RUSSIAN MARITIME REGISTER OF SHIPPING

CIRCULAR LETTER **No. 315-23-1877c** dated 14.12.2022

Re:
amendments to the Rules for the Classification and Construction of Sea-Going Ships, 2022, ND No. 2-020101-152-E

Item(s) of supervision:
lighting fittings; electrical equipment for a voltage in excess of 15 kV

Entry-into-force date:
01.01.2023

~~Cancels/amends/adds Circular Letter No.~~ ~~dated~~

Number of pages: 1 + 39

Appendices:
Appendix 1: information on amendments introduced by the Circular Letter
Appendix 2: text of amendments to part XI "Electrical Equipment"

Director General Konstantin G. Palnikov

Text of CL:
We hereby inform that the Rules for the Classification and Construction of Sea-Going Ships shall be amended as specified in Appendices to the Circular Letter.

It is necessary to do the following:

1. Bring the content of the Circular Letter to notice of the RS surveyors, as well as interested organizations and persons in the area of the RS Branch Offices' activity.
2. Apply the provisions of the Circular Letter during review and approval of the technical documentation on ships contracted for construction or conversion on or after 01.01.2023, in the absence of a contract, during review and approval of technical documentation on ships requested for review on or after 01.01.2023.

List of amended and/or added paras/chapters/ sections:
Part XI: paras 1.2.1, 1.3.2.1.13 and 6.1.8 and Sections 19 — 26

Person in charge: M.A. Iukhnev 315 +7 (812) 605-05-17
"Thesis" System No. 22-211803

Appendix 1 to Circular Letter
No.315-23-1877c dated 14.12.2022

Information on amendments introduced by the Circular Letter
(for inclusion in the Revision History to the RS Publication)

No.	Amended paras/chapters/ sections	Information on amendments	No. and date of the Circular Letter introducing the amendments	Entry-into-force date
1	Para 1.2.1	A new definition "Portable lighting fitting" has been introduced	315-23-1877c of 14.12.2022	01.01.2023
2	Para 1.3.2.1.13	Requirement for survey of onboard lighting has been specified	315-23-1877c of 14.12.2022	01.01.2023
3	Para 6.1.8	New para with the requirements for the lighting fittings of domestic services has been introduced	315-23-1877c of 14.12.2022	01.01.2023
4	Sections 19 — 26	New Section 19 with the requirements for underwater power cables and electrical equipment of ships for which this type of power supply is used, as well as for electrical equipment for a voltage in excess of 15 kV has been introduced; existing Sections 19 — 25 (with paras and references thereto) have been renumbered 20 — 26 accordingly	315-23-1877c of 14.12.2022	01.01.2023

RULES FOR THE CLASSIFICATION AND CONSTRUCTION OF SEA-GOING SHIPS, 2022,

ND No. 2-020101-152-E

PART XI. ELECTRICAL EQUIPMENT

1 GENERAL

1 **Para 1.2.1**. After the definition "Down conductor" a new definition "Portable lighting fitting" shall be introduced reading as follows:

"Portable lighting fitting is a lighting fitting that, in standard use, may be easily moved without disconnecting from the supply network.".

2 **Para 1.3.2.1.13** is replaced by the text reading as follows:

"**.13** lighting (main lighting in accordance with to 6.1.1, emergency lighting in accordance with 9.3.1 and 19.1.2.1.1);".

6 LIGHTING

3 **New para 6.1.8** is introduced reading as follows:

"**6.1.8** Portable lighting fittings of domestic services are not included in the list of items of technical supervision.".

4 New **Section 19 with Appendix 1** is introduced reading as follows:

"19 ADDITIONAL REQUIREMENTS FOR ELECTRICAL EQUIPMENT FOR A VOLTAGE OF 15 TO 220 KV

19.1 GENERAL

19.1.1 Application.
These requirements apply to three-phase alternating current systems with rated voltages from 15 kV to 220 kV, where rated voltage means the voltage between phases.
Requirements for design and installation of low voltage electrical equipment (up to 1000 V) set out in this part also apply to high voltage electrical equipment, unless specified otherwise in this Section.
19.1.2 Rated voltage of the system.
19.1.2.1 Rated voltages in electrical power distribution systems shall not exceed the values specified in Table 19.1.2.1.

Table 19.1.2.1

Rated interphase voltage, in kV	Rated frequency, in Hz
15	50 (60)
20	50 (60)
35	50 (60)
110	50 (60)
150	50 (60)
220	50 (60)

19.1.3 Dividing of high voltage and low voltage equipment.

19.1.3.1 Electrical equipment for voltages in excess of 1000 V shall not be installed in the same housings (enclosures) as low voltage equipment unless suitable separation is provided or suitable measures are taken to ensure safe access for the maintenance of the low voltage equipment.

19.1.3.2 Insulating materials for electrical equipment shall ensure the insulation resistance appropriate for the operating conditions of the equipment during the plant's continuous service.

19.1.3.3 Warning notices indicating the voltage value shall be provided at the entrance of special electrical spaces. Warning notices shall also be provided for enclosures of electrical equipment installed outside special electrical spaces.

19.2 SYSTEM DESIGN

19.2.1 Distribution systems.

The following systems of electrical power distribution are permitted for high voltage three-phase alternating current installations:

three-wire insulated system;

a three-wire system with the neutral point connected to the ship hull via a high-value resistor or reactor;

three-wire system with effectively earthed neutral;

three-wire system with a dead earthed neutral.

Two-wire system of electrical power distribution is permitted for high voltage direct current installations.

19.2.1.1 Configuration of 15 — 35 kV network for ensuring uninterruptible power supply.

The main switchboard design for distribution boards of 15, 20, 35 kV shall provide for the possibility of its separation into, as a minimum, two independent parts by means of a circuit breaker or disconnector.

Each part of sections shall be connected to, as a minimum, one electric power source of the appropriate voltage.

Where two independent main switchboards interconnected by cable jumpers are provided, circuit breakers shall be fitted at its both sides. All the duplicated electrical drives shall be supplied from different main switchboards or split sections of the main switchboard.

19.2.1.2 Configuration of 35 — 220 kV network for ensuring uninterruptible power supply.

For integrated gas-insulated switchgear (GIS), in general, the same circuits are used as for open switchgear of the appropriate voltage except where deviations in the circuits are caused by a process necessity, higher reliability, etc.

In GIS (gas-insulated switchgear) the main elements of the circuit, including the apparatus (switches, disconnectors, earthing switches, measuring instruments, etc.) and collecting busbars shall be enclosed in a gas-tight aluminium alloy enclosures, which constitute a complete assembly unit-modules. The individual hardware modules (units) shall be connected to each other by gas-tight flange connections. A set of the specified modules representing a complete circuit chain is called a cell. The switchgear (GIS) is assembled from cells and individual modules.

The following circuits specified in Appendix 1 to this Section shall be used to organize the 110 kV switchgear:

unit (line — transformer) with disconnectors (refer to Fig. 1 (diagram 110-1));

unit (line — transformer) with switcher (refer to Fig. 2 (diagram 110-3N));

two units with switchers and non-automatic jumper at the line side (refer to Fig. 3 (diagram 110-4N));

bridge with switchers in the line circuits and repair jumper at the line side (refer to Fig. 4 (diagram 110-5N));

bridge with switchers in the transformer circuits and repair jumper at the transformer side (refer to Fig. 5 (diagram 110-5AN));

entry — termination (refer to Fig. 6 (diagram 110-6));

triangle (refer to Fig. 7 (diagram 110-6N));

quadrangle (refer to Fig. 8 (diagram 110-7));

hexagon (refer to Fig. 9 (diagram 110-8));

one operating busbar sectioned by the switcher (refer to Fig. 10 (diagram 110-9));

one operating busbar sectioned by the transformer number, with connecting the transformers to bus sections via the switcher junction (refer to Fig. 11 (diagram 110-9N));

two operating busbars (refer to Fig. 12 (diagram 110-13));

The following curcuits shall be used to organize the 220 kV switchgear (refer to Appendix 1):

unit (line — transformer) with disconnectors (refer to Fig. 13 (diagram 220-1));

unit (line — transformer) with switcher (refer to Fig. 14 (diagram 220-3N));

two units with switchers and non-automatic jumper at the line side (refer to Fig. 15 (diagram 220-4N));

bridge with switchers in the line circuits and repair jumper at the line side (refer to Fig. 16 (diagram 220-5N));

bridge with switchers in the transformer circuits and repair jumper at the transformer side (refer to Fig. 17 (diagram 220-5AN));

entry — termination (refer to Fig. 18 (diagram 220-6));

triangle (refer to Fig. 19 (diagram 220-6N));

quadrangle (refer to Fig. 20 (diagram 220-7));

hexagon (refer to Fig. 21 (diagram 220-8));

one operating busbar sectioned by the switcher (refer to Fig. 22 (diagram 220-9));

one operating busbar sectioned by the transformer number, with connecting the transformers to bus sections via the switcher junction (refer to Fig. 23 (diagram 220-9N));

two operating busbars (refer to Fig. 24 (diagram 220-13));

transformer busbar with one-and-a-half line connection (refer to Fig. 25 (diagram 220-16));

one-and-a-half breaker circuit (refer to Fig. 26 (diagram 20-17)).

High speed earthing switches shall be provided at GIS line entries.

GIS shall be connected to transformers by cables or closed gas-insulated current leads to avoid overhead entries.

The need for an excess-voltage suppressor in GIS circuits is determined by overvoltage calculations during design.

19.2.1.3 Neutral earthing systems.

It is recommended to make a 20 kV network with neutral earthed through a resistor. In this case, a step-down transformer with a "star — star" winding connection with a resistor in the neutral of the 20 kV winding is used or a special "star — delta" transformer connected to the 20 kV switchgear busbars with a grounding resistor in the"star" neutral is used.

To ensure the selectivity of the operation of the relay protection, the resistance of the earthing resistor shall be such that the single-phase fault current in the 20 kV network is at least 1000 A.

It is permitted to perform 20, 35 kV switchgear circuit with neutral earthing through an arc suppression reactor.

19.2.1.4 Systems with earthed neutral.

19.2.1.4.1 Shall be provided with deadly earthed neutrals:

.1 110 — 150 kV transformers with on-load tap changers (OLTC) with 35 kV neutral insulation level (50 Hz neutral test voltage is equal to 85 kV);

.2 transformers with generating sources on the low- or medium-voltage side, irrespective of the neutral insulation class. Part of the neutrals of such transformers may be ungrounded if, during maintenance or emergency modes, it is not possible to separate them for operation with a network section without transformers with earthed neutrals, or if disconnection of the transformers with insulated neutral points during earth faults before disconnection of the transformers with earthed neutral points is ensured.

At that, neutrals with incomplete insulation shall be protected by suitable surge arresters/surge suppressors.

19.2.1.4.2 Neutral winding protection for 110 kV and 150 kV transformers shall be provided by a valve arrester: RVS35 + RVS15 or RVM35 + RVM15 for 110 kV transformers and RVS 60 (2RVS20 + RVS15) or 2RVM35 (four components) for 150 kV transformers. Valve-type arresters for neutral line protection shall be located immediately at the transformers.

19.2.1.4.3 When the system is energized, at least one neutral earthing point shall be closed.

The electrical equipment in systems with a deadly earthed neutral connected to the hull through a high capacity resistor or reactor shall bear without damage the single phase-to-earth fault current during the time needed for protection device activation.

19.2.1.5 Neutral opening.

If a transformer with an incomplete neutral-point insulation is being switched on or off, its neutral shall be earthed during the operation. All new power transformers with a neutral insulation level in accordance with IEC 60076-3 shall provide for operation with both insulated and earthed neutral, for which a ZON-110 (transformer neutral earthing switch) and an arrester shall be installed in their neutral points.

19.2.2 Degrees of enclosures protection.

19.2.2.1 Each part of electrical equipment shall have shielded enclosures corresponding to its location and effecting environmental conditions. The requirements of IEC 60092-201 may be considered as minimum.

19.2.2.3 A protection degree of transformer enclosures shall be at least IP23.

Transformers installed in spaces accessible to unqualified personnel shall have the degree of protection of at least IP4X.

The requirements of 18.7.1 apply to transformers having no enclosure.

19.2.2.4 A degree of metal enclosures protection for switchgear, control panels, static converter cabinets shall be at least IP32. Panels installed in spaces accessible to unqualified personnel shall have the degree of protection of at least IP4X.

19.2.3 Insulation clearances.

19.2.3.1 Air clearances.

The air clearance between live parts with different potentials or between live parts and earthed metal parts or the casing shall be not less than that specified in Table 19.2.3.1.

Table 19.2.3.1

Rated interphase voltage, in kV	Minimum air clearance, in mm
15	160
20	180
35	290
110	700
150	1100
220	1700

Minimum clearances for intermediate values of working voltages are assumed as for the next larger value of a standard voltage.

If selecting lesser clearance, special high-voltage impulse tests shall be conducted to confirm admissibility of such an option.

19.2.3.2 Creepage clearances.

Creepage clearances between live parts with different potentials and between live parts and the hull shall be selected on the basis of national and international standards.

19.2.4 Protection devices.

19.2.4.1 Faults to earth.

19.2.4.1.1 An audible and visual alarm shall be activated in a system (on control panels) at any earth faults.

19.2.4.1.2 Protection automatically disconnecting a faulted circuit at earth faults shall be activated in low-impedance (deadly-earthed) systems.

19.2.4.1.3 In high-impedance earthed systems (systems with neutral earthed through a high-capacity resistor), where the feeders outgoing from the main switchboard cannot be disconnected at an earth fault, the insulation of electrical equipment supplied from these feeders shall be designed for the line voltage of the system.

Notes: 1.The systems to be classified as effectively earthed (low impedance) if a coefficient of earthing is below 0,8, and ineffectively earthed (high impedance), 0,8 and over.

2. The efficient of earthing means a ratio between a voltage "phase — earth" in a healthy, i.e. intact phase and a line ("phase — phase") voltage.

19.2.4.2 Power transformers.

Power transformers shall be protected against a short circuit and overloading with automatic electrical switching devices (breakers).

Where the transformers are intended for running in parallel, the activation of protection on the primary side shall cause their automatic disconnection on the secondary side as well.

19.2.4.3 Voltage transformers for control systems and instruments.

Transformers intended for supply of control circuits and instruments shall be protected against overloading and short circuits on the secondary side.

19.2.4.4 Fuses.

Protective fuses shall be used for short-circuit protection. No fuses for overload protection are permitted.

19.2.4.5 Low-voltage systems.

Low-voltage distribution systems (up to 1000 V) supplied from high-voltage transformers (systems) shall be protected against overvoltages associated with the ingress of a high voltage on the secondary (low voltage) side.

This may be achieved by:

earthing of the low voltage system;

appropriate neutral voltage limiters;

earthed screen between the primary and secondary windings of the transformer.

19.2.4.6 Protective earthing.

Metal enclosures of electrical equipment shall be earthed with external flexible copper conductors having a cross-section designed for a single-phase short-circuit current, but not less than 16 mm^2. Earthing wires shall be marked.

Earthing conductors may be joined by welding or with bolts not less than 10 mm in diameter.

19.3 POWER TRANSFORMERS

19.3.1 General requirements.

19.3.1.1 Dry-type transformers shall meet the requirements of IEC 60076-11.

Dry-transformers in use shall have earthed screens between high and low voltage windings.

Liquid-cooled transformers shall meet the requirements of IEC 60076-1.

Oil-immersed transformers shall, as a minimum, be provided with the following alarms and protections:

"Minimum liquid level" — alarm and automatic trip;

"Maximum liquid temperature" — alarm and automatic trip or load reduction;

"High gas pressure in enclosure" — automatic trip.

19.3.1.2 Transformers located in spaces accessible to unqualified personnel shall have a degree of protection provided by enclosure of at least IP4X.

19.3.1.3 To protect transformer equipment against lightning overvoltages, arresters are installed on the high-voltage side as well as on the 6 — 10 kV side. The number of 35 — 220 kV arrester sets and their location are selected in accordance with the requirements of national standards, the level of test voltages of the equipment to be protected, based on the diagrams of electrical connections adopted for the design period, the number of cable lines and transformers (auto-transformers).

19.3.1.4 The neutral earthing mode of 110 — 150 kV high-voltage windings is selected taking into account the neutral insulation class, ensuring the earthing coefficient within permissible limits, permissible single-phase short-circuit currents in accordance with the equipment selection conditions, and the operation of relay protection and emergency automation.

19.3.1.5 Permanent neutral earthing shall be provided for all 220 kV auto-transformers and windings. 110 kV T winding neutrals which may be isolated from earth during operation shall be protected by surge arresters of the non-linear arrester or arrester-110 type with a limiting level coordinated with the isolation level of the neutral point to be protected.

19.3.1.6 In order to reduce single-phase short-circuit currents, the neutral point of a 220 kV auto-transformer may be earthed through low-resistance current-limiting resistors or reactors.

19.3.1.7 Provision shall be made for effective measures (e.g., heating) to prevent moisture condensation and accumulation inside the transformers when deenergized.

19.4 CABLES

19.4.1 General requirements.

Cables shall be constructed in accordance with the requirements of IEC 60840 and 62067 or other equivalent national standards.

19.4.1.1 For three-phase cable systems, triple-core cables with multiwire cores shall be used.

19.4.2 Requirements for underwater cables.

19.4.2.1 Conducting cores shall be class 1 or class 2, made of uncoated or metal-coated annealed copper in accordance with IEC 60228. All conductive cores require measures to achieve longitudinal watertightness.

19.4.2.2 The insulation of cables with voltages of 15 — 220 kV shall be made of cross-linked polyethylene or ethylene propylene rubber with a normal operating temperature not exceeding 90 °C.

19.4.2.3 The rated insulation thickness of cables shall comply with the requirements of IEC 60502-2, IEC 62067, IEC 60840 or shall be specified by the manufacturer.

19.4.2.4 The shielding of the individual wires of single-core and triple-core cables shall consist of a conductor core and an insulation shield.

19.4.2.5 The conductive core shield shall be non-metallic and shall consist of an extruded semi-conductive compound, which may be applied to the semi-conductive tape. The extruded semi-conductive compound shall have adhesion to the insulation.

19.4.2.6 The insulation screen shall consist of a non-metallic semi-conductive layer in combination with a metallic screen.

19.4.2.7 For optimal resistance to mechanical stresses during cable laying, the semi-conductive shields of underwater cables shall be adhesively bonded.

19.4.2.8 A layer of semi-conductive tape or semi-conductive compound may be applied separately to each wire or bundle of wires.

19.4.2.9 Metal shielding shall be applied to individual wires or to a bundle of wires and shall consist of one or more tapes, a braid, or a concentric layer of wire, or a combination of wire and tape(s), or a metal sheath.

19.4.2.10 Armour of power cables shall be made of round or flat wire; the wire shall be of galvanized or stainless steel, copper, tinned copper or other corrosion-resistant metal alloy. When selecting the armouring material, the possibility of corrosion shall be taken into account, not only for mechanical safety reasons, but also for electrical safety reasons.

19.4.2.11 The outer covering of cables shall be of textile origin or made as an extruded layer.

19.4.3 Requirements for the laying of underwater marine cables with a voltage of 15 kV — 220 kV when connecting fixed offshore platform consumers from external power supply sources.

19.4.3.1 The laying of underwater marine power cable lines in areas of regular ship moorings is not permissible.

19.4.3.2 Depending on the specific conditions of the site design, design solutions may include options for laying the cable directly on the bottom of the water body (both with and without cable protection by means of pipe work, rip-rap, etc.), with cable burial in the ground, using additional armouring.

The cable laying option and depth of cable laying shall be determined by the project taking into account data on depth, speed and way of water movement at the transition point, prevailing winds, bottom profile and chemical composition of the bottom, chemical composition of water. The minimum depth of burial in coastal areas and shallow water shall be at least 1 m.

19.4.3.3 Cable lines shall be laid on the bottom so that in uneven areas they are not suspended; sharp projections shall be eliminated. Banks, rock ridges and other underwater obstacles in the route shall be avoided or trenches or passages shall be provided in them.

19.4.3.4 Newly constructed underwater cable lines shall be laid at a distance of at least 1,25 m from existing cable lines, but not less than 20 m. This distance may be reduced with appropriate justification during the project documentation development.

19.4.3.5 The horizontal distance from cables buried in the bottom of water bodies to pipelines (oil and gas pipelines, etc.) shall be determined by the project, depending on the type of dredging carried out when laying pipelines and cables, and shall be at least 50 m. This distance may be reduced to 15 m by agreement with the organizations in charge of the cable lines and pipelines.

19.4.3.6 On shores without improved embankments at the point of underwater cable crossing, a reserve of at least 30 m in length shall be provided for offshore laying, which shall be laid in a figure-eight fake pattern. Improved embankment cables shall be laid in pipes. Cable wells shall be provided at the cable exit point. The upper pipe end shall enter the onshore well and the lower end shall be at least 1 m deep from the lowest water level. On shore sections, the pipes shall be firmly sealed.

19.4.3.7 In areas where cables come ashore and are exposed to shore scouring, measures shall be taken to prevent exposure of cables during ice drifts and floods by strengthening the shores (patching, berms, piles, sheet piles, slabs, etc.).

19.4.3.8 Crossing of underwater marine cables with each on subsea sections is prohibited.

19.4.3.9 Justification for the choice of cable line technology is determined by the project and shall be justified both in terms of safe construction technology and in terms of the least manmade impact on the ecosystem of the water body.

19.4.3.10 Cable lines shall be so constructed that dangerous mechanical stresses and damage are avoided during installation and operation, to ensure which:

cables shall be laid with a length allowance sufficient to compensate for possible ground movements and thermal deformations of the cables and the structures through which they are laid; Laying cable allowance in the form of rings (coils) is prohibited;

it is necessary to provide a cable length margin for re-terminating or replacing the cable sleeves;

cables laid horizontally or vertically on structures, walls and ceilings shall be rigidly fixed at the end points, directly at the sleeves, on both sides of the bends, and on straight sections as designed, but at least every 1 m (this distance may vary by agreement with the manufacturer);

110 — 220 kV cable lines may not be co-located in cable structures with cable lines below 110 kV with the exception of 0,4 kV cables for technological needs;

it is not permitted to lay 110 — 220 kV cable lines together with heating pipelines and other utility lines.

19.4.3.11 When laying cable lines, the three phase cables shall be laid in parallel and arranged in a triangle or in the same plane. Other layouts are possible and shall be justified and agreed upon with the cable manufacturer.

19.4.3.12 Individual cables (not connected in a triangle) shall be laid in such a way that there are no closed metal loops of magnetic materials around each cable. In this respect, the use of magnetic materials for banding, fastening or other products (brackets, clamps, sleeves, shields) covering the cable in a closed circuit is prohibited. Routing individual cables inside pipes made of magnetic materials (e.g. steel or cast iron) is prohibited. Cable labels shall be attached with capron, plastic strands or non-magnetic metal wires (e.g. made of stainless steel or copper).

19.4.3.13 During installation, cables shall not be subjected to mechanical stress beyond the cable design limits, including stretching, bending, torsion and crushing.

19.4.3.14 The protection of underwater cable lines may include the following means and combination thereof: additional armour, burial, protection without burial, including pipe work, mats and rip-rap.

19.4.3.15 Recommendations for running cables through walls and deck. In addition to the general requirements for the arrangement of cable routes, the following shall be taken into account:

integrity: the passageways shall meet the fire and watertightness requirements of the wall or deck;

thermal insulation: cable sections shall not be mounted in thermal protection or covered with thermal insulation, but they may pass through such insulation;

mechanical passageway supports: with the exception of the cable suspension system, the passageways shall be so designed that they do not accommodate forces resulting from movements, vibrations or temperature fluctuations of the offshore installation.

19.4.4 Selection of cable according to loads, selection of cross-sectional area for permissible voltage drop.

19.4.4.1 Calculation of the current rating of the cable shall be carried out in accordance with IEC 60287-1-1. The type of electric current to be transmitted (direct current, alternating current), the climatic conditions for cable laying and the nature of the ground shall be taken into account.

Calculation shall be carried out using the values of maximum permissible conductor temperature, conductor resistance, losses and thermal specific resistance. Next, the rated current load derived from the calculation is compared with the rated current load of the consumer/installation to be designed and a conclusion is made as to the suitability of the selected cable, or the need to recalculate based on the ratio:

$$I_{\text{length nom.calc.}} > I_{\text{length nom.inst.}},$$

where . $I_{\text{length nom.calc.}}$ — rated current load for the cable line, obtained from the calculation of IEC 60287-1-1;

$I_{\text{length.nom.inst.}}$ — the rated current load of the consumer/installation being designed.

The calculation shall be adjusted subject to the conditions specified in 19.4.4.2 and 19.4.4.3.

For the calculation, the voltage deviation at the consumer/receiving unit shall not exceed 10 % of the standardized voltage level of the electrical consumer according to IEC 60038. The necessity of reducing the voltage deviation shall be substantiated by technological conditions as well as by national standards.

19.4.4.2 Calculation of losses due to eddy currents in metal sheaths of single-core cables laid in the same plane in two parallel three-phase networks shall be carried out in accordance with IEC 60287-1-2. This calculation is necessary for estimating the reduction of the current capacity for circuits laid in parallel. The type of cable sheathing, phase rotation, and geometric parameters of the cable line route shall be taken into account.

19.4.4.3 Calculation of current distribution between phase conductors of single-core cables arranged in parallel and losses due to circulating currents shall be carried out in accordance with IEC 60287-1-3. The type of cable sheathing, phase rotation, and geometric parameters of the cable line route shall be taken into account.

19.4.4.4 Calculation of ambient thermal resistances for different cable laying options (thermal resistance between single core and sheath, thermal resistance between sheath and armour, thermal resistance of outer protective covering) shall be performed in accordance with IEC 60287-2-1 and IEC 60287-2-2. The specified data shall be used to calculate the current capacity of the cable in accordance with the requirements of 19.4.4.1.

19.4.4.5 Reference operating conditions, deviations from these conditions and cable selection shall be carried out in accordance with the requirements given in IEC 60287-3-1.

19.4.4.6 Calculation of cables for cyclic and fault tolerance shall be carried out in accordance with IEC 60853-1 and IEC 60853-2. In carrying out this calculation, the ability of cable of the selected size to withstand potential short-circuit currents and earth faults of an appropriate duration is checked.

19.4.4.7 Calculation of thermally permissible short-circuit currents with respect to nonadiabatic/adiabatic heating and short-circuit temperature shall be carried out in accordance with IEC 60949. Once the calculation is completed, the maximum permissible core temperature for the cable insulation type in question is compared with the calculated core temperature based on the condition:

$$\theta_{f.\text{calc.}} < \theta_{f.\max},$$

where $\theta_{f.\text{calc.}}$ – final temperature of the conductor during a steady-state short-circuit, ºC;

$\theta_{f.\max}$ – maximum permissible temperature of the conductive core during a steady-state short-circuit for a given cable type, ºC.

19.4.4.8 Calculation of the economic cross-section of the cable and its selection in accordance with economic criteria shall be made in accordance with IEC 60287-3-2. The specified calculation and selection are carried out after calculation of the rated current load of the cable, the voltage drop in accordance with 19.4.4.1 and verification of the cable thermal and dynamic resistance in accordance with 19.4.4.6 in order to clarify the economic component of the design decisions.

19.5 SWITCHGEAR AND CONTROLGEAR ASSEMBLIES

19.5.1 General requirements.

Switchgear and controlgear shall be constructed in accordance with the requirements of IEC 60298. 110 — 220 kV GIS shall be manufactured in compliance with IEC 62271-203 and the following additional requirements.

19.5.2 Design.

19.5.2.1 Mechanical design.

Distribution boards shall be made of metal and be of closed type — in accordance with IEC 60298, or shall be made of insulating materials and be of closed type — in accordance with IEC 60466 or in compliance with the requirements of national standards.

19.5.2.1.1 Switchboards shall be locked with a special key other than those for low-voltage switchboards and switchgear. Opening of doors or drawing separate components out shall be possible only after disconnection of the panel or switchboard from the electrical power supply.

19.5.2.1.2 Passageways shall be provided along the switchboards for the switchboard (up to 35 kV inclusive) and electrical equipment inspection. Their width shall be at least 1000 mm between the bulkhead and switchboard, and at least 1200 mm between the parallel sections of the switchboard. Where such passageways are intended for maintenance, their width shall be increased up to 1200 mm and 1500 mm respectively.

The specified width of those passageways is required regardless of the type of contact protection means used like doors, guard nets and insulating rails.

Doors, continuous bulkheads and net screens shall be at least 1800 mm high.

Perforated bulkheads or net screens shall ensure the degree of protection not below IP2X.

Insulated handrails shall be fitted on the front side of the switchboards. Insulated handrails shall be fitted to the rear of such shields if it is necessary to access the rear of such shields for operation or maintenance.

Arrangement of the gas-insulated switchgear shall be symmetrical, i.e. all three phases of the same cell shall be adjacent to each other, with the possibility to extend the GIS in both directions to two cells, unless the design specification provides otherwise.

The width of the gangway along the cell poles (sufficient on the cell front side) for the transport of gas-handling, test equipment and dismantled switchgear components shall be at least 3 m for 110 kV GIS and 4 m — for GIS of 220kV and above. Space shall be provided in the GIS room to accommodate the high-voltage test installation, dismantling and technological work on the equipment.

19.5.2.1.3 Live parts of the electrical installation shall be spaced from protective guards at a distance not less than that specified in Table 19.5.2.1.3.

Table 19.5.2.1.3

Rated voltage, in kV	Minimum height of the passageway	Minimum distance of live electrical parts from different types of safety barriers, in mm		
		Solid doors and partitions	Mesh doors and partitions	Insulating handrails
15	2500	160	240	800
20	2500	210	280	900
35	2500	320	390	1000
110	2500	730	800	1500
150	2500	1130	1200	1800
220	2500	1730	1800	2000

19.5.2.2 Interlocking devices.

Automatic withdrawable circuit breakers used in switchboards must be provided with a device for locking them both in the service and retracted positions. Locking keys and lockable disconnectors shall be provided to ensure safe maintenance of withdrawable switches and other apparatus.

The withdrawable circuit breakers shall be fixed in the operating position so that relative movements between the movable and fixed parts are avoided.

19.5.2.3 Shutters.

The fixed current-carrying contacts of withdrawable circuit breakers shall be automatically covered by insulating shutters when the circuit breaker is drawn out.

19.5.2.4 Earthing and interphase fault devices.

In order to ensure the safe maintenance of high-voltage switchgear, an adequate number of devices for forced busbar fault and earthing for busbars and outgoing feeders shall be provided.

The device shall be rated for the maximum short-circuit current.

19.5.3 Auxiliary supply system for switchgear.

19.5.3.1 Source of supply.

Where a separate auxiliary electrical or other source of power is required for operation of circuit breakers and other switches, and also for protection devices, in addition to the main source, a stand-by source with sufficient power supply for at least two operations of all the components shall be provided.

However, the circuit breaker releases activated due to overload, short-circuit or undervoltage shall be independent of any sources of electrical power.

This requirement does not preclude using shunt releases (releases activated by an operating voltage), provided that the control of tripping circuits and their supply system integrity (continuity) will be ensured, i.e. if the integrity of the circuits is broken or their supply system is faulty (fails), an alarm will be activated.

19.5.4 High-voltage tests.

Every main and other switchboards shall be tested by a high voltage of standard frequency. The test procedure and voltage values shall meet the requirements of an appropriate national standard or IEC 60298 and IEC 62271-203.

19.6 METAL SHEATHED 110 — 220 KV INTEGRATED GAS-INSULATED SWITCHGEAR (GIS)

19.6.1 General requirements.

Metal-sheathed 110 — 220 kV gas-insulated switchgear (GIS) shall be manufactured in accordance with IEC 62271-203 and the following additional requirements.

19.6.2 Design.

19.6.2.1 GIS shall be so designed as to ensure the safety of personnel during standard operation as well as during emergencies and repair work, including maintenance of switchgear, earthing of connected cables, identification of cable faults, voltage tests of connected cables or other apparatus and removal of dangerous electrostatic charges, and checking the phase sequence after installation or extension.

19.6.2.2 The unit design shall ensure that the agreed permissible foundation shifts and mechanical or thermal influences do not affect the equipment parameters. Compensators for mechanical displacements and expansions are placed where necessary to ensure GIS mechanical flexibility. All components with the same rating and design that may need to be replaced shall be interchangeable.

19.6.2.3 GIS shall be divided into compartments in such a way that normal operating conditions are met and measures are taken to limit the arc impact on the internal cavities. For this purpose, partitions shall be used, the design of which shall meet the following requirements:

the partitions used to separate GIS compartments shall be gas-tight to prevent contamination from penetrating into the adjacent compartment;

the partitions shall be made of a material with such insulating and mechanical properties as to ensure their proper functioning during the entire GIS service life;

the partitions shall retain their dielectric properties under operating voltage when they are contaminated by electronegative gas decomposition products from switching operations.

19.6.2.4 GIS partitions (insulators) shall be calculated:

for the pressure difference when vacuuming gas from a compartment (element) on one side of the bulkhead at normal operating pressure on the other side of the bulkhead;

for excessive pressure on one side of the bulkhead at normal operating pressure on the other side during the electrical testing of circuit equipment;

for non-symmetrical partitions to the worst pressure direction;

for additional loads and vibrations;

for the serviceability of the component, when servicing is carried out with a pressurized partition.

19.6.2.5 GIS components to be installed in enclosures shall comply with the requirements of the relevant standards.

Due to small dimensions, extended service life and maintenance intervals, GIS components shall be designed with fitted devices that allow for in-service monitoring of the equipment and ensure increased operational reliability:

trigger counters in switchgear;
conductivity current monitoring sensors in gas-insulated surge arresters;
in metering transformers, the execution of a separate winding for electricity metering.

GIS components shall be equipped with auxiliary means (heating, ventilation, protective measures, etc.) to ensure normal operation of the equipment over the entire range of actual operating conditions.

Switchgear connection and disconnection controls and emergency network termination controls must be located at a height of between 0,4 m and 1,8 m above the service level.

19.6.2.6 Cable connections.

GIS components that remain connected to the cable shall be able to withstand the test voltages specified in the relevant standards for cables of the same rated voltage.

During the testing of cable electric strength, neighbouring GIS parts shall be disconnected and earthed to prevent GIS live parts from being affected by disruptive discharges in the cable. For this purpose, a process isolator (disconnector) shall be installed in GIS cable connection.

An entry for cable diagnostics and testing with DC and AC voltages shall be provided on the cable sheath or on GIS for each phase (IEC 62271-209).

When 35 — 220 kV GIS or cable lines and cable inserts are used, surge arresters shall be used to protect them against lightning surges. The choice of location and parameters for the surge arrester is determined on the basis of the calculations made in the design documentation.

19.6.2.7 Direct connections between GIS and transformer shall be made in accordance with IEC 62271-211. A process isolator (disconnector) shall be installed at the transformer inlet to enable preventive testing of transformers in GIS gas-insulated current lead.

19.6.2.8 "Electronegative gas — air" ("air — gas") entries shall comply with the climatic version specified for the operating conditions.

19.6.2.9 In the design of current leads for intra-substation connections, the shells, current carrying parts, contact assemblies, bulkheads and support insulators used in the main GIS components shall be primarily used. The design of the current leads shall comply with all test standards applicable to GIS — IEC 62271-203.

19.6.2.10 Insulating devices.

In order to arrange the possibility of GIS testing with overvoltage rated for transformer connection and entries, it shall be possible to provide an isolating gap from the mating equipment. For overhead entries it may be sufficient to disconnect the conductor from the outer (overhead) side.

For checking the electrical resistance of GIS main supply circuit, it shall be possible to access the main supply circuit without having to dismantle the GIS components.

19.6.2.11 Corrosion protection.

The choice of GIS materials and protective coatings shall be determined by the operating conditions, standards of the Unified system of corrosion and ageing protection (USCAP) and specified in the operating instructions.

All bolted or screwed connections of the sheath shall remain easily dismantled. The continuity of the earthing circuits shall be guaranteed taking into account the corrosion of bolted and screwed connections.

The number of earthing points and GIS grounding scheme shall be such as to preclude any occurrence of electrochemical corrosion of current lead metal where they intersect the overlaps.

19.6.2.12 GIS gas system.

Controlled pressure system in GIS shall not be used where the gas volume is automatically fed from an external compressed gas source or from an internal gas source.

Autonomous pressure system and closed pressure system shall be used in GIS. Means shall be provided to enable safe and convenient make-up of gas systems when the equipment is in operation. The use of external gas make-up pipes is not permissible.

Stand-alone gas pressure systems.

The recommended leakage rate of a single GIS compartment to atmosphere and between compartments for autonomous pressure system is not more than 0,5 % per year.

Closed pressure systems.

In a closed pressure system, a gas leakage rate of 0,1 % per year is assumed to fulfil the expected lifetime requirement.

Pressure coordination is specified in IEC 62271-203. The manufacturer shall select the minimum permissible electronegative gas pressure for the insulation and switching capacity P_{me} and the pressure for the pressure drop alarm activating.

Depressurizing.

For safety reasons and limitation of the consequences for GIS, a pressure relief device shall be installed in each compartment, except for high volume compartments where the overpressure is self-limiting to values which do not exceed the type test pressure.

Pressurization devices (valves with opening and closing pressures and devices for relieving pressure without reclosing the relief hole, diaphragms and frangible discs) shall have a deflector to direct the release and ensure that there is no hazard to the operator's work where it may be encountered.

19.6.2.13 Enclosure design.

The enclosures shall be designed in accordance with the requirements of PB 03-576-03 "Regulations for the Construction and Safe Operation of Pressure Vessels".

The enclosure shall be capable of withstanding the normal and transient pressures to which it is subjected in operation, as well as the possible effects of internal arcing overlap.

Measures shall be provided to reduce the effects of internal arcing on GIS equipment and to minimize the time interval of the power failure. The arc shall not penetrate into neighbouring gas compartments. The effects of an internal arc shall be localized within the same compartment where the arc occurred.

Recommended protection criteria in accordance with IEC 62271-203 for different arc durations according to the protection system configuration are given in Table 19.6.2.13.1.

Table 19.6.2.13.1

Rated short-circuit current	Degree of protection	Current duration	Status criteria
≤ 40 kA (actual value)	1	0,2 s	No external effects other than the operation of pressure relief devices
	2	≤ 0,5 s	No fragmentation (allow for burning)
≥ 40 kA (actual value)	1	0,1 s	No external effects other than the operation of pressure relief devices
	2	≤ 0,3 s	No fragmentation (allow for burning)

19.6.2.14 Interlocking.

Self-contained and closed pressure systems filled with compressed gas for insulation and/or operation and having a minimum operating pressure for insulation and/or operation greater than 0,2 MPa (absolute pressure) shall be fitted with pressure (or density) monitoring devices for continuous or at least periodic monitoring as part of the maintenance programme, taking account of the requirements of the relevant standards.

For GIS components and control equipment with a minimum operating pressure not exceeding 0,2 MPa (absolute pressure), such means shall be subject to agreement between the manufacturer and the consumer.

The gas density or temperature-compensated gas pressure in each compartment shall be continuously monitored. The indicator-type control device shall provide at least two pressure or density settings (pressure/density alarm and minimum functional pressure or density).

Gas monitoring devices shall be accessible for inspection and replacement when high voltage equipment is in operation.

For the main circuits, the following interlocking devices, which are used for creating insulation gaps and earthing, are mandatory:

interlocks to prevent switching on — for apparatus installed in the main circuit, which are used to provide an isolation gap during maintenance work;

interlocks to prevent tripping — for the earthing switches.

GIS interlocking components (intermediate disconnector/earthing switch interlock relays, disconnector/earthing switch contactors) made by the manufacturer shall have additional status interlock contacts to collect discrete signals about the status of these components to the feeder controllers.

Interlocking relays with normally closed contacts shall be provided in GIS interlocking circuits to implement additional interlocking conditions (software interlocks in feeder controllers).

Earthing switches with a short-circuit making capacity smaller than the nominal peak of the short-circuit withstand current shall be mechanically interlocked with the corresponding disconnectors so that when the main current-carrying circuit is high, it is not possible to switch on earthing circuit on and when the earthing circuit is switched on, it is not possible to switch on the main current-carrying circuit.

Quick-release earthing switches shall have an interlock to prevent switching on when there is voltage on the main current-carrying circuit and a mechanical interlock for the drive in the disconnected and switched-on positions.

Load-break switches with a short-circuit making capacity less than the nominal peak withstand short-circuit current or with a breaking capacity less than the nominal operating current and disconnectors shall be interlocked with the corresponding switch to prevent the load-break switch or disconnector from tripping or opening if the switch is not tripped.

19.6.2.15 During GIS operation, the level of noise generated by the equipment shall not exceed the value specified by the manufacturer.

19.6.2.16 Earthing of GIS and control equipment.

The enclosures of GIS components and auxiliary equipment shall be fitted with a reliable earthing terminal with a clamp screw or bolt for connection to an earthing conductor.

Metal sheath parts connected to the earthing system may be regarded as an earthing conductor.

It is permitted to earth the GIS in accordance with the manufacturer's instructions.

Provision shall be made for earthing all parts of the main live circuits to ensure the safety of maintenance personnel during repair work.

Earthing switches installed on collecting busbars and outgoing lines shall have a short-circuit making capability and a short-circuit making capacity.

In addition, after opening the enclosure for the period of repair work, it shall be possible to connect portable earthing switches to those parts of the circuit which were previously earthed through earthing switches.

The enclosures and all metal parts that are not part of the main or auxiliary circuit must be earthed. For continuity of the chain, the connections between the enclosures, frame and other metal parts may be made by bolting or welding.

In case of phase-by-phase GIS design, loop circuits connecting the three phase enclosures shall be installed to ensure the flow of induced currents. Each of these loop circuits shall, as far as possible, be directly connected to a common earthing system by means of a conductor capable of carrying short-circuit current.

19.6.2.17 Degrees of protection.

Degrees of protection in accordance with IEC 60529 shall be determined for the control equipment permitting external penetration and for the enclosures (cabinets) of the corresponding control circuits and/or auxiliary low-voltage circuits and control drives of all high voltage switchgear, control equipment and switchgear.

19.6.2.18 Electromagnetic compatibility.

For the main circuit of the switchgear in normal operation without switching operations, the emission level is checked by measuring the radio interference voltage, if applicable. The test procedure for the radio interference test shall be in accordance with IEC 60060-1.

Electromagnetic compatibility requirements apply to interfaces and inputs of auxiliary circuits, control circuits, auxiliary assemblies that have electronic components, the effect of interference on which can lead to incorrect functioning. The limit values for radio interference tests shall not exceed the limit values specified in the standards for the particular type of electrical equipment.

19.6.2.19 Position indicators.

In switchgear, if the contacts are invisible, a clear and reliable indication of the position of the main circuit contacts must be provided, which is mechanically connected to these contacts. Possibility of easy monitoring of the position indicator during maintenance work on the equipment shall be provided.

The colors and markings of the positions of the signalling device in the disconnected, activated or, where provided, earthed position shall comply with IEC 62271-203.

The disconnector or earthing switch disconnected position can be detected if one of the following conditions is fulfilled:

the insulating gap is visible;

the position of the movable contact, ensuring the insulating distance or gap, is indicated by a visual indicator device.

19.6.3 Requirements to electrical insulation strength.

The insulation of GIS main circuits, control circuits, auxiliary circuits must comply with the requirements of the IEC 60071-1.

The rated test voltages of the GIS main circuits must comply with IEC 60071-1.

The insulation of the GIS control and auxiliary circuits with respect to earth shall withstand a short-term (one-minute) alternating voltage test in accordance with IEC 60071-1.

The leakage path of the external insulation of "electronegative gas — air" ("air — gas") entries shall comply with at least II* contamination degree in accordance with IEC/TS 60815-1 and IEC 60694.

19.6.4 Requirements for through-current short-circuit resistance.

GIS shall withstand the effects of rated short-time currents and rated peak currents (thermal and electrodynamic withstand currents) under short-circuit conditions without damage preventing its further proper operation. The value of the electrodynamic withstand current i_d shall be at least 2,5It.

GIS earthing circuits shall be resistant to the effects of through short circuit currents for their duration.

19.6.5 Heating requirements for normal operation and short-circuits.

GIS heat dissipation, during continuous normal operation, shall meet the requirements of IEC 60694.

The temperature of the GIS enclosure parts under normal operating conditions, accessible to touch, shall not exceed 70 °C, those not accessible to touch must not exceed 80 °C.

Permissible temperature rise above the temperature of the GIS secondary circuits shall comply with IEC 60694.

19.6.6 Requirements for gases.

The manufacturer shall specify the type, required quality, quantity and density of the gas (gas mixture) used in the GIS components and the control equipment, and shall give the consumer the necessary instructions for gas renewal and maintenance of the required quantity and quality.

The manufacturer shall specify the requirements for new and used gas applied in the GIS. New gas to be used in GIS shall comply with IEC 60376. When using new electronegative gas, IEC 62271-203 recommendations in case of pre-commissioning of equipment and IEC 60376 recommendations for monitoring gas properties and maintenance of GIS during operation shall be applied.

Mixtures of gases such as ultra-pure nitrogen and carbon tetrafluoride may be used as insulating and arc quenching media in GIS components.

Methods of preparing mixtures, filling the equipment with mixtures and maintaining the composition of mixtures during operation shall comply with the instructions of the equipment manufacturer.

19.6.7 Tests.

GIS shall be subject to prototype testing of products as well as product testing during steady-state production at the installation site. As agreed between the manufacturer and the customer, the test item may be GIS in assembly or parts whereof.

The prototype tests are carried out on equipment after the production technology has been mastered and when the design, materials and production technology and technical characteristics have been altered. The tests shall be carried out on each GIS when it leaves the manufacturer's and also in order to verify the stability of GIS technical characteristics during their serial production.

These tests shall be carried out in compliance with IEC 62271-203.

The on-site tests are carried out after the GIS has been installed at the facility. The scope and procedure of the on-site tests shall be agreed with the customer.

19.7 CURRENT LEADS FOR A VOLTAGE OF 6 — 220 KV

19.7.1 General.

19.7.1.1 For voltages of 6 — 35 kV inclusive, cast (solid) insulated or shielded current leads shall be used; for voltages of 110 — 220 kV, gas-insulated current leads shall be used.

19.7.1.2 Requirements for contact joints, metal coatings, types, thicknesses and quality requirements for coatings shall be in accordance with IEC 60999-1 and IEC 60999-2.

19.7.2 Cast (solid) insulated current leads 6 — 35 kV.

19.7.2.1 The degree of protection provided by the current lead enclosure is IP44 for indoor conductors. The current lead is naturally cooled.

19.7.2.2 Copper, aluminium or aluminium alloys shall be used for busbars, flanges and busbar compensators of current leads. Special compounds, e.g. epoxy resins, shall be used for insulation.

19.7.2.3 Permanent terminations of current leads made of copper and copper alloy shall be made by soldering with copper-phosphorus solder with silver additive.

19.7.2.4 Design.

19.7.2.4.1 The current lead shall consist of differently configured sections. The set and location of the current lead components is determined by the assembly drawing of the route designed for the specific site.

19.7.2.4.2 The current lead section shall consist of a copper or aluminium busbar, covered with a layer of rigid insulation with a thickness depending on the value of the rated voltage. The ends of the sections shall be provided with pins with holes for bolting the sections together and to the electrical equipment. Section length shall not exceed 10 m.

19.7.2.4.3 For equipment to be built into the current lead (disconnectors, voltage and current transformers, overvoltage limiters), enclosures of the appropriate type shall be provided.

19.7.2.4.4 The connection between the sections along the entire length of the line shall be split (bolted) by means of special couplings with thermal expansion joints, which shall be installed along the current lead at intervals of not more than 10 m. Joints without thermal expansion joints can be filled at the installation site with the same compound as the busbar.

19.7.2.4.5 The connections between the current leads and the outlets of the electrical apparatus shall be made demountable, using busbar compensators and (at the customer's request) protective sheaths.

19.7.2.4.6 The configuration of the sections shall ensure that the current lead can be laid in any spatial position taking into account the configuration of the route.

19.7.2.4.7 The design of the current lead shall allow for a vertical run of up to 10 m.

19.7.2.4.8 The fastening components of the current lead shall ensure that the conductor is securely fastened to the supporting structure and that it can move within ±20 mm in case of temperature variations in the busbars.

19.7.2.5 Electrical parameter requirements.

19.7.2.5.1 Requirements for insulation strength according to IEC 60071-1 for apparatus with normal insulation.

19.7.2.5.2 Partial discharge intensity in the current lead insulation of level "a" as per IEC 60071-1 shall not exceed 5 pC for the voltage of $I{,}05 \cdot U_m \cdot \sqrt{3}$ or 10 pC for the voltage of $I{,}5 \cdot U_m \cdot \sqrt{3}$.

19.7.2.5.3 Continuous heating temperature of the current lead components at the rated current must not exceed:

for copper or aluminium busbars and contact connections: +90 °C in accordance with IEC 60694;

for the outer surface of the current lead insulation layer: +70 °C.

19.7.2.5.4 The current lead shall be resistant to the electrodynamic and thermal effects of short-circuit currents, the parameters of which do not exceed the specified values:

the current of electrodynamic resistance i_d or its multiplicity K_d in relation to the rated current amplitude;

the current of electrodynamic resistance $I_т$ or its multiplicity $K_т$ in relation to the rated current;

thermal resistance current flow time $t_к$, 1 and 3 s.

19.7.2.5.5 The ratio $i_д \geq 1{,}8\ \sqrt{2}\ I_т$ shall be observed between the Id and It values.

19.7.2.5.6 Each section of the current lead shall have a grounding conductor terminal (clamp) made in accordance with IEC 60947-4-1 and IEC 60417-DB-12M. The earthing bolt shall be of at least 10 mm in diameter.

19.7.3 Gas-insulated current leads 110 — 220 kV.

19.7.3.1 With respect to the phase conductor arrangement, the current leads shall be either three-phase (with three phases in a common enclosure) or single-phase (with the phases placed in separate enclosures).

19.7.3.2 In terms of the termination design, the current leads shall be of the following types:

with "air — electronegative gas" entry;
with "electronegative gas — air" entry;
with "electronegative gas — electronegative gas" entry.

19.7.3.3 Gas-insulated current leads shall be designed for fault-free operation under both normal conditions and under short-circuit, overvoltage and standardized overload conditions.

19.7.3.4 Requirements for electrical insulation strength.

19.7.3.4.1 Standardized test voltages of the GIS main circuits shall comply with Table 19.7.3.4.1.

Table 19.7.3.4.1

Voltage class	Test voltage, in kV				
	full lightning impulse		switching impulse	short-term alternating voltage	
	relative to the ground	between phases for GICL*	relative to the ground	relative to the ground	between phases for GICL
110	450	450	–	230	230
150	650	650	–	300	300
220	900	900	–	440	440
* Gas-insulated current lead with all three phases housed in the same enclosure.					

19.7.3.4.2 The insulation of GICL control and auxiliary circuits in relation to earth shall withstand a test short-term (one-minute) alternating voltage of 2,0 kV applied alternately between live and earthed parts and between live parts of different circuits.

19.7.3.4.3 The partial discharge intensity in the GICL insulation shall not exceed the value of 10 — 11 C when an alternating current voltage equal to $1{,}1U_{w.v.}/\sqrt{3}$ is applied in accordance with IEC 60071-1.

19.7.3.5 Requirements for through-current short-circuit resistance.

19.7.3.5.1 GICL shall withstand the effects of rated short-time currents and rated peak currents under short-circuit conditions without damage preventing its further proper operation. The value of the electrodynamic resistance i_d shall be at least $2{,}5I_t$.

19.7.3.5.2 The rated current flowing time of 1s, 2s or 3s is specified in the GICL documentation.

19.7.3.5.3 GICL earthing circuits shall be resistant to the effects of through short circuit currents for their duration equal to 1 s.

19.7.3.6 Heating requirements for normal operation and short-circuits.

19.7.3.6.1 The temperature of the GICL enclosure parts under normal operating conditions, accessible to touch, shall not exceed 70 °C. The temperature of the GICL enclosure parts not accessible to touch under standard operating conditions, shall not exceed 80 °C.

19.7.3.6.2 Permissible temperature rise above the temperature of the GICL secondary circuits shall comply with the IEC 60999-1 and IEC 60999-2. The permissible temperature limits for contact heating of live parts during the passage of fault currents shall not exceed the permissible values in accordance with IEC 60999-1 and IEC 60999-2.

19.7.3.7 Design.

19.7.3.7.1 All sheaths of the individual sections and components of the current lead shall be electrically connected and earthed.

19.7.3.7.2 The connection of individual sections and/or pivoting sections shall be carried out with bolts.

19.7.3.7.3 Compensation devices shall be provided to compensate for dimensional variations in current leads due to temperature fluctuations, as well as dimensional deviations during manufacture and installation.

19.7.3.7.4 The GICL design shall allow for the use of sectionalizing and termination devices in the form of "air — insulated gas", "cable — insulated gas", "insulated gas — insulated gas" entries, as well as the use of rotating elements along with the line sections of the current lead to provide the necessary routing.

19.7.3.7.5 Entry of "cable — insulated gas/electronegative gas" type for connecting power cable and GICL shall comply with the recommendation of IEC 62271-305.

19.7.3.7.6 The GICL sheathing shall be resistant to burning through inward arc over time (in accordance with IEC 61640):

at arc currents of 40 kA and above — from 0,1 s to 0,3 s;

at arc currents under 40 kA — 0,2 s to 0,5 s.

The specific time at which the GICL heath shall be resistant to burning through at internal arc overlap is determined by the manufacturer on the test basis.

19.7.3.7.7 Each sealed section of the current lead shall be equipped with protection against excessive pressure build-up of electronegative gas.

19.7.3.7.8 Each pressurized section of the current lead shall be fitted with an electronegative gas density gauge and electronegative gas filling and venting valves. Density sensors shall be so designed that their operation can be verified without purging gas from the compartment.

19.7.3.7.9 The electronegative gas density (pressure) gauges shall have settings for an alarm and interlock output:

the electronegative gas density (pressure) at which the refilling of electronegative gas is required;

the minimum density (pressure) of electronegative gas at which the conductor shall be taken out of service (disconnected by the circuit-breakers on both sides).

19.7.3.7.10 Components for the control and signalling circuits of the current lead shall be housed in cabinets.

The cabinets shall be fitted with outputs for centralized control circuits.

Protection degree of the cabinets against contact with or proximity to lived parts, contact with moving parts inside the enclosure, ingress of solid foreign bodies and water in accordance with IEC 60529 shall be specified in the company (manufacturer) technical documentation.

19.7.3.7.11 The earthing circuits of the enclosure and the main GICL circuit elements, as well as the method of their attachment, shall be selected in accordance with the requirements of IEC 60947-4-1 and IEC 60417-DB-12M.

19.7.3.8 Requirements for testing.

GICL shall be subjected to qualification, acceptance, type and commissioning tests on site. As agreed between the manufacturer and the customer, the test item may be GISL in assembly or parts whereof.

19.8 DRY CURRENT-LIMITIMG REACTORS

19.8.1 Basic parameters.

19.8.1.1 The reactor voltage classes shall comply with the IEC 60071-1, IEC 60071-2.

19.8.1.2 Rated current and rated inductive reactance of single reactors at 50 Hz shall be taken from Table 19.8.1.2.1. Rated current and rated inductive impedance of twin reactors at 50 Hz shall be taken from Table 19.8.1.2.2.

Table 19.8.1.2.1

Rated current, in A	250	400	630	1000	1600	2500	4000
Rated inductive impedance, in Ohm	1,00	0,35	0,25	0,14	0,14	0,14	0,10
	1,40	0,45	0,40	0,22	0,20	0,20	0,18
	2,00	–	0,56	0,28	0,25	0,25	–
	2,50	–	0,70	0,35	0,35	0,35	–
	–	–	1,00	0,45	0,56	–	–
	–	–	1,60	0,56	–	–	–
	–	–	2,00	0,70	–	–	–
	–	–	–	1,00	–	–	–

Table 19.8.1.2.2

Rated current, in A	2 x 630	2 x 1000	2 x 1600	2 x 2500
Nominal inductive impedance, in Ohm	0,25	0,14	0,14	0,14
	0,40	0,22	0,20	0,20
	0,56	0,28	0,25	0,25
	–	0,35	0,35	0,35
	–	0,45	–	–
	–	0,56	–	–

At 60 Hz, the rated current values shall be in accordance with Tables 19.8.1.2.1 and 19.8.1.2.2 and the rated inductive reactance value — in accordance with 19.8.1.2.1 and 19.8.1.2.2 multiplied by a factor of 1,2.

19.8.1.3 Reactors shall be made with vertical, stepped or horizontal phase arrangement.

19.8.1.4 Reactors shall be manufactured with natural air or forced air cooling.

19.8.2 Design requirements.

19.8.2.1 Reactor outputs shall comply with the requirements of IEC60999-1 and IEC 60999-2.

19.8.2.2. The angle between the reactor leads shall be 0°, 90° or 180°. The specific value is set in accordance with consumer's requirements.

The identical terminals of the beginning, middle and end of the winding of vertically and staggered phases shall be placed on the same vertical line. The tolerance for the angles between the leads shall not exceed ±10°.

Reactors with alternatively arranged contact leads as well as twin reactors with different angles between lower and middle or middle and upper leads can be manufactured by agreement between the consumer and the manufacturer.

19.9 3 — 220 KV SURGE ARRESTERS

19.9.1 Basic electrical characteristics.

19.9.1.1 The residual voltages of the arrester shall be specified by the manufacturer in the technical documents for the particular types of arrester at 30/60 μs, 8/20 μs and 1/10 μs current pulses with the maximum pulse values given in Table 19.9.1.1.

Table 19.9.1.1

Rated maximum values of current pulses through the arrester

Arrester class by capacity	Rated discharge current, in A	Maximum current values, in A, at pulses, in μs		
		30/60	8/20	1/10
1	5000	125, 250, 500	2500, 5000, 10000	5000
	10000	125, 250, 500	5000, 10000, 20000	10000
2	10000	250, 500, 1000	5000, 10000, 20000	10000
3	10000	500, 1000, 2000	5000, 10000, 20000	10000
4	10000	500, 1000, 2000	5000, 10000, 20000	10000
	20000	500, 1000, 2000	10000, 20000, 40000	20000
5	20000	500, 1000, 2000	10000, 20000, 40000	20000

N o t e . A pulse means a unipolar wave of voltage or current rising without noticeable oscillation at high speed to a maximum value and decreasing, usually at a slower speed, to zero with little, if any, transition to the opposite polarity. The parameters specifying voltage or current pulses are polarity, maximum value (amplitude), conditional edge length and conditional pulse duration:

.1 conditional pulse edge time (duration) T1: time expressed in microseconds and determined by multiplying by 1,25 the time in microseconds required to increase the maximum (amplitude) value of the pulse from 10 % to 90 %;

.2 conditional pulse duration T2: the time, expressed in microseconds, between the conditional start of the pulse and the moment when the voltage or current decreases to half of the maximum value;

.3 pulse shape indication: a combination of two numbers in microseconds, the first indicating the rising edge and the second the duration of the pulse. This combination shall be recorded as T1/T2 (the "/" sign has no mathematical meaning)

19.9.1.2 The manufacturer shall specify the value of the classification current and the corresponding minimum classification voltage of the arrester:

.1 classification current of the arrester I_{cl}: the amplitude value (the higher amplitude value of the two polarities if the current is asymmetrical) of the active component of the power frequency current, which is used to determine the classification voltage of the arrester and is rated by the manufacturer;

.2 classification voltage of the arrester U_{cl}: the maximum (amplitude) value of the power frequency voltage divided by 2, which shall be applied to the arrester to obtain the classification current. The classification voltage of a multi-element arrester is defined as the sum of the classification voltages of the individual elements.

19.9.1.3 The arrester shall withstand without damage 18 rectangular current pulses of 2000 μs with a maximum value (amplitude) equal to the current carrying capacity specified by the manufacturer.

19.9.1.4 The arrester shall withstand without damage 20 pulses of rated discharge current and 2 pulses of high current with an amplitude:

.1 65000 A — for arresters of capacity class 1 and rated discharge current of 5000 and 10000 A;

.2 100000 A — or arresters of capacity class 2 — 5 and nominal discharge current of 10000 and 20000 A.

19.9.1.5 Arresters shall withstand a combination of operating and simulated operational tests, which shall not result in damage or loss of thermal stability:

.1 for arresters of capacity class 1 and rated discharge current 5000 and 10000 A — 20 pulses of rated discharge current and 2 pulses of high current with an amplitude of 65000 A;

.2 for arresters of capacity classes 2 to 5 and rated discharge currents 10000 and 20000 A — 20 pulses of rated discharge current, 2 pulses of high current with an amplitude of 100000 A and 2 pulses of current carrying capacity.

19.9.2 Requirements for external insulation.

19.9.2.1 Leakage path length of the external insulation of the arrester operating under conditions corresponding to pollution degree I shall be at least 1,8 cm/kV of the highest operating voltage of the network, while for pollution degrees II, III, IV — at least 2,0; 2,5 and 3,1 cm/kV respectively.

19.9.2.2 Insulation of arresters made with organic (polymer) materials shall be traction-erosion-resistant.

19.9.2.3 Insulation of the limiter enclosure shall withstand the lightning pulse, switching pulse, one-minute power frequency voltage tests.

19.9.2.4 Lightning pulse voltage test shall be carried out for all types of arresters. The maximum value of the test pulse voltage shall not be less than the residual voltage at the limiter at rated discharge current multiplied by 1,3.

19.9.3 Design requirements.

19.9.3.1 The arresters shall be tight.

19.9.3.2 The design of the plastic-insulated arrester shall be resistant to moisture penetration.

19.9.3.3 Arresters shall have contact terminals for connection to current-carrying and earthing wires. The input terminals shall be suitable for the connecting of copper or aluminium cables and busbars, including stranded wires.

19.9.3.4 All metal parts of the arresters shall be protected against corrosion. The sealing material for tightening shall be ozone-resistant.

19.9.3.5 In case of multi-column arrester design, the manufacturer shall specify the maximum permissible irregularity in the distribution of currents over the columns.

19.9.3.6 If the arrester has an insulating base, it shall withstand the bending moment and climatic tests without any damage capable of affecting its proper functioning.

19.9.3.7 Arresters shall be explosion-proof. The manufacturer shall specify the maximum effective value of the steady-state high and low (800 A) short-circuit current of the internal fault, which the arrester shall withstand without hazardous explosive failure.

19.9.3.8 Arresters with the maximum continuous permissible operating voltage of 73 kV or higher shall have no partial discharge level at $1{,}05 \cdot U_{ct}$ above 10 pC.

19.9.3.9 Arresters with the maximum continuous permissible operating voltage of 73 kV and above shall have a radio interference level at $1{,}05 \cdot U_{ct}$ and at all lower voltages not exceeding 2,500 μV.

19.10 ENTRIES AND BUSHINGS FOR 110 - 220 KV.

19.10.1 The voltage classes of the entries and their corresponding maximum working voltages ($U_{w.v.}$) shall be selected from a range of standard values according to IEC 60137.

19.10.2 Overall and mounting dimensions, connection dimensions and nominal weight of the entries shall be in accordance with the design documentation approved in accordance with the established procedure.

19.10.3 Entries shall have:

the metering lead for measuring the dissipation factor (tgδ) and capacitance (C) or a special lead at the bushings with a measuring capacitor for connecting a voltage measuring device under operating conditions and for measuring the dissipation factor and capacitance. These outputs can be used to measure partial discharge intensity and also to connect an input insulation monitoring device;

built-in or remote compensators to compensate for temperature variations in oil volume, ensuring that the oil pressure in the inlet is within the specification limits for the design temperature range. Inlets with overpressure shall be provided with an oil pressure gauge in the inlet;

inlets without overpressure having integrated expansion joints;

entry lifting attachments located on the coupling sleeve.

19.10.4 The entry design shall allow for the installation of current transformers below the supporting flange at the distances specified in the agreed dimensional drawings of the entries.

19.10.5 The insulation resistance of the measuring lead shall be at least 1500 Mohm, the capacitance with respect to earth (C_e) shall not exceed 10000 pF and the dissipation factor (tgδ*z*) at power frequency shall not be greater than 0,05.

19.10.6 The measuring lead shall withstand a test voltage of 2 kV of power frequency for 1 min without breakdown and overlap.

19.10.7 The temperature of the metal parts of the entries in contact with the insulating material, when the rated current is flowing, shall not exceed:

105 °C — for BMI entries (class A);

120 °C — for entries with solid RIP or RIN insulation (class E);

130 °C — for gas insulation (class B).

The maximum temperature rise of the contact parts for connection to external conductors shall not exceed 65 °C. Inlets used as part of apparatus, e.g. switchgear, shall comply with the requirements to thermal mode of the appropriate apparatus.

19.10.8 The entry design shall be tight and moisture-proof.

19.10.9 The supporting flange of the entries shall be sealed.

19.10.10 The polymeric outer insulation of the entries shall be made of moulded silicon-organic compositions of RTV-2 type or similar, providing tracking-erosion resistance and resistance to ignition.

19.10.11 Entries designed to replace previously produced entries shall be interchangeable in terms of connection and installation dimensions. The specifics of replacing a particular type of entry shall be specified in the operating instructions for the relevant entry points.

19.10.12 The current-carrying resistance of entries for oil circuit-breakers at DC at 20 °C shall not exceed 70 μOhm.

19.11 LAYOUT (MOUNTING)

19.11.1 Electrical equipment.

19.11.1.1 Where high voltage equipment without containment is installed in a special space actually serving as its containment, the space doors shall be so locked that they cannot be opened unless the voltage is disconnected and the conductive parts of the equipment are earthed.

Warning notices shall be provided at entrances to spaces or areas where high voltage equipment is located to warn against dangerous high voltages.

19.11.1.2 In justified cases, the equipment may be installed outside special electrical spaces provided its enclosure degree of protection is at least IP44 and current-carrying parts are accessible only when de-energized or using special tools.

19.11.1.3 The diagram of connections and electrical equipment arrangement drawing shall be available in the special electrical space.

19.11.2 Cables.

19.11.2.1 Cable route laying.

Cables shall not run through accommodation spaces.

19.11.2.2 Separation.

High-voltage cables shall be laid separately from cables for voltages below 1000 V. In particular, high voltage cables shall not be laid in the same routes or in the same ducts or pipes, or in the same conduits.

If high voltage cables of different rated voltages are laid in the same routes, the insulation distances between the cables shall not be less than those set for the higher voltage cable, as indicated in 19.2.3.1.

19.11.2.3 Cable installation.

High-voltage cables in three-phase version shall be laid in metal conduits or in metal ducts, or they shall be protected by metal sheaths.

Open cabling (on load-bearing pressed panels) is permitted if they have continuous metal armouring which shall be reliably (repeatedly) earthed.

19.11.2.4 Cable terminations.

The terminations of all high-voltage cables shall be made of suitable insulating material. In junction boxes, if the cable wires are not insulated, the phases shall be separated from the hull and each other by means of solid partitions made of suitable insulating material. High-voltage cables having a conductive layer between the phases for monitoring the electric field strength of the cable insulation shall have leads intended for such monitoring.

The insulation material of the leads shall be compatible with the cable sheathing and sheath material, and the leads shall be fitted with earthing devices for all metal shielding components of the cable (metal strips, wires, etc.).

When terminating power cables, the appropriate sleeve design and grade for the operating and ambient conditions shall be used. Termination sleeves on cable lines shall be so designed that they protect the cables against the penetration of moisture and other harmful substances from the environment and that the sleeves withstand the test voltages for cable lines and comply with the requirements of the technical documentation.

Installation of cable fittings shall be carried out by personnel specially trained and authorized by the cable fitting manufacturer, under the supervision of the firms (manufacturers) and the technical supervision of the operating company. The use of couplings from different firms (manufacturers) shall be agreed with the cable manufacturer and the operator.

19.11.2.5 High voltage cable fittings.

The number and types of cable fittings to be used shall be defined in the cable line project documentation. The fittings shall have the highest possible degree of factory-assembled availability to minimize the influence of human element during assembly and the likelihood of damage to the sleeve structure during assembly and transport.

When selecting cable fittings for cable lines of 35, 110 kV and above, the following requirements shall be met:

pre-qualified cable fittings tested for reliability according to IEC 60840 and IEC 62067 shall be used;

end fittings (terminations and gas-insulated entries) shall be demountable, preferably with an outer insulator of fiber-reinforced materials, designed to avoid the use of liquid dielectric media and feeder fittings (except as specified in the design documentation), and shall allow removal of the insulator for preventive maintenance and shall be adjusted for the installation of cables with optical fibers integrated in the cable shield. Composite insulators for outdoor end sleeves shall be used with different creepage path lengths, depending on the degree of atmospheric contamination at the site;

fittings shall be used that are designed to protect against mechanical damage, water and dust ingress;

end fittings with special adapters for periodic monitoring of partial discharge levels by means of mobile measuring units shall be used, and such fittings shall be designed to allow installation of fixed partial discharge sensors and measurement of currents in cable shields;

for the installation and fixing of terminations, it is recommended to use corrosion-resistant steel structures with factory-applied hot-dip galvanization or thermodiffusion galvanization;

the service life of the cable harness shall be at least 30 years.

The following cable fittings for 1 — 35 kV cable lines shall be used:

fittings based on heat-shrinkable antitreking, non-combustible, flame-retardant tubes and products;

cold shrinkage cable fittings and those based on prefabricated elastomeric elements.

19.11.2.6 Marking.

High-voltage cables shall be fitted with easily readable identification marking.

19.11.2.7 Testing upon the installation completion.

All cables and their components (terminations, earth leads, etc.) shall be subjected to a high voltage test before commissioning a new high-voltage cable system or after modification (repair or installation of additional cables).

The tests shall be carried out following the measurement of the insulation resistance.

For 15 — 220 kV power cable lines, the following tests shall be carried out to confirm the quality and proper installation of the cables and to determine the technical characteristics of the cables:

a.c. voltage, sinusoidal waveform and frequency in the range of 20 — 300 Hz, test voltage level in accordance with Table 10.7.27.7.1, or rated operating line voltage for 24 h without load;

determination of cable core integrity and phasing of cable cores and cable shields is carried out in operation after assembly, installation of sleeves or disconnection of cable cores has been completed;

determination of cable core resistance;

determination of the electrical operating capacity of cables;

measurement of current distribution over single-core cables and shields;

checking the earthing device (measuring the earthing resistance);

testing of cable sheaths with d.c. voltage;

measurement of partial discharge characteristics;

thermovision inspection of terminations and cable entries in GIS (for 110 — 220 kV cable lines);

measurement of the dissipation factor;

checking the integrity of the fiber optic cables (at the customer's request, this check can also be carried out immediately after laying the construction cable lengths, before installation of the coupling and termination sleeves).

Electrical tests of cable lines after laying are carried out upon completion of the cable installation.

Electrical circuit schematic diagrams of 110 — 220 kV switchgear. Standard solutions:

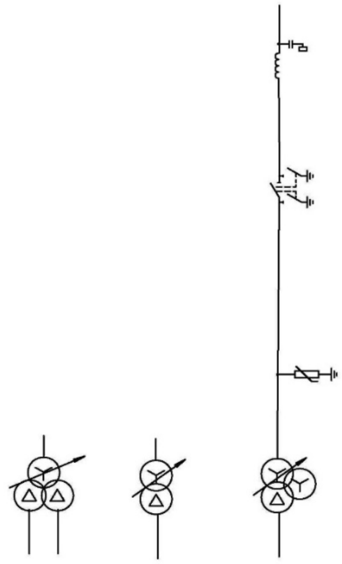

Fig. 1
unit (line — transformer) with disconnectors (diagram 110-1)

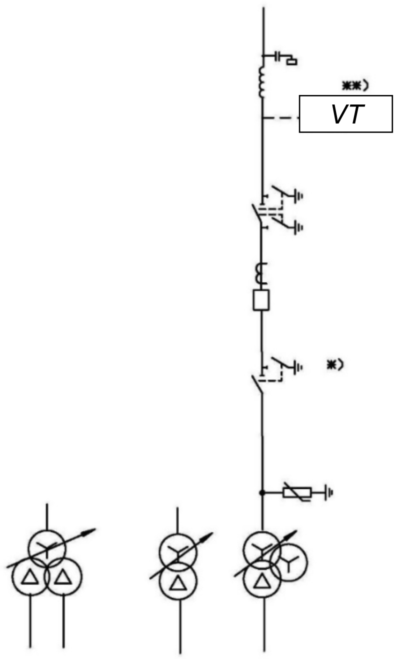

Fig. 2
unit (line — transformer) with switcher (diagram 110-3N):

1. the disconnector marked with *) is provided in case of supply on the MV side;
2. the voltage transformer marked with**) shall be installed with appropriate justification

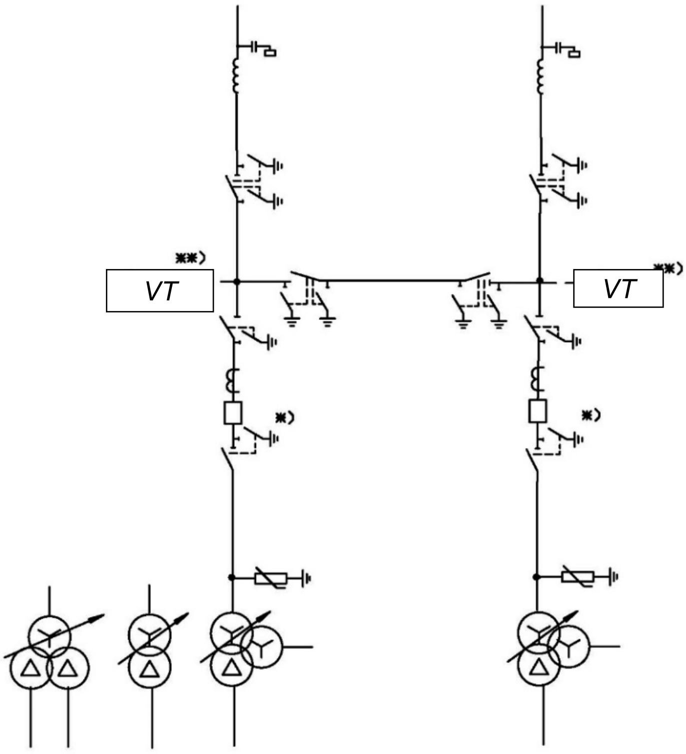

Fig. 3

Two units with switchers and non-automatic jumper at the line side (diagram 110-4N):

1. the disconnectors marked with *) are provided in case of supply on the MV side;
2. the voltage transformers marked with**) shall be installed with appropriate substantiation

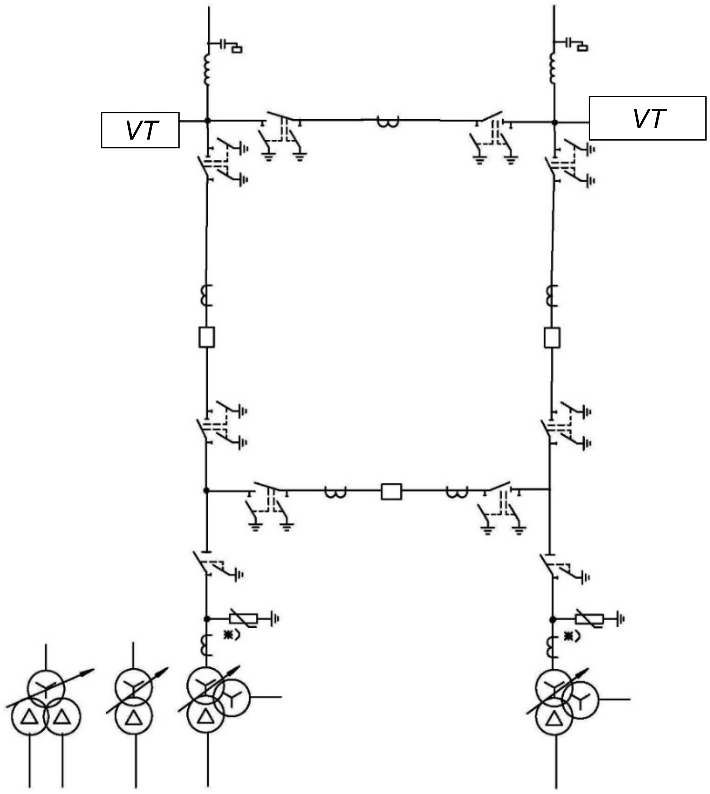

Fig. 4

Bridge with switchers in the line circuits and repair jumper at the line side (diagram 110-5N):

1. the voltage transformers marked with*) shall be installed with appropriate justification

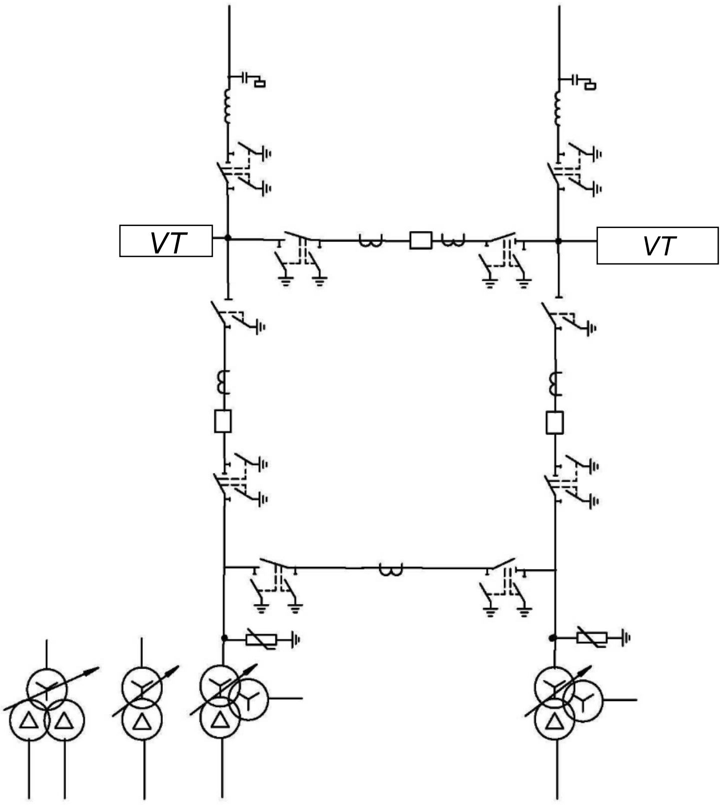

Fig. 5
Bridge with switchers in the transformer circuits and repair jumper at the transformer side (diagram 110-5AN)

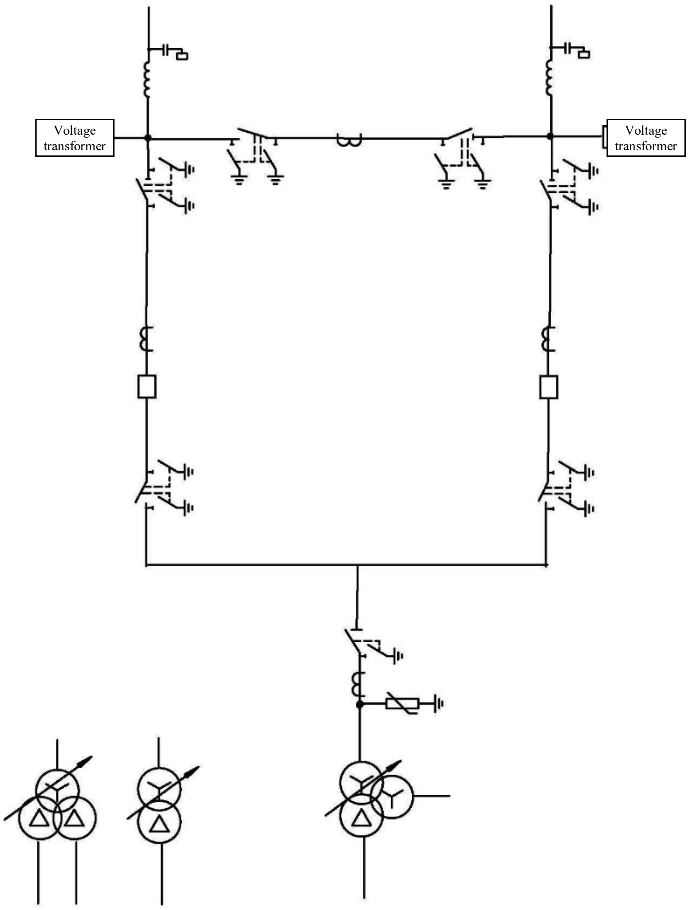

Fig. 6
Entry — outlet (diagram 110-6)

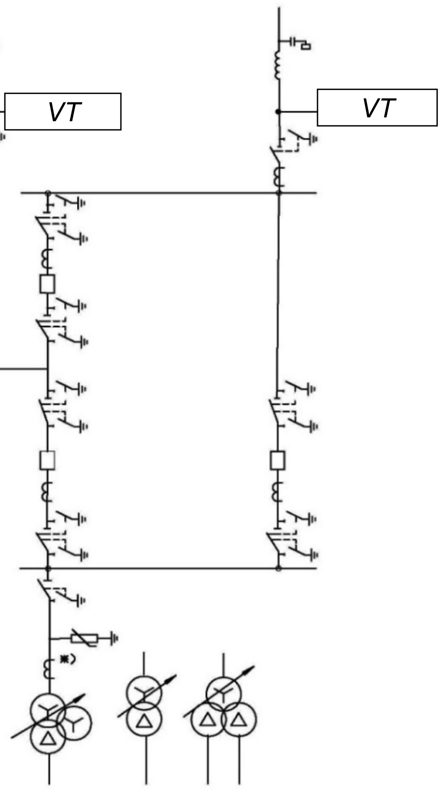

Fig. 7
Triangle (diagram 110-6N):
1. the voltage transformers marked with*) shall be installed with appropriate justification

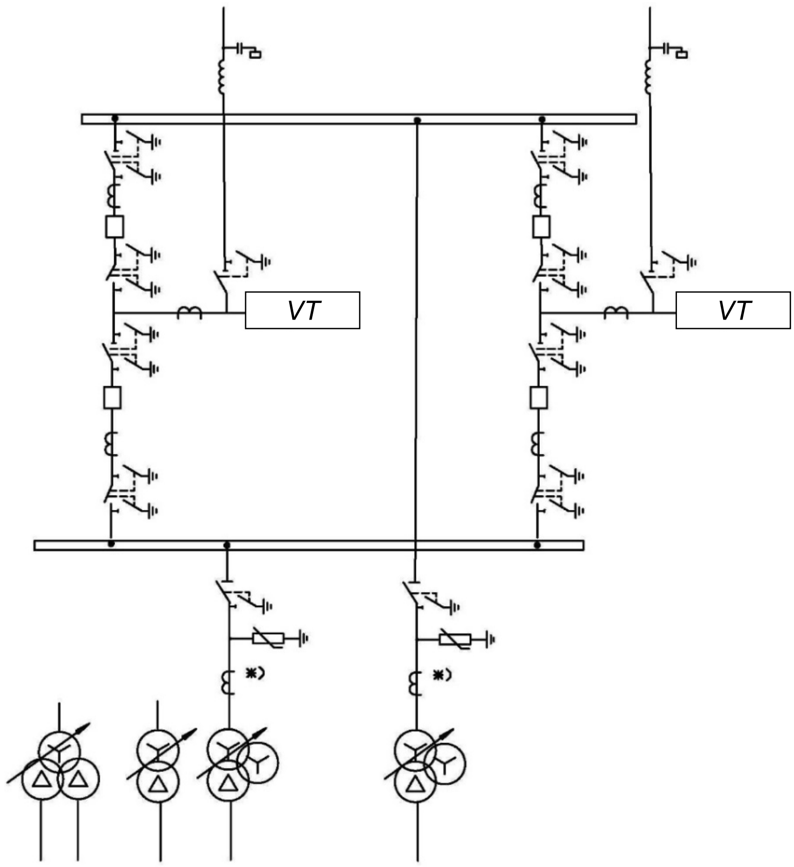

Fig. 8
Quadrangle (diagram 110-7):
1. the voltage transformers marked with*) shall be installed with appropriate justification

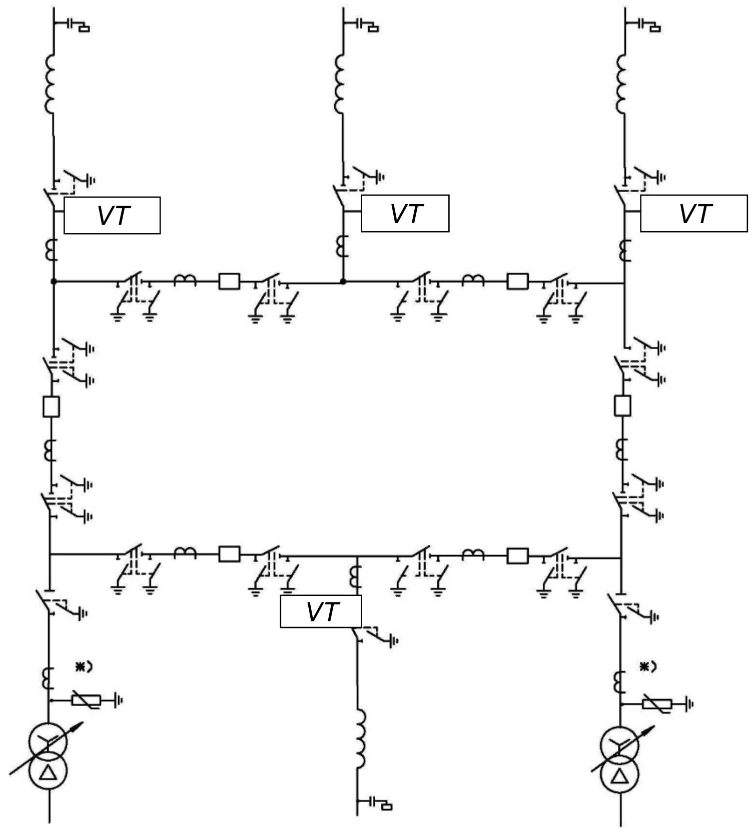

Fig. 9
Hexagon (diagram 110-8):
1. the voltage transformers marked with*) shall be installed with appropriate substantiation

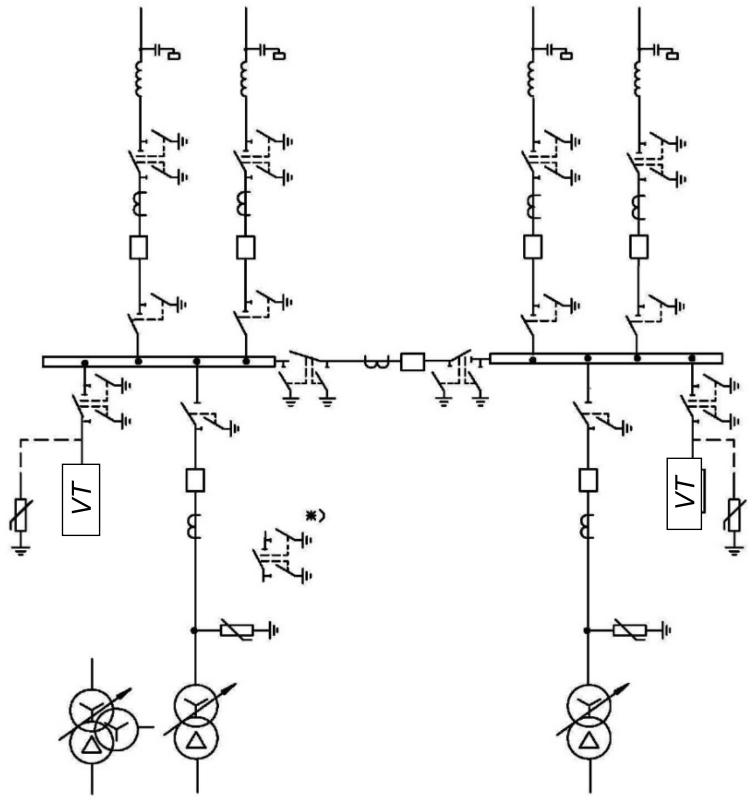

Fig. 10
One operating busbar sectioned by the switcher (diagram 110-9):
1. disconnectors marked with *) are installed with three-winding transformers or autotransformers in transformer circuits;
2. the need for surge arresters on busbars is indicated in the specific design

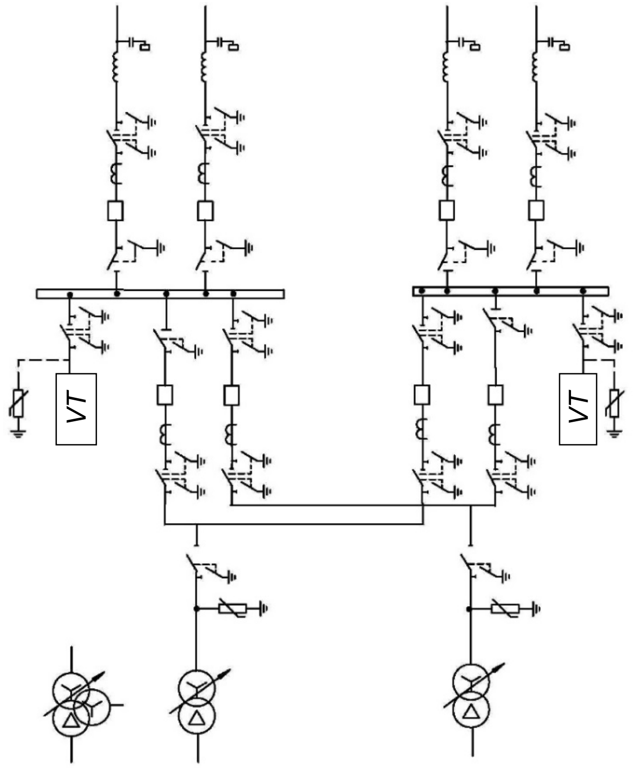

Fig. 11

One operating busbar sectioned by the transformer number, with connecting the transformers to bus sections via the switcher junction (diagram 110-9N):

1. the need for surge arresters on busbars is indicated in the specific design.

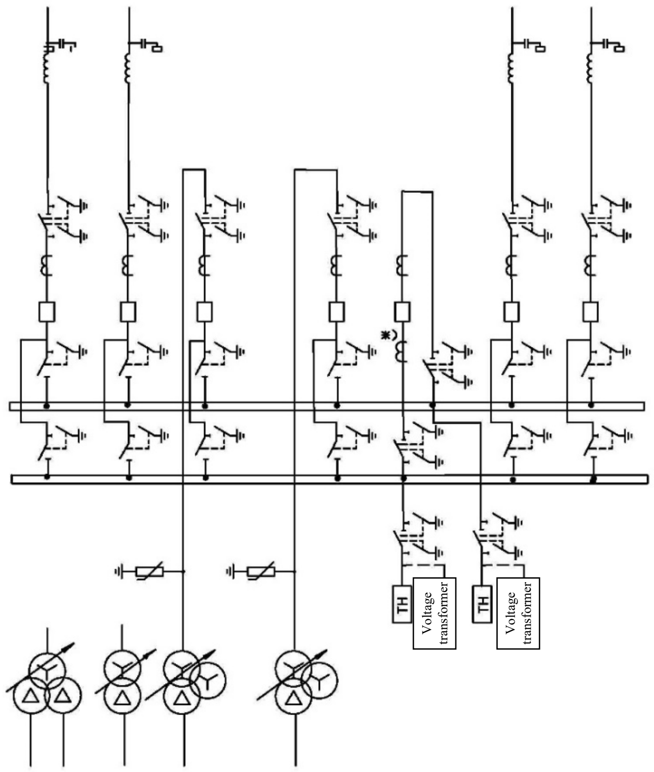

Fig.12

Two operating busbars (circuit 110-13):

1. the voltage transformers marked with*) shall be installed with appropriate justification;
2. the need for surge arresters on busbars is indicated in the specific design

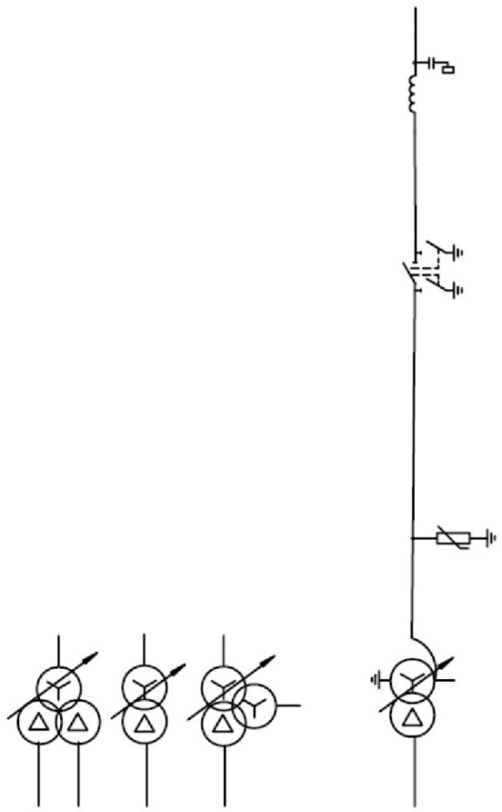

Fig. 13
Unit (line — transformer) with disconnectors (diagram 220-1)

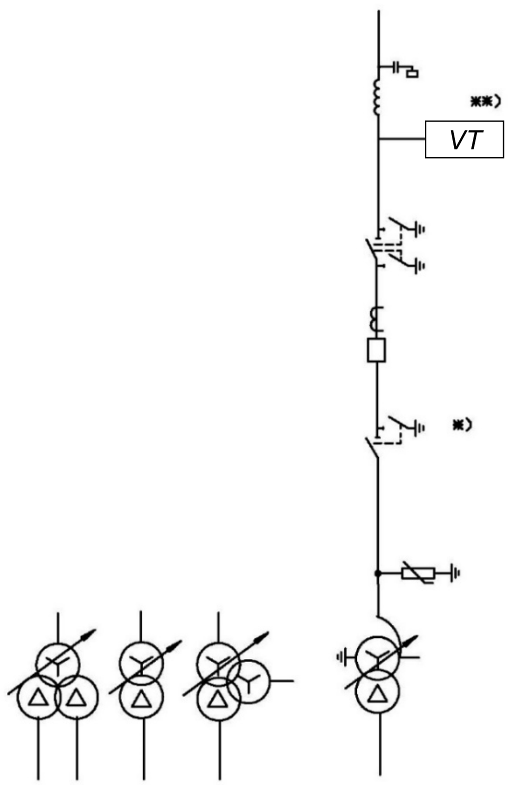

Fig. 14
Unit (line — transformer) with switcher (diagram 220-3N):

1. the disconnector marked with *) is provided in case of supply on the MV side;
2. the voltage transformer marked with**) shall be installed with appropriate justification

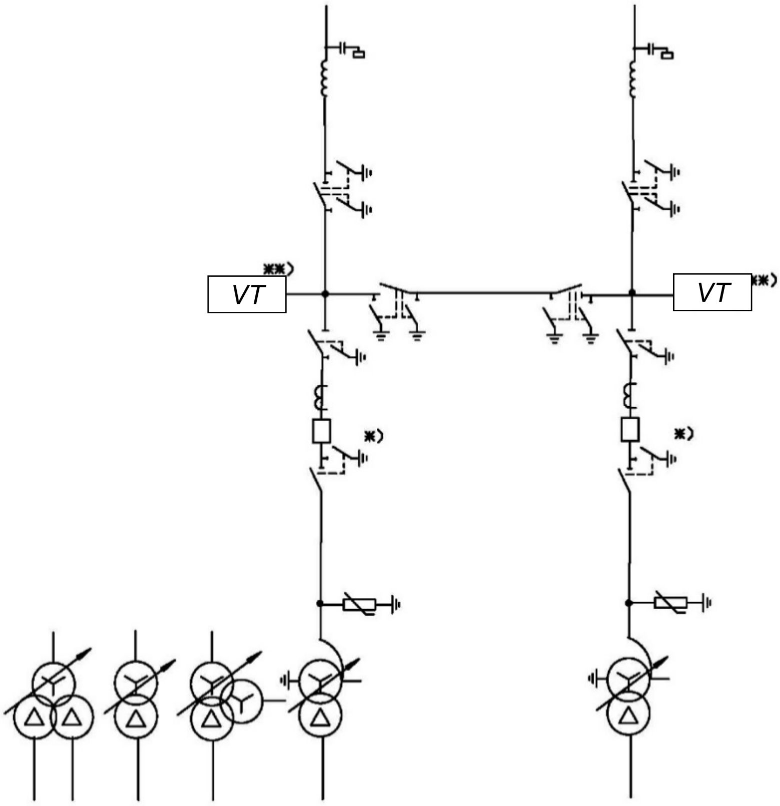

Fig. 15

Two units with switchers and non-automatic jumper at the line side (diagram 220-4N):

1. the disconnectors marked with *) are provided in case of supply on the MV side;
2. the voltage transformers marked with**) shall be installed with appropriate justification

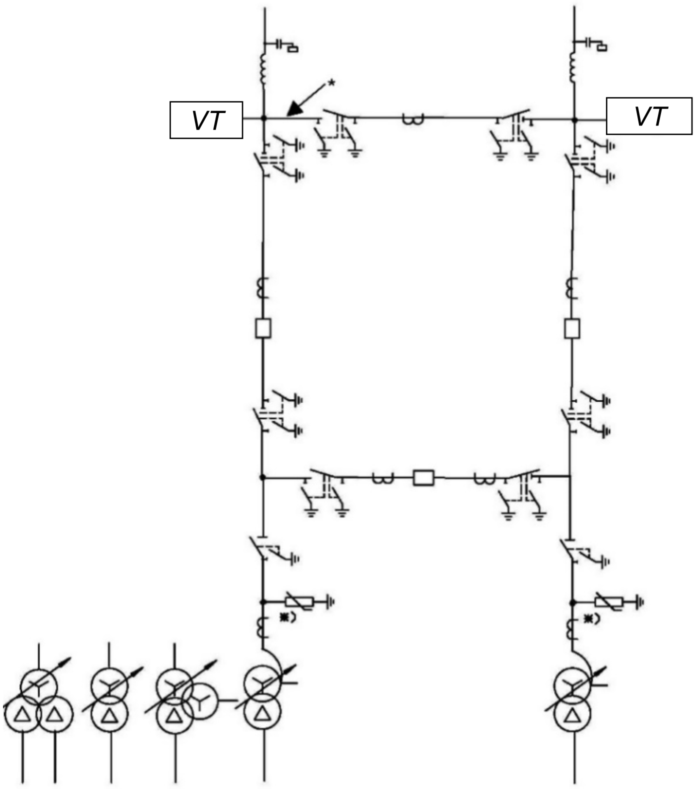

Fig. 16

Bridge with switchers in the line circuits and repair jumper at the line side (diagram 220-3N)

1. The voltage transformers marked with*) shall be installed with appropriate justification;
2. * — repair jumper shall be installed with appropriate justification

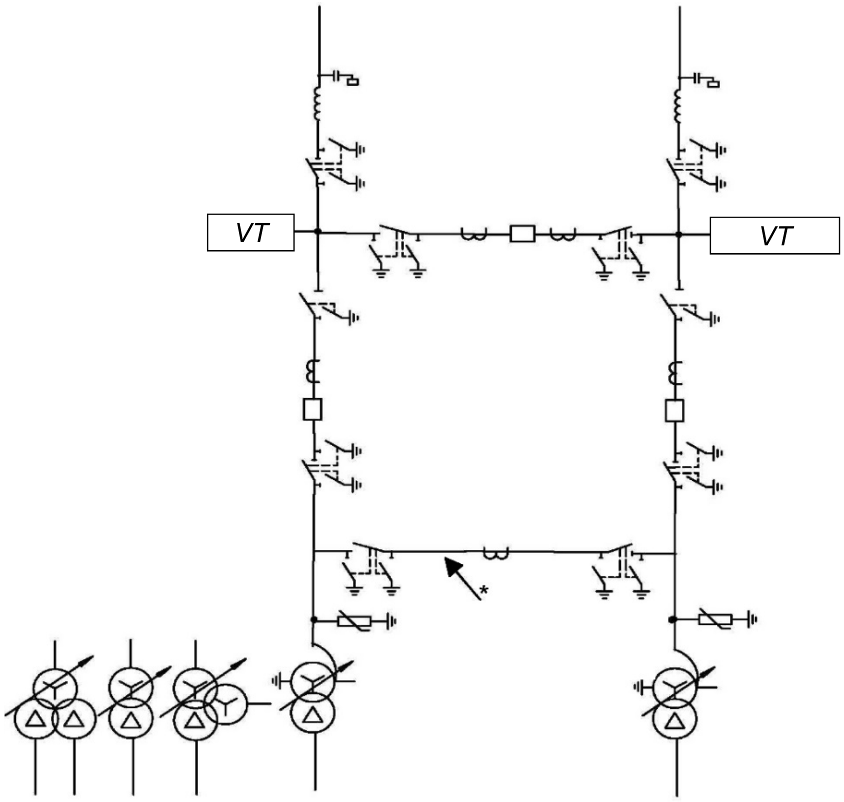

Fig. 17
Bridge with switchers in the transformer circuits and repair jumper at the transformer side (diagram 220-5AN):
1. * — repair jumper shall be installed with appropriate justification

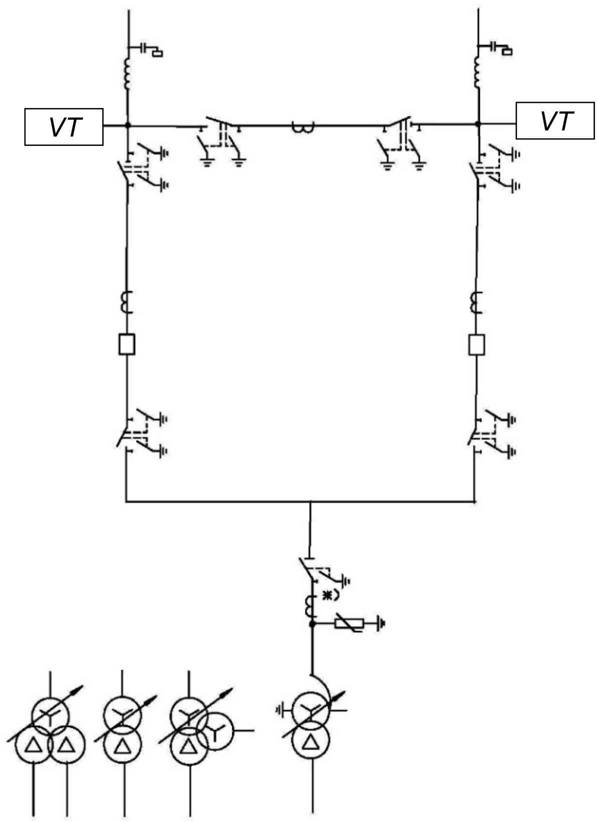

Fig. 18
Entry — outlet (diagram 220-6):
1. the voltage transformers marked with*) shall be installed with appropriate justification

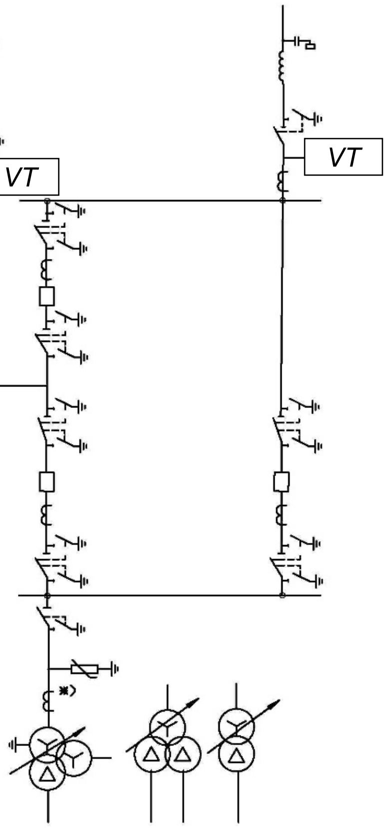

Fig. 19
Triangle (diagram 220-6N):
1. the voltage transformers marked with*) shall be installed with appropriate justification

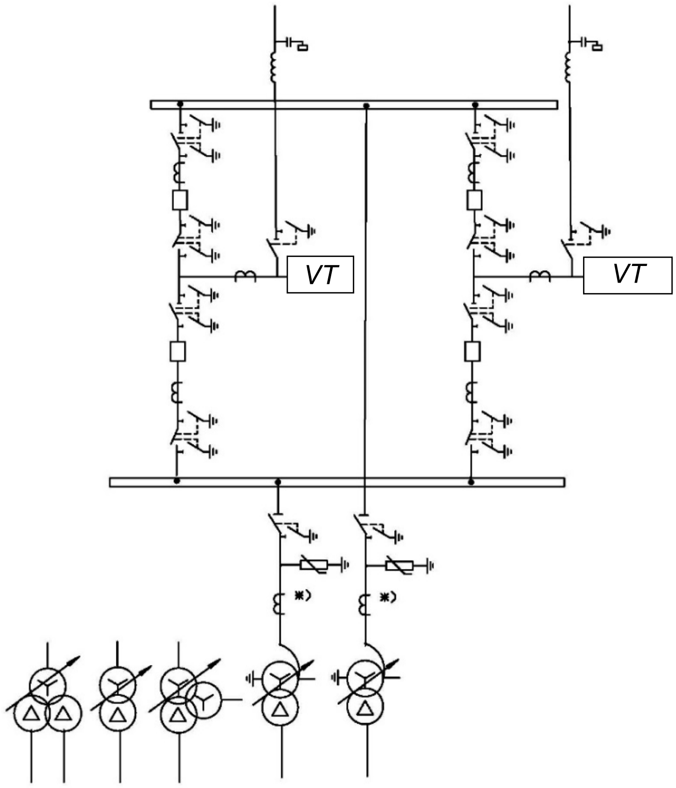

Fig. 20
Quadrangle (diagram 220-7):
1. the voltage transformers marked with*) shall be installed with appropriate justification

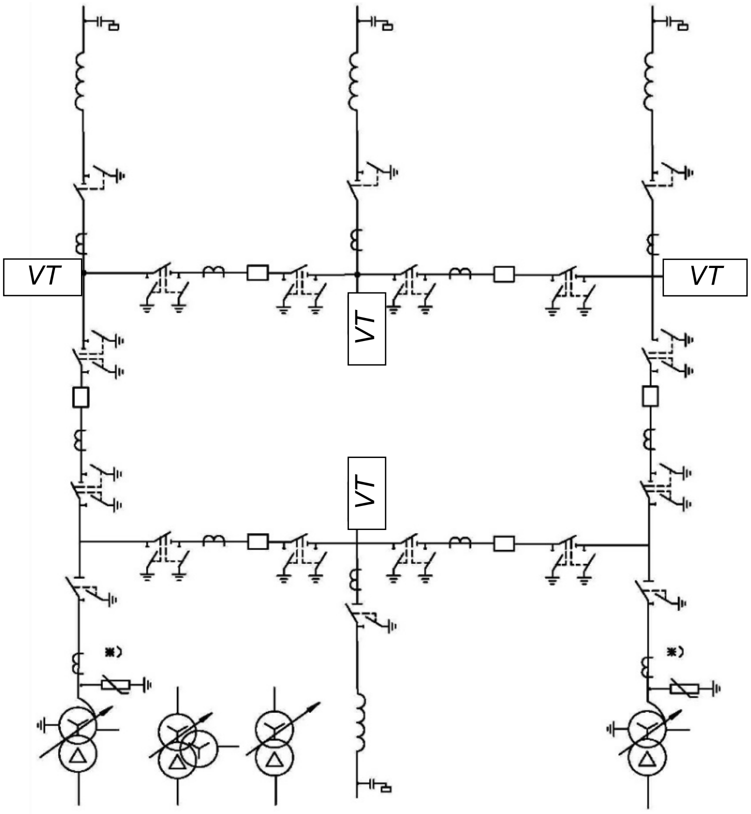

Fig. 21
Hexagon (diagram 220-8):
1. the voltage transformers marked with*) shall be installed with appropriate justification

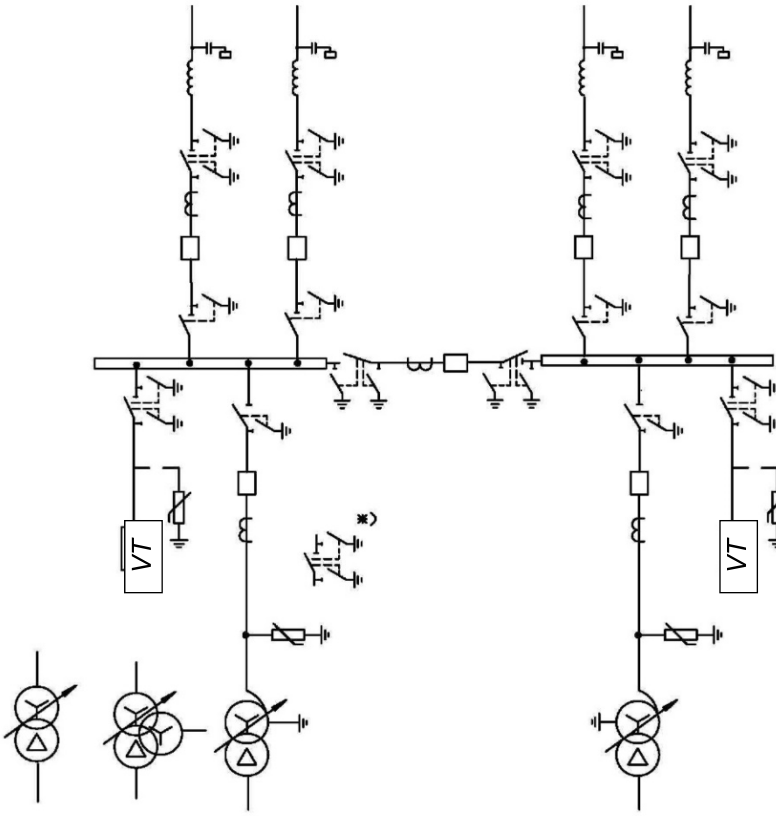

Fig. 22
One operating busbar sectioned by the switcher (diagram 220-9):
1. disconnectors marked with *) are installed with three-winding transformers or autotransformers in transformer circuits;
2. the need for surge arresters on busbars is indicated in the specific design

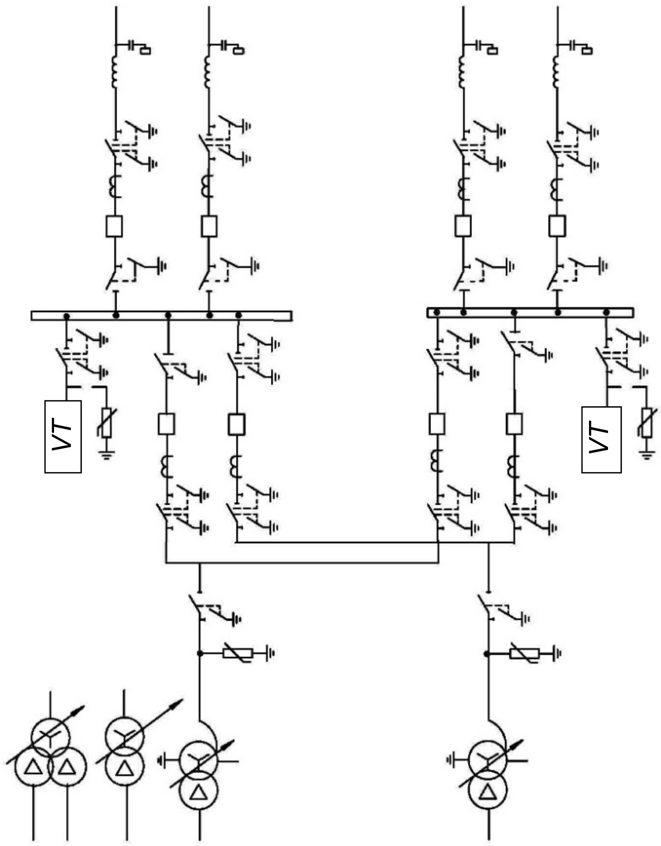

Fig. 23

One operating busbar sectioned by the transformer number, with connecting the transformers to bus sections via the switcher junction (circuit 220-9N):

1. the need for surge arresters on busbars is indicated in the specific design

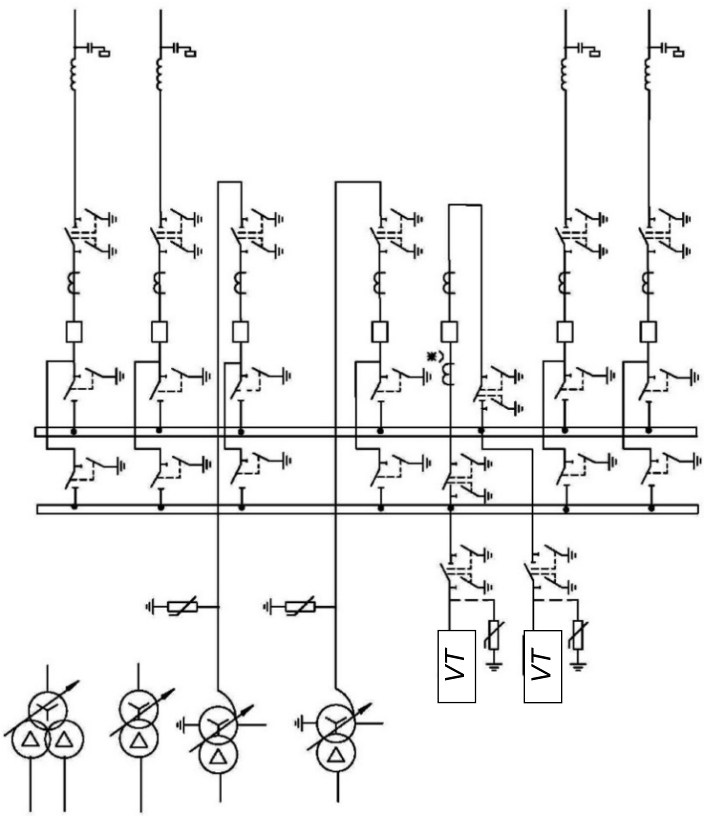

Fig. 24

Two operating busbars (diagram 220-13):

1. the voltage transformers marked with*) shall be installed with appropriate substantiation;
2. the need for surge arresters on busbars is indicated in the specific design

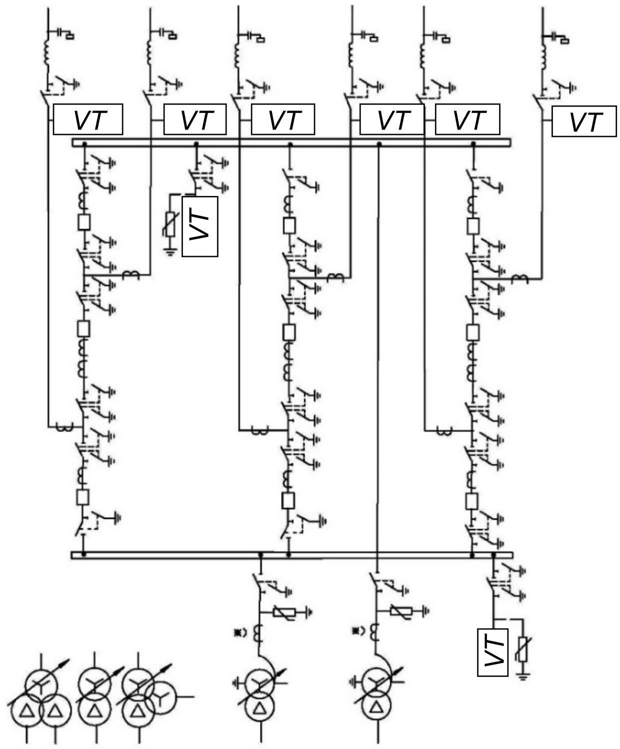

Fig. 25

Transformer busbar with one-and-a-half line connection (diagram 220-16)

1. the voltage transformers marked with*) shall be installed with appropriate justification;
2. the need for surge arresters on busbars is indicated in the specific design

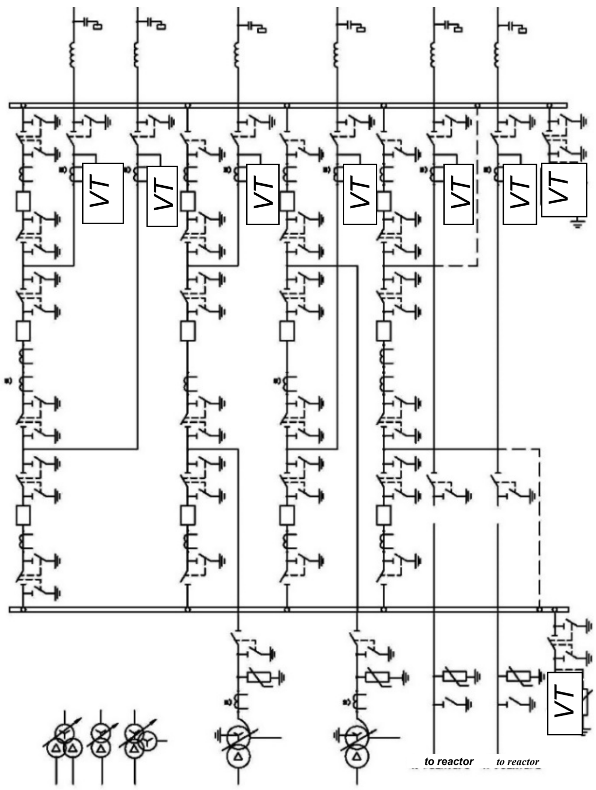

Fig. 26

One-and-a-half circuit (diagram 220-17):

1. the solid line shows the connection of the reactors to the lines and the dotted line — directly to the busbars;
2. the voltage transformers marked with*) shall be installed with appropriate justification;
3. the need for surge arresters on busbars is specified in the specific design

5 **Existing Sections 19 — 25** (with paras and references thereto) shall be renumbered **20 — 26** accordingly.