Riga Technical University
Institute of Power Engineering
Department of Electric Power Supply

INTRODUCTION TO HIGH-VOLTAGE TECHNOLOGIES

Methodical Guidelines for Practical Works

RTU Press
Riga 2019

K. Bērziņa. Introduction to High-voltage Technologies. Methodical Guidelines for Practical Works. Riga, RTU Press, 2019, 27 p.

This material presents an introduction to high-voltage technologies: theoretical description of technological equipment of medium-voltage distribution network and practical operation procedure assignments. The methodological guidelines have been developed for regular, external, and part-time students of electrical power engineering studies.
This material includes the assignments, methodological materials, final examination materials developed and collected by the Department of Electric Power Supply.

Prepared by: Associate Professor Dr. sc. ing. K. Bērziņa.
Reviewed by: Associate Professor Dr. sc. ing. A. Podgornovs

Proofreading: Daina Ostrovska
Design: Baiba Puriņa
Cover Design: Paula Lore
Cover picture from shutterstock.com

Published within the activity "Enhancement of the mobility and employability of Lithuanian and Latvian specialists in the field of electrical engineering and high voltage technologies (LitLatHV)".

ISBN 978-9934-22-154-5 (pdf)

Contents

1. THEORETICAL GROUNDS FOR HIGH-VOLTAGE EQUIPMENT

1.1. Transformer substations

Kiosk transformer substation (KTS) are designed for receiving electrical energy, transformation of voltage from medium-voltage (6 kV, 10 kV, or 20 kV) to low-voltage (0.4 kV or 0.23 kV), and distribution (and record, if necessary). They have one or two transformers with a power of up to 2500 kVA and frequency of 50 Hz.

Transformer substation (TS) consists of one or several power transformers, primary and secondary voltage switchgears of a transformer (higher voltage and lower voltage), as well as control and protective devices [23].

1.1.1. Kiosk transformer substation (KTS)

KTS are installed in factories, cities, towns, and villages, and they are designed for receiving electrical energy, transformation of voltage from 6 kV, 10 kV, or 20 kV to 0.4 kV or 0.23 kV, and distribution (and record, if necessary). They have one or two transformers with a power of up to 2500 kVA and frequency of 50 Hz. KTS is designed for electrical power supply to various residential and industrial, including infrastructure objects. In the body of KTS there are special openings under the ground level through which cables are let in (incoming and outgoing lines). If necessary, KTS can also be connected to overhead lines by ensuring a special transition from the ground to an overhead line [32]. Figures 1.1 and 1.2 present the constructive execution and simplified general circuit diagram with primary cells.

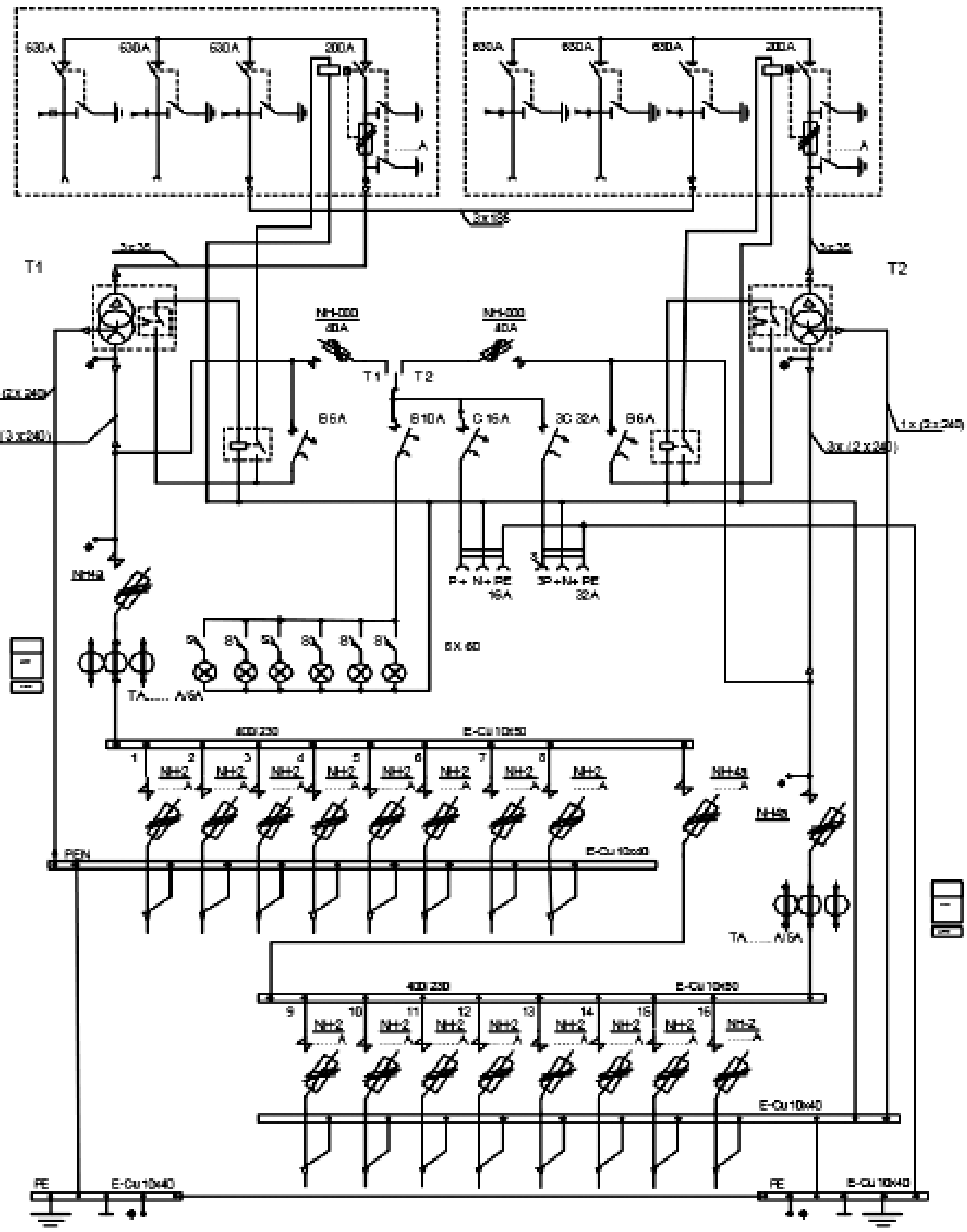


Fig. 1.1. General circuit diagram for KTS 10/20 kV / 0.42 kV with two transformers [32].

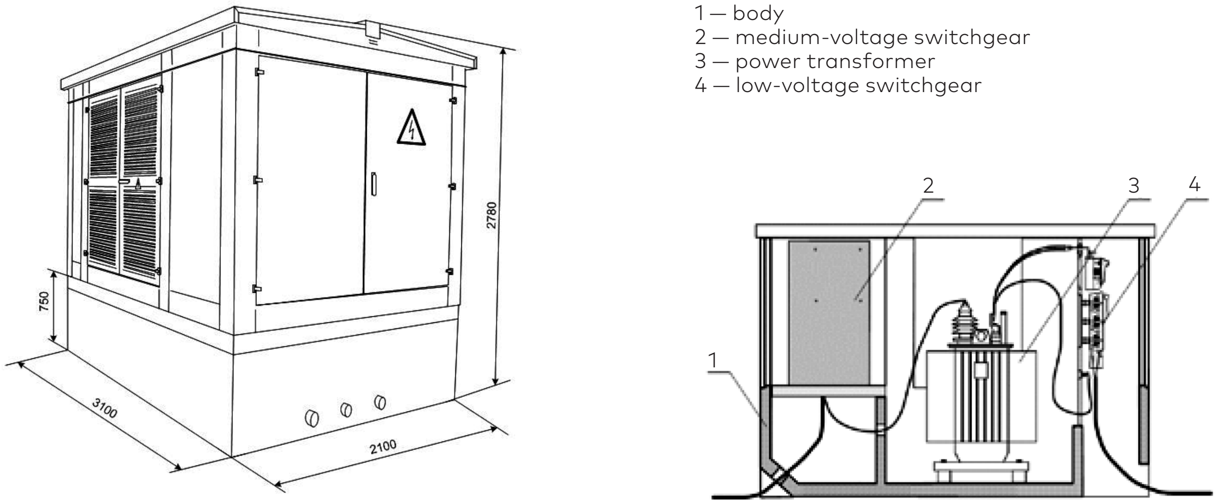


Fig. 1.2. Construction of KTS with one transformer [32].

1.1.2. Outdoor transformer substation (OTS)

Outdoor transformer substation and the higher-voltage switchgear are located outdoors. One of the types of an outdoor transformer substations is pole-mounted transformer substation (PMTS) [14]. Three-phase transformers with power of 25–100 kVA are included in the construction of an OTS on a pole, A-pole, or portal support, as shown in Fig. 1.3. Portal supports are mostly used as intermediate line supports and terminal supports; poles are used for the supply of separate households with electricity in places without explicit load centres with several consumers of electrical energy [33].

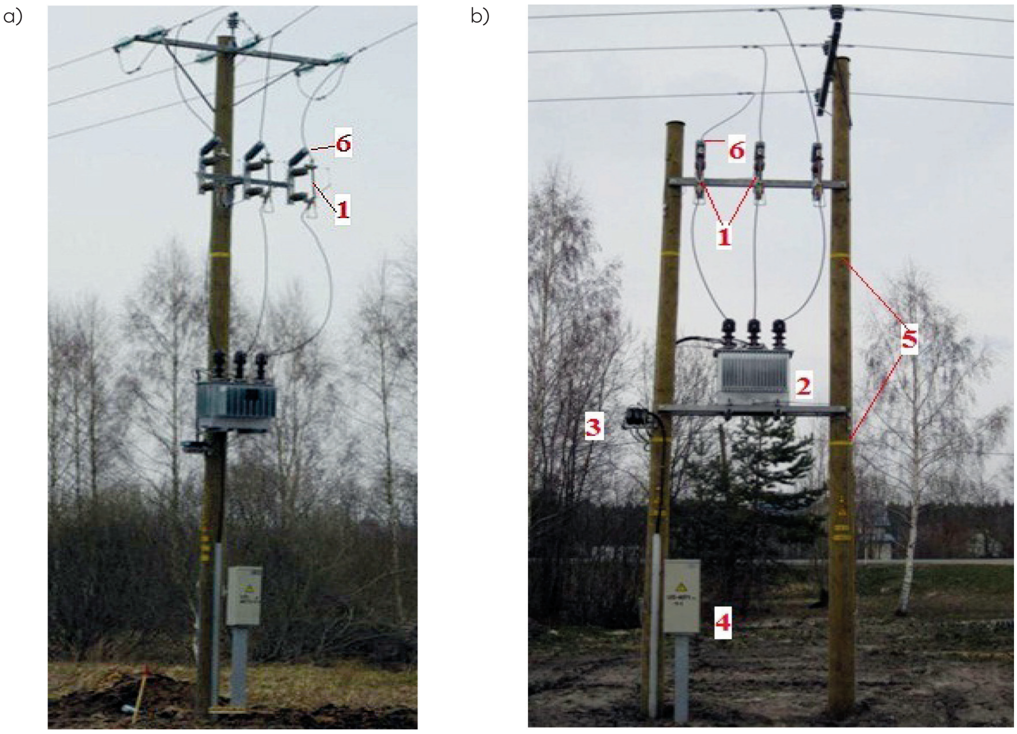


Fig. 1.3. Transformer on a pole (a) and a portal support (b): 1 — transformer protection, high-voltage fuses with disconnecting switch; 2 — transformer; 3 — low-voltage switchgear; 4 — metering switchgear; 5 — wooden pole, pole armature, guy-wires to the earthing system, warning ribbon; 6 — surge arresters [1].

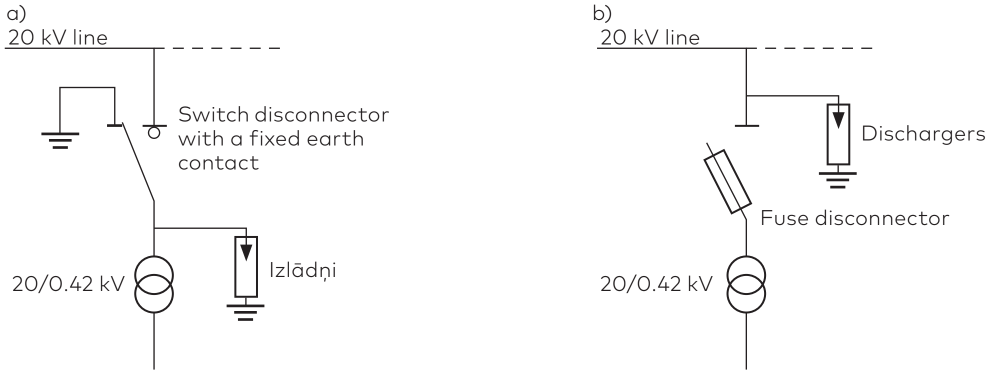


Fig. 1.4. General circuit diagram of the possible single-line of the medium-voltage part of an PMTS: a) with a switch disconnector with a fixed earth contact; b) with a fuse disconnector.

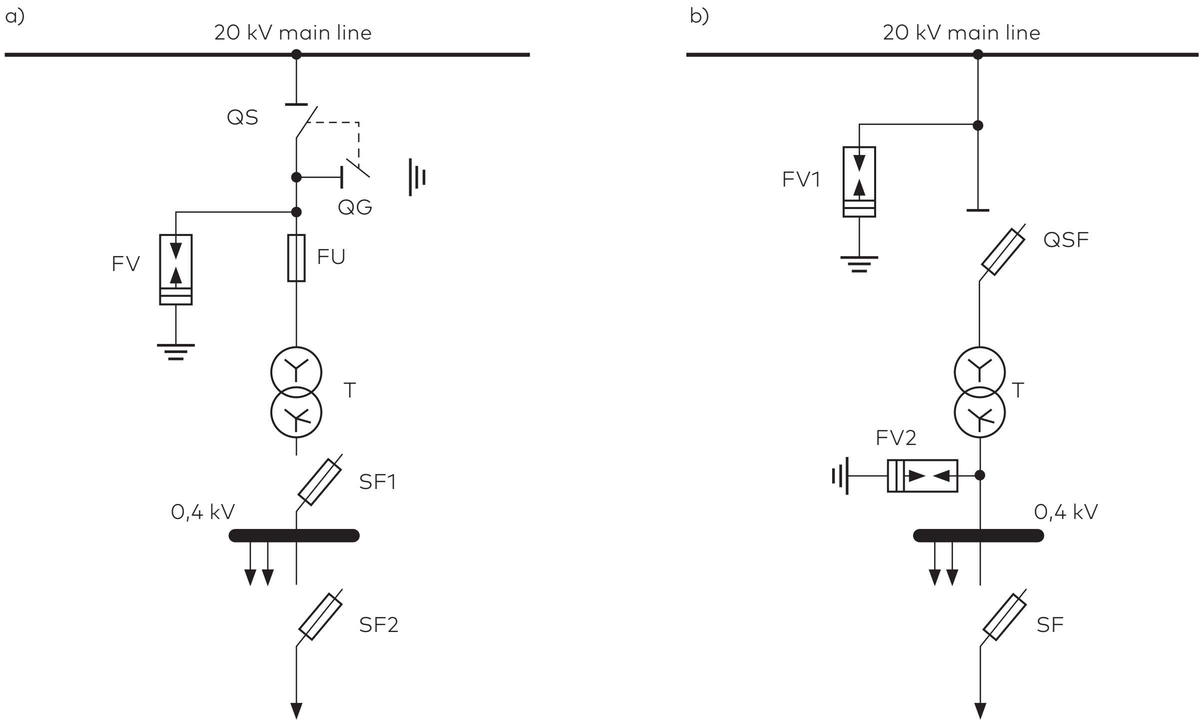


Fig. 1.5. Circuit diagram of 20 kV and 0.4 kV parts of a PMTS: a) with a disconnector and fuses; b) with fuse disconnector [3].

The constructive execution of PMTS is presented in Fig. 1.5, where QSF — fuse disconnector; QS — disconnector; FU — medium-voltage fuse; FV — valve-type arrester; SF — fuse-combination unit; QG — disconnector with a fixed earth electrode [3]. The PMTS circuit diagrams shown in Fig. 1.5. can be used in all cases without any special conditions.

The construction, installation, structures, materials, and main technical requirements of a 20/0.4 kV are regulated by the Latvian Energy Standards LEK 083 and LEK 119. Pole-mounted transformer substations are used both in densely populated places (cities, towns) and in power supply systems in rural territories. Considering the little amount of maximum loads consumed by one consumer that is located far from other consumers, the so-called deep 20 kV lead (basically small-power 25–100 kV pole-mounted transformer substations located as close to load centres as possible) is therefore used as the basic principle for power supply in rural territories. TS must be connected to a 20 kV medium-voltage line, main line, or branch as close as possible as a transit or terminal element of an overhead line.

Diagram of distribution network of PMTS is illustrated in Fig. 1.6. Three feeders lead from the low-voltage switchgear of PMTS, that can supply electrical energy to 5–6 households located comparatively closely. A switching unit with a disconnector and fuse must be mounted on an intermediate support to break-down a 20 kV main line or to disconnect a branch.

Circuit diagram on the 20 kV part of a PMTS can be:

1) with disconnector, without fuses;
2) with fuse disconnectors;
3) with disconnector and fuses;
4) without disconnector and fuses.

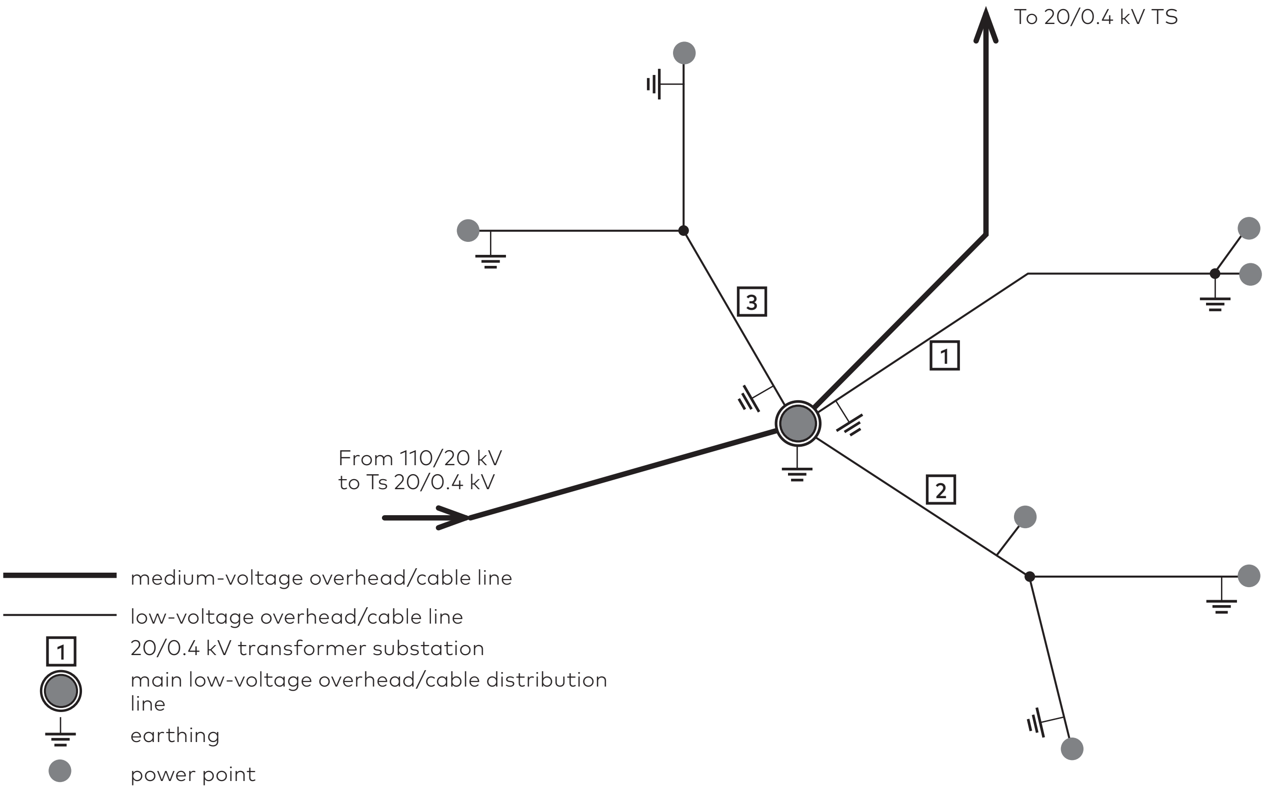


Fig. 1.6. Diagram of a PMTS distribution network.

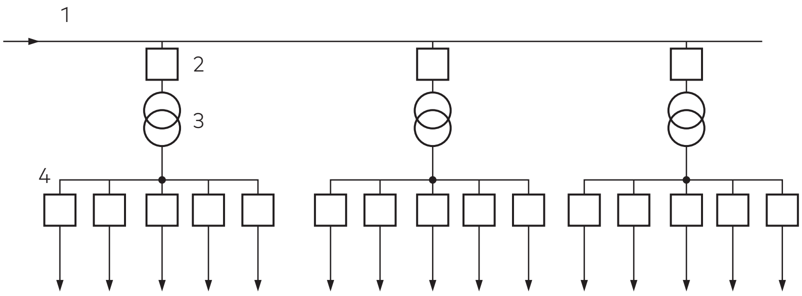
By placing TS as close to load centres as possible, which in the specific case are households and farms located in rural territories, the quality of supplied electricity improves and the power and voltage loss in the network reduces. Low-power PMTS with simple construction and comparatively low costs may allow to provide quality electricity to households located in rural territories in the near future, which is of importance these days [3].

Working and protective earthing must be installed at pole-mounted transformer substations:

- transformer's neutral conductor, neutral conductors of low-voltage lines, and neutral busbar of the switchgear must be connected to the working earthing;
- all constructions of 20 kV devices, distribution cabinet, and other metal constructions that normally are not under voltage must be connected to the protective earthing.

1.2. Secondary switching unit of medium-voltage

Switchgears are electrical installations in which electricity is split within one voltage level. But the part of switchgear in which feeder elements (busbars, switching devices, instrument transformers) are located is bay. Bays are named according to the functionality of the feeder: line bay, transformer cell, tie-switch bay, etc. The switchgears used in the Latvian distribution network are selected, constructed and tested according to the international European standards, and the Latvian standard LEK 047 "Medium-voltage switchgears and substations. Key technical requirements" and LVS EN 62271 "High-voltage switchgear and controlgear".



1 — medium-voltage lead
2 — protection switch
3 — step-down transformer
4 — low-voltage switchgear

Fig. 1.7. Informative diagram of distribution network.

1.2.1. SafeRing SF6 compact switching units

Thanks to the technological progress in the last 30 years, secondary SF_6 (electronegative gas) switching units have developed rather rapidly, as a result of which their functionality has increased but dimensions have decreased. Separate modules of switching units have been replaced with a complete switchgear system.

As one of the pioneers in switchgear development ABB constantly improve the compact switching units according to the customer needs to ensure maximum functionality. ABB switching units SafeRing and SafeRing are secondary switching units that are designed for distribution networks. ABB switching units SafePlus can fulfil the most complicated specifications of a system and necessity of operation scenarios. But ABB switching units SafeRing (Figs. 1.8 and 1.9) consist of standard switches, they can have various configuration, and are convenient for using in distribution networks. ABB switching units are available in 10 configurations, and they can be used for main switchgear functions in medium-voltage networks: 12 kV and 24 kV. In addition, SafeRing switching unit can be connected to other SafeRing or SafePlus switching units by using external busbars.

Places that use SafeRing:

- kiosk transformer substation (KTS);
- wind power stations;
- buildings;
- mining;
- airports;
- railway systems;
- underground buildings;
- small industry.

Fig. 1.8. SafeRing switching unit with three compartments.

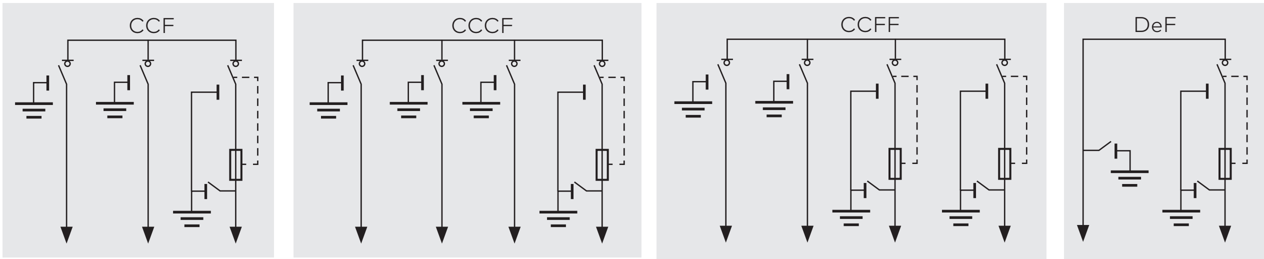


Fig. 1.9. Typical diagrams of SafeRing switching unit with power switches, where C — cable power switch; F — fuse switch; De — direct cable feeder.

The main elements of a switchgear are: busbar sections, switching devices, and protection devices. Division of electricity in a medium-voltage network takes place at supply substations and distribution points located within a network.

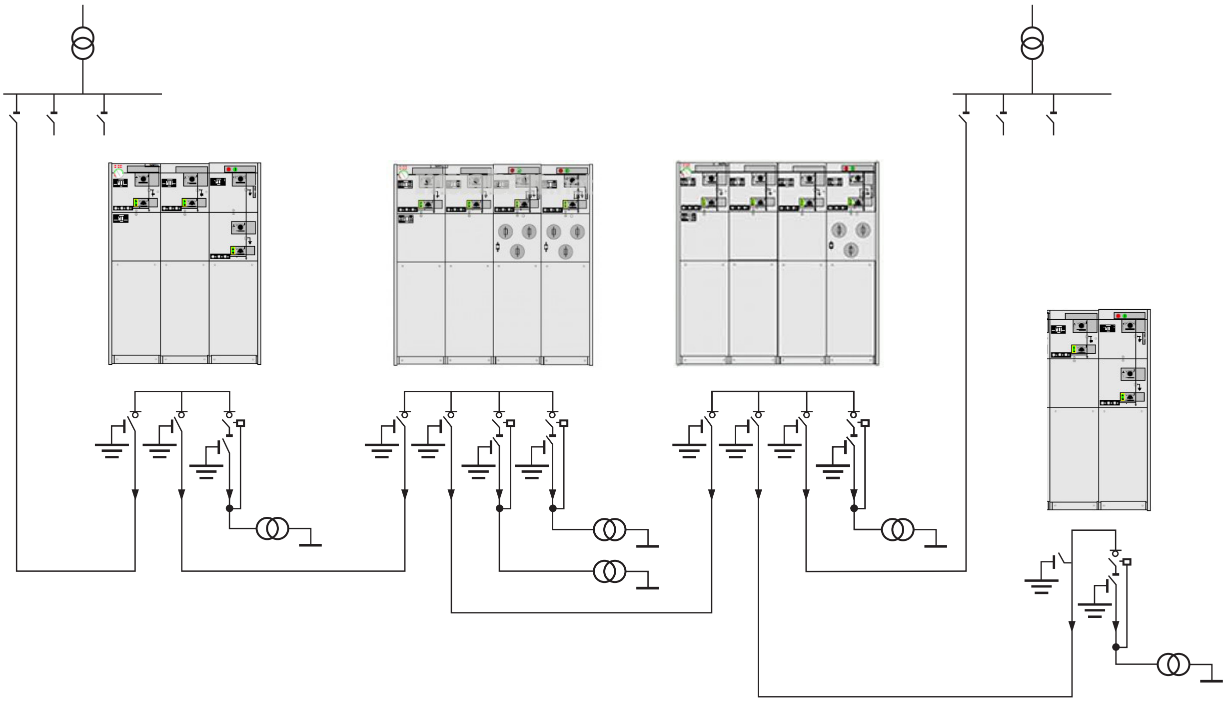


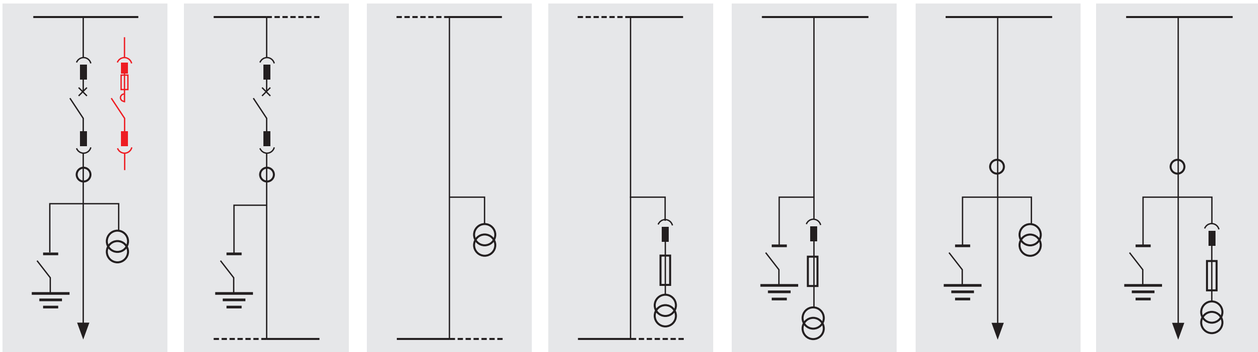
Fig. 1.10. Structural diagram of distribution network, using SafeRing switching units.

1.2.2. UniGear ZS1 power switch

The medium-voltage switchgear UniGear ZS1 (Figs. 1.11 and 1.12) is an ABB-manufactured switching and protection equipment for the primary electricity distribution to 24 kV, rated supply current up to 4000 A, short-time maximum current up to 50 kA / 3 s, for indoor installation. UniGear ZS1 switchgears are used to distribute electricity in various power supply schemes, like shipping, ports, coastal power stations, user substations, or chemical plants. Constructive solutions of switchgears: single busbar, double or two-level busbar.

1 — control device unit
2 — power switch unit
3 — cable feeder unit

Fig. 1.11. Air-insulated power switch UniGear ZS1.



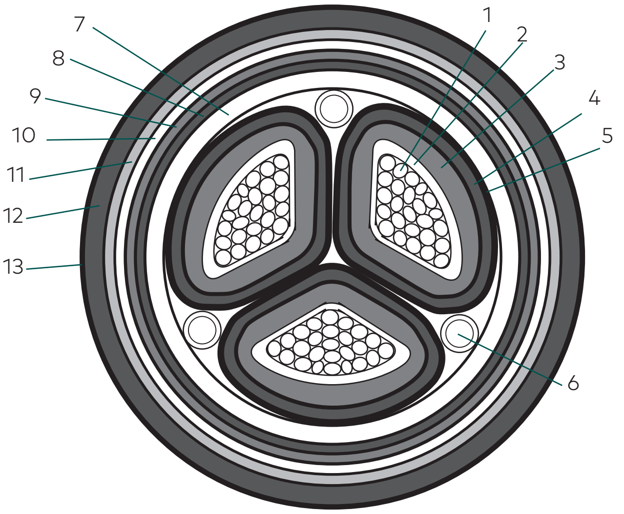
1 — supply switchgear; 2 — sectionalising switch; 3 — rising main; 4 — rising main with measuring device; 5 — measuring device switchgear; 6 — direct supply switchgear; 7 — direct supply switchgear with measuring device

Fig. 1.12. Air-insulated power switch UniGear ZS1 standard sets.

1.3. Medium-voltage power cables

Medium-voltage power cables are usually used in cities, towns, and populated places as it is practically impossible and very dangerous to build medium-voltage overhead lines in territories where they run above people; in addition, overhead lines ruin the city looks. Medium-voltage cables are becoming more popular also in rural territories and places where it is difficult to access power transmission lines and in woods where there are damages often due to strong winds [10]. Recently, in the construction of medium-voltage cable lines single-core cables *ААГ*, *АСГ*, *СГ*, and *ААШв* were widely used; the cross-section of these cables varies from 25 mm^2 to 400 mm^2. Nowadays, these cables are not used in the design of medium-voltage cable lines any more.

In 10–110 kV cable lines, also gas-filled cables are used (Fig. 1.13). The insulating paper of these cables is impregnated with comparatively small amount of resin oil mixture and is under 1–15 atmospheres of inactive gases (nitrogen). These are divided in high-pressure (1.0–1.5 MPa), medium pressure (0.1–0.3 MPa), and low-pressure cables [15].



1 — compacted sectoral conductor
2 — semiconducting paper shield
3 — slightly impregnated insulation
4 — shield on perforated metal paper
5 — textile ribbon with tinned copper wires
6 — galvanised steel coils
7 — lead sheath
8 — PVC sheath
9 — fixing copper ribbons
10 — bitumen
11 — band iron armour
12 — cable insulating paper impregnated with anti-rot agent
13 — chafer from cable yarns

Fig. 1.13. Construction of a gas-filled cable [15].

In the last years, paper insulation in cables is replaced with extruded thermoplastic or thermo-set material insulation. Lately, more and more often cables with plastic insulation are used that have complete construction and that are made of economic and modern high-quality insulation materials [1].

Further, some medium-voltage cables widely used in Latvia will be examined: *AHX-AMK-W*, *AHXCMK-WTC*, *AXLJTT*, and *AXQJ-TT*.

1.2.1. Technical data of medium-voltage power cables

Since cables with voltage above 1 kV must have metal shield, the minimum cross-section is established in harmonisation document HD 620 S2:2010. Minimum cross-section of 12 kV, 24 kV, and 36 kV cables is shown in Table 1.1, but now we will look at cables with the rated voltage of 20 kV (Table 1.2).

Table 1.1

Minimum cross-section of metal shield

Cross section of copper conductor, mm^2	Minimum cross-section of metal shield		
	12 kV	24 kV	36 kV
25	16	16	–
35	16	16	–
50	16	16	25
70	16	16	25
95	25	25	25
120	25	25	35
150	25	25	35
185	35	35	35
240	35	35	35
300	35	35	35
400	35	35	35
500	35	35	35

Table 1.2

Rated voltage

	U_0/U	U_m
Rated voltage, kV	12/20	24

where U_0 — rated voltage between phase and earth, kV;
U — rated voltage between phases, kV;
U_m — operating voltage that affects any part of the network and short-term voltage fluctuation of which does not relate to what has been generated at starting, disconnecting, or in case of problems, kV.

The following cable data changes according to the cable cross-section and insulation material (Table 1.3).

Table 1.3

Technical data of cables

	AHXAMK-W	*AHXCMK-WTC*	*AXLJ-TT*	*AXQJ-TT*
Conductor cross-section	3 × 50 + 35Cu to 3 × 300 + 70Cu	3 × 70/16 to 3 × 300/35	3 × 25/16 to 3 × 240/25	1 × 50/16 to 1 × 800/50
Maximum conductor operating temperature, °C	+90	+90	+90	+90
Maximum short-circuit temperature in conductor, up to 5 s, °C	+250	+250	+250	+250
Maximum direct current resistance of conductor at 0°C, Ω/km	0.100–0.443	0.100–0.640	–	–
Maximum permitted short-circuit current for 1 s, kA	6.8–28.9	4.7–28.3	2,5–22.7	4.7–75.6
External cable diameter, mm	60.0–88.4	54–83	47.2–75.3	27.5–55.0
Minimum permitted bend radius at cable laying	15*D*	0.65–1.00 m	From 8*D* (using plough) to 12*D* (using traction)	From 8*D* (using plough) to 15*D* (using traction)
Minimum permitted installation temperature *, °C	–20	–20	–20	–20

* Special caution must be taken if under 0 °C.

1.3.2. Medium-voltage power cable construction

AHXAMK-W brand cables consist of three conductors that are intertwined around a non-insulated central copper conductor, as illustrated in Fig. 1.14. These cables are designed for installation in wiring ducts, outside, in the ground, and under water. These cables are longitudinal and radial waterproof and may be buried using cable plough.

Table 1.4

Construction of AHXAMK-W cable

Conductor	50–300 mm^2	Intertwined, multiplex, round aluminium conductor according to IEC 60228 Class 2, longitudinal waterproof
	Construction	Three conductors twined around a non-insulated central copper conductor
	Wire shield	Extruded semiconductor
	Insulation	XLPE (cross-linked polyethylene), minimum thickness 5.5 mm
	Insulation shield	Pressed fixed semiconductor that is twined with a waterproof ribbon
	Shield	Aluminium foil that is closely fixed to shield to ensure radial water-tightness
	Sheath	Black PE
	PE conductor	Round and twined multiplex copper wire pursuant to IEC 60228 Class 2
Conductor identification	Phase wires	Numeration (Core 1; Core 2; Core 3)
	Central wire	Round and twined multiplex copper wire without insulation
Marks on the cable sheath		AHXAMK-W 12/20 kV 3x240+70Cu DRAKA SE "year"
Usage		Transmission and distribution of electricity in stationery equipment, designed for laying in cable channels, outside, in the ground and under water.

AHXCMK-WTC three-conductor cables consist of three conductors that are placed in PVC sheath, as illustrated in Fig. 1.14. These cables are designed for installation in wiring ducts, industrial premises, outside (trenches). These cables are longitudinal water-resistant. These cables do not burn and are flame resistant if installed in bundles [11].

Table 1.5

Construction of AHXCMK-WTC

Conductor	70–300 mm^2	Intertwined, multiplex, round aluminium conductor according to IEC 60228 Class 2, longitudinal waterproof
	Construction	Three conductors in PVC sheath
	Wire shield	Extruded semiconductor
	Insulation	Extruded cross-linked polyethylene
	Insulation shield	Extruded semiconductor that is twined with a waterproof ribbon
	Shield	Copper wire winding (diameter 0.7–2.0 mm) twined with a copper band (0.1 mm), and a transparent mounting tape
	Sheath	Black, weather-resistant PVC compound
	PE conductor	Copper wire winding (diameter 0.7–2.0 mm) twined with a copper band (0.1 mm)
Conductor identification	Phase wires	Numeration (Core 1; Core 2; Core 3)
	Earthing conductor	No special identification
Marks on the cable sheath		AHXCMK-WTC-12/20kV 3X120/35 DRAKASE "year", metric mark
Usage		Transmission and distribution of electricity in stationary equipment, designed for installation in wiring ducts, industrial premises, outside (trenches)

Fig. 1.14. Construction of medium-voltage cables [12].

AXLJ-TT brand cables consist of three conductors that are placed in black LLD PE sheath, as illustrated in Fig. 1.15. These cables were initially constructed to replace the non-insulated aerial cables used outside. Developed for cable laying using plough but thanks to the solid and reliable construction they are suited for load arising in a cable when pulling in a water body with calm water and in small depth. These cables are designed for installation in wiring ducts, outside, in the ground, and under water. Thanks to the construction (Fig. 1.6), waterproof thread and aluminium foil that is fixed with a case makes cable longitudinal and radial waterproof [12].

Table 1.6

Construction of AXLJ-TT

Conductor	25–240 mm^2	Intertwined, multiplex, round aluminium conductor according to IEC 60228 Class 2, longitudinal waterproof
	Construction	Three conductors twined with a watertight tape, gaps between the conductors and tape are filled with watertight thread and placed in a LLD PE shell
	Wire shield	Extruded semiconductor
	Insulation	XLPE (cross-linked polyethylene), minimum thickness 4.85 mm
	Insulation shield	Pressed fixed semiconductor
	Shield	Copper wire winding and aluminium foil that is closely fixed to shield to ensure radial water-tightness
	Sheath	Black LLD PE
	PE conductor	Copper wire winding
Conductor identification	**Phase wires**	Numeration (Core 1; Core 2; Core 3)
	Earthing conductor	No special identification
Marks on the cable sheath		AXLJ-TT 14/24 kV 3x95/16 DRAKA SE "date", metric marks
Usage		Transmission and distribution of electricity in stationery equipment, designed for laying in cable channels, outside, in the ground and under water

AXOJ-TT cables consist of one conductor, as shown in Fig. 1.15. These cables are designed for installation in wiring ducts, outside, in the ground, and under water by forming a three-phase system (of three separate conductors). They are especially suited for using in closed substations and switching units as they do not burn and are flame resistant. In case of fire, these cables emit little smoke and as they do not contain any hallucinogens this smoke is not hazardous to electronics and equipment. These cables are longitudinal and radial water-resistant. It is not advised to bury them using plough [6], [12].

Table 1.7

Construction of AXQJ-TT

Conductor	50–800 mm^2	Intertwined, multiplex, round aluminium conductor according to IEC 60228 Class 2, longitudinal waterproof
	Construction	One conductor
	Wire shield	Extruded semiconductor
	Insulation	XLPE (cross-linked polyethylene), minimum thickness 4.85 mm
	Insulation shield	Pressed fixed semiconductor that is twined with a semi-conducting waterproof ribbon
	Shield	Burnt copper wire winding
	Sheath	Aluminium foil coated with black halogen-free and fire-resistant compound for radial water-tightness
	PE conductor	Burnt copper wire winding
Conductor identification	Phase wires	No special identification
	Earthing conductor	No special identification
Marks on the cable sheath		AXQJ-TT 24 kV 1x50 AFR/16 F4B DRAKA "date and time", metric marks
Usage		Transmission and distribution of electricity in stationery equipment, designed for laying in cable channels, outside, in the ground and under water. It is especially suited for using in closed substations and switching units as it does not burn and is flame resistant

Fig. 1.15. Construction of medium-voltage cable [12].

1.4. Cable connection accessories

When connecting power cables and trimming the ends, cable connection accessories suited for the construction and working and surrounding environment must be used. Cable end stripping and cable coupling sleeves must be used according to the technical documentation issued by the manufacturing factory. In new cable lines the permitted number of coupling sleeves per kilometre may not exceed:

- 3 pcs (1–10 kV three-phase cables with cross section to 3×95 mm^2);
- 4 pcs (1–10 kV three-phase cables with cross section to 3×120 mm^2);
- 5 pcs (medium-voltage three-phase cables);
- 2 pcs (single-core medium-voltage cables).

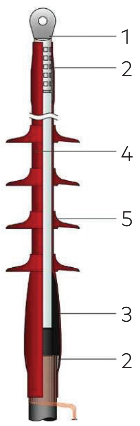
In new cable lines coupling sleeves may not be situated:

- under the carriageways;
- where it is crossed by existing or planned engineering communications;
- in basements and on building walls;
- in cable channels, cable blocks, pipes, tunnels, or levels.

1.4.1. Connection accessories for medium-voltage cables

Cable end stripping for medium-voltage cables can be subdivided in three groups: heat-shrink tubing, cold-shrink tubing, and connection system switching units.

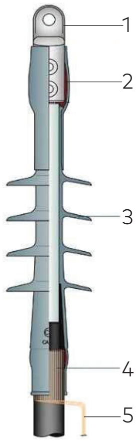
The cracking and erosion resistant heat-shrink tube is lined with weather and cracking resistant materials that melt when heated thus ensuring air-tightness. The pipe is also lined with nonlinear impedance controlling material or the so-called voltage-control layer; heating of the heat-shrink pipe makes this layer warm and stick to even unevenly insulated surfaces providing close connection without empty pores. On the insulation shield cut-back, a stress-control element made of silicone rubber is put on the stripped cable end using the slip-on method to protect against discharge in the shield cut-back caused by increased electric field. Earthing conductor or winding is placed in a sealing mastic to prevent from humidity. Construction of the described 20 kV cable end stripping is shown in Fig. 1.16 [13].



1 — cable terminal plug
2 — insulation
3 — stress-control element
4 — leakage-current resistant outgoing pipe
5 — leakage-current resistant silicone protection caps

Fig. 1.16. Medium-voltage cable end stripping with heat-shrink insulation tube.

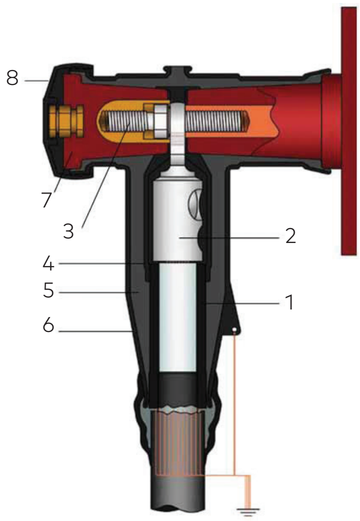
Also cold-shrink tubing consists of one single insulation shield. These are made of high-voltage resistant silicone rubber in a controlled injection process. The insulation set includes also a stress-control element and silicone protective caps. The compact and optimised design reduces the related assembly, storage, and transport costs. The silicon rubber used in the insulation material is specially resistant against ozone and UV radiation. These end connections can also be used in harsh weather, according to the quality requirements of CENELEC and IEC 60816. Figure 1.18 shows the construction of cold-shrink tubing (20 kV) [13].



1 — cable terminal plug
2 — insulation
3 — one-piece insulation shield with stress-control element
4 — shield connection
5 — earthing braid

Fig. 1.17. Construction of cold-shrink tubing.

Adapters are used in compact 20 kV switchgears, and the composition thereof is basically similar to the design of cold-shrink tubing to ease the assembly of the adapters as much as possible. The plug-in adapters are specially designed to make connections with plastic-insulated VS cables. All the parts of the connection are compatible ensuring safe, quick, and easy assembly. This guarantees more security and less space for mistakes in the assembly. The insulation materials used in plug-in adapters are made with high electric and mechanic resistance. They are made of high-voltage resistant EPDM in a controlled injection process. Reduction of the electric field is ensured using silicone stress element with all the aforementioned characteristics. Construction of an adapter is shown in Fig. 1.18 [13].



1 — silicone stress-control element
2 — screw type cable terminal plug with screw and built-in fastening
3 — contact screws
4 — internal electrode
5 — main insulation
6 — insulation frame
7– protection cap

Fig. 1.18. Construction of medium-voltage adapter.

1.4.2. Medium-voltage connection systems

Similar to low-voltage power cables, there are also many types of connection systems for medium-voltage cables: hybrid connections with elements that do not require heating and elements that are of heat-shrink type; systems that do not require heating similarly to the described cold-shrink tubing because the insulation jacket made of silicone rubber contains all the necessary technology; branching systems for single-conductor cables and pre-stretched elastomer connection systems for single-conductor cables.

Figure 1.19 presents a hybrid heat-shrink connection system.

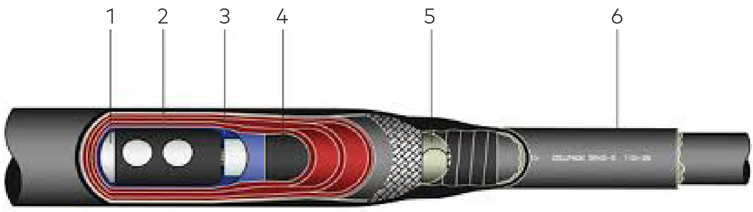


Fig. 1.19. Hybrid connection system for medium-voltage single-conductor cables [13].

2. PRACTICAL PART

The practical part presents a scenario of an emergency in distribution network and includes switching operation using the power switch and load switches.

2.1. Diagrams of distribution network

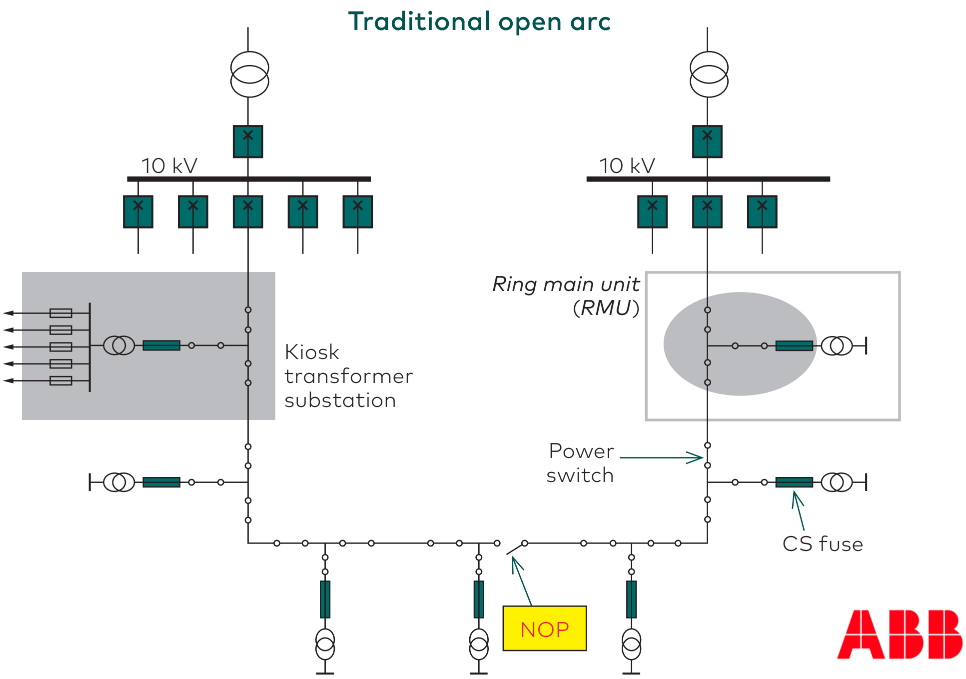


Fig. 2.1. Transformer on a pole and a portal support [1].

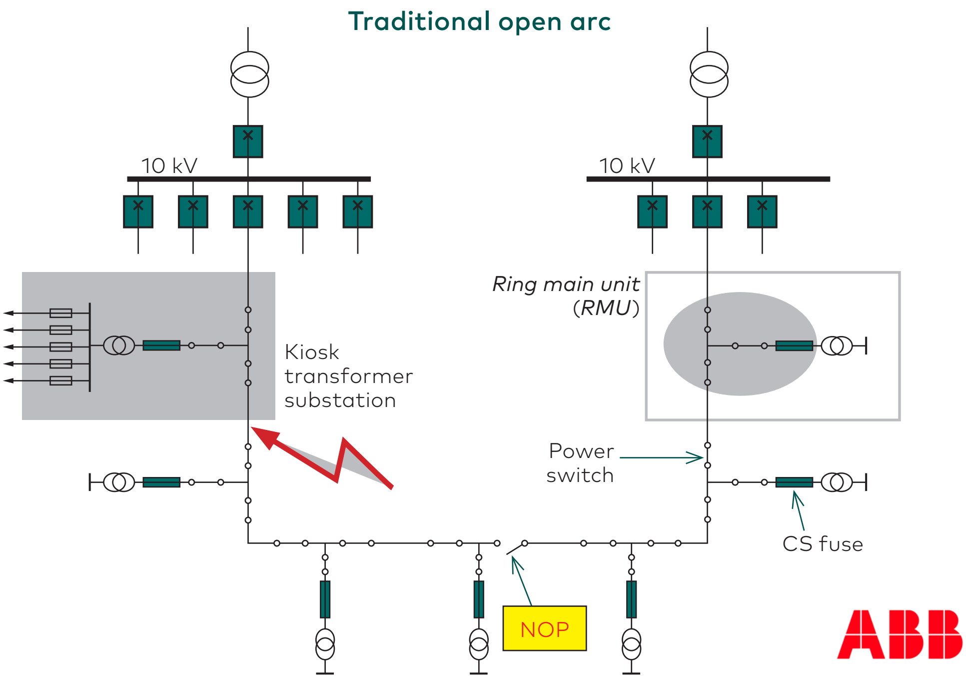


Fig. 2.2. Transformer on a pole and a portal support [1].

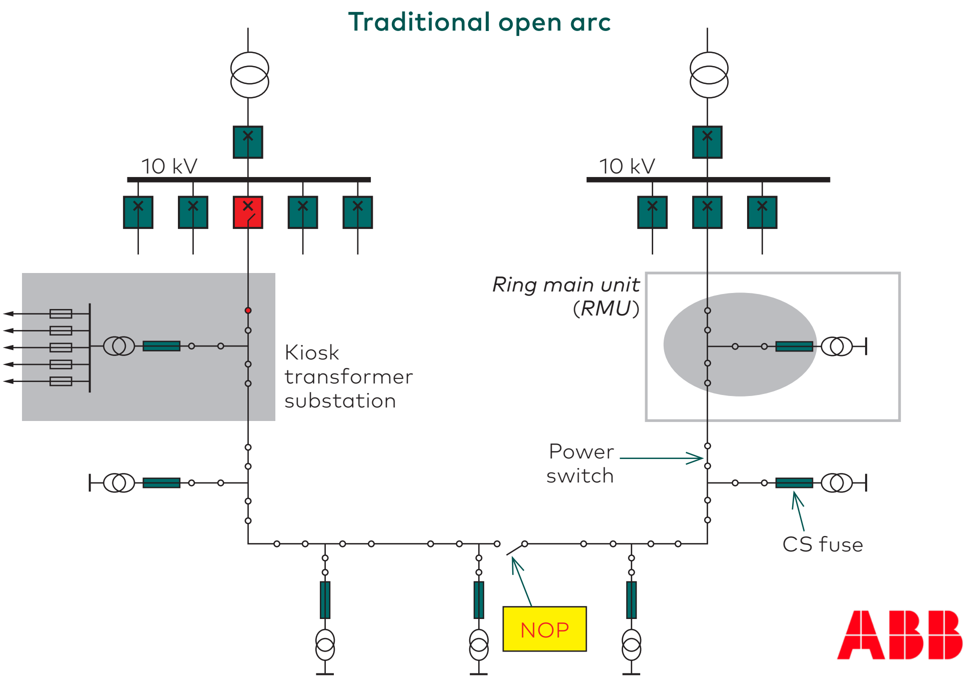


Fig. 2.3. Transformer on a pole and a portal support [1].

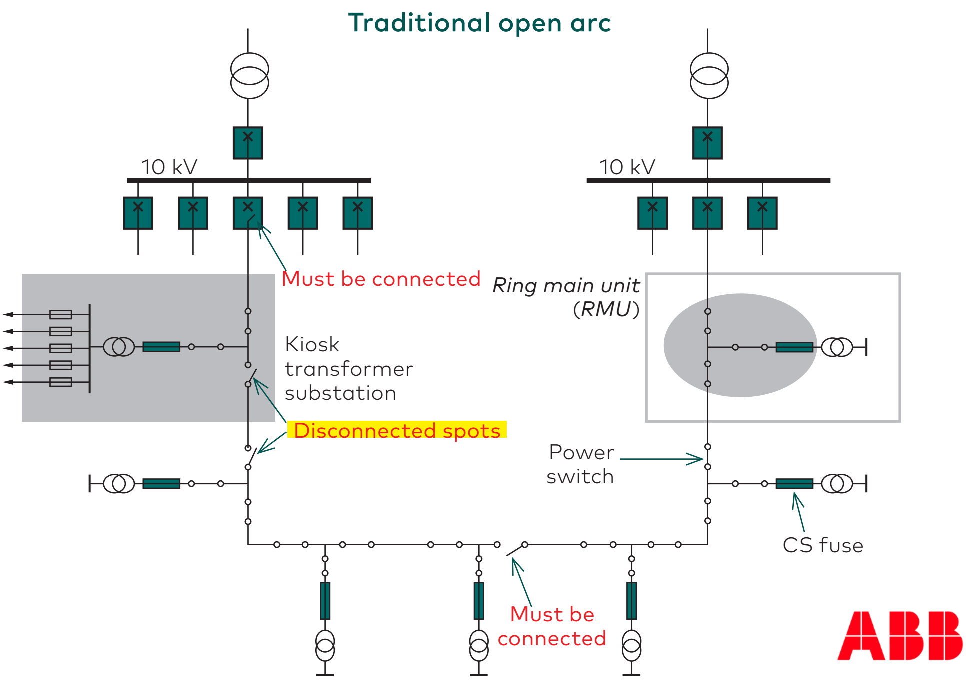


Fig. 2.4. Transformer on a pole and a portal support [1].

2.2. Description of switchgear UniGear ZS1

In studying the switching strategies as a part of practical assignments in the course "High-voltage systems", the UniGear ZS1 training unit is used. Within the practical assignments, training for the following tasks is provided:

1) corrective measures and complex of measures in case of damage to high-voltage systems;
2) switching procedures in a high-voltage system, in line with safety requirements;
3) selection of appropriate equipment for testing of insulation and high-voltage devices;
4) switching and insulation procedures in the high-voltage system of a ship, and filling in of the necessary documentation;
5) methods for testing insulation resistance and polarisation index of a high-voltage device.

The training unit UniGear ZS1 is a 12 kV, 1250 A switchgear manufactured by ABB, is air-insulated modular type with a metal enclosure, 630 A circuit breaker and earthing blades, and is suited for indoor usage according to the standard IEC 62271-200.

2.2.1. Functionalities

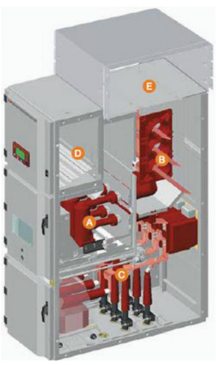
The modular switchgear UniGear ZS1 with commutation and earthing blades is designed for the protection of 12–24 kV networks. Commutation switch and earthing blades can be operated when the doors of the switchgear are locked. The front panel ensures management of devices and turning on and off of the switchgear.

The switchgear includes control block with operation and maintenance procedures and software with a single user interface. Switchgear cell consists of a low-voltage control compartment, arc suppression camera and three 12–24 kV power compartments:

1) circuit breaker compartment;
2) busbar compartment;
3) cable compartment.

Compartments are separated by metal partition walls. The cable compartment is equipped with earthing switch. The circuit breaker is retractable using an additional device — special cart. This device can be used in medium-voltage (12–24 kV) systems on ships. The position of earthing switch can be seen on the commutation front panel, thanks to an indicator.

Figure 2.4 presents the cell switch of ZSI switchgear.



A – circuit breaker compartment
B – busbar compartment
C – cable compartment
D – control block
E – arc suppression camera

Fig 2.4. Overview of UniGear ZS1.

2.3. Practical assignment

The course "Operation of high-voltage equipment on a ship" includes a practical part. A variant of practical assignments is distributed to the students. The practical assignment has two parts.

1. Preparation

Within the practical assignments, each student is provided with a power supply scheme in which maintenance and repairs must be performed for an equipment, depending on the variant. A safe insulation and earthing algorithm must be prepared, and the measures to be taken step-by-step must be written down in the practical task sheet.

2. Practical part

The algorithm from the second stage must be carried out in practice using the training unit UniGear ZS1 (According to the variant number).

The practical assignment is checked in each stage and all irregularities and discrepancies are pointed out, if there are such. During the practical assignment, all students are trained for the following skills:

1) to take corrective steps during the damage to a high-voltage system;
2) to understand the switching strategy and to insulate the parts included in the high-voltage system;
3) to ensure switching and insulation procedures in a high-voltage system, and to fill in the necessary documentation.

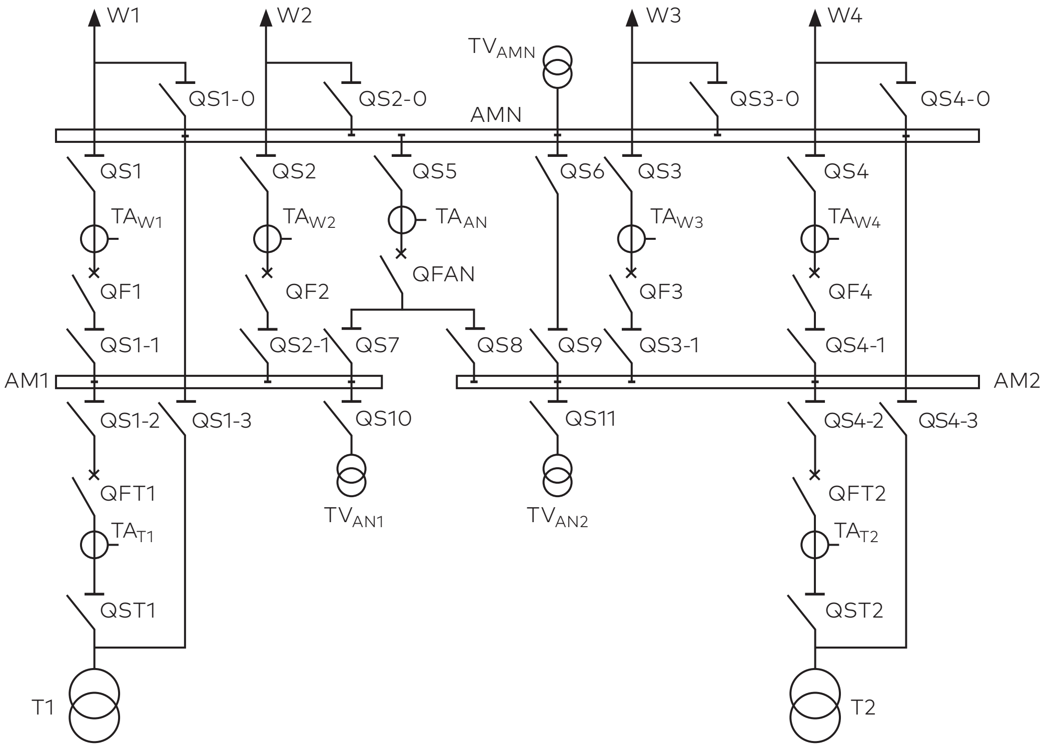


Fig 2.5. Practical assignment: Single-line circuit diagram No. 1.

Table 2.1

Network apparatus	Circuit	Operation	Test

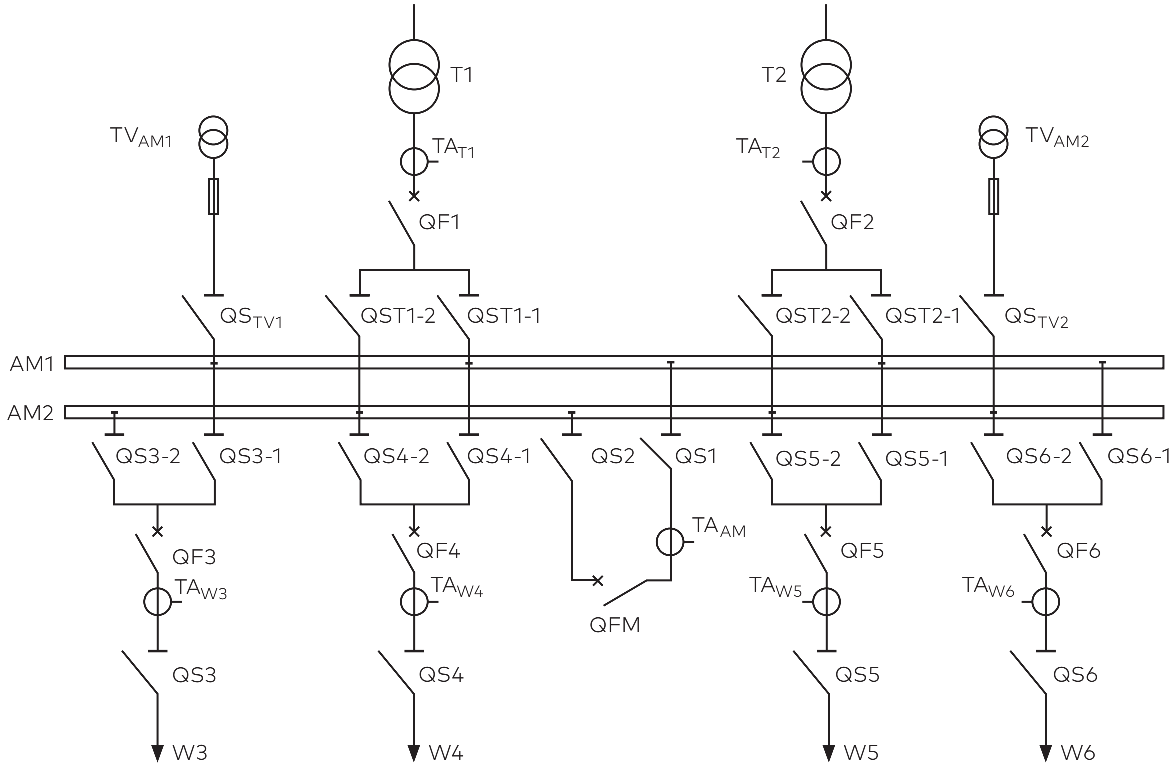


Fig 2.6. Practical assignment: Single-line circuit diagram No. 2.

Table 2.2

Network apparatus	Circuit	Operation	Test

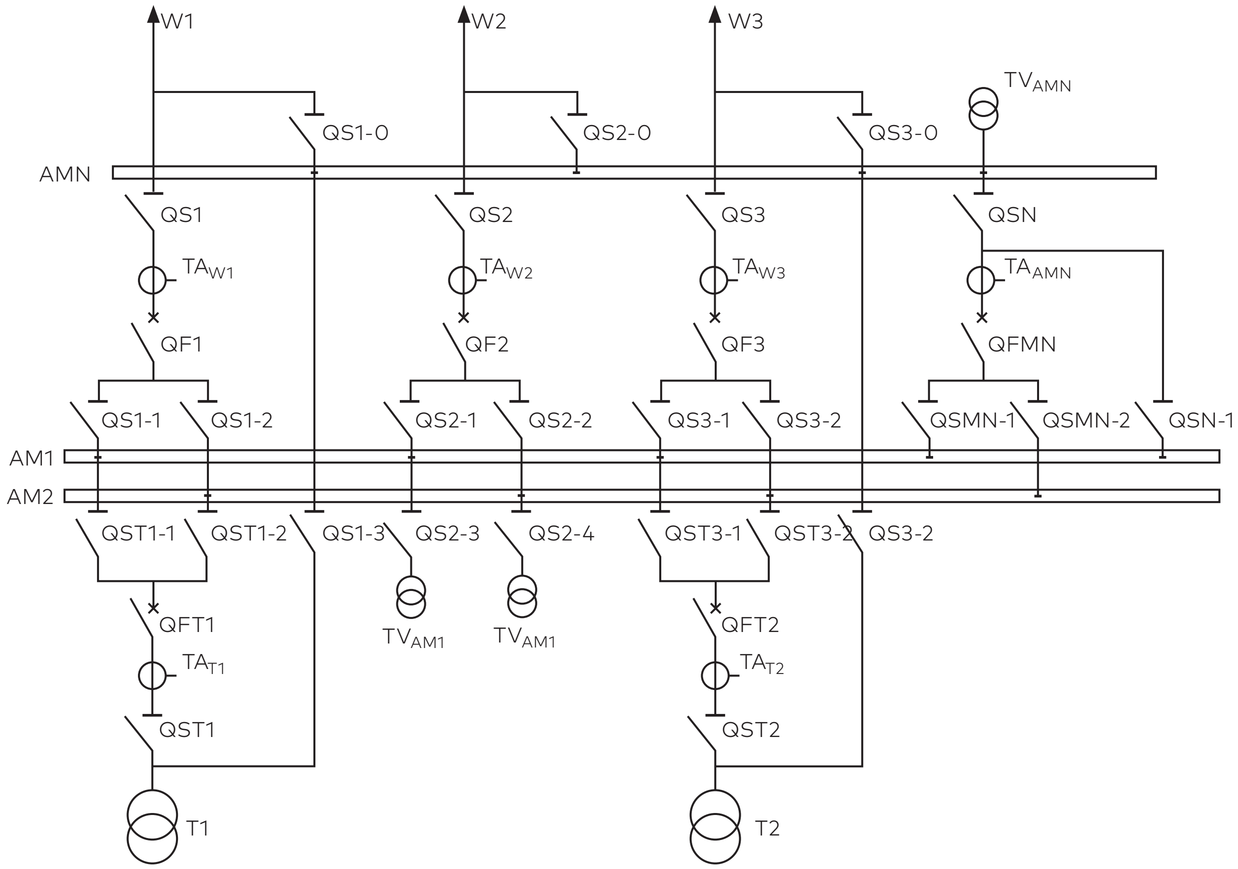


Fig 2.7. Practical assignment: Single-line circuit diagram No. 3.

Table 2.3

Network apparatus	Circuit	Operation	Test