant moment of the wooden pole (Mr) is given the following formula:

$$M_r = f \cdot Z = \frac{P(1000)^2}{F} \cdot \frac{\pi}{32} \left(\frac{D'_0}{100} \right)^3 = \frac{\pi}{32} \cdot \frac{P(D'_0)^3}{F} \text{ (N?m)}$$

(1) Single Pole without Guys

$$\mathbf{Mr} \geq \mathbf{K(Mp + Mw)}$$

$$\frac{\pi}{32} \cdot \frac{\mathbf{P(D'_0)^3}}{\mathbf{F}} \geq \mathbf{K} \left\{ \frac{\mathbf{K_1}}{100} \left(\frac{\mathbf{D_0 H^2}}{2} - \frac{\mathbf{k H^3}}{3} \right) + \mathbf{K_2} \frac{\mathbf{S(\sum dh)}}{1000} \right\}$$

$$\frac{\mathbf{P}}{\mathbf{F}} \geq \frac{32\mathbf{K}}{\pi} \left\{ \frac{\mathbf{K_1}}{100} \left(\frac{\mathbf{D_0 H^2}}{2} - \frac{\mathbf{k H^3}}{3} \right) + \mathbf{K_2} \frac{\mathbf{S(\sum dh)}}{1000} \right\} / (\mathbf{D'_0})^3$$

Therefore $\mathbf{K_1=520(N/m^2)}$, $\mathbf{K_2=680(N/m^2)}$, $\mathbf{k=0.9(cm/m)}$ are substituted to this formula:

$$\frac{\mathbf{P}}{\mathbf{F}} \geq \mathbf{K} \frac{265\mathbf{D_0 H^2} - 158\mathbf{H^3} + \mathbf{S(\sum 69dh)}}{10(\mathbf{D'_0})^3}$$

(2) Single Pole with Guys

$$\mathbf{Mr} \geq \frac{1}{2} \mathbf{K(Mp + Mw)}$$

$$\frac{P}{F} \geq \frac{16K}{\pi} \left\{ \frac{K_1}{100} \left(\frac{D_0 H^2}{2} - \frac{k H^3}{3} \right) + K_2 \frac{S(\sum dh)}{1000} \right\} / (D'_0)^3$$

Therefore $\mathbf{K_1=520(N/m^2)}$, $\mathbf{K_2=680(N/m^2)}$, $\mathbf{k=0.9(cm/m)}$ are substituted to this formula:

$$\therefore \frac{\mathbf{P}}{\mathbf{F}} \geq \mathbf{K} \frac{133\mathbf{D_0 H^2} - 79\mathbf{H^3} + 0.5\mathbf{S(\sum 69dh)}}{10(\mathbf{D'_0})^3}$$

4.4 Vertical Load

Calculation of the strength of iron poles and reinforced concrete poles used as the supporting structure of a distribution line against vertical load and bending moment shall take place as follows:

$$\sigma \geq \frac{W}{\mu A} + \frac{M}{Z}$$

Where:

σ : the allowance bending moment(N/cm²) of the structural material
of the supporting structure

W : the vertical load(N) present above the cross section in which strength calculation takes place

M : the bending moment (N · cm) due to the load present above the cross section in which strength calculation takes place

μA : the equivalent sectional area(cm²)

< Calculation method of μA >

$$\text{In case of } 0 < \lambda_2 < \sqrt{\frac{mE}{\sigma_p} \cdot \frac{A_2}{A_1}}, \Rightarrow \mu A = A_2 \left\{ \left(\frac{A_1}{A_2} \right) - \frac{\sigma_p}{mE} \left(1 - \frac{\sigma_p}{\sigma_y} \right) \left(\frac{A_2}{A_1} \right)^2 \lambda_2^2 \right\}$$

$$\text{In case of } \lambda_2 > \sqrt{\frac{mE}{\sigma_p} \cdot \frac{A_2}{A_1}}, \Rightarrow \mu A = A_2 \frac{1}{\sigma_y} \cdot \frac{mE}{\lambda_2^2}$$

$$m = \begin{cases} 0.0804 \left(\frac{I_1}{I_2} \times 10^4 \right)^{0.4133} & \dots\dots\dots \text{in case of } 0.0001 < \frac{I_1}{I_2} < 0.01 \\ 0.114 \left(\frac{I_1}{I_2} \times 10^4 \right)^{0.3373} & \dots\dots\dots \text{in case of } 0.01 < \frac{I_1}{I_2} < 0.4 \\ 1.472 + 0.995 \left(\frac{I_1}{I_2} \right) & \dots\dots\dots \text{in case of } 0.4 < \frac{I_1}{I_2} < 1.0 \end{cases}$$

λ_2 : the slenderness ratio of the pole

$$\left(\lambda_2 = \frac{\text{Length of the pole from the point of load action to the ground level(cm)}}{\text{Radius of gyration of area of the pole at the ground level(cm)}} \right)$$

E : Young's modulus (N/cm²)

σ_y : the yield point (N/cm²)

σ_p : the elastic limit($\sigma_p = 0.8\sigma_y$)

I_1 : the moment of inertia(cm⁴) of the pole at the point of load application

I_2 : the moment of inertia(cm⁴) of the pole at the ground level

A_1 : the sectional areas(cm²) of the pole at the point of load application

A_2 : the sectional areas(cm²) of the pole at the ground level

Z : the modulus of section(cm³) of the cross section concerned.

4.5 Calculation of Safety Factor of Foundations of Supporting Structures

The safety factor of the foundation of a supporting structure is calculated as follows:

$$f \geq \frac{KD_0 t^4}{120P(H + t_0)^2} \quad (\text{without a guy anchor}) \quad \text{----- (ex40-15)}$$

Where:

f: Safety factor of the foundation of the supporting structure.

D₀: Diameter of the supporting structure at the ground level if columnar pole (m)

Edge length of the cross section of the supporting structure at the the ground level

if square pole (m)

t: Embedded depth of the supporting structure (m)

H: Height of the point of action of concentrated loads from the ground surface (m)

P: Load converted into a concentrated load at the top of the supporting structure (N)

t₀: Depth of the center of gyration of the supporting structure from the ground surface (m)

$$t_o = \frac{2}{3}t \quad (\text{m})$$

K: Soil coefficient taking the value given in the following table.

Table ES40H: Soil Coefficient

Classification of soil		Soil coefficient (N/m ⁴)
Normal soil	[A] Aggregated soil or sand, and soil with plenty of gravel or stone belonging under hard soil	3.9×10 ⁷
	[B] Aggregated soil or sand, and soil with plenty of gravel or stone belonging under soft soil	2.9×10 ⁷
Soft soil	[C] Quicksand (with no soil mixed)	2.0×10 ⁷
	[D] Moist clay, humus, fill and other soft soils (excluding deep rice fields)	0.8×10 ⁷

4.6 Reinforcement of the Foundation by the Foundation Block

If a foundation block will be buried to reinforce the foundation, the safety factor of the foundation of a supporting structure is calculated as follows:

$$f \geq \frac{r K D_0 t^4}{120 P (H + t_0)^2} \quad \text{----- (ex40-16)}$$

Where:

f: Safety factor of the foundation of the supporting structure.

D_0 : Diameter of the supporting structure at the ground level
if columnar pole (m)

Edge length of the cross section of the supporting structure
at the the ground level if square pole (m)

t: Embedded depth of the supporting structure (m)

H: Height of the point of action of concentrated loads
from the ground surface (m)

P: Load converted into a conce ntrated load at the top
of the supporting structure (N)

t_0 : Depth of the center of gyration of the supporting structure
from the ground surface (m)

$$t_o = \frac{2}{3} t \quad (\text{m})$$

K: Soil coefficient

?:Increasing coefficient of resisting moment in the foundation
by a concrete foundation block(coefficient of reinforcement)

$$\rho = 36 \left[\frac{\gamma^2}{2} \{1 + \beta^2 (\alpha - 1)\} - \frac{2}{3} \gamma \{1 + \beta^3 (\alpha - 1)\} + \frac{1}{4} \{1 + \beta^4 (\alpha - 1)\} \right]$$

$$\alpha : \frac{D_c}{D_0}, \quad \beta : \frac{t_c}{t}, \quad \gamma : \frac{t_0''}{t}$$

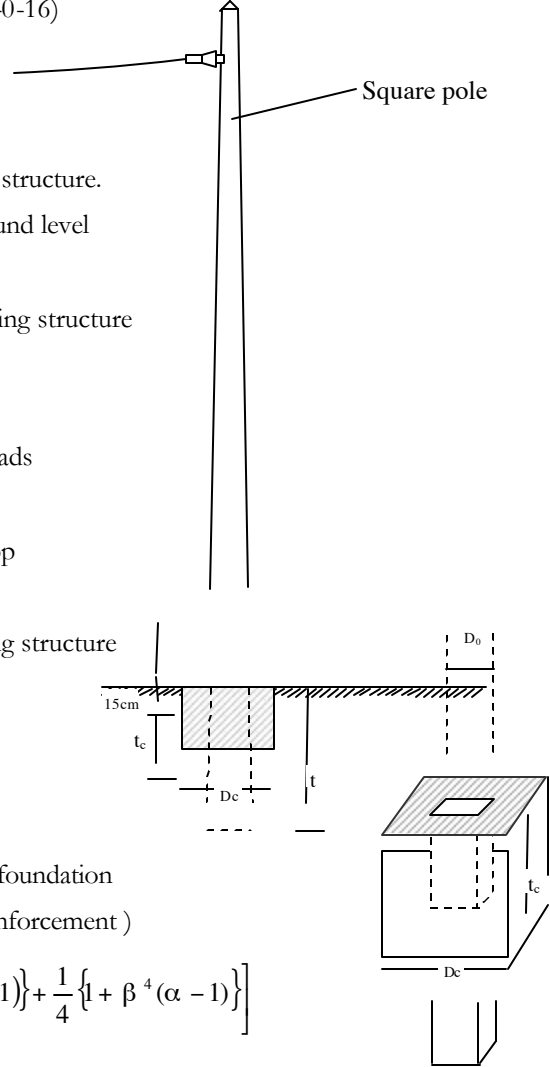
t_0'' : Depth of the center of gyration of the supporting structure from the ground surface
if a foundation block is buried (m)

$$t_0'' = \frac{2}{3} t \left\{ \frac{1 + \beta^3 (\alpha - 1)}{1 + \beta^2 (\alpha - 1)} \right\} \quad (\text{m})$$

D_c : Diameter of the foundation block if the foundation block is columnar (m),

Transverse breadth of the foundation block if the foundation block is a rectangular
parallelepiped (m)

t_c : Depth of the foundation block

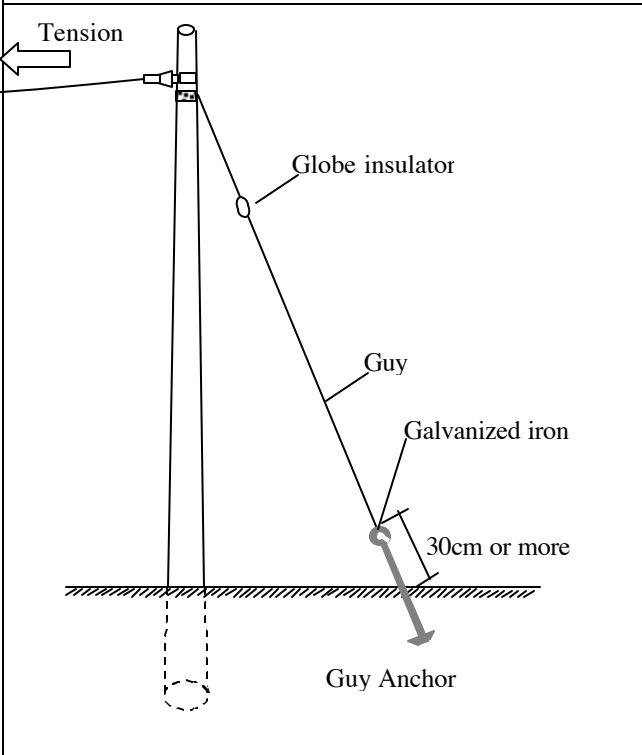
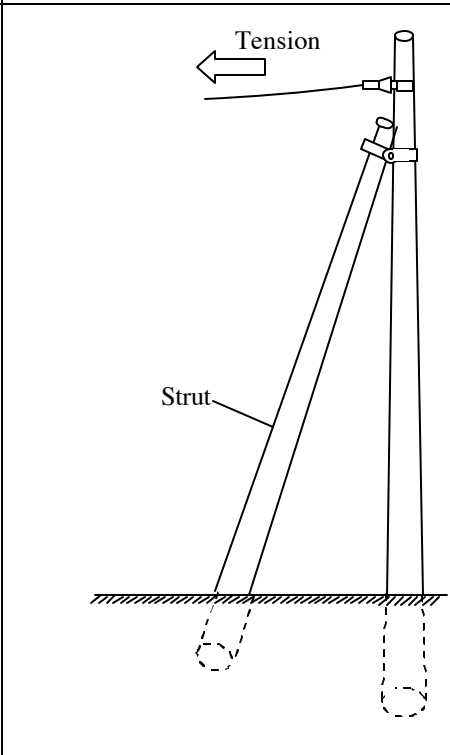


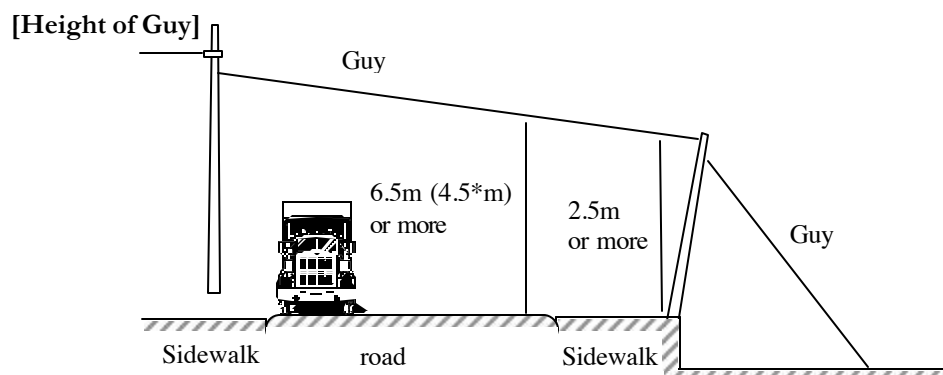
(It shall be taken into consideration that t_c does not include 15cm below the ground surface if soil condition is normal.)

5 Reinforcement for Supporting Structures by Guys

5.1 Installation and safety factor of guys

Figure ES40B: Example of Guy and Strut

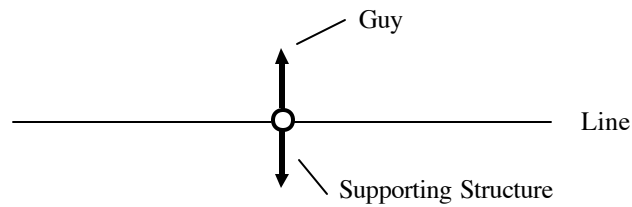
Guy	Strut
	
<p>A globe insulator shall be inserted in the upper part of the guy, if a guy installed on an overhead distribution line in danger of touching an electrical conductor.</p>	<p>A strut that has equivalent or higher effect can be substitutable for a guy.</p>



* Only in the case that 5m is impossible for technical reasons and there is no danger of interfering with traffic.

[Condition of Installation of Guys]

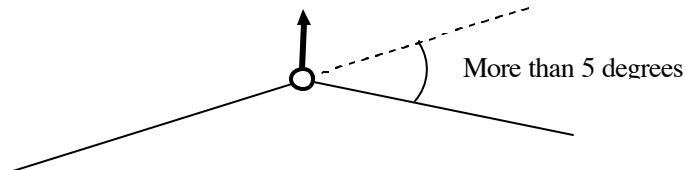
- (1) When a supporting structure lacks the strength against the wind pressure lateral to guys, guys shall be installed at right angle to the lines.



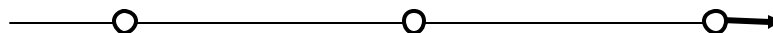
- (2) When spans on both sides of supporting structure are too different, guys shall be installed on both sides of lines. (Supporting structures are installed without strength calculation.)



- (3) When lines on both side make an angle more than 5 degrees, the guy that endures the horizontal lateral component of the assumed maximum tension shall be installed. (Supporting structures are installed without strength calculation.)



- (4) The guy that endures the horizontal force of all strung wires shall be installed at the end of a distribution line. (Supporting structures are installed without strength calculation.)



[Calculation of Strength of Guy]

(1) Guys for the Wind Pressure Lateral to a Line (Single Pole)

$$P \geq \frac{K}{h_0 \times 10^3} \left\{ 1.25K_2S \left(\sum dh \right) + 12.5K_1 \left(\frac{D_0 H^2}{2} - \frac{kH^3}{3} \right) \right\} \cdot \text{cosec} \alpha \quad \text{----- (ex40-17)}$$

In the case of $K_1=520(\text{N/m}^2)$, $K_2=680(\text{N/m}^2)$;

$$P \geq \frac{K}{h_0 \times 10^3} \left\{ 850S \left(\sum dh \right) + 3,250D_0 H^2 - 2,167kH^3 \right\} \cdot \text{cosec} \alpha \quad \text{----- (ex40-18)}$$

Where:

P: Tensile strength of the guy (N)

h_0 : Height of the installed point of the guy (m)

α : Angle of the pole and the guy

S: Span (m)

(S is one half of the sum of spans on both sides of the pole If they are not same l length.)

d: Diameter of the conductor (mm)

h: Height of the installed point of the conductor (m)

H: Height of the pole (m)

D_0 : Diameter of the pole at surface of earth (cm)

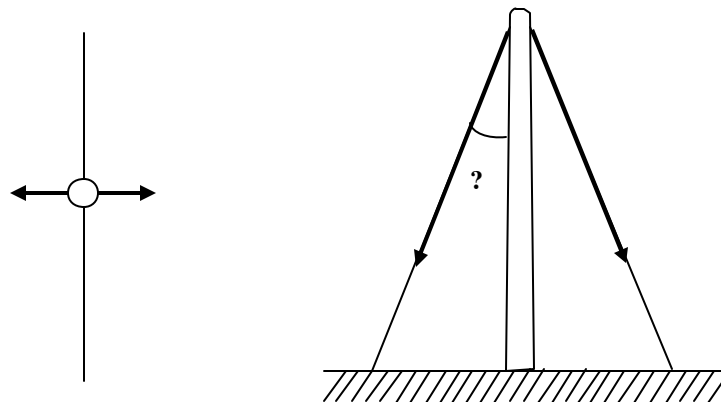
k: Increasing rate of the diameter of the pole(cm/m)

K: Coefficient for the wind pressure ($K=1$ is suitable in Cambodia)

K_1 : Wind pressure per 1 m^2 of vertically projected area of the supporting structure (N/m^2)

K_2 : Wind pressure per 1 m^2 of vertically projected area of the distribution conductors (N/m^2)

Explanation Drawing



(2) Guys for the Wind Pressure Lateral to a Line (H-type Pole)

$$P \geq \frac{K}{h_0 \times 10^3} \left\{ 0.625K_2 S \left(\sum dh \right) + 12.5K_1 \left(\frac{D_0 H^2}{2} - \frac{kH^3}{3} \right) \right\} \cdot \text{cosec} \alpha \quad \text{---- (ex40-19)}$$

In the case of $K_1=520(\text{N/m}^2)$, $K_2=680(\text{N/m}^2)$;

$$P \geq \frac{K}{h_0 \times 10^3} \left\{ 425S \left(\sum dh \right) + 3,250D_0 H^2 - 2,167kH^3 \right\} \cdot \text{cosec} \alpha \quad \text{---- (ex40-20)}$$

Where:

P: Tensile strength of the guy (N)

h_0 : Height of the installed point of the guy (m)

α : Angle of the pole and the guy

S: Span (m)

(S is one half of the sum of spans on both sides of the pole If they are not same l length.)

d: Diameter of the conductor (mm)

h: Height of the installed point of the conductor (m)

H: Height of the pole (m)

D_0 : Diameter of the pole at surface of earth (cm)

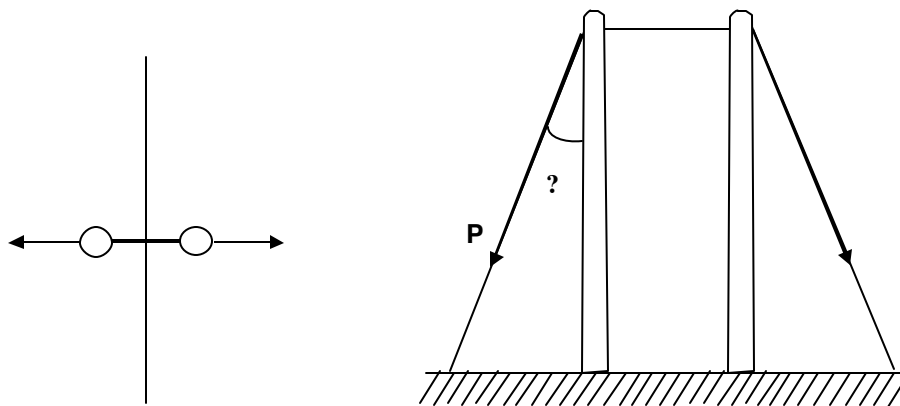
k: Increasing rate of the diameter of the pole(cm/m)

K: Coefficient for the wind pressure ($K=1$ is suitable in Cambodia)

K_1 : Wind pressure per 1 m^2 of vertically projected area of the supporting structure (N/m^2)

K_2 : Wind pressure per 1 m^2 of vertically projected area of the distribution conductors (N/m^2)

Explanation Drawing



(3) Guys for the Tension Unbalance

$$P \geq \frac{f}{h_0} \left(\sum Th \right) \csc \alpha \quad \text{----- (ex40-21)}$$

Where:

P: Tensile strength of the guy (N)

h_0 : Height of the installed point of the guy (m)

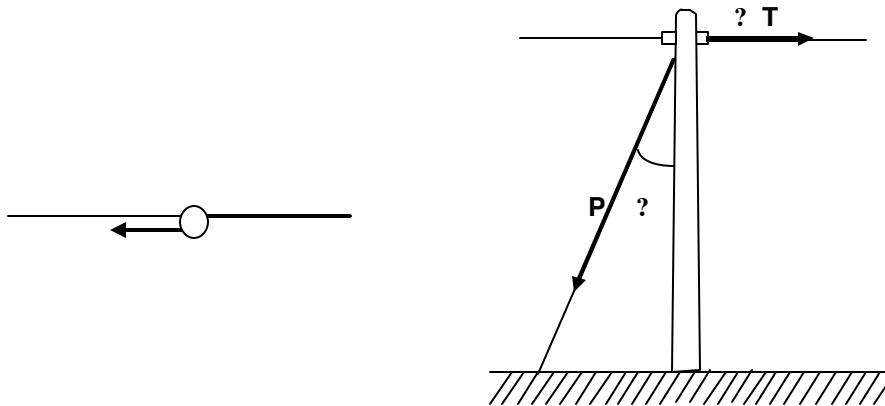
α : Angle of the pole and the guy

T: Assumed maximum tension unbalanced of a conductor (N)

h: Height of the installed point of the conductor (m)

f: Safety factor

Explanation Drawing



(4) Guys for the Pole Supporting the End of a Line (Simplified formula)

$$P \geq f \sum T \cos \alpha$$

$$P \geq f \sum T \sqrt{\left(\frac{h_0}{l}\right)^2 + 1} \quad \text{----- (ex40-22)}$$

Where:

P: Tensile strength of the guy (N)

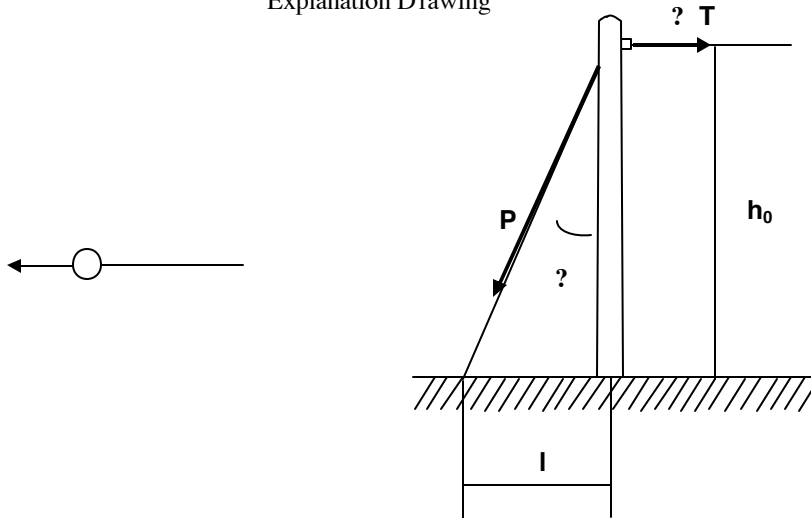
h_0 : Height of the installed point of the guy (m)

T: Assumed maximum tension unbalance of a conductor (N)

l: Length between the pole and the guy at the surface of earth (m)

f: Safety factor

Explanation Drawing



(5) Guys for the Pole of which Line is not Straight (Simplified formula)

$$P \geq f \sum T \sqrt{\left(\frac{h_0}{l}\right)^2 + 1}$$

$$T = \sqrt{T_A^2 + T_B^2 - 2T_A T_B \cos j}$$

If $T_A = T_B$, then

$$P \geq 2f \sum T_A \sin \frac{j}{2} \sqrt{\left(\frac{h_0}{l}\right)^2 + 1}$$

Where:

P: Tensile strength of the guy (N)

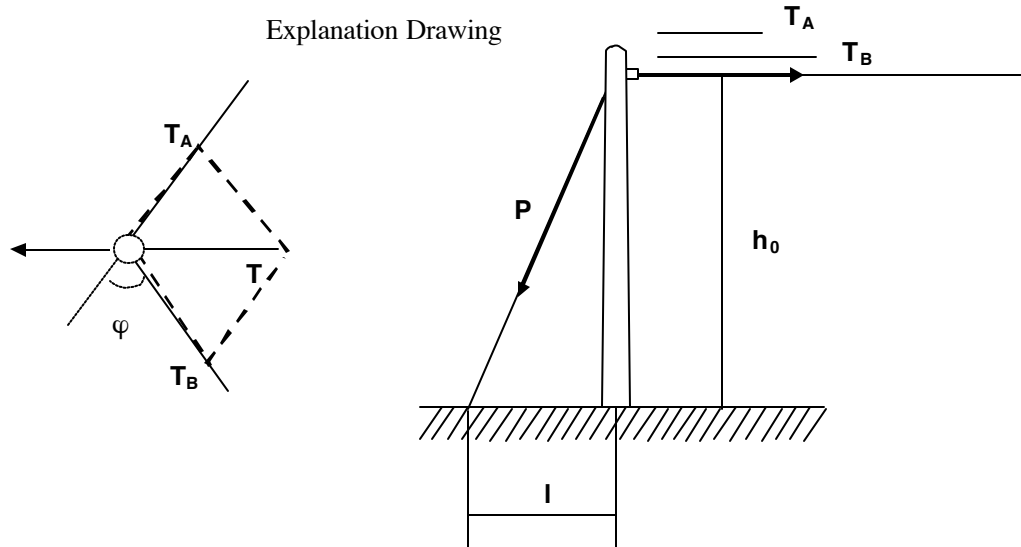
h_0 : Height of the installed point of the guy (m)

T: Assumed maximum tension unbalance of a conductor (N)

l: Length between the pole and the guy at the surface of earth (m)

f: Safety factor

Explanation Drawing



[In Case of no Guys]

If the calculation of the strength of a supporting structure is surely conducted and the safety factor of foundation of the supporting structure shall be 2.0 or more prescribed in the article 40.2, guys are not necessary.

[Example 1(a. Supporting structures lacking strength against the wind pressure - Calculation of the horizontal transverse strength)]

(Condition)

(1) MV Line (AAC150mm²×3wire, Diameter $d_1=0.0168\text{m}$)

(2) LV Line (PVC75mm²×3wire, Diameter $d_2=0.0170\text{m}$)

(3) Span ($S_1=60\text{m}$, $S_2=40\text{m}$, $S=(S_1+S_2)/2=50\text{m}$)

(4) Supporting Structure (Square pole)

Top end breadth $D_1=0.15\text{m}$,

Ground-level breadth $D_0=0.30\text{m}$

Height above the ground $H=11.7\text{m}$

Embedded depth $t = 2.3\text{m}$

(5) Wind pressure to 1m² of the vertical projected area

Iron-reinforced concrete pole (square pole) : $K_1=1,290\text{Pa}$

Conductor : $K_2= 680\text{Pa}$

(6) Foundation block (a rectangular parallelepiped)

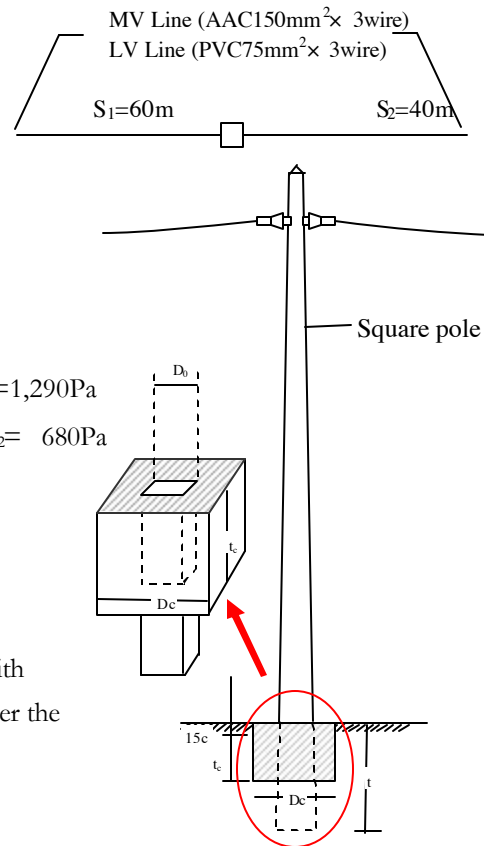
Transverse breadth $D_c = 1.0\text{m}$

Depth $t_c = 1.5\text{m}$

(7) Classification of soil

Classification : [B] Aggregated soil or sand, and soil with plenty of gravel or stone belonging under the soft soil

Soil coefficient $K = 3.9 \times 10^7 (\text{N/m}^4)$



$P = P_p$ (Wind pressure for the pole into a concentrated load at the top)

+ P_w (Wind pressure for the conductors into a concentrated load at the top)

$$= K_1 \times \frac{(2D_1 + D_0)H}{6} + K_2 S \sum d$$

$$= 1,290 \times \frac{(2 \times 0.15 + 0.30) \times 11.7}{6} + 680 \times 50 \times (0.0168 \times 3 + 0.0170 \times 3) = 4956.9 [\text{N}]$$

$$\alpha = \frac{D_c}{D_0} = 3.33 \quad \beta = \frac{t_c}{t} = 0.652 \quad t''_0 = \frac{2}{3} t \left\{ \frac{1 + \beta^3 (\alpha - 1)}{1 + \beta^2 (\alpha - 1)} \right\} = 1.27 \quad \gamma = \frac{t'_0}{t} = 0.552$$

$$\rho = 36 \left[\frac{\gamma^2}{2} \{1 + \beta^2(\alpha - 1)\} - \frac{2}{3} \gamma \{1 + \beta^3(\alpha - 1)\} + \frac{1}{4} \{1 + \beta^4(\alpha - 1)\} \right] = 1.87$$

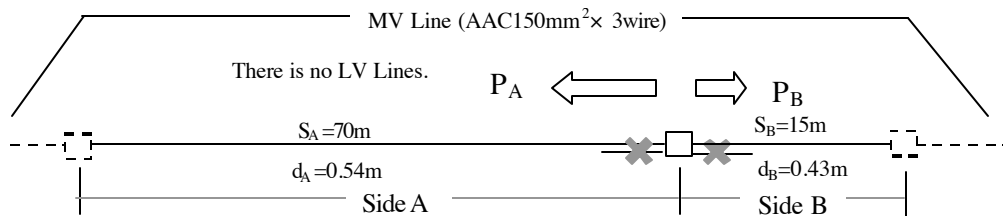
Therefore, the safety factor of foundation f is calculated as follows;

$$f = \frac{\rho K D_0 t^4}{120 P (H + t_0)^2} = \frac{1.87 \times 3.9 \times 10^7 \times 0.30 \times 2.3^4}{120 \times 4956.9 \times (11.7 + 2/3 \times 2.3)^2} = 5.88$$

(t_0 : Depth of the center of gyration of the supporting structure from the ground surface (m); $t_0 = 2/3t$)

? Because the safety factor 5.88 of foundation is more than 2, guys are not necessary.

[Example 2(b. Supporting structure of which spans on both side are too different - Calculation of the horizontal longitudinal strength)]



(Condition)

(1) MV Line (AAC150mm² x 3wire, Weight $W=0.434\text{kg/m}$)

(2) Span $S_A=70\text{m}$ (Side A), $S_B=15\text{m}$ (Side B)

(3) Sag for overhead MV conductors

$d_A=0.54\text{m}$ (Side A), $d_B=0.43\text{m}$ (Side B)

(4) Supporting Structure (Square pole)

Top end breadth $D_1=0.15\text{m}$, Ground-level breadth $D_0=0.30\text{m}$

Height above the ground $H=10.0\text{m}$, Embedded depth $t = 2.0\text{m}$

(5) Wind pressure to 1m^2 of the vertical projected area

Iron-reinforced concrete pole (square pole) : $K_1=1,290\text{Pa}$

(6) Foundation block (a rectangular parallelepiped)

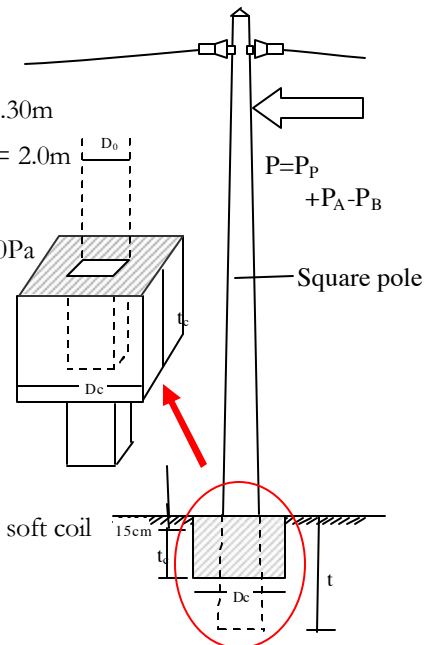
Transverse breadth $D_C = 1.0\text{m}$

Depth $t_c = 1.5\text{m}$

(7) Classification of soil

Classification : [B] Aggregated soil or sand, and soil with plenty of gravel or stone belonging under the soft soil

Soil coefficient $K = 3.9 \times 10^7 (\text{N/m}^4)$



If the wind direction is as same as " P_A ", the pole has to be burdened with the maximum load " P ".

$P = P_P$ (Wind pressure for the pole into a concentrated load at the top)

+ P_A (Horizontal Transverse Component of the maximum tension of Conductors on the side A)

- P_B (Horizontal Transverse Component of the maximum tension of Conductors on the side B)

$$= K_1 \times \frac{(2D_1 + D_0)H}{6} + \left(\frac{W_g S_A^2}{8d_A} \times 3 - \frac{W_g S_B^2}{8d_B} \times 3 \right)$$

$$= 1,290 \times \frac{(2 \times 0.15 + 0.30) \times 10.0}{6} + \frac{0.434 \times 9.8 \times 70^2}{8 \times 0.54} \times 3 - \frac{0.434 \times 9.8 \times 15^2}{8 \times 0.43} \times 3 = 14,928 \text{ [N]}$$

$$\alpha = \frac{D_c}{D_0} = \frac{1.0}{0.30} = 3.33 \quad \beta = \frac{t_c}{t} = \frac{1.5}{2.0} = 0.75 \quad t'_0 = \frac{2}{3} t \left\{ \frac{1 + \beta^3(\alpha - 1)}{1 + \beta^2(\alpha - 1)} \right\} = 1.144 \quad \gamma = \frac{t''_0}{t} = 0.572$$

$$\rho = 36 \left[\frac{\gamma^2}{2} \{1 + \beta^2(\alpha - 1)\} - \frac{2}{3} \gamma \{1 + \beta^3(\alpha - 1)\} + \frac{1}{4} \{1 + \beta^4(\alpha - 1)\} \right] = 2.022$$

Therefore, the safety factor of the foundation f is calculated as follows;

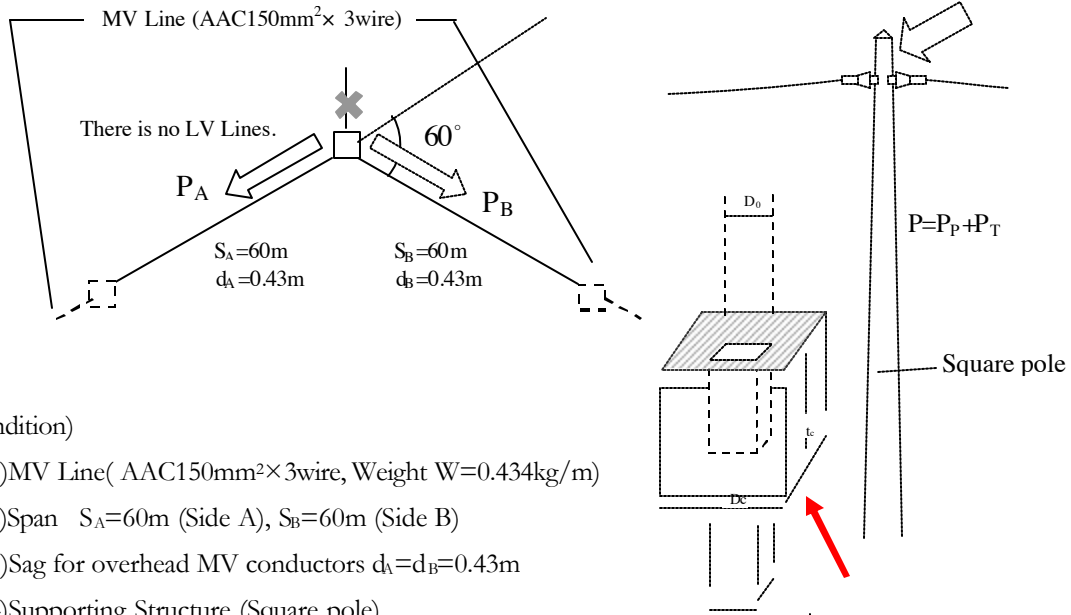
$$f = \frac{\rho K D_0 t^4}{120 P (H + t_0)^2} = \frac{2.02 \times 3.9 \times 10^7 \times 0.30 \times 2.0^4}{120 \times 14,928 \times (10.0 + 2/3 \times 2.0)^2} = 1.64$$

(t_0 : Depth of the center of gyration of the supporting structure from the ground surface (m);

$$t_0 = 2/3 t)$$

? Because the safety factor 1.64 of foundation is less than 2, guys are necessary and cannot be omitted.

[Example 3(c. Supporting structure of which lines on both side make an angle more than 5 degrees)]



(Condition)

(1) MV Line(AAC150mm²×3wire, Weight W=0.434kg/m)

(2) Span SA=60m (Side A), SB=60m (Side B)

(3) Sag for overhead MV conductors dA=dB=0.43m

(4) Supporting Structure (Square pole)

Top end breadth D₁=0.15m, Ground-level breadth D₀=0.30m

Height above the ground H=10.0m, Embedded depth t = 2.0m

(5) Wind pressure to 1m² of the vertical projected area

Iron-reinforced concrete pole (square pole) : K₁=1,290Pa

(6) Foundation block (a rectangular parallelepiped)

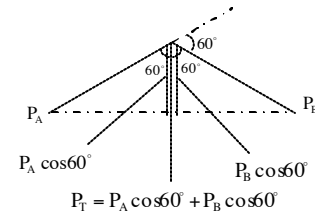
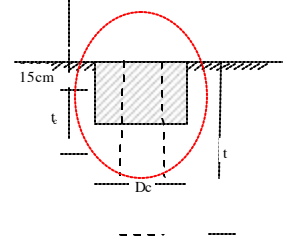
Transverse breadth DC= 1.0m

Depth tc = 1.5m

(7) Classification of soil : [B] Aggregated soil or sand, and soil with

plenty of gravel or stone belonging under the soft soil

Soil coefficient K = 3.9×10⁷ (N/m⁴)



$P = P_p$ (Wind pressure for the pole into a concentrated load at the top)

+ P_T (Horizontal Transverse Component of the maximum tension of Conductors)

$$(P_T = P_A \cos 60^\circ + P_B \cos 60^\circ)$$

$$= K_1 \times \frac{(2D_1 + D_0)H}{6} + \left(\frac{WgS_A^2}{8d_A} \times 3 \times 0.5 + \frac{WgS_B^2}{8d_B} \times 3 \times 0.5 \right) \quad (\because \cos 60^\circ = 0.5)$$

$$= 1,290 \times \frac{(2 \times 0.15 + 0.30) \times 10.0}{6} + \frac{0.434 \times 9.8 \times 60^2}{8 \times 0.43} \times 3 \times 0.5 + \frac{0.434 \times 9.8 \times 60^2}{8 \times 0.43} \times 3 \times 0.5$$

$$= 14,634 \text{ [N]}$$

$$\alpha = \frac{D_c}{D_0} = \frac{1.0}{0.30} = 3.33 \quad \beta = \frac{t_c}{t} = \frac{1.5}{2.0} = 0.75 \quad t'_0 = \frac{2}{3} t \left\{ \frac{1 + \beta^3 (\alpha - 1)}{1 + \beta^2 (\alpha - 1)} \right\} = 1.144 \quad \gamma = \frac{t'_0}{t} = 0.572$$

$$\rho = 36 \left[\frac{\gamma^2}{2} \{1 + \beta^2 (\alpha - 1)\} - \frac{2}{3} \gamma \{1 + \beta^3 (\alpha - 1)\} + \frac{1}{4} \{1 + \beta^4 (\alpha - 1)\} \right] = 2.022$$

Therefore, the safety factor of the foundation f is calculated as follows;

$$f = \frac{\rho K D_0 t^4}{120 P (H + t_0)^2} = \frac{2.02 \times 3.9 \times 10^7 \times 0.30 \times 2.0^4}{120 \times 14,928 \times (10.0 + 2/3 \times 2.0)^2} = 1.67$$

(t_0 : Depth of the center of gyration of the supporting structure from the ground surface (m); $t_0 = 2/3t$)

? Because the safety factor 1.67 of foundation is less than 2, guys are necessary and cannot be omitted.

[Example 4(d. Supporting structure which supports the end of a line - Calculation of the horizontal longitudinal strength)]

(Condition)

(1) MV Line(AAC150mm²×3wire, Weight $W_1=0.434\text{kg/m}$)

(2) Span ($S_1=60\text{m}$)

(3) Sag for overhead MV conductors ($d_1=1.25\text{m}$)

(4) Supporting Structure (Square pole)

Top end breadth $D_1=0.15\text{m}$,

Ground-level breadth $D_0=0.30\text{m}$

Height above the ground $H=10.0\text{m}$

Embedded depth $t = 2.0\text{m}$

(5) Wind pressure to 1m² of the vertical projected area

Iron-reinforced concrete pole (square pole) : $K_1=1,290\text{Pa}$

(6) Foundation block (a rectangular parallelepiped)

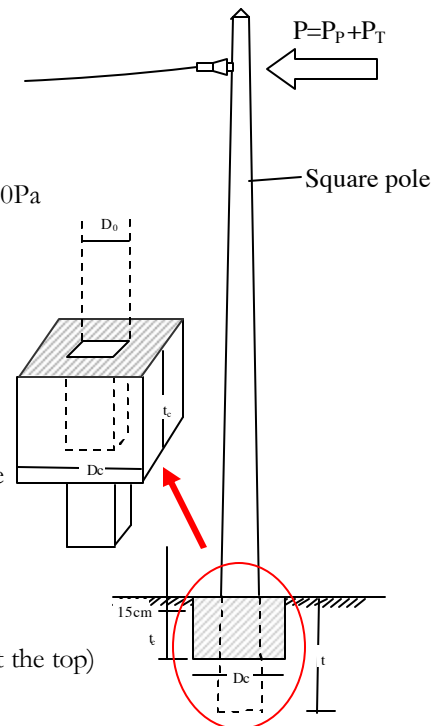
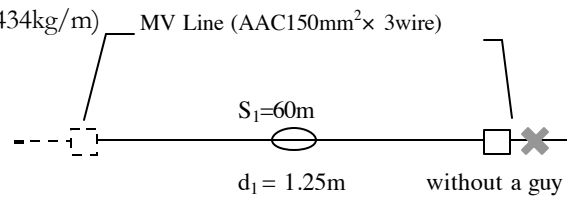
Transverse breadth $D_c = 1.0\text{m}$

Depth $t_c = 1.5\text{m}$

(7) Classification of soil

Classification : [B] Aggregated soil or sand, and soil with plenty of gravel or stone belonging under the soft soil

Soil coefficient $K = 3.9 \times 10^7 \text{ (N/m}^4\text{)}$



$P = P_p$ (Wind pressure for the pole into a concentrated load at the top)
 $+ P_t$ (Horizontal Transverse Component of the maximum tension of Conductors)

$$= K_1 \times \frac{(2D_1 + D_0)H}{6} + \left(\frac{W_1 g S_1^2}{8D_1} \times 3 \right)$$

$$= 1,290 \times \frac{(2 \times 0.15 + 0.30) \times 10.0}{6} + \frac{0.434 \times 9.8 \times 60^2}{8 \times 1.25} \times 3 = 5,883 \text{ [N]}$$

$$\alpha = \frac{D_c}{D_0} = 3.33 \quad \beta = \frac{t_c}{t} = 0.75 \quad t_0'' = \frac{2}{3} t \left\{ \frac{1 + \beta^3 (\alpha - 1)}{1 + \beta^2 (\alpha - 1)} \right\} = 1.144 \quad \gamma = \frac{t_0''}{t} = 0.572$$

$$\rho = 36 \left[\frac{\gamma^2}{2} \{ 1 + \beta^2 (\alpha - 1) \} - \frac{2}{3} \gamma \{ 1 + \beta^3 (\alpha - 1) \} + \frac{1}{4} \{ 1 + \beta^4 (\alpha - 1) \} \right] = 2.022$$

Therefore, the safety factor of the foundation f is calculated as follows;

$$f = \frac{\rho K D_0 t^4}{120 P (H + t_0)^2} = \frac{2.02 \times 3.9 \times 10^7 \times 0.30 \times 2.0^4}{120 \times 5,883 \times (10.0 + 2/3 \times 2.0)^2} = 4.161$$

(t_0 : Depth of the center of gyration of the supporting structure from the ground surface (m); $t_0 = 2/3t$)

? Because the safety factor 4.161 of foundation is more than 2, guys are not necessary.

[Calculation of the equation ex40-17, 18, 19 and 20]

(1) Guys for the wind pressure lateral to a line (Single pole)

If each guy burdens a half of the wind pressure and the supporting structure itself burdens another half of the wind pressure, the resistant moment of the guy(Mr) is

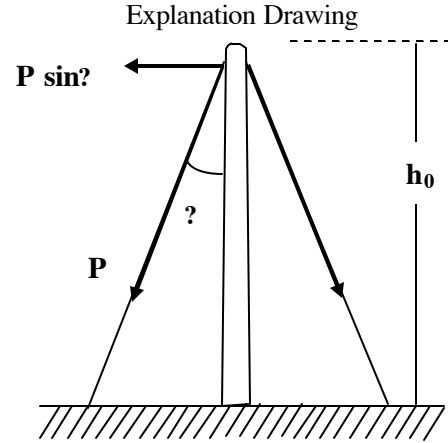
$$M_r \geq F \cdot K \cdot \frac{1}{2} (M_p + M_w)$$

M_p : The bending moment due to the wind pressure

for a pole converted into the top position of the pole

M_w : The sum of the bending moment due to the wind pressure for each conductor

F : Safety Factor



$$P \sin q \cdot h_0 \geq F \cdot K \cdot \frac{1}{2} \left\{ \frac{K_1}{100} \left(\frac{D_0 H^2}{2} - \frac{k H^3}{3} \right) + K_2 \cdot \frac{S(\sum dh)}{1000} \right\}$$

$$P \geq \frac{K}{h_0 \times 10^3} \left\{ 0.5 F \cdot K_2 S(\sum dh) + 5 F \cdot K_1 \left(\frac{D_0 H^2}{2} - \frac{k H^3}{3} \right) \right\} \operatorname{cosec} q$$

In the case of the safety factor F = 2.5(referred to Table 40C), the equation ex40-17 is obtained;

$$P \geq \frac{K}{h_0 \times 10^3} \left\{ 1.25 \cdot K_2 S(\sum dh) + 12.5 \cdot K_1 \left(\frac{D_0 H^2}{2} - \frac{k H^3}{3} \right) \right\} \operatorname{cosec} q$$

In the case of K₁=520(N/m²), K₂=680(N/m²), the equation ex40-18 is obtained;

$$P \geq \frac{K}{h_0 \times 10^3} \left\{ 850 S(\sum dh) + 3,250 D_0 H^2 - 2,167 k H^3 \right\} \operatorname{cosec} q$$

(2) Guys for the wind pressure lateral to a line (H-type pole)

As the bending moment due to the wind pressure for each conductor is distributed to two supporting

structure, the resistant moment of the guy(Mr) is ;

$$M_r \geq F \cdot K \cdot \frac{1}{2} \left(M_p + \frac{M_w}{2} \right)$$

$$P \sin q \cdot h_0 \geq F \cdot K \cdot \frac{1}{2} \left\{ \frac{K_1}{100} \left(\frac{D_0 H^2}{2} - \frac{k H^3}{3} \right) + \frac{1}{2} \cdot K_2 \cdot \frac{S(\sum dh)}{1000} \right\}$$

$$P \geq \frac{K}{h_0 \times 10^3} \left\{ 0.25 F \cdot K_2 S(\sum dh) + 5 F \cdot K_1 \left(\frac{D_0 H^2}{2} - \frac{k H^3}{3} \right) \right\} \operatorname{cosec} q$$

In the case of the safety factor $F = 2.5$, the equation ex40-19 is obtained;

$$\mathbf{P} \geq \frac{\mathbf{K}}{\mathbf{h}_0 \times 10^3} \left\{ 0.625 \cdot \mathbf{K}_2 \mathbf{S} \left(\sum \mathbf{d} \mathbf{h} \right) + 12.5 \cdot \mathbf{K}_1 \left(\frac{\mathbf{D}_0 \mathbf{H}^2}{2} - \frac{\mathbf{k} \mathbf{H}^3}{3} \right) \right\} \mathbf{cosec} \boldsymbol{q}$$

In the case of $\mathbf{K}_1=520(\text{N/m}^2)$, $\mathbf{K}_2=680(\text{N/m}^2)$, the equation ex40-20 is obtained;

$$\mathbf{P} \geq \frac{\mathbf{K}}{\mathbf{h}_0 \times 10^3} \left\{ 425 \mathbf{S} \left(\sum \mathbf{d} \mathbf{h} \right) + 3,250 \mathbf{D}_0 \mathbf{H}^2 - 2,167 \mathbf{k} \mathbf{H}^3 \right\} \cdot \mathbf{cosec} \boldsymbol{q}$$

Article 41: Overhead Medium-voltage and Low-voltage Lines

1 Cables for Overhead Lines

When cables are used for overhead lines, cables shall be installed not to inflict tension to cables directly. Generally cables are installed hanging on a messenger wire. Cables usually consist of soft annealed copper, therefore, its tensile strength is generally smaller than that of other conductors.

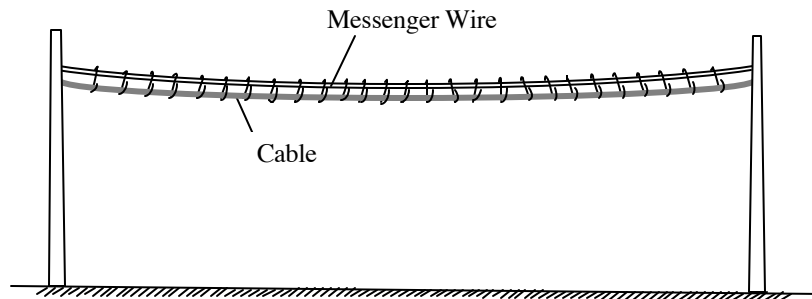


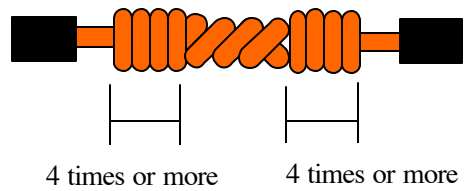
Figure ES41A: Messenger Wire and Cable

Class D grounding shall be provided to metallic members to be used for covering messenger wires and cables. Provided that, when cables are used as low-voltage overhead electrical wires, the messenger wire need not be provided with class D grounding if insulated wires or members providing an insulating effect equivalent to or superior to that of the insulated wire are used as the messenger wire.

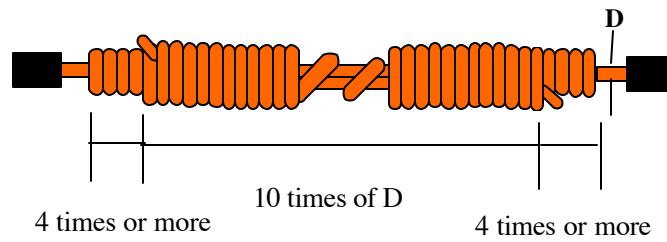
2 Connecting Methods of Overhead Conductors

2.1 Single Connection

(1) Twist joint

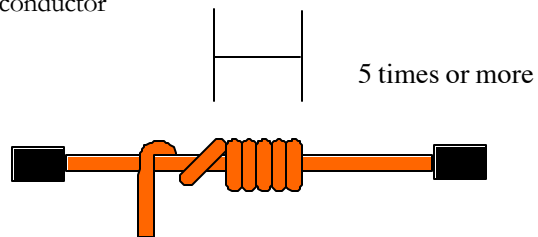


(2) Britania joint

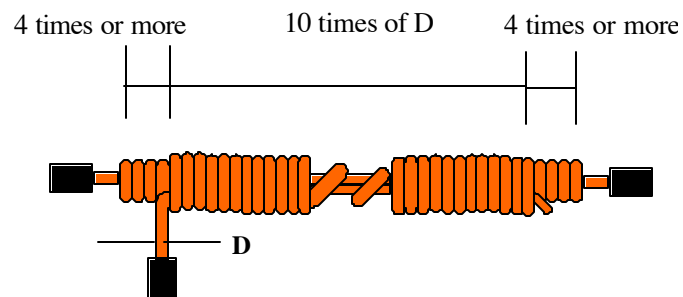


2.2 Separate Connection

(1) Narrow conductor



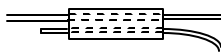
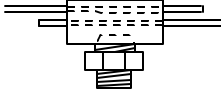


(2) Thick conductor

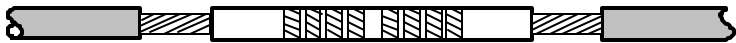


2.3 Splicing Devices

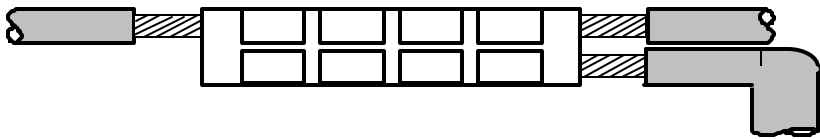
Table ES41A: Examples of Splicing Devices

Type	Classification of usage	Figure and usage situation
Straight Sleeve	Connection conductors when tension acts the connection point	 Twist (applied to Cu conductor)  Compression (applied to Cu, Al conductor)
	Connection a conductor used as a main line and a conductor used as a branch line or jumper, when tension acts the connection point	 Compression (applied to Cu, Al conductor)
Bolt-type Clamp-down Connector	Connection conductors when tension does not act the connection point	 Clamp-down (applied to "Cu and Cu" or "Cu and Al")

(1)Straight Type



(2)Branch Type



(Insulating effect at splice)

When splicing insulated conductors, or an insulated conductor and a cable, the splice shall be sufficiently covered with an insulating material having an insulating power equal to or more than the insulated conductor or a splicing device having equal or larger insulating effect shall be used.

(Example)



The connecting part shall be sufficiently covered with an insulating material

3 Branching of Overhead Lines

If branching of overhead lines is made on the overhead line, no tension is exerted on the electrical conductor at the branch.

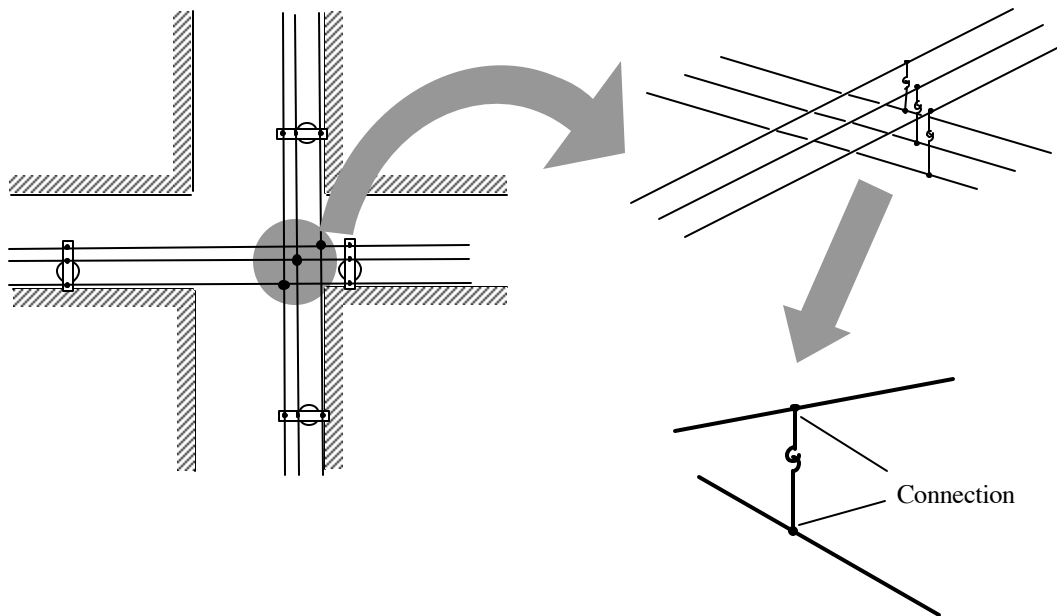



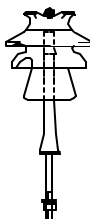
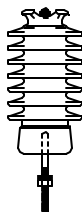
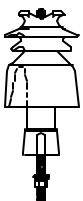




Figure ES41B: Example of Branching of Overhead Lines

Article 42: Mechanical Strength of Insulators

1 Generals of Mechanical Strength of Insulators

1.1 Type of insulator

Table ES42A: Type of Insulator

Type	Tension Insulator	Pin Type Insulator	Line Post Insulator	Pin Post Insulator
Figure				
Picture				

2 Safety Factor of Insulators

2.1 Tension Insulator (Insulator that anchors electrical lines)

[Safety factor] =
$$\frac{[\text{Tensile break strength}]}{[\text{Assumed maximum tension of the lines}]}$$

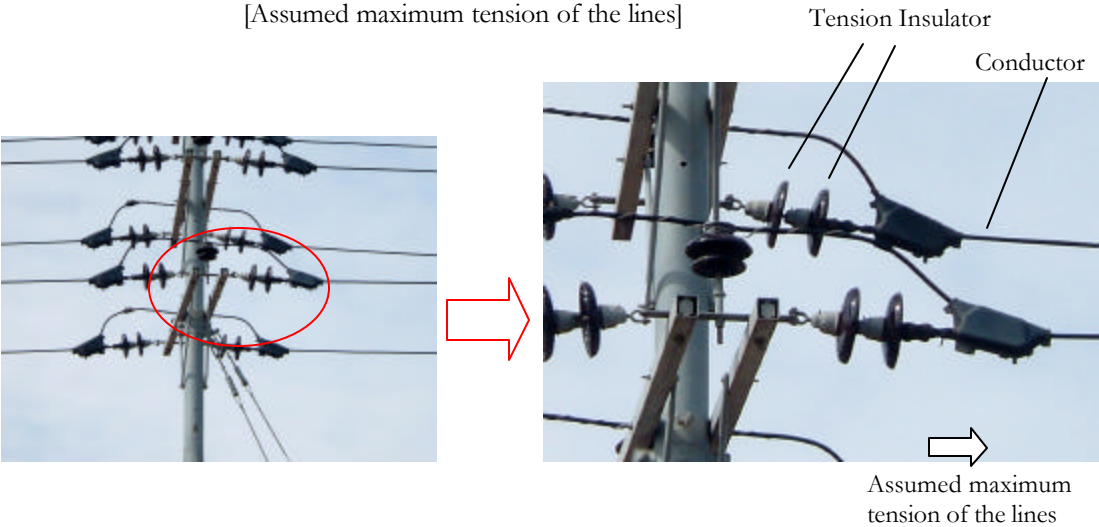


Figure ES42A: Tension Insulators

(?) Supporting Insulator (pin type insulator, line post insulator, etc.)

$$[\text{Safety factor}] = \frac{[\text{Tensile break strength}]}{[\text{Horizontal transverse load or vertical load applied perpendicular to the axis of the insulator device}]}$$

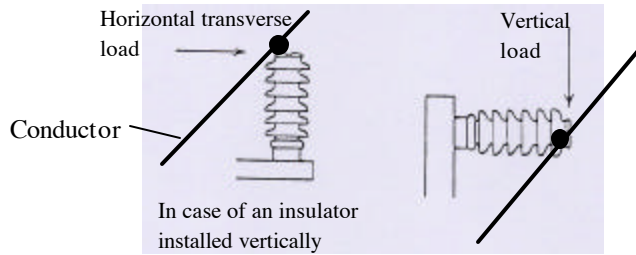


Figure ES42B: Supporting Insulators

3 Assumed Load

3.1 Vertical Load

$$V = (W_i + W_c \times S) \times g \quad (N)$$

Where:

V= Vertical Load (N)

W_i : Weight of insulator device (kg)

W_c : Weight of conductor (a length unit) (kg/m)

S : Weight span (m)

g : Gravity Acceleration(=9.80665 m/s²)

3.2 Horizontal Transverse Load

$$H_t = H_i + H_c \times d \times S + T_1 \sin \theta + T_2 \sin \theta \quad (N)$$

Where:

H_t : Horizontal Transverse Load (N)

d : Diameter of conductor (m)

S : Weight span (m)

g : Gravity Acceleration(=9.80665 m/s²)

T_1, T_2 : Horizontal component of maximum assumed tension of the electrical conductors (N)

H_i : Wind pressure load of insulator device(N)

$$[= 900 \text{ (N/m}^2) \times \text{cross sectional area of insulator (m}^2)]$$

H_c : Wind pressure load of conductor = 680 (N/m²)

θ : Horizontal angle

Table ES42B: Wind Pressure Loads

Segment of an object receiving wind pressure	Wind pressure to 1m ² of the vertical projected area (N/m ²)
Electrical conductor and other strung conductor	680
Insulation device	900

*The wind pressures are obtained from 32m/s wind velocity as same as Table 40C.

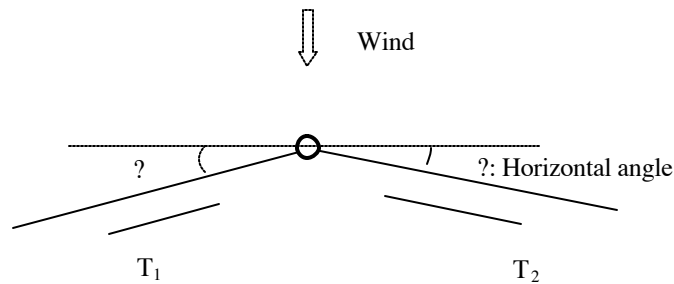


Figure ES42C: Explanation of Horizontal Angle

4 Assumed Maximum Tension of the Lines

4.1 Load Generated by the Weight of the Electrical Conductor

Load generated by the weight of the electrical conductor is a tension in the longitudinal direction calculated by the following formula approximately.

$$T = \frac{WgS^2}{8D} \quad [\text{N}] \quad \text{????????(ex42-1)}$$

Where;

T : Tension in the longitudinal direction (N)

D : Sag for overhead conductor (m)

W : Weight per unit conductor length (kg/m)

g : Gravity Acceleration(=9.80665 m/s²)

S : Span between two poles (m)

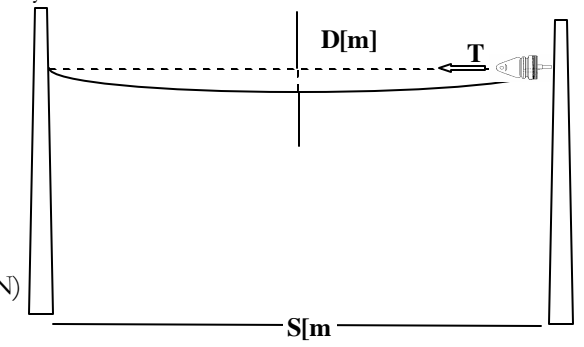


Figure ES42D: Calculation of Tension

[Example]

$$W = 1.0(\text{kg/m})$$

$$g = 9.8(\text{m/s}^2)$$

$$S = 48(\text{m})$$

$$D = 1.4(\text{m})$$

$$\Rightarrow T = \frac{WgS^2}{8D} = \frac{1.0 \times 9.8 \times 48^2}{8 \times 1.4} = 2,000[N]$$

4.2 Horizontal Load Generated by the Horizontal Wind Pressure

Horizontal load generated by the horizontal wind pressure is calculated by the following formula approximately.

$$W_h = H_i + H_c \times d \times S' \quad (N)$$

Where;

Wh: Horizontal Load (N)

d : Diameter of conductor (m)

S' : Weight span (m)

g : Gravity Acceleration(=9.80665 m/s²)

Hi : Wind pressure load of insulator device (N)

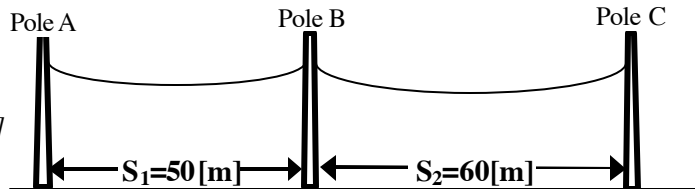
[= 900 (N/m²) × cross sectional area of insulator (m²)]

Hc : Wind pressure load of conductor (N/m²)

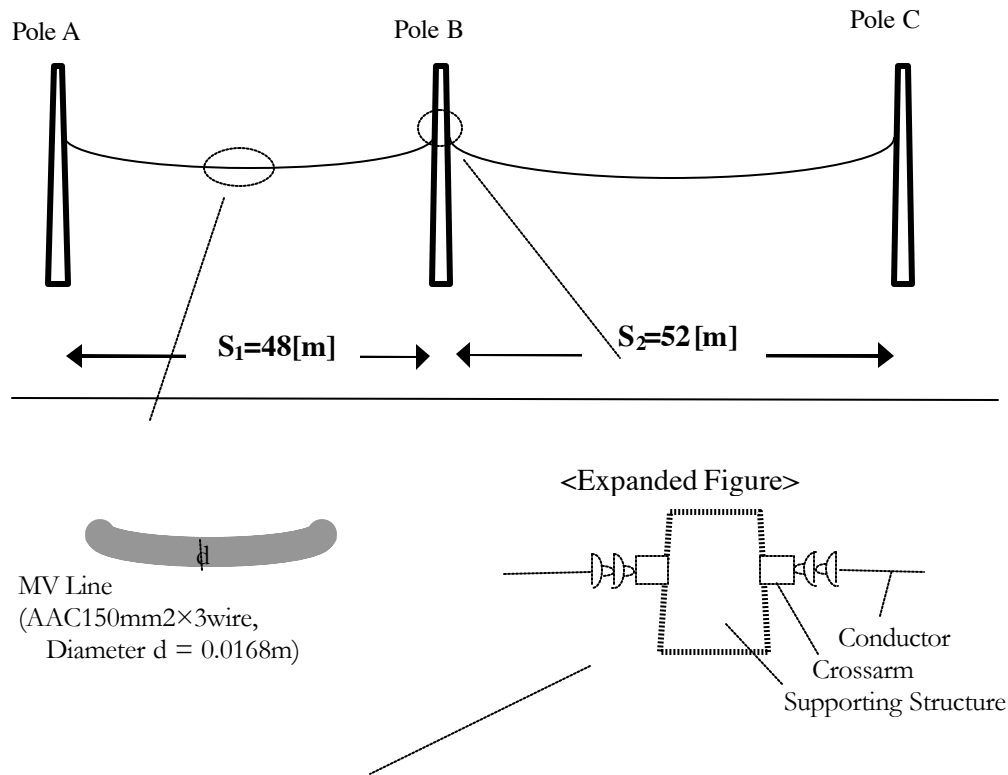
[Example of calculation of a weight span]

In the case shown in right figure,
the weight span of “Pole B” is
calculated as following;

$$S' = \frac{S_1 + S_2}{2} = \frac{50 + 60}{2} = 55[m]$$



[Example of calculation of a horizontal load]



<Tension Insulator>

- There are 3 insulators on the both side of the supporting structure. (Total number is 6.)
- The cross sectional area of the insulator is 0.06m²

$$S' = \frac{S_1 + S_2}{2} = \frac{48 + 52}{2} = 50[m]$$

$$W_h = 900(N/m^2) \times 0.06(m^2) \times \underset{\text{Number of insulators}}{6} + 680(N/m^2) \times 0.0168(m) \times \underset{\text{Number of wires}}{50(m)} \times 3$$

$$\Rightarrow W_h = 324 + 1,714 = 2,038(N)$$

4.3 Assumed Maximum Tension of the Lines

Assumed maximum tension of the lines, which is the composite load of (a) and (b), is calculated by the following formula.

$$\text{Assumed maximum tension of the lines} = \vec{T} + \vec{W}h = \sqrt{T^2 + Wh^2}$$

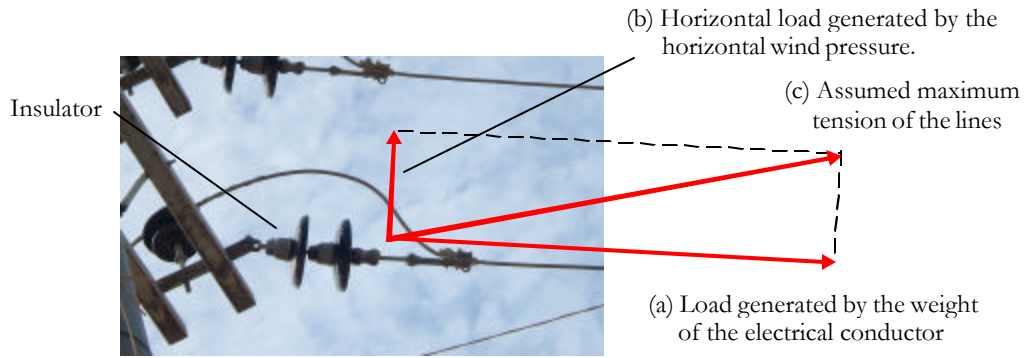


Figure ES42E: The Assumed Maximum Tension of the Lines (View from the Ground)

Article 43: Medium-voltage/Low-voltage (MV/LV) Transformers

- 1 In order to prevent third persons from electrical shock, live parts of MV/LV transformers shall be at a height of not less than 5.0m above the ground. In this case, live parts include bushings and insulators of the transformers.

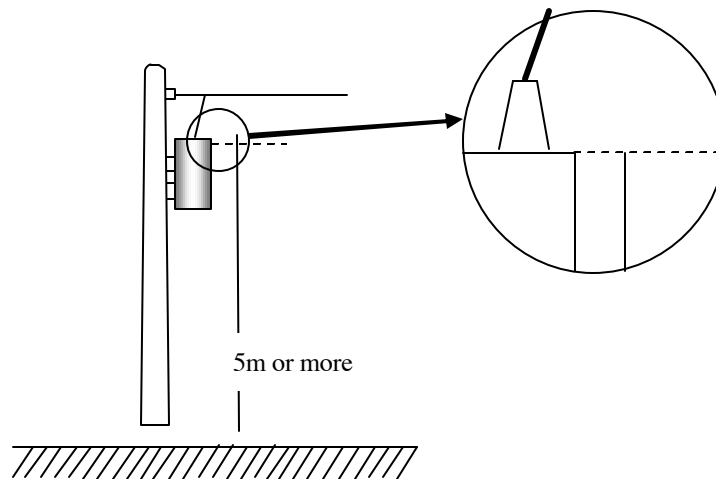


Figure ES43A: Installation of a MV/LV Transformer (Example)

- 2 Appropriate fences shall be installed around the MV/LV transformers in order that persons cannot touch them easily and warning signs to indicate the danger shall be displayed. Otherwise MV/LV transformers, the charged parts of which are not exposed shall be installed so that persons cannot touch them easily.

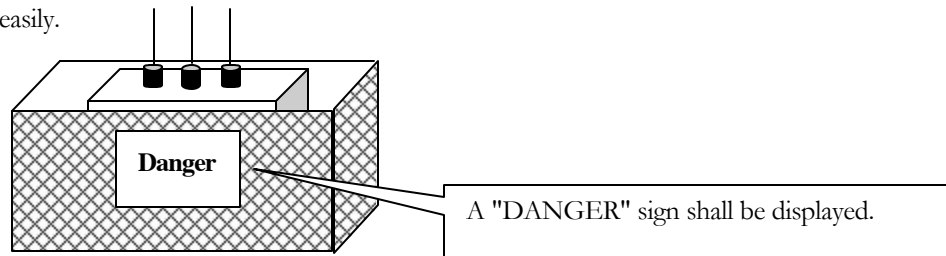
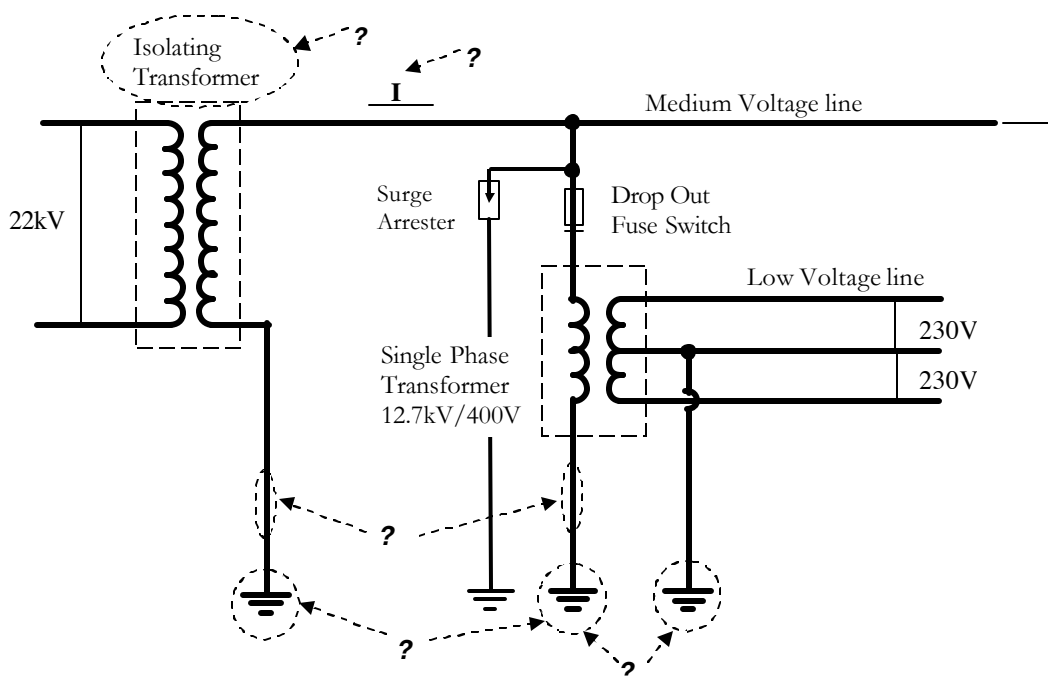


Figure ES43B: Example of a “Danger” Sign

Article 44: Installation of Distribution Transformers for Single Wire Earth Return (SWER)

Systems

SWER (Single Wire Earth Return) is an electricity distribution method using one conductor with the return path through the earth and is a method of supplying single-phase electric power to remote areas in which the electrical demand is very small at low installation cost. SWER lines have been successfully used to supply electricity to sparsely populated areas in New Zealand, Australia, Canada, India, Brazil, Africa and some of other Asian countries. Some requirements in this clause such as the grounding resistance, cross-sectional areas and maximum permissible load current are decided according to the standards of Australia and New Zealand have much experience of the SWER system.



- ? ? The grounding resistance shall be not more than 5 ohms.
- ? Warning signs to alert third persons' attention shall be installed near the grounding point.
- ? ? The cross-sectional areas of grounding conductors shall be not less than 16mm².
- ? The grounding conductors placed up to a depth of 75cm underground or up to a height of 2.0 m aboveground shall be covered by a synthetic resin pipe or another shield of equivalent or higher insulating effect and strength.
- ? ? The grounding of medium voltage lines and the grounding of low voltage lines are completely separated to keep the safety of low voltage line systems.
- ? ? The load current in any earth-return circuits shall be not more than 8 amperes.
- ? ? SWER circuits shall be supplied from double-wound transformers (isolating transformers).
[Direct connection to a generator or a connection to a high voltage lines by a single-wound transformer shall be absolutely prohibited.]

Figure ES44A: Configuration of SWER (Example)

<Grounding for SWER>

The distance between the grounding for SWER and the Class B grounding is desirable to be not less than 1m to keep the safety of the low-voltage circuit.

<Prohibition of Common Use of Grounding for SWER and Class B Grounding>

If an electrode is shared by both grounding for SWER and Class B grounding, medium voltage may break into the low-voltage circuit in the worst case. As a result, dielectric breakdown accidentally occurred on a low voltage load, because it usually does not have enough dielectric strength against medium voltage.

This phenomenon causes a failure of low-voltage electrical equipment and an electric shock on a person.

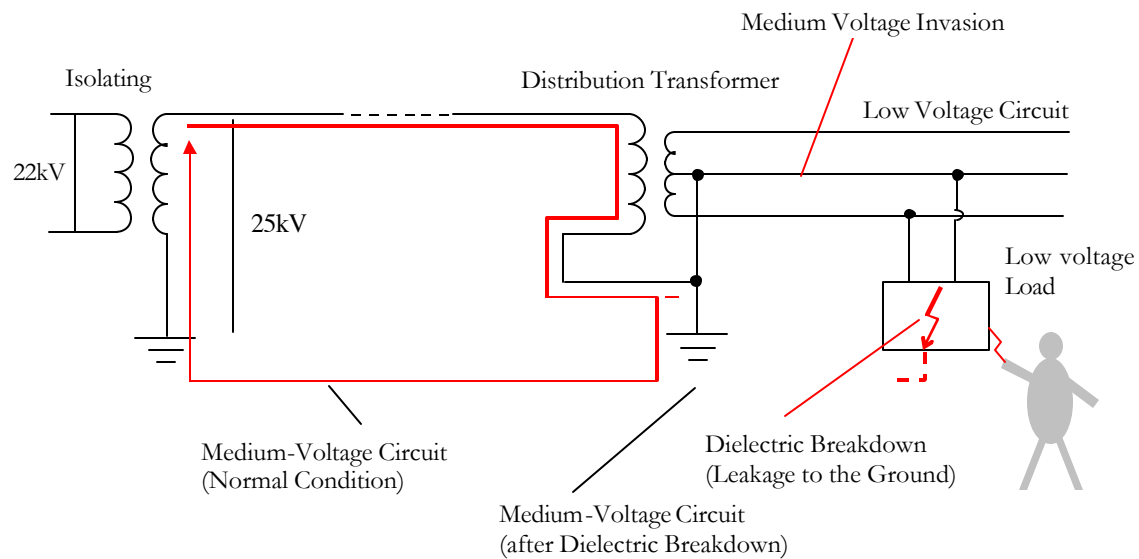


Figure ES44B: Prohibition of Common Use of Grounding for SWER and Class B grounding

1 Merits and Demerits

The SWER system has both merits and demerits as shown in Table ES44A.

Table ES44A: Merits and Demerits of SWER System

Merits	Demerits
? A low capital cost	? Potential step-and-touch problems for livestock and humans
? Simplicity of design	? Worse interference in a communication line than that by three-phase line system or single-phase two-wire system
? Reduced maintenance cost	? Load density limitations
? Reduced bushfire hazard, avoidance of conductor clashing	? Inability of provision of three-phase electric power
	? High voltage drops and low reliability
	? Frequent power outages by lightning (in case of the shield wire SWER system)

[Merits]

- ? ? A low capital cost, ? Simplicity of design

That is because it needs fewer conductors, fewer pole-top fittings, and fewer switching and protection devices.

- ? ? Reduced maintenance cost

That is because there is only one conductor and no cross-arm.

But the grounding resistance is restricted to such a low value for the purpose of the security that a periodical check for the grounding resistance shall be required.

- ? ? Reduced bushfire hazard

That is because conductor clashing does not occur even in high winds. But in Cambodia, wind velocity is not so high, and there may be few conductor clashing.

[Demerits]

? ? Potential step-and-touch problems for livestock and humans

In a SWER system, a step-and-touch potential occurs, because the current flowing through the earth causes the voltage between the different points of the ground.

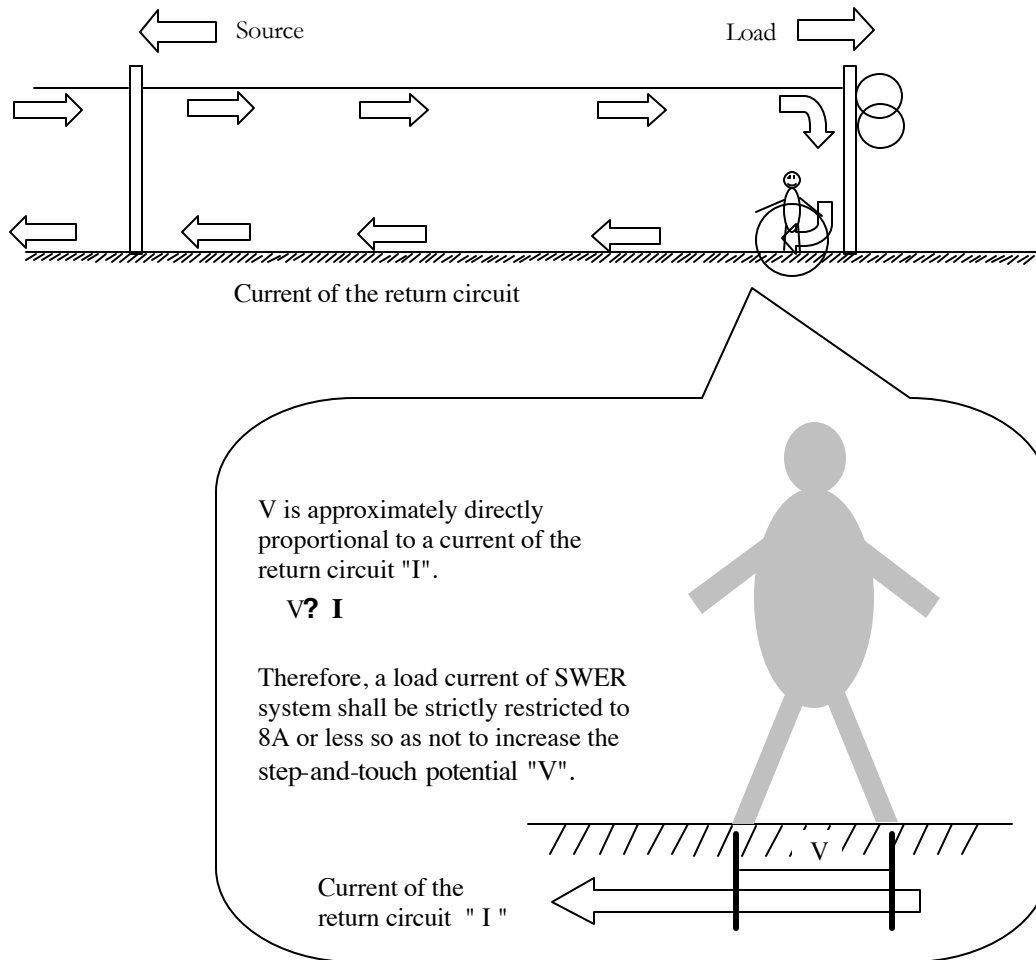
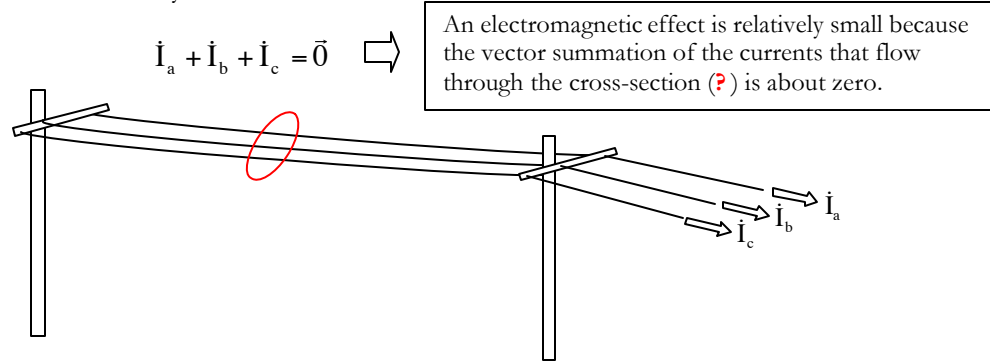


Figure ES44C: Explanation of Potential Step-and-touch Problems

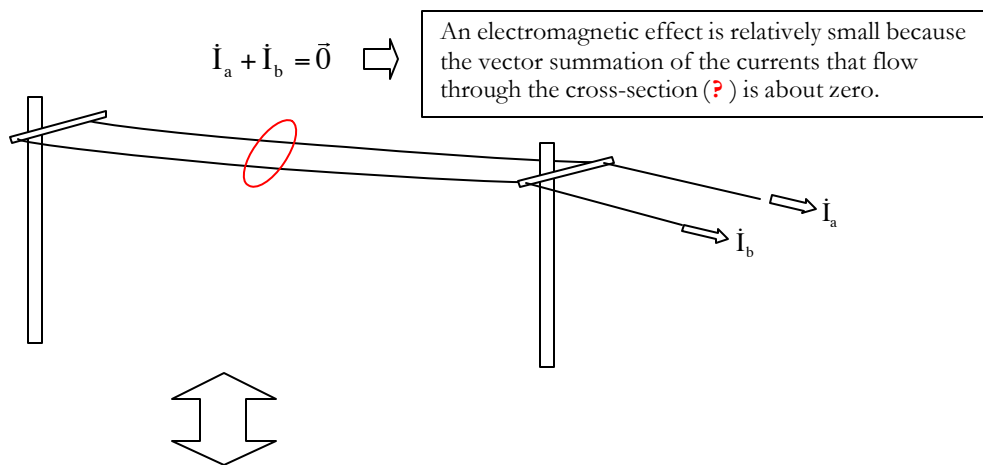
As for the step-voltage and touch-voltage, refer to Explanation Sheet Article 23 of SREPTS for All Electric Power Facilities.

? ? Worse interference in a communication line than that by three-phase line system or single-phase two-wire system

<Three-phase three-wire system>



<Single-phase two-wire system>



<SWER>

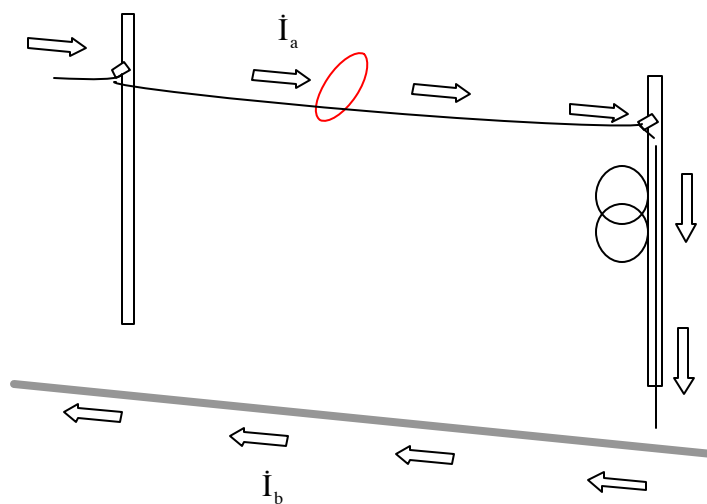


Figure ES44D: Comparison between SWER and Other Systems

An electromagnetic effect is relatively large because of the line current " I_a ". In case of a SWER system, the current " I_b " that flows under the ground cannot offset the electromagnetic effect of " I_a ". Therefore interference in a communication line by SWER is worse than that by three-phase line system or single-phase two-wire system.

? ? Load density limitations

If loads of a SWER increase in the future and the earth-return current becomes over 8 amperes, it is necessary to change the distribution line to two-wire system at much expense.

? ? Inability of provision of three-phase electric power

If three-phase electric power loads, such as rice mills, irrigation pumps, large air-conditioners, welders, etc., are required, it is necessary to change the distribution line to three-phase three-wire system at much expense.

? ? High voltage drops and low reliability

Since SWER systems are usually installed in remote areas, the line length must be long and voltage drops must increase. Also any fault in a part of the line will result in the downstream parts losing electricity supply.

? ? Frequent power outages by lightning (in case of the shield wire SWER system)

The shield wire SWER system is a different type of SWER which uses the shield wire (ground wire) on a transmission line at the single overhead feeder conductor. Because the conductor is installed on the top of the transmission line, lightning strikes it frequently. As a result, distribution transformers are broken and then power outage occurred so often.

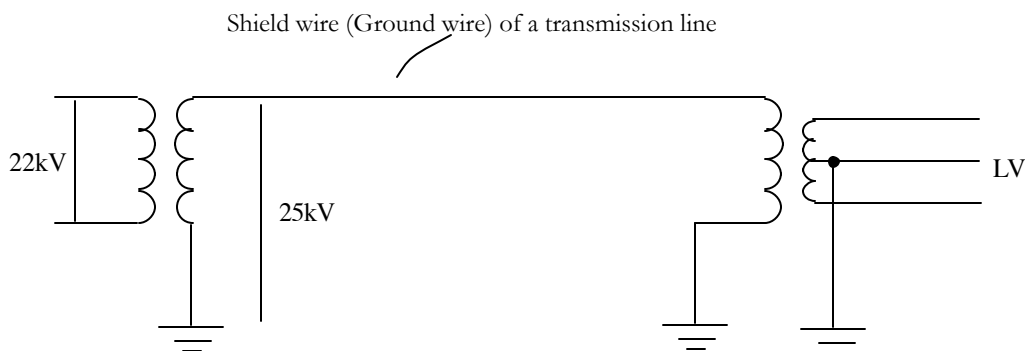


Figure ES44E: Example of a Shield Wire SWER System

The SWER system has many demerits to be solved and it is applicable to such areas that people live very far from other supply areas and the demand will not increase so much in the future.

Upon considering the installation, not only the installation cost but also the cost to solve the demerits, future development in the area and safety for livestock and humans should be studied very carefully.

Article 45: Protective Devices

Protection devices shall be installed for the following purposes:

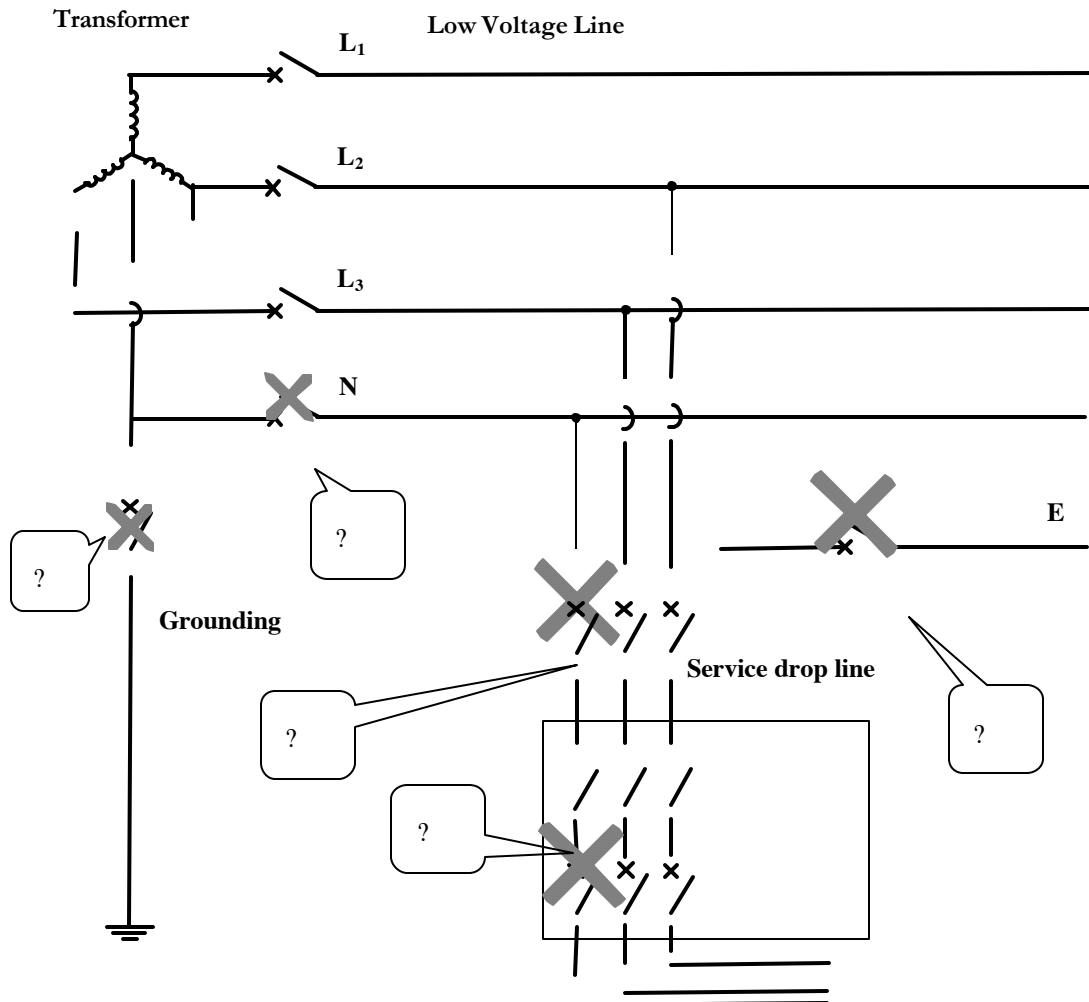
- ? In case an over-current fault or a ground fault occurs, protection devices detect the occurrence of the fault and break the faulty section in order to protect electric equipment such as conductors and transformers from damaging and to prevent a fire accident or an electric shock accident.
- ? Groundings prevent a danger, in case of an electric leak or an erroneous contact between MV and LV.
- ? Protection devices prevent the faults, such as an insulation destruction that results from a lightning surge.

Table ES45A: Type of Protection Devices

Objects		Type of protection devices
?	Medium-voltage line	- Over-current fault : Over-current Circuit Breaker - Ground fault : Ground Fault Breaker
	Distribution Transformer	- Over-current fault : Drop fuse (Cutout switch)
	Low-voltage line	- Over-current fault : Low-voltage fuse
	House wiring	- Over-current fault : Fuse
?	Grounding Works	- Erroneous contact between MV and LV. : Class B grounding - Outer case of device and equipment : Class B,C and D grounding
?	Lightning protection	- Countermeasure against flashovers : Surge Arrester, Grounding wire - Prevention of the destruction of materials : Differential Insulation

1 Exceptions to Installation of an Over-current Breaker

It is prohibited to install over-current breakers such as a fuse at the grounding conductor of grounding work or neutral conductor of an electrical line etc., because when earth fault occurs, the over-current breaker shut off the earth fault current.



- ? Grounding conductor of grounding work
- ? Neutral conductor of an electrical conductor. However, an over-current circuit breaker may be installed if all the poles are shut off simultaneously.
- ? Grounding conductor of a low-voltage overhead electrical conductor whose circuit is provided with class B grounding work in part.

Figure ES45A: Exceptions to Installation of an Over-current Breaker

Article 46: Height of Overhead Medium-voltage and Low-voltage Lines

1 Regulations for Medium and Low-voltage Overhead Distribution Conductors

When the height of the distribution conductor is examined, the following factors must be taken into consideration.

- Being safe for human being, animals and buildings
- Not being an obstruction of traffic

The height of the distribution conductor is decided in GREPTS based on the following conditions in Cambodia, and the standard is a little strict compared with those of other countries.

- A truck often passes a road with much load.
- The understanding about the danger of electricity is relatively poor, especially in rural areas.

The height of a medium and low-voltage overhead distribution conductor shall be no less than the values in the following table as the same as Clause 54 of GREPTS.

Table ES46A: The Minimum Height of a Medium and Low-voltage Overhead Distribution Conductor

(Unit: meter)

	Low-voltage	Medium-voltage		
		Urban area		Other area
		Cable	Others	
Crossing a road	6.5	8.0	8.0	6.5
Others	5.5	5.5	6.5	5.5

2 Urban Area to be Included

The concept of ‘Urban and Others’ is very important when the reasonable electrification. However it is very difficult to define ‘Urban’, because the area cannot be decided uniformly and the scale of each city or village has been changing.

Therefore, for the time being, the following areas are regarded as the urban area.

2.1 Area

- Phnom Penh city and other cities
- Provincial towns

2.2 Road

- The National Road
- The Provincial Roads leading to the border

3 Exclusions for Road Crossings

The height of the overhead distribution conductor for 'Crossing a road' is decided on the assumption that vehicles pass through the road. Therefore if vehicles cannot pass through the road, the minimum height for 'Crossing a road' shall not be applied supposing that a conductor is crossing the road and the height for 'Others' shall be applied.

4 Mitigation of Height for Low-voltage Conductor

The regulation was decided based on the general conditions. On the other hand, there is a room for mitigation only for the limited place with some conditions. In concrete, the exception will be considered in the following situations.

- 1) In such a place as a private land where a vehicle does not run, the danger of electrical shock by accident will not be so much, in case of low voltage. Therefore, the height of the low voltage conductor can be mitigated.
- 2) If vehicles cannot pass through the road, the height of 6.5m is not necessary.

The minimum height of the low-voltage conductor is mitigated up to 4.0 m on the place other than a road. Furthermore, the minimum height of the low -voltage conductor is mitigated up to 3.0 m on the following conditions:

- The licensee owing the distribution line is a small licensee in the area other than urban areas;
- The insulation of the conductor(s) must be always kept in good condition;
- Vehicles including carts never pass under the line.

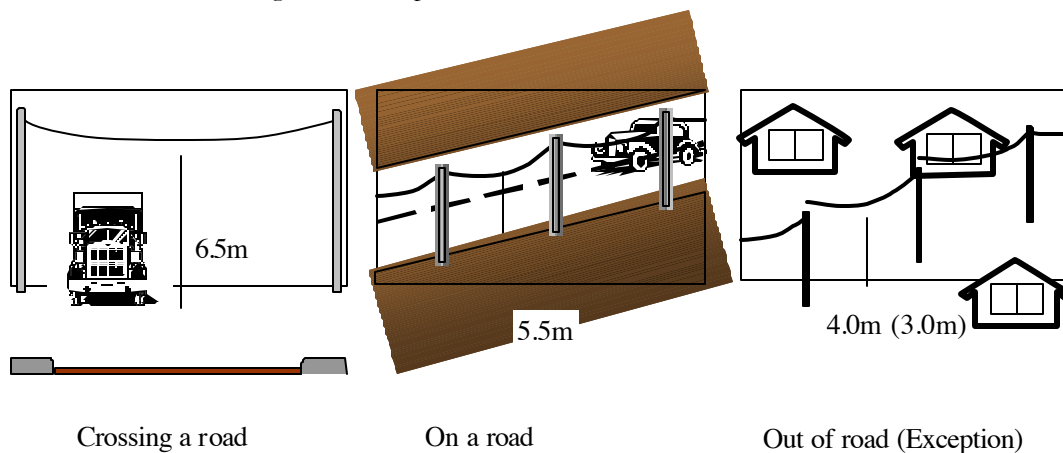


Figure ES46A: Height of Limitation of Low-voltage Lines

Table ES46B: Height of Limitation of Low-voltage Lines in Some Countries

Installed Place		Cambodia	Japan	USA (NESC***)	Bhutan	Ghana
Crossing a road		6.5	6.0	5.6	5.5	6.0
Others	On a road	5.5	5.5	4.4	4.5****	5.0
	Others	4.0* (3.0) *	4.0 (3.0) **			

* Exception of the Standards

** Exception for only above pedestrian bridges

*** National Electric Safety Code

**** The value is applied only for ABC (Aerial Bundled Cable)

Article 47: Clearance between Overhead Medium-voltage and Low-voltage Lines and Other Objects

1 Clearance between Overhead Distribution Lines and a Road

GREPTS regulates ‘the Height of Overhead Lines’ and ‘Clearance between Overhead Lines and Other Objects’.

In Cambodia, we can find some poles installed on the ground below a road. (Figure ES47A)

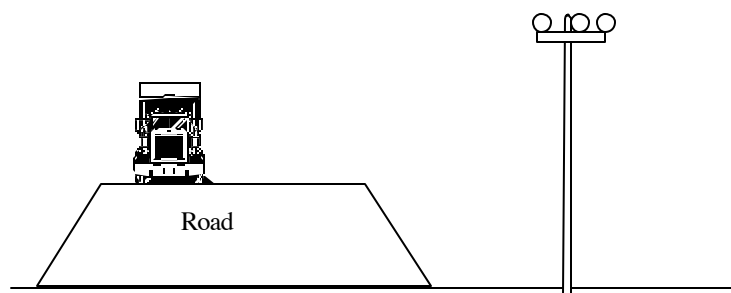


Figure ES47A

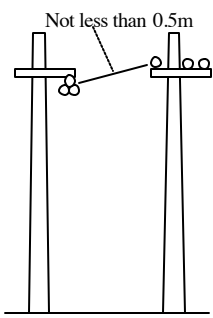
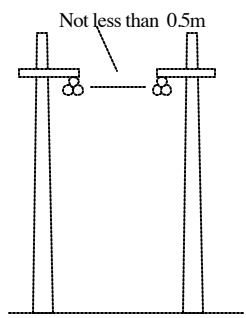
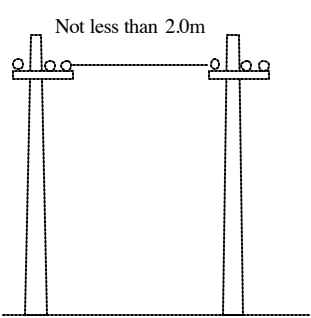
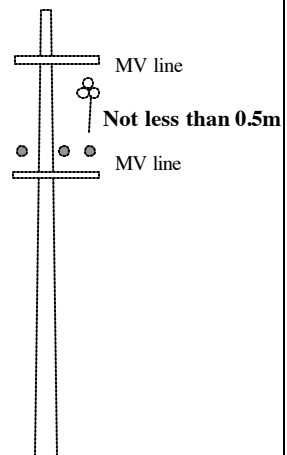
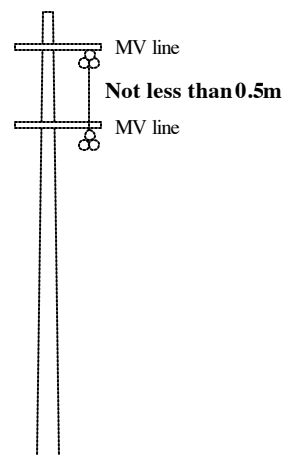
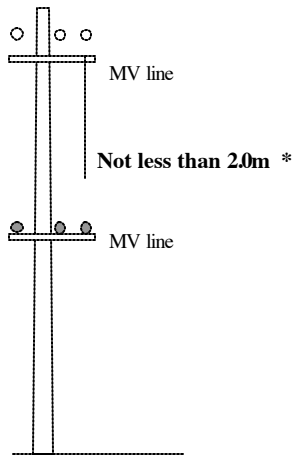
In this case, it is very difficult to decide the clearance between the overhead line and the road in accordance with GREPTS. Therefore we show the explanation for this case in the SREPTS.

Incidentally, as for the national road, the distribution pole must be installed more than 25m apart from the center of the national road, according to the ordinance issued by the Ministry of Public Works and Transport.

Article 48: Proximity and Crossing of Overhead Medium-voltage and Low-voltage Lines

1 Multiple Medium-voltage Lines

Table ES48A: The Clearance between Two Medium-voltage Lines

Type of Conductor	Cable and Insulated conductor	Cable and Cable	Others
Figure			
			 <p>* Clearance of not less than 1.5m can be adopted only for existing facilities untill the time of its renewal or replacement, if the clearance of 1.5m between MV lines does not affect safety to human beings, animals and trees. (See Clause 5 of General Requirements of Electric Power Technical Standards of Kingdom of Camdodia).</p>

2 Medium-voltage Lines and Low-voltage Lines

2.1 Installation of Medium -voltage Lines under Low -voltage Lines

In principle, the medium-voltage line shall not be installed under the low-voltage line.

If the medium-voltage line maintains the horizontal clearance of not less than 3.0m from the low-voltage line, and the low-voltage line does not come in contact with the medium-voltage line when the supporting structure of the low-voltage line collapses, this may not be applicable.

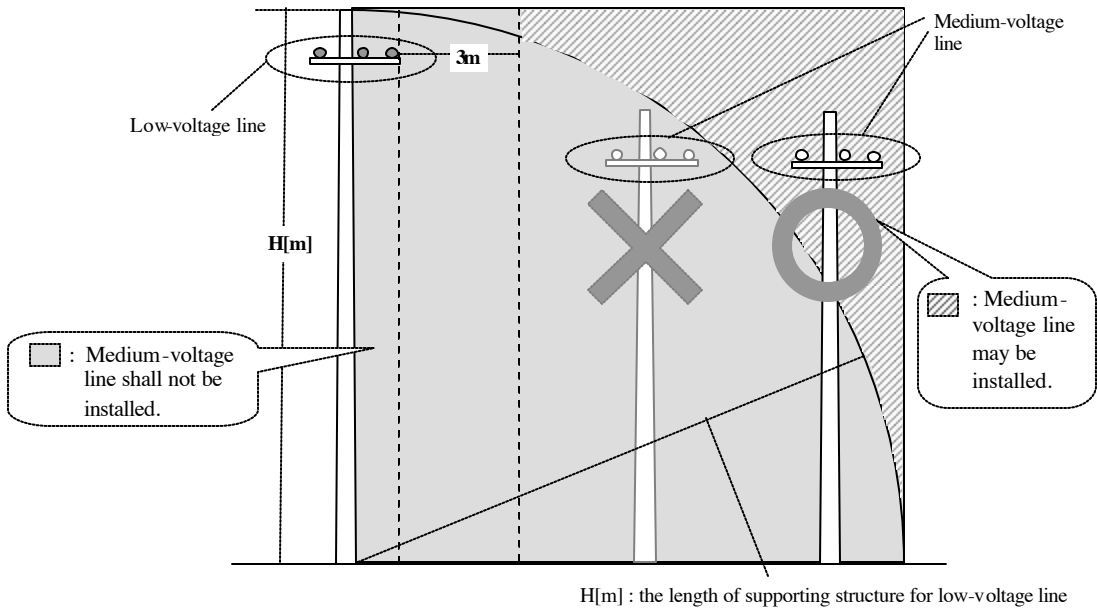
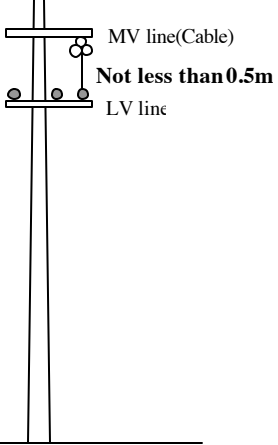
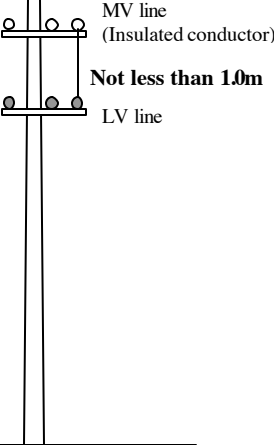
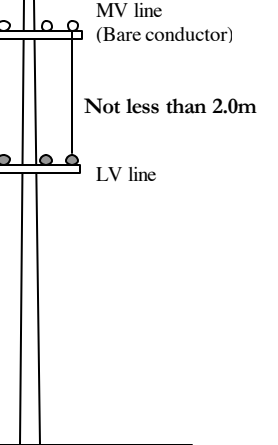


Figure ES48A: A Medium-voltage Line Installed under a Low-voltage Line

2.2 Clearance between the Medium -voltage Line and the Lower-voltage Line

Table ES48B: Clearance between the Medium-voltage Line and the Low-voltage Line

Type of Conductor	Cable	Insulated conductor	Bare conductor
Figure			

2.3 Crossing of the Medium-voltage Line under the Low-voltage Line

In principle, the medium-voltage line shall not be crossed under the low-voltage lines.

If the medium-voltage line is a cable and the clearance between the medium-voltage line and the low-voltage line is not less than 0.5m, this may not be applicable.

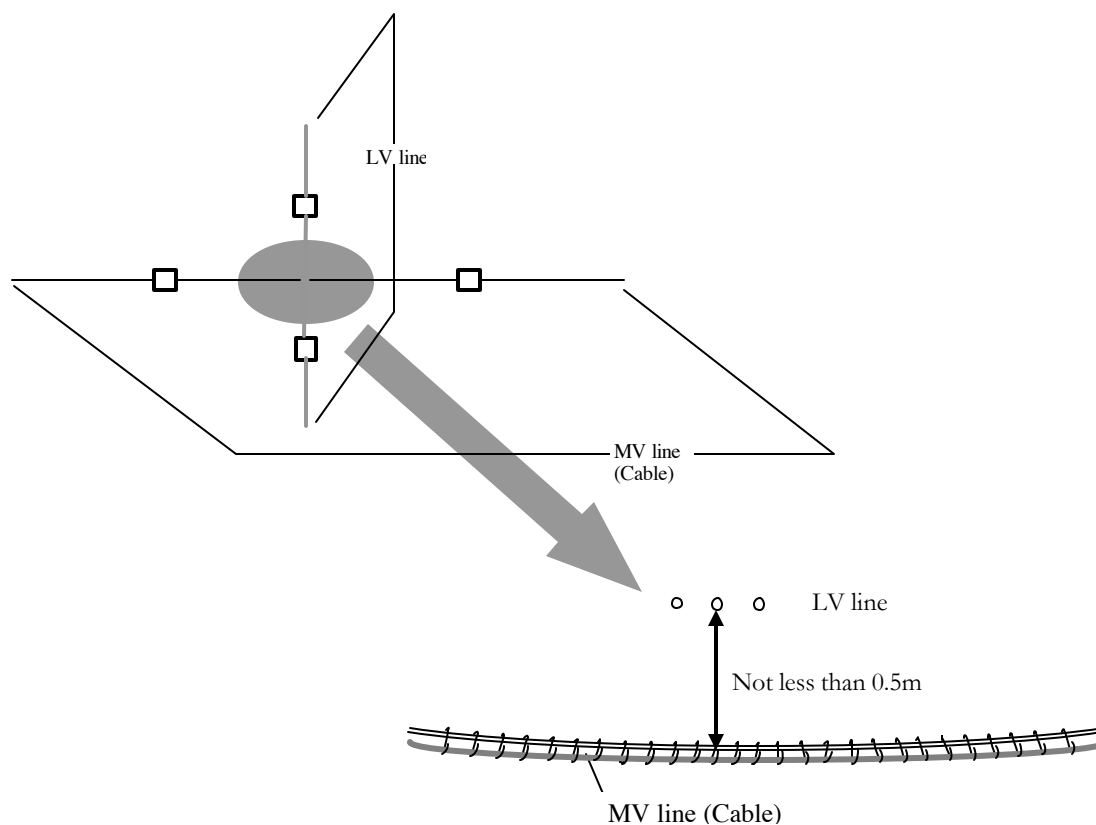
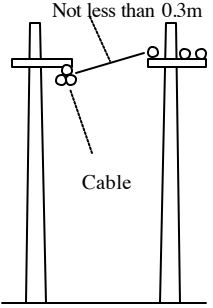
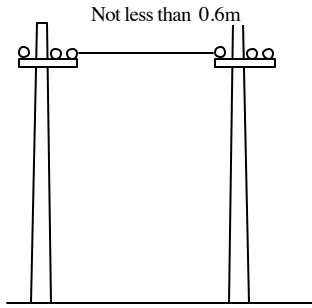


Figure ES48B: A Medium-voltage Line crossing under a Low-voltage Line

3 Multiple Low-voltage Lines

Table ES48C: Clearance between Two Low-voltage Lines

Type of Conductor	Cable	Others
Figure		

4 Medium-voltage Lines and Communication Lines

4.1 Installation of Medium -voltage Lines under Communication Lines

In principle, the medium-voltage line shall not be installed under the communication line.

If the medium-voltage line maintains the horizontal clearance of not less than 3.0m from the communication line, and the communication line does not come in contact with the medium-voltage line when the supporting structure of the communication line collapses, this may not be applicable.

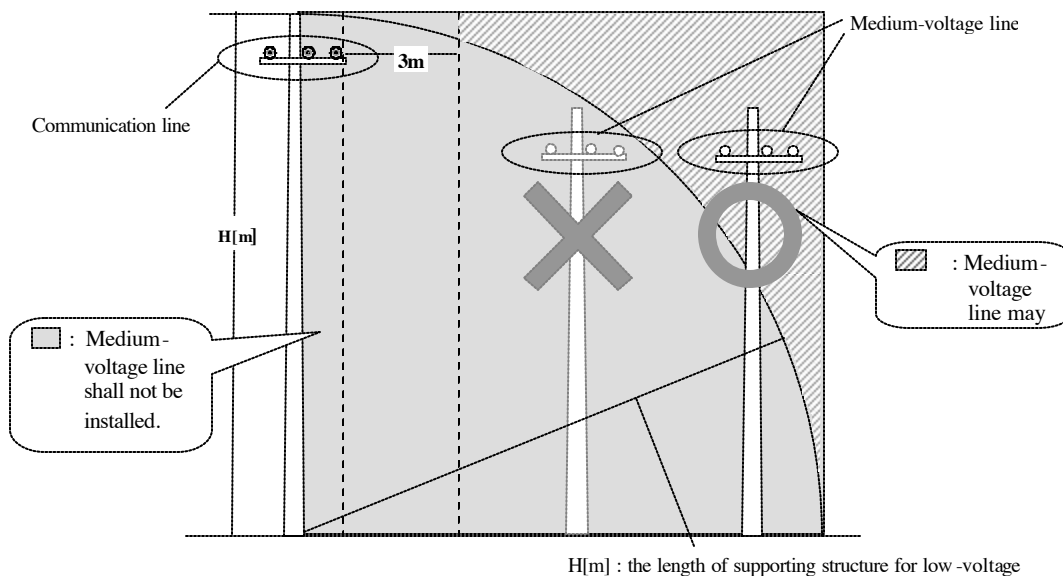
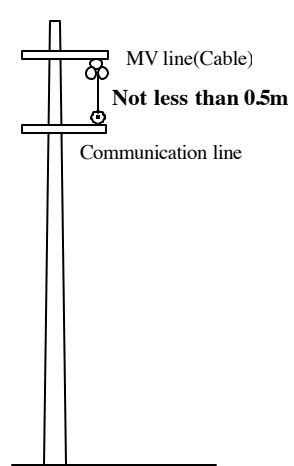
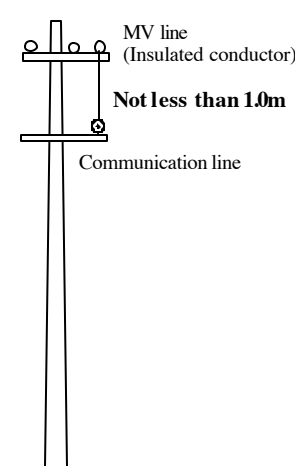
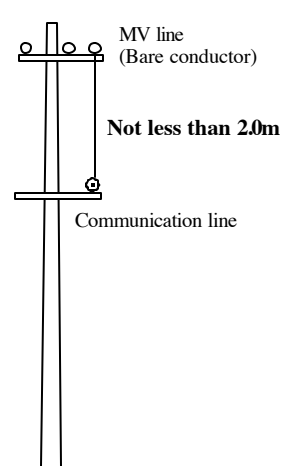


Figure ES48C: A Medium-voltage Line installed under a Communication Line

4.2 Clearance between the Medium-voltage Line and the Communication Line

Table ES48D: Clearance between the Medium-voltage Line and the Communication Line

Type of Conductor	Cable	Insulated conductor	Bare conductor
Figure	 <p>MV line(Cable) Not less than 0.5m Communication line</p>	 <p>MV line (Insulated conductor) Not less than 1.0m Communication line</p>	 <p>MV line (Bare conductor) Not less than 2.0m Communication line</p>

4.3 Crossing of the Medium-voltage Line under the Communication Line

In principle, the medium-voltage line shall not be crossed under the communication lines.

If the medium-voltage line is a cable and the clearance between the medium-voltage line and the communication line is not less than 0.5m, this may not be applicable.

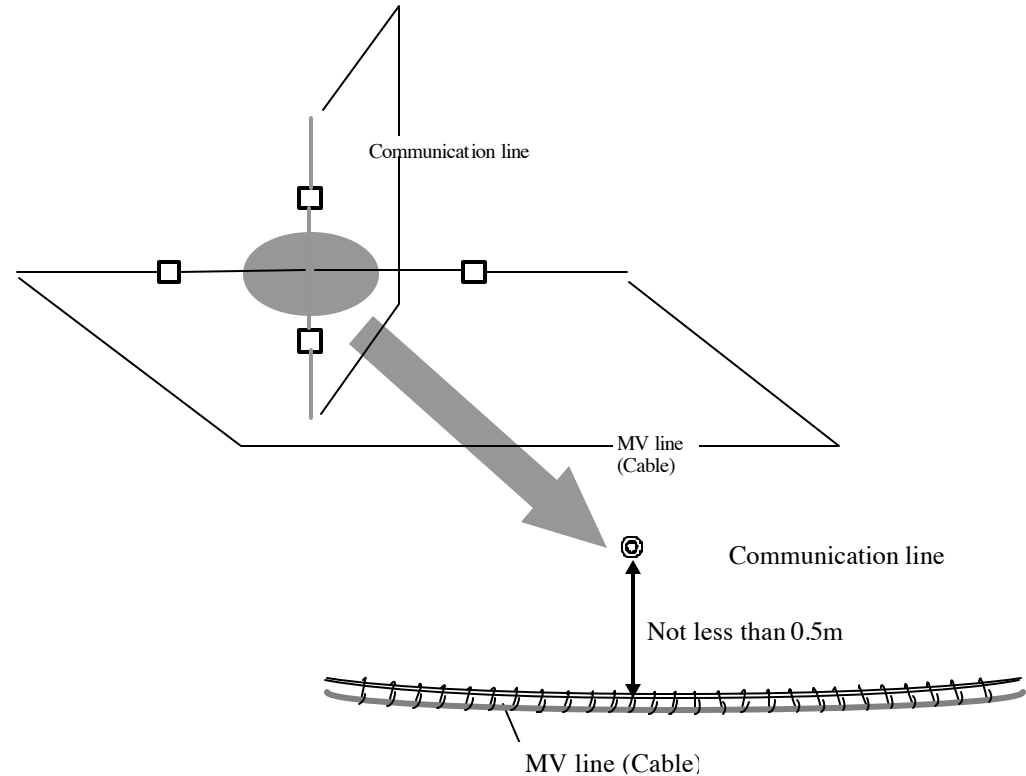


Figure ES48D: A Medium-voltage Line crossing under a Communication Line

**Explanation Sheet for
Thermal Power Generation Facilities**

Explanation Sheet of Electric Power Technical Standards for Thermal Power Generating Facilities

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- Article 14: Requirements related to the Design of Electrical Power facilities
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CHAPTER 3 Requirements for Steam Turbine Generating Facility

- Article 17: Steam Turbine Generating Facility

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CHAPTER 1

INTRODUCTION

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<IEC>

The International Electrotechnical Commission (IEC) is an international standards organization dealing with electrical, electronic and related technologies. Some of its standards are developed jointly with ISO.

The IEC charter embraces all electrotechnologies including energy production and distribution, electronics, magnetism and electromagnetics, electroacoustics, multimedia and telecommunication, as well as associated general disciplines such as terminology and symbols, electromagnetic compatibility, measurement and performance, dependability, design and development, safety and the environment.

Today, the IEC is the world's leading international organization in its field, and its standards are adopted as national standards by its members. The work is done by some 10 000 electrical and electronics experts from industry, government, academia, test labs and others with an interest in the subject.

<ISO>

The International Organization for Standardization (ISO) is an international standard-setting body composed of representatives from national standards bodies. Founded on February 23, 1947, the organization produces world-wide industrial and commercial standards, the so-called ISO standards.

While the ISO defines itself as a non-governmental organization (NGO), its ability to set standards which often become law through treaties or national standards makes it more powerful than most NGOs, and in practice it acts as a consortium with strong links to governments. Participants include several major corporations and at least one standards body from each member country.

ISO cooperates closely with the International Electrotechnical Commission (IEC), which is responsible for standardization of electrical equipment.



Figure ES4A: Authorized Logo of ISO

Article 5: Facilities regulated in this Specific Requirements

CHAPTER 2

Requirements for all types of Thermal Generating Facility

Article 6: Prevention of Electric Power Disasters from the Facility

< Installing Restrictions for Switches with Oil >

If an internal short-circuit accident occurs inside a switch, a disconnecter, or a circuit breaker installed on the supporting structure of an overhead electrical line due to a lightning attack and so on, there is a fear that erupting insulation oil causes a serious damage to third persons or buildings.

Therefore, switches, disconnectors, or circuit breakers with insulation oil shall not be installed on the supporting structure of an overhead electrical line.

As for a switching device installed on the supporting structure of an overhead electrical line, a vacuum switch, air switch or gas switch (SF₆) is mostly adopted.

Licensees have an obligation to supply electricity to their consumers stably. Moreover, careful and special consideration should be paid for safety of the employees as well as third persons. In this article, safety measures for prevention of accidents for their employees are required.

There are various hazards in electric power facilities such as generating facilities, substations, switching stations. For example;

- Turbines and engines have rotational and moving parts.
- Generators, transformers, switches, etc. have charged parts with dangerous voltage to human beings.
- Hydro power stations have some big civil structures which should be protected for their employees not to fall down.
- There may be some holes on the floor during maintenance and construction.

As mentioned above, licensees have to pay attention to safety for their employees. It is very important not only to install a fence, a cover and other protection facilities but also to provide safety training to their employees and establish working procedures for safety.

Article 7: Safety of Third Persons

It is provided in Clause 11 of GREPTS that a suitable measure is taken so that a third person may not come into a power station, a substation, and a switching station.

Also when people enter a power station, a substation, a switching station, etc. where live parts are exposed, an electric shock accident may occur and it may cause accident influencing an electric power system. Fences or walls, therefore, shall be installed so that people don't enter within the enclosure. This paragraph shows the height of the fence and the level clearance between the fence and the live part. These values are based on IEC 61936-1.

Moreover, signs warning that the high-voltage and medium-voltage facilities are dangerous to any person other than operators shall be provided and appropriate locking mechanism shall be taken so that no person other than operators can easily enter the closed electrical operating area.

However, in case people can't enter the station because it is surrounded by the cliff, a ditch, etc., there is no necessity for a fence or a wall.

Table ES7A: Boundary Clearance

Nominal voltage [kV]		Boundary clearance [mm]	Minimum line to ground insulating clearance N [mm]
160kV or less	22	Wall: N+1,000	1,100
	115		
Over 160kV	230	Fence: N+1,500	1,900

Source: IEC61936-1

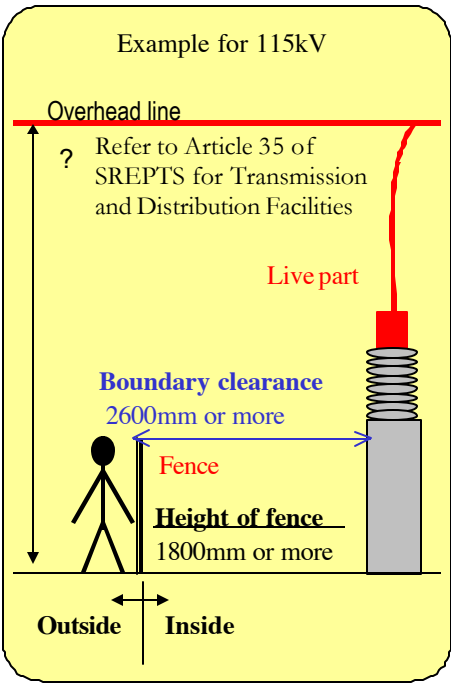


Figure ES7A: Boundary Clearance (Example for 115kV)

Article 8: Requirements related to the Fuel

1 Handling of Fuel and Chemical Materials at Power Stations

1.1 Basic Information of Fuel for Thermal Power Plants

Many kinds of hazardous materials are used in a thermal power plant.

Normally, a greater amount of hazardous materials or different kinds of hazardous materials increase the frequency of accidents. It is thus becoming more and more important to prevent accidents caused by hazardous materials.

1.1.1 Risks from Hazardous Materials

Each hazardous material has specific characteristics and properties associated with risk. Some easily catch fire near flames, some ignite in specific conditions, some explode, some cause inflammation of skin, some corrode other materials, and some cause infection when inhaled.

Personnel working in a thermal power plant shall be familiar with the specific risks related to hazardous materials. They shall also learn how to store and handle materials, bearing in mind the particular risks involved. Measures for preventing disasters shall be noted, first-aid measures shall be set down, and education and training shall be given to the persons concerned.

1.1.2 General Instructions

(1) General matters

- a. The appropriate legal and administrative formalities shall be completed before using hazardous materials.
- b. Persons managing or handling shall be qualified for the operations they perform and shall be educated and trained for these operations.
- c. Specific management standards, procedures and instructions shall be defined for hazardous materials.
- d. Maintenance and inspection work shall be carried out before and during using hazardous materials.

(2) Storage

- a. The storage facilities and the vessels shall be acceptable to store fuel.
- b. The materials in the storage facilities shall be identified by specific marks, which will allow everyone to recognize the contents, and **HAZARDOUS MATERIAL** signs.
- c. Measures shall be taken to prevent third persons from entering storage facilities or touching the containers or contents.

For example: locks and ropes with **HAZARDOUS MATERIAL** signs.

- d. Fire extinguishers adapted for use with hazardous materials shall be supplied.
- e. The storage area shall be designed and maintained, taking into account easy and safety work. For example: lighting equipment, working spaces, floors and so on

(3) Transportation

- a. Vehicles and devices for transporting hazardous materials that can be used safely shall be supplied.
- b. A person in charge shall observe transportation work.
- c. The place and time at which hazardous materials are carried in or out, and the quantity of the materials shall be communicated and checked properly.
- d. Suitable protective equipment and tools shall be prepared for each type of material before it is transported.
- e. The working environment shall be appropriate. For example: lighting equipment, working spaces and handling tools.
- f. Hazardous materials shall be marked with **HAZARDOUS MATERIAL** and **FLAMMABLE MATERIAL** signs.
- g. Fire extinguishers and alarm systems shall be available.
- h. The operators and workers shall be familiar with procedures before starting handling materials, and these procedures shall meet the appropriate standards and requirements.

1.1.3 Selection of Fire Extinguishers

The type of fire extinguisher shall be selected based on the effects on fires

- a. Eliminating inflammable materials (eliminating effect)
- b. Creating a drop in temperature (cooling effect)
- c. Separation from oxygen (choking effect)
- d. Cutting chains of reactions (repressing effect)

1.2 Heavy Oil

1.2.1 Physical Characteristics

Appearance	Color	Dark brown
Density	g/cm ³ (at 15 °C)	0.82-1.00
Quantity of heat	kJ/kg (kcal/kg)	41.86-46.05(10,000-11,000)
Ignition point	°C	250-410
Specific heat	kJ/kg K (kcal/kg °C)	1.88 (0.45)
Boiling point	°C	≥ 150

1.2.2 Chemical Properties

a. Combustibility

Heavy oil is composed of about 90% carbon and about 10% hydrogen. It is highly combustible in air.

b. Inflammability

Heavy oil is categorized as petrol oil with a flashing point of 60°C or more, which is higher than normal room temperature. Accordingly, it does not catch fire in normal conditions.

c. Ignitability

Heavy oil has an ignitability of 250 to 410°C. Even if there is no ignition source present in the air, it can ignite when the surrounding temperature reaches or exceeds this temperature range.

d. Explosiveness

Heavy oil is less explosive than light oil, since it has a higher boiling point and is less volatile.

1.2.3 Instructions on Storage (Heavy oil and Light oil)



(1) General precautions

- a. The appropriate signs shall be marked clearly on storage facilities for heavy oil and light oil (tanks and warehouses).
- b. Third persons shall never be allowed to have access to oil storage facilities without official permission.

(2) Storage tanks

- a. Vent pipes and other safety devices shall be installed on the storage tanks.
- b. The main feed valve of the storage tank shall be kept closed, except while heavy oil is being transferred.
- c. Suitable fire extinguishing equipment or fire extinguishers shall be supplied near storage tanks.
- d. Storage tanks, pipes, oil level gauges, thermometers and vent pipes shall be inspected frequently to prevent oil from leaking.
- e. Oil fences shall be installed around storage tanks. Drain holes shall normally be kept closed. Water shall be drained from the tanks occasionally.
- f. The amount (level) of heavy oil in storage tanks shall be monitored.

(3) Storage warehouses

- a. The appropriate fire extinguishing equipment shall be installed in and around storage warehouses.
- b. Fire shall never be used in or around the storage warehouses.
- c. The interior of storage warehouses shall be kept clean. Inflammable products and unnecessary objects shall never be kept in warehouses.

- d. Groundings, fire extinguishing equipment and alarm systems shall be inspected and serviced periodically.
- e. The amounts (levels) of heavy oil in storage warehouses shall be monitored.

1.3 Light Oil (Diesel Oil)

(1) Physical Characteristics

Appearance	Color	Transparent yellow liquid
Odor		Odor of petrol
Density	g/cm ³ (at 15 °C)	0.80-0.89
Quantity of heat	kJ/kg (kcal/kg)	46.05 (11,000)
Ignition point	°C	≈ 240
Boiling point	°C	145-390

(2) Chemical Properties

a. Combustibility

Light oil is mainly composed of carbon hydride and is highly combustible in air.

b. Inflammability

Light oil is categorized as petrol oil with a flashing point of 50°C or more. The risk of its catching fire is lower than gasoline and kerosene.

(Note) However, that light oil can catch fire when it is a fog or vapor state in the air, even at lower temperature than its flashing point.

c. Ignitability

Light oil has an ignitability of around 240°C. Even if there is no ignition source present in the air, it can ignite when it is heated to this temperature level or above.

d. Explosiveness

A mixture of light oil and vapor and air is an explosive gas if it is in a mixture of 1 to 7 % (volume). Light oil is less explosive than gasoline, since it has higher boiling point and is less volatile.

1.4 LNG

Natural gas is a combustible substance in a gaseous state composed mainly of methane produced from the ground.

Liquefied natural gas (LNG) is a clear colorless refined natural gas in a liquid state.

(1) Physical Characteristics

State	(0°C)	Gas
	(-162°C)	Liquid
Appearance	Color	Transparent/colorless
Odor	(LNG)	Odorless
	(Natural gas)	Oily odor

Notes: 1. Natural gas in a gaseous state is lighter than dry air at temperatures of over -113°C .

2. LNG increases in volume (by about 600 times) when vaporized.

(2) Chemical Properties

a. Combustibility

Natural gas burns well in air and produces large flames. Water and carbon dioxide are produced by the combustion.

b. Inflammability

Natural gas is a gaseous state at room temperature and has a very low flashing point. It catches fire immediately near flames or electric sparks.

c. Ignitability

Natural gas has an ignitability of roughly 500°C . Even if there is no ignition source present in the air or oxygen, it can ignite if the surrounding temperature reaches or exceeds this temperature.

d. Explosiveness

Natural gas has a low explosion limit, less than 5 %. It can explode even if there is a small amount of leaking gas.

(3) Instructions on Storage



- a. Storage facilities shall be installed at a sufficient distance from offices of personnel and workshops. Measures shall be taken to prevent third persons from having access to storage facilities without permission.
- b. “LNG” warning signs shall be displayed in visible places on the storage facilities.
- c. Fire shall never be used in or near storage facilities. Inflammable objects such as oil, gasoline, and cloths shall not be left in the area.
- d. Fire extinguishing equipment (fire hydrants, CO₂ fire extinguishers and dry-chemical fire extinguishers) shall be installed in and near storage facilities.
- e. Storage facilities shall be installed in well-ventilated places.
- f. Protective equipment, including helmets, leather gloves and air-fed masks, shall be made ready for immediate use in the storage facilities.
- g. Explosion-proof electrical facilities (including the lighting equipment) shall be used for the storage facilities. Facilities and equipment shall be grounded.
- h. Gas sensors and alarm devices for gas leaks shall be installed in places where gas can leak and stay present.
- i. All storage tanks shall be marked with “LNG” signs in red letters so that they can easily be recognized.
- j. The actual amount stored shall never exceed 90 % of the capacity of tanks.
- k. A safety valve, pressure regulator, manometer, thermometer, liquid level gauge and deluge system for cooling shall be installed on storage tanks.
- l. Emergency shutoff devices shall be installed at the inlet and outlet of storage tanks.
- m. Before the tank is cleaned or repaired, the LNG in the storage tank and pipes shall be replaced with nitrogen gas or water, and then with air, and it shall be ensured that the oxygen concentration in the tank is correct.

Article 9: Requirements related to the Handling of Chemical Materials

Article 10: Requirements related to the Natural Disasters

Article 11: Requirements related to the Operation of Generating Facility with Power System

Article 12: Requirements related to the Environment

1 Compliance with the Environmental Standards

A lot of special terms are used in environmental issues. To make the discussion for environmental protection easy, the important terms are picked out and provided as follows;

1.1 Atmosphere

[Down wash]

A phenomenon that flue gas diffusion is extremely disturbed by the wind whirled by a barometric pressure different at the back of a building or funnel.

NO_x (nitrogen oxides)

Generic term of nitrogen oxides generated in combustion processes. NO and NO₂ occupy most of the NO_x. In general, it is divided into “thermal NO_x” generated when nitrogen in the air is combined with oxygen during combustion and “fuel NO_x” generated when nitrogen oxides in fuel are oxidized.

SO_x (sulphur oxides)

Generic term of sulfur oxides, which are generated as fuel with much amount of sulfur is burnt.

Suspended particulate matter

Refers to the floating dust with a diameter of 10 μm or less.

Soot and dust

Solid grains contained in combustion gases, such as soot, ash, etc. generated in combustion processes.

Sulfuric-acid mist

Foggy sulfuric acid, which is one of the harmful air pollution substance. It is said that this mist is generated when sulfurous acid gas is mixed with water content in the air to form sulfurous acid, then oxidization by oxidant and change in sulfuric acid mist.

Acid rain

A phenomenon that sulfurous oxides (mainly SO₂) discharged by high sulfuric fuel combustion, etc, and oxidized gradually in the air into dilute sulfuric acid mist and it is solved in raindrops in a distant area.

Dust

Substance generated or scattered as a result of mechanical treatment, such as crushing and selection of material or heaping material.

1.2 Water Quality

pH (Potential of hydrogen)

A symbol used to indicate the concentration of hydrogen ion (hydrogen ion gram quantity existing in 1,000 ml). It is represented by a common logarithm of the inverse number of the hydrogen concentration in water.

$$pH = \log \frac{1}{(H)^+} = -\log(H^+)$$

Pure water pH is 7.

BOD (biochemical oxygen demand)

This BOD indicates the amount of oxygen consumed when organic substances in water are decomposed by breeding or breathing of aerobic bacteria. This value is desirable 5ppm or less in rivers.

COD (Chemical oxygen demand)

Indicated the amount of oxygen consumed by oxidized substances in water, which is analyzed by a chemical method. This value is desirable 5ppm or less.

DO (dissolved oxygen)

This DO in clean water is 7 to 14ppm. At least, 5ppm is needed for fishes.

Activated sludge

Flocked deposit generated by rapid breeding of aerobic micro organism in sewage and waste water it can decompose sludge significantly.

SS (suspended solids)

Substances floating in water. It is harmful, since it sticks on living organism in water and is precipitated on river beds. The SS value is desirable 10ppm or less.

1.3 Noise

Sound pressure level (dB)

20 times of the common logarithm of the ratio between sound pressure P and reference sound pressure P_0 . In other words, it means $20 \log_{10} (P/P_0)$. In this case, $P_0 = 0.0002\mu\text{b}$. In the case of parallel progressive waves, it can be assumed to be the same sound strength level for practical use.

Volume level of sound

The sound pressure level of 1,000Hz pure sound it judges that the volume that a listening person was the same as could hear it. For example, it is 60 phon when the volume that is the same as 1,000Hz pure sound of 60dB can hear it

Noise level (phon or dB value)

Value measured using a noise level meter.

Background noise

When a specific noise is measured at a place, if no sound is detected there, then the noise heard at that place is referred to as the background noise at that place.

Low frequency air vibration

How to call sounds below 20 Hz or special low sounds is not defined in Japan. They are referred to as low frequency sound, low frequency micro barometric pressure change, low frequency noise, etc.

1.4 Waste

Industrial waste

Combustion residue, sludge, waste oil, waste acid, waste alkalis, waste plastic, etc., generated from business activities.

Municipal waste

Waste other than industrial one.

PCB (polychlorinated biphenyl)

One of organic chlorine compound. Since it is excellent in heat resistance and insulation properties, it has been used widely for insulator of the electric equipment, as well as additives such as paint, ink, etc. However, it was found to be harmful to human bodies and its manufacture and use was prohibited.

1.5 Others

Environmental standard

Defined by the government for the atmospheric air, water quality, so noise, etc. in order to protect the human health and preservation of the living environment.

ppm (parts per million)

In the case of gas, this value indicates the ml quantity of the substance existing 1 m³. In case of solid or liquid, it indicates the mg quantity of the substance existing in 1 kg.

ppb (parts per billion)

Indicates the concentration of 1/1,000 of 1ppm.

pphm (parts per hundred million)

Indicates the concentration of 1/100 of 1ppm.

Global warming problem

It has been found through climate data analysis that the temperatures on the earth are getting steady higher and higher in these 100 years, although there are some exceptions in some years. If this phenomenon is continued on, then, it will affect many things including agriculture, sea level, etc. Increasing of the concentration of greenhouse gases such as CO₂, methane, freon, N₂ etc. in the air is pointed out as the main factor.

Depletion of ozone layer:(Greenhouse Gas)

When CFC (chlorofluorocarbon, a kind of the so-called freon) and Halon which are widely used for the refrigerant, the cleaning agent, the foaming agent, etc. are released into the environment, it reaches the stratosphere, and so it is exposed to the strong ultraviolet radiation there, chlorine is emitted, and an ozone layer is destroyed by these disrupters.

As a result, the amount of the irradiation of harmful ultraviolet rays, which reach on the ground, increases, and there is a possibility that the increase in skin cancer, a bad influence to the ecosystem, etc. might be caused.

<Sulfur hexafluoride Gas (SF₆ gas)>

SF₆ gas is used by the electric power industry as an insulation material and is contained in gas blast circuit breakers, gas insulated switchgears (GIS) and other electrical equipment, because SF₆ gas has a much higher dielectric strength than air or dry nitrogen and this property makes it possible to significantly reduce size of electrical gear and to develop its reliability in long-term operation.

At the same time, SF₆ gas is said to be the most potent greenhouse gas that it has evaluated, with a global warming potential of about 23,000 times that of CO₂ (carbon dioxide) over a 100 year period.

When electric equipment that contains SF₆ gas is removed and scrapped, the SF₆ gas shall be collected appropriately so as not to scatter into air for the purpose of reduction of greenhouse gas emissions.

Dioxin

Although it is originally the name of a specific molecule (2, 3, 7, 8-tetrachlorodibenzo-p-dioxin, TCDD for short), polychlorodibenzo-dioxin (PCDD for short), generally, the general term of varieties indicate. It was presumed that the all are poisonous and they had carcinogenic, TCDD slightly contained in 2, 4, 5-T of a herbicide especially had the strongest toxicity as tetratogen, and after the U.S Forces use it for defoliation operation by the Vietnam War, malformed children occurred frequently. Generating dioxin in large quantities by incineration of the organic chlorine compounds including vinyl chloride is pointed out, and the immediate measurement needed.

2 Prohibition of Installation of Electrical Machines or Equipment Containing Polychlorinated Biphenyls (PCBs)

PCB oils were initially proposed as dielectric fluids for use in electrical equipment such as transformers, capacitors, circuit-breakers, voltage regulators, etc. because of their excellent dielectric properties and also because of their very low flammability.

However, when PCBs do burn, for example if a transformer or capacitor is present in a factory or domestic fire, very toxic chemicals are formed. These have the deleterious effects on health. PCBs also are dangerous substances because of their great stability, and their oleophilic nature, meaning that they are easily absorbed

by the fatty tissues of humans and animals. PCB concentrations can then build up in the body, for example in the fat, the liver etc., and molecules are very difficult to eliminate.

Therefore newly installation of electric equipment with PCB should be prohibited.

2.1 Properties of Polychlorinated Biphenyls (PCBs)

PCBs are a family of organic chemicals consisting of two benzene rings linked by a carbon-carbon bond. Chlorine atoms displace any or all of the ten remaining available sites (Hydrogen atoms).

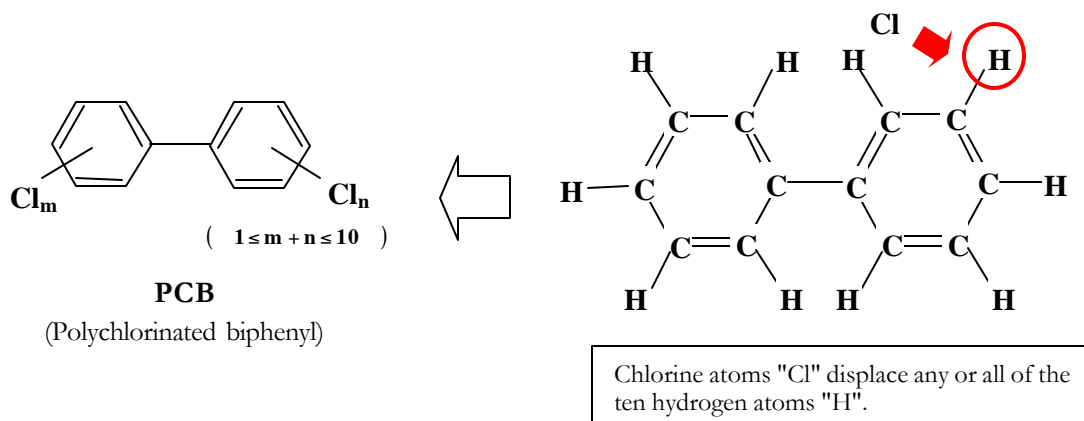


Figure ES12A: Structure of PCB

PCBs are among the most stable organic chemicals known. Their low dielectric constant and high boiling point make them ideal for use as dielectric fluids in electrical capacitors and transformers. In summary, PCBs have:

- Low dielectric constant;
- Low volatility;
- Good fire resistance;
- Low water solubility;
- High solubility in organic solvents; and
- Good ageing properties, with no deterioration in service.

However, the disadvantages of PCBs fluids are now seen as considerable, since they are:

- Non-biodegradable;
- Persistent in the environment;
- Able to accumulate in fatty tissues in the body; and
- Suspected of being carcinogenic

The effects of PCBs on humans can be serious:

- Leading to failure of kidneys and other human organs;

- Producing headaches, sickness, etc., if inhaled; and
- Causing chlor-acne if absorbed through the skin.

2.2 Reference

This paragraph is based on "The Stockholm Convention" which is a global treaty to protect human health and the environment from persistent organic pollutants (POPs). "The Stockholm Convention" is the first of a series of world environmental conferences in relation to United Nations Environment Programme (UNEP) Chemicals.

The Cambodian Government has not ratified "The Stockholm Convention" yet, but many other countries have already ratified it. Therefore "The Stockholm Convention" can be regarded as a world-widely unified view.

"The Stockholm Convention" suggests the elimination of the use of PCBs in equipment (e.g. transformers, capacitors or other receptacles containing liquid stocks) by 2025 and for its realization, there are some regulations with respect to the treatments of PCBs.

Article 13: Life of Electrical Power Facilities

Article 14: Requirements related to the Design of Electrical Power Facilities

1 Insulation Co-ordination

1.1 Concept of insulation co-ordination

The concept of insulation co-ordination for stations and HV and MV users' sites shall conform to IEC60071-1 and other relevant IEC standards. The insulation co-ordination means choices of dielectric strength level of electrical equipment in consideration of normal or abnormal voltage on the power system and the characteristic of protective devices on the power system.

When the insulation co-ordination is considered, the following should be cared.

- Arrange arresters appropriately
- Control surge voltage with improvement of power system composition, circuit-breakers, control devices, protective devices and so on
- Design the insulation rationally
- Carry out a rational examination for proving the design

1.2 Standard Withstand Voltage

Standard withstand voltage conforms to IEC60071-1. The IEC standard shows that the standard insulation level of equipment is determined by the following two kinds of standard withstand voltages.

For equipment in the range of above 1kV to 245kV:

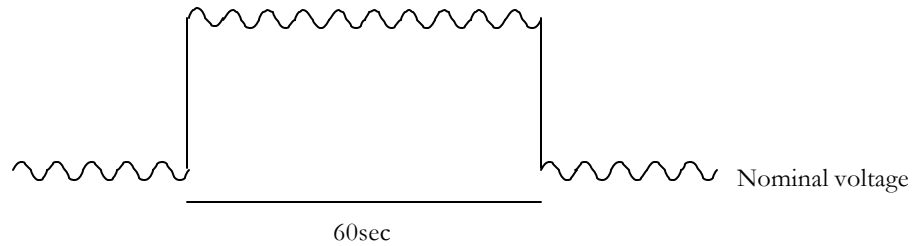
- a) The standard lightning impulse withstand voltage
- b) The standard short-duration power frequency withstand voltage

For equipment in the range of above 245kV

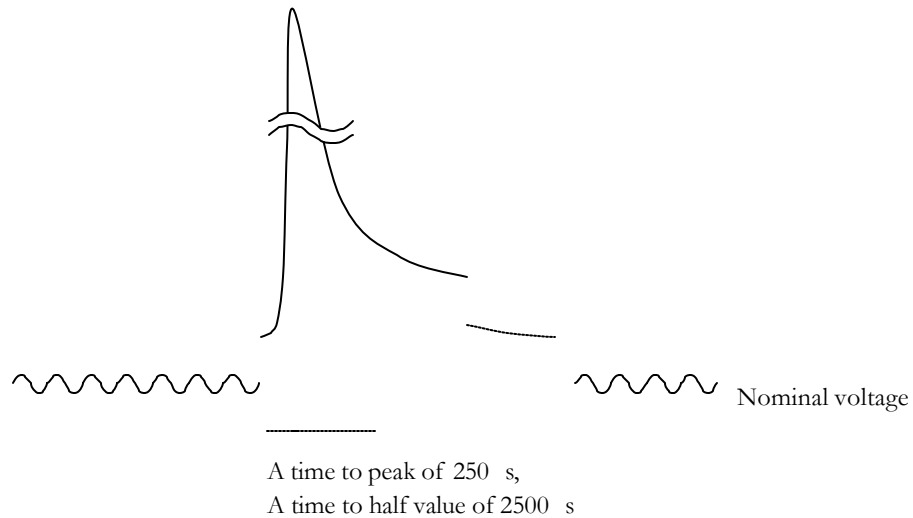
- a) The standard switching impulse withstand voltage
- b) The standard lightning impulse withstand voltage

(Standard voltage shapes)

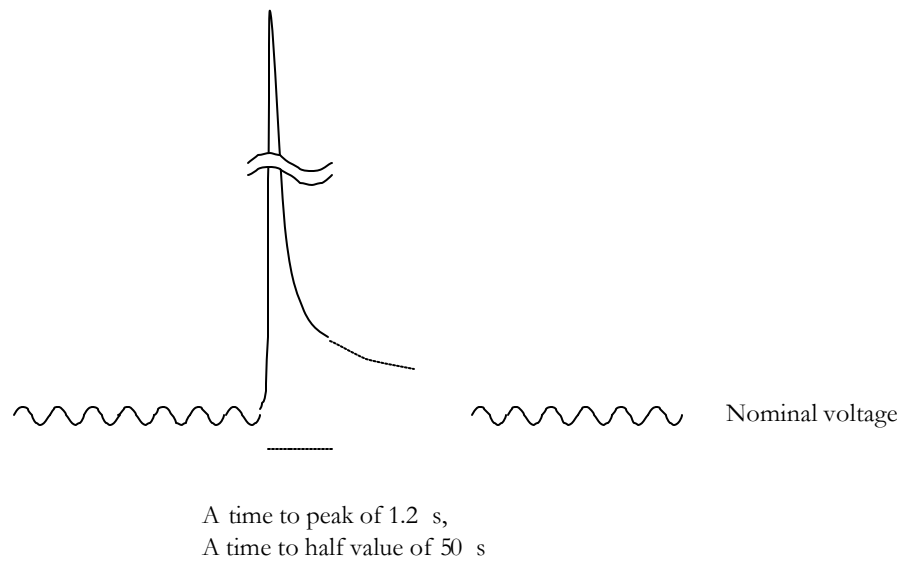
- The standard short-duration power-frequency voltage
a sinusoidal voltage with frequency between 48Hz and 62Hz, and duration of 60s
- The standard switching impulse
an impulse voltage having a time to peak of 250 μ s and a time to half-value of 2500 μ s
- The standard lightning impulse
an impulse voltage having a front time of 1.2 μ s and a time to half-value of 50 μ s.



a. The standard short-duration power frequency voltage



b. The standard switching impulse



c. The standard lightning impulse

Figure ES14A: Image of Standard Withstand Voltage

3 Insulation Co-ordination by Surge Arresters

Insulation co-ordination of stations is basically performed by suitable arrangement of metal oxide surge arresters.

However, in case a detailed examination of composition of equipment or arrangement of surge arresters is needed, it is desirable for the co-ordination to be analyzed with EMTP and so on.

(Note) EMTP: Electromagnetic Transient Program, which is a digital simulation program of transient phenomena for the power system. This program is widely used in the world.

2 Dielectric Strength of Electrical Circuits

(The need for insulation)

In case electrical circuits are not insulated sufficiently, it might cause an electric shock, a fire by leakage current and some trouble such as power loss increasing. Then all of electrical circuits must be sufficiently insulated according to the classification of voltage.

(Check of insulation)

As understood from the reasons mentioned above, the insulation needs to be judged before using it. As a judgment method, the insulation resistance measurement and the dielectric strength charge examination are generally adopted.

In order to judge the level of insulation, it is the most ideal to check the insulation with the dielectric strength charge examination. Its impressed voltage and time is a good index to confirm the level.

As for low voltage electrical circuits, however, the insulation resistance measurement is generally adopted because it is very easy to measure and it is available to judge the possibility of preventing a fire.

In case it is difficult to carry out the insulation resistance measurement with outage, leakage current measurement can be adopted for checking insulation of electrical circuits instead of the insulation resistance measurement.

(High and Medium voltage lines)

As for high and medium voltage lines, temporary over voltage occurred by a single phase grounding fault and switching surge shall be considered when the dielectric strength charge examination are examined.

However, in case it is assumed that the insulation performance, which was checked and confirmed according to IEC, JIS and other equivalent standards, is kept at the construction site, the dielectric strength may be checked by impressing nominal voltage continuously for 10 minutes.

(Electric Power Technical Standards of Japan)

The dielectric strength test of high voltage lines on Japanese Electric Power Technical Standards is as follows.

The insulation of high voltage lines shall withstand the test voltage given in Table ES15A which is impressed between the ground and the line continuously for 10 minutes. (In case the conductor of the line is cable, DC voltage is used for the test and the voltage 2.0 times of the test voltage shall be adopted.)

Table ES14A: Test Voltage of Dielectric Strength Test in Japan

The type of electrical circuit	Test voltage
Lines with the highest voltage over 7kV but not higher than 60kV	The voltage 1.25 times of the highest voltage (10.5kV when it is lower than 10.5kV) is impressed
Lines with the highest voltage over 60kV to be connected to the electrical circuit of the isolated neutral system	The voltage 1.25 times of the highest voltage is impressed
Lines with the highest voltage over 60kV to be connected to the electrical circuit of the solidly earthed neutral system	The voltage 1.1 times of the highest voltage (75kV when it is lower than 75kV) is impressed
Lines with the highest voltage over 170kV to be connected to the electrical circuit of the directly earthed neutral system	The voltage 0.72 times of the highest voltage is impressed

3 Thermal Strength of Electrical Equipment

It shall be confirmed that the temperature rise of the electrical equipment does not exceed the allowable maximum temperature of the electrical equipment or the maximum temperature under which there is no risk of damage to the electrical equipment, when the temperature rise test based on the following items and the standard concerning the electrical equipment is carried out.

3.1 Generators

The temperature rise of generators when operated with the rated load shall not exceed the allowable maximum temperature corresponding to its thermal strength class, and the thermal strength of generators shall be such that there is no risk of damage within the range of the allowable maximum temperature.

3.2 Bearings of hydraulic turbines and generators

The thermal strength of bearings of hydraulic turbines and generators shall be such that there is no risk of damage due to the maximum temperature to be generated in the bearing with the rated load.

3.3 Transformers

The temperature rise of transformers when operated with the rated load shall not exceed the allowable maximum temperature corresponding to its thermal strength class, and the thermal strength of transformers shall be such that there is no risk of damage within the range of the allowable maximum temperature.

3.4 Machines

This item shall apply to electrical circuits in switching devices, circuit breakers, reactors, power capacitors, instrument transformers, surge arresters, other machines, bus bars, and connection conductors for machines.

The temperature rise of machines when operated with the rated load shall not exceed the allowable maximum temperature corresponding to its thermal strength class, and the thermal strength of machines shall be such that there is no risk of damage within the range of the allowable maximum temperature.

4 Prevention of Damage to Pressure Tanks

- (1) The maximum operation pressure of pressure tanks has to be designed in consideration of the pressure rise by the operation pressure range and the maximum operation temperature.
- (2) “To withstand the gas pressure rising during fault continuous time at internal failure” means that there is not leakage of gas during failures and after failure removal in case the tank does not have devices for controlling the pressure rises.
- (3) Although standards such as sorts of material, allowable stress, and structure are not specified, the pressured part has to withstand the maximum operation pressure and it must be safe.

Article 15: Requirements related to the Technical Document of Electrical Power Facilities

Article 16: Requirements related to the Grounding

CHAPTER 3

Requirements for Steam Turbine Generating Facility

Part 1

Boiler

Article 17: Steam Turbine Generating Facility

Article 18: Requirements for Materials of Boiler and its Accessories

1 Materials for Boiler and its Accessories

Selection of material

When we design a boiler, the calculation of tube-wall temperature is the most important thing to choose superheater and reheater materials.

But the tube-wall temperature is not uniform, so that installation conditions should be thoroughly considered. As it is understood from the following figure, the maximum temperature in the tube is fairly high compared to the average temperature.

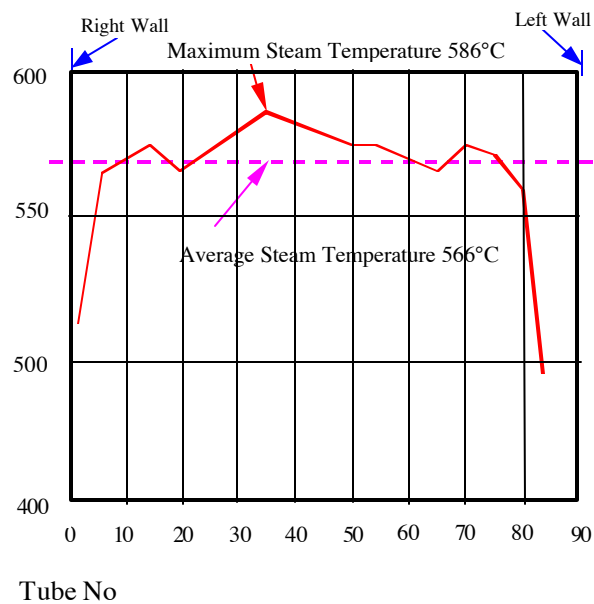


Figure ES18A: Distribution of Tube-wall Temperature of Steam Turbine

On the side of the boiler, the heat absorption rate depends on the location of the tube in both radiated heat case and circulated heat case. Those superheater and reheater cases in particular are affected by combustion gas speed passing through their tube. (The gas speed in the center of their tubes is higher than that in the wall side.)

Article 19: Requirements for Structure of Boiler and its Accessories

1 Structure of Boilers and its Accessories

A boiler system consists of burners, evaporation tubes, superheaters, reheaters, gas duct, air duct and auxiliary equipment.

1.1 Boiler Main Body

(1) Furnace

A furnace consists of evaporation tubes. Various types of furnaces are available. The boiler's main body has a structure that enables the heat absorption in the furnace.

The dimensions (depth and width) of a furnace are determined, taking into account the position of the burner. The essential point is that flames should not touch the water wall of the furnace. Water wall tubes (evaporation tubes) which comprise a furnace are made of steel and have a diameter of 60 to 75 mm in a natural circulation boiler, 40 mm in a controlled circulation boiler, and 20 to 50 mm in a once-through boiler.

These types of boilers are radiation boilers in which the furnace has a large radiation heating surface. The water in the evaporation tubes boils under the effect of the radiation of the combustion heat on the burner provided.

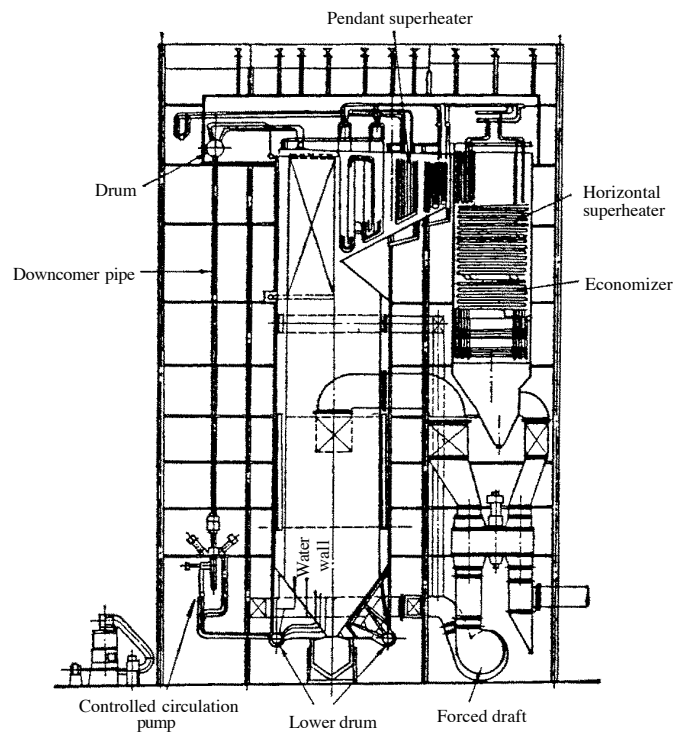


Figure ES19A: Controlled Circulation Boiler (Coal Burning Thermal Power Station)

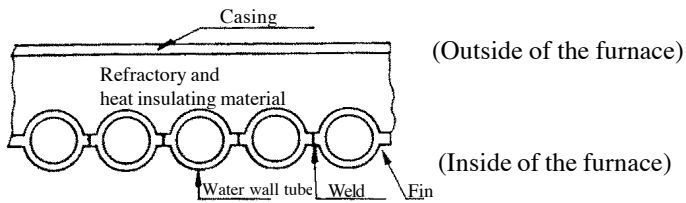


Figure ES19B: Section of Water Wall Tubes

The evaporation tubes have fins that increase the heat transmission area.

A supercritical pressure once-through boiler is characterized by the spiral windings of evaporation tubes provided on the furnace to homogenize the collection of heat in the evaporation tubes. This type of boiler has a greatly improved efficiency: it is free from the mixed condition of steam and water under supercritical pressures and can be operated with partial or full load.

(2) Superheaters

A superheater is a device which heats saturated steam generated in the evaporation tubes up to the temperature of the steam used in the turbine. Two installation positions are adopted for superheaters: a vertical superheater and a horizontal superheater. The pipes of the superheater are made of molybdenum (Mo) steel, chrome-molybdenum (Cr-Mo) steel or chrome-nickel (Cr-Ni) steel because they are exposed to high temperatures.

(3) Reheaters

A reheater is used to heat again the steam coming from the outlet of the turbine high-pressure part. A reheater has almost the same structure as a superheater. Reheaters are installed in the same locations as superheaters. A reheater contains an internal pressure of 3 to 5 MPa. For this reason, all pressure drops in a reheater may not exceed 10% of the internal pressure.

- The numbers in circles indicate the sequence of the water/steam flow.
- The numbers in squares indicate the sequence of the fuel/combustion gas flow.

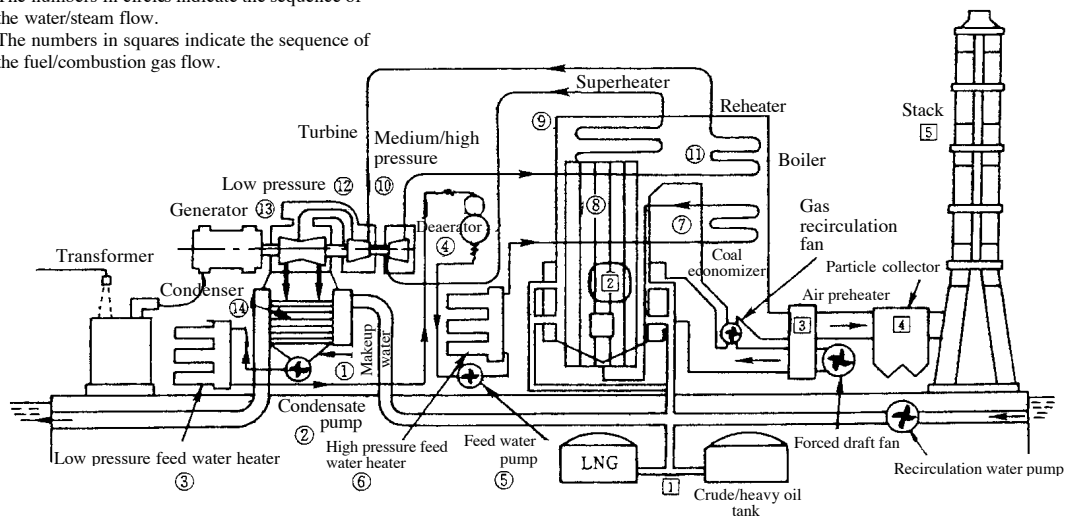


Figure ES19C: Example of a Thermal Power Plant

(4) Economizers

Economizers are tubes like other heaters and installed in the gas duct to heat the feed water with the heat of exhaust gas. Economizers enhance the thermal efficiency of the plant. To support directly the feed water pressure, economizers are based on steel pipes of 35 to 50 mm in diameter. Economizers play the role of hot water storage tanks, and are ready for responding to sudden changes of the load.

(5) Drum

The drum of a natural circulation boiler or a controlled circulation boiler has a structure shown in Figure ES2E. After passing through the economizer, the feed water is sent to the drum and then to the evaporation tubes. Water is separated from the saturated steam generated in the evaporation tubes. The steam is transferred to the dryer provided on the upper portion of the drum where a dry steam of liquid water content of less than 0.1% is produced and sent to the superheater.

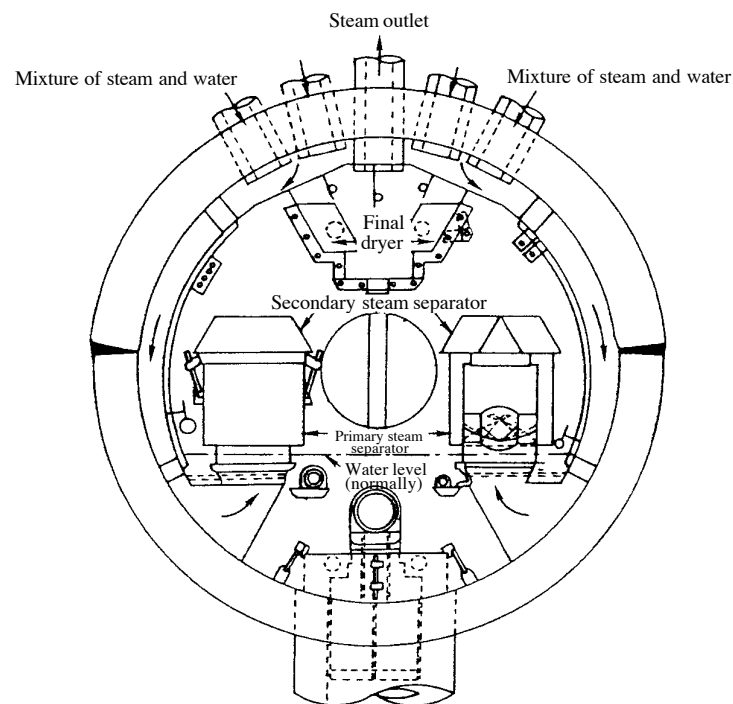


Figure ES19D: Internal Structure of the Steam Drum in a Controlled Circulation Boiler

2 Safety Margins against the Maximum Stress

2.1 Water Pressure Test

The resisting pressure test by air is executed by 1.25 times the maximum allowable working pressure because it is dangerous. However, in general, the water pressure test is executed by 1.5 times the maximum working pressure.

3 Prevention against Overheat

3.1 Protection against Overheat

The improvement of the water quality technology and the advancement of the technology of the boiler composition material contribute to high temperature boilers, high pressure boilers, and large capacity boilers.

The raw water is contained with impurities that cause corrodes and scale. (When the scale layer becomes thick, the heat transmission is obstructed and the boiler efficiency decreases. And also, it causes boiler overheating).

It is necessary to remove impurities from the raw water, and to adjust the water quality so that corrosion of the boiler materials is minimized.

3.2 Softeners and Demineralizers

A softener and a demineralizer are devices that remove impurities such as calcium and/or magnesium in raw water by using the ion exchange resin etc.

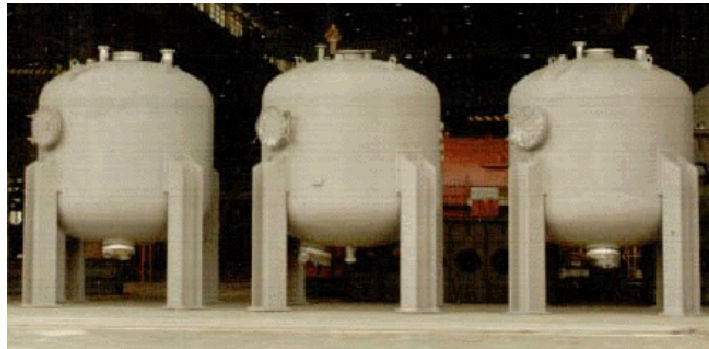


Figure ES19E: Demineralizer

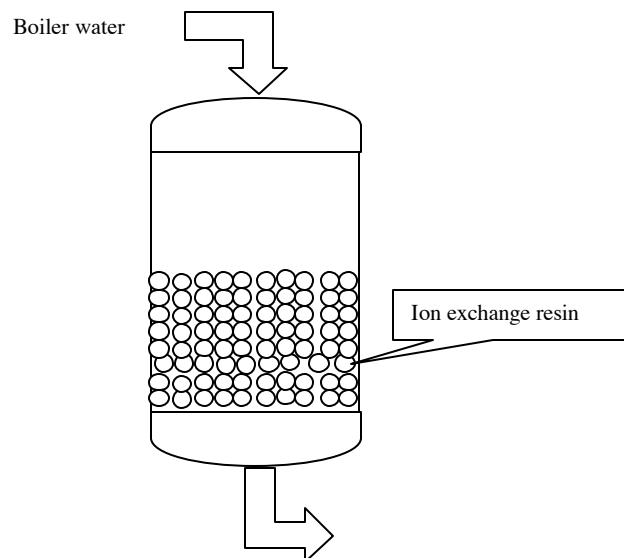


Figure ES19F: Mechanism of demineralizer

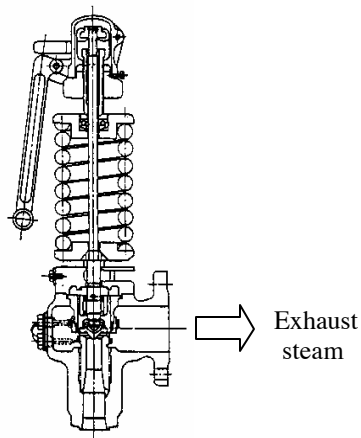
Article 20: Safety Valve for Vessels and Tubes of the Boiler

Several safety valves are provided on the boiler drums and superheater headers for preventing the steam pressure from exceeding the limit value.

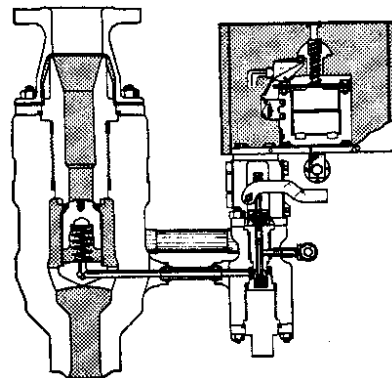


Figure ES20A: Safety Valve

- (1) In case of overpressure such as when the steam pressure power of a boiler goes up beyond regulation limits, it is prepared in a drum, super-heater and re-heater, in order to protect the pressure parts.
- (2) A Safety valve test shall be examined to confirm that it is set in the regulation pressure after inspection and repair of the safety valve.
- (3) There are some kinds of safety valves, Spring Type Valve, Power Control Type Valve (PCV).



Spring Type Valve



**Power Control Type Valve (PCV)
for large capacity Boiler**



The safety valves with a spring loaded pilot valve.

Figure ES20B: Type of Safety Valve

(4) Spring loaded pilot valve type: Mainly, it is used for the boiler and the superheater of the ship, and it is easy handling safety valve. Even if the situation is shaking or vibration condition, the safety valve is not leaking.

The size and weight of these safety valves are compact compared with a normal spring safety valve.

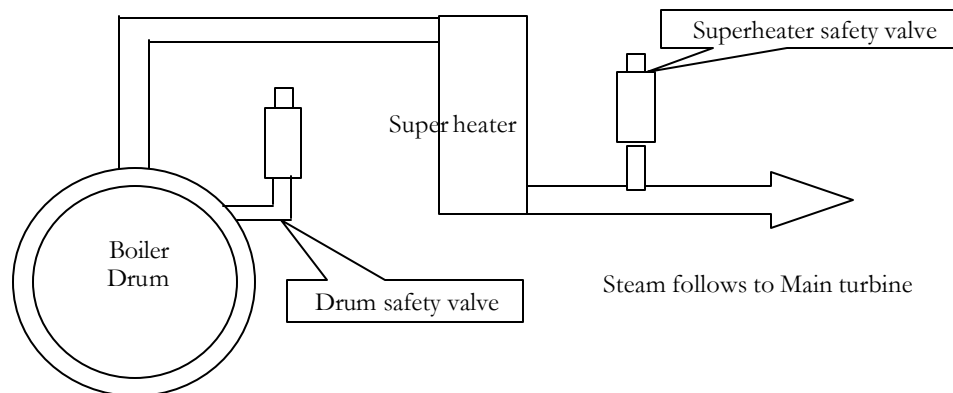


Figure ES20C: Safety Valve Positions for a Boiler Drum and a Superheater

Article 21: Feed Water System of Boiler

1 Feed Water System

1.1 Feed Water Pump

A main feed water pump accident may result in serious damage to the boiler. A thermal power station always has a reserve pump installed. In case of failure in the main pump, the line is automatically switched to the reserve pump for uninterrupted water feed.

1.2 Type of Pump

These pumps force the feed water into the boiler. A feed water pump is one of the most important elements of the facility. If it fails, this will have a great effect on operations in the entire plant. Even if the feed water pump stops for a short time, the water tube may fracture. Therefore, water feed pumps need to be highly reliable, easy to maintain, easy to control and reliable when starting up.

Thermal power stations usually use the barrel type multistage centrifugal feed pump. The feed water pumps are recently used for large-capacity, high-pressure and high-temperature boilers. These cases require to increase the number of blades and to lengthen the pumps. Some of these pumps are sized in smaller dimensions and are capable of working at higher speeds.

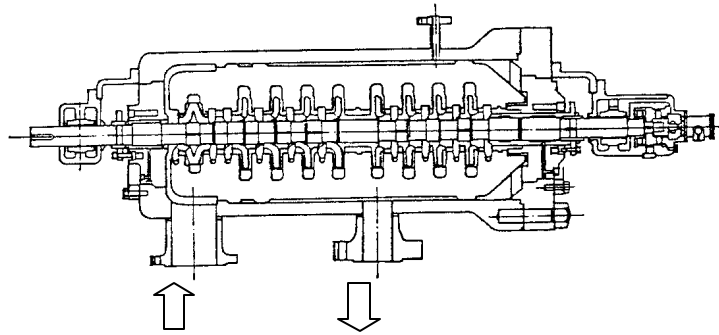


Figure ES21A: Barrel type multistage centrifugal feed pump

A power plant requires at least one service pump and a reserve pump with at least 25% of the capacity of the service pump. For practical reasons, two service pumps with a capacity of 50% and one reserve pump with a capacity of 50% are often installed.

2 Capacity of Boiler

Regarding “the maximum evaporation condition” of the boiler, the design capacity of the boiler depends on a manufacture’s policy and decision. It is necessary to consider the steam condition and the operating condition for the power plant design.

The relation between the generator output and the boiler capacity is as follows:

(Actual data in Japan)

Turbine out put(kW)	Generator (kVA)	Boiler capacity (t/h)
175,000	224,000	590
220,000	259,000	660
265,000	339,200	900
350,000	448,000	1,100
600,000	700,000	1,950
1000,000	1,154,700	3,110

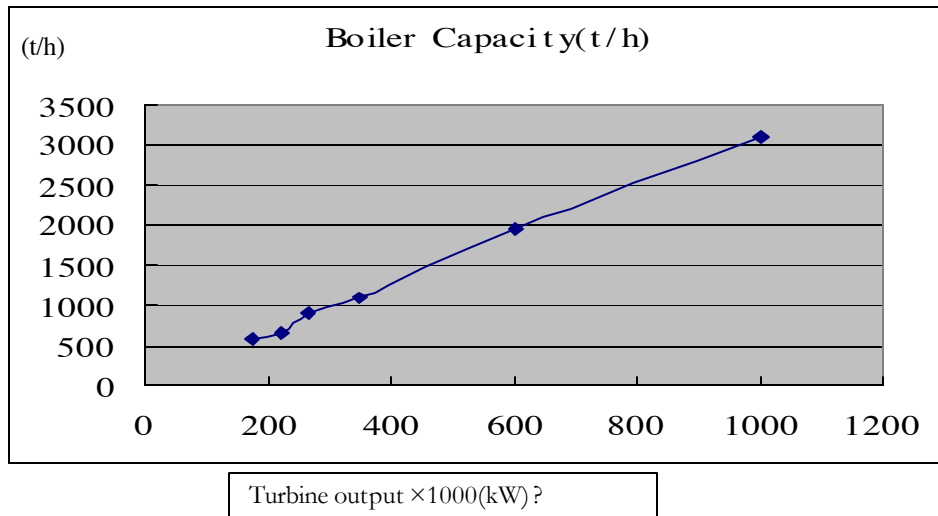
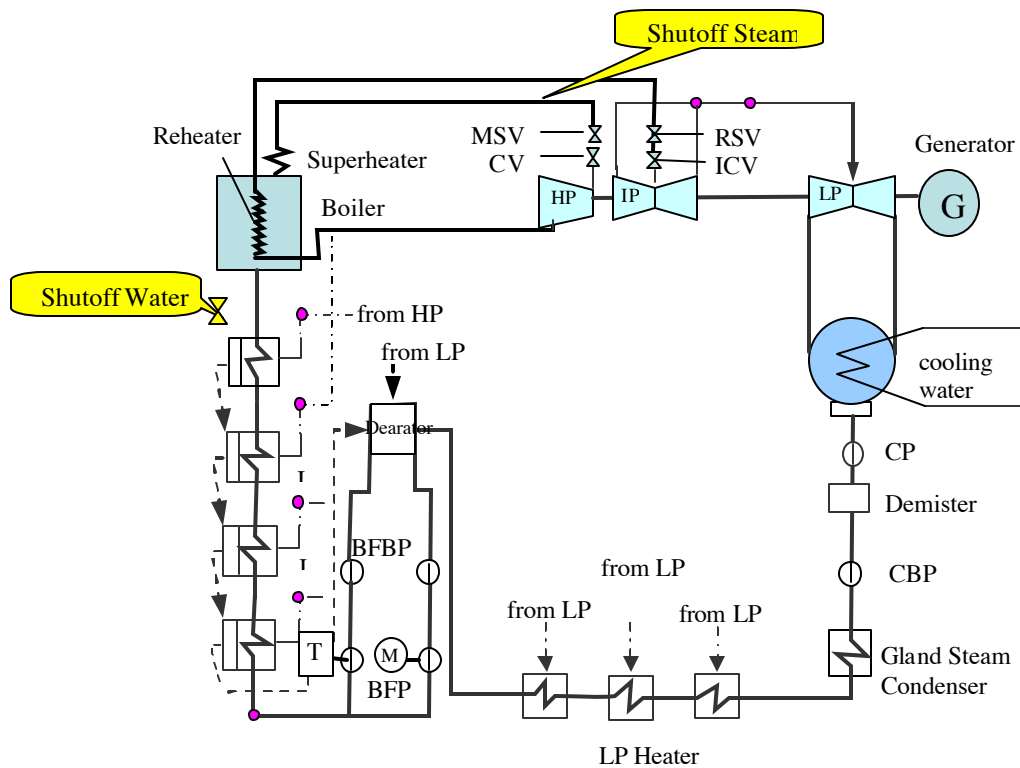


Figure ES21B: Boiler Capacity

Article 22: Water Feeding and Steam Outpouring of Boiler

1 Shutoff of Steam and Feed Water

The position of a shutoff steam valve and a shutoff feed-water valve is as follows:



CP: Circulation Pump, CBP: Circulation Booster Pump
 LP: Low Pressure Heater, HP: High Pressure Heater
 BFP: Boiler Feed water Pump, BFBP: Boiler Feed water Booster Pump

Figure ES22A: Steam and Water Cycle of Thermal Power Plant

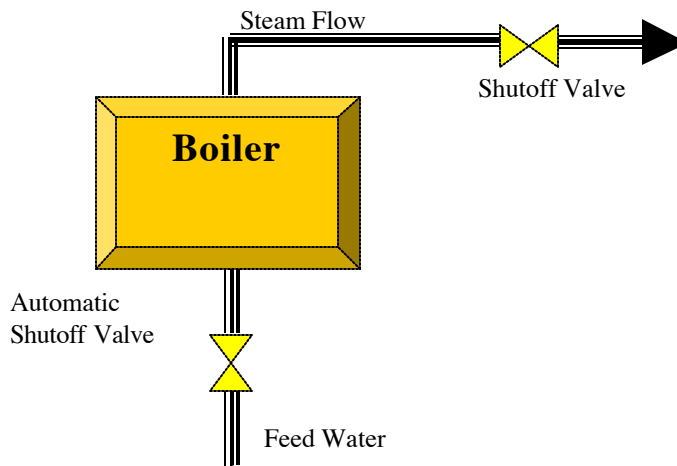


Figure ES22B: Explanation Model

2 Drain Off Device For Boiler

In case of a circulation boiler, part of the concentrated boiler water is drained from its water system to be replaced by feed water. This reduces the over-all concentration in the boiler caused by both dissolved and suspended solids.

The boiler may be blown down intermittently or continuously. Whenever the concentration builds up above the tolerance limit, the boiler is blown down manually to bring down the concentration by incoming low-concentration fresh feed water.

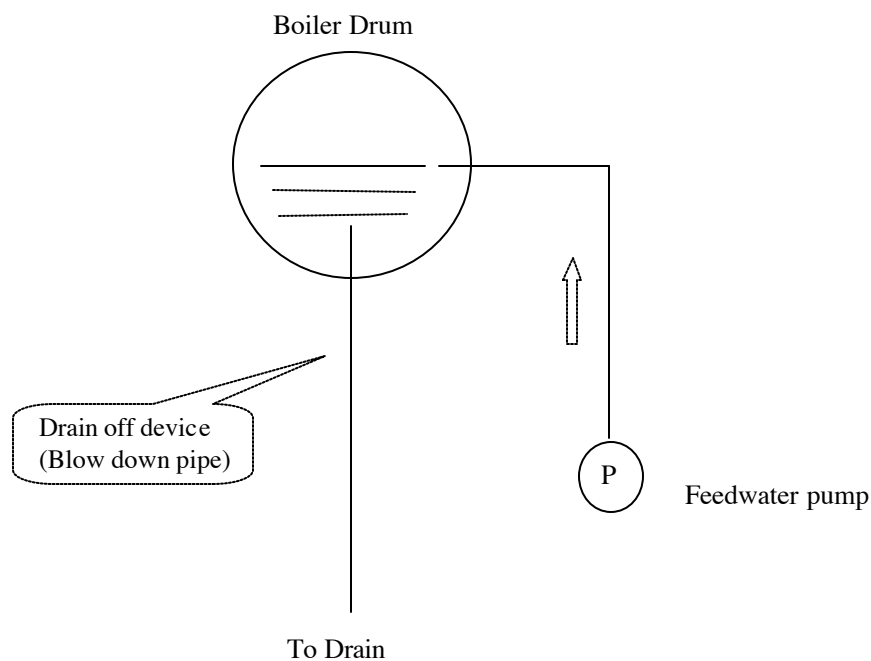


Figure ES22C: Drain Off Device

Article 23: Monitoring the Running Condition of Boiler and Safety and Alarm System

1 Monitor and Alarm System

Boiler Drum Level

To prevent boiler trouble, monitor and alarm systems shall be equipped as follows;

The circulation boiler is to be provided with at least two independent water level indicators, one of which is to be a glass water gauge and the other is to include either one of the following requirements:

- (1) Glass water gauge located at a position where the water level is readily sighted
- (2) Remote water level indicator

Structure of water level indicators is to include the following requirements.

- (1) The stop valves (or cocks) for the water gauge and the connection pipes to the boiler drum shall be of the shape free from scale and other sediment from the boiler water.
- (2) The water gauge(s) attached shall be strongly supported so that it may maintain its correct position.

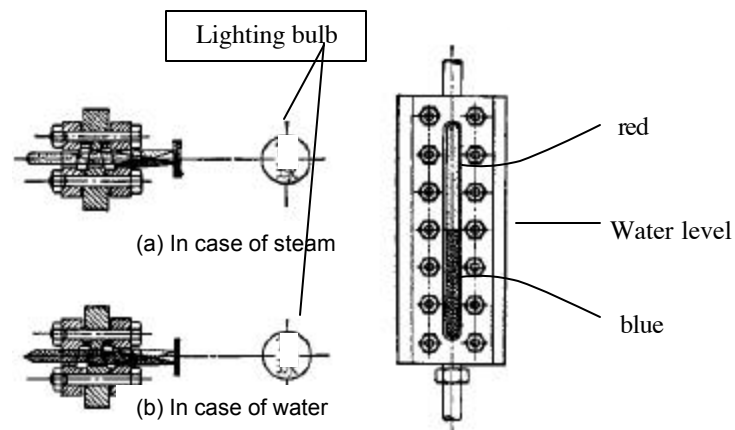
Pressure and Temperature Measuring devices

- (1) The boiler shall be equipped with one set of pressure measuring device at the superheater outlet respectively, and pressure indicators are to be arranged in the monitoring station.
- (2) The pressure indicator shall be such that it has a scale of 1.5 times or over the set pressure of the safety valve. The approved working pressure for the drum or the super heater is to be specially marked on the scale of the pressure gauges respectively.
- (3) At the steam outlet of the superheater or reheater, temperature measuring devices shall be provided.

Type of Boiler Drum Water Level Gauge

- (1) Two color water level gauge

The water level is measured by utilizing light beam refraction between water and steam.



[Mechanism]

The water level is measured by using the difference of the refraction of the light between steam and water. In this gauge, the steam appears in red and the water appears in blue.

Figure ES23A: Two Color Water Level Gauge

(2) Multi-port water level gauge

The water level is measured by some pieces of circular hard glass.

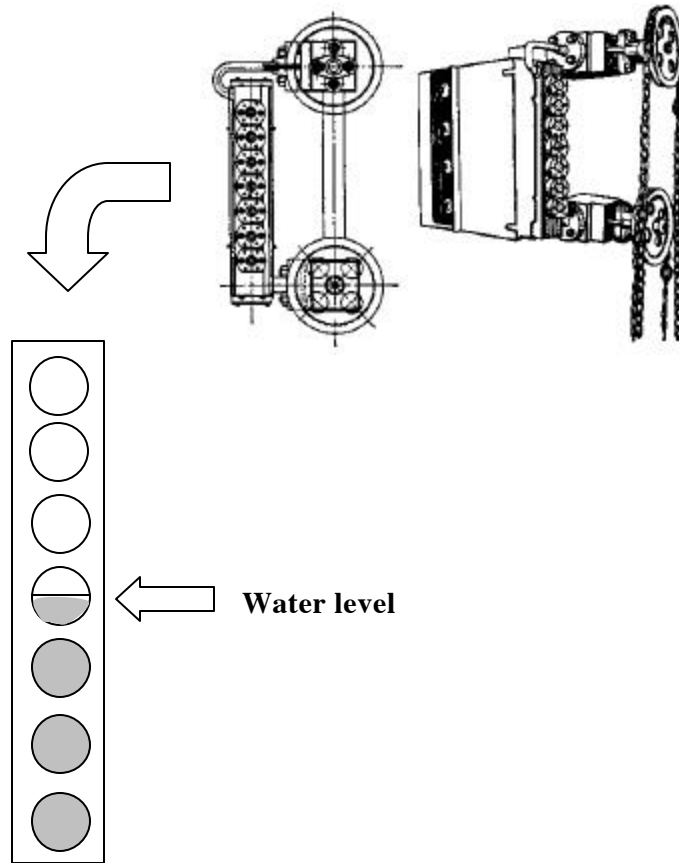


Figure ES23B: Multi-port Water Level Gauge

Monitoring items for boilers

(1) Installation places

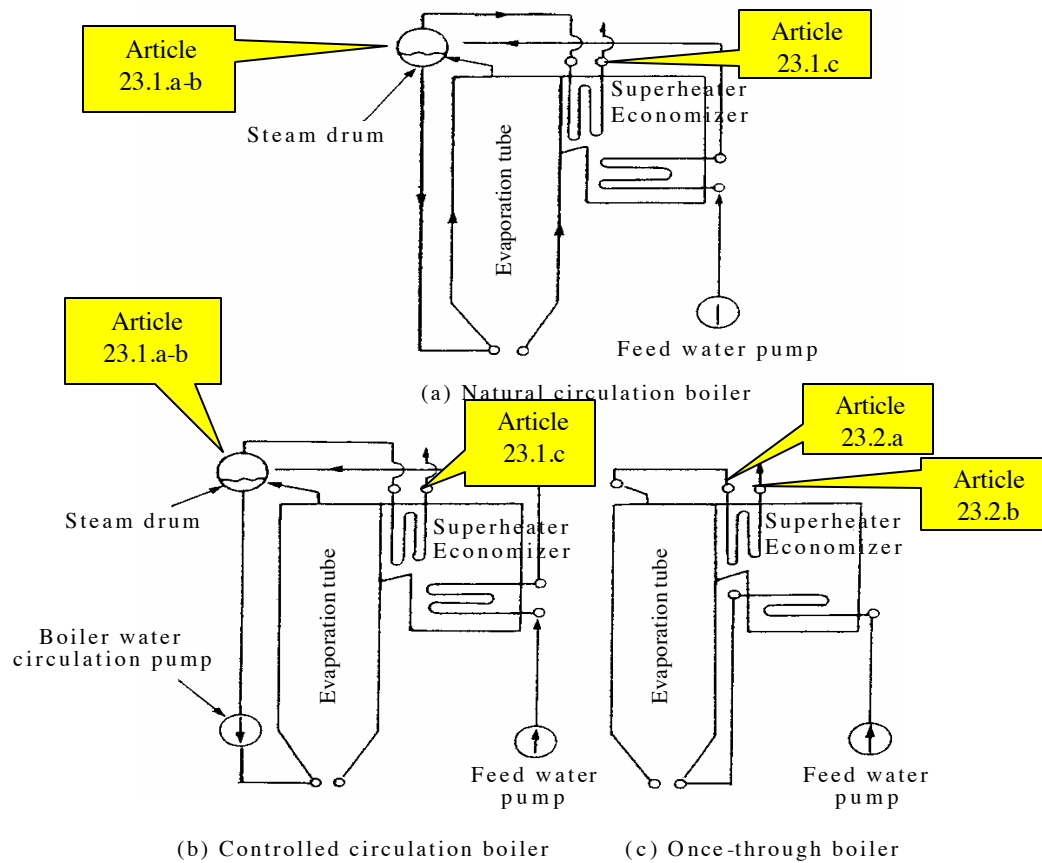


Figure ES23C: Examples of monitoring items

(2) Monitoring of boiler water

The boiler water shall be analyzed and observed about items of dissolved oxygen, density of silica, PH, conductivity and density of hydrogen.

2 For monitoring Boiler Water

A water analyzer or other suitable devices supervise and control the quality of the feed water and boiler water.

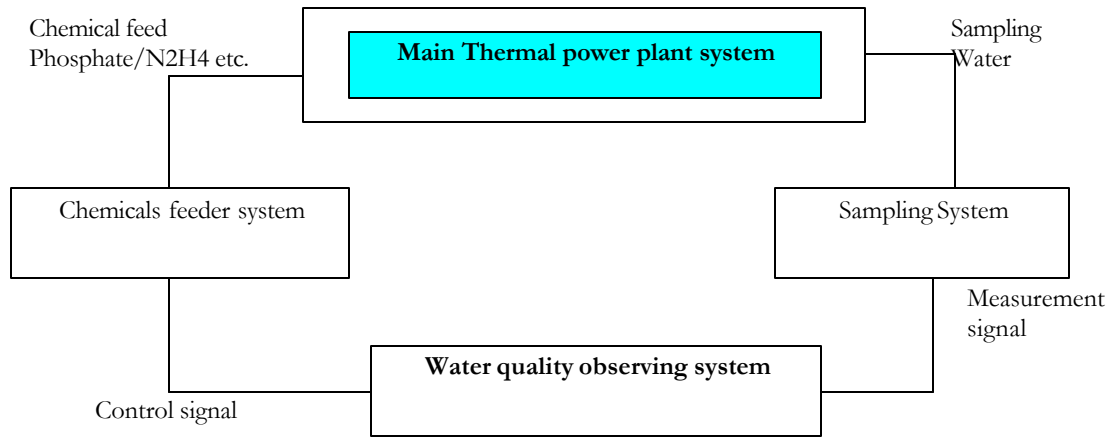


Figure ES23D: Basic components for Water Quality Control Devices

The main components of a water quality control system consist of Sampling system, Water quality observing system and Chemicals feeder system.

The function of that system needs to harmonize each work.

The most consideration point of boiler feed water is as follows:

- (1) Dissolved oxygen
- (2) pH figure
- (3) Impurities

PART 2

Steam Turbine

Article 24: Requirements for Materials of Steam Turbine and its Accessories

Article 25: Mechanical Strength of Steam Turbine and its Accessories

1 Materials for Steam Turbine and its Accessories

The suitable material shall be used for the main parts of the steam turbine to maintain designed performance and the life of a turbine. The following table is an example of the material generally used for each part of the turbine.

Table ES25A: Examples of Major Materials for Thermal Power Plant Turbines

Items	Materials
Casing	Cast steel, steel plate, Mo cast steel, Cr-Mo steel, Cr-Mo-V steel
Bolts	Carbon steel, Cr-Mo steel, Cr-Mo-V steel, Cr-Mo W-V steel, Ni-Cr-Co Ti-Mo steel
Rotors	Carbon steel, Cr-Mo steel, Cr-Mo-V steel, Ni-Cr-Mo-Nb-V steel, 12Cr steel
Blades	12Cr steel, Ni-Cr steel, Ti, Cr-Mo-W-V steel, Cr-Mo-Nb-V steel, Ni-Cr-Co-Ti-Mo steel
Nozzles and static blades	12Cr steel, 13Cr steel, Cr-Mo-Nb-V steel, Cr-Mo-W-V steel

The main steam pressure and temperature (steam conditions) of the thermal plant turbine depends upon type of turbine, combination of conditions and purpose of application, etc. The manufacturer shall select a suitable material of turbine for each steam condition.

Table ES25B: Examples of Applicable Materials for Turbine Hot Parts

Steam conditions			
Main steam pressure	24.1 MPa	24.1MPa	24.1MPa
Main steam temperature	538℃	566℃	593℃
Reheat steam temperature	566℃	593℃	593℃
Rotor (high pressure)	Cr-Mo-V Forged steel		12Cr Forged steel
1st stage bucket (high pressure)	1 2 Cr Forged steel		Improved 1 2 Cr forged steel
Nozzle box (high pressure)	Cr- Mo- V Cast steel		12Cr Cast steel or Cr-rich forged steel
Outer casing (high pressure)	Cr-Mo-V Cast steel		12Cr cast steel
Inner casing (high pressure)	Cr-Mo-V Cast steel		12Cr cast steel
Rotor (intermediate pressure)	12Cr Forged steel	Improved 12Cr forged steel	
1st stage bucket (intermediate pressure)	12Cr Forged steel	Improved 12Cr forged steel	
Outer casing (intermediate pressure)	Cr-Mo-V cast steel		
Inner casing (intermediate pressure)	Cr-Mo-V cast steel	12Cr cast steel	
Main steam stop valve and control valve	Cr-Mo-V cast steel or Cr-Mo-V Forged steel	Cr-Mo-V cast steel	12Cr cast steel
Reheat steam stop valve	Cr-Mo-V cast steel	12Cr cast steel	

Explanation of each part of Steam Turbine

(1) Casing

The casing is the part which covers the rotor and forms the external face of a turbine. A high-pressure or a medium-pressure casing has a double structure composed of an inner casing and an outer casing, in consideration of thermal stress, thermal strain, and thermal expansion.

These casings are supported by the horizontal coupling plane and can be extended in the right and left and upward and downward directions. Nozzles are mounted on the partition plate in the casing.

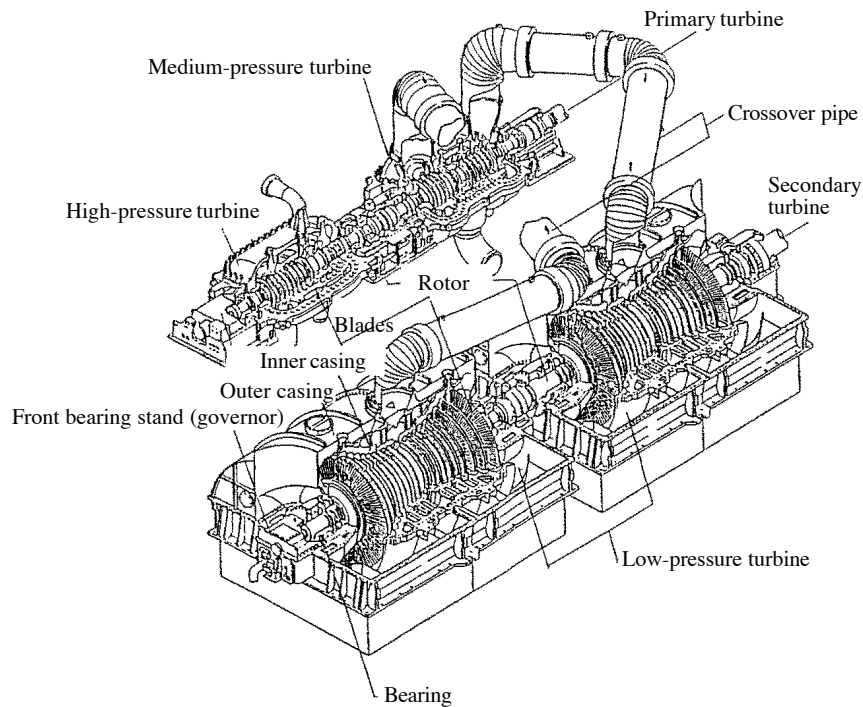


Figure ES25A: Turbine Main Body (Cross compound type turbine)

(2) Impeller

An impeller is a device which rotates with the steam's velocity energy and transmits torque to the generator. An impeller consists of a shaft, blades and shaft couplings. Impellers are generally constructed by forging. Several rotors are jointed with each other for an impeller because of limitations on the material. The blades rotate together with the shaft under the impact of the incoming steam. These blades are exposed to centrifugal force. The blades have the shapes as shown in Figure ES3B. In particular, the long blade for the final stage of the low-pressure unit has a strong hydrodynamic shape, on account of the vibration. The casing and impeller are exposed to high temperatures and high pressures. The impeller, which is additionally exposed to great centrifugal force, must be made of a material that has great strength at high temperatures.

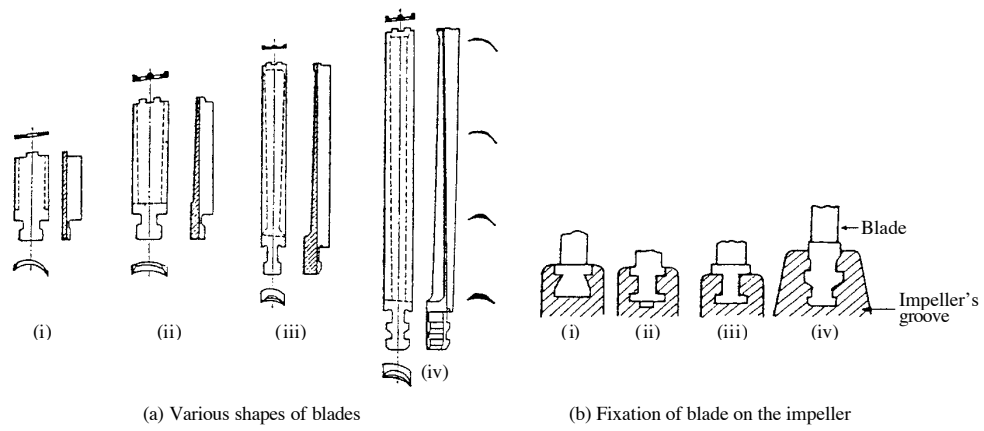
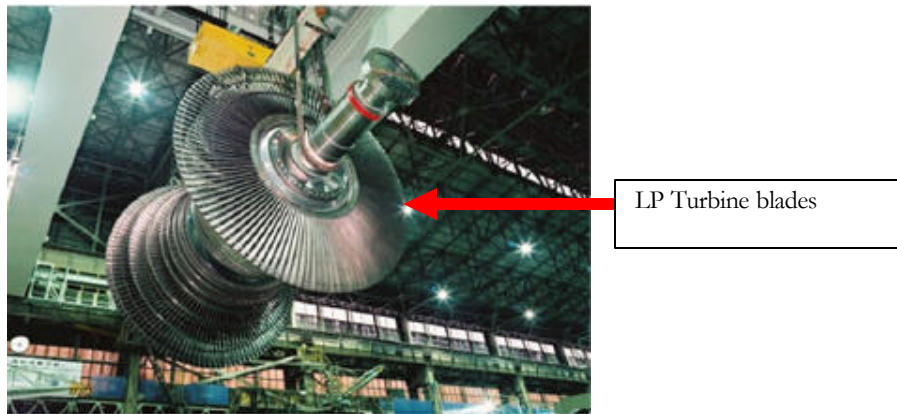


Figure ES25B: Turbine Impeller



2 Overpressure Protection Devices

[Protection devices against pressure rise at the exhaust of steam flow]

The exhaust of the low pressure cylinder or condenser shall be equipped with relief valves or atmosphere relief diaphragms having a sufficient capacity to suppress the pressure within the allowable level in order to protect pressure devices.

The following pictures show LP (Low Pressure) turbine relief diaphragms position.

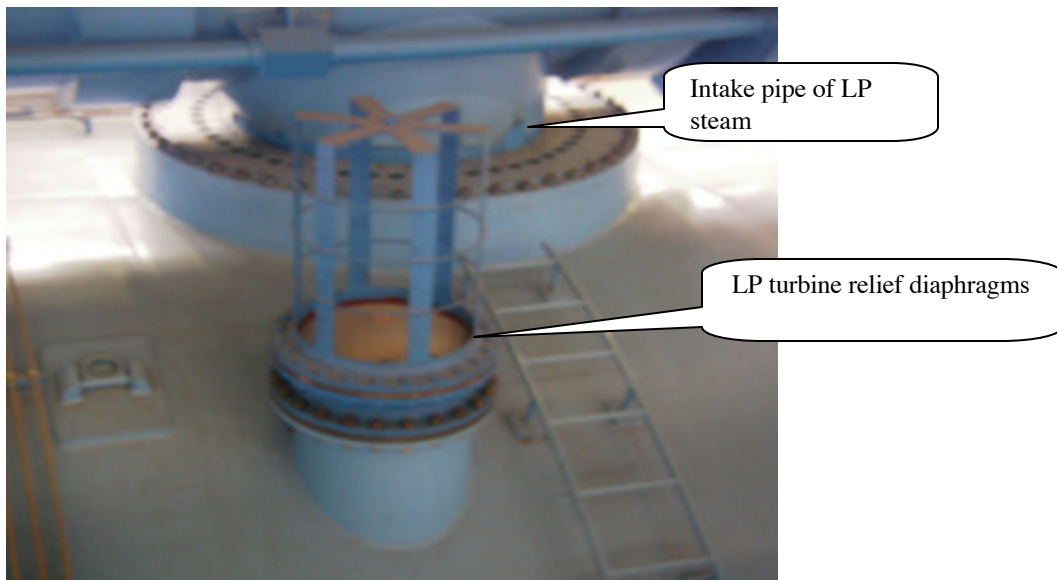
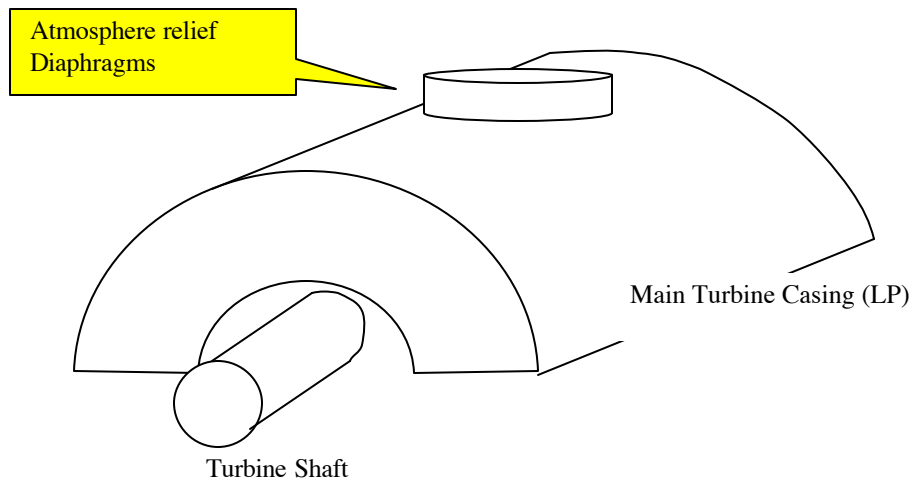


Figure ES25C: LP Turbine Relief Diaphragms Position

Article 26: Bearing of Steam Turbine

The turbine bearings shall be set on both sides of the turbine respectively. The equipment plays the most important role for supporting the main turbine rotor.

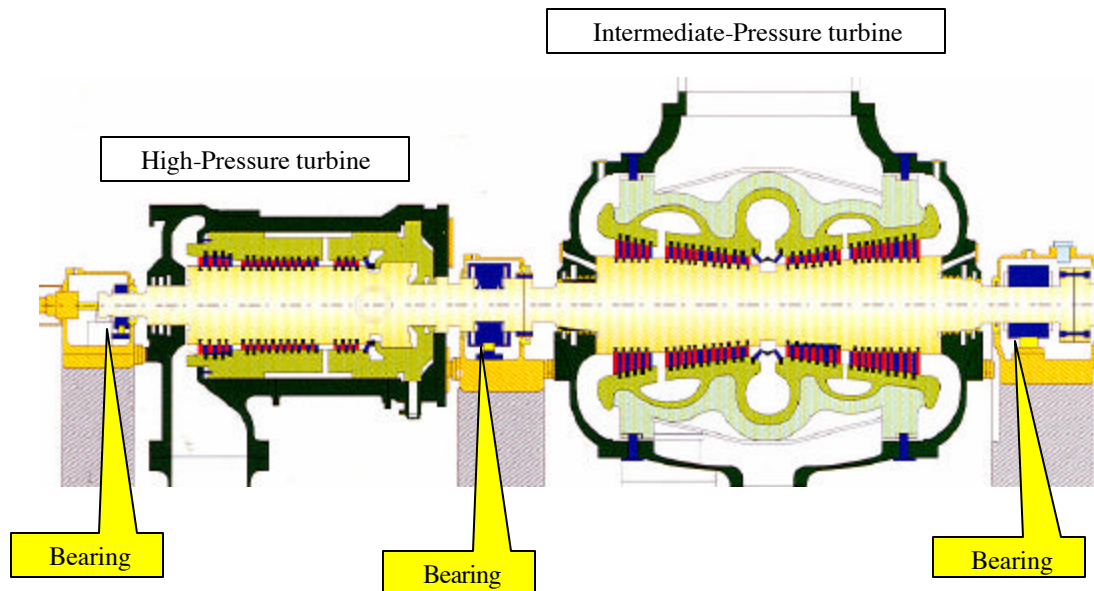


Figure ES26A: Turbine bearings

Article 27: Governance of Turbine Speed

1 Speed Governor

A steam turbine for the power generation needs a governor that controls the turbine inlet steam flow.

This control works for the change of the load and the rotation speed.

The main governor is the equipment that amplifies the difference and detects the rotation speed of the turbine.

There are a mechanical type, an oil pressure type, and an electric type of governors.

It controls the turbine speed by using the difference of the centrifugal force.

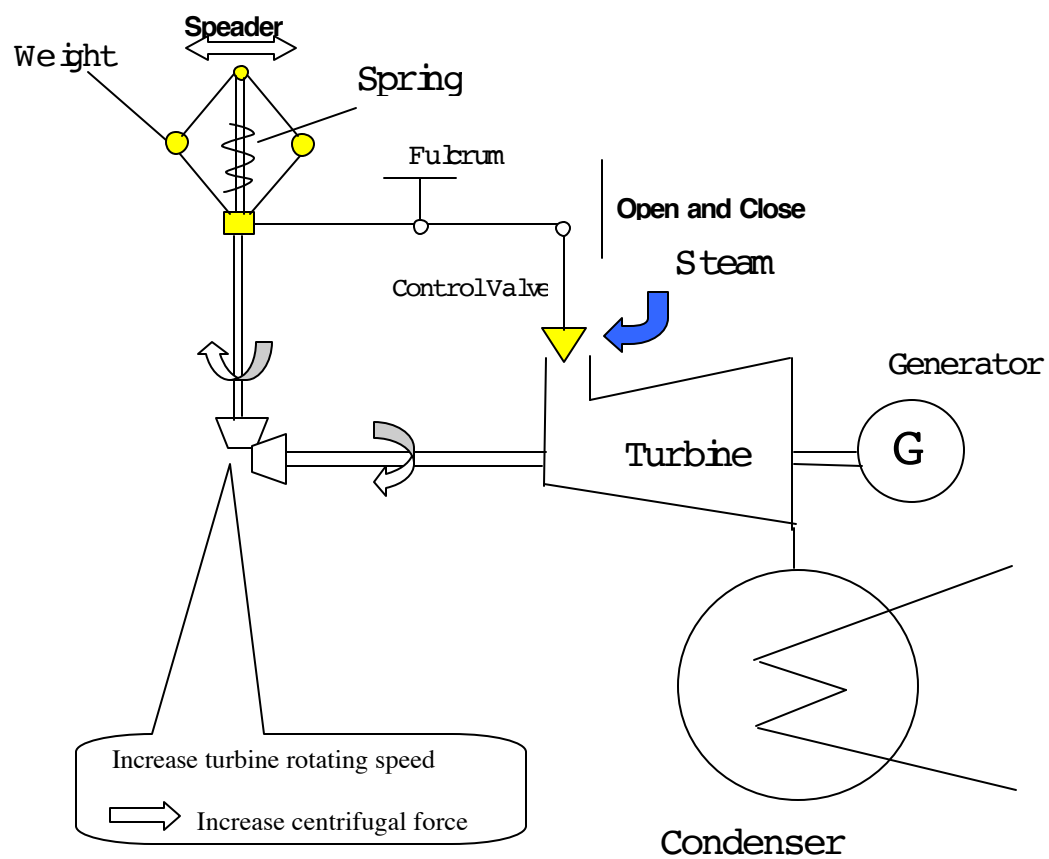


Figure ES27A: Mechanical Type Governor

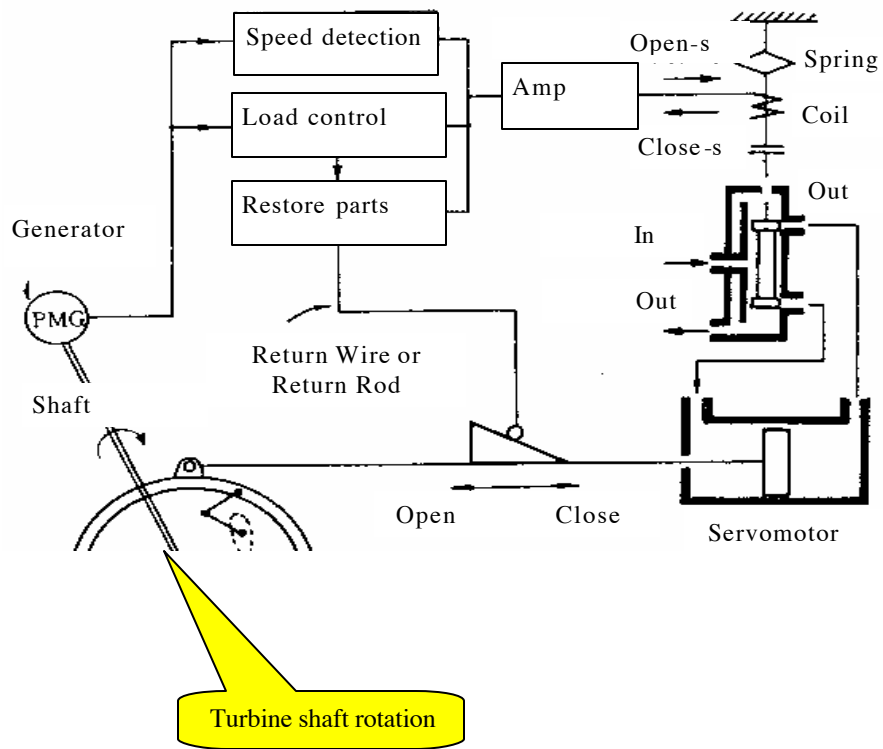


Figure ES27B: Electrical Type Governor

2 Percentage Speed Variation

The percentage speed variation is the rate of the turbine speed change, when the generator output has changed while turbine governor normal operation.

The percentage speed variation is shown by the following formula.

$$R = \frac{(N2-N1) / Nn}{(P1-P2) / Pn} \times 100 (\%)$$

Where:

N1: Turbine speed before load change point

N2: Turbine speed after load change point

P1: Generator output before load change point

P2: Generator output after load change point

R : Speed variation (in case of steam turbine generator, 3 - 5%)

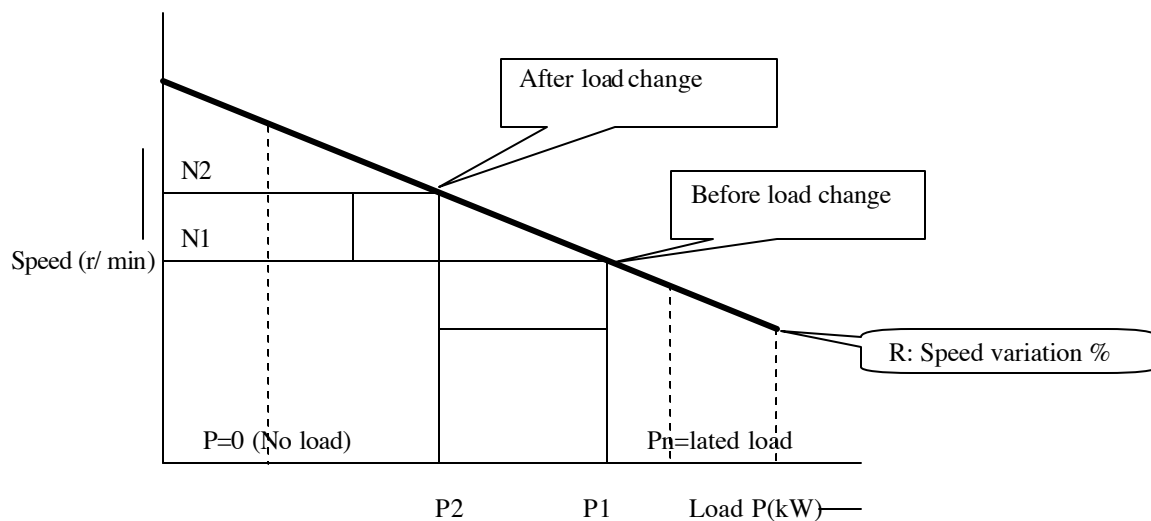


Figure ES27C: Percentage Speed Variation

For Example

1. If some grid systems' load are down,
2. Grid frequency or/and the turbine speed will increase from N1? N 2
3. Generator output will decrease from P1? P2

3 Turbine Speed

Turbine speed is categorized as follows:

① Rated speed

Rated speed is the speed which rotate at rated frequency.

② Normal speed

Normal speed shall be in between 98% to 101% of the rated speed.

③ Operational variation

Operational variation shall be in between 95% to 105% of the rated speed. At all loads in a range between no load and the rated load, the permanent speed variation shall be within $\pm 5\%$ of the rated speed.

④ Over speed

Over speed shall be above 101% of the rated speed.

⑤ Emergency Speed Governor activated speed

Emergency Speed Governor shall be activated at $110\%(\pm 1\%)$ of the rated speed. Momentary variations shall be not more than 10% of the rated speed when the rated output of generator is suddenly thrown off.

⑥ Critical speed

⑥-1 Critical speed shall be beyond the turbine speed which reaches when the rated load is cut off without its Speed Governor's operation.

⑥-2 Critical speed shall be below 94% of the rated speed.

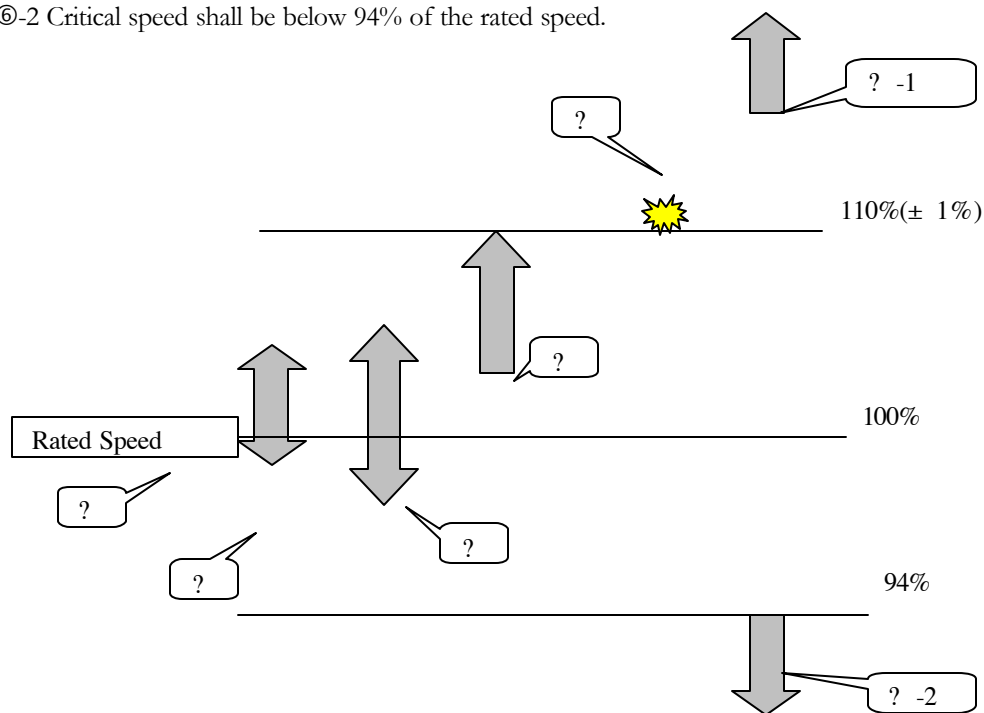


Figure ES27D: Turbine Speed

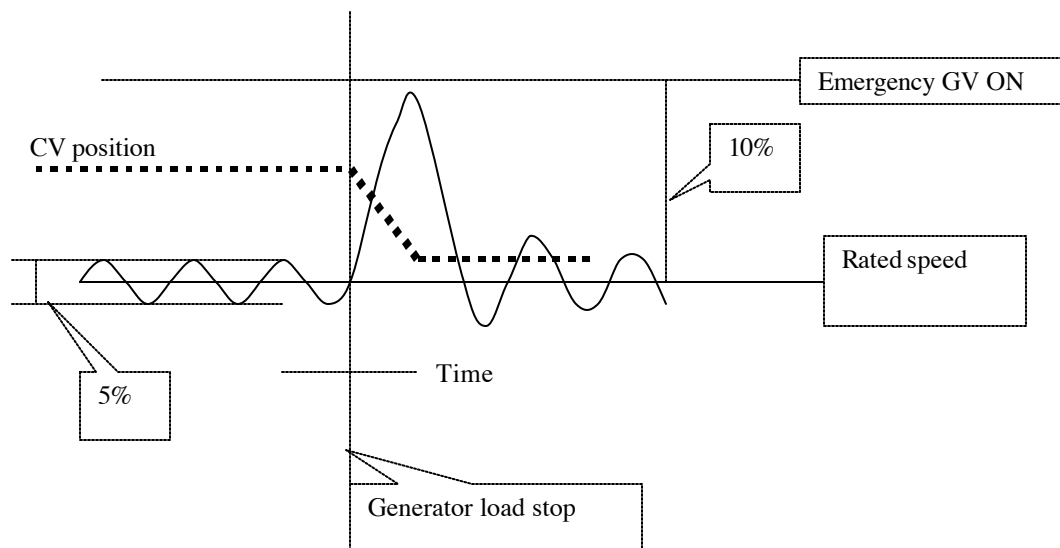


Figure ES27E: Variation of Turbine Speed in Case of Load Stop

4 Control valves

The turbine shall be provided with an appropriate number of governing (control) valves. These shall be suitable for controlling the initial steam supply to the turbine over the entire speed and load range.

In addition, suitable emergency stop valve(s) shall be provided in series with these governing valves. The valves which first receive steam shall respectively be provided with a steam strainer located at close, practicable and upstream point of the valve.

5 Critical Speed of Turbine

(1) Critical speed

In general, the rotational machine has the peculiar frequency itself because of eccentric. The vibration of the turbine increases suddenly when the turbine speed increases and decreases. This is caused by turning to the rotational speed of the turbine with the peculiar frequency, and this rotational speed is called a critical speed.

The rotor might be collided or broken by large displacement at the critical speed. Therefore, the critical speed is designed to be higher than the rated speed in turbines, and consideration that avoids the resonance of a rotational speed and a critical speed is necessary. (Refer to Explanation sheet Article 3-4.)

The combined critical speed of turbines shall be sufficiently apart from the range between 94% of the rated speed and the speed which reaches when the load is cut off completely under the condition of the speed governor not functioning.

(2) Other causes of vibration

Refer to Explanation sheet Article 28:2.1 (3)

6 Protection against Over-speed

Sudden and complete loss of load will tend to over-speed a turbine. Usually the speed governor will instantly respond by closing down the control valves and reducing steam flow to the no-load condition. If the speed governor fails, the rotor will quickly speed up because it will be attempting to absorb all the energy of the steam jets.

An over-speed trip device or an emergency governor should be tested regularly and at every opportunity to ensure their being in proper operating condition.

The over-speed trip device shall operate normally at a speed of 10% in excess of the rated speed, with a tolerance of 1 % of the rated speed in each direction (i.e. at a speed of not more than 11% and not less than 9% in excess of the rated speed, these activated points of the emergency governor come from IEC 45-1 and Japanese Electric Power Technical Standards.)

Following drawing shows “Turbine Governor System” and “Exciter System”.

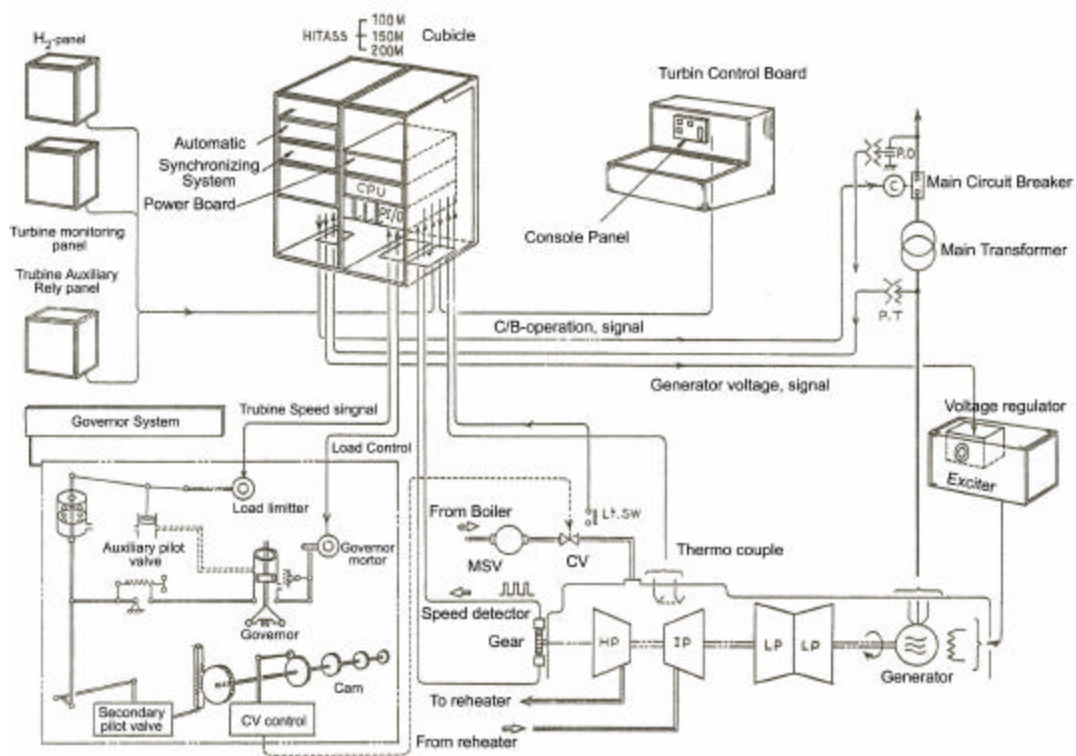


Figure ES27F: Turbine Generator Control System

Article 28: Requirements to Alarm and to Stop the Turbine in Emergency Case

1 Emergency Protection System or Tripping System

1.1 Condenser

A Condenser cools and condenses the exhaust steam from turbine, makes to water again, maintains the vacuum level, lowers the exhaust back pressure, and improves the output and the efficiency of the steam turbine.

(Lowers the back pressure \Rightarrow Lowers windage loss of turbine)

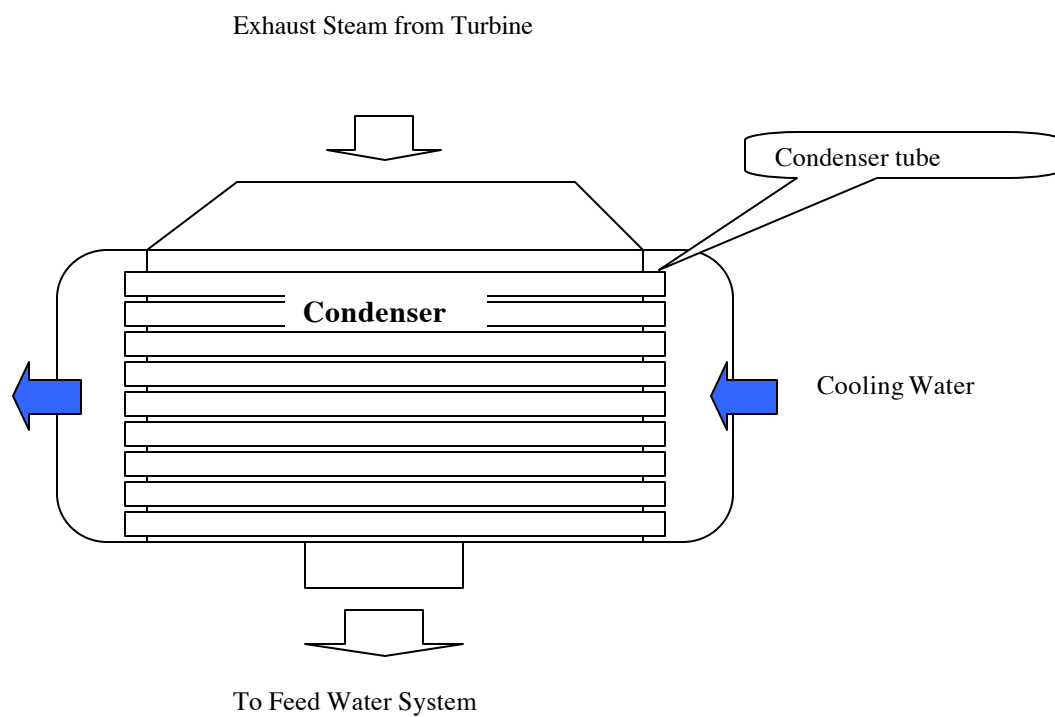


Figure ES28A: Condenser Model

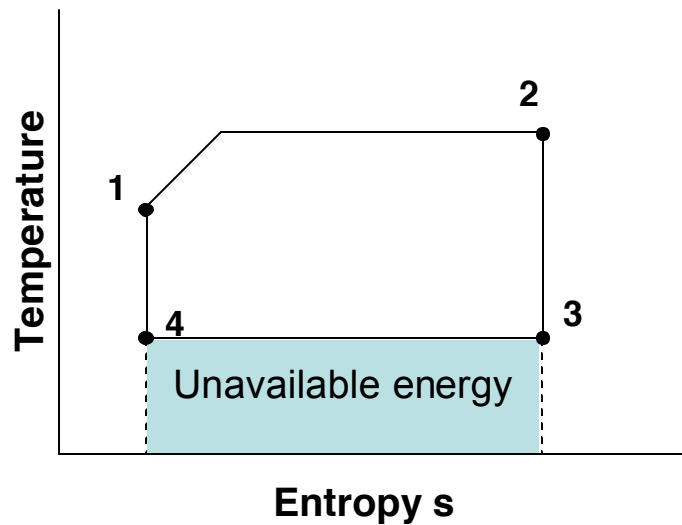


Figure ES28B: T-s diagram (rankine cycle)

Process 4-1: First, the working fluid is pumped up from low to high pressure by a pump.

Process 1-2: The high pressure water enters a boiler where it is heated at constant pressure by an external heat source to become a superheater steam.

Process 2-3: The superheater steam expands through a turbine to generate power output.

Process 3-4: The steam enters a condenser where it is cooled to become a saturated water. This water then re-enters the pump and the cycle repeats.

2 Emergency Alarm System

Table - Allowable level of maximum double amplitude of vibrations

? In case of speed less than rated speed

? In case of speed not less than rated speed

?	Below over speed (3,270r/min)
?	Rated speed (3,000r/min or 1,500r/min)
	0 r/min

Figure ES28C: Allowable level of vibrations

2.1 Outline of Vibration

(1) Vibration

If a rotor is perfectly uniform in its weight distribution about the center of the shaft, it can rotate at any speed up to its strength limit without vibrating, provided it remains perfectly stiff. But all turbine rotors have a certain degree of flexibility and, when supported between the bearings, they will bend under their own weight.

It is difficult to achieve perfect balance of the rotor. Therefore, a small unbalanced weight may be left in the rotor, even after adjustment with balancing weights.

(It is the same as balancing weight for car wheels)

(2) Vibration of Turbine Generator

Vibration monitor

Normally, vibration of each bearing or each bearing pedestal is measured by double amplitude of the turbine shaft.

In any case, a recorder of vibration must be prepared and be capable to record any change of amplitude.

Vibration amplitudes

The allowable value of the vibration amplitude at the rated speed differs from turbine manufactures. Refer to the operation guide or manual. If the vibration amplitude exceeds the allowable limit, the cause shown in the following section must be checked to correct vibrations.

[Reference] (Cited from IEC Standard “Specification for Steam Turbines IEC60045-1 (1991)”)

Rated speed of turbine	r/min	1,000	1,500	1,800	3,000	3,600	6,000	12,000
Double amplitude of bearing vibration	mm	0.075	0.050	0.042	0.025	0.021	0.012	0.006

The acceptable shaft vibration is considered normally to be more than twice as large as the bearing vibration above. But the shaft vibration is not included as the evaluation criteria.

(Note): These allowable values apply to well-balanced turbines.

(3) Cause of vibration

a. Eccentricity:

- Improper centering
- Eccentricity of coupling
- Unequal dipping / deformation of turbine foundation
- Wear of bearing
- Deformation of casing

- b. Unbalanced force:
 - Imperfect balancing
 - Bending of rotor
 - Lack of rotor material homogeneity
 - Damage, erosion, wear of rotating part
 - Adhesion of scale
 - Liquid stored in center bore
 - Shift of balancing weight
- c. Contact between rotating part and stationary part
 - Damage of thrust bearing
 - Admission of steam containing air and water
- d. Foreign matters
 - Damage in turbine
 - Improper cleaning at the assembly including admission of drain
- e. Critical speed
 - Resonance of foundation included
- f. Instability of oil film in bearings
- g. Low oil temperature in bearings
- h. Quick change or inappropriateness of load, speed or steam conditions
- i. Improper sliding of bearing pedestal

2.2 Turning gear equipment (preventing vibration)

Before a turbine is started, or after it is stopped, this equipment is operated to rotate the turbine shaft at 2 to 3 r/min so that the temperature distribution may be maintained homogeneously in the casing to prevent the shaft from bending.

Interlock shall be provided, if necessary, to ensure that turning cannot commence until an adequate supply of lubricating oil is available and the drive is fully engaged.

The turning gear shall disengage automatically when the turbine speed exceeds the turning gear speed.

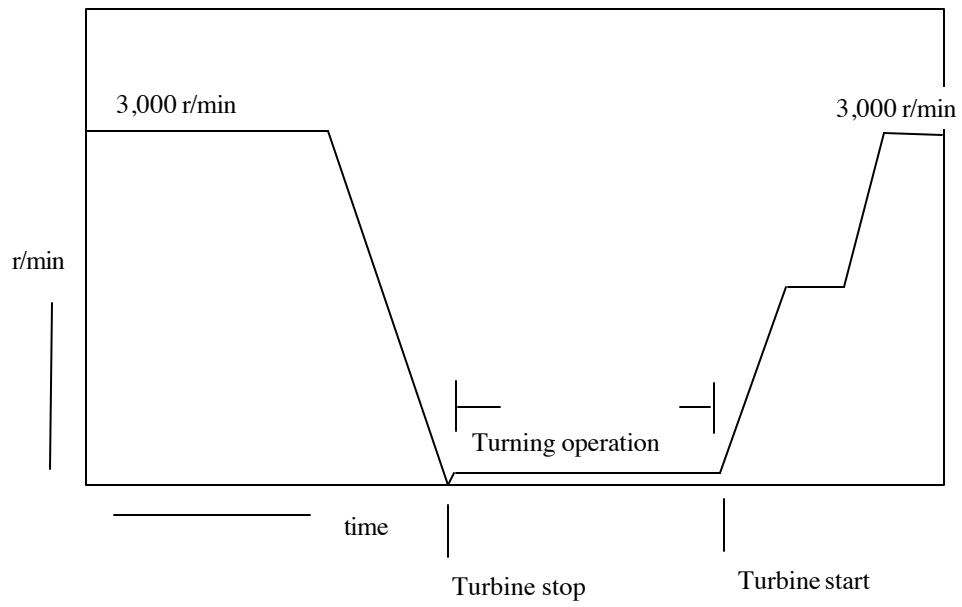


Figure ES28D: Turbine Operation Schedule Model

Article 29: Monitoring the Condition of Turbine Operation

Monitor and Alarm System for Steam turbine

To prevent steam turbine trouble, monitor and alarm systems shall be equipped as shown in Figure ES3H.

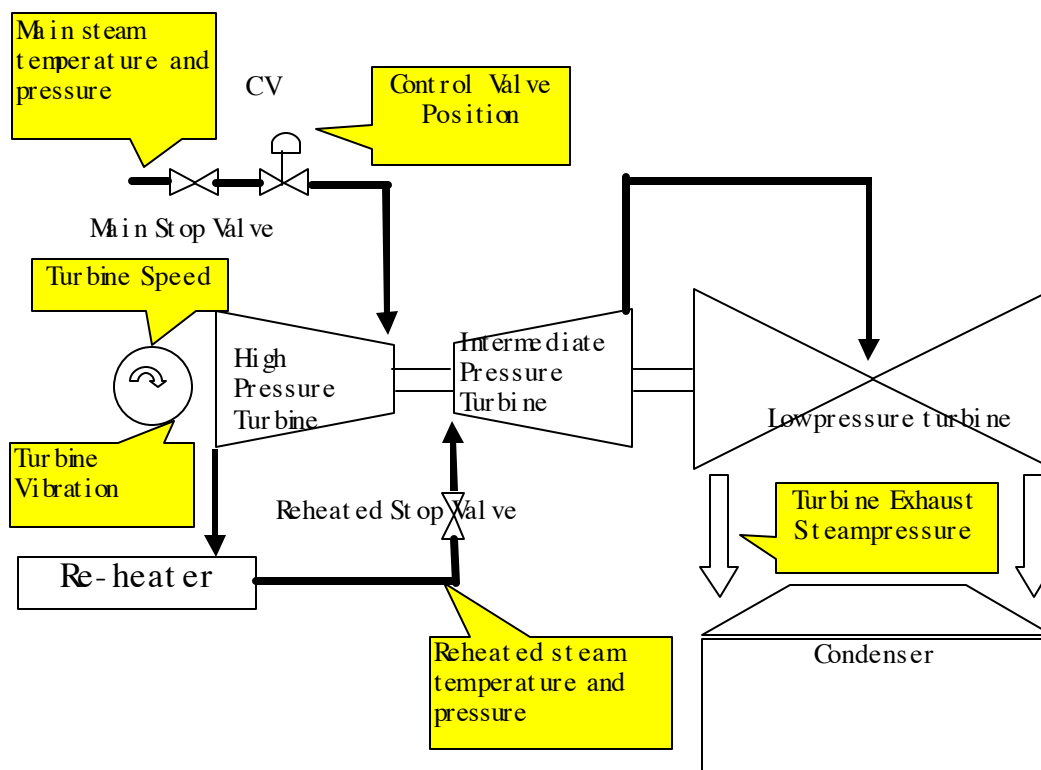


Figure ES29A: Monitor and Alarm System

Precautions for turbine operation

The steam turbine manufacture shows the precautions for operation and operation procedures including start up, shut down, load variation, etc. of the steam turbine. The user (licensee) must follow its guide manual.

General precaution points for turbine operation are as follows:

- (1) Main and reheated steam temperature and its pressure (it depends on boiler operation)
- (2) Turbine vibration (the allowable value of the vibration amplitude at the rated speed differs from turbine manufactures.)
- (3) Turbine lubricating oil pressure and temperature

To observe turbine lubricating oil pressure and temperature

Bearing

Bearings are important parts for supporting the turbine shaft. Two types of bearings are used: journal bearings, which support the weight of the shaft, and thrust bearings, which support the axial force. Thrust bearings support the thrust generated in the axial direction of the impeller to maintain its axial position.

Lubricating oil/control oil equipment

While the turbine operates, the main oil pump supplies oil to the bearing and the control unit and the bearing oil re-circulates. This equipment includes a main oil pump, an auxiliary oil pump, a turning gear oil pump, an oil cooler, an oil cleaner, etc.

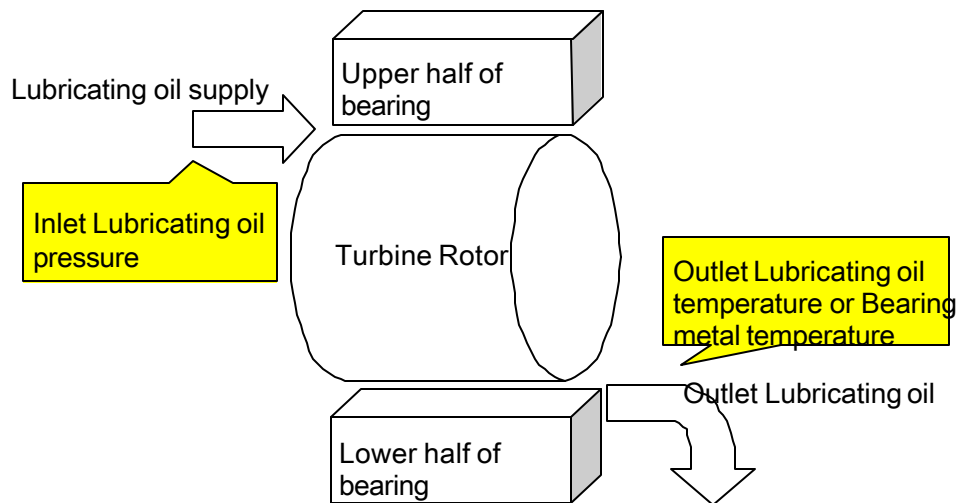


Figure ES29B: Lubricating Oil

Lubricating system

- (1) Keep the lubricating system clean. Use an oil purifier in order to remove the involved water whenever necessary.
- (2) Pay attention to the bearing temperature.
- (3) Pay attention to the temperature difference between the inlet oil and outlet oil of bearings.
- (4) Pay attention to variation of the oil pressure.

Basic Safety Device for Steam Turbine

Following items are basic safety systems for a steam turbine. Main purpose of these items is to protect the main steam turbine from serious trouble.

(1) Emergency governor system

This system is activated when the turbine speed exceeds $110 \pm 1\%$ of the rated speed.

(2) Bearing oil pressure drop trip system

This system starts to work when the bearing oil pressure excessively drops.

(3) Shaft position failure trip system

This system starts to work when the rotor has deviated from the normal position because of wear of the thrust.

(4) Exhaust steam temperature rise trip system

In case of excessive rise of the temperature, this system is immediately activated to prevent the casing from being deformed and/or vibrating excessively.

(5) Vacuum drop trip system

In case of excessive drop of the vacuum in the condenser, this mechanism is immediately activated to prevent the temperature in the exhaust chamber from rising.

(6) Abnormal vibration trip system

Whenever the value obtained by comparing the vibration change rate to the amount of change exceeds the specified level during start-up operation of the turbine, this system is activated.

Type of Measurement

Measurement shall be taken for plant operation, control, heat balance and equipment efficiency calculations.

(1) Pressure Measurement

Normal operating point shall be approximately 60% of the range, over-range protection of at least 1.3 times the maximum scale reading shall be furnished on all pressure instruments. Accuracy shall be plus/minus 0.5% of calibrated span.



Figure ES29C: Pressure Gauge

(2) Temperature Measurement

The temperature of a turbine, exhaust gas, rotor shaft bearings, stator windings, critical turbine metal points, lube oil, radiators, etc. shall be measured.

In general, temperature elements shall be thermocouples and resistance detectors may be used as sensors for control loops.

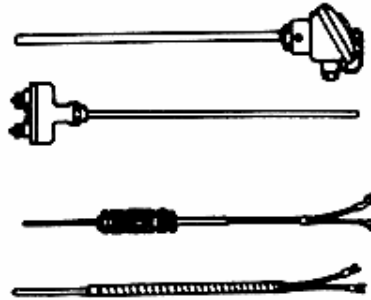


Figure ES29D : Sample of Thermocouples

(3) Level Measurement

Liquid level shall be measured in all tanks and vessels. Measurement of liquid level in large or pressurized vessels shall be made by differential pressure. Local level indication of small tanks shall be made by gauge glass for clear liquids, and by a top mounted float or bubbler for viscous liquids.

Level controllers shall be of the differential pressure or external cage displacement type.

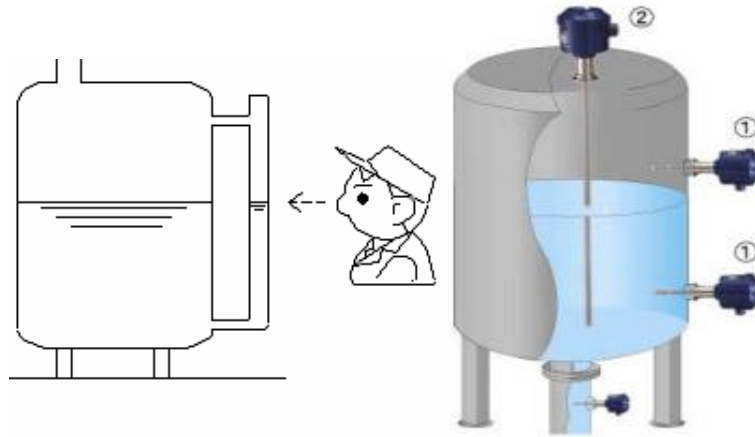
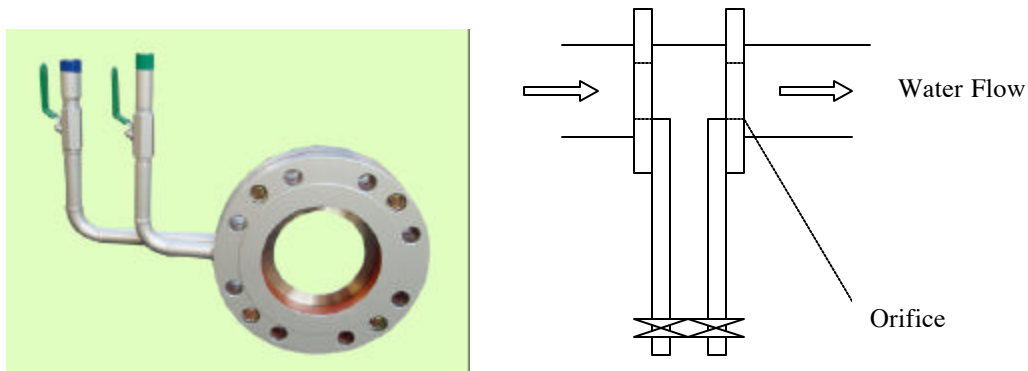


Figure ES29E: Example of Level Gauge

(4) Flow Measurement

Flow meters with the exception of an float meter shall operate on the relationship which exists between the differential pressure and the fluid velocity. The flow meters shall have linear outputs. Accuracy for the fuel flow meter shall be within 1.5% at higher fluid velocity than 80% of the rated flow.

For flow metering of oil or water, positive displacement of meters or area meters shall be used.



If an orifice is in the pipe, there is the differential pressure between the upstream side and the downstream side. Quantity of flow is measured from this differential pressure.

Figure ES29F: Principle of Differential Pressure Measuring

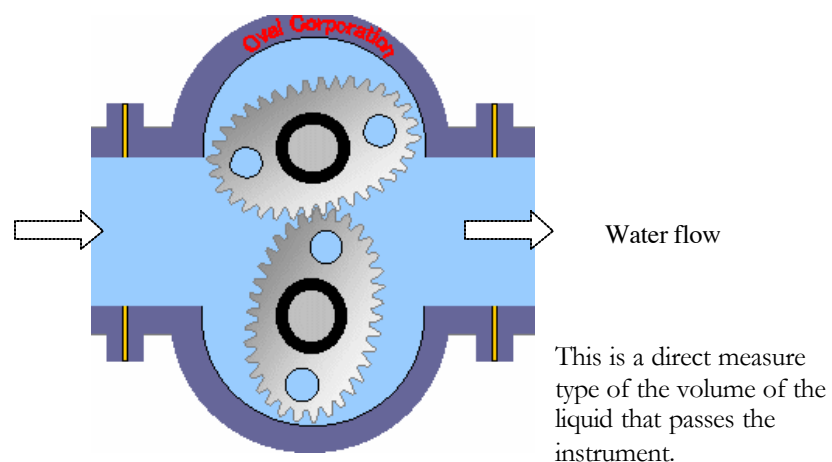


Figure ES29G: Positive Displacement Measurement

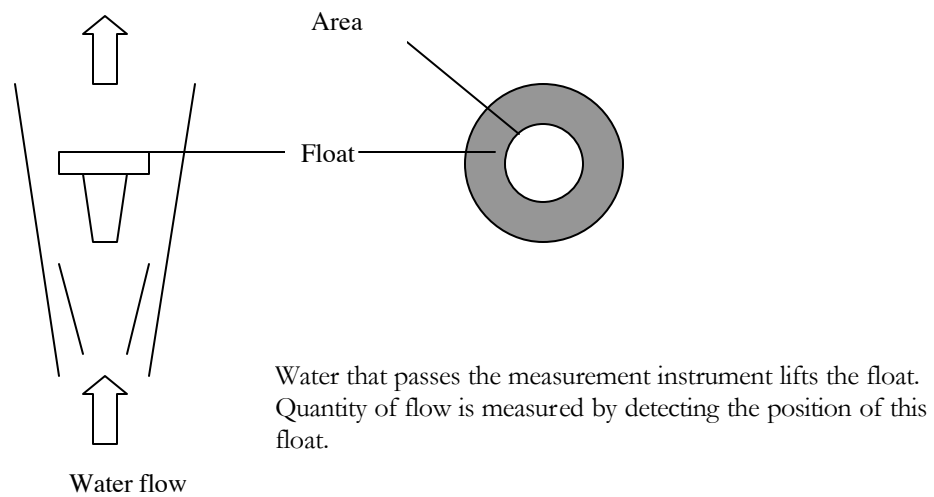


Figure ES29H: Principle of Area Measurement (Float type)

Article 30: Reviewing the Safety of Steam Turbine and its Accessories

CHAPTER 4

Requirements for Gas Turbine Generating Facility

Article 31: Gas Turbine Generating Facility

Description of Gas Turbine

This is a way of generating power using a gas turbine. Air is taken into the air compressor, where it is compressed.

Energy is added to gas stream in the combustor, where air is mixed with fuel and ignited. Combustion increases the temperature, velocity and volume of the gas flow. This is directed through a diffuser (nozzle) over the turbine's blades, and then rotates the turbine and powers the compressor.

1. The compressed air is transferred to the combustor (combustion chamber).
2. Fuel oil is injected into the compressed air in the combustor, and the resulting mixture of air and fuel is heated to generate a high-temperature high - pressure combustion gas.
3. During the expansion process, the combustion gas is sent to the turbine to rotate it and generate electric power.

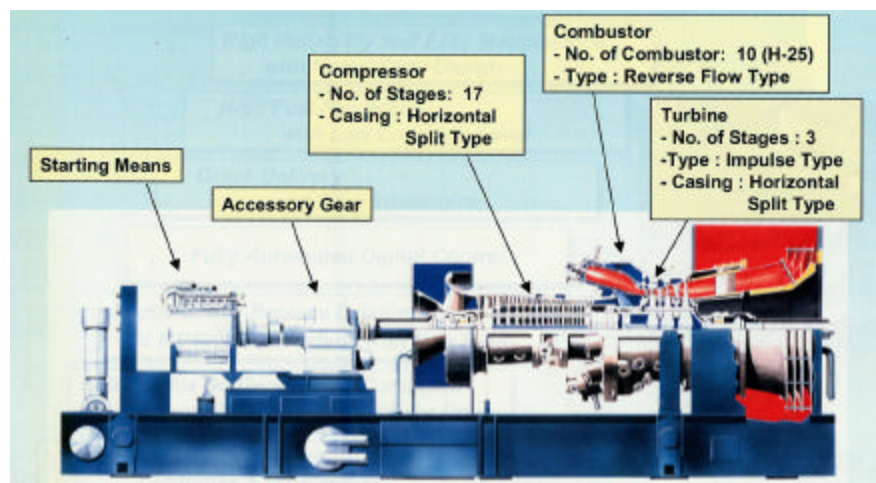


Figure ES31A: Example of Heavy Duty Type Gas Turbine

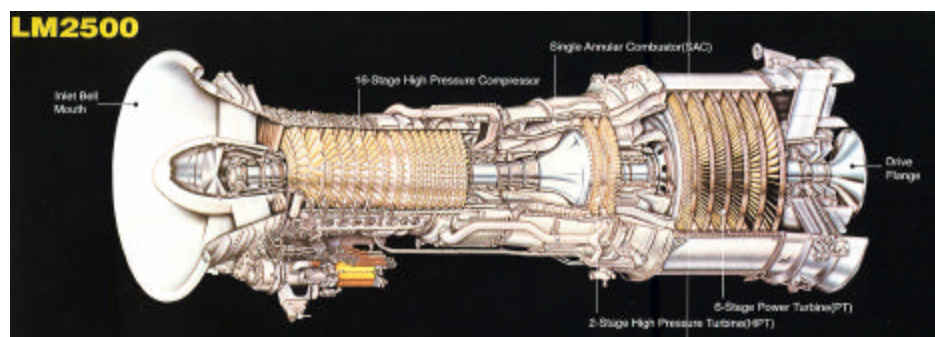


Figure ES31B: Example of Aero-derivative Type Gas Turbine

The standard gas turbine cycle consists of four processes:

1. compression,
2. heating (combustion),
3. expansion, and
4. heat release (the isobaric combustion cycle).

Mechanically, gas turbines can be considerably less complex than internal combustion piston engines. Simple turbines might have one moving part: the shaft, compressor, turbine, alternator-rotor assembly, not counting the fuel system.

The largest gas turbines operate at 3,000 or 3,600 r/min to match the AC power grid.

[Gas Turbine Component]

(1) Compressors

This machine compresses the air to supply high pressured air to a combustor. Axial-flow compressors are generally used in thermal power stations. These compressors are multiple-stage compressors which are capable of efficiently compressing a large amount of air under high pressures.

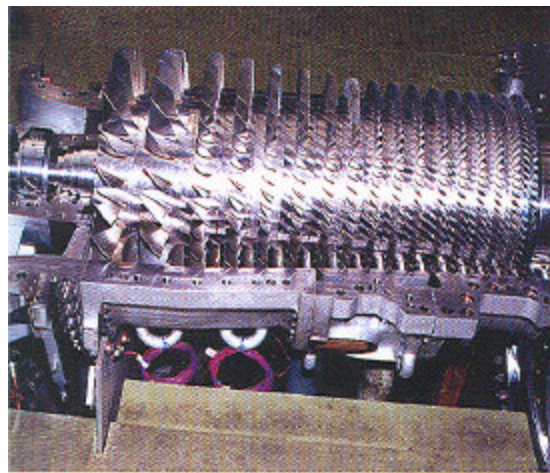


Figure ES31C: Compressor

(2) Heaters (Combustors)

The heaters are used to heat high-pressure air. Internal combustion heaters (combustors) are applied to the open cycle system.

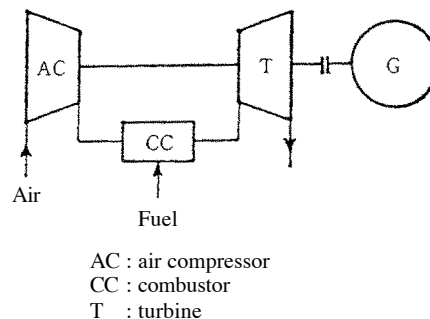


Figure ES31D: Open cycle

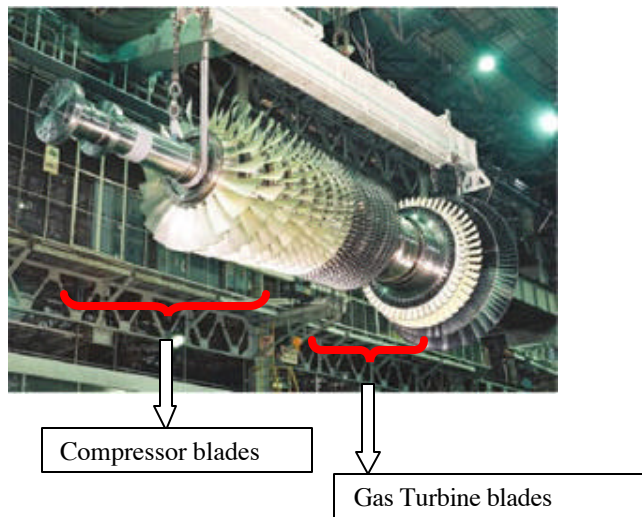


Figure ES31E: Gas Turbine and Compressor

(3) Gas turbine

The gas turbine performs adiabatic expansion of a high-temperature high-pressure gas to generate torque.

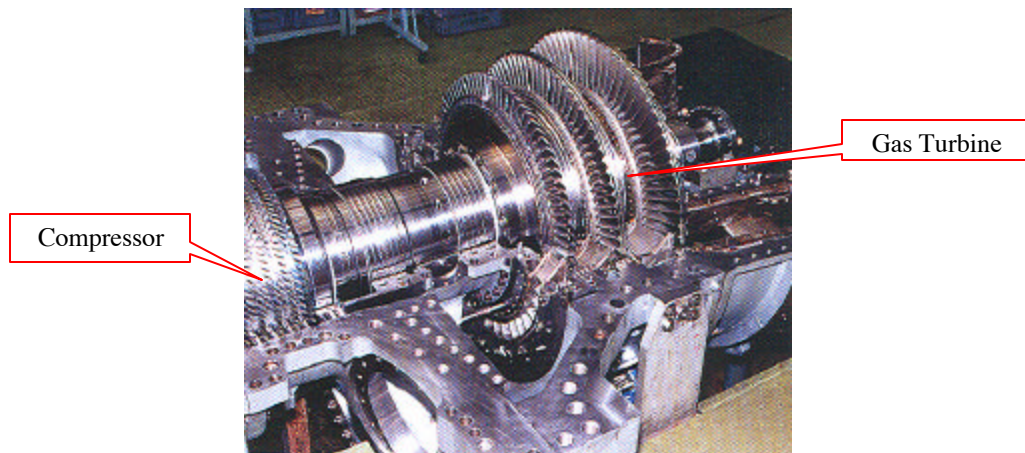


Figure ES31F: Gas Turbine

(4) Regenerators (heat exchangers: HE)

The regenerators recover the heat retained in the turbine exhaust gas for use as combustion air to greatly improve the thermal efficiency.

(5) Intercoolers

The intercoolers lower the temperature of the air during the compression process to boost the compressor's efficiency.

(6) Pre-coolers

The pre-coolers lower the temperature of the fluid air in the closed cycle at the compressor inlet to boost the compressor's efficiency.

(7) Silencers

A gas turbine power station generates a noise because it intakes and discharges large amounts of air at high speed. For this reason, a noise insulating material is installed to cover the ducts and silencers are provided at the intake side. At the discharge side, the air is discharged upward through a chimney to the atmosphere.

Fuel for Gas Turbines

The major using liquid or gas fuels are as shown below;

Liquid fuels: Kerosene oil, light oil, naphtha, heavy oil, and other petroleum

Gas fuels: Natural gas (LNG), LPG, municipal gas, mine gas, coke furnace gas and blast furnace gas

Material of Gas Turbine rotor

The rotor and blades are made of a special heat resistant alloy to meet the temperature requirements for the service gas.

Recently, new heat resistant materials have been developed and the cooling structure of the blades has been modified. High-efficiency gas turbines have been commercialized for service temperatures around 1100°C.

The most commonly used type is a simple open-cycle turbine. An open gas turbine is a turbine which integrates a combustor and a compressor.

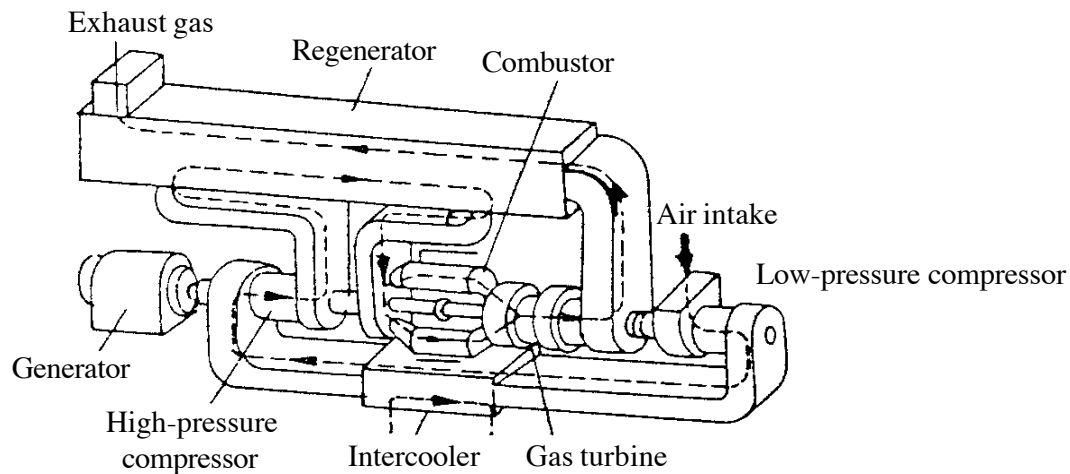


Figure ES31G: Open gas turbine

The air placed under high pressures in the compressor is transferred to the combustion chamber. A small part of this air is used to burn the fuel in the combustion unit. A large amount of high-temperature, high-pressure gas obtained by mixing the majority of high-pressure gas with the high-pressure, high-temperature combustion gas performs expansion in the turbine. This process generates torque to the impeller. The exhaust enters the regenerator and preheats the combustion air before being discharged to the external environment.

Package Gas Turbines

Package gas turbine power plants are widely used. They are designed to make full use of the advantages of the open cycle gas turbines, which are the simplest construction, light weight, small size and small installation area for the output, small quantity of cooling water, etc.

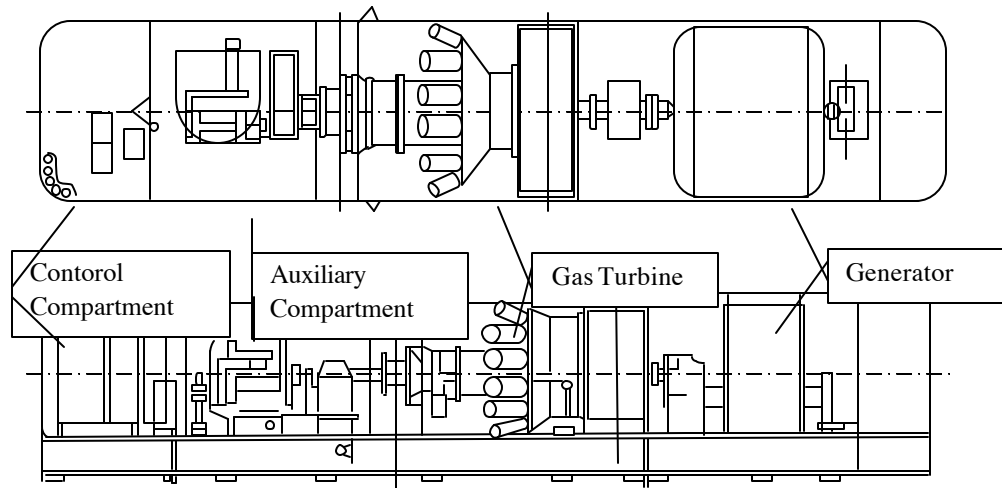


Figure ES31H: Package Gas Turbine

To improve the turbine's thermal efficiency, a regenerator, a re-heater and an intermediate or a pre-posed cooler can be added to the standard cycle equipment given above, as necessary. Closed-cycle turbines are based on an air recirculation system, in which exhaust gas from the turbine is not discharged to the environment, but instead led to a cooler and converted into air. The resulting air is sent to the air compressor.

More than 50% of the power output from a gas turbine power generation plant is consumed by driving the air compressors. Gas turbines therefore have low thermal efficiency (30 to 32%). The net output of gas turbine power generator ranges from 100 kW to 100 MW depending on the application. The materials for combustors and turbines and the cooling system are constantly improved in order to enhance the turbine's thermal efficiency. In some cases, gas turbine power generation is combined with steam turbine power generation (in a composite power generation plant).

Types of Gas Turbine

Gas turbines can be classified into two types, looking at the way in which the working fluid is moved around them: open-cycle turbines and closed-cycle turbines. They have four types of thermodynamic cycle: simple cycles, regeneration cycles, intercooling cycles, and reheating cycles. They also use rotating shafts in two ways: there are a single-shaft turbine and a multi-shaft turbine.

(1) Open-cycle turbines

The suction side and the discharge side of these gas turbines are both exposed to the air. The large amount of gas taken in and discharged makes a large amount of noise. As the room temperature rises, the output of the turbine drops. The thermal efficiency of open-cycle turbines is lower than closed-cycle turbines. Despite these disadvantages, open-cycle gas turbines are the most popular turbines, because they are easy to install, have a short starting and stopping time, and are easy to maintain.

(2) Closed-cycle turbines

In closed-cycle turbines, the working fluid is isolated from the atmospheric air and made to circulate. Since the exhaust gas is not directly discharged to the atmosphere, this type of turbine makes less noise than open-cycle turbines. Their thermal efficiency and output do not depend on room temperature. Their thermal efficiency is several percent higher than open-cycle turbines. The complicated setup of closed-cycle turbines makes them less easy to operate and maintain. Their starting and stopping time is longer than open-cycle turbines.

Characteristics of Gas Turbine Power Plants

Compared with steam power plants, gas turbine power plants have the following characteristics:

- (1) They are simple to set up, cost less to construct, and require a shorter construction period.
- (2) They are easier to operate, do not require highly skilled personnel, and require fewer operators.
- (3) They require less cooling water, and the water does not require treatment before use.
- (4) Suitable to medium- and small-scale power plants (up to 240 MW) ranging from steam power plants to internal combustion power plants.
- (5) Short starting time (from start to full loading): They are utilized for a peak load and an emergency power source.
- (6) The location for installing the turbine can be chosen freely, as long as the fuel supply is taken into account.
- (7) The high temperature of the gas turbine means that expensive heat-resistant materials are required.
- (8) Large-capacity plants have a thermal efficiency of approximately 30%, behind internal combustion plants and large-capacity steam power plants.
- (9) High noise levels.
- (10) Some models in the facility impose restrictions on the usable type of fuel, and the output depends on the room temperature: If the room temperature rises, the output drops.
- (11) A large amount of motive power, more than 50% of the output of the turbine, is required to compress the air.

Creep Phenomenon

When the stress load goes into a metallic material at the high temperature, the material is gradually deformed as time goes on. It is called creep phenomenon.

Relaxation Phenomenon

The relaxation of the stress is opposite to the creep phenomenon. It is a phenomenon of the load stress decreasing to a metallic material with the passage of time under the constant warp condition at the high temperature.

Maintenance of Gas Turbine (major points)

(1) Inlet air filter

The Gas turbine inhales a large amount of air. Moreover, the resistance of the air filter makes large influence on the output of a generator and on the turbine efficiency.

(2) Cleaning of compressor

When a compressor is dirty, it is necessary to be washed by clear water.

(3) Inhalation accident of foreign object

It is necessary to equip the screen to prevent an accident (FOD: foreign object damage) because of the inhalation of the foreign object at the entrance of the compressor.

(4) High temperature corrosion of turbine blade

The cause of the turbine blade corrosion is compounds such as sulfur in the combustion gas, sodium, potassium, vanadium, and so on.

Prevention of high temperature corrosion

? To minimize salinity goes into the inlet air filter.

? To remove moisture in fuel

? To select fuel with a little vanadium and lead

(5) Overheat of turbine

Because the turbine thermal capacity is small, short time rising gas temperature brings overheat damage.

For this prevention

? Cleaning and/or replacement of fuel nozzles.

? To improve atomization and to raise the viscosity of the fuel.

? Quick acceleration speed when it starts and keeps enough power for the starter system.

(6) Prevention of vibration

Causes of vibration are:

- ? Unbalanced rotor
- ? Defective alignment
- ? Thermal deformation
- ? Defect in bearing

Article 32: Requirements for Materials of Gas Turbine and its Accessories

Article 33: Mechanical Strength of Structure of Gas Turbine and its Accessories

Article 34: Bearings of Gas Turbine

Article 35: Governance of Turbine Speed

Article 36: Emergency Alarm and to Stop Devices

Article 37: Monitoring and Alarm Systems

Article 38: Reviewing the Safety of Gas turbine

Article 39: Requirements for Gas-Turbine Combined Cycle and its Accessories

Gas turbines have a thermal efficiency of 20 to 30%. This means that 70 to 80% of the heat generated from the fuel is lost in the exhaust gas. To raise the thermal efficiency, a gas turbine can be combined with a steam turbine. Power plants with this structure are known as combined cycle power plants. Their thermal efficiency is as much as 10% higher than a normal steam power plant.

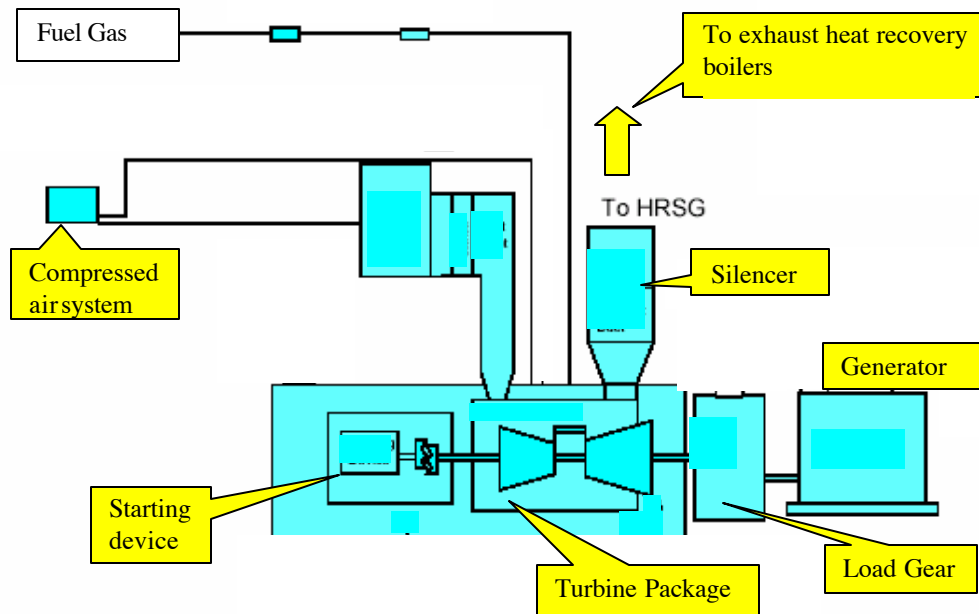


Figure ES39A: Gas-Turbine for Combined Cycle

- (1) Several type of systems for combined cycles
 - a. Exhaust heat recovery type,
 - b. Exhaust-assisted combustion type,
 - c. Secondary combustion of exhaust type,
 - d. Supercharged boiler type,
 - e. Feed water heating type, and
 - f. Mono-axial system.

The following figure shows the overall characteristics of a multi-shaft system and a single-shaft system.

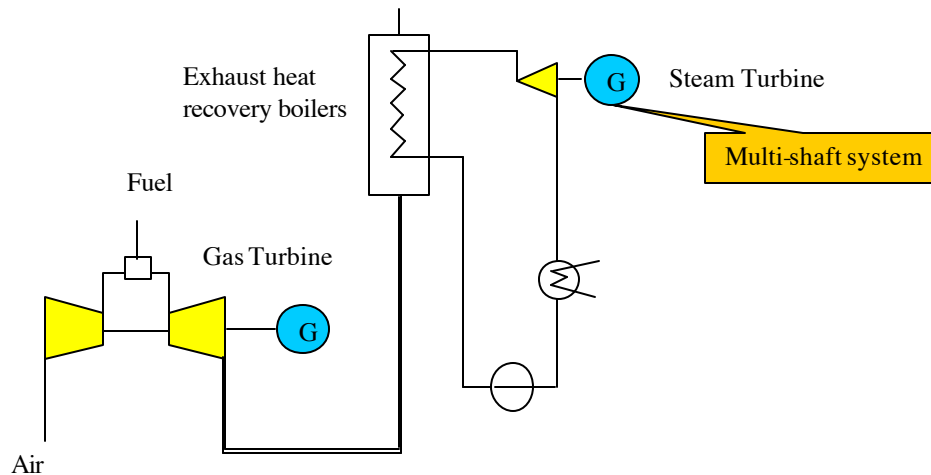


Figure ES39B: Multi-shaft System

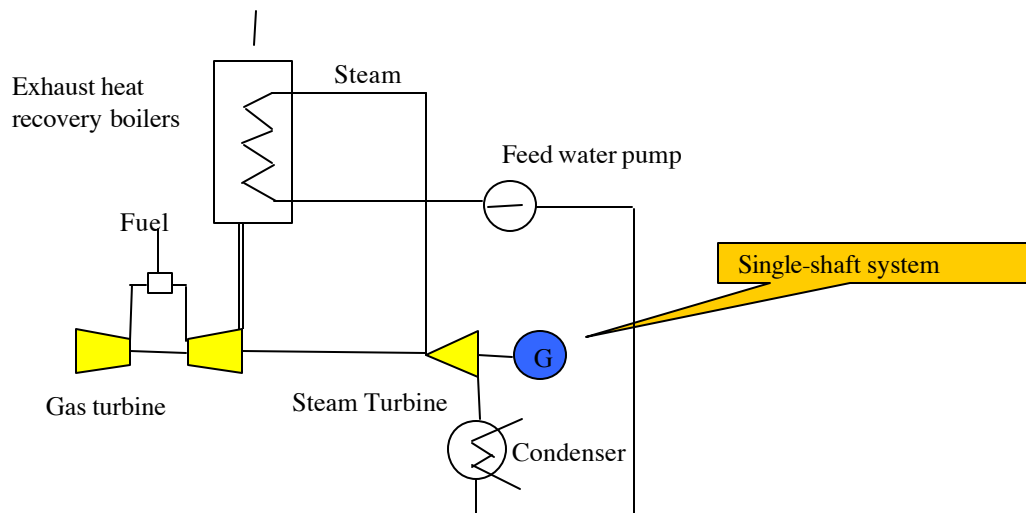


Figure ES39C: Single-shaft System

(2) Characteristics of combined cycle thermal power plants

- ① Higher thermal efficiency: the thermal efficiency of a combined cycle thermal power plant can be up to 10% higher than a large-capacity steam power plant (40%). This type of power plant has a higher thermal efficiency even under partial load.
- ② The power plant combines several small-capacity units. This allows the facility to be partially stopped for maintenance or repair or similar purposes, reducing the output during stoppage.
- ③ Easier to start up and stop, and take less time to do so.

- ④ They have a simpler setup, are easy to operate, and require only a short construction period.
- ⑤ Less cooling water is used for the condenser per unit output, with the exact amount depending on the contribution ratio of the gas turbine and the steam turbine: roughly 70% of a conventional steam power plant. This makes it easy to control thermal effluent.
- ⑥ The gas turbine requires a large amount of air: three times as much exhaust gas is required per unit output compared to a steam power plant.
- ⑦ Combustion is performed at high temperatures in the gas turbine: exhaust gas has a high nitrogen oxide content, meaning that a de-nitrizer must be installed.
- ⑧ Fuel containing sodium or vanadium can result in high temperature corrosion: high-quality fuel is required.
- ⑨ The output depends on the room temperature.
- ⑩ Much noise is generated, which must be dealt with properly.

(3) Combined cycle power generation

This is an exhaust heat recovery power generation system in which the exhaust from an open gas turbine is sent for steam generation to the exhaust heat recovery boiler in a steam power station. Another system is based on a supercharged boiler. The air from the compressor in the gas turbine is fed to the boiler in the steam power station to be combusted as combustion air. The resulting combustion gas is sent to the gas turbine.

Use of combined cycle power generation will improve the total thermal efficiency up to 43%.

CHAPTER 5

Requirements for Internal Combustion Engine

Article 40: Internal Combustion Engine**Article 41: Requirements for Materials of Internal Combustion Engine****Article 42: Mechanical Strength of Structure of Internal Combustion Engine**

Materials intended for the principal components of diesel engines and their non-destructive test are to conform to the requirements given in Table ES5A. In case of ultrasonic test, submission or presentation of the test results to the surveyor may be regarded as following the requirements.

Cylinders, pistons and other parts subjected to high temperature or pressure, and parts for transmitting propulsion torque are to be of materials suitable for the temperature and load to which they are exposed.

1 Non-Destructive Testing (NDT)

The following tests are normally adopted to detect the defect.

(1) Magnetic Particle Test

This test uses the magnetic powder. The magnet powder is attracted to the leakage flux of magnetic induction that begins to leak from a defective part. (It is used for the defect detection on the surface.)

(2) Liquid Penetration Test

This test uses the infiltration method. The colored infiltration liquid infiltrates the defect on the surface of the metal. (It is used for the defect detection on the surface.)

(3) Ultrasonic Test

The ultrasonic test wave is reflected by the defect part of material. The test equipment receives this ultrasonic wave from the defective point. (It is used for the defect detection of internal of materials).

Table ES42A: Application of Non-destructive Test to Principal Components of Diesel Engines

Principal components			Cylinder bore D(mm)					
			D<300		301<D<400		401<D	
			?	?	?	?	?	?
1	Crankshaft	Solid forged type	?	?	?	?	?	?
		Web, pin and journal of built-up or semi-built-up type	?	?	?	?	?	?
		Others (for example: welded type)	?	?	?	?	?	?
2	Steel piston crowns			?		?	?	?
3	Piston rods		?		?		?	
4	Connecting rods together with connecting rod bearing caps		?		?		?	
5	Steel parts of cylinder liners				?			
6	Steel cylinder covers			?		?	?	?

For example (KEP: 320mm, C6:320mm)

- (1) Marked with circlets in Column ? are to be tested by magnetic particle test or liquid penetrate test.
- (2) Marked with circlets in Column ? are to be tested by ultrasonic test.

2 Structure of Internal Combustion Engines and Their Accessories

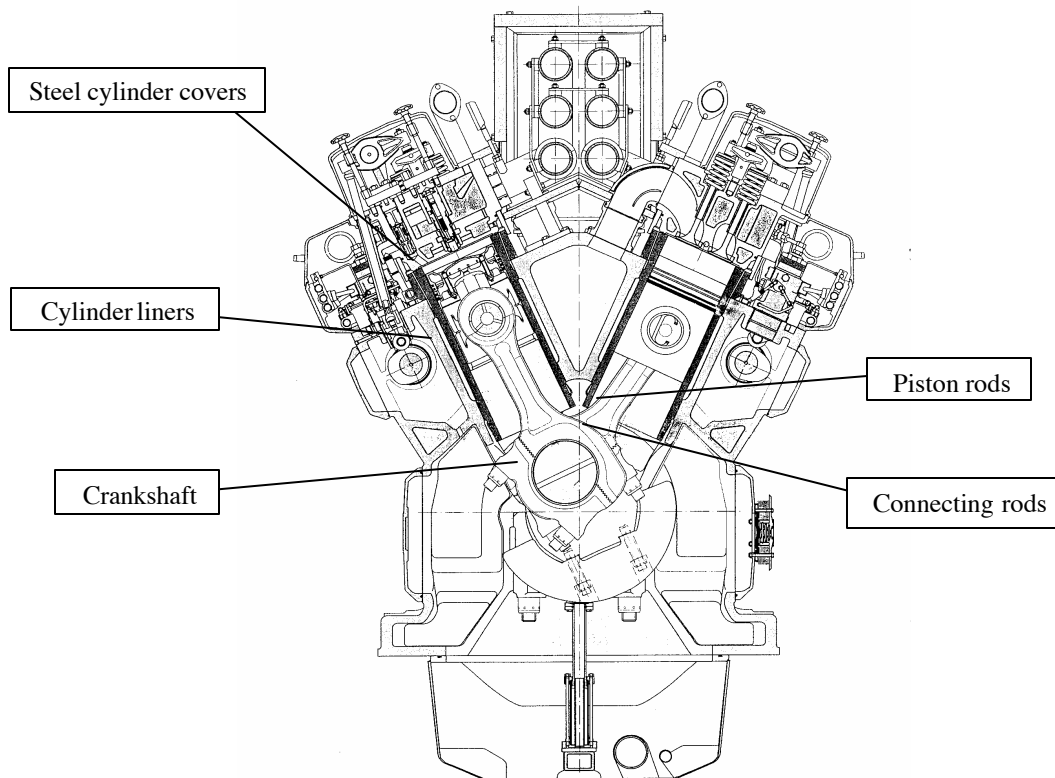


Figure ES42A: Example of Internal Combustion Engine

3 Governor

Refer to Article 27, 35

4 Emergency Stop and Alarm Devices

Refer to Article 28, 36

5 Overpressure Protection Devices

To avoid over-pressurization, cylinders must be equipped with a suitable device for preventing overpressure if they have a diameter of more than 230mm and the maximum pressure of more than 3.4MPa, and that sealed crankcases must be equipped with such a device if the diameter of their cylinder exceeds 250mm. (These figures come from Japanese Electric Power Technical Standards.)

Gas engines do not require devices to relieve over-pressurization of their cylinders; if an overpressure prevention device (relief valve) is installed on a cylinder in this type of engine, knocking or backfiring may result.

6 Monitor and Alarm System

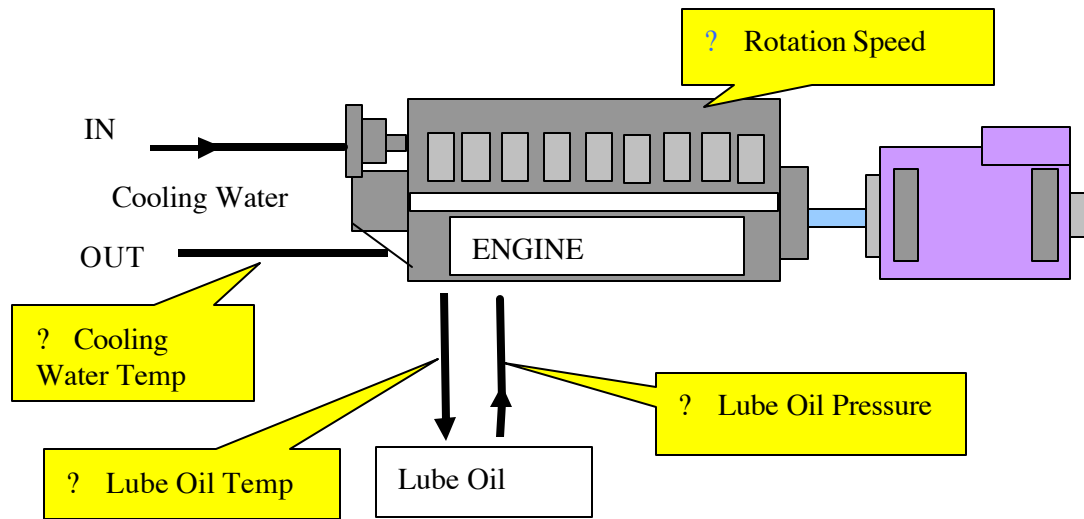


Figure ES42B: Monitoring System for Diesel Generator

Explanation

Item ① is the rotation speed of the internal combustion engine. If there is no speed indicator, the frequency indicator of the generator directly connected to the engine is taken to be a measure of the rotation speed.

Item ② is the temperature of the cooling water at the outlet of the engine.

Item ③ is the pressure measurement of the lubricating oil at the inlet of the engine. If forced lubrication is not performed, an oil level gauge or an oil quantity indicator may be used as a substitute.

Item ④ is the temperature of the lubricating oil at the outlet of the engine.

Diesel Power Plant

The outline of the equipment of diesel plant

(1) Main engine

Main parts of the main engine are a cylinder, a crank, a cam, valves and a flywheel.

(2) Fuel equipment

Fuel equipment supplies oil to a cylinder, an oil tank, a strainer, an oil pump and an injection valve.

(3) Exhaust equipment

Exhaust equipment consists of an exhaust manifold, a silencer and so on.

(4) Supercharger

A supercharger supercharges the air to a cylinder. Most type is exhaust gas drive. It can increase power by 50% - 100%.

(5) Cooling unit

Cooling unit controls main engine temperature.

(6) Lubricating oil

Lubricating oil system consists of an oil tank, an oil pump, an oil cooler, oil pipes and oil strainers.

Diesel Control and Alarm System

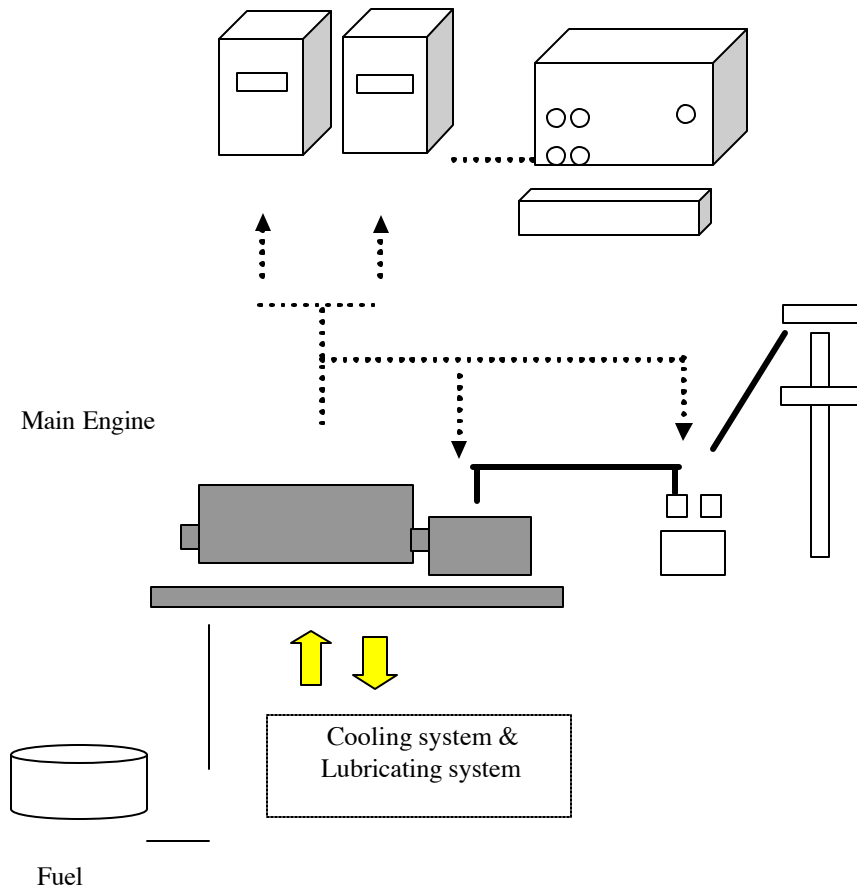
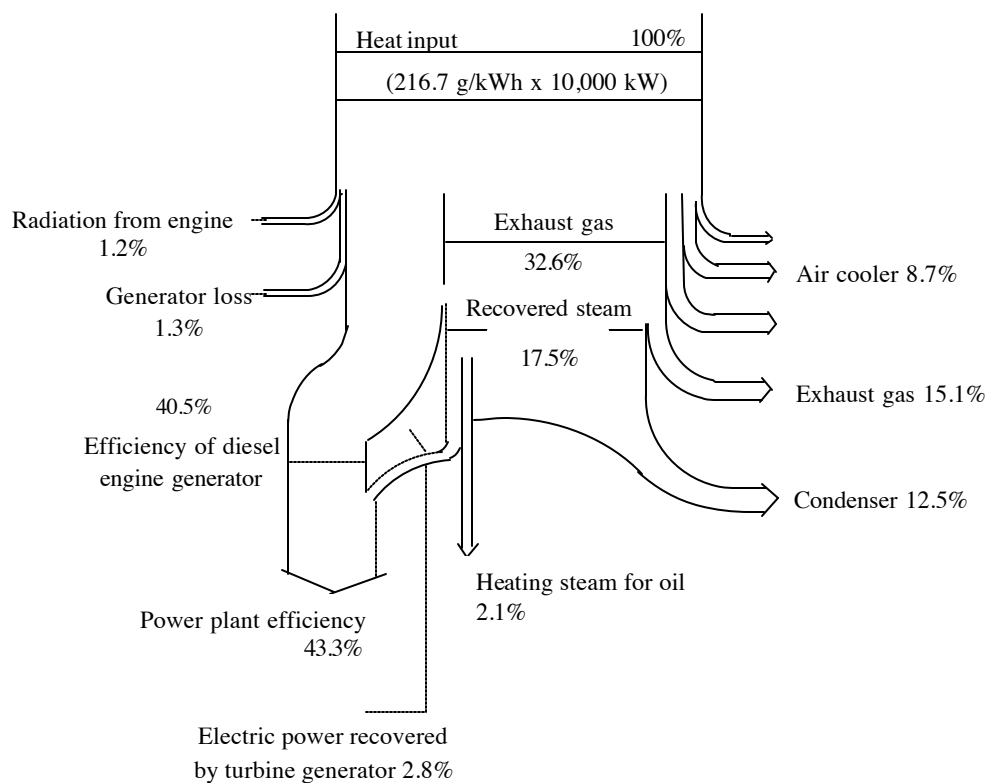


Figure ES42C: Control and Monitoring System of Diesel Power Plant

1. The power plant equipment such as generators, transformers and distribution lines are under centralized monitoring system at the central control room.
2. The Diesel generators are designed to be started, stopped and restarted from the central control room; not at the sites by the operators.
3. Those systems consist of an ITV monitor, an automatic load regulator, a data logger, a remote monitoring and control equipment.

Table ES42B: Heat Balances of 4 Cycle Diesel Engines and Related Data

No	Items	High speed small engine		Low speed large engine	
		Heat load kJ/kWh	Heat input Ratio (%)	Heat load kJ/kWh	Heat input Ratio (%)
1	Cooling water loss	1,590	16.7	2,010	12.0
2	Lubricant loss	340	3.6	637	3.8
3	Exhaust gas loss	3,190	33.5	2,530	15.1
4	Radiant heat loss	340	3.6	200	1.2
5	Air cooler loss	455	4.8	1,460	8.7
6	Condenser loss	-	-	2,090	12.5
	Remarks	Example of 1,200r/min Eng		Example of 400r/min Eng	



Note: Diesel engine generator with heat recovery steam turbine generator.

The exhaust gas loss 32.6% is converted and recovered as steam energy.

Figure ES42D: Example of Heat balance

Article 43: Bearings of Internal Combustion Engine

Article 44: Governance of Internal Combustion Engine Speed

Article 45: Emergency Stop and Alarm Devices

Article 46: Overpressure Protection Devices

Article 47: Monitoring and Alarm Systems

CHAPTER 6

Requirements for Generators

Article 48: Protection of Generators

Article 49: Electrical Equipment

Article 50: Cables in Thermal Power Plants

Article 51: Installation of Hydrogen Cooling Type Generators

1 Capacities of Turbine Generator and Cooling System

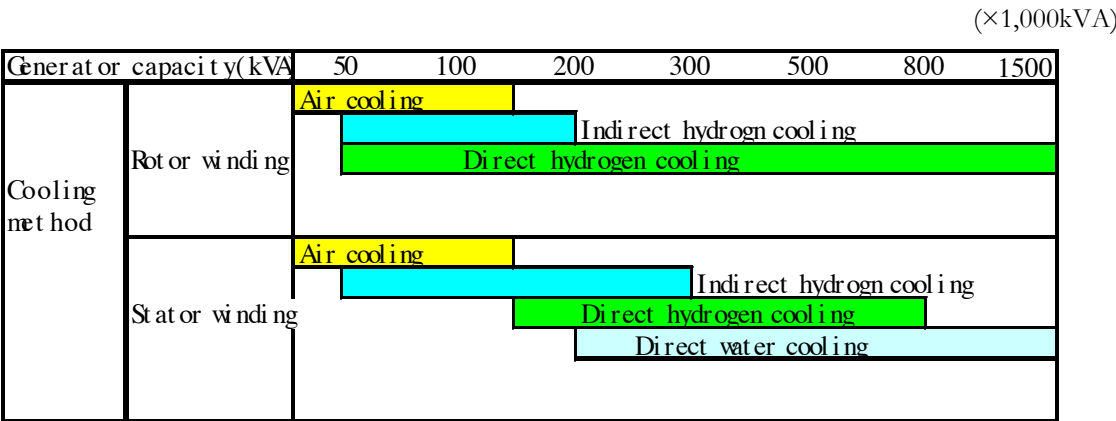


Figure ES51A: Installation Capacities of Hydrogen cooling generator

Note:

Indirect cooling: The system which cools exothermic parts, such as conductor, through insulator, core, etc.

Direct cooling: The system which cools exothermic parts, such as conductor, directly by coolant.

Direct water cooling: The system which cools stator directly by water.

(Source: Hand book for Thermal and Nuclear Power Engineers)

1.1 Replenishment (make up) of Hydrogen Gas

The shaft of a turbine generator is sealed up with oil for preventing the hydrogen gas leaking from inside of the generator.

Since part of the hydrogen gas dissolves into the oil, the replenishment of hydrogen gas is needed while even normal operation.

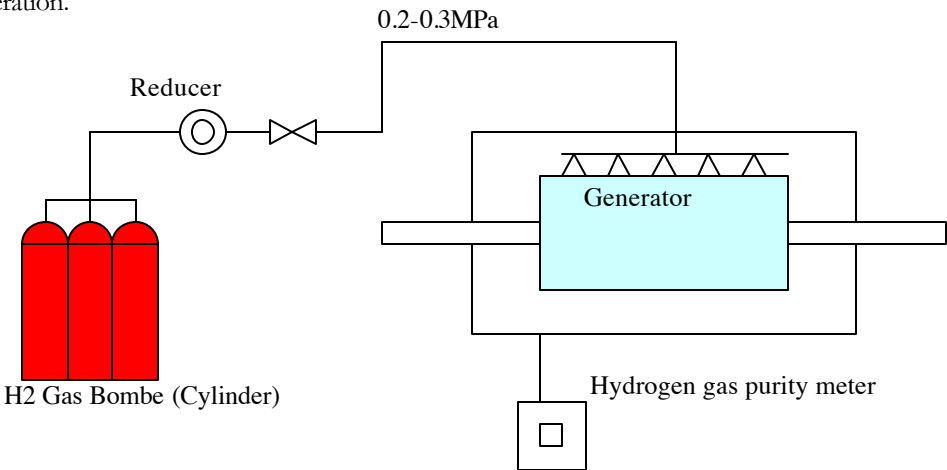


Figure ES51B: Generator Hydrogen Gas Make Up System

1.2 Hydrogen gas Seal Oil System

A hydrogen cooling system generator shall be equipped with a hydrogen gas seal oil system for preventing hydrogen gas leak from inside of the generator.

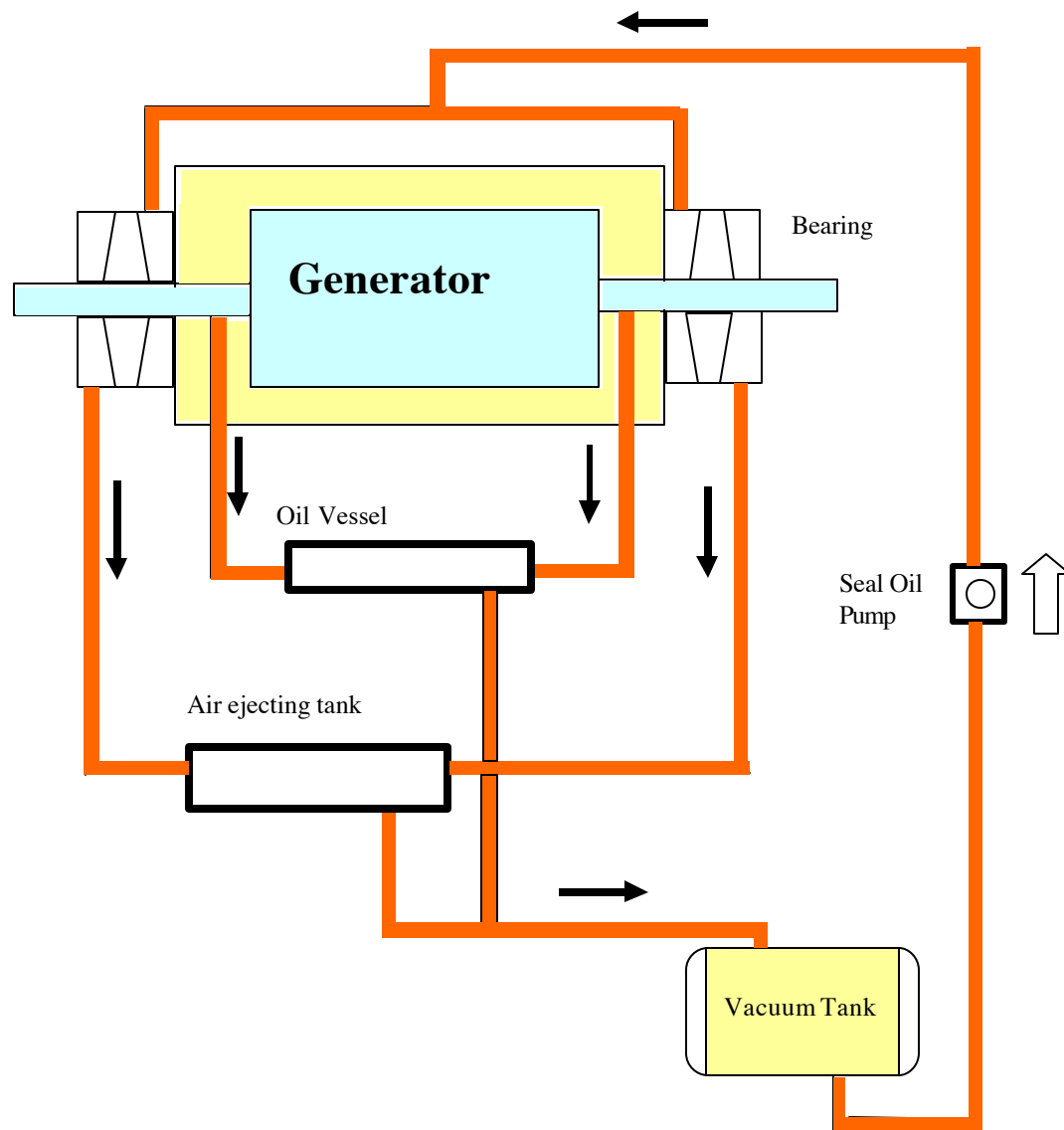


Figure ES51C: Generator Hydrogen Gas Seal Oil System

1.3 The Range of Explosion Limit (range of the explosion in air)

H₂ : 4~ 75%

The figure is a range of the density with the explosion hazard.

1.4 Prevention of Hydrogen Leakage

When something goes wrong with hydrogen seal system of a generator, the nitrogen seal system blows nitrogen gas to the generator shaft to prevent leaking hydrogen gas from generator inside, the method of this

is to enclose the hydrogen gas by using nitrogen gas. Some gas escape lines are equipped to discharge the hydrogen gas of the generator goes outside through the pipe.

Article 52: Control Systems

Unit interlock system of Thermal Power plant

A separate and independent turbine protection system shall be provided. This system shall be designed so that in the event of a trip signal occurring, its operation will result in the immediate closure of all steam valves.

1. The basic unit interlock system between boiler, steam turbine and generator is shown below.

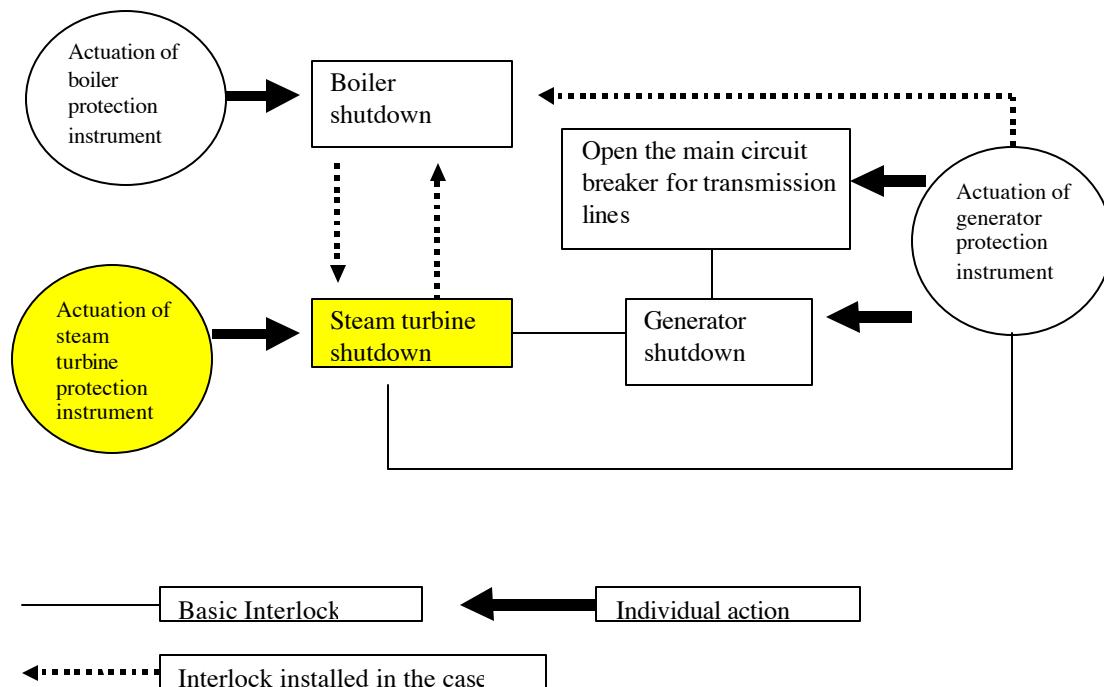


Figure ES52A: Interlock System

Explanation of above action case

When the protection instrument of steam turbine is actuated, after confirmation of each turbine valve closed condition, it leads to generator shutdown and to open main circuit breaker in general.

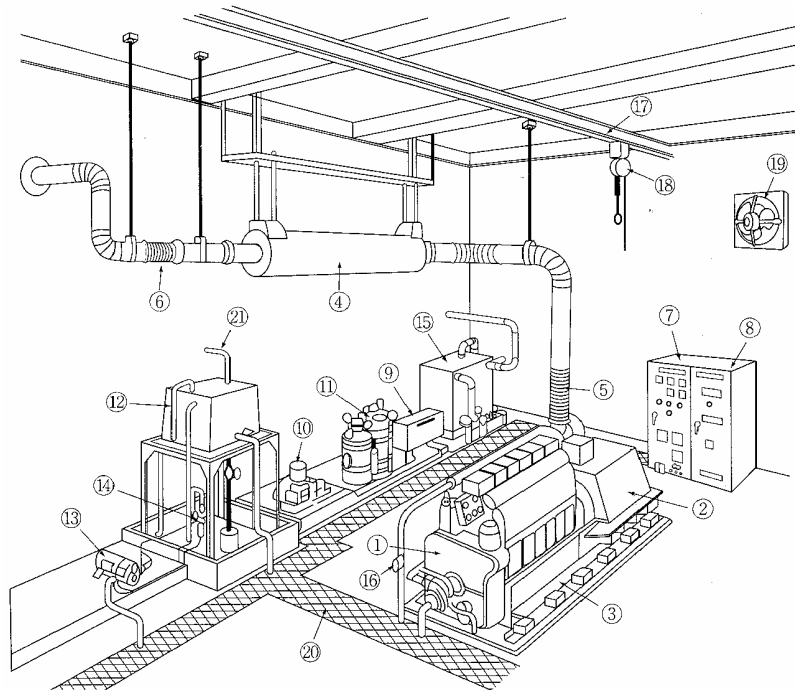
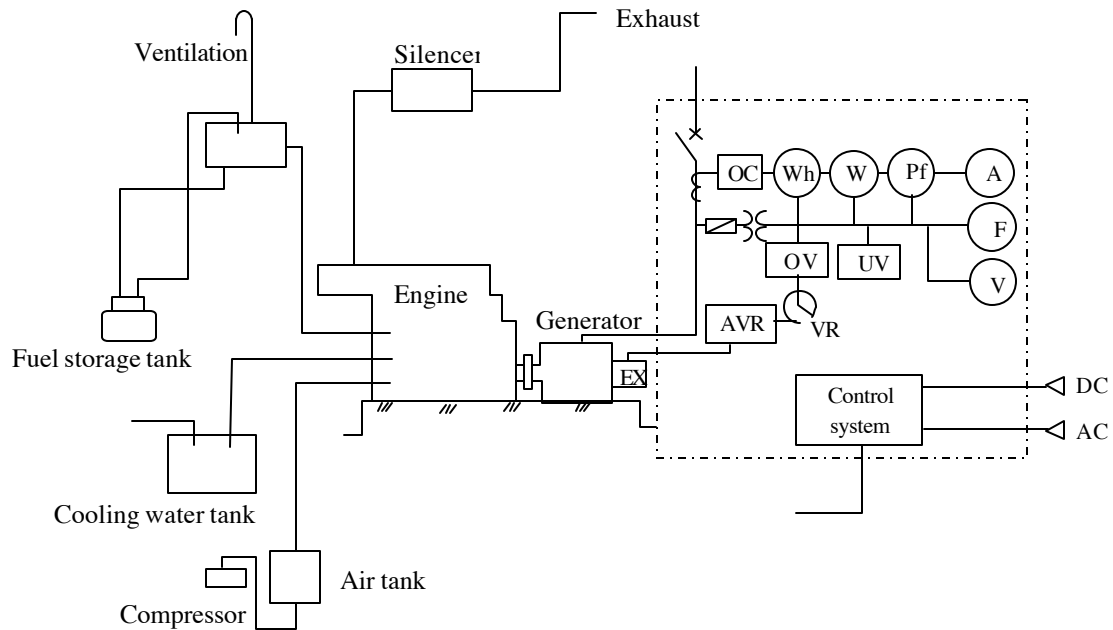
In another case, when the protection instrument of steam turbine is actuated, there are two systems as follows:

- One system is to shutdown the boiler automatically and immediately after steam turbine shutdown.
- Another system is not to shutdown the boiler automatically when certain required conditions are satisfied.

The protection equipment shall be designed on a fail-safe principle.

CHAPTER 7

Transitional Provisions



- | | | | | |
|---------------------------|-----------------|-------------------------|--------------------|--------------------------------|
| 1 Diesel engine | 2 Generator | 3 Foundation | 4 Silencer | 5 Flexible pipe |
| 6 Flexible coupling | 7 Control panel | 8 Automatic start panel | 9 Air control unit | 10 Compressor |
| 11 Air tank for a starter | 12 Fuel tank | 13 Fuel feeding pump | 14 Manual pump | 15 Cooling water tank |
| 16 Water checking device | 17 I beam | 18 Chain block | 19 Fan | 20 Pit for wiring and plumbing |
| 21 Ventilation pipe | | | | |

Figure ES53A: Example of a Diesel Generator (In case of Air starting system)

Article 54: Prevention of Electric Power Disasters

Examples of requirements prescribed in Article 54 are shown in Figure ES54A and ES54B.

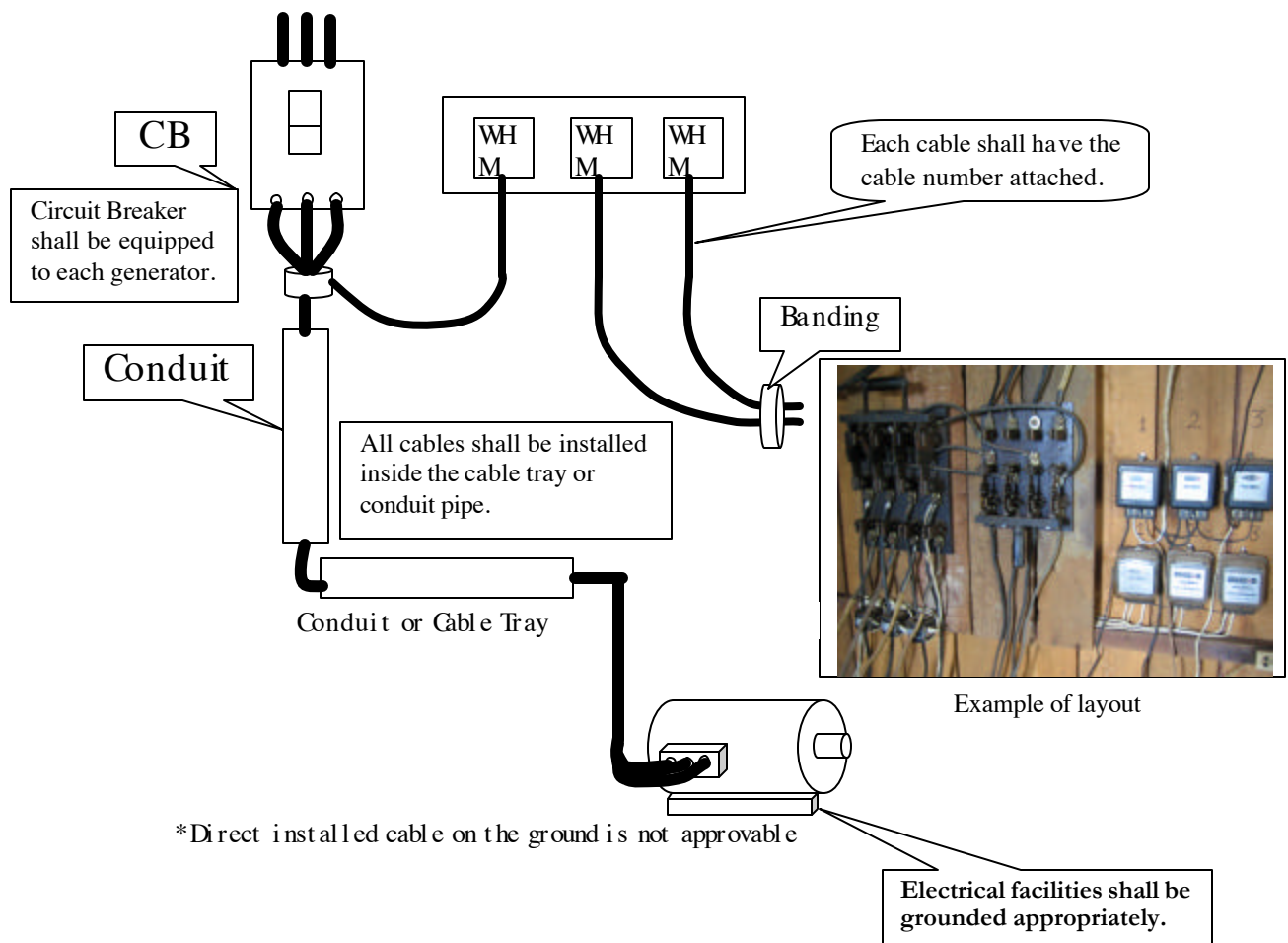


Figure ES54A: Examples of Measures for Prevention of Electric Power Disasters (1)

If the small or medium licensee can not install a conduit or a tray for cable, at least cable shall be banded in order.

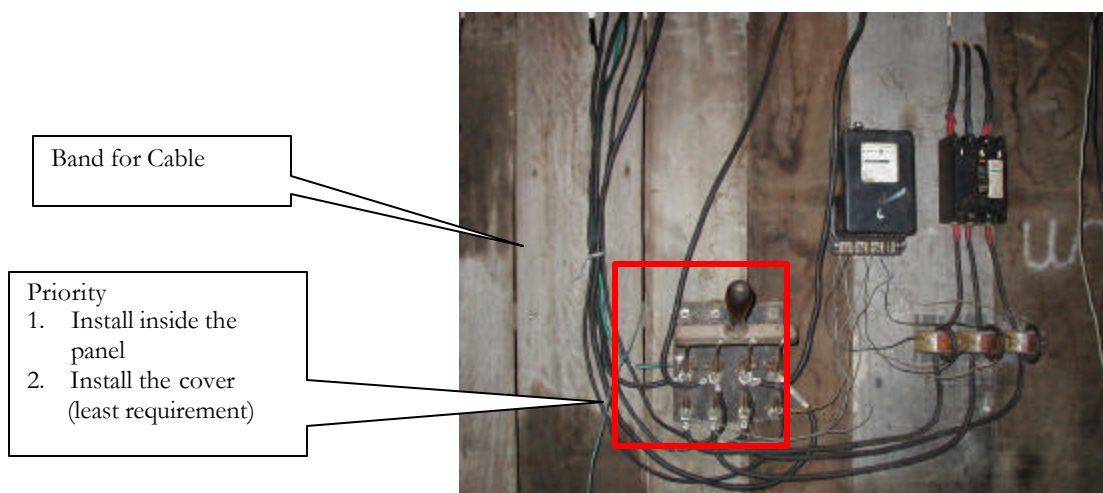


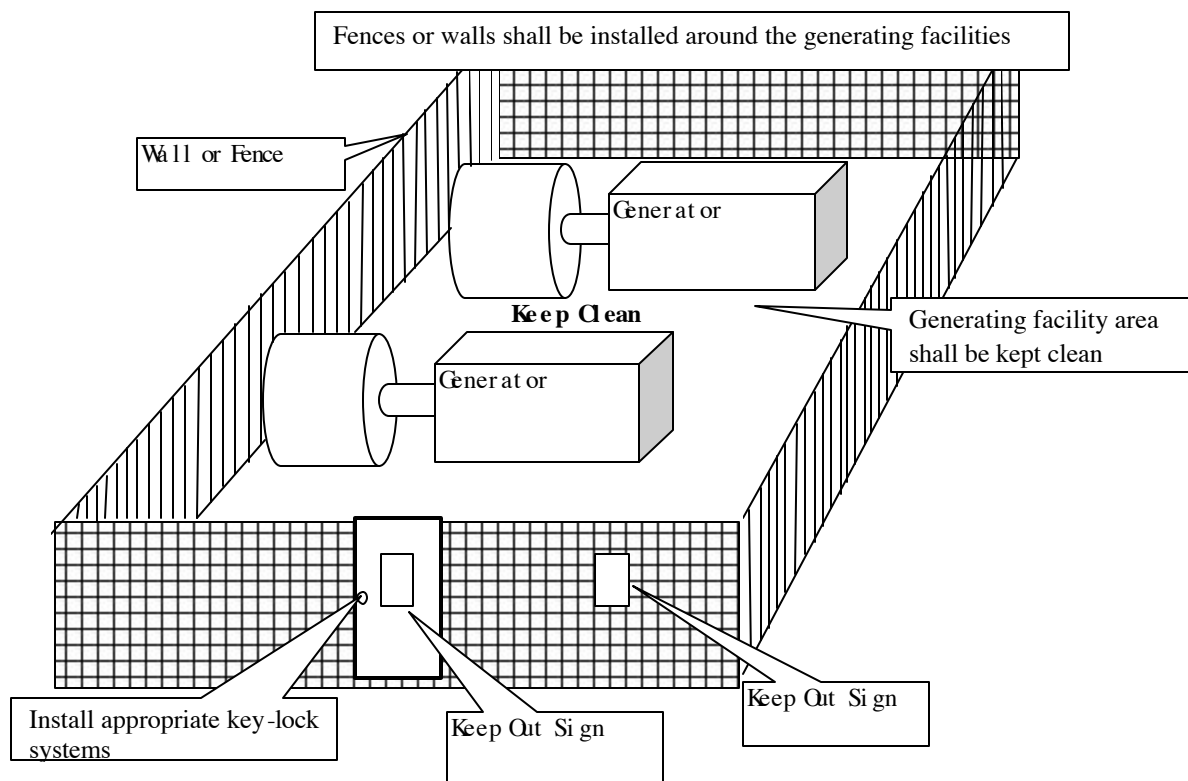
Figure ES54B: Examples of Measures for Prevention of Electric Power Disasters (2)

Article 55: Safety of Third Persons

Examples of requirements prescribed in Article 55 are shown in Figure ES55A, ES55B and ES55C.



Figure ES55A: Example of Measures for Safety of Third Persons (1)



The generation facility shall be enclosed by fences or walls and "Keep Out" signs shall be indicated.



Figure ES55B: Examples of Measures for Safety of Third Persons (2)

[Power transmission system]

In general, engine power is transmitted through power transmission equipment to a generator rotor. But even in case of small licensees, belt drive transmission systems are not approved due to the following reasons.

Reasons

- (1) It is dangerous for generator operators, when the belt is broken or come off from the pulley.
- (2) It is in danger for someone or something to be caught in a pulley or belt.
- (3) It increases the power transmission loss.

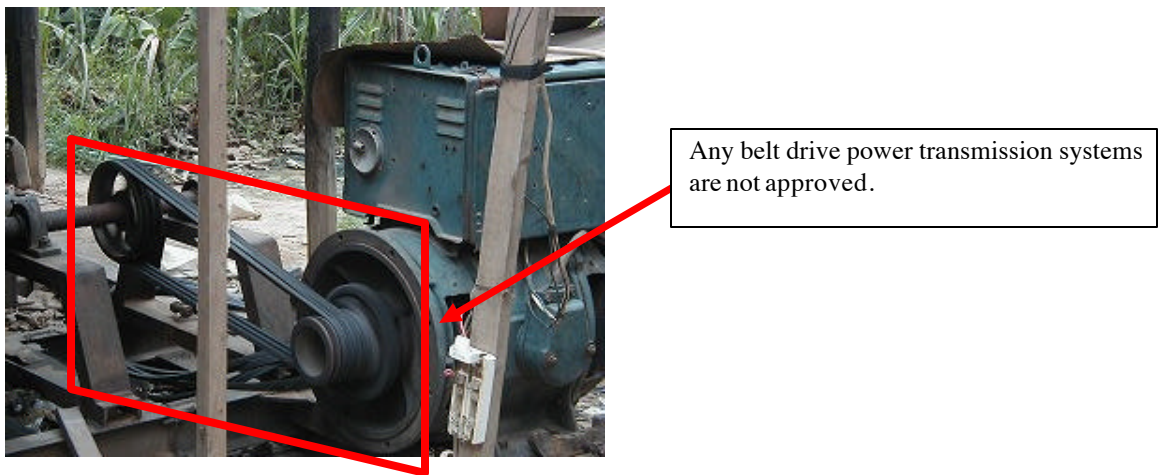


Figure ES55C: Example of Measures for Safety of Third Persons (3)

Article 56: Safety Measures for Fuel and Chemical Materials

Examples of requirements prescribed in Article 56 are shown in Figure ES56A, ES56B, ES56C and ES56D.

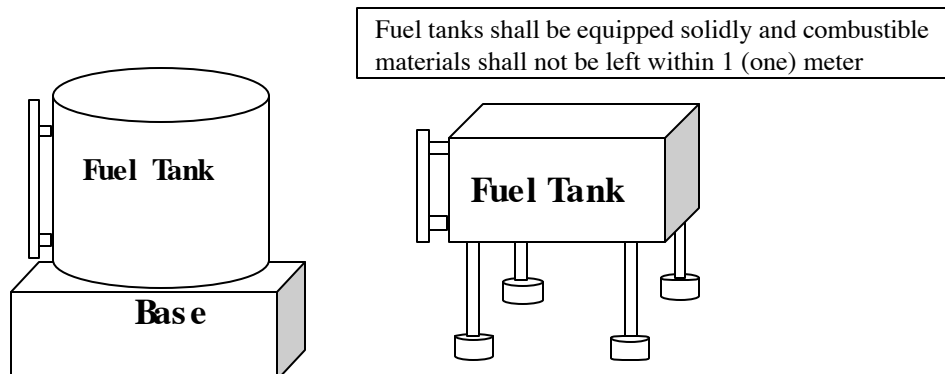


Figure ES56A: Installation for Fuel Tank



Movable fuel tanks are not approved.

Over 1 m

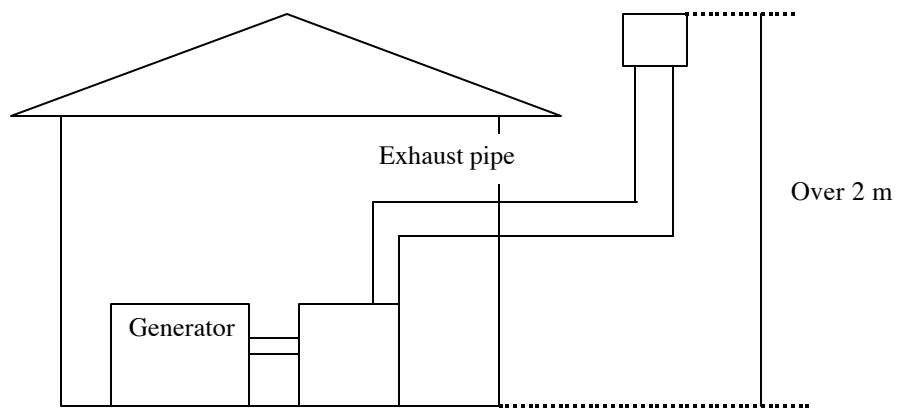
Fuel tanks shall be equipped at least 1 (one) meter away from electrical facilities

Figure ES56B: Prohibition of Movable Fuel Tank

Example of “FIXED TANK” for Fuel



Figure ES56C: Example of Fixed Fuel Tank



Exhaust gas shall be discharged at least 2 (two) meters high outside of the power house building.

Figure ES56D: Example of Exhaust Gas Equipment

Article 57: Environmental Protection

1 Noise limitation (From Environmental Regulations and Standards in Cambodia)

1.1 Cambodia Standards

Cambodia noise standards are included in the sub-decree on air pollution and noise. The sub-decree does not propose standards for stationary sources.

For limits on vehicles, all permissible levels are between 80 and 90 decibels (dB (A)). Cars for less than 12 passengers are 80 decibels. Cars for more than 12 passengers are 85 decibels. Motorcycles are between 85 and 90 decibels. All trucks are between 85 and decibels.

Ambient noise levels are proposed for daytime, evening and nighttime as follows:

Table ES57A: Ambient Noise Level Regulated

Area	Period of Time		
	06:00-18:00	18:00-22:00	22:00-06:00
Quiet areas -Hospitals -Libraries -Schools -Kindergartens	45	45	35
Residential areas -Hotels -Administrative Offices -Houses	60	50	45
Commercial/ service areas	70	65	50
Small industrial factories Intermingling in residential Areas	75	70	50

Noise control standards for workshops, factories and industries regulate the following noise levels and time intervals:

Table ES57B: Noise Level for Workshops and Factories Regulated

Noise Levels (dB (A))	Maximum Period of Time (Hours)	Level for Protective Equipment
75	32	In areas with levels above 80 (dB (A))
80	16	
85	8	
90	4	
95	2	
100	1	
105	0.5	
110	0.25	
115	0.125	

1.2 Other International Standards of Possible Interest

The World Bank's position of noise control for power plants is set forth on page 419 of the Pollution Prevention and Abatement Handbook as follows:

"Noise abatement measures should achieve either the levels given below or a maximum increase in background levels of 3 decibels (measures on the A scale) [dB (A)]. Measurements are to be taken at noise receptors located out-side the projected property boundary.

Table ES57C: Regulation by World Bank

Receptor	Maximum allowable log equivalent (hourly Measurements, in dB (A)	
	Day 07:00-22:00	Night 22:00-07:00
Residential, institutional, educational	55	45
Industrial, commercial	70	70

Article 58: Requirements for Operation

1 Report Requirement

1.1 Trouble record

(Serious accidents to be reported and Investigation by the EAC)

Whenever an accident or fire has occurred in connection with an electric power plant or equipment, the licensee shall report the accident or fire to the EAC by the quickest means available according to the related standards provided by the EAC, and subsequently with the least possible delay shall report in writing to the EAC.

The EAC will as soon as –

- a. visit the place where the accident or fire occurred;
- b. make a preliminary investigation of the circumstances;
- c. record in writing his findings which may be supported by relevant photographs, upon the investigation.

Article 59: Safety and Technical Training

1 Related Standards

The following standards are acceptable when the new thermal power plant is constructed.

Applicable Codes and Standards

The design, materials, manufacture, testing, inspection and performance of all electrical and electromechanical equipment shall, unless otherwise specified in the Technical Standards, comply with the latest revision of the International National Standard in accordance with the following standards.

Table ES-Ap-1: Applicable Codes and Standards

Abbreviation	Official name
ANSI	American National Standards Institute
ISO	International Organisation for Standardisation
JIS	Japanese Industrial Standards
NFPA	National Fire Protection Association

In the event that a conflict arises between codes and standards of practice nominated, the more stringent criteria will govern (each item of equipment and section of design will comply with one or more of the above codes).

(1) Mechanical Standards

The aforementioned mechanical standards and codes may include but not be limited to the following;

Table ES-Ap-2: Mechanical Standards

Abbreviation	Official name
ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing and Materials
AWS	American Welding Society
AWWA	American Waterworks Association
JSME	Japan Society of Mechanical Engineers
NFPA	National Fire Protection Association (USA)

(2) Electrical Standards

The aforementioned electrical standards and codes may include but not be limited to the following;

Table ES-Ap-3: Electrical Standards

Abbreviation	Official name
IEC	International Electro technical Commission
IEEE	Institute of Electrical and Electronics Engineers
JEC	Japanese Electro technical Committee
JEM	Japanese Electrical Manufacturers Association
NEMA	National Electrical Manufacturers Association

(3) Performance Testing Standards

Performance tests shall be in accordance with testing standards and codes that include but not be limited to the following;

Table ES-Ap-4: Performance Testing Standards

Number of Code/Standard	Name of Code/Standard
ASME PTC 46-1996:	Test Code on Overall Plant Performance
ISO 2314:1989:	Gas turbine acceptance tests
ASME PTC 22-1985	Gas turbines power plant: performance test codes
ISO 5167-1991	Measurement of fluid flow by means of orifice plates, nozzles and venture tubes inserted in circular cross-section conduits running full
ASTM 3588 -1989	Gas properties
ASME PTC 4.4-1981	Heat Recovery Steam Generator
ASME PTC 3.3	Gaseous fuels
ASTM 1945 -1991	Standard test method for analysis of natural gas by gas Chromatography

(4) Others

Fire detection and protection systems shall be provided to all areas and equipment within the plant and site area. These shall include fixed water protection systems, with gas protection to enclosures, fire alarms and portable appliances. The design of these systems shall comply with the current requirements of the National Fire Prevention Authority (NFPA).

Electrical installation work must be executed in accordance with statutory regulations and generally accepted International Standards and shall permit safe working.

2 Troubleshooting for reference of Small and Medium licensees

[Abnormal sound and vibration of DG]

Malfunction	Probable cause		Corrective measures
Knocking	untimely fuel injection		readjustment
	Low cetane value of fuel oil		Fuel oil replacement
	Uneven fuel injection		readjustment
	Fuel injection valve malfunction	Fuel spray defective	Injection test, replacement
		Fuel valve spring breakage	replacement
	Over cooling of engine		Water temperature control

Malfunction	Probable cause		Corrective measures
Abnormal sound in gear case	Abnormal gear	Foreign object stuck in gear	replacement
		Damaged gear	replacement
		Excessive back lash	Inspection, repair

Malfunction	Probable cause		Corrective measures
Abnormal sound around cylinder head	Loose bolts and nuts		Inspection, tightening
	Inlet and exhaust valve stick		Inspection, repair or replacement
	Widened gap in inlet and exhaust valve tappet		readjustment

Malfunction	Probable cause		Corrective measures
Abnormal sound in feed pipe	Stick or blow-by in inlet		Inspection, repair or replacement

Malfunction	Probable cause		Corrective measures
Abnormal sound cam chamber	Damaged cam and cam roller		Repair or replacement
	Damaged roller guide		Repair or replacement

Malfunction	Probable cause		Corrective measures
Abnormal sound and vibration of supercharger	Damaged bearing		Replacement
	Damaged rotor	Foreign object stuck in rotor	Replacement

Glossary for

Electric Power Technical Standard

Glossary for

Transmission and Distribution Facilities

1. Accuracy

“Accuracy” means the degree to which the result of a measurement conforms to be the correct value.

2. Armor rods

“Armor rods” means a device used to reduce damage as much as possible when flashover occurs on a suspension insulator assembly.

3. Arcing horn

“Arcing horn” means a device used to reduce damage as much as possible when flashover occurs on an insulator assembly.

4. Arcing horn gap

“Arcing horn gap” means a gap between the two parts of arcing horn of insulator assembly.

5. Arrestor

“Arrestor” means a device which prevent from abnormal voltage.

6. Auxiliary

“Auxiliary” is an adjective to provide supplementary or additional help and support to the main equipments.

7. Apparatus/device

“Apparatus/device” means a thing made or adapted for a particular purpose.

8. Backbone system

“Backbone system” means a major transmission system.

9. Bulk (power)

“Bulk (power)” means a large amount of electricity.

10. Bundle

“Bundle” means a collection of things tied up together.

11. Bus-bar

“Bus-bar” means the electrical conductor in a station on which power is concentrated for distribution

12. Bond strength (of concrete)

“Bond strength (of concrete)” means strength between a round bar or a shaped steel etc. and a concrete of a foundation.

13. Cable

“Cable” means an insulated wire or wires having a protective casing and for transmitting electricity or telecommunication signals

14. (Electrical) Circuit

“(Electrical) Circuit” means a path that transmits electric current

15. Circuit breaker

“Circuit breaker” means an automatic device for stopping the flow of current in an electric circuit as a safety measures.

16. Communication system

“Communication system” means a system to communicate among dispatching centers, substations and power generation facilities in order to send and receive data, information, etc.

17. Compression strength

“Compression strength” means a strength that flatten something.

18. Consumer

“Consumer” means an end user of electricity.

19. Conductor

“Conductor” means a material that transmit electricity.

20. Conduit

“Conduit” means a tube or trough for protecting electric wiring.

21. Corrosion resistant

“Corrosion resistant” means offering resistance to corrosion.

22. Corona

“Corona” means the glow around a conductor at high electric field strength.

23. Corrosion

“Corrosion” means chemical change which makes something bad in quality.

24. Culvert

“Culvert” means a tunnel many cables are laid in.

25. Cross arm

“Cross arm” means component parts of the supporting structure, which is out of its body to support conductors.

26. Cross sectional area

“Cross sectional area” means an areas of the surface shape exposed by making a straight cut through something, especially at right angles to an axis.

27. Dispatching center

“Dispatching center” means the electric power facility which monitors and controls the electric power flow and facilities.

28. Distribution

“Distribution” means supply electricity to consumers.

29. Dielectric strength

“Dielectric strength” means the strength to withstand a specified voltage.

30. Damper

“Damper” means a device of overhead lines for reducing aeolian vibration caused by wind (Phenomenon of Karman’s vortex street).

31. Discharge current

“Discharge current” means the current to release or neutralize the electric charge of something

32. Earth

“Earth” means the ground which has zero electrical potential in the grounding system.

33. Electrode

“Electrode” means a conductor which electricity enters or leaves an object.

34. Electrical equipment

“Electrical equipment” means electrically-charged facilities.

35. Exhaust

36. Exhaust

“Exhaust” means a verb to make useless gas go out.

37. EPR

“EPR” means ethylene propylene rubber.

38. EDS

“EDS” is abbreviation of every day stress for transmission lines, and expressed as the percentage of ultimate tensile strength under windless condition.

39. Electric field

“Electric field” means the region around an electric charge in which an electric force is exerted on another charge.

40. Faults

“Faults” means an accident which may cause power outage.

41. Safety factor

“Safety factor” means a margin of security against risks

42. Electric power facility

“Electric power facility” means generation facilities, substations, switching stations, electrical lines, and dispatching centers, including equipment, buildings, etc.

43. Failure

“Failure” means an accident which may cause power outage.

44. Optical fiber

“Optical fiber” means a thin fiber through which light can be transmitted

45. Frequency

“Frequency” means the number of cycles of alternative current.

46. Flashover

“Flashover” means an electric short circuit made through the insulation materials between exposed conductors.

47. GREPTS

“GREPTS” is abbreviation of General Requirements of Electric Power Technical Standards

48. Generation

“Generation” means the production of electricity.

49. Generator

“Generator” means machine that converts mechanical energy to electricity.

50. Grounding

“Grounding” means electrical connection to the ground, regarded as having zero electrical potential.

51. Guy wire

“Guy wire” means a wire to reinforce the foundation of a supporting structure.

52. High-voltage

“High-voltage” means the voltage higher than 35kV.

53. Horizontal

“Horizontal” is an adjective to be parallel to the plane of the horizon; at right angles to the vertical.

54. Insulation

“Insulation” means the materials or action to prevent the passage of electricity to or from something

55. IEC

“IEC” is abbreviation of International Electrotechnical Commission.

56. Impulse

“Impulse” means a pulse of electrical energy; a brief current.

57. Intrusion voltage

“Intrusion voltage” means voltage going into power system, usually abnormal high voltage.

58. Impulse spark-over voltage

“Impulse spark-over voltage” means the impulse voltage that makes electric short through the insulation material between two conductors.

59. Low-voltage

“Low-voltage” means the voltage not more than 600V.

60. Lightning

“Lightning” means the occurrence of a natural electrical discharge of very short duration and high voltage between a cloud and the ground or within a cloud, accompanied by a bright and typically also thunder.

61. Lightning guard

“Lightning guard” means the protection against lightning.

62. Longitudinal

“Longitudinal” is an adjective to run lengthwise rather than across

63. Metalwork

“Metalwork” means a material used for grounding work.

64. Metallic

“Metallic” means an adjective relating to metal.

65. Metal plate

“Metal plate” means a material used for grounding work.

66. Metal rod

“Metal rod” means a material used for grounding work.

67. Metal tape

“Metal tape” means a material used for grounding work.

68. Messenger wires

“Messenger wires” means a wire to string conductor when power line or ground wire is installed.

69. Medium-voltage

“Medium-voltage” means the voltage more than 600V but more than 35kV.

70. ISO

“ISO” is abbreviation of International organization for Standardization.

71. Overhead line

“Overhead line” means a transmission line or distribution line supported by tower or pole in the air.

72. Phase

“Phase” means as follows:

1. AC power system usually consists of three circuits. These circuits are called phase
2. Voltage and current in AC power system consist of three components; zero-phase-sequence component, positive-phase-sequence component, and negative-phase-sequence component. These components are called phase.

73. Polyethylene

“Polyethylene” means a tough, light flexible synthetic resin made by polymerizing ethylene, chiefly used for plastic bags, food containers, and other packaging.

74. Pole

“Pole” means a kind of supporting structures; usually a long, slender, round piece of wood, metal or concrete.

75. Power transmission

“Power transmission” means sending electricity.

76. Power outage

“Power outage” means shutdown of electricity supply.

77. Pressure

“Pressure” means a force produced by the gas or liquid.

78. PVC

“PVC” means polyvinyl chloride.

79. RTU

“RTU” is an abbreviation of “Remote Terminal unit” for the SCADA system, installed at electric power facilities for monitoring and controlling those facilities.

80. Rack

“Rack” means a shelf which supports cables.

81. Relay

“Relay” means an electrical device which detect a fault or abnormal condition of power system or electric power equipment.

82. Remote

“Remote” is an adjective to control or operate objects from other places.

83. Remote areas

“Remote areas” means an area whose electric power demand is too small and whose grids are not connected to other grids.

84. Resistance

“Resistance” the degree to which substance or device opposes the passage of an electric current, causing energy dissipation.

85. SCADA

“SCADA” is abbreviation of “Supervisory, Control, and Data Acquisition” and means equipment used for monitoring and receiving data.

86. SREPTS

“SREPTS” is abbreviation of Specific Requirements of Electric Power Technical Standard.

87. SWER

“SWER” is an abbreviation of “Single Wire Earth Return system”. “SWER” is an electricity distribution method using one conductor with the return path through the earth.

88. Electric shock

“Electric shock” means a sudden discharge of electricity through a part of the body.

89. Shield

“Shield” means a device or material which protects the object against something else.

90. Shunt reactor

“Shunt reactor” means the reactor connected to the electric power system in parallel to supply reactive power.

91. Slenderness

“Slenderness” ratio means the ratio of the length of long side divided by the turning radius.

92. Spark gap

“Spark gap” means a space between electrical terminals across which a transient discharge passes.

93. Standard

“Standard” means the Electric Power Technical Standards in the Kingdom of Cambodia.

94. Station

“Station” means a place where electrical activities are based: power station, substation, switching station.

95. Stabilize winding

“Stabilize winding” means a supplementary delta-connected winding provided in a star-star-connected or star-zigzag-connected transformer to decrease its zero-sequence impedance. This is not intended for three-phase connection to an external circuit.

96. Structure

“Structure” means as follows:

1. A object which consists of parts connected together in an ordered way
2. The arrangement of and relationship between the parts or elements of something complex

97. Insulator string

“Insulator string” means a set of things tied together.

98. Stress

“Stress” means pressure or tension exerted on a material object.

99. Strength

“Strength” means the capacity to withstand great force, heat, etc.

100. Surge

“Surge” means a sudden marked increase in voltage or current in an electric circuit.

101.Substation

“Substation” means the electric power facilities where voltage of electrical power is transformed and including transformers, lightning arresters, circuit breakers, disconnecting switches, voltage transformers, current transformers, bus bars, protective relay systems, RTU for SCADA system, telecommunication facilities, etc.

102.Switching Station

“Switching Station” means the electric power facilities used to change-over the electrical lines, which include disconnecting switches, circuit breakers, bus-bars, protective relay system, the RTU for the SCADA system, etc.

103.System

“System” means a set of things working together as parts of a mechanism or an interconnecting network.

104.Synthetic resin

“Synthetic resin” means a solid or liquid synthetic organic polymer used as the basis of plastics, adhesives, varnishes, or other products.

105.Tensile strength

“Tensile strength” means the resistance of a material to breaking under tension.

106.Thermal

“Thermal” an adjective to Relate to heat.

107.Tower

“Tower” means a kind of supporting structures for transmission line or distribution line.

108.Torsional load

“Torsional load” means a load of the action of twisting or the state of being twisted.

109.Transient

“Transient” means lasting only for a short time.

110.Transformer

“Transformer” means an apparatus for reducing or increasing the voltage of an alternating current.

111. Withstand voltage

“Withstand voltage” means the test voltage to be applied under specified conditions in a withstand test.

112. XLPE

“XLPE” means crosslinked polyethylene insulated cable.

113. UTS

“UTS” is the abbreviation of ultimate tensile strength.

114. Velocity

“Velocity” means a speed at which something moves in a particular direction.

115. Vertical

“Vertical” means a direction to the right angles to a horizontal plane.

116. Valve

“Valve” means a device for controlling the passage of fluid through a pipe or duct, especially an automatic device allowing movement in one direction only.

117. Voltage

“Voltage” means an electromotive force or potential difference expressed in volts.

Glossary for

Thermal Power Generating Facilities

1. Accessory

“Accessory” is an adjective to contribute to or aiding an activity or process in a minor way.

2. Alarm

“Alarm” means a warning sound or device.

3. Arrester

“Arrester” means a device which prevent from abnormal voltage.

4. Atomization

“Atomization” means spraying fine water.

5. Auxiliary

“Auxiliary” is an adjective to provide supplementary or additional help and support to the main equipments.

6. (Bus) bar

“(Bus) bar” means the electrical conductor in a station on which power is concentrated for distribution.

7. Barrel

“Barrel” means a cylindrical tube forming part of machinery.

8. Bearing

“Bearing” means a part of a machine that allows one part to rotate or move in contact with another part with as little friction as possible.

9. Biphenyl

“Biphenyl” means an organic compound containing two phenyl groups bonded together.

10. Blade

“Blade” means a flat, wide section of a device or equipment.

11. Boiler

“Boiler” means a tank for generating steam under pressure in a steam engine.

12. Bolt

“Bolt” means a long pin with a head that screws into a nut, used to fasten things together.

13. Bore

“Bore” means a hollow part inside material shaped like a pipe or a tube.

14. Cable

“Cable” means an insulated wire or wires having a protective casing and for transmitting electricity or telecommunication signals.

15. Capacitor

“Capacitor” means a device used to store an electric charge, consisting of one or more parts of conductors separated by an insulator.

16. Casing

“Casing” means a cover or shell that protects or encloses something.

17. Centrifugal

“Centrifugal” means adjective to move or tend to move away from a centre, peculiar to circular motion.

18. Chamber

“Chamber” means an enclosed space or cavity for air, steam, etc. of equipment.

19. (Electrical) Circuit

“(Electrical) Circuit” means a path that transmits electric current.

20. Combustibility

“Combustibility” means the degree to burn.

21. Compressor

“Compressor” means a machine used to supply air or other materials at increased pressure.

22. Condenser

“Condenser” means an apparatus or container for condensing vapor.

23. Consumer

“Consumer” means an end user of electricity.

24. Corrosion/erosion

“Corrosion/erosion” means chemical change which makes something bad in quality.

25. Cylinder

“Cylinder” means a piston chamber in a steam or internal-combustion engine.

26. Dam

“Dam” means an artificial barrier across a stream including embankments, its foundations and affiliated facilities such as spillways, constructed to store flowing water or divert it to intakes for power generation.

27. Detector/sensor

“Detector/sensor” means an instrument which is used to discover that something is present, or to measure how much of something there is.

28. Dielectric strength

“Dielectric strength” means the strength to withstand a specified voltage.

29. Diesel

“Diesel” means an internal-combustion engine in which heat produced by the compression of air in the cylinder is used to ignite the fuel. A heavy petroleum fraction used as fuel in diesel engines.

30. Diffuser

“Diffuser” means a device for broadening a gas flow and reducing its speed.

31. Dispatching center

“Dispatching center” means the electric power facility which monitors and controls the electric power flow and facilities.

32. Distribution

“Distribution” means to supply electricity to consumers.

33. Device

“Device” means a thing made or adapted for a particular purpose.

34. Drum

“Drum” means a part of the Boiler.

35. Economizer

“Economizer” means a part of the Boiler.

36. Engine

“Engine” means a machine that can convert any of various forms of energy into mechanical power or motion.

37. Exhaust

“Exhaust” means a verb to make unuseful gas go out.

38. Extinguisher

“Extinguisher” means a thing or equipment to put off fires.

39. Frequency

“Frequency” means the number of cycles of alternative current.

40. Fuel

“Fuel” means a substance such as coal, oil, or petrol which is burned to provide heat or power.

41. Furnace

“Furnace” means a part of the Boiler.

42. Gauge

“Gauge” means a device which measures the amount or quantity of something and shows the amount measured.

43. Generator

“Generator” means a machine that converts mechanical energy to electricity.

44. Governor

“Governor” means a device automatically regulating the supply of fuel, steam, or water to a machine, controlling the speed.

45. Grid

“Grid” means a network of cables or wires for distributing power, especially high-voltage transmission lines for electricity.

46. Grounding

“Grounding” means electrical connection to the ground, regarded as having zero electrical potential.

47. Homogenize

“Homogenize” means the verb to make uniform or similar.

48. Hydraulic

“Hydraulic” is an adjective related to equipment or machinery which involves or is operated by a fluid which is under pressure, such as water or oil.

49. IEC

“IEC” is abbreviation of International Electrotechnical Commission.

50. Impeller

“Impeller” means the part rotated by the flow of fluid, such as water, steam, etc.

51. ISO

“ISO” is an abbreviation of International Organization for Standardization.

52. Lightning

“Lightning” means the occurrence of a natural electrical discharge of very short duration and high voltage between a cloud and the ground or within a cloud, accompanied by a bright and typically also thunder.

53. (Electrical) Line

“(Electrical) Line” means the part of electric power facilities used to transmit or supply electricity, which connects power stations, substations, switching stations and user’s sites, and includes lines and associated protective devices and switchyards.

54. Load

“Load” means the amount of electricity supplied by a generating system at any given time.

55. Lubricant

“Lubricant” means a substance used for lubricating an engine or component, such as oil and grease.

56. Nozzle

“Nozzle” means a cylindrical or round spout at the end of a pipe, hose, or tube used control a jet of gas or liquid.

57. Oil

“Oil” means a viscous liquid derived from petroleum.

58. Outpouring

“Outpouring” means something that streams out rapidly.

59. Overpressure

“Overpressure” means a condition that the pressure is beyond its criterion.

60. Overheat

“Overheat” means a condition that the temperature is beyond its criterion.

61. Petroleum

“Petroleum” a liquid mixture of hydrocarbons which is present in suitable rock strata and can be extracted and refined to produce fuels including petrol, paraffin, and diesel oil.

62. Piston

“Piston” means a disc or short cylinder fitting closely within a tube in which it moves up and down against a liquid or gas, used in an internal-combustion engine to drive motion, or in a pump to impart motion.

63. (Power) plant

“(Power) plant” means a place where electricity is generated.

64. Polychlorinated

“Polychlorinated” mean a chemical material Related to PCB.

65. Pressure

“Pressure” means a force produced by the gas or liquid.

66. Pump

“Pump” means a mechanical device using suction or pressure to raise or move gases/liquids, or to compress gases/liquids.

67. Radiator

“Radiator” means a cooling device that radiates heat.

68. Raw water

“Raw water” means the water before purification.

69. Reheater

“Reheater” means a part of the Boiler.

70. Resistance

“Resistance” means the degree to which substance or device opposes the passage of an electric current, causing energy dissipation.

71. Rotor

“Rotor” means a rotary part of a machine, in particular:

- The rotating assembly in a turbine,
- The rotating part of the distributor of an internal-combustion engine which successively makes and breaks electrical contacts so that each spark plug fires in turn.

72. Rotor

“Saturated steam/water” means a steam/water containing the largest possible amount of a particular solute.

73. Silencer

“Silencer” means a device used to reduce the noise.

74. SREPTS

“SREPTS” is abbreviation of Specific Requirements of Electric Power Technical Standard.

75. Standard

“Standard” Standard means the Electric Power Technical Standards in the Kingdom of Cambodia.

76. Station

“Station” means a place where electrical activities are based: power station, substation, switching station.

77. Stator

“Stator” means the stationary portion of an electric generator or motor, especially of an induction motor.

78. Steam

“Steam” means the vapour into which water is converted when heated, forming a white mist of minute water droplets in the air.

79. Stream

“Stream” means a continuous flow of liquid, air, or gas.

80. Strength

81. Strength

“Strength” means the capacity to withstand great force, heat, etc.

82. Stress

“Stress” means pressure or tension exerted on a material object

83. Structure

“Structure” means as follows:

1. A object which consists of parts connected together in an ordered way
2. The arrangement of and relationship between the parts or elements of something complex

84. Substation

“Substation” means the electric power facilities where voltage of electrical power is transformed and including transformers, lightning arresters, circuit breakers, disconnecting switches, voltage transformers, current transformers, bus bars, protective relay systems, RTU for SCADA system, telecommunication facilities, etc.

85. Superheater

“Superheater” means a part of the Boiler.

86. Switchgear

“Switchgear” means a switching equipment for electric power.

87. Thermal

“Thermal” is an adjective to relate to heat.

88. Thermocouple

“Thermocouple” means a thermoelectric device for measuring temperature, consisting of two wires of different metals connected at two points, a voltage being developed between the two junctions proportion to the temperature difference.

89. Torque

“Torque” means a force that tends to cause rotation.

90. Transformer

“Transformer” means an apparatus for reducing or increasing the voltage of an alternating current.

91. Tube-wall

“Tube-wall” means a part of a boiler

92. Turbine

“Turbine” means a machine for producing continuous power in which a wheel or rotor, typically fitted with vanes, is made to revolve by a fast-moving flow of water, steam, gas, air, or other fluid.

93. Vacuum

“Vacuum” means a space which contains no air or other gas.

94. Valve

“Valve” means a device for controlling the passage of fluid through a pipe or duct, especially an automatic device allowing movement in one direction only.

96. Velocity

“Velocity” means a speed at which something moves in a particular direction.

97. Vessel

“Vessel” means a hollow container, especially one used to hold liquid.

98. Vibration

“Vibration” means the continuous and rapid movement to and fro.

99. Viscosity

“Viscosity” means the state of being thick, sticky, and semi-fluid in consistency, due to internal friction.

100. Voltage

“Voltage” means an electromotive force or potential difference expressed in volts.

101. Waterway

“Waterway” means a general term of channels and auxiliaries including gates and valves that take flowing water, convey it to hydro-turbines, and discharge it into a river and so on for power generation. “Waterway” is generally composed of intakes, forebays (settling basins), headraces, head tanks or surge tanks, penstocks, tailraces, outlets, and other facilities.

Parameter	Standard	
Lead	mg/kg	70
Iron	mg/kg	-
Chromium	mg/kg	64
Mercury	mg/kg	6.6

Appendix I - Part 3 ADB Prohibited Investment Activities List

1. Production or activities involving harmful or exploitative forms of forced labour ¹ or child labour ²
2. Production of or trade in any product or activity deemed illegal under host country laws or regulations or international conventions and agreements or subject to international phase outs or bans, such as pharmaceuticals ³ , pesticides, and herbicides ⁴ , (b) ozone-depleting substances ⁵ , (c) polychlorinated biphenyls ⁶ and other hazardous chemicals ⁷ , (d) wildlife or wildlife products regulated under the Convention on International Trade in Endangered Species of Wild Fauna and Flora ⁸ , and (e) trans-boundary trade in waste or waste products ⁹
3. Production of or trade in weapons and munitions, including paramilitary materials
4. Production of or trade in alcoholic beverages, excluding beer and wine ¹⁰
5. Production of or trade in tobacco
6. Gambling, casinos, and equivalent enterprises
7. Production of or trade in radioactive materials ¹¹ , including nuclear reactors and components thereof
8. Production of, trade in, or use of un-bonded asbestos fibres ¹²
9. Commercial logging operations or the purchase of logging equipment for use in primary tropical moist forests or old growth forests
10. Marine and coastal fishing practices such as large-scale pelagic drift net fishing and fine mesh net fishing, harmful to vulnerable and protected species in large numbers and damaging to marine biodiversity and habitats.

¹ Forced labour means all work or services not voluntarily performed, that is, extracted from individuals under threat of force or penalty

² Child labour means the employment of children whose age is below the host country's statutory minimum age of employment or employment of children in contravention of International Labor Organization Convention No. 138 "Minimum Age Convention" (www.ilo.org).

³ List of pharmaceutical products subject to phaseouts or bans is available at <http://www.who.int>.

⁴ A list of pesticides and herbicides subject to phaseouts or bans is available at <http://www.pic.int>.

⁵ A list of the chemical compounds that react with and deplete stratospheric ozone resulting in the widely publicized ozone holes is listed in the Montreal Protocol, together with target reduction and phaseout dates. Information is available at <http://www.unep.org/ozone/montreal.shtml>.

⁶ A group of highly toxic chemicals, polychlorinated biphenyls are likely to be found in oil-filled electrical transformers, capacitors, and switchgear dating from 1950 to 1985.

⁷ A list of hazardous chemicals is available at <http://www.pic.int>.

⁸ A list is available at <http://www.cites.org>.

⁹ As defined by the Basel Convention; see <http://www.basel.int>.

¹⁰ This does not apply to investee companies who are not substantially involved in these activities. Not substantially involved means that the activity concerned is ancillary to an investee company's primary operations.

¹¹ This does not apply to the purchase of medical equipment, quality control (measurement) equipment, and any equipment for which ADB considers the radioactive source to be trivial and adequately shielded.

¹² This does not apply to the purchase and use of bonded asbestos cement sheeting where the asbestos content is less than 20%.