THE SOCIALIST REPUBLIC OF VIETNAM

MINISTRY OF INDUSTRY

REGULATIONS

ON ELECTRICAL INSTALLATIONS

PART I

GENERAL PROVISIONS

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CONTENT

PART 1

GENERAL PROVISIONS

CHAPTER I.1

GENERAL

Scope and definitions

I.1.1. These regulations are applied to power works that are newly constructed and renovated, with the voltage up to 500 kV, except those of special use.

I.1.2. Electrical installations are equipment that are connected and used for the power production, transformation, transmission, distribution and consumption. In these regulations, electrical installations are classified by two groups:

• Electrical installations with the voltage up to 1kV

• Electrical installations with the voltage above 1 kV

I.1.3. Outdoor electrical installations mean power equipment installed outdoor.

Outdoor open-type electrical installations: Electrical equipment that are not protected against direct contact and not covered to prevent environmental impacts.

Outdoor close-type electrical installations: Electrical equipment that are covered against direct contact and to prevent environmental impacts.

I.1.4. Indoor electrical installations: Electrical installations installed indoor or in a closed room.

Indoor open type electrical installations: Electrical installations that are not fully protected against direct contact.

Indoor close type electrical installations: Electrical installations that are fully protected against direct contact.

I.1.5. Power room means a room or a part of the house/building that is separated to install electrical equipment and/or electrical cabinet and panel.

I.1.6. Dry room means a room with a relative humidity below 75%. Room that could not be specified by conditions stated in Article I.1.9, 10, 11, is regarded as a normal room.

I.1.7. Humid room means the room where the relative humidity is over 75%.

I.1.8. Extreme humid room means the room where the relative humidity is approximately 100% (The water stagnates in ceiling, walls, floor and furnishings.)

I.1.9. Hot room means the room where the temperature exceeds +35°C during more than 24 consecutive hours.

I.1.10. Dusty room or place means the room or place which is very dusty.

Dusty room or place is classified by two types: Room or place where the dust is conductive and room or place where the dust is not conductive.

I.1.11. Place with chemical activity environment means the place regularly or in long period of time contains steam, gas, liquid substances which can produce mold, resulting in the damage of the insulating part and/or of the conductive part of the electrical devices.

I.1.12. Based on the level of danger caused by the electricity to people, the rooms or places with electrical equipment installed are classified by the followings:

1. Dangerous room or place means the room or place having one of the following factors:

a. Humidity or conductive dust (see Article I.1.7 and Article I.1.10).
b. Floor having electrical conductivity (Floor made of metal, soil, concrete, brick, etc.).
c. High temperature (see Article I.1.9).

d. Possibility for people to touch metal structure of building or equipment, machinery, etc. which are earthed one side, and the metal casing of electrical equipment the other side.

e. Electric field intensity which is greater than the permitted level.

2. Very dangerous room or place means room or place having one of the following factors:

   a. Very high humidity (see Article I.1.8).
   b. Chemical activity environment (see Article I.1.11).
   c. Two factors of the dangerous room at the same time.

3. Room or place which is not of the two types above is regarded as non-dangerous room or place.

I.1.13. Noise level: When newly construct or renovate power works, it is necessary to take measures to reduce noise to be sure that the noise does not exceed the level permitted in the tables I.1.1 and I.1.2.

The measures for noise reduction purpose are:

• Technical measures: To design industrially, to isolate noise source, to use technology process of low noise level, devices having low sound power level.

• Acoustic measures in the construction: To use sound-proof or attenuation materials.

• Applying the remote control and automation technology.

I.1.14. Solar radiation: For indoor electric installations the influence of solar radiation can be ignored. But in some special cases, the device placed in a position under the radiation intensity, the attention is to be drawn for the temperature rise of the surface.

For the outdoor power installations, it is necessary to take special measures to ensure that their working temperature does not exceed the allowed temperature.

I.1.15. SF_6 gas leakage

In the power room having SF_6 containers placed above or on the ground, it is required that the half of the area of the vents must be located near the ground. If the above requirement can not be met, the forced ventilation is required.

In the power room having SF_6 containers placed on the ground, the forced ventilation required if the emissions affect the health and safety of people. The rooms, tubes, tunnels etc. below and connected with the room having devices using SF_6 gas, the ventilation is required.

Table I.1.1: Maximum allowed noise level in public and residential areas (Unit: dB):

Areas	**Times**		
	From 6h to 18h	From 18h to 22h	From 22h to 6 h
Special areas, such as: Hospitals, schools, libraries, sanatorium, kindergartens, churches, temples	50	45	40
Residential areas, hotels, motels, administrative agencies	60	55	50
Residential areas intermixed with commercial and services areas	75	70	50

I.1.16. Insulating oil leakage

For transformers or electric resistances using oil, the individual oil tank or individual oil tank combined with common oil collection pit is required.

For indoor electrical equipment, the impermeable floor with ledge high enough to be used as oil collecting pit can be used if the number of transformers is not greater than 3 and the oil volume of each transformer is less than 1,000 liters.

For outdoor power equipment, the oil collecting pit may not be necessary if the volume of oil for transformer is less than 1.000 liters. This is not applied to the water collecting areas and/or areas where water resources are protected.

For outdoor distribution substation having transformer hung on the pole, the oil tank is not necessary.

I.1.17. Oil immersed electrical equipment means the equipment having parts immersed in oil to avoid contact with the surrounding environment, to enhance the insulation, to be cooled and/or to extinguish the arc.

Table I.1.2: Sound pressure level at some working locations

Working locations	**Sound pressure equal to, not exceeding, [dB]**	**Sound levels at octave of the intermediate frequency [Hz], not exceeding [dB]**							
		63	125	250	500	1000	2000	4000	8000
Working, manufacturing places	85	99	92	86	83	80	78	76	74
Remote control room, laboratory, experimental room having noise source	80	94	87	82	78	75	73	71	70
Remote control room, laboratory, experimental room having no noise source	70	87	79	72	68	65	63	61	59
Functional department (Accounting, planning, statistics, etc.)	65	83	74	68	63	60	57	55	54
Research laboratory, design, computer and data processing room	55	75	66	59	54	50	47	45	43

I.1.18. Electrical equipment of explosion-proof type means electrical equipment or appliance allowed to be used in areas where the environment is flammable and explosive at all levels.

I.1.19. Electrical engineering materials mean materials that have the determinant nature to the electromagnetic fields for use in electrical engineering.

I.1.20. Based in the physical nature, electrical engineering materials are classified into:

1. Fire-resistant materials mean materials that are fireproof or not burned into charcoal, and when set on fire they can not continue burning themselves or smolder.

2. Arc-resistant materials mean materials whose properties do not change under the impact of the arc during normal working conditions.

3. Moisture resistant materials mean materials whose properties do not change under the impact of moisture.

4. Fire-resistant materials mean materials whose nature does not change under the impact of high or low temperatures.

5. Chemical-resistant materials mean materials whose properties do not change under the impact of chemicals.

I.1.21. Based on the fire-resistance level, building materials and structures are classified into three groups mentioned in the Table I.1.3.

I.1.22. Nominal voltage of a system

It means an appropriate voltage value used to define or identify a power system.

I.1.23. Rated value

It means the value of a quantity, usually determined by the manufacturer for the specified operating conditions for an element, a device or equipment.

I.1.24. Operating voltage in a system

It means the voltage value in normal conditions, at a given time and point of the power system.

I.1.25. Highest (lowest) voltage of a system

It means the highest (or lowest) operating voltage value in normal operating conditions at any time and at any point in the system.

I.1.26. Highest voltage for equipment

It means the highest value of voltage phase - phase, consequently the insulation and other relevant characteristics of the device should be designed to ensure this voltage and the corresponding criteria.

Table I.1.3: Classification of building components according to fire-resistance level

Grouping according to the level of fire	**Fire level of materials**	**Fire level of building components**
Fire-resistant group	Under the impact of flame or high temperature, materials do not catch fire, smolder and are not carbonized.	Building components made of fire-resistant materials and having the same fire level as fire-resistant materials.
Slow-burning group	Under the impact of flame or high temperature, they can hardly catch fire, smolder or be carbonized; just continue burning or smoldering when exposed to fire sources. When being isolated from fire sources, they stop burning.	Components made of fire-resistant or flammable materials, but they must be protected by a layer of fire-resistant material and have the same fire level as fire-resistant materials.
Flammable group	Under the impact of fire or high temperature, they catch fire, smolder and are carbonized; they continue firing, smoldering or being carbonized after being isolated from the fire source.	Components made of combustible materials and have no protective fire-proof materials and the same fire level as flammable materials.

I.1.27. Voltage level

It means one of the nominal voltage values used in a certain system. For example: Voltage of 110kV, 220kV or 500kV...

I.1.28. Voltage deviation

The voltage deviation is expressed by a percentage, between the voltage at a given time at a point of system and comparison voltage, such as: nominal voltage, average value of operating voltage, the voltage supplied as per contract.

I.1.29. Line voltage drop

It means the difference in voltage at a given time between the voltages measured at two determined points on the line.

I.1.30. Voltage fluctuation

A series of voltage changes or periodic variation of the envelope of voltage.

I.1.31. Overvoltage (in a system)

Value of voltage between phase and ground or between phases, with peak value exceeding the corresponding peak value of the highest voltage of the equipment.

I.1.32. Temporary overvoltage

A value of the overvoltage fluctuation (at the frequency of the grid) at a specific point – it can not drop or diminish in a relatively long time.

I.1.33. Transient overvoltage

It takes place in a very short time (in about milliseconds or less), with fluctuation or without fluctuation, it usually diminishes quickly.

I.1.34. Voltage surge

It is a transient overvoltage wave that travels along a line or circuit, characterized by a very fast increase in voltage, and then it decreases slowly.

I.1.35. Voltage recovery

The recovery of voltage to a value approximate to the previous after the voltage is decreased, collapsed or lost.

I.1.36. Voltage unbalance

It's the difference between the voltages on the phase, at a point in multi-phase system, caused by the difference between the load currents or by the geometric asymmetry on the line.

I.1.37. Switching overvoltage

It is transient voltage having shape similar to the one of standard switching impulse voltage, being used for insulation coordinating purposes.

I.1.38. Lightning overvoltage

Transient overvoltage having the shape similar to the one of the standard lightning impulse, used for the insulation coordinating purpose.

I.1.39. Resonant overvoltage
Overvoltage caused by the resonance oscillation maintained in the power system.

I.1.40. Unbalance factor

In the three-phase power system, the level of unbalance is represented by the percentage ratio between the value of the effectiveness of negative sequence (or zero sequence) element to the positive sequence of voltage or current.

I.1.41. Insulation level

It is s a characteristic determined by one or more values specifying insulation withstand voltage for a specific part of the device.

I.1.42. External insulation

It is the distance in the atmosphere and the surface exposed to the air of solid insulator of equipment which is affected by the dielectric stress, the effects of atmosphere and other external impacts, such as: Pollution, humidity, etc.

I.1.43. Internal insulation

It is the solid, liquid or gas insulator inside the device to protect it against the impacts of the atmosphere and other external impacts.

I.1.44. Self-restoring insulation

The insulating properties of insulator are restored completely after discharge.

I.1.45. Non-self-restoring insulation

The insulating properties of insulator are lost or not restored completely after discharge.

I.1.46. Main insulation

- The insulator of the energized part, acting to protect people against electric shock.

- The main insulator does not necessarily include part used exclusively for the purpose of the function.

I.1.47. Auxiliary insulation

It is independent insulator added to main insulator in order to protect people against electric shock in case that the main insulator is damaged.

I.1.48. Double insulation

Protection by both main and auxiliary insulators.

I.1.49. Insulation co-ordination

The selection of insulation level of equipment and the characteristics of protective devices, taking into consideration that the voltage can appear on the system.

I.1.50. Transmission of electricity

The transmission of power from a power source to consumption areas.

I.1.51. Distribution of electricity

The distribution of power to a customer in the consumption area.

I.1.52 Interconnection of power systems

The connection of power transmission systems using power lines or transformers for power exchange between systems.

I.1.53. Connection point

It is s the connection point of the power distribution unit or of user's grid or of power transmission grid to the national grid.

I.1.54. System diagram

It is the layout of an electrical system represented geometrically, containing essential information for specific requirements.

I.1.55. System operational diagram

A system diagram showing a certain mode of operation.

I.1.56. Power system planning

All researches and programs related to the development of the electrical system, ensuring the economic-technical features and to satisfy the requirements of the electricity growth.

I.1.57. Power system stability

Ability to restore the set state of a power system, characterized by the synchronous operation of generators after a disturbance, by the variation, for example, of the capacity or of the total resistance.

I.1.58. Load stability

Ability to reset mode after the load disturbance.

I.1.59. Steady state stability of a power system

Stability of the power system after the disturbance having relatively small amplitude and slow rate of variation.

I.1.60. Transient stability of a power system

Stability of the power system in which the disturbance could have a relatively fast amplitude and/or rate of variation.

I.1.61. Conditional stability of a power system

The stability of the power system can be achieved without the impact of the automatic control devices.

I.1.62. Synchronous operation of a system

The state of the electrical system in which all power stations operate synchronously.

I.1.63. National load dispatch center

It is the commandment unit, controlling the operations of the national electricity system, including: power generation planning, mode of operation and controlling the power generating system connected to the national grid, controlling the operation of power transmission grid, controlling the electricity trading with external power system.

I.1.64. SCADA System (Supervisory control and data acquisition system)

It is the system which supervises controls and collects data on the operation of the power system for the process at the control centers.

I.1.65. Operation regulation

They are regulations on economic criteria, technical standards, synchronism and safety, reliability of power systems issued by competent state agencies for the purpose of planning, establishment of operation mode of the national grid system.

I.1.66. System demand control

It is the control of the power demand at the consumption side in the power system.

I.1.67. Management forecast of a system

It is the preparation and verification of power generation program, i.e. the forecast and operation stages, including the analysis of the grid scheme to ensure power supply most economically for the expected additional load at required safety levels within the given time, systems, taking into consideration all existing restrictions and possible situations.

I.1.68. Reinforcement of a system

Supplement or replacement of some equipment in the electrical system (such as transformers, transmission lines, generators, etc.) so that the system have the ability to meet the load growth or to ensure the quality of power supply.

I.1.69. Minimum working distance

It is the minimum safe distance, in the air, maintained between regularly energized parts and a personnel working in a station or operate it directly with electrical tools.

I.1.70. Minimum insulation clearance

It is the required minimum safe distance between energized parts or between energized parts and earth.

I.1.71. Cold start-up thermal generating set

It is the procedure in which the generators groups speed up, are connected into the power system to carry load after a long period without operation.

I.1.72. Hot start-up thermal generating set

It is the procedure in which the generators groups speed up, are connected into the power system to carry load after a long period without operation that changes much the thermal condition of turbines.

I.1.73. Overload capacity

Highest load that can be maintained during a short time.

I.1.74. Load shedding

The process of discharging some loads which is previously chosen to solve the unusual status in order to maintain the integrity of the remaining system.

I.1.75. Available capacity of a unit (of a power station)

Maximum capacity at which generators unit (or a power plant) can operate continuously in real conditions.

I.1.76. Reserve power of a system

It's the difference between the total available capacity and capacity needs of the power system.

I.1.77. Hot stand-by

It's the total available capacity of the generators which run without load or underload to generate fast power into the system.

I.1.78. Cold reserve

Total available capacity of the backup generators whose the start-up could take several hours.

I.1.79. Outage reserve

The power reserve which can be mobilized to the operation in a period not exceeding 24 hours.

I.1.80. Load forecast

The estimated load of a grid at a certain time of the future

I.1.81. Generation mix forecast

Forecasting components of the generator system at a given future time.

I.1.82. Steady state of a power system

The operating conditions of a grid in which the parameters of the system state are considered as stable.

I.1.83. Transient state of a power system

Operation mode of the grid in which at least one state parameter is changing, usually in a short time.

I.1.84. Balanced state of a polyphase network

State in which voltage and current in phase conductors forming the polyphase equilibrium system.

I.1.85. Unbalanced state of a polyphase network

State in which voltage and/or current in phase conductors do not form a balanced polyphase system.

I.1.86. Service reliability

The ability of a power system to meet the supply functions in stable condition, according to the specified time.

I.1.87. Service security

Ability to fulfill the electrical providing function of a power system at a given point in time when operational problems occur.

I.1.88. Economic loading schedule

The exploitation of the available components of the grid in the most economical efficient.

I.1.89. Balancing of a distribution network

The distribution of power for consumers in different phases of the distribution system so that current balance is the highest.

I.1.90. Load recovery

After voltage recovery, the increase of the power consumption households or of a system, at a faster or slower level, depends the characteristics of the load.

General guidelines for electrical installations

I.1.91. In the said regulations, the following terms are used with the below meanings:

- Required: Mandatory implementation.
- Necessary: Needed but not required.
- Facultative: Not mandatory but it will be better if it is performed, done.
- General or ordinary: Commonly, widely used.
- Allowed or permitted: It is permitted to carry out, such as adequate and necessary.
- Not less than or at least: The minimum.
- No greater than or at most: The maximum.
- From ... to ...: Including the both ends values.
- Distance: From one point to the other.
- Space: From one edge to the other in the space.

I.1.92. Structure, purpose, method of installation, level of insulation materials and electrical installations must conform to the nominal voltage of electricity grid or electrical installations, to environmental conditions and to he requirements set out in these regulations.

I.1.93. Electrical installations used in electrical works must have technical features in line with the working conditions of the works.

I.1.94. Power switching devices used in the air in the highlands above 1.000 m compared with sea level must be checked by switching electrical conditions in the respective atmospheric pressure.

I.1.95. Electrical installations and associated structures must be protected against rust and corrosion by coating, painting, etc. to withstand the impact of the environment.

Coating, paint colors must conform to the overall color of the buildings, building structures and technological equipment, if used outdoor, it is necessary to use paint with a good reflection.

I.1.96. The selection of equipment, power tools and related structures, other than standards on functions, it is required also to satisfy the standards of humidity, salt fog, wind speed, ambient temperature, earthquake etc.

I.1.97. The construction part of the works (houses and their structural parts, ventilation, drainage, etc.) must comply with national standards and regulations.

I.1.98. For unmanned power works, control room, spare room for operators, as well as repair facilities are not necessary.

I.1.99. The design and selection of plans for power projects to be based on a comparison of economic-techniques indicators, on application of simple and reliable diagrams, qualification and experienced of operators, new technology applications and on the optimal choice of materials.

I.1.100. In power projects, it is necessary to take measures to distinctive elements in the same department, such as: plan, scheme of arrangement of equipment, calligraphy, numbering with different colors etc.

I.1.101. The colors of conductive bar of the same name in all electrical works must be the same.

Conductive bars must be painted as follows:

1. For three-phase AC grid: Phase A: Yellow, phase B: Green, phase C: Red, neutral bar: White for neutral isolated network, neutral bar: Black for neutral direct grounding grid.

2. For single-phase power grid: The earthling wire connected to the initial point of power coil: Yellow, wire connected to the end point of power coil: Red. If the conductor bar of the grid branched from the

conductor bar of the three-phase system, it must be painted the color of the phases in the three-phase grid.

3. For single-phase power grid: The positive bar (+): Red, the negative bar (-): blue, the neutral bar: White.

I.1.102. It is required to position and paint the conductive bars as per the instructions below:

1. For indoor distribution equipment, three-phase AC:

a. If the bus conductive bar is positioned vertically: The upper bar (A): Yellow, middle bar (B): Green; lower bar (C): Red. If the conductive bar is positioned horizontally, on tile position or in the triangle shape: The far bar (A): Yellow, the middle bar (B): Green, the near bar (C): Red. In the case that people can access from both sides, the bar near the fence (A): Yellow, the bar far from the fence (C): Red.

b. For the bar branched from the bus bar: If viewed from the operation corridor, the left bar (A): Yellow, the middle bar (B): Green, the right bar (C): Red.

2. For outdoor distribution equipment, three-phase AC:

a. The bus bar and circle bar: The bar nearest to power transformer (A): Yellow, the middle bar (B): Green, the farthest bar (C): Red.

b. Bars branched from the bus bar system: If viewed from the outdoor distribution equipment to the output of power transformer, the left bar (A): Yellow, the middle bar (B): Green, the right bar (C): Red.

c. For ingoing lines to stations: If viewed from the ingoing line to the station, at the connection point, the left bar (A): Yellow, the middle bar (B): Green, the right bar (C): Red.

d. For outdoor distribution equipment which use flexible wire as conductive bar, it is to paint the color of phase at porcelain base of equipment or stipple on the bus bar beam.

3. For DC power grid:

a. When the bus bar is positioned vertically: The top bar (the neutral bar): White, middle bar (-): Blue; the lower bar (+): Red.

b. When the bus bar is positioned horizontally: If viewed from the operation corridor, the farthest neutral bar: White, middle bar (-): Blue, the nearest bar (+): Red.

c. The bars branched from the bus bar: If viewed from the operation corridor, the left bar (neutral bar): White, middle bar (-): Blue, the right bar (+): Red.

d. In individual cases: If it's difficulty to paint the bars as above in terms of installation or it is necessary to build more pillars to mount bars at the substation for the phase reversal purpose, it is allowed to change the order of the colors of bars.

I.1.103. In order to avoid jamming and danger to communications projects, it is required to comply with current relating standards and regulations. It is required to have anti-interference measures of industrial power to information and telecommunications systems.

I.1.104. In power projects, it is required to have measures to ensure the safety as followings:

• To use the appropriate type of insulation. In individual cases, it is required to use reinforced insulating method.
• To have an appropriate distance to the conductive part or to shield the conductors.
• To set up fences.
• To use interlock for electrical tools and to set up fences to prevent the wrong operation.

• To use reliable switchover and to isolate rapidly the electrical equipment under short circuit and the damaged area of power grid.

• To earth the covers of electrical equipment and every element of power projects which may short circuited.

• To equilibrium the potential by using isolation transformers or voltage of 42V or less.

• To use signals system, signs and banning tables.

• To use protective equipment.

I.1.105. For up to 1 kV power grid, for area where the safety conditions can not allow the direct connection of power consumption to the grid, it is required to use an isolation transformer or step-down transformer with secondary voltage less than 42V. When using above mentioned transformers, it is required to follow the instructions below:

1. The insulation transformer should have safe structure and can to withstand higher voltages than normal.

2. Each isolation transformer is to power only one device and is protected by a fuse or a switch having nominal current not exceeding 15A at the primary phase. Primary voltage of the transformer must not exceed 380V.

3. It is prohibited to ground the secondary winding of isolation transformers and equipment of its electricity consumption. The shell of the transformer must be grounded.

4. The step-down transformers having secondary voltage of 42V or less may be used as an isolation transformer if they meet the above mentioned characteristics.

The step-down transformer which is not used as isolation transformer must be earthed at the following parts: Cover, one of the outputs or midpoint of secondary winding.

I.1.106. In housing, public areas, shops etc. the cover or shield must not be perforated. In the manufacturing or power rooms, it is allowed to use perforated or grid covers.

I.1.107. Cover and fences should be structured so that they can only be removed or opened with just particular wrench or instruments.

I.1.108. Fences and the cover must have sufficient mechanical strength. For the device of above 1 kV, the thickness of a metal cover must not less than 1mm. Conductor casing cover should be put into the machine, equipment and power tools.

I.1.109. To avoid accidents due to electric current and caused by the arc, all electrical equipment must be equipped with appropriate protective equipment for regulations on use, testing and with electrical safety regulations.

I.1.110. The fire fighting measures for the electrical equipment containing oil, being oil soaked, insulating painted, and etc. must comply with the requirements specified in the corresponding part of these Regulations and in the regulations of local fire agencies.

In addition, when putting the above electrical equipment into production, it is required to fully equip them with fire-fighting means prescribed by regulations of fire prevention and fighting.

Connecting the power works to the power grid

I.1.111. When connecting electrical work to the power system, in addition to the basic construction procedures, it is required to have agreement from the power system management agency, it is required to comply with current regulations and technical conditions for connection as follows:

1. To make plan for construction in electrical systems.

2. To gather data on the load in the region where the power project will be built.

3. To project connection points in power systems (power stations, power plants or transmission lines), the voltage at the connection points, equipment at the connection points.

4. To select voltage, cross-section and category of overhead lines or cable lines and voltage regulating means, to know the requirements on lines. For big projects, it is also required to have the alternative

solutions of selecting the numbers of connection.

5. To mention the need to strengthen the existing power grid due to the addition of new projects (Wires cross-section will be increased, the transformers will replaced or their capacity will be increased).

6. To mention the particular requirements for power sub-stations household electricity consumption equipment connected to the system, such as: the need of automatic protection device at the input, allowing the line to work in parallel, the need of power backup etc.

7. To identify the short-circuit current

8. To mention the requirements of protection by relay, automation, insulation and protection against excessive voltage.

9. To mention the measures to improve power factor.

10. To mention the requirements for electricity counting.

11. To determine the conditions for connection of electrical furnace, high-frequency electrical equipment etc.

12. To mention the requirements for auxiliary works and other works (such as communication works etc.).

I.1.112. Electrical works and installations after construction/installation must be tested for acceptance, delivery and putting into operation according to the current regulations.

Chapter I.2
POWER GRID AND POWER SUPPLY

Scopes and definitions

I.2.1. This chapter is applied to the power grid of electrical system, of industrial enterprises and cities etc.

The supply of electricity to the underground works, trams etc, in addition to the requirements stated in this chapter, must also comply with specialized regulations.

I.2.2. Energy system means a combination of power plants, thermal net that are connected, have closely and continuously interactions in the process of production, transformation and distribution of electricity and heat.

I.2.3. Power system means an energy system without thermal net.

I.2.4. Power station means a part of the electrical system, possibly generating stations and substations, switching station or reactive power compensation station, etc.

I.2.5. Substation means a transformer station connecting two or more power grids of different voltages.

I.2.6. Switching station means a station composed of switchgear station, the bus bar and without power transformer.

I.2.7. Reactive power compensation station consists of two types:

• Reactive power compensation station by capacitors.

• Reactive power compensation station by synchronous compensators.

I.2.8. Gas Insulated Substation (GIS): The station located in the grounded metal chamber, insulating for main electrical equipment by the compressed gas (not by air).

I.2.9. Independent power supply for a load means power sources which keeps supplying power on when other power sources fail.

The power distribution stations which receive power from two power plants or from two segments of bus bar of power plants or form power stations are considered as independent power supply, if they satisfy two following conditions:

• Each segment is supplied from independent power sources.

• The segments are not linked, if linked, they are automatically disconnected when a segment has problem.

I.2.10. Deep power supply means the method to supply high-voltage power to consumers with least power transformation levels.

I.2.11. Voltage adjusting means an operation to adjust the voltage at the bus bar of power plant or substations to maintain the allowed voltage levels.

General requirements

I.2.12. The power supply to the consumers, including the selection of the number and arrangement of the power stations must be resolved overall depending on the situation of energy in the area (hydro resources, local energy supply, fuel waste, the demand for heat, electricity supply capacity of large power plants in the surrounding area, etc.) on the basis of load survey and plans to develop the local economy in 10 years, it is also necessary to consider preventions. Besides, it is necessary to consider the possibilities and measures to reduce short circuit currents and to reduce power loss.

I.2.13. The selection of power supply solution should be done after the technical specifications are ensured, comparison of investment capitals and annual operating costs for the project with a payback period of 5 to 8 years, comparison of advantages of each plan.

I.2.14. The design, new construction and renovation of power grids should meet the demand for electricity development in each period and the ability to expand at least 10 years in the future.

I.2.15. Power transmission capability of transmission lines and power transformers connecting the exclusive power plants of industrial enterprises to the power system must ensure:

• To put the residual capacity of exclusive power plants d in the electrical system in any working mode.

• Get a shortage capacity when the biggest generator of power plants shut down due to special problems, routine repair and inspection.

I.2.16. All power plants when put to operate in parallel with the national grid, managing boards of the said should have agreements with national grid managing agencies.

I.2.17. When the consumption power of industrial enterprises is lower than carrying capacity of exclusive power supply lines, it is possible to associate with the power supply to the households as agreed.

When building new industrial plants that will be neighbored by a new city or residential areas, it is required to take into consideration the ability to separate the load in the scheme of new power supply of the enterprise.

I.2.18. The 500, 220, 110 kV grids are the neutral types and directly earthed. The 6, 10, is 35 kV grids are the neutral types which can be earthed through the arc extinguishing coil, in special cases, they can be directly grounded. The 15, 22 kV grids are the neutral types, direct earthed , in special cases, they can be isolated or earthed through small capacity resistors.

For 6 ÷ 35 kV power networks having neutral grounding point via arc extinguishing coil, the capacitive current compensation when grounding is done in the following cases:

1. At 35 kV grid: When the earth-fault current is greater than 10A.
2. At 10 kV grid: When the earth-fault current is greater than 20A.
3. At 6 kV grid: When the earth-fault current is greater than 30A.
4. At 6 ÷ 22 kV generator - transformer combination block: When the earth-fault current is greater than 5A.

I.2.19. Generally, the power station of 35 kV or less is designed unmanned but with automatic equipment, when necessary, to use the remote control device and signal system to notice the incidents. The control panel is only to be placed at power supplying station to power the stations.

I.2.20. All electrical equipment that are connected to the line equipped with the reactance coil must be chosen according to the short circuit current after the reactance coil (see Article I.4.7).

I.2.21. Disconnector and standard auto disconnector are allowed to switch on and off:

1. Voltage transformers, charge current of bus bar and electrical equipment.
2. Balance current of the line if the voltage difference of disconnector or automatic disconnector after switching off is ≤ 2% of nominal value.
3. 5A earth fault current, for 22 ÷ 35 kV lines and 3A of 10 kV transmission line or lower.

It is also allowed to use disconnector to switch on and off:

- The neutral earthling point of transformers.
- The arc extinguishing coil when no earth-fault current occurs in the grid.
- Loops (when the breaker is connected in parallel to the disconnector in the ON position).

The determination capacity with no load of a transformer and the length of power lines in the voltage level allow the use of disconnector or standard auto-disconnector for switching on and off, the selection of measures for the installation of the said disconnectors and the determination of the distance between the edges of the disconnectors are subject to manufacturer's instructions as well as to the current technical regulations.

I.2.22. It is allowed to alternative current as the internal manipulate resources to simplify and reduce costs.

I.2.23. In areas where there is no stable planning it is possible to use overhead lines, and for the urban and industrial areas whose the planning has already been approved, it is possible to use the underground cable.
For low-voltage lines it is advised to use shielded cables. For the 22 kV or lower lines in areas where the operational corridors are narrow, crowded of trees it is required to use shielded cables.

It is allowed to mount the lines of different voltages and uses on the common column with overhead lines, but it is required to comply with the provisions stated in the Part II of these regulations.

I.2.24. Cross- section of the conductors, conductive bars and cables must be selected according to:

1. Economic current density stated in Chapter I.3.
2. Transmission capability in the temperature rise of the cables in normal mode and incident mode as described in Chapter I.3.
3. Voltage loss in the conditions stated in the Article I.2.39.
4. Stability, temperature rise and the electrodynamic force in the short-circuit regimes outlined in the Chapter I.4.
5. The physico-mechanical data of the lines.
6. Electric corona (Article I.3.31).

Power consumption household categories, power supply reliability

I.2.25. Depending on electricity supply reliabilities, power consumption households are divided into three following categories:

• Group I: The power consumption households that the power supply interruption will affect national security, affecting the vital organs of the State, causing fatal, serious economic losses or the power supply is subject to special power needs of the customer.

• Group II: The power consumption households that the power supply interruption will cause major economic loss, disorders in complex technological process, disturbances of the normal operation of the city.

• Group III: The power consumption households that do not belong to the two above groups.

I.2.26. For the power consumption households of group I, the power is provided by at least two independent power sources and a redundant power source in place. The power supply interruption is only allowed during the automatic closing time of power backup.

The power backup in place could be the fixed or mobile stations having generators or UPS, etc.

I.2.27. For the power consumption households of group II, the power must be provided by at least one main power source and a redundant power source. The power supply interruption is only allowed in the required time to close backup source.

I.2.28. For the power consumption households of group III, The power supply interruption is only allowed during repairs or troubleshooting period.

Diagram of power supply

I.2.29. For the new construction or renovation of power grids, it is necessary to use the simple, reliable and diagram of high voltage power supply. Power sources must be placed closer to load center of the industrial enterprises and cities by deep power supply with the voltage of 110 ÷ 220 kV, power stations should be built near load center or even in factories, the power stations should be split into small capacity ones.

To supply electricity to individual station, it is advised to use widely the direct branching from one or two parallel lines, at branching point the disconnection switch should be placed.

To ensure the power supply for the city's power grid, it is necessary to use power supply circuit diagram for the station.

It is recommended to use widely the power station with simple diagram, having no circuit-breaker at the input and no bus bar at high-voltage side or only a single bus bar system. The double bus bar system is used only when there are justifiable arguments.

I.2.30. To place the circuit-breaker at the input in the following cases:

1. At the input of stations of 110 kV or greater.

2. At the input of substations of up to 35 kV with a capacity greater than 1600 kVA.

I.2.31. It is recommended to use the cut-out fuse or high voltage cut-out fuse coordinated with load breaker and/or disconnector to protect short-circuit for transformers of less than 35 kV (see Article I.2.21) and for the capacitors.

I.2.32. When designing the power station, it is necessary to take measures to limit short-circuit capacity in the power grid receiving the largest allowed breaking capacity of the circuit-breaker placed in the grid.

When limiting short-circuit capacity by impedance on the output line, it is allowed to use common general impedance for various power lines, but each line must be connected via the individual disconnector. In this case, it is recommended to use the dividing impedance.

I.2.33. While designing the power grid, it is required to calculate the load of all consumers in the incident mode. In some cases, when designing the power substations, it is allowed to compute the automatic discharge of load of less importance in incident situation.

I.2.34. When taking into consideration the backup, it is necessary to take into consideration the possibility of overloading of the electrical equipment (according to the manufacturer's notice) and the redundant power.

I.2.35. When taking into consideration the incident mode, do not take into consideration the situation of simultaneous breaking due to fault voltage and for repair, simultaneous breaking due to fault voltage or simultaneous breaking for repair in many grids or in many lines.

I.2.36. All lines of the power supply system are required to carry load according to the power distribution needs to ensure the minimal power loss, except for short backup

I.2.37. When designing the power grid, it is required to use the auto-switch, auto-switch backup and auto load-discharge devices under frequency.

I.2.38. The structural diagram of power distribution networks in the enterprise must ensure electricity supply for technological lines working in parallel and ensure the mutual backup for the all units by receiving power from the different stations or transmission lines or from different segments of the same station.

Voltage quality and voltage regulation

I.2.39. The voltage levels at various points in the grid must be determined by the method of operation and according to the maximum and minimum load. In normal conditions, the voltage deviation is allowed to fluctuate within ± 5% compared with the nominal voltage and is determined at the location of electrical measuring device or at another location by mutual agreement.

In cases the grid is not stable, the voltage is allowed to vary from -10% to +5%.

I.2.40. In a normal working mode of the power system, the voltage transformer of up to 35 kV must be adjusted within ± 5% of nominal voltage.

I.2.41. In a normal working mode of power supply stations, within the time the total load is decreased to 30% compared with the highest load value, the voltage at the bus bar must be maintained at the nominal voltage of the grid.

I.2.42. To adjust the voltage in the power grids of 110kV and above, it is required to use a transformer with lower voltage regulator with adjustment range ± (10 ÷ 15%).

Also to consider the usage of the device to adjust the voltage in the place as follows:

- Synchronous motors
- Synchronous compensator
- Compensation capacitor
- Contact line at the voltage up to 1kV between substations enabling to switch off a number of transformers in the minimum load mode.

I.2.43. The selection of voltage and power supply system for the dynamic and lighting power network in the workshops using the voltage of 660V or less must be addressed in a comprehensive way. If using a transformer to power the dynamic and lighting network, the schema of the network should allow the switching off the transformer in non-working hours or in days-off and the switching to the permanent powering for lighting to separate transformers of small capacity or to power line connected to one of transformers that are still working.

I.2.44. In normal conditions, the frequency of the electrical system is allowed to fluctuate within ± 0.2 Hz at to the nominal frequency of 50Hz. In case that power system is unstable, the frequency deviation of ± 0.5 Hz is allowed.

At the power consumption household's side with the electricity capacity from 80kW or the transformer with a capacity of 100KVA and above, the value cosφ ≥ 0.85 must be ensured at the place of power meters. Where the value cosφ is lower than 0.85, it is required to take the following measures:

• To install the reactive power compensator to rise the cosφ value to 0.85 or higher.

• To buy more reactive power on the power system at the supplier side.

Where the consumer has the ability to deliver the reactive power to the grid, the two parties may discuss the purchase contract.

City's power grid with the voltage up to 35 kV

I.2.45. According to the reliability of power supply, the electricity consumption households in the city are classified as per the Article I.2.25.

I.2.46. When studying the expanding of the city, it is required to set up the schema of power supply for the future; to take into consideration the possibility of partial implementation of the scheme to meet each stage of development of the city.

For the old power grid which can not meet technical requirements for exploitation or more than 50% of all parts of the network are expired, it is required to study a comprehensive renovation.

I.2.47. The cross- section of the cables under the first phase of construction must be selected in line with the general scheme of power supply as planned.

I.2.48. The calculated load of power consumption households connected to 380 V grids should be determined by the existing load plus the annual growth rate of 10 ÷ 20%.

I.2.49. Factors to calculate the maximum load of power consumption households is below:

- Public lighting load: $K_{dt} = 1$
- Living load: $K_{dt} = 0,9$
- Commercial services, offices load: $K_{dt} = 0,85$
- Handicrafts trade load: $K_{dt} = 0,4 \div 0,5$

I.2.50. When the basis for selection factors due to the mix load is not available, the following approximate formula can be applied:

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

Where:

P_{assh}: The total capacity needs for living lighting

$P_{cn,tcn}$: The total power demand for industrial or handicraft trade

P_{nn}: The total demand for agricultural activities

K_{dt} is the capacity factor of the loads in the area, it can be selected as follows:

When $P_{assh} = 0.5$ SP, to take $K_{dt} = 0.6$

When $P_{assh} = 0.7$ SP, to take $K_{dt} = 0.7$

When $P_{assh} =$ SP, to take $K_{dt} = 0.9$

In other cases the K_{dt} can be interpolated

I.2.51. Factors to calculate the load for the 6 - 35 kV lines:

- For power line with from 3 to 5 transformers, to take $K_{dt} = 0.9$
- For power line with from 6 to 10 transformers, to take $K_{dt} = 0.8$
- For power line with from 11 to 20 transformers, to take $K_{dt} = 0.75$
- For power line with more than 20 transformers, to take $K_{dt} = 0.7$

I.2.52. Depending on the requirements of the load, for power grid of from 1 kV, it is required to add in the diagram the automatic redundant power equipment.

I.2.53. In the power network with automatic redundant power equipment for consumers, it is required to make the transmission of signal of the fault voltage circuit breaker at the distribution stations to the control station.

I.2.54. To power the loads in the stably planned area, all the grids of all voltage levels should be the underground type, while in areas without a stable planning, the lines should be the overhead type. In the city it is required to use twisted and/or underground cables.

I.2.55. For low-voltage power distribution networks, for new construction or renovation, the power network should be 380/220V 3 phases 4 cables with neutral direct earthing.

I.2.56. Only to connect the load to the distribution network or to the 380V end of the substation if the voltage fluctuation when switched on does not exceed ± 5% of the nominal voltage of the grid. If the number of switching on and off day and night is not more than five times, the voltage variation is not specified.

I.2.57. The power network coming from the electricity supply center to consumers must be checked for the allow voltage deviation, taking in to consideration the voltage mode at the bus bar of power supply center. If the voltage deviation exceeds the permitted limits, it is required to take measures to adjust the voltage.

I.2.58. When determining the voltage deviation in the grid, the voltage drop in the farthest power consumption device should not exceed 2.5%

Chapter I.3

SELECTION OF CROSS- SECTION OF CONDUCTOR

Scope

I.3.1. This chapter applies to the selection of cross- section of cables, including bare wires, coated wires and cables and conductive bars, by the economic current density, by the allowed voltage loss, temperature rise and corona conditions. In cases that the cross- section selected by the conditions above is smaller than cross- section selected by other conditions such as mechanical strength, overload protection, electrical stability and thermal stability, to take the largest section.

Selecting cables by the economic current density

I.3.2. To select the cross- section of the conductor and cable of over 1kV by economic current density using the formula:

$$S = \frac{I}{j_{kt}}$$

Where:

• I is the highest calculated current of the line in the normal working mode, taking into consideration the load growth in the planning, not to mention the current increased due to a system incident or power cut-off to fix any element on the power grid.

• j_{kt} is the economic current density, refer to the Table I.3.1.

Then to the calculated cross- section is converged to the nearest standard cross- section.

I.3.3. The increase of number of circuit lines or lines selected under the cross- section by the economic current density must be based on technical and economic calculations to ensure the reliability of electricity supply.

In some cases, when upgrading, to avoid the increase of the number of lines or circuits, it is allowed to increase the economic current density to the level twice greater than the value given in Table I.3.1.

When calculating technically and economically, to take into consideration all the additional capital investment, including transmission lines and equipment at both ends, also the plan to upgrade to the line voltage for options comparison purpose.

These guidelines also apply to the upgrading the cross- section of the lines due to overload. In such case, renovation costs to the price must include new equipment and supplies costs minus the recovered value.

Table I.3.1: Economic power density

Conductors	**Economic current density (A/mm^2)**		
	Number of hours used at the maximum load in the year (h)		
	Over 1000 to 3000	Over 3000 to 5000	Over 5000
Bared bars and cables:			
+ Copper	2,5	2,1	1,8
+ Aluminum	1,3	1,1	1,0
Paper insulated cables, rubber or PVC coated conductor:			
+ Copper core	3,0	2,5	2,0
+ Aluminum core	1,6	1,4	1,2
Synthetic rubber or plastic insulated cables :			
+ Copper core	3,5	3,1	2,7
+ Aluminum core	1,9	1,7	1,6

I.3.4. Not to select the cross- section of the conductors by the economic current density in the following cases:

1. Power grid of the enterprises or of industrial works having capacity up to 1kV and peak load hours up to 5000h.
2. Up to 1 kV voltage distribution network (see Article I.3.6) and lighting network selected by the

allowed voltage loss.

3. Bus bars of all voltage levels.

4. The cables to the adjustable resistor, the starting rheostat.

5. Temporary grid and grid with the usage time of less than 5 years.

I.3.5. When using the table I.3.1, it is required to apply the following:

1. If the maximum load occurs in the night time , the j_{kt} will be increased by 40%.

2. For the insulated cables with the cross- section up to 16mm^2 of the j_{kt} will be increased by 40%.

3. For lines with uniform cross- section having n branches along the length, the j_{kt} in the end of the line will be increased by K_1 times. The K_1 is determined by the formula:

$$K_1 = \sqrt{\frac{I_1^2.L}{I_1^2.l_1 + I_2^2.l_2 + ... + I_n^2.l_n}}$$

Where:

$I_1, I_2, ... I_n$ is the current in each line. $l_1, l_2, ... l_n$ is the length of each line.

L is the total length of the lines.

4. If the lines have many loads along them, the line should be divided into two sections to select the two different types of cross- section as per instructed the Section 3. Do not select up to 3 types of cross-section for one overhead line.

5. For underground cables having many loads along their length, it is required to select only one cross-section as per instructed in the Section 3.

6. When selecting a cross- section for conductor for many consumers having the same type of mutual provision (e.g. water pumps, rectifiers, etc.) of n devices, of which m devices work in the same time, the remaining devices are the standby, j_{kt} shall be increased by K_2 times:

$$K_2 = \sqrt{\frac{n}{m}}$$

Selecting cables by the allowed the voltage loss

I.3.6. In the electricity distribution network of up to 1 kV, the cable cross- section will be selected by the voltage loss and to re-examine the allowed long temperature rise:

$$\Delta Umax \leq [\Delta Ucp]$$

In the 1 kV to 22 kV power network, the selection of cable cross- section should be done by the economic and technical comparison between the Article I.3.2 and the Article I.3.6.

I.3.7. The allowed voltage loss for each specific case depends on the requirements of the load types, including the startup of electric motors and taking into account the load growth in the future, especially for the underground cables .

I.3.8. For the load requesting the stability at the special high level, if the selection of the cross- section of cable by the voltage loss results in the great cost, it is necessary to compare with the voltage upgrade solution with the low voltage transformer at the end of the line or the solution ensuring the normal level.

Selecting conductors by the allowed temperature rise

I.3.9. The cases stated in the Article I.3.4 are the cases selected by the allowed temperature rise, then checked by other criteria, such as the allowed pressure drop, electromotive stability, limit of the cross-section of the corona loss, for other cases, the allowed temperature rise is allowed only to check the cable after being selected by the economic current density or by the allowed voltage loss.

I.3.10. All conductors are required to satisfy the allowed temperature rise, not only in normal mode but in the fail mode of the system, i.e. the mode that has a number of other elements that were removed from the system increasing the current at the element under consideration.

The maximum load into consideration is the average maximum load for half an hour, taking into consideration the development in 10 years for overhead lines and after 20 years for underground cables.

I.3.11. For the short-term working mode and repeatable short-term working mode of the load (total time cycle is 0 minutes and working time of the cycle does not exceed 4 minutes), to examine the cross-section of the conductor by the allowed temperature rise, the calculated load shall be converged to the continuous working mode, then:

1. For the copper cables with the cross-section up to 6mm^2 and aluminum cables with the cross-section up to 10 mm^2, the calculated load is the short-term load and is considered as the continuous load.

2. For the copper cables with the cross-section of over 6mm^2 and aluminum cables with the cross-section of over 10 mm^2, the calculated load is the short-term load and multiplied by the factor:

$$\frac{0,875}{\sqrt{t_{lv}}}$$

Where:

t_{lv} is the ratio between the working time in the cycle and the total time of the constant cycle.

I.3.12. For the short-term working mode with the switching-on time of under 4 minutes and the time between the two switching-on times is enough to cool the power cable to the ambient temperature, the allowed maximum load is determined as per the Article I.3.9 .

When the switching-on time is greater than 4 minutes and the time between the two switching-on times is not enough to cool off the power line, the maximum load is regarded as the continuous working load.

I.3.13. For two or more cables that often work simultaneously, when considering the temperature rise of a line in fault mode, i.e. the mode in which one of the said cables does not work temporarily, it is allowed to calculate the left cable in the overload mode by the manufacturer's documentation.

I.3.14. The neutral cable in the 3 phase 4 wire networks must have electrical conductivity of not less than 50% of the conductivity of phase cable.

I.3.15. While determining the permanent allowed current for the bare and shielded cables, underground cable, bar and the environment temperature is different from the temperatures stated in the Article I.3.16, 18, to use the correction factor stated in the Table I.3.30.

I.3.16. The permanent allowed current for the rubber or PVC coated cables, rubber or synthetic resin with shell lead coated cables, PVC or rubber cables is specified by the manufacturer, otherwise to refer to the table I.3.3 ÷ I.3.9, that are calculated with the temperature rise of the core of +65^{o}C when the ambient temperature of the air is +25^{o}C or when soil temperature is +15^{o}C.

When determining the number of cables in the same tube (or number of core of a multi-core cable), not to take into consideration the neutral cable of the 3 phase 4 wires system (or the grounded core).

Table I.3.2: Correction factor

Characteristics of soil	**Thermal resistivity, cm.^{o}K/W**	**Correction factor**
Sand with humidity of over 9%, sandy clay with humidity of over 1%	80	1,05
Soil and sand with with humidity 7- 9%, sandy clay with humidity of 12-14%	120	1,00
Sand with humidity of over 4% and bellow 7%, sandy clay with humidity 8-12%	200	0,87
Sand with humidity of 4%, soil and rock	300	0,75

Table I.3.3: The allowed permanent current for low-voltage cable, copper core, rubber or PVC coated

Cross-section of the core, mm²	**Allowed currents (A)**					
	Not placed in tube	Cables placed in the same tube				
		2 cables, single core	3cables, single core	4cables, single core	Single cable, 2 cores	Single cable, 3 cores
0,5	11	-	-	-	-	-
0,75	15	-	-	-	-	-
1,0	17	16	15	14	15	14
1,5	23	19	17	16	18	15
2,5	30	27	25	25	25	21
4	41	38	35	30	32	27
6	50	46	42	40	40	34
10	80	70	60	50	55	50
16	100	85	80	75	80	70
25	140	115	100	90	100	85
35	170	135	125	115	125	100
50	215	185	170	150	160	135
70	270	225	210	185	195	175
95	330	275	255	225	245	215
120	385	315	290	260	295	250
150	440	360	330	-	-	-
185	510	-	-	-	-	-
240	605	-	-	-	-	-
300	695	-	-	-	-	-
400	830	-	-	-	-	-

Table I.3.4: Allowed permanent current for low-voltage rubber coated copper cable, protect by the metal shield, rubber coated copper cable, protect by the lead shield, PVC or rubber, with or without steel belt.

Cross-section of the core, mm^2	**Allowed currents** (*) (A)				
	Wires and cables				
	Single core	2 cores		3 cores	
	Positions				
	Overhead	Overhead	Underground	Overhead	Underground
1,5	23	19	33	19	27
2,5	30	27	44	25	38
4	41	38	55	35	49
6	50	50	70	42	60
10	80	70	105	55	90
16	100	90	135	75	115
25	140	115	175	95	150
35	170	140	210	120	180
50	215	175	265	145	225
70	270	215	320	180	275
95	325	260	485	220	330
120	385	300	445	260	385
150	440	350	505	305	435
185	510	405	570	350	500
240	605	-	-	-	-

Note: (*) For wire or cable with or without neutral core.

Table I.3.5: Allowed permanent current for low-voltage rubber or PVC coated aluminum cables

Cross-section of the core, mm^2	**Allowed currents (A)**					
	Not placed in tube	Cables placed in the same tube				
		2 cables, single core	3cables, single core	4cables, single core	Single cable, 2 cores	Single cable, 3 cores
2,5	24	20	19	19	19	16
4	32	28	28	23	25	21
6	39	36	32	30	31	26
10	60	50	47	39	42	38
16	75	60	60	55	60	55
25	105	85	80	70	75	65
35	130	100	95	85	95	75
50	165	140	130	120	125	105
70	210	175	165	140	150	135
95	255	215	200	175	190	165
120	295	245	220	200	230	190
150	340	275	255	-	-	-
185	390	-	-	-	-	-
240	465	-	-	-	-	-
300	535	-	-	-	-	-
400	645	-	-	-	-	-

Table I.3.6: Allowed permanent current for low-voltage rubber or synthetic resin coated aluminum cable, metal, PVC or rubber shielded, with or without steel belt.

Cross-section of the core, mm^2	**Allowed currents** (*) (A)				
	Wires and cables				
	Single core	2 cores		3 cores	
	Positions				
	Overhead	Overhead	Underground	Overhead	Underground
2,5	23	21	34	19	29
4	31	29	42	27	38
6	38	38	55	32	46
10	60	55	80	42	70
16	75	70	105	60	90
25	105	90	135	75	115
35	130	105	160	90	140
50	165	135	205	110	175
70	210	165	245	140	210
95	250	200	295	170	255
120	295	230	340	200	295
150	340	270	390	235	335
185	390	310	440	270	385

Note (*): For 4-cores cables insulated by synthetic resin, with voltage up to 1kV, it is possible to select cables according to this table as for 3-cores cable but multiplied by factor of 0.92.

Table I.3.7: Allowed permanent current for low-voltage flexible rubber coated cables for mobile devices

Cross-section of the core, mm^2	**Allowed currents $^{(*)}$ (A)**		
	Single core	2 cores	3 cores
0,5	-	12	-
0,75	-	16	14
1,0	-	18	16
1,5	-	23	20
2,5	40	33	28
4	50	43	36
6	65	55	45
10	90	75	60
16	120	95	80
25	160	125	105
35	190	150	130
50	235	185	160
70	290	235	200

Note: (*) For cables with or without neutral core.

Table I.3.8: Allowed permanent current for flexible rubber coated copper cables for mobile devices

Cross-section of the core, mm^2	**Allowed currents $^{(*)}$ (A)**		
	0,5kV	3kV	6kV
6	44	45	47
10	60	60	65
16	80	80	85
25	100	105	105
35	125	125	130
50	155	155	160
70	190	195	-

Note: (*) For cables with or without neutral core.

Table I.3.9: Allowed permanent current for flexible rubber coated copper cables for mobile devices

Cross-section of the core, mm^2	**Allowed currents (*) (A)**	
	3kV	6kV
16	85	90
25	115	120
35	140	145
50	175	180
70	215	220
95	260	265
120	305	310
150	345	350

Note: (*) For cables with or without neutral core.

Allowed permanent current of the load line

I.3.17. The allowed permanent current of oil impregnated paper insulated cables up to 35kV, metal or PVC sheathed, is taken by the allowed temperature rise of the core of the cable: at the nominal voltage of 6 kV: +65° C; at 10 kV: 60°C; at 22 and 35kV: +50°C; or according to the specifications of the manufacturer.

For insulated rubber or synthetic plastic cables, metal or synthetic resin sheathed, is allowed to take the allowed permanent current and temperature rise according to the specifications of the manufacturer.

I.3.18. The allowed permanent current of the underground cable is specified by the manufacturer; otherwise to refer to the tables I.3.10, 13, 16 ÷ 18, for the case that the cable is buried at the depth of 0.7 ÷ 1 m, the soil temperature is +15°C and the thermal resistivity of earth is 120cm. °K/W.

If the value of the thermal resistivity of the soil is different from the above values, the allowed current of the cable should be multiplied by the factor given in the Table I.3.2.

I.3.19. The maximum allowed permanent current of the overhead cables is specified by the manufacturer; otherwise to refer to the tables I.3.11, 14, 18, 19, it is calculated with the water temperature of +15^{o}C.

I.3.20. The allowed permanent current of the overhead cable is specified by the manufacturer; otherwise to refer to the tables I.3.12, 15 ÷ 21, it is calculated with the distance of not less than 35mm between the cables when placed indoors, outdoors and in the trenches, but when placed in the ditch, the distance is not less than 50mm, with any quantity of cables and the air temperature is +25^o C.

I.3.21. The allowed permanent current of the underground cable without artificial ventilation must be taken such as the overhead cables.

I.3.22. When the cable lines pass through many different environments, the allowed current is calculated for the cable placed the worst conditions if the length of this cable is greater than 10m. In that case, it is necessary to replace the said cable by a cable with larger cross-section.

I.3.23. When placing a cable in the ground or in the tubes, the allowed permanent current should be reduced by multiplying by the factor specified in the Table I.3.22, excluding the redundant cable. When placing the cable in the ground, the distance between them should not be less than 100mm.

I.3.24. The allowed permanent current for cables containing oil pressure, gas, XLPE and EPR cables, single core cables with steel belt is calculated according to the manufacturer's documentation.

I.3.25. For the allowed currents of the cables mentioned above is given at the calculated temperature of the air of +25°C, the calculated water temperature of +15^o C.

I.3.26. The allowed permanent current of the cables placed in the ducts with artificial ventilation shall be deemed to have cables placed overhead with the temperature of the air as the temperature of the soil.

I.3.27. When the cables are placed in bundle, to comply with the manufacturer's instructions.

Table I.3.10: The allowed permanent current for the copper cable, oil impregnated paper, plastic and non-flammable synthetic resins insulated, metal sheathed.

Cross-section of the core, mm²	**Allowed currents (A)**				
	Single core cable – Up to 1kV	2-cores cable – Up to 1kV	4-cores cable – Up to 1kV	3-cores cable – Up to 6kV	3-cores cable – Up to 10kV
6	-	80	-	-	-
10	140	105	85	80	-
16	175	140	115	105	95
25	235	185	150	135	120
35	285	225	175	160	150
50	360	270	215	200	180
70	440	325	265	245	215
95	520	380	310	295	265
120	595	435	350	340	310
150	675	500	395	390	355
185	755	-	450	440	400
240	880	-	-	510	460
300	1000	-	-	-	-
400	1220	-	-	-	-
500	1400	-	-	-	-
625	1520	-	-	-	-
800	1700	-	-	-	-

Table I.3.11: The allowed permanent current for the copper cable, tall oil impregnated paper, infusible plastic insulated, lead sheathed, placed in water.

Cross-section of the core, mm²	**Allowed currents (A)**			
	3-cores cables			4-cores cables
	Up to 3kV	6kV	10kV	Up to 1kV
16	-	135	120	-
25	210	170	150	195
35	250	205	188	230
50	305	255	220	280
70	375	310	275	350
95	440	375	340	410
120	505	430	395	470
150	565	500	450	-
185	615	545	510	-
240	715	625	585	-

Table I.3.12: The allowed permanent current for the copper cable, tall oil impregnated paper, infusible plastic insulated, lead sheathed, overheaded.

Cross-section of the core, mm²	**Allowed currents (A)**				
	Single-core cables, up to 1kV	2-cores cables, up to 1kV	4-cores cables, up to 1kV	3-cores cables	
				Up to 6kV	Up to 10kV
6	-	55	-	-	-
10	95	75	60	55	-
16	120	95	80	65	60
25	160	130	100	90	85
35	200	150	120	110	105
50	245	185	145	145	135
70	305	225	185	175	165
95	360	275	215	215	200
120	415	320	260	250	240
150	470	375	300	290	270
185	525	-	346	325	305
240	610	-	-	375	350
300	720	-	-	-	-
400	808	-	-	-	-
500	1020	-	-	-	-
625	1180	-	-	-	-
800	1400	-	-	-	-

Table I.3.13: The allowed permanent current for the aluminum cable, tall oil impregnated paper, infusible plastic insulated, lead or aluminum sheathed, undergrounded.

Cross-section of the core, mm²	**Allowed currents (A)**				
	Single-core cables, up to 1kV	2-cores cables, up to 1kV	3-cores cables		4-cores cables, up to 1kV
			6kV	10kV	
6	-	60	-	-	-
10	110	80	60	-	65
16	135	110	80	75	90
25	180	140	105	90	115
35	220	175	125	115	135
50	275	210	155	140	165
70	340	250	190	165	200
95	400	290	225	205	240
120	460	335	260	240	270
150	520	385	300	275	305
185	580	-	340	310	345
240	675	-	390	355	-
300	770	-	-	-	-
400	940	-	-	-	-
500	1080	-	-	-	-
625	1170	-	-	-	-
800	1310	-	-	-	-

Table I.3.14: The allowed permanent current for the aluminum cable, tall oil impregnated paper, infusible plastic insulated, lead sheathed, placed in water.

Cross-section of the core, mm^2	**Allowed currents (A)**		
	3-cores cables		4-cores cables, up to 1kV
	6kV	10kV	
16	105	90	-
25	130	115	150
35	160	140	175
50	195	170	220
70	240	210	270
95	290	260	315
120	330	305	360
150	385	345	-
185	420	390	-
240	480	450	-

Table I.3.15: The allowed permanent current for the aluminum cable, tall oil impregnated paper, infusible plastic insulated, lead or aluminum sheathed, overheaded.

Cross-section of the core, mm^2	**Allowed currents (A)**				
	Single-core cables, up to 1kV	2-cores cables, up to 1kV	3-cores cables		4-cores cables, up to 1kV
			6kV	10kV	
6	-	42	-	-	-
10	75	55	42	-	45
16	90	75	50	46	60
25	125	100	70	65	75
35	155	115	85	80	95
50	190	140	110	105	110
70	235	175	135	130	140
95	275	210	165	155	165
120	320	245	190	185	200
150	360	290	225	210	230
185	405	-	250	235	260
240	470	-	290	270	-
300	555	-	-	-	-
400	675	-	-	-	-
500	785	-	-	-	-
625	910	-	-	-	-
800	1080	-	-	-	-

Table I.3.16: The allowed permanent current for the 6kV 3-cores copper cable, oil impregnated insulated, common lead sheathed, undergrounded and overheaded.

Cross-section of the core, mm²	**Allowed currents (A)**		**Cross-section of the core, mm²**	**Allowed currents (A)**	
	Undergrounded	Overheaded		Undergrounded	Overheaded
16	90	65	70	220	170
25	120	90	95	265	210
35	145	110	120	310	245
50	180	140	150	355	290

Table I.3.17: The allowed permanent current for the 6kV 3-cores aluminum cable, oil impregnated insulated, common lead sheathed, undergrounded and overheaded.

Cross-section of the core, mm²	**Allowed currents (A)**		**Cross-section of the core, mm²**	**Allowed currents (A)**	
	Undergrounded	Overheaded		Undergrounded	Overheaded
16	70	50	70	170	130
25	90	70	95	205	160
35	110	85	120	240	190
50	140	110	150	275	225

Table I.3.18: The allowed permanent current for the 6kV 3-cores copper cable, tall oil impregnated paper insulated, infusible plastic insulated, separated lead sheathed, undergrounded, placed in water and overheaded.

Cross-section of the core, mm^2	**Allowed currents (A)**					
	22kV voltage			35kV voltage		
	Positioned					
	Undergrounded	In water	Overheaded	Undergrounded	In water	Overheaded
25	110	120	85	-	-	-
35	135	145	100	-	-	-
50	165	180	120	-	-	-
70	200	225	150	-	-	-
95	240	275	180	-	-	-
120	275	315	205	270	290	205
150	315	350	230	310	-	230
185	355	390	265	-	-	-

Table I.3.19: The allowed permanent current for the 6kV 3-cores aluminum cable, tall oil impregnated paper insulated, infusible plastic insulated, separated lead sheathed, undergrounded, placed in water and overheaded.

Cross-section of the core, mm^2	**Allowed currents (A)**					
	22kV voltage			35kV voltage		
	Positioned					
	Undergrounded	In water	Overheaded	Undergrounded	In water	Overheaded
25	85	90	65	-	-	-
35	105	110	75	-	-	-
50	125	140	90	-	-	-
70	155	175	115	-	-	-
95	185	210	140	-	-	-
120	210	245	160	210	225	160
150	240	270	175	240	-	175
185	275	300	205	-	-	-

Table I.3.20: The allowed permanent current for the 6kV 3-cores copper cable, tall oil impregnated paper insulated, infusible plastic insulated, lead sheathed, overheaded.

Cross-section of the core, mm²	Allowed currents (*) (A)	
	22kV cables	35kV cables
25	105/110	-
35	125/135	-
50	155/165	-
70	185/205	-
95	220/255	-
120	245/290	240/265
150	270/330	265/300
185	290/360	285/335
240	320/395	315/380
300	350/425	340/420
400	370/450	-

Note (*): The numerator is used for the cables placed on the same plane, 35-125mm apart.
The denominator is used for the cables placed on the three gables of an equiangular triangle.

Table I.3.21: The allowed permanent current for the 6kV 3-cores aluminum cable, tall oil impregnated paper insulated, infusible plastic insulated, lead or aluminum sheathed, overheaded.

Cross-section of the core, mm²	Allowed currents (*) (A)	
	22kV cables	35kV cables
10	-	-
16	-	-
25	80/85	-
35	95/105	-
50	120/130	-
70	140/160	-
95	170/195	-

120	190/225	185/205
150	210/255	205/230
185	225/275	220/255
240	245/305	245/290
300	270/330	260/330
400	285/350	-
500	-	-
625	-	-
800	-	-

Note (*): The numerator is used for the cables placed on the same plane, 35-125mm apart.

The denominator is used for the placed on the gables of an equiangular triangle.

Table I.3.22: Correction factor when many cables are placed in parallel in the soil, with or without tube.

Number of cables / Space distance between cables (mm)	1	2	3	4	5	6
100	1,0	0,00	0,85	0,80	0,78	0,75
200	1,0	0,92	0,87	0,84	0,82	0,81
300	1,0	0,93	0,90	0,87	0,86	0,85

Allowed permanent current for bare conductors and bars

I.3.28. the allowed permanent current for bare conductors and bars is subject to the manufacturer's documentation, otherwise, to refer to the tables I.3.23 ÷ I.3.29 and calculated with the allowed temperature rise of $+70^{o}$ C at the air temperature of $+25^{o}$ C. When selecting the conductors the bars, it is necessary to check the allowed permanent current by the temperature rise conditions consistent with the working conditions of the conductors and bars. The calculation of the allowed permanent current is done as per the instructions stated in the Annex I.3.1.

I.3.29. When placing the conductive bars according to Figure 1 (Table I.3.28), the currents specified in the Table I.3.28 should be reduced by 5% for the bars with the width (h) of up to 60mm and by 8% for the bars having the width (h) larger than 60mm.

I.3.30. When selecting the bars with large cross-section, it is necessary to select according to the economic current density and appropriate structure to minimize the stray losses due to surface effects, proximity effects, and to ensure the best cooling.

Table I.3.23: The allowed permanent current by the temperature rise of the copper, aluminum cables, steel-core aluminum cables (the allowed temperature rise is +70° C, when the air temperature is 25° C)

Cross-section of the copper/aluminum core, mm²	**Allowed currents (A) by the cables codes**					
	AC,ACK, ACKC, ACKП, ACSR		M	A, AKП	M	A, AKП
	Outdoor	Indoor	Outdoor		Indoor	
10/1,8 *	84	53	95	-	60	-
16/2,7*	111	79	133	105	102	75
25/4,2*	142	109	183	136	137	106
35/6,2	175	135	223	170	173	130
50/8	210	165	275	215	219	165
70/11	265	210	337	265	268	210
95/16	330	260	422	320	341	255
120/19	390	313	485	375	395	300
120/27	375	-				
150/19	450	365	570	440	465	355
150/24	450	365				
150/34	450	-				
185/24	520	430	650	500	540	410
185/29	510	425				
185/43	515	-				
240/32	605	505	760	590	685	490
240/39	610	505				
240/56	610	-				

300/39	600	713				
300/48	585	705	1050	815	895	690
300/66	680	-				
330/27	730	-	-	-	-	-
400/22	830	713				
400/51	825	705	1050	815	895	690
400/64	860	-				
500/27	960	830	-	980	-	820
500/64	945	815				
600/72	1050	920	-	1100	-	955
700/86	1180	1040	-	-	-	-

Note: (*) This kind of cross-section is not available for the cables of ACSR code.

Table I.3.24: The allowed permanent current for the round/tube-shaped bar, copper or aluminum.

Diameter (mm)	**Round bar**		**Tube shaped copper bar**		**Tube shaped aluminum bar**	
	Current(*) (A)		Inner/Outer diameter	Current (A)	Inner/Outer diameter	Current (A)
	Copper	Aluminum				
6	155	120	12/15	340	13/16	295
7	195	150	14/18	460	17/20	345
8	235	180	16/20	505	18/22	425
10	320	245	18/22	555	27/30	500
12	415	320	20/24	600	26/30	575
14	505	390	22/26	650	25/30	640
15	565	435	25/30	830	36/40	765
16	610/615	475	29/34	925	35/40	850
18	720/725	560	35/40	1100	40/45	935
19	780/785	605/610	40/45	1200	45/50	1040
20	835/840	650/655	45/50	1330	50/55	1150
21	900/905	695/700	49/55	1580	54/60	1340
22	955/965	740/745	53/60	1860	64/70	1545
25	1140/1165	885/900	62/70	2295	74/80	1770
27	1270/1290	980/1000	72/80	2610	72/80	2035
28	1325/1360	1025/1050	75/85	3070	75/85	2400
30	1450/1490	1120/1155	90/95	2460	90/95	1925

35	1770/1865	1370/1450	95/100	3060	90/100	2840
38	1960/2100	1510/1620	-	-	-	-
40	2080/2260	1610/1750	-	-	-	-
42	2200/2430	1700/1870	-	-	-	-
45	2380/2670	1850/2060	-	-	-	-

Note: (*) The numerator is the allowed alternating current, the denominator is the allowed direct current.

Table I.3.25: The allowed permanent current for the copper conductive bar, rectangular cross-section

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

Note: (*) The numerator is the allowed alternating current, the denominator is the allowed direct current.

Table I.3.26: The allowed permanent current for the aluminum conductive bar, rectangular cross-section

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

Note: (*) The numerator is the allowed alternating current, the denominator is the allowed direct current.

Table I.3.27: The allowed permanent current for the bare brass conductors or steel-core brass conductors.

Brass conductors		**Steel-core brass conductors**	
Conductors code	Allowed current$^{(*)}$(A)	Conductors code	Allowed current$^{(*)}$(A)
B-50	215	BC-185	515
B-70	265	BC-240	640
B-95	330	BC-300	750
B-120	380	BC-400	890
B-150	430	BC-500	980
B-185	500		
B-240	600		
B-300	700		

Note: (*) The allowed current corresponding to the brass with resistivity ρ_{20} = 0,003 Ω.mm^2/m.

Table I.3.28: Allowed permanent current of bus bars arranged in the square shaped (Figure 1), copper or aluminum.

Dimension (mm)				**Cross-section of four bars (mm2)**	**Allowed current for the set**	
h	b	h_1	H		Copper	Aluminum
80	8	140	157	2560	5750	4550
80	10	144	160	3200	6400	5100
100	8	160	185	3200	7000	5550
100	10	164	188	4000	7700	6200
120	10	184	216	4800	9050	7300

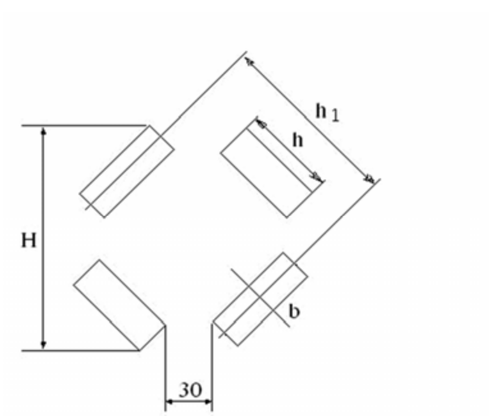


Figure 1

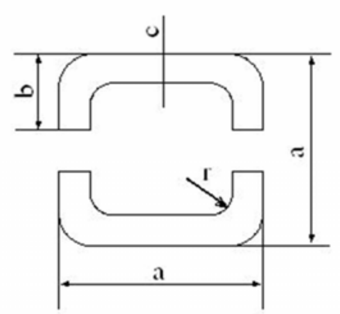


Figure 2

Table I.3.29: Allowed permanent current of the conductive bar in box-shaped (Figure 2), copper or aluminum.

Dimension (mm)				**Overall cross-section (mm^2)**	**Allowed current (A)**	
a	b	c	r		Copper	Aluminum
75	35	4	6	1040	2730	-
75	35	5,5	6	1390	3250	2670
100	45	4,5	8	1550	3620	2820
100	45	6	8	2020	4300	3500
125	55	6,5	10	2740	5500	4640
150	65	7	10	3570	7000	5650
175	80	8	12	4880	8550	6430
200	90	10	14	6870	9900	7550
200	90	12	16	8080	10500	8830
225	105	12,5	16	9760	12500	10300
250	115	12,5	16	10900	-	10800

Table I.3.30: Correction factor for the allowed permanent current of bare and insulated cables, underground cables, bus bar under the temperature of the soil and air.

Ambient calculating temperature (^oC)	Standard temperature of the cable cores (^oC)	Correction factor of the allowed permanent current by the ambient temperature (^oC)							
		15	20	25	30	35	40	45	50
15	80	1,00	0,96	0,92	0,88	0,83	0,78	0,73	0,68
25	80	1,09	1,04	1,00	0,90	0,80	0,80	0,80	0,74
25	70	1,11	1,05	1,00	0,94	0,88	0,81	0,74	0,67
15	65	1,00	0,95	0,89	0,84	0,77	0,71	0,63	0,55
25	65	1,12	1,06	1,00	0,94	0,87	0,79	0,71	0,61
15	60	1.00	0,94	0,88	0,82	0,75	0,67	0,57	0,47
25	60	1,13	1,07	1,00	0,93	0,85	0,76	0,66	0,54
15	55	1,00	0,93	0,86	0,79	0,71	0,61	0,50	0,36

25	55	1,15	1,08	1,00	0,91	0,82	0,71	0,58	0,41
15	50	1,00	0,93	0,84	0,76	0,66	0,54	0,37	-
25	50	1,18	1,09	1,00	0,89	0,78	0,63	0,45	-

Selecting conductors by the corona conditions

I.3.31. For the voltage level of 110kV and above, the conductor must be tested under corona conditions, at the average temperature and air density depending on the elevation above sea level. The maximum electric field strength (E) on the outside of the conductors should not exceed $0.9E_0$ (E_0 is the electric field strength when the corona starts to occur at the conductor.)

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

The actual electric field strength is calculated as follows::

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

Where:

• U: Nominal voltage, kV

• n: Number of phase-dividing conductors, if not divided, n = 1

• a: Distance between the phase-wires, cm

• r: Radius of each wire, cm

• D_{tb}: Average geometric distance between the phases

• r_{td}: Equivalent radius, calculated by the formula:

$$r_{td} = R\sqrt[n]{\frac{n.r}{R}}\ [cm]$$

Where: $$R = \frac{a}{2\sin\frac{180}{n}}\ [cm]$$

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

For the voltage level of 220kV and above, to take the measure of dividing the cable into 2 to 4 small wires to limit the corona.

It is also necessary to check the level of radio communication interference of the corona.

Selecting lightning conductor

I.3.32. When selecting lightning conductor, in addition to ensuring the conditions for the physico-mechanical calculating listed in Part II, it is necessary to check the thermal stable conditions when a phase short circuit occurs, to follow the instructions in the Annex I.3.2 .

Chapter I.4
SELECTING EQUIPMENT AND CONDUCTORS UNDER SHORT CIRCUIT CONDITIONS

Scope

I.4.1. This chapter applies to the selection of equipment and conductors under short circuit conditions using alternating current of 50Hz.

General requirements

I.4.2. To check the short circuit mode (except the cases stated in Article I.4.4):
1. For electrical equipment of above 1 kV:

a. Electrical equipment, cables, conductors, structural supports and bearing structure thereof.
b. Overhead lines having the impact short circuit current of 50kA and above to avoid the shorting due to the electromotive force when the short circuit occurs. Also, for the phase dividing lines, it is required to check the distance between the positioning frame in each phase.

For overhead lines with fast acting self-closing devices, it is necessary to check the thermal stability.

2. For the electrical equipment of up to 1 kV, to check only the distribution panels, electrical lines and the dynamic cabinets. Do to check the short-circuit for the current conversion.

3. For the electrical equipment used to switch off the short circuit line, to test the manipulation while a short circuit occurs.

The electrical equipment which can withstand short circuit current is the device which, when the short circuit current calculation occurs, is not destroyed or distorted, but continues the normal operation.

I.4.3. For the electrical equipment of above 1 kV, it is not necessary to check:

• Stability of the electrical equipment and conductors that are protected by fuses with nominal currents up to 60A.

• Thermal stability of the equipment and conductors which are protected by any kind of fuse. The fuse must be able to be sensitive enough to cut the smallest short circuit current.

I.4.4. It is not necessary to check under short-circuit mode:

1. The conductors supplying electricity to individual households using electricity, including workshops transformers with a total capacity of 1MVA, primary voltage up to 22kV, if the following conditions are simultaneously satisfied:

- The power consumption household have the preventive measures not to interrupt the technology process when the power if off.
- When a short circuit occurs, the broken conductors will not cause the explosion.
- The replacement of conductors is easy.

2. Conductors of overhead lines, except the item b of the Article I.4.2.

3. The conductive bars and equipment of the voltage modulator are placed in a separate compartment or placed behind the auxiliary resistance.

I.4.5. When selecting the short circuit diagrams, to consider only the permanent working mode of electrical equipment, not to consider the temporary short-term working mode.

To calculate the short circuit current in the power grid development plan at least 10 years after putting the equipment into operation (for calculus of approximation).

I.4.6. To consider the following types of short circuit:

1. 3-phase short circuit to check the stability of electrical equipment, conductive bars, conductors and the associates support structures.

2. 3-phase short circuit to check the thermal stability of the equipment, conductive bars, and conductors. At the voltage of generator, to select the 2 phase or 3 phase short circuit in the type which causes the greater heat.

3. For the 3-phase short circuit and a single phase grounding, to take the larger value to select or to check the availability of short-circuit switching device. If the breaker has two breaking values of three phase and single phase, it is required to select both the said short circuit types .

I.4.7. The equipment and conductor of the circuit to be selected by the highest short-circuit current running through.

Not to consider the case of different phases simultaneously grounding at two different points.

I.4.8. On the circuit having the reactance at the indoor station in which equipment and conductors placed before the reactor are separated from the bus bars (in the branch from the main circuit) with the ceiling, walls etc. they shall be selected by the short circuit after the reactor, if the reactor is placed in the same station and is connected by conductive bars.

The conductive bar branching from the bus bar to the deflector plate and bushing must be selected by the short circuit before the reactor.

I.4.9. When checking the thermal stability, the calculation time is taken as the short circuit releasing time.

Determining the short circuit current to select the equipment and conductors

I.4.10. The determination of short circuit current to select equipment, conductive bars, conductors, to check the load equipment, result from the following requirements:

1. All power supplies for short-circuit points work simultaneously with the nominal load.

2. All self-synchronous devices have the automatic voltage regulation and forced excitation function.

3. The short circuit occurs at the time that structural system make up the highest short circuit current.

4. The electromotive force of any power source are in the phase.

5. The calculation voltage at each level is equal to 105% of nominal voltage of the grid.
6. To consider the impact of the synchronous compensator, synchronous and asynchronous motors. Not to consider the impact of asynchronous motors of up to 100kW connected through transformers to the short circuit point and of the asynchronous motors of higher capacity that are connected to the short-circuit point through 2 or more transformers, through the lines having considerable impedance.

I.4.11. For the grid from 1 kV, to calculate only the electrical impedance of the equipment and lines. To calculate the total resistance for a small cross-section lines, long cable lines having small cross-section.

I.4.12. For the power grid up to 1 kV, to calculate the reactance and resistance of all elements, including the contact resistance of the contacts. It is allowed to ignore the resistance or impedance if the variation of the total resistance does not exceed 10%.

I.4.13. For the power grid up to 1 kV receiving the power from the step-down transformer, when calculating the short circuit, it is necessary to consider the voltage to the transformer as constant and equal to the nominal voltage of the grid.

I.4.14. For the elements protected by fuses, having the current limiting features, to check the dynamic stability under the highest immediate short-circuit current, passing through the fuse.

Selecting the conductors and the insulation, checking the bearing structure by the electromotive force of the short-circuit current

I.4.15. The electromotive force acting upon the rigid conductive bars, and transmitted to the insulation and the rigid supporting structure must be calculated by the maximum instantaneous three-phase short-circuit current, taking into consideration the phase difference between the current and ignoring the mechanical oscillation of the conductor structure.

The impulse force acting upon the soft conductors, the insulation, the output and the conductor structures is calculated by the quadric mean of the average value of the short circuit current between two adjacent phases. For the phase dividing conductor and soft electrical conductivity system, the interactive force of the short-circuit current in the isophasal conductor is determined by the effective value of the three-phase short circuit currents.

To check to ensure that the soft electrical conductivity system is not touching.

I.4.16. The mechanical forces due to short-circuit current determined according to the Article I.4.15 passing through the rigid conductive bars to the support insulators and through insulators may not exceed 60% of the minimum breaking strain of the insulator if it is the single, and not exceed 100% of the breaking strain of the insulator if it is the double.

If the conductive bars consisting of many flat or U-shaped bars are used, the mechanical stress is equal to the total stress caused by the interaction force between phases and between the elements of each bar.

The maximum mechanical stress in the rigid conductive bars should not exceed 70% of the immediate breaking strain.

Selecting conductors under the temperature rise at the short-circuit

I.4.17. The temperature rise of conductors at the short circuit should not exceed the allowed values in the following table:

Conductive materials	Highest allowed temperature (^oC)
Conductive bars: • Copper • Aluminum	 300 200
Oil impregnated paper insulated cables, voltage up to 10 kV	200
As above, voltage from 15 kV to 220 kV	125
Copper or aluminum cores cables and conductors, insulated: • PVC and rubber • PE • XLPE or EPR	 150 120 250
Bare copper conductors with pull force up to 20 N/mm^2	250
Bare copper conductors with pull force above 20 N/mm^2	200

Bare aluminum conductors with pull force up to 10 N/mm^2	200
Bare aluminum conductors with pull force above 10 N/mm^2	160
Aluminum part of steel-core aluminum conductors	200

I.4.18. The cable checking under the temperature rise conditions at short circuit as stated in Article I.4.2 shall be conducted for:

1. Single cable with the homogeneous cross-section when the short circuit occurs at the end of the cable.
2. Single cable with different cross-section at many segments when short circuit occurs at the end of each cable.
3. Cable line consisting two or more cables laid in parallel, when short circuit occurs at the end of the cable bundle.

I.4.19. When checking the thermal stability of the equipment and conductors of the line having fast self-switching off devices, to consider the temperature rise due to the increase of the total duration of short circuit. When examining the temperature rise under short circuit conditions, the phase dividing conductors are regarded as a single conductor having a cross-section equal to the total cross-section of the phase dividing conductors.

Selecting electrical installations by switching capability

I.4.20. To select a circuit breaker above 1kV, it is necessary to select:

1. According to the switching-off capability: To identify the calculation switching current under the conditions stated in the Article I.4.5 to Article I.4.9.

The calculation switching current is the overall utility short-circuit current (including the non-cyclical component), determined with release time of the breaker, equal to the individual total break time of breaker (from the break instruction time to the release time to extinguish the arc) plus the arc extinguishing time.

2. According to the switching-on capability: For the breaker of the generator placed at the voltage side of the generator, it is necessary only to check when switching on asynchronously under anti-phase condition.

I.4.21. When selecting a fuse according to the switching-off capability, to take the utility value of the short circuit current of the initial cycle as the calculation current (To ignore the current limiting feature of the fuse.)

The load breaker and the short-circuit knife must be selected by the allowed short circuit when switching on.

I.4.22. In addition to the selection by the ability of short-circuit switching off, the circuit breakers have to be selected according to the transient recovery voltage (TRV). The TRV capability of the circuit breaker must be greater than TRV values ,calculated for each specific position of the circuit breaker in the system.

The selection according to the TRV is only applied to the breakers 500kV and 220kV placed at the end of a long line, to the breakers placed at the terminal of the generator and breakers placed near the reactor.

Chapter I.5

COUNTING POWER

Scope and definitions

I.5.1. This chapter is applied to the power counting in the power works, electricity consumption households etc.

The tool for power counting is called watt-hour meter.

The system including watt-hour meter, current transformer, voltage transformer and the wires connecting the said devices is called the power counting system.

I.5.2. The payment watt-hour meter is the electricity meter for count the electricity payment purpose between the electricity buyer and seller, including power production, power consumption of electricity consumption households or power purchasing at the boundary. The selection of electronic or electronic meter and the data transmission requirements of meters away should comply with the current regulations.

I.5.3. The watt-hour meters must be placed in the buyer management areas, unless the parties have other agreements. The location and the installation of the watt-hour meters must ensure the safety, aesthetics and convenience for the buyer to check the measured value and for the sellers to read it.

Where the electricity can be exchanged in both directions at the boundary, two directed watt-hour meters or one watt-hour meter counting for both directions must be placed.

I.5.4. The proofing meter is used to monitoring purpose. Do not use the data recorded by the proofing meter for payment.

General requirements

I.5.5. The active energy counting must ensure the determination of the active energy:

1. Generated by each power unit.

2. Self used in power plants, power stations including the compensating station and diesel stations.

3. Supplied by the power plant to the transmission grid, distribution network.

4. Supplied to or received from other electrical systems.

5. Supplied to power consumption households.

In addition to counting the power for payment purpose, the power counting must also ensure the ability to check the use of electricity of households, to check the power exchange at the boundary, the power balancing, to set up the technical and economic indicators and to forecast the load.

I.5.6. The reactive energy counting must ensure the determination of the amount of reactive energy:

1. Generated by each power generator.

2. Supplied by the power plant to the transmission grid, distribution network.

3. Generated by the rotary compensator or the static compensator.

4. Supplied to or received from other electrical systems.

5. Of households using electricity for production and services in accordance with the current regulations. In addition to counting reactive power for the payment purpose, to ensure the monitoring function just like the active energy counter mentioned in the Article I.5.5.

Watt-hour meter location

I.5.7. In power plants, the active energy counter must be placed at:

1. Each generator.

2. At each booster transformer, placed on the secondary coil, except the un-exploited balance coil. If at the secondary side there is no individual current transformer to count the power, to place the meter in the primary coil connected to the generator.

On the side of power exchange of the transformer, to place two directed meters or meter which can count both directions.

3. Each voltage line of generator. To place two directed meters or meter which can count both directions

at the power exchange line.

4. Each auxiliary transformer. To place the meter placed on the high-voltage side of the auxiliary transformer. If it is difficult to place the meter at the high-voltage side, to place it at the low-voltage side.

5. Each auxiliary generator. If the auxiliary generator has also its own the electronic auxiliary parts to place the meter at this part.

I.5.8. In the grid, the active meter must be placed at:

1. Both ends the communication lines of the system, at each end to place two directed meters or a meter which can count both directions.

2. At the low-voltage of the two-windings transformer.

3. At the low-voltage of three-windings transformer, except the un-exploited balance winding.

4. Each line coming from the station, except for low-voltage line for living power and exclusive lines having meter placed at the end of line.

5. Each auxiliary transformer.

I.5.9. The watt-hour meters for payment purpose for households must be placed:

1. According to the Article I.5.3 or Article I.5.8, item 3

2. At the input of consumers station if there is no line connected to another station or to other consumers at the voltage supplied for the former.

3. At the high-voltage side of the transformer of households, if this station continues supplying or connected to the other consumers at the supplied voltage. If there is no current transformer with the exact the level specified at the voltage 35kV or higher, it is allowed to place the meter at the low-

voltage side of the transformers.

4. At the low-voltage side of the transformer, if at the high-voltage side there is load breaker, auto disconnector or fuse circuit breaker.

I.5.10. The var-hour meter must be placed at:

1. The generators with a capacity of more than 1.000kW.

2. The medium-voltage winding and low-voltage winding of transformer and at the locations in the grid substation where the active energy meter is placed. If there is no current transformer with the exact level according to the regulations, it is allowed not to place the var-hour meter at the medium-voltage winding of transformer.

3. At the 35 kV line, if the payment of electricity of households is based only on the active energy meter of that line.

4. At the output of the compensator or at the distribution transformer of the capacitor with a capacity from 1MVAr.

5. Near the active energy meter for payment of households of large power consumption.

6. In the elements of power system, at the boundary, where the watt-hour are required for payment purpose or the reactive energy should be monitored.

7. In the households where the reactive energy is generated, two directed var-hour meters must be placed.

8. At the boundary with power exchange, two directed var-hour meters or one watt-hour meter which may count both directions must be placed.

Requirements for watt-hour meter

I.5.11. The watt-hour meter cover, watt-hour meter wire clamp cover, meter box or cabinet cover must be sealed by the state accreditation body or authorized electricity supply bodies.

I.5.12. To count the active energy and reactive energy in the three-phase circuit by the three-phase watt-hour meter.

I.5.13. The watt-hour meter and related equipment such as: current transformation, voltage transformation measurement instruments must be tested under the current regulations.

The tolerance of the active energy meter of the generator must comply with the table I.5.1. The said tolerances are determined at the power level from 50% to 100% of nominal capacity by cosφ = 1 and 0.5 at the nominal frequency and voltage.

Table I.5.1: Allowable tolerances of the meter of generator

Objects for power counting	**Allowable tolerances, %**
Generator with capacity to 12MW	±1
Generators with capacity from 12MW to 100mW	±0,7
Generators with capacity over 100MW	±0,5

I.5.14. The watt-hour meter for payment connected to current transformation, voltage transformation measurement instruments must be compatible with current standards for the degree of accuracy of 0.5, 1 or 2 for active energy meter and 2 or 2.5 for reactive energy meter.

The current transformation, voltage transformation measurement instruments must also have corresponding tolerances.

Counting the power through the measuring transformer

I.5.15. The current transformation, voltage transformation measurement instruments connected to the payment watt-hour meter must have the degree of accuracy not greater than 0.5. It is allowed to connect voltage transformer having the degree of accuracy not greater than 1.0 meters to the payment watt-hour meter having the degree of accuracy of 2.0.

For technical meter, it is allowed to use current transformer having the degree of accuracy of 1.0 or to connect the built-in current transformer of the meter having the degree of accuracy lower than 1.0, in order to get the degree of accuracy 1.0, the secondary current transformer is necessary.

When using the technical meter, it is allowed to use voltage transformer with the degree of accuracy of 1.0 and the voltage transformer with the degree of accuracy lower than 1.0.

I.5.16. The meter should be connect to the individual coil for measuring at the secondary current transformer, in the individual cases, it is possible to combine the counting power, measuring power and placing the relay at the secondary coil of the current transformer if the tolerance is guaranteed and the characteristics of the relay are not altered.

When the payment meter is connected to other devices after the voltage and current transformers it is required to be seal the power counting circuit.

I.5.17. The load at the secondary circuit of measuring transformer including the watt-hour meter shall not exceed the nominal mentioned at label of the measuring transformer.

I.5.18. The cross-section and length of wires connecting the meter to the current transformer or voltage transformer must ensure the corrective operation of the measuring transformer and that the voltage loss in the voltage circuit to the meter does not exceed 0.5% of nominal voltage.

I.5.19. Do not use clamps in the circuit of the payment meter placed in households. If mandatory, to seal the clamps.

I.5.20. To count the power of the generator, to use a current transformer with the degree of accuracy of 0.5 and the tolerance correspond to 50% to 100% of nominal current of the generator, the tolerance should not exceed the values specified in Table I.5.2.

Table I.5.2: Allowable tolerances of the current when the current it is equal to 50% to 100% of the nominal value of the generator.

Current transformers	Current tolerances, %	Phase displacement, minutes
Used for power transmitter to 12MW	± 0,20	± 20
Used for power transmitter over 12MW	± 0,15	± 10

I.5.21. To supply voltage to the meter, it is possible to use any kind of voltage transformer with secondary voltage and tolerances in accordance with the requirements of the meter.

I.5.22. The secondary windings of the current transformer of 500V and above must be grounded at one pole of the wiring clamp.
At the voltage transformer, the neutral point of the pilot wire must be earthed and at one point only, when the winding is delta connected, the a common point of the secondary windings is to be earthed.

It is prohibited to earth the secondary winding of the current transformer used at the bus bar with the voltage up to 1kV whose the primary winding is not insulated (the bus bar and the steel core is energized). In this case, the outside secondary winding must be earthed.

Outside the meter, if the acting circuit or synchronizing circuit is connected to the pilot wire of the voltage transformer, it is allowed to earth directly the secondary winding through the disruptive fuse.

I.5.23. The voltage transformer up to 35 kV should be protected by at the primary winding.

Before the payment meter, the wiring clamp box should be placed to connect short-circuit the secondary winding of the current transformer before removing the circuit from the meter.

I.5.24. If the station is equipped with many bus bar and each system is equipped with voltage transformer, all circuits must be equipped with switching key to switch the circuit of the meter when necessary.

I.5.25. The meter circuit in the power plant and the substations must be equipped with separate wiring clamp or a separate segment at the common wiring clamp.

I.5.26. The protecting boxes of the voltage transformer powering the meter, if they are protected by fuse, should be protected by the wire mesh or a place enabling to seal.

The handle of the disconnector at the primary winding must have a place enabling the sealing.

Placing and connecting the watt-hour meter

I.5.27. The meter must be placed upright in a dry place with the frequent ambient temperature not exceeding 45^{o}C, convenient for reading indicators, checking and removing/hanging.

When placed outdoors, the meter must be placed in iron or composite cabinet/boxes. If the cabinet or box is made of iron, they must be earthed from the cover of cabinet or box, except the circuit in the cabinet or box is dually insulated. The protection grade of the meter must be IP43.

Payment meter, if placed in the territory's power consumer, placed indoor or outdoor should be placed in the protective box.

It is allowed to place the meter in the corridor of the distribution room of power plants and power stations.

Living payment meter can be hung on the column, outdoor or indoor, but must be in sealed box and ensure the objectivity for both buyer and seller.

Meters in the large household should be placed in a locked, separate cabinet or box, sealed. The secondary winding for measuring power should be separate. Cables from measuring device to the meter should be separate, sheathed metal, sealed at the connection positions.

I.5.28. To place the meter in the electrical panel, electrical cabinet or in the sturdy box. It is allowed to place the meter on the metal, stone or plastic panel. Do not place the meter on the wooden panel.

The meter box should be spaced from the floor 1.4 to 1.7 m.

I.5.29. If placed in a location easy for collision, dust, where many people pass by or vulnerable to external impacts, the meter must be placed in a locked cabinet or box, sealed, with transparent glass window.

It is possible to place many meters in a cabinet or box, or to place together with the low voltage transformer.

I.5.30. For the wiring on the meter, to comply with the requirements set out in the Chapter II.1 - Part II, Chapter IV.4 - Part IV.

I.5.31. The wire to the meters is to be connected, even by welding.

I.5.32. The wire close to the meter should be in excess at least 120mm. The cover 100mm long of the neutral wire before the meter must have a distinguishing color.

I.5.33. The distance between the conductor on the panel where the meter is placed and the current transformer must comply with the requirements set out in Article III.1.14 - Part III.

I.5.34. In low-voltage grid, when placing the meter and current transformer in the dangerous time or very dangerous room, to connect the meter casing and the current transformer cover to the earthing wire (neutral wire) with the separate copper wire.

I.5.35. When 2 meters or more are placed near each other, the label with the address of each meter is required.

In the power plants or power stations having 2 meters or more, the label with the address of each meter is required.

Checking meter (technical)

I.5.36. In the industrial factories, offices, power plants and power stations, the counting of proof power is necessary.

When placing the checking meter, the agreement with the electricity supplier is not necessary.

I.5.37. In the power plants, the checking meter for each circuit and each auxiliary circuit is necessary.

I.5.38. In the power stations, to place the checking meter for the general circuit at various levels of voltage, in the circuit without the payment meter that needs to be checked.

I.5.39. In the enterprises, to place the checking meter at each workshop, each production line for internal accounting purpose and to determine the energy consumption for product unit.

When the payment meter is placed at the line of stations or power plant powering the factories, it is allowed to place the choking meter at input point at the factory.

I.5.40. The checking meter, current transformer, voltage transformer in the consumer’s premise are the property of the buyer and managed by the buyer. The checking meter must meet the requirements of the Article I.5.13 and I.5.16.

Chapter I.6

MEASURING THE CURRENT

Scope

I.6.1. This chapter applies to the electrical measurement by fixed measuring instrument, does not apply to the electrical measurement in the laboratory, portable measuring instruments and measuring instrument in incident mode.

I.6.2. The electrical measuring instruments, in addition to meeting the provisions of this chapter, must also meet the requirements of the manufacturer.

General requirements

I.6.3. Electrical measuring instruments must meet the following basic requirements:

1. Indicating or automatic recording instrument must have the degree of accuracy of 1.0 to 2.5.

The amperemeterhaving no zero (0) value in the scale, installed at the low voltage distribution station and at electric motors, is allowed to have the degree of accuracy of 4.

2. The degree of accuracy of shunt, additional resistor and measuring transformer is not smaller than the values indicated in the Table I.6.1.

Table I.6.1: The degree of accuracy of shunt, additional resistor and measuring transformer

Degree of accuracy of the measuring device	**Degree of accuracy of shunt, additional resistor**	**Degree of accuracy of measuring transformer**
1	0,5	0,5
1,5	0,5	0,5
2,5	0,5	1
4	-	3

3. The limits of the measurement scale or limit of the display of values must satisfy the measured values of the entire parameters to be measured.

I.6.4. The connection of the current winding of measuring instrument and protective device to the secondary winding of the current transformer powering the payment meters must comply with the provisions stipulated in the Article I.5.17.

I.6.5. At the un-manned low voltage distribution station, it is allowed not to place the measuring instruments to measure the indicator current, but a room to connect the checking instruments or to use the snap around ammeter.

I.6.6. The power measuring instrument needle-type should have the red indicator line showing the functional rate on the scale.

I.6.7. The power measuring instrument having the "zero" bar in the middle of the scale must have the directions on both sides of the "zero" bar.

I.6.8. The power measuring instruments must have the label indicating the measurement point, except the case that it is placed next to the measurement points on the relief diagram.

I.6.9. In addition to display the measuring value on the meter in place, in separate cases, this value should be self-recorded or put into memory or transmitted to the remote location, according to the required operating procedures.

Measuring the current

I.6.10. To measure the alternative current at:

1. The circuit that checks the process of operating in a systematic way.

2. The generator, the beginning of line or the load of high and middle-voltage line, the beginning of line or the important load of low voltage line.

3. The secondary or primary circuit of transformer with capacity from 1MVA.

In the circuit of the arc extinguishing coil there must be a place to connect the registered or portable ammeter.

I.6.11. To place the registered ammeter if required.

I.6.12. To measure the direct current at:

1. The circuit of the DC generator and rectifier.
2. The battery circuit, solar cell.
3. Generator's excitation circuit, compensator and synchronous motor.

I.6.13. To place 3 ampere meters at:

- 3-phase AC generator with nominal power from 200kW.
- Transmission line having control in each phase.
- Line with series capacitor.
- Line that can operate for long periods in non-full phase mode.
- 500kV line.
- Line for electric arc furnace.

It is allowed to place one ampere meter with switch key to measure three-phase generator with a capacity up to 200kW.

I.6.14. When selecting the ampere meter and the current transformer, to take into consideration the possibility of temporary circuit overload at starting time. The current transformer should not saturated and the ampere meter must withstand the inrush current.

I.6.15. The one-dimensional ampere meter must have the 2-side scale or polarity reversal switch if the measured circuit can be reversed.

I.6.16. It is possible to connect the AC ampere meter directly the bus bar or wire, to connect the AC ampere meter to the current transformer, if the direct connection could not be done.

I.6.17. When connecting directly the ampere meter to the AC circuit above 1kV and to the DC circuit above 500V and, it is required to meet the following conditions:

1. The safety for operator, checker and repairer, the convenience for reading index, and to comply with the current electrical safety regulations.

2. To isolate the energy part of the ampere meter to the earth by isolation method which can withstand the corresponding voltage, or to connect directly on the conductive bar between the two adjacent ceramic insulators and to ensure the space phase-phase and phase-earth of the ampere meter.

3. The base of the ampere meter should be painted red on the scale there must be red sign showing high voltage value.

I.6.18. For the ampere meter place at DC electrical equipment, it is possible to connect directly or through the shunt.

Measuring voltage and checking insulation

I.6.19. To put a voltage meter at:

1. Each segment of the bus bar of the AC or DC voltage when the segment can work separately.

It is allowed to place one voltmeter with switch key to measure multiple positions of the phase.

At the low voltage distribution stations, it is possible to measure only the voltage at the low-voltage side if there is no voltage transformer at the high-voltage side.

2. AC and DC circuits of generators, synchronous compensators.

3. At the excitation circuit of synchronous generators with a capacity of 1MW or above. It is not required for hydro-electric generators.

4. At the batteries set, loader and load.

5. In the circuit of the arc extinguishing coil.

I.6.20. At the checking nodes of the power system, the voltmeter must have the degree of accuracy not greater than 1.0.

I.6.21. In the three-phase power grid, to place usually place voltmeter for line voltage.

In the 1 kV power grid with effect neutral earthing (see Article I.7.16), it is allowed to measure the three voltage lines using a measuring instrument with switch key.

I.6.22. To place the insulation tester on the 1 kV current grid with is a small earth-fault current, in the up to 1kV power grid with neutral isolation and in the DC power grid points with middle isolated point. The insulation tester can be an indicator, instruments operating under the relay principle (sound signal, lighting system) or a combination of the two instruments.

The insulation tester must meet the following requirements:

• To detect the earth-fault current when the network operates separately and when being connected to a voltage transformer star – delta connected.

• To detect easily the earth-fault current where the station is manned or un-manned.

• When necessary, the tester should send sound, light signal at place or to the control center.

I.6.23. The insulation tester in the power grid up to 1 kV and in the DC grid should determine the insulation resistance value, when necessary, the tester should send sound, light signal, while insulation values are under the set values.

I.6.24. It is not necessary to place the insulation tester in the simple and unimportant DC circuit, in the DC circuit with the voltage up to 48V.

It is required to check periodically the insulation tester by the voltmeter.

I.6.25. It is allowed to use the voltmeter to check the insulation periodically of each earthed electric pole of the excitation circuit of electric rotating machiner.

It is possible to use a voltmeter with switch key to check the insulation on some points of the excitation circuit.

I.6.26. It is required to use single phase voltage transformer or three phase and five-pole transformer to connect to the voltmeter to check the insulation. The high-voltage coil of the voltage transformer should be star-connected with earthed-neutral system.

To supply electricity to the electric circuit and measuring circuit form a voltage transformer, two secondary coils are required, one coil is star-connected and the other coil is open-delta connected.

Measuring power

I.6.27. To measure the power by the following requirements:

1. To measure the effective power and reactive power for each generator.

For generators 100mW or above, it is required to use the meter with the degree of accuracy of 1.0.

2. To measure the effective power for each transformer and for power lines 6 kV and above supplying the auxiliary electricity to the power plants.

3. To measure the reactive power of synchronous compensator and capacitor 25MVAr or above.

4. To measure the effective power and the reactive power of the two-coils step-up voltage transformer of power plant.

To measure the effective power and the reactive power at the low and middle-side of the three-coils step-up voltage transformer (including autotransformer using third windings) of the power plant. For the voltage transformer working in the block with the generator, the power measurement at low-voltage side should be done at the circuit of the generator.

5. At the step-down voltage substations, to measure the effective power and the reactive power for each

voltage transformer 110kV and above, for other transformers, to measure only the effective power.

For the three-coils step-down voltage transformer – to measure at the middle and low-voltage side. For two- coils step-down voltage transformer - to measure at the low-voltage side.

It is not required to measure the power of the low-voltage distribution transformer. At the transformer under the power control by season, a room to connect the mobile meter is necessary.

6. For 110kV and above line with bi-dimensional powers, including circuit breakers - to measure the effective and quadrature power.

7. To provide expected positions to connect the mobile power meter for the periodical power measurement of the effective and quadrature power.

I.6.28. To use bi-dimensional scale measuring instrument for bi-dimensional power circuit.

Measuring frequency

I.6.29. To measure the frequencies at:
1. Each segment of the voltage bus bar of the generator.
2. The output of the generators unit.
3. Each high-voltage bus bar system of power plant.
4. Nodes having the ability to divide the power system into various parts that work asynchronously.

I.6.30. To place the registered frequency meter at:

1. Power plant with a capacity of 200 MW or above in the system.

2. Power plants with capacity of 6MW and above which operate independently.

I.6.31. The absolute error of the registered frequency meter in the power plants that modulate frequencies do not exceed ± 0.1 Hz.

Measuring while synchronizing

I.6.32. To get the exactly synchronization, the following tools are required:

• Two voltmeters or a one dual voltmeter.

• Synchronometer or null voltmeter.

• Two frequency indicators or one dual frequency indicator.

• Timing relay.

Placing power meter

I.6.33. To place power measuring instruments on metal or insulated panel, except wood panel.

Conventionally, the power measuring instruments must be placed indoor, only to place them outdoors when it is allowed by the manufacturer.

The placing height should be from 1.2 m to 2.0 m from the floor. For power measuring instruments type of high precision or small scale division, the placing height should not be more than 1.7 m.

The self-recording instrument should be placed so that the horizontal line passing through the center of the instrument should be from 0.6 m to 2.0 m from the floor.

I.6.34. Do not earth the cover of the power measuring instruments mounted on metal structure that is already grounded.

I.6.35. The power measuring instruments must be placed in the environment in accordance with the requirements of the manufacturer or placed in a location easy to read, well-lit, the glass do not dazzle the eyes when lit.

Chapter I.7
EARTHING

Scope and definitions

I.7.1. This chapter applies to the design and installation of grounding devices for equipment working in AC or DC grid at every voltage level.

I.7.2. The earth fault is the phenomenon of contact between the energized parts of electrical equipment and non-isolated structures to the earth, or direct contact to the earth.

The cover-fault is the circuit phenomenon that occurs in machinery and equipment, between energy components and the covers that are earthed.

I.7.3. Grounding devices are the combination of grounding electrodes and grounding wires.

I.7.4. Grounding electrodes are conductive materials or group of conductive materials that are connected together, buried on the ground and directly contacted to the ground.

I.7.5. Earthing wire is metal conductive wires or bars to connect the grounding parts of electrical equipment to the grounding electrodes.

I.7.6. Grounding of certain parts of electrical equipment means the connection of the equipment parts to the grounding devices.

I.7.7. The voltage to the earth at the cover-fault is the voltage between the cover to the earth with the "zero" voltage area.

I.7.8. The voltage on the grounding devices is the voltage between the current to the grounding electrode and the "zero" voltage area when the current from a grounding electrode goes into the earth.

I.7.9. "Zero" voltage area is the area outside of the dissipation area of the earth-fault current.

I.7.10. The resistance of the grounding device (earth resistance) is the total of the resistance of the grounding poles, earthing wire and contact resistance between them.

I.7.11. The earth-fault current is the current that goes to the earth through the grounding point.

I.7.12. The electrical equipment having a large earth-fault current is the equipment with the voltage greater than 1 kV and single phase earth fault current greater than 500A.

I.7.13. The electrical equipment having a small earth-fault current is the equipment with the voltage greater than 1 kV and single phase earth fault current lower or equal to 500A.

I.7.14. The direct neutral earthing point is the neutral point of the voltage transformer or generator being connected directly with the grounding device or connected to the ground via a small resistor (e.g. current transformer, etc.).

I.7.15. The insulated neutral point is neutral point of voltage transformer or generator that is not connected to grounding devices or connected to grounding devices through the signaling equipment, measurement, protection instrument, arc extinguishing coil that are grounded or other similar devices having high resistance.

I.7.16. The effective neutral earthing point is neutral point of the three-phase power network with voltage greater than 1 kV having overvoltage factor at earth-fault short circuit not greater than 1.4.

The overvoltage factor at earth-fault short circuit in the three-phase power network is the ratio of voltage of the unfaulted phase at earth fault short-circuit and the voltage of the phase before the earth-fault short circuit had occurred.

I.7.17. Neutral conductor is the conductor of the circuit directly connected to the neutral point of the voltage transformer or generator.

a. Work neutral wire (also known as "zero" working wire) is the wire that supplies the power to the electrical equipment.

In the three-phase 4-cable grid, this wire is connected to the direct earthed neutral point of the voltage transformer or generator.

For single-phase power source, the neutral wire is connected to the directly grounded output.

For DC power source, this wire is connected to the direct middle grounding point of the source.

This is also the balancing grounding wire that conduct the current when the load on the phase is imbalanced.

b. Neutral protection wire (also known as "zero" protection wire) of the electrical equipment up to 1 kV is to connect the parts that need to be connected to the direct neutral earthed point of the voltage transformer or generator in the three-phase power grid.

For single-phase power source, this wire is connected to the directly earthed output. For DC power source, this wire is connected to the direct grounding point of the source.

(See Appendix 1.7.1)

I.7.18. Protective switch is the automatic switch by a protection system of all the phases or poles when the problem occurs in a section of the grid with a switching time not more than 0.2 seconds counted from the time when the single-phase earth-fault current occurs.

I.7.19. Double insulation is the combination of working insulation (main) and protection insulation (auxiliary) (see Article I.1.46 ÷ 48). The coordination has to ensure that when there is damage in one of two insulation layers that will not cause danger when contacted.

General requirements

I.7.20. For electrical equipment with voltage up to 1kV and above, one of the following protection measures should be taken: grounding, neutral grounding, protection switching, using isolation transformers, using low voltage, double insulating, equi-pressure in order to ensure the safety for people in the working mode of the power grid, to protect against lightning for electrical equipment, to protect against internal overvoltage.

In order to ground electrical equipment, the priority must be given to the natural earthing, such as metal structures, concrete reinforced structure, metal tubes buried in underground in case that they meet the regulations, except the flammable liquids, gases and flammable mixtures tubes etc.

If these metal structures have the earth resistance that meet the grounding requirements, the grounding devices are not necessary.

I.7.21. It is necessary to a common grounding devices for electrical equipment having different functions and voltages. Except for some cases that are only allowed if they meet the prescribed requirements of these regulations.

The resistance of the common grounding devices must meet the requirements of the equipment and it must be less than or equal to the minimum resistance of one of those equipment.

I.7.22. In case that the grounding or the protection switching required by this Regulations are difficult or impossible to perform technically, it is allowed to use of electrical equipment that are equipped with insulating floor.

The structure of the insulating floor is only deemed to be qualified when standing on the floor, people can contact the un-grounding parts. In addition, to exclude the possibility of simultaneous contact between the un-grounding part of these equipment and the grounding part of the other equipment or parts of the building structure.

I.7.23. For up to 1 kV power grid having direct neutral earthing, it is required to ensure the ability of automatic switching, with the shortest switching time in order to isolate the damaged elements from the grid when the short-circuit happens one the grounding parts. To ensure the above requirements, the neutral point at the low-voltage side of the voltage transformer up to 1 kV must be connected to the earthing pole by earthing wire, for the DC 3- wire grid, the middle wire must be grounded directly. The cover of these equipment must be connected to a grounding neutral wire. It the cover of the equipment is not connected to a grounding neutral wire, it is not allowed to ground the cover of the said equipment.

I.7.24. For neutral isolation voltage transformer having and voltage transformer with arc extinguishing coil and voltage higher than 1kV, to ensure the ability to quickly detect and identify the damaged elements placing voltage testing equipment at each phase and segment of the grid, when necessary, the signal for protection or automatic switching for damaged elements is required.

I.7.25. For electrical equipment with voltage up to 1 kV, it is allowed to use the direct or isolated neutral grounding point.

It is recommend to apply the neutral isolation for electrical equipment with high safety requirements, provided:

a. These equipment are equipped with the protection and insulation inspection devices, it is possible to use circuit breakers or fuses.

b. It is possible to quickly detect and fix in time when the earth-fault or the earthing of automatic switching device occurs.

In the three-phase 4 wire AC grid or 3 wire DC grid, it is required to directly ground the neutral point.

For 3-phase electrical equipment, rated voltage 500V or 660V, to isolate the neutral point.

I.7.26. For three-phase grid or a single phase grid with voltage up to 1kV, neutral isolation point being connected to the grid with voltage higher than 1kV through transformer, to place insulated disruptive protection equipment in the neutral point or at low voltage phase of voltage transformers to prevent danger when the insulating materials between high voltage winding and low voltage winding is damaged.

I.7.27. In the following cases, the special security measures for automatic switching operation of equipment when the cover-fault occurs:

a. The grid having the isolated neutral points and high demands for electrical safety (in mine etc.).

b. The grid having the direct grounding neutral point and voltage up to 1 kV.

To replace the grounding of the equipment cover by neutral grounding, it is required to place grounding devices that satisfy the requirements as for the grid having isolated neutral points.

c. For mobile devices if the grounding is not capable of satisfying the requirements of these regulations.

I.7.28. Size of poles of artificial grounding devices (tubes, rods, etc.) should ensure the ability to evenly distribute the voltage to ground on the area where the electrical equipment are located. For electrical equipment having large earth-fault current, it is required to put the loop earthing circuit around the equipment (except electrical equipment in the station 35kV or less).

I.7.29. To ensure the safety, the electrical equipment having large earth-fault current is to be equipped with voltage balancing grid (except electrical equipment in the station 35kV or less).

I.7.30. To ensure the required value of earth resistance in a year, when designing the grounding system, to take into consideration the changes in the resistivity of the ground (changed by climate).

To ensure the above requirements, the calculation must include correction coefficient, depending on the status of the ground resistivity at the time of measurement.

Parts/equipment that must be earthed

I.7.31. To ground the metal parts of machinery, electrical equipment in workshops as well as outdoors. Parts that must be earthed are:

a. Cover of generator, cover of transformer, power tools, overhead lines columns, lighting equipment etc.

b. Drive unit of electrical equipment.

c. Secondary coil of measuring transformer (current transformer, voltage transformer).

d. Metal frame of the power distribution cabinet, control panel, electrical panel and cabinet, as well as parts which can be assembled/dissembled if on it placed are electrical equipment with voltage 42V AC or voltage 110V DC.

e. Metal structure of the electric equipment and metal casing of the bearing cable and pilot wire, junction box, cable passing metal tubes, electrical equipment rack and cover.

f. Electrical equipment that are located at the mobile part of machines and structures.

g. Metal casing of mobile or hand generator.

Parts/equipment that do not require the grounding

I.7.32. Equipment/parts of equipment that do not require the grounding:

a. Electrical equipment with voltage up to 380V AC or up to 440V DC and placed in less dangerous room (see Article I.1.12); i.e. in the dry room and its floor is of low conductivity (such as wood, asphalt) or in the clean and dry room (such as laboratory, office).

Note: The above equipment must be earthed if at work, people can simultaneously exposed to electrical equipment and other grounded parts.

b. Equipment placed on metal structures which are grounded if the electrical contact at the contact surface of that structure is ensured (the contact surface must be scraped clean, smooth and should not be painted.)

c. Structure to lay cables of any voltage level and the cables are metal shielded grounded at both ends.

d. Rails which go out of the station, transformer station, distribution station and power stations areas of industrial enterprises.

e. Tool cover which is double insulated.

f. The parts that can be dissembled or removed of metal frame of the distribution chamber, cabinet, barriers separating the electrical cabinets, doors etc, if on the said parts are not placed the electrical equipment or electrical equipment that are placed on the parts are of the voltage up to 42V AC and up to 110V DC.

g. Metal structures of the room where are placed the battery of the voltage up to 220V.

It is allowed to ground electric motors and individual machinery on the working machine or other equipment by direct grounding of the machine or other equipment, if the contact between the individual motors or machines and working machine or other equipment is ensured.

Grounding electrical equipment
with voltage over 1kV on effect neutral earthing

I.7.33. For electrical equipment with voltage above 1 kV on effective neutral earthing (see Article I.7.16), to ensure the earth resistance value or sealing voltage, and to ensure the voltage on the grounding devices (according to the Article I.7.35) and structural measures (according to the Article I.7.36).

I.7.34. The resistance of the grounding devices in the area whose the resistivity of the earth is not over 500Ωm should not be greater than 0.5 Ω (in any time of the year, taken into consideration the natural earth resistance) (For the area whose the resistivity is higher than 500Ωm see Article I.7.41 to I.7.45). This requirement does not apply to grounding devices of overhead lines columns and station 35kV and under.

For stations 35 kV and under, to apply the Article I.7.46 (including effective grounding).

I.7.35. Voltage on the grounding devices when short circuit earth-fault current runs through should not exceed 10 kV. This voltage is allowed if the ability to transmit the power from the grounding devices to the outside of the buildings and of the fences surrounding the electrical equipment is eliminated. When the voltage on the grounding devices is greater than 5kV, the insulation measures to protect cables and information systems and remote control system and measures to prevent a dangerous voltage transmission to the outside of the electrical equipment are required.

I.7.36. To balance the voltage and to ensure the connection of electrical equipment to the grounding system, in the area where are located electrical equipment, to lay the earthing pole horizontally along the length and width of the area and to connect them together into grounding grid.

The grounding electrodes laid by the length must be laid in the middle of electrical equipment at the operation corridor, at a depth of 0.5 to 0.7 m and far from the base of the electrical equipment from 0.8 m to 1.0 m. If the electrical equipment are placed into rows, with aisles in between, the distance between two rows should not exceed 3 meters, it is allowed to place a common voltage balancing pole between two rows of electrical equipment.

The grounding electrodes placed by the width should be placed at the convenient location between the electrical equipment at the depth of 0.5 to 0.7 m. The distance between them should be taken up from the perimeter to the center of the grounding grid. So the first distance and the next distances from the perimeter should not exceed 4.0, 5.0, 6.0, 7.5, 9.0, 11.0, 13.5, 16.0 and 20.0 m. The size of the grounding grid next to the junction of the neutral point of the voltage transformer and short-circuit knife and the grounding devices should not exceed 6x6 m^2.

In any case, the distance between the poles laid horizontally should not larger than 30 meters.

The poles placed horizontally should be place by the edge of the area where are located grounding devices to form a closed loop.

If the grounding loop is laid within the outer fence of the electrical equipment, under the door, close to the outer horizontal pole of loop, to place two additional grounding electrodes to balance the voltage. These two poles must be from 3 to 5 meters in length and a the width between them should be equal to the width of the door.

I.7.37. The installation of grounding devices should satisfy the following requirements:

• The earthing wire of devices or structures of grounding electrodes must be placed at a depth of not less than 0.3 m.

• To place a horizontal earthing loop surrounding the neutral grounding points of the voltage transformer and the short-circuit knife.

• When the grounding devices are beyond the fence of electric equipment, the horizontal grounding electrodes in the outer area of the electrical equipment must be placed at a depth of not less than 1m. In this case the outer grounding loop should have the form of polygon with obtuse angles or high-angles.

I.7.38. The outside fence of electrical equipment should not be grounded with grounding devices.

If there are 110kV or higher overhead lines coming from the electrical equipment, the fence must be earthed by the grounding clamps of a length of 2 - 3m and buried next to the fence pillar by the entire perimeter of the fence and the grounding clamps are from 20 - 50m apart. The grounding clamps are not required for the fence with the metal or reinforced concrete pillar, of the concrete reinforcing steel of those pillar is connected with the metallic parts of the fence.

To eliminate the electrical contact between the outside fences and the grounding devices, the distance from the fence to the grounding devices placed along the fence on the inside or on the outside or at both sides of every fence, must not be less than 2m. Grounding electrodes, metal shielded cables, and metal tubes going outside of the fence must be placed between the pillars of the fence, at a depth not less than 0.5 m. The junction between the outer fence and the houses or building, as well as the junction of the outside fence and the inside metal fence must be built of brick or wood with a length not less than 1m.

I.7.39. If the grounding devices of industrial electrical equipment are connected to the grounding grid of equipment with voltage greater than 1 kV, the effective neutral earthing is performed by metal sheathed cable or by metal wire, the voltage balancing around the building or the area of the electrical equipment must meet the following conditions:

a. To place a grounding loop around the buildings or area of the electrical equipment and to connect the loop to the metal structures of building, to production equipment and to the grounding grid (neutral connection). The loop must be placed at a depth of 1 meter and 1 meter far from the base of the building or the perimeter of the electrical equipment. At the door, to place two grounding wires, 1m and 2m far from the grounding loop and at the depth of 1 m and 1.5 m respectively and to connect these grounding wires to the loop.

b. It is allowed to use the reinforced concrete base as grounding base if the voltage balancing is ensured.

It is allowed not to comply with the conditions set forth in the sections a and b above, if the area surrounding the buildings and the entrance way had been asphalt overlaid.

I.7.40. The value of the calculated current to calculate the earthing wires should be the greatest value (the stable value) of the single-phase earth-fault currents of the electrical system and taking into account the distribution of earth-fault current between the neutral grounding points of the system.

Grounding in areas with high resistivity

I.7.41. For the grounding for electrical equipment with voltages greater than 1kV in effective neutral grounding grid, in the area of the resistivity (ρ) greater than 500Ωm, determined in the most unfavorable time of the year (measured in dry season), to take the following measures:

a. To increase the grounding pillar length if the resistivity of the earth decreases with depth.

b. To place the grounding electrodes (with length from 1 to 2 km) if there are nearby places whose the earth resistivity is smaller.

c. To reform the earth to reduce the resistivity (using clay powder, bentonite or graphite powder, etc., mixed with other additives).

In the rocky area, it is which allowed to place the electrode shallower than required but not less than 0.15 m. Also do not place grounding electrodes at the entrances.

I.7.42. For the grounding for electrical equipment with voltages greater than 1kV, in the area of the resistivity greater than 500Ωm, it is allowed to increase the value of earth resistance of grounding devices up to 0.001 ρ [Ω], but not greater than 5Ω, if the implementation as per required by the Article I.7.41 is very costly.

I.7.43. If the grounding is implemented as per required by the Article I.7.42 and the requirements are still not achieved, it is allowed to implement according to the allowed sealing voltage and step voltage. The way to determine the sealing voltage and step voltage is stated in the Annex I.7.2.

I.7.44. The grounding devices should have the sealing voltage and step voltage value which are not greater than the value specified at any time of year when a short circuit current passes through.

I.7.45. When determining the value of the allowed sealing voltage and step voltage, the calculated impact time should be equal to the total impact time of protection and full switching-time of the breaker. In working places when the switching operation is performed, the short circuit may occur to the structures that workers can reach, the impact time of protection device must be taken by the impact time of backup protection.

Grounding the electrical equipment
with the voltage above 1kV neutral isolated

I.7.46. For electrical equipment above 1 kV neutral isolated, the earth resistance value is determined in accordance with the following formula, but not greater than 10Ω:

a. If the grounding devices is used for both electrical equipment with voltage higher than 1kV and less than 1 kV.

$$R_{nd} \leq \frac{125}{Icd} \ [\Omega]$$

In such case, the grounding requirements for electrical equipment with voltage up to 1kV still have to be performed.

b. If the grounding devices is only used for of electrical equipment with voltage higher than 1kV.

$$R_{nd} \leq \frac{250}{Icd} \ [\Omega]$$

Where:

R_{nd}: Value of the largest earth resistance when taking into account the change of resistivity of the earth (ρd) by the weather of the year, [Ω]
Icd: Calculated earth-fault current, [A]

I.7.47. Calculated earth fault current:

1. For the grid without capacitive current compensator : It is the total earth fault current.

2. For the grid with the capacitive current compensator:

- Grounding device with compensator – equal to 125% of nominal current of the compensator.

- When the grounding device is not connected via compensator, the calculated current is residual earth fault current when switching off compensator having the maximum power, or switching off the biggest branch of the network.

I.7.48. The earth fault current value must be determined according to the operation diagram of the grid when the short circuit currents have the greatest value.

I.7.49. For electrical equipment neutral isolated, the earth resistance is calculated in accordance with the Article I.7.46. The calculated earth fault current may be determined by the pick-up current of the single-phase ground protection relay or short circuit between the phases if the short circuit between phases ensures the earth-fault switching.

The calculated earth fault current is not less than 1.5 times the impact current of the protection relay or 3 times of the nominal current of fuse wires.

Grounding the electrical equipment
with voltage up to 1 kV, direct neutral earthing

I.7.50. The neutral cable of the power supply (generators, transformers) must be tightly connected to grounding devices by earthing wire and these grounding devices should be placed close to the said equipment. The cross-section of the earthing wire should not be less than that prescribed in the table of the Article I.7.1 I.7.72.

In other cases, such as substations inside the factory, it is allowed to place the grounding devices near the wall (at the outside).

I.7.51. The phase and neutral wires of the transformer, generator to the distribution control panel, usually are the conductive bar.

The conductivity of the neutral conductor must not be less than 50% of the conductivity of the phase. If the cables are used instead of conductive bars, they must be the 4-core cables.

I.7.52. The earth resistance value of the neutral point of the generators or transformers, or of the output of single-phase power supply at any time of the year should net be not greater than 2Ω, 4Ω voltage corresponding to 660V, 380V, the voltage of the lines of three-phase power supply or to 380V, 220V, the voltage of the phase of the single-phase power supply. The value of this resistance is calculated by both natural grounding and multiple earthing of the overhead lines. The earth resistance of grounding electrodes placed close to the neutral point of the voltage transformers, generators or output of the single-phase power supply does not exceed 15; 30Ω, corresponding voltage values mentioned above .

When the resistivity of the earth is greater than 100Ωm, it is allowed to raise the earth resistance by 0.01 ρ time, but not by more than 10 times.

I.7.53. The neutral wire must be grounded repetitively at the last column and the branching columns of overhead lines. Along the neutral wire, to ground repetitively by the distance from 200 to 250m.

For the multiple grounding in the AC grid, it is recommended to use natural grounding materials, and in DC grid, the artificial grounding materials are required.

I.7.54. The resistance of the multiple grounding (including natural grounding) for the neutral wire of the overhead lines at any time of year should not be greater than 5, 10Ω, corresponding to 660V, 380V, voltages of the lines of the three-phase power supply or to the 380V, 220V voltages of the phase of the single-phase power supply. In which the resistance value of multiple grounding must not be greater than 15; 30Ω corresponding voltage values mentioned above.

Grounding the electrical equipment with the voltage up to 1kV, neutral isolation

I.7.55. For electrical equipment with neutral isolation, the earth resistance value of the electrical equipment must not be larger than 4Ω.

If the capacity of the generators or transformers is lower than 100KVA, the earth resistance must not be greater than 10Ω.

Where the generators or transformers operate in parallel with a their total capacity not greater than100KVA, the earth resistance value should not be greater than 10Ω.

I.7.56. It is prohibited to use the earth as the phase or neutral wire for electrical equipment with voltage up to 1kV.

Grounding portable electric appliances

I.7.57. Portable electrical appliances may only be powered directly from the grid when the grid voltage is not greater than 380/220V.

I.7.58. The metal cover of portable electrical appliances with voltage above 36V AC and above 110V DC in the dangerous or very dangerous room must be grounded, except where such appliance is double insulated or powered from the isolated transformer.

I.7.59.To ground or neutral ground the portable electrical appliances by the individual wires (The third wire for DC single-phase and AC single-phase appliances, the fourth wire for three-phase appliances). This wire should be put in the same shield of the phase and connected to the casing of electrical appliances. It is not allowed to use the neutral wire as the grounding wire.

I.7.60. To power the portable electrical appliances, the single-purpose electrical sockets and plugs should be used. Such electrical sockets and plugs should ensure that the grounding electrode is not connected to the current electrode and when plugged, the grounding electrode will be contacted before the current electrode, and when unplugged it should be disconnected after current electrode. If the socket cover is metal, to connect the metal cover to the grounding electrode. The conductor to the supply side must be connected to the socket, and the wire to the appliance must be connected to the plug.

I.7.61. The grounding ire of the portable electrical industry appliances must be the soft copper wire with the cross-section larger than 1.5 mm^2, and for portable home electrical appliances, the cross-section must be greater than 0 , 75 mm^2.

Grounding mobile electrical equipment

I.7.62. The mobile power stations must be equipped with grounding devices as specified in Article I.7.59.

I.7.63. For mobile equipment which is powered from the fixed power supply or mobile power stations, to connect the casing of the said equipment to the grounding devices of the power supply.

In the grid which is neutrally isolated, to place the grounding devices right next to the mobile equipment. The earth resistance values must comply with the requirements of the Article I.7.55. The use of the natural grounding materials nearby is the priority.

I.7.64. If the grounding for mobile equipment is impossible or can not meet the requirements of these regulations, to replace the grounding by the protection switching to switch off the voltage to the equipment when the earth-fault current occurs.

I.7.65. The grounding is not require for mobile equipment in the following cases:

a. If mobile equipment have an individual generator (It does not power other equipment) placed directly on the equipment and on a common base metals.

b. If mobile equipment (with quantity not greater than 2) is powered from individual mobile power station (It does not power other equipment) and the distance from mobile devices to the power station does not exceed 50 m and the cover of the equipment device is connected to the casing of the power supply by conductor.

I.7.66. The selection of grounding wire, casing connecting wire for the mobile equipment must conform to the requirements of these regulations.

The grounding wire, neutral protection wire and casing connecting wire should be soft copper wires with cross-section equal to the cross-section of phase and put in the same shield of phase.

In the neutral isolated grid, it is allowed that grounding wire and casing connecting wire are separate from the phase. In this case their cross-section should not less than 2.5 mm^2.

To connect casing connecting wire of the power supply to the cover of mobile equipment, it is possible to use:

a. 5th core of the cable in three-phase grid with working neutral wire.

b. 4th core of the cable in three-phase grid without working neutral wire.

c. 3rd core of cable in single-phase grid.

Grounding devices

I.7.67. When designing the grounding devices, to determine the value of the resistivity of the earth by measuring in the field. The resistivity values used in the designing must be determined by multiplying the measured value by the season factor.

Note: The season factor is the factor which depends on the weather change in one year (between the rainy season and dry season) to reach the most unfavorable resistivity value.

I.7.68. When designing the grounding, the natural grounding materials are recommended.

The followings are used as natural grounding materials:

a. Water tubes and metal tubes that are buried in the ground, except the flammable liquids, gases and compound explosion tube lines.

b. Tubes buried in the wells.

c. Metallic structures and reinforced concrete in buildings and construction works.

d. Metal tubes in irrigation works.

e. Lead-sheathed cables placed in the earth. Do not use wire aluminum cover as natural grounding electrode.

f. Crane rails, internal rails in factories if the rails are connected together by a bridge.

The natural grounding components shall be connected to artificial grounding devices (main grounding) at least 2 points.

I.7.69. For the artificial grounding electrode , the steel tubes, round, flat, angle steel which can be driven vertically or round, flat steel, etc. which is laid horizontally can be used.

The smallest size of the electrodes of the grounding devices should comply with the provisions prescribed in the Table I.7.1. In places of corrosion, the electrodes of grounding devices must be copper or zinc plated. In special cases, in areas of high corrosion, in addition to the coating, to increase the cross-section of the electrodes of the grounding devices and to check periodically.

The electrodes that are buried in the earth of grounding devices should not be covered with asphalt or other insulating coatings.

Earthing wire and neutral protection wire

I.7.70. To prioritize the use of the working neutral wire as neutral protection wire.

For the auxiliary earthing wire and neutral protection wire, it is allowed to use of the following natural conductive materials:

a. Metal structure of the buildings (truss, column, equipment rack, concrete reinforcing steel, etc.).

b. Metal structures of factories (rails, cranes, metal frame of the transportation devices (elevators, basement floors, etc.)).

c. Steel tube of electrical equipment.

d. Metal drainage, steam heat, water tubes (except the flammables and explosive liquids tubes) of the electrical equipment with voltage up to 1 kV.

e. Aluminum cable casing.

f. Metal structure of spun or cast concrete columns.

When using them as the main earthing wire, the requirements for the earthing wire in this regulations should be met.

The natural conductive materials shall be connected to the equipment reliably, seamlessly.

I.7.71. It is prohibited to use metal casing of tube wire, aerial cable, the metal cover of the insulating tube, metal handle, the lead cover of wires and cables as grounding wire or neutral protection wires.

It is allowed only to use the lead cover of the cable for the above purpose in improving the city's power grid with voltage 380/220V.

In the outdoor space and equipment requiring the grounding, neutral connection, the above metal casing must be grounded firmly on the entire length. The cable box and the junction box should be connected to the metal cover by welding or by bolts.

For joints by bolt, to take measures against the rust and looseness.

The indoor and outdoor earthing wire and neutral protection wire should be easily accessible for checking. The checking does not apply to neutral wire of the armored cable, concrete reinforcing steel, as well as grounding wire placed in tubes, boxes or building structures.

The outdoor earthing wire should be steel galvanized.

I.7.72. The copper or aluminum or steel earthing wire must have a size not smaller than the value specified in the Table I.7.1.

It is prohibited to use the buried bare aluminum wire as the ground wire.

I.7.73. For electrical equipment with voltage higher than 1kV and high earth-fault current, the cross-section of earthing wire must ensure that when the single-phase calculated earth-fault current running through and the temperature of earthing wire does not exceed 400°C (the short-term temperature rise conditions are adequate to the switching time of the main protection device).

Table I.7.1. The smallest size of the earthing wire and neutral protection wire

Description	Copper	Aluminum	Steel		
			Indoor	Outdoor	Buried
Bare wires: - Cross section, mm^2 - Diameter, mm	4 -	6 -	- 5	- 6	- 10
Insulated wire cross-section, mm^2	1,5(*)	2,5	-	-	-
Cross-section of grounding core neutral core of the cable in protective casing with the phase core, mm^2	1	2,5	-	-	-
Angle bar thickness, mm	-	-	2	2,5	4
Steel bar cross-section, mm^2 Thickness, mm	- -	- -	24 3	48 4	48 4
Tube: Tube thickness, mm	-	2,5	2,5	2,5	3,5
Thin steel tube: Thickness, mm	-	-	1,5	2,5	Not allowed

Note: When placing wires in the tube, the cross- section of neutral protection wire is allowed to be $1mm^2$ if the phase has the same cross-section.

I.7.74. For the electrical equipment with the voltage higher than 1kV and small earth-fault current, the cross-section of the earthing wire must ensure that when the single-phase calculated earth-fault current occurs, long temperature rise of grounding wire placed underground must not exceed 150°C.

I.7.75. For electrical equipment with the voltage up to 1kV and neutrally isolated, the inductance of earthing wire should not be smaller than 1/3 of the inductance of the phase, its cross-section should not be smaller than the value indicated in the Table I.7.1, and not bigger than 20 mm^2 for steel wire, 35 mm^2 for aluminum wire, 25 mm^2 for copper wire.

In the factory, the grounding grid should be the steel bar with the cross-section of not less than 100 mm^2. The round steel with the same cross-section can be used.

I.7.76. For electrical equipment with voltage up to 1kV direct neutral earthing, to ensure the ability to automatically switch off the incident area, the cross-section of the phase and neutral wires must be selected that if the cover fault or the short circuit of the neutral protection wire occurs, the short circuit current should not be less than:

a. 3 times of the nominal current of the nearest fuse or fuse.

b. 3 times of the nominal current of the switching element that can not be adjustable or of the setting current of the adjustable switching element of the breakers having the characters of the reverse current.

To protect the power grid by breaker having only the magnetic cutout element (fast switching), the wire cross-section must ensure that the value of the current passing through should not be lower than the setting value of the exciting current multiplied by the coefficient of dispersion (as per the manufacturer's data) and storage coefficient of 1.1. Otherwise, for breakers having nominal current up to 100A, the multiple of the short circuit current compared to the setting value shall not be lower than 1.4; for breakers having nominal current over 100A - not lower than 1.25.

The cross-section of neutral protection wire, in any case, should not be smaller than 50% of the cross-section of the phase.

If the above requirements can not satisfy the cover fault current value or the short circuit of the neutral protection wire, the short circuit will be cut off by special protection device.

I.7.77. Electrical equipment with voltage up to 1kV directly earthed neutral, neutral protection wire should be put together and near the phase.

The working neutral wire should be calculated to ensure the long working time of the current.

The working neutral wire can be the insulated wire with insulation nature such as the phase. The insulation of the working neutral wire as well as the neutral protection wire are required if the use of the bare wire can generate the twisting couple or cause the damage to the insulation of the phase by the sparks of the phase between the bare neutral wire and the covers or structures (such as placing wires in the tubes, boxes, trays). The insulation is not required if the cover or the structural support of the bus bar (on the support or in the system) as the working neutral and protection wire, as well as for the aluminum or lead shields of the cable (see Article I.7.71).

In workshops, with normal environment, it is allowed to use metal structures, tubes, casing and supports of bus bar as the working neutral wire (see Article I.7.70) when:

• Powering the single-phase individual loads of low capacity, voltage up to 42V.

• Powering, in single-phase current, the make-and-break coil of the magnetic starter or contactor.

• Powering, in single-phase current, the lighting equipment and signal control circuit of the crane in one phase.

I.7.78. It is not allowed use the working neutral wire as the neutral protection wire for a single phase or DC electrical portable tools. The neutral wire should be is the third wire and connected to the three-pole socket.

I.7.79. Do not place the fuse or circuit breaker in the grounding wire and neutral protection wire.

The working neutral circuit and simultaneously the neutral protection wire may be cut off simultaneously with the phase.

If the single-pole electric cutout is used, it is required to be placed at the phase, and not in neutral wire.

I.7.80. It is not allowed to use the working neutral wire of one line as the neutral wire of electrical equipment powered by other lines.

It is allowed to use the working neutral wire of the lighting line as the neutral wire of the electrical equipment powered by from another line if the said line is powered from the same transformer, the cross-section of the neutral work wire must be large enough to satisfy in all cases and eliminate the possibility to be cut off when the other line mentioned above is working. In this case, do not use the cutout to cut the neutral working wire together with the phase.

I.7.81. In the overhead lines with voltage up to 1 kV with direct neutral grounding wire, the short circuit current value used to test the cutting ability under the short circuit between the phase and the neutral wire is determined by the approximate formula hereunder:

$$I_k = \frac{Up}{Ztp + \frac{Zbt}{3}}$$

Where:

- *Up*: Phase voltage of power grid

- $Ztp = \sqrt{r_{tp}^2 + x_{tp}^2}$: Total resistance at the node of the loop circuit between the phase and the neutral wire, equal to 0.6 Ω / km.
- *Zbt*: Total resistance of the voltage transformer.

To take in account only Zbt on the above formula if connected to the three-phase voltage transformers Y/y - 12 and then Zbt is taken according to the manufacturer's specification. In other cases, do not taking in account Zbt in calculations.

I.7.82. In the humid room with corrosive vapor, to place the grounding wire far from the wall at least 10mm.

I.7.83. The earthing wire must be protected against mechanical and chemical damage, especially in places with crossing cables, tubes, metal bar etc. The protection against chemical damage should be specially attentive in areas of the corrosive environment.

I.7.84. The earthing wires which go through walls must be placed in the holes, in the tubes or in hard covers.

I.7.85. It is not allowed to use the earthing wires for other purposes. It is only allowed to use the earthing wires to connect temporarily to the welding devices if the cross-section of the earthing wires can ensure the welding current. To only use the neutral grounding wire to connect to the control circuit of the machine tool in special cases.

I.7.86. At the place where the grounding wire is connected to the project, there must be visible symbols.

The earthing wire laid in the ground, the structure of grounding devices laid above ground must be painted purple or black.

In the places where the decoration is needed, it is allowed to paint the grounding wire the color of the room, but at the junction or branching points, the grounding wire should be painted black or purple in lines which are 150mm apart. For 2-core branch lines, of which the neutral wire is used as a grounding wire, at the welded joints or junction the neutral wire must also be painted purple.

I.7.87. The connections between the ground wire and neutral protection wire in order to ensure the good contact should be done by direct welding or special connector. The weld joint should have the length equal to 2 times the width of the bar, if the cross-section is rectangular, or 6 times of the diameter of the bar if the cross-section is round.

For overhead lines, it is allowed to connect the neutral wire like to connect the phase.

The joint in the humid room, with metal corrosive gas should be done by welding. If it is impossible to welded, it is allowed to connect with bolts, but the joint must be painted for protection. The joints must be accessible for inspection.

I.7.88. When using the conductive materials specified in Article I.7.70 as grounding wire the following requirements should be satisfied:

a. Their connections must be reliable and ensure the electrical continuity throughout the length of the conductor.

b. When using the metal structure next to each other as the earthing wire, to connect them together by the conductive bars whose cross-section is not less than 100 mm^2, and joined by welding. When using such structures for electrical equipment with voltage up to 1 kV, direct neutral earthed, to connect by bridge whose cross-section is equal to the cross-section of earthing wire.

I.7.89. The steel tube for inserting electrical wires, box gutters and other structures that are used as a grounding wire or neutral protection wire, must be connected together reliably.

• Where the tubes that are laid on the ground, the turnbuckle on the minium coating or other structures that are connected reliably can be used.

• Where the tubes that are buried under the ground, it is only allowed to connect by the turnbuckle on the minium coating.

• When the connections have the long threaded steel bar, on each side of it the brake nut is needed.

Whether the tubes are laid on the ground or buried d in the neutral earthing grid openings, both sides of the tube must be welded (in this case brake nuts are not needed if they are laid on the ground.)

When the conductors are inserted in the steel tubes and these tubes are used as earthing wire, the end of steel tube and the metal casing of electrical equipment must be welded by metal.

I.7.90. When connecting the earthing wire to the extended grounding electrode (e.g. tubes), it should be done by welding. Otherwise, it is allowed to use the belt, to wash the tube and to plate with tin at the contact surface before using the belt.

I.7.91. The connection of the grounding wire to the grounding structure should be done by welding, the connection of grounding wire to the equipment etc. can be done by welding or bolted. For the joints on vibrating parts or on the parts that are exposed to the impact, to take measures to ensure good contact (by brake nuts, lock washers).

The ground or neutral protection wires that are often removed or on moving parts must be the soft wires.

I.7.92. The neutral points of transformer or generator that are grounded directly or through the capacitive compensator must be connected to the grounding grid or to the main earthing bar by the individual earthing wire.

I.7.93. The safety grounding, the work grounding and lightning protection grounding system must be connected to a grounding grid by the individual wire.

Appendix I.3.1

Calculate to check the permanent allowed current of the bare wires

The permanent allowed current of the bare wires under the temperature rise conditions due to the current and to the solar radiation is calculated by the following formula:

$$I = \sqrt{\frac{\left[h_w + \left(h_r - \frac{W_s}{\pi.\theta}\right).\eta\right]\pi.d.\theta}{R_{20dc}.\beta\left[1+\alpha.(T+\theta-20)\right]}}$$

Where:

I: The permanent allowed current	[A]
d: External diameter of the wire	[cm]
θ: The allowed increase in temperature of the wire	[° C]
T: The air temperature corresponding to the time of inspection and usually the highest air temperature is selected	(°C)
α: Resistance-temperature coefficient	(1/°C)
R_{20}dc: Resistance of electrical wire at 20°C in DC	(Ω/cm)
Ws: Energy of solar radiation	(W/cm)

η: Thermal emissivity (0.9)

β: The ratio of AC and DC resistances

v: Calculated wind speed (m / s)

hw: Heat dissipation coefficient due to convection, calculated by Rice's formula as follows:

$$h_w = 0.000572.\frac{\sqrt{\frac{v}{d}}}{\left(273+T+\frac{\theta}{2}\right)^{0.123}} \qquad (W/°C.cm^2)$$

Hr: Thermal emissivity coefficient due to the radiation (Stefan - Boltzmann's Law), calculated by the following formula:

$$h_r = 0.000567.\frac{\left(\frac{273+T+\theta}{100}\right)^4 - \left(\frac{273+T}{100}\right)^4}{\theta} \qquad (W/°C.cm^2)$$

I. The selected values in the calculation

1. Solar radiation energy: To refer to the calculated data of the countries in the region, selected:

$$Ws = 0,1\ W/cm^2$$

2. Calculated wind speed:

$$v = 0.6\ m / s$$

3. The air temperature T depends on the testing time of the allowed permanent current, the most unfavourable conditions are to select the highest air temperature and suitable to the climate conditions in Vietnam T = 40° C.

4. Resistance coefficient increases due to temperature depending on the wire materials

- For steel-core aluminum wires, typically $\alpha = 0.00403$
- For aluminum wire $\alpha = 0.00360$
- For copper wire $\alpha = 0.00393$

5. For the ratio β between the AC resistance and DC resistance, to refer to the Table 1 for commonly used steel-core aluminum wires.

6. The allowed temperature rise θ for the conductor depends on the allowed temperature on the wire and the air temperature T (= 40° C in the climatic conditions in Vietnam).

- For the steel-core aluminum wires, aluminum alloy wires: the allowed temperature of the wires reaches 90° C in normal operating conditions, i.e.:

$$\theta = 90°C - 40°C = 50°C$$

- For the super hot wire (TAL): the allowed temperature of the wires reaches 150° C in normal operating conditions, i.e.:

$$\theta = 150°C - 40°C = 110°C$$

- For hyper heating wires (ZTAL): the allowed temperature of the wires reaches 210° C in normal operating conditions, i.e.:

$$\theta = 210°C - 40°C = 170°C$$

The allowed permanent current of wires depends on the time of inspection. For example: If the inspection is carried out on night tine, the air temperature T = 25° C, the solar radiation energy Ws = 0, resulting that the allowed permanent current significantly increases, compared with the daytime.

II. The ratio between resistances AC/DC (R_{AC}/R_{DC})

Of the reinforced steel-core aluminum wires (ACSR type)

Temperature, °C	60		70		80		90		R_{DC} at 20°C(Ω/km)
Frequency, Hz	50	60	50	60	50	60	50	60	
240 mm^2 R_{AC}/R_{DC}	1.002	1.003	1.002	1.003	1.002	1.002	1.002	1.002	0.1200
330 mm^2 R_{AC}/R_{DC}	1.004	1.006	1.004	1.006	1.004	1.005	1.004	1.005	0.0888
410 mm^2 R_{AC}/R_{DC}	1.007	1.010	1.006	1.009	1.006	1.009	1.006	1.008	0.0702
610 mm^2 R_{AC}/R_{DC}	1.032	1.039	1.041	1.048	1.045	1.052	1.048	1.055	0.0474
810 mm^2 R_{AC}/R_{DC}	1.048	1.063	1.056	1.070	1.060	1.073	1.061	1.074	0.0356
Temperature, °C	100		110		120				R_{DC} at 20°C(Ω/km)
Frequency, Hz	50	60	50	60	50	60			
240 mm2 R_{AC}/R_{DC}	1.002	1.002	1.002	1.002	1.001	1.002			0.1200
330mm2 R_{AC}/R_{DC}	1.003	1.005	1.003	1.004	1.003	1.004			0.0888
410mm2 R_{AC}/R_{DC}	1.005	1.008	1.005	1.007	1.005	1.007			0.0702
610mm2 R_{AC}/R_{DC}	1.050	1.055	1.051	1.056	1.052	1.057			0.0474
810mm2 R_{AC}/R_{DC}	1.062	1.074	1.063	1.074	1.063	1.074			0.0356

Appendix I.3.2

Selecting lightning wire

The lightning wire are mainly selected to meet the thermal stability conditions when a single phase short-circuit occurs. The allowed short circuit current on the lightning wires is calculated by the following formula:

$$I = \frac{K.S}{\sqrt{t}}$$

Where:

I: Allowed short-circuit current (A)

t: Short circuit time (seconds)

S: Cross-section of lightning wire (mm^2)

K: Constant depending on the lightning wire materials :

- For steel-core aluminum wire k = 93
- For galvanized steel wire k = 56
- For aluminum wire k = 91 ÷ 117

Usually used for lightning wires combined with fiber.

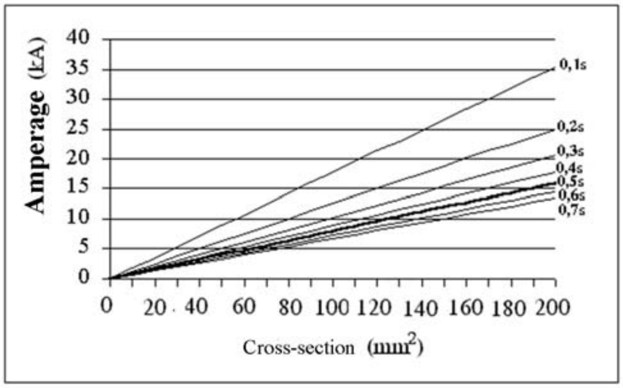
The thermo stabilization capacity when the single-phase short-circuit occurs of the lightning wires is compared with the characteristic quantity [kA^2s].

For example: The allowed short-circuit current on the lightning wire I = 10kA, short-circuit time t = 0.5s, the thermo stabilization capacity of the lightning wire will be:

$$(10kA)^2.0,5s = 50kA^2s$$

In practice, it is possible to use chart to calculate the allowed instant current and to compare to the short-circuit current $I_N^{(1)}$, single-phase of the power system at the checking place, the thermo stabilization will be guaranteed when: $I \leq I_N^{(1)}$

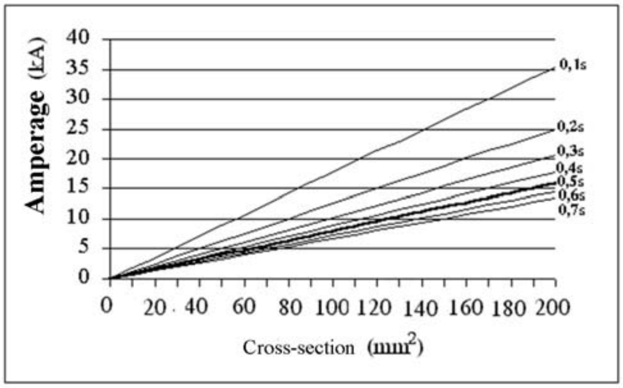
Allowed instant current for the steel-core wire



Time (s) / Cross-section (mm^2)	0.1	0.2	0.3	0.4	0.5	0.6	0.7
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	2.94	2.08	1.70	1.47	1.32	1.20	1.11
20	5.88	4.16	3.40	2.94	2.63	2.40	2.22
30	8.82	6.24	5.09	4.41	3.95	3.60	3.33
40	11.76	8.32	6.79	5.88	5.26	4.80	4.45
50	14.70	10.40	8.49	7.35	6.58	6.00	5.56
60	17.65	12.48	10.19	8.82	7.89	7.20	6.67
70	20.59	14.56	11.89	10.29	9.21	8.40	7.78
80	23.53	16.64	13.58	11.76	10.52	9.60	8.89
90	26.47	18.72	15.28	13.23	11.84	10.81	10.00
100	29.41	20.80	16.98	14.70	13.15	12.01	11.12
110	32.35	22.87	18.68	16.18	14.47	13.21	12.23
120	35.29	24.95	20.38	17.65	15.78	14.41	13.34
130	38.23	27.03	22.07	19.12	17.10	15.61	14.45
140	41.17	29.11	23.77	20.59	18.41	16.81	15.56
150	44.11	31.19	25.47	22.06	19.73	18.01	16.67
160	47.05	33.27	27.17	23.53	21.04	19.21	17.79
170	50.00	35.35	28.86	25.00	22.36	20.41	18.90
180	52.94	37.43	30.56	26.47	23.67	21.61	20.01
190	55.88	39.51	32.26	27.94	24.99	22.81	21.12
200	58.82	41.59	33.96	29.41	26.30	24.01	22.23

Instance current values (kA)

Allowed instant current for the steel-core aluminum and aluminum-covered steel wires



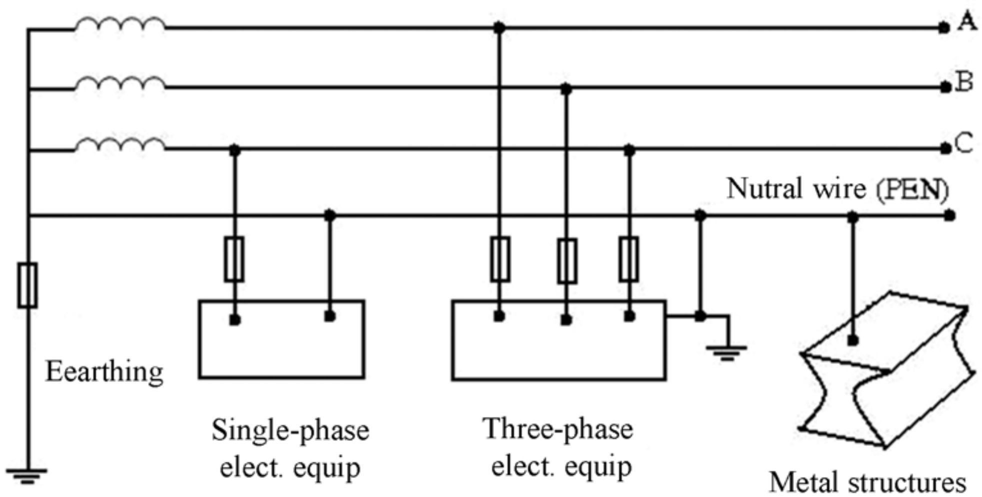
Time (s) / Cross-section (mm²)	0.1	0.2	0.3	0.4	0.5	0.6	0.7
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	2.94	2.08	1.70	1.47	1.32	1.20	1.11
20	5.88	4.16	3.40	2.94	2.63	2.40	2.22
30	8.82	6.24	5.09	4.41	3.95	3.60	3.33
40	11.76	8.32	6.79	5.88	5.26	4.80	4.45
50	14.70	10.40	8.49	7.35	6.58	6.00	5.56
60	17.65	12.48	10.19	8.82	7.89	7.20	6.67
70	20.59	14.56	11.89	10.29	9.21	8.40	7.78
80	23.53	16.64	13.58	11.76	10.52	9.60	8.89
90	26.47	18.72	15.28	13.23	11.84	10.81	10.00
100	29.41	20.80	16.98	14.70	13.15	12.01	11.12
110	32.35	22.87	18.68	16.18	14.47	13.21	12.23
120	35.29	24.95	20.38	17.65	15.78	14.41	13.34
130	38.23	27.03	22.07	19.12	17.10	15.61	14.45
140	41.17	29.11	23.77	20.59	18.41	16.81	15.56
150	44.11	31.19	25.47	22.06	19.73	18.01	16.67
160	47.05	33.27	27.17	23.53	21.04	19.21	17.79
170	50.00	35.35	28.86	25.00	22.36	20.41	18.90
180	52.94	37.43	30.56	26.47	23.67	21.61	20.01
190	55.88	39.51	32.26	27.94	24.99	22.81	21.12
200	58.82	41.59	33.96	29.41	26.30	24.01	22.23

Instance current values (kA)

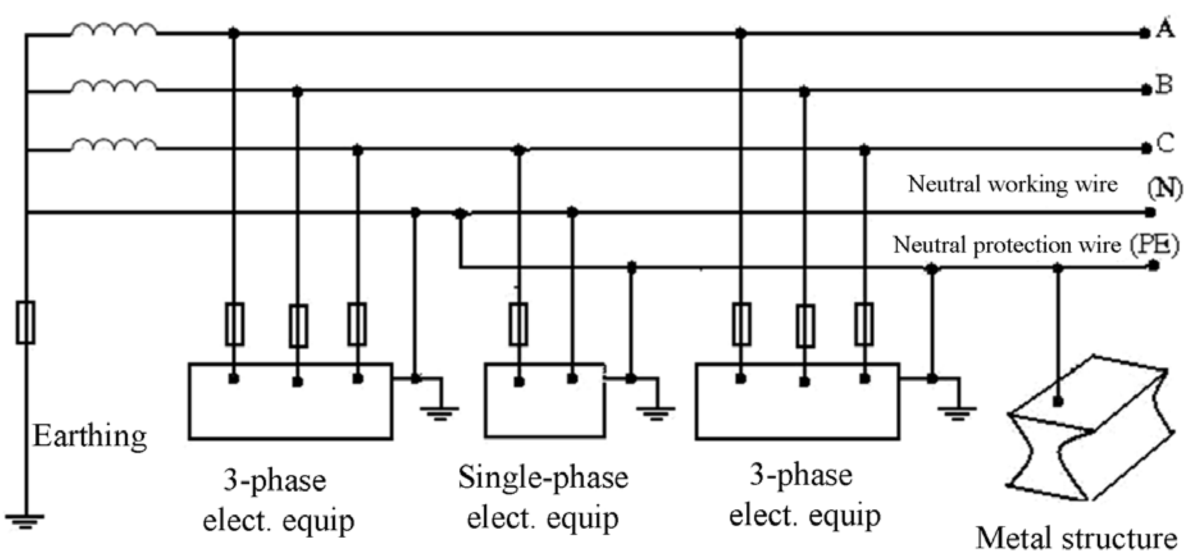
Appendix I.7.1

Schemas for neutral connection

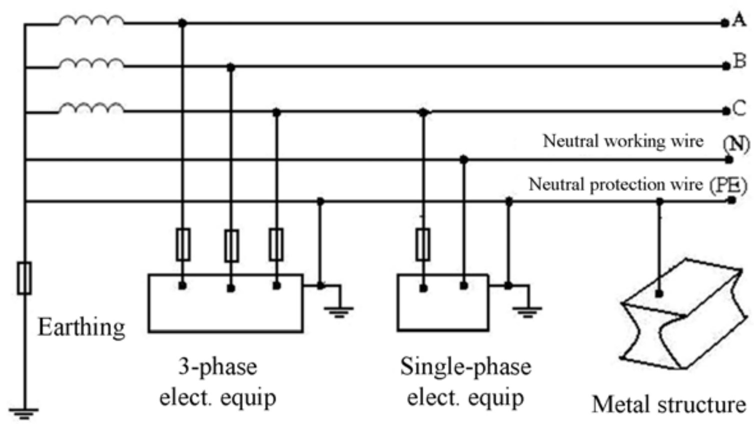
1. Schema with neutral protection wire and working neutral wire:



2. Schema with partially separated neutral protection wire:



3. Schema with individual neutral protection and neutral working wires:



Appendix I.7.2

The calculation method for touch voltage and allowed step voltage

(To refer to IEEE 80-2000 for details)

The allowed touch voltage and step voltage value is calculated as follows:

1. $E_{touch} = (1000 + 1{,}5C_s.\rho_s)\dfrac{0{,}116}{\sqrt{t_s}}$

2. $E_{step} = (1000 + 6C_s.\rho_s)\dfrac{0{,}116}{\sqrt{t_s}}$

Where:

E_{touch}: Allowed touch voltage, V

E_{step} : Allowed step voltage, V

$C_s = 1 - \dfrac{0{,}09(1 - \dfrac{\rho}{\rho_s})}{2h_s + 0{,}09}$: Coefficient of flat attenuation

ρ_s: Resistivity of the surface layer material, Ωm

ρ: Resistivity of the earth, Ωm

h_s: Thickness of surface material

t_s: Time of current going through body (to take the total impact time of the protection and full switching off time of the breaker), second

If there is no surface layer: $\rho = \rho_s$ and $C_s = 1$.