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Ternopil Ivan Pul'uj National Technical University
(full name of higher education institution)
Faculty of Applied Information Technologies and Electrical Engineering
(faculty name)
Electrical engineering department
(full name of department)

QUALIFYING PAPER

For the degree of

Bachelor
(educational-proficiency level)

topic: **Ensuring the reliability functioning of the distribution network in Borshchiv District Electrical Networks**

Submitted by: fourth year student group IEE-42
Specialism (field of study) 141 Electrical Power Engineering, Electrical Engineering and Electromechanics
(code and name of specialism (field of study))

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Ministry of Education and Science of Ukraine
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Faculty Faculty of Applied Information Technology and Electrical Engineering
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ASSIGNMENT
FOR QUALIFYING PAPER

for the degree of Bachelor
(degree name)

specialty 141 Electrical Power Engineering, Electrical Engineering and Electromechanics
(code and name of the specialty)

student *Abdullah Ahmed Ali Mohamed*
(surname, name, patronymic)

1. Paper topic *Ensuring the reliability functioning of the distribution network in Borshchiv District Electrical Networks*

Paper supervisor *Sysak Ivan Mykhailovych, Ph.D.*
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Transformers installed at substations of a given network
4. Paper contents (list of issues to be developed)
ANALYTICAL SECTION
CALCULATION AND RESEARCH SECTION
PROJECT DESIGNING SECTION
LABOUR OCCUPATIONAL SAFETY AND SECURITY IN EMERGENCY SITUATIONS
5. List of graphic material (with exact number of required drawings, slides)
Presentation

6. Advisors of paper chapters

Chapter	Advisor's surname, initials and position	Signature, date	
		assignment was given by	assignment was received by
Labour occupational safety	*Ph.D., Assistant professor Okipnij I.B.*		
and security in emergency			
situations			
Compliance check	*Ph.D. Sysak I.M.*		

7. Date of receiving the assignment ______________________

TIME SCHEDULE

LN	Paper stages	Paper stages deadlines	Notes
1	Preparation of the «ANALYTICAL SECTION»	01.01.21 – 20.01.21	
2	Preparation of the «CALCULATION AND RESEARCH	21.01.21 – 20.02.21	
	SECTION»		
3	Preparation of the «PROJECT DESIGNING SECTION»	21.02.21 – 30.03.21	
4	Preparation of the «LABOUR OCCUPATIONAL	01.04.21 – 20.04.21	
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	SITUATIONS»		
5	Preparation of introduction, conclusions,	20.04.21 – 05.05.21	
	Content and summary.		
6	Preparation, execution and printing graphic material	05.05.21 – 10.06.21	
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ABSTRACT

Abdullah Ahmed Ali Mohamed. Ensuring the reliability functioning of the distribution network in Borshchiv District Electrical Networks. Ternopil Ivan Puluj National Technical University. Faculty of Applied Information Technologies and Electrical Engineering. Department of Electrical Engineering, group IEE-42. – Ternopil.: TNTU, 2021.

Pages – __; Tables – __; Illustrations – __; Sources – __; Blueprints – __; Additions – __.

In qualification work carried out the characteristic of network and calculation of loads of substation 110/10 kV. Considered versions of electrical networks development. Carried out calculations wires of overhead transmission lines and calculations and selection of transformers of substations 110/10 kV. Substantiated the choice of main circuit of electrical connections.

Keywords: electricity, transformer substation, relay protection, electric parts, power transformer.

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INTRODUCTION

Various methods, including redundancy, can be used to increase the efficiency of electrical networks. In the general case, the required power reliability for the power supply system can be provided by the required number of generators, transformers, busbar sections and power lines.

Reliability is characterized by the ability of the power supply system and its elements, which include overhead and cable lines, power transformers, electrical appliances, to provide consumers with electricity of proper quality without emergency breaks, leading to violations of the production plan, accidents in electrical and technological parts of equipment.

The reliability of the power supply system depends on the construction of its scheme, the degree of redundancy and the reliability of individual elements, taking into account their overload capacity.

When assessing the degree of reliability, it is necessary to combine both electrical and technological part of the mechanism, units or installations. The category of consumer reliability should be determined taking into account the redundancy in the technological part of the unit. It is impractical to reserve the electrical part of the unit or its power supply circuit in the absence of a reserve in the technological part.

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1 ANALYTICAL SECTION

1.1 Distribution networks

Electricity distribution networks - networks designed for the transmission and distribution of electricity.

The most common electrical networks are: radial circuits (parallel connection of consumers), trunk (serial connection), mixed (radial-trunk or otherwise serial-parallel connection) and loop circuits (ring) [1].

In fig. 1.1 shows a radial electrical network (parallel connection).

It should be noted that the consumer S2 is present in the scheme. This is a responsible consumer and its power is supplied from two different sections of tires - Section I and Section II. If the voltage on either of the two sections, I or II, disappears, the other section will automatically receive power via the section switch. This is an important difference between consumer S2 and other consumers, shown in Fig. 1.1.

The advantage of the scheme is the high reliability of power supply.

The disadvantage of the scheme is the high cost due to the large number of equipment and the laying of separate power lines to each of the consumers.

In fig. 1.2 shows the main electrical circuit (series connection).

The responsible consumer S2 is also present in this scheme. As in the case of a radial circuit, if the voltage on any of the two sections, I or II, disappears, the other section will automatically receive power through the section switch.

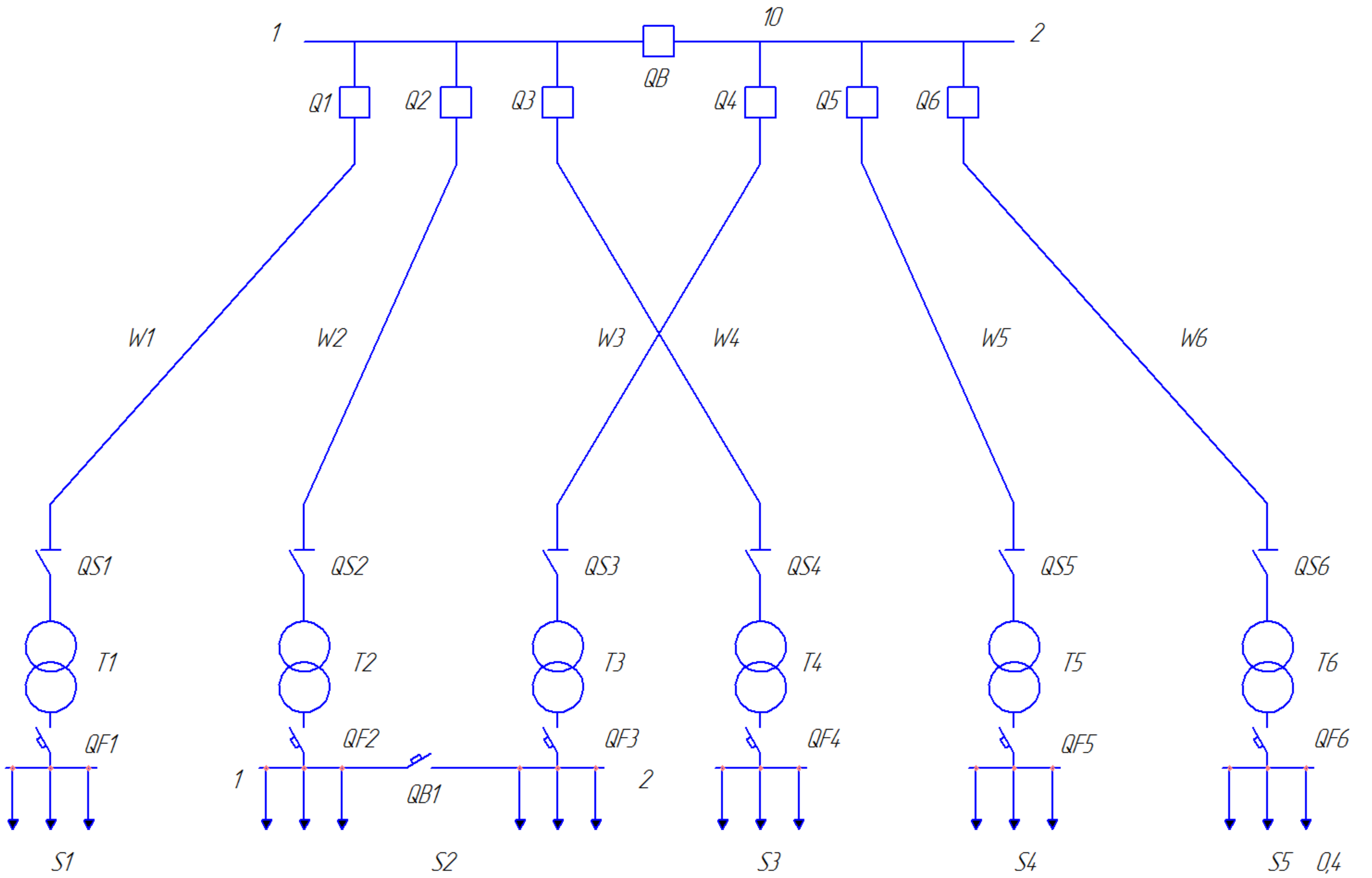

Figure 1.1 - Radial electrical network (parallel connection)

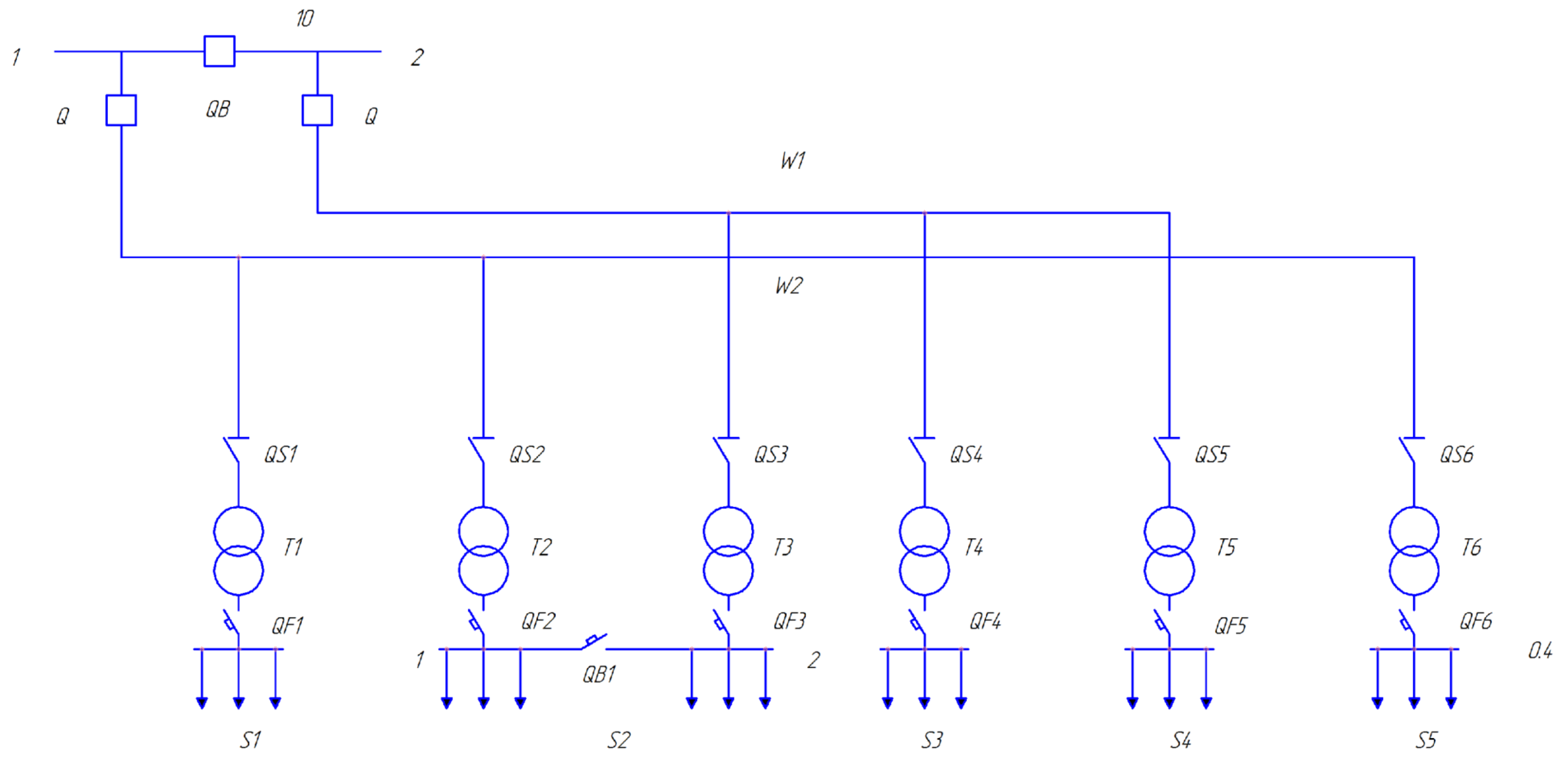

Figure 1.2 - Main electrical network (serial connection)

The advantage of this scheme is low cost, because less equipment is used, compared to the radial scheme. Consumers also connect in series. This saves wires.

The disadvantage of this scheme is the disconnection of all consumers connected in series, for example, in the event of a break at the beginning of the line.

In fig. 1.3 shows a loop (ring) electrical network (series-parallel connection). Also, this scheme can be described as a radial-trunk scheme.

This scheme is a connection of consumers in a circle, ie in a ring. Every consumer who is connected according to this scheme can get power from any section of tires - I or II.

The advantage of the scheme is a reliable power supply to consumers. The disadvantage of the scheme is the high cost, as it uses a large number of switching devices.

In fig. 1.4 shows a combined scheme (radial-main).

In this diagram, the electrical consumers are connected to the switchgear in a radial circuit. Power supply of the switchgears is carried out from the main busbars.

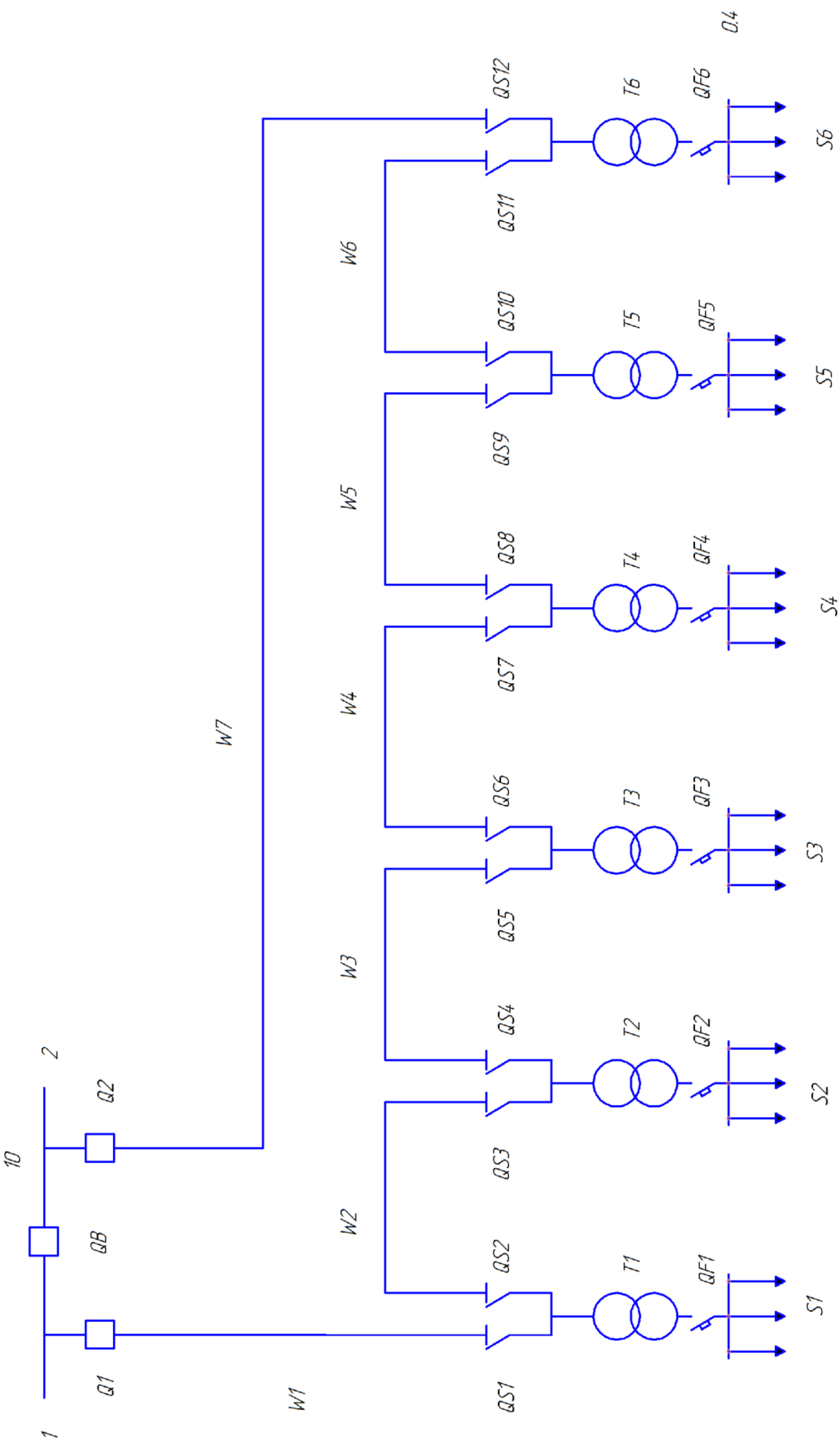

Figure 1.3 - Ring electrical network

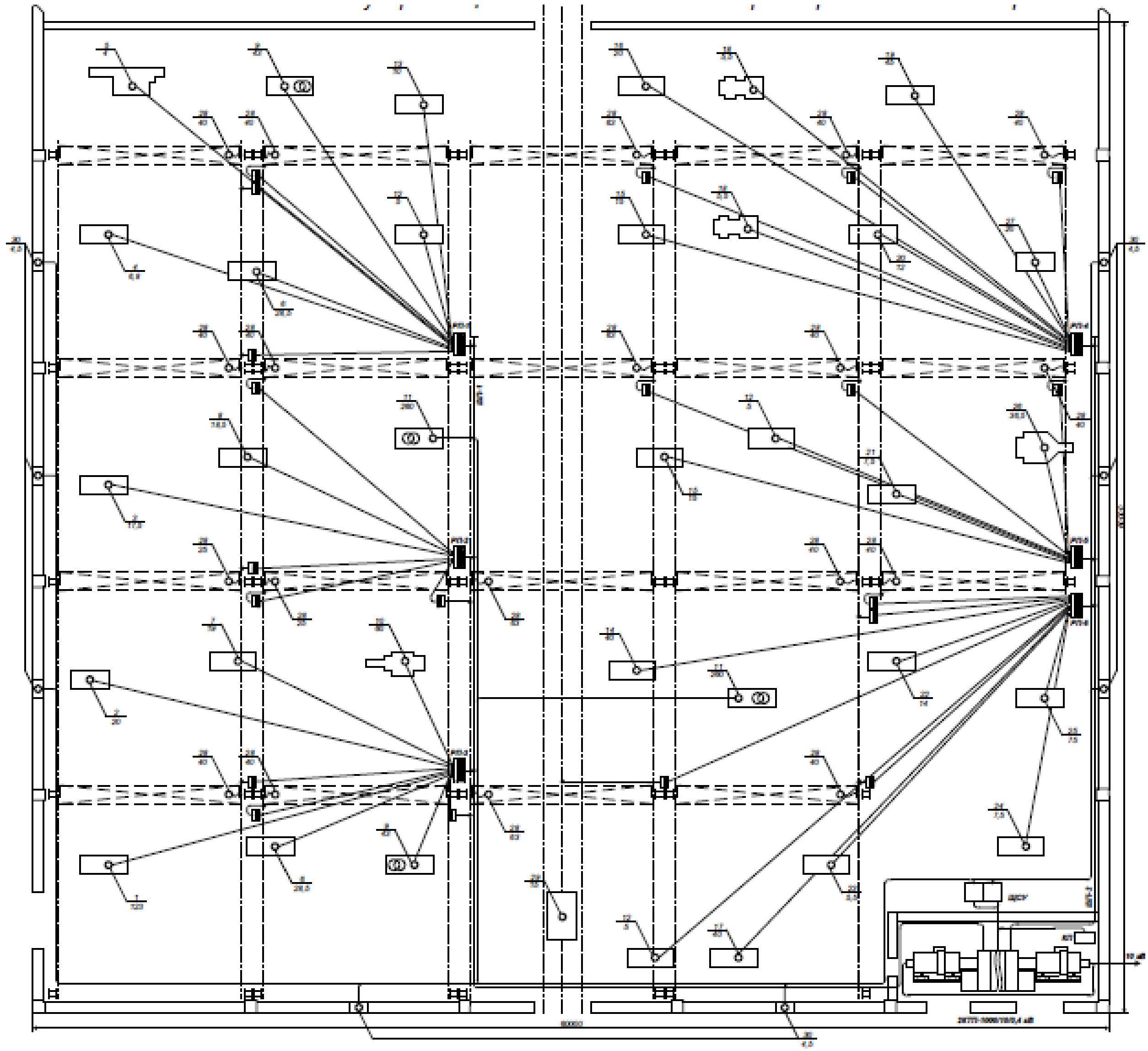

Figure 1.4 - Combined power supply scheme (radial-main)

1.2 Classification of electricity consumers according to the reliability of the power supply system

The main requirement of consumers to the grid is to provide electricity with the required capacity with regulated quality indicators and the level of reliability and continuity of supply. According to the "Rules for the arrangement of electrical installations" [2] on the reliability and continuity of electricity supply is divided into three categories (I, II, III).

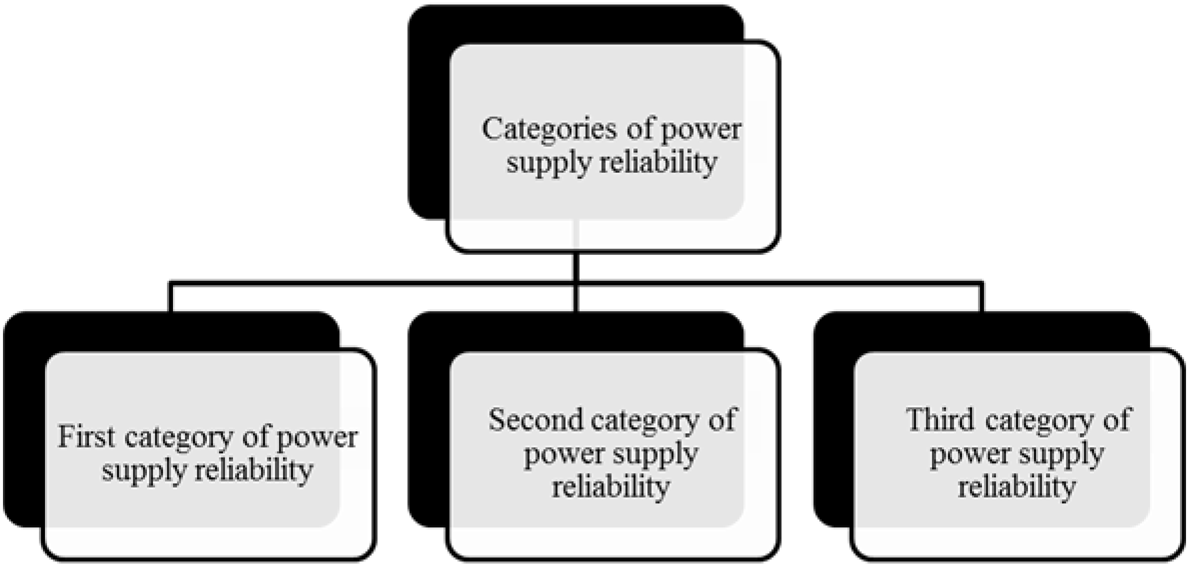

Figure 1.5 - Classification of electricity consumers according to the reliability of the power supply system

The first category (I) includes consumers whose power outages endanger human life, the destruction of particularly important elements of the economy, which causes significant material damage, violations of the technological process of enterprises, leads to long-term disruption of the technological process or mass shortage of products. Examples of category I consumers are ventilation systems and elevators of mines, metallurgical, chemical facilities - blast furnaces and steelmaking furnaces, open-hearth furnaces and converters, reactors, hospitals, telephone and telegraph companies, telecentres, radio stations. Category I consumers must have electricity from two independent power sources. Interruption in the power supply of consumers of the I category can be allowed only for the time of automatic commissioning of the backup power supply (AVR). [1]

The second category (II) includes consumers whose power outages lead to significant losses of products, downtime, disruption of normal activities of the enterprise, village, city. It can be metallurgical equipment - rolling mills, electric arc furnaces, shops of textile factories, shops of metalworking enterprises. For the second category, a power outage is allowed for the time required to turn on the backup power supply by the actions of the duty personnel (up to 1 hour). At high reliability of overhead lines of 6,3 kV and above, their ability to fast recovery at damages power supply of receivers of the II category on one overhead power line (transmission line) is allowed. When powered by a power line, it must be split into two cables connected by separate disconnectors. [1]

The third category (III) for the reliability of electricity supply includes all consumers who do not fall under I and II categories. For consumers of III category, interruptions in the power supply are allowed for the time necessary for repair and replacement of damaged equipment, but not more than one day (up to 24 hours). [1]

1.3 Redundancy is a way to ensure the reliability of electricity supply

"Redundancy - a way to ensure the reliability of the object through the use of additional tools and (or) capabilities that are excessive relative to the minimum necessary to perform the required functions" [3].

In power systems, redundancy is used to increase the reliability of electrical network schemes [3]:

- loading.

In fig. 1.6 shows a closed electrical network with lines and. These lines have increased bandwidth compared to that required for normal operation. These lines will accept additional load if other lines fail.

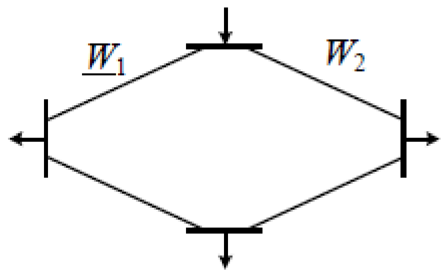

Figure 1.6 - Load redundancy.

- separate.

In fig. 1.7 main section of the distribution line and a parallel line. Redundancy occurs for individual elements of the object or their groups.

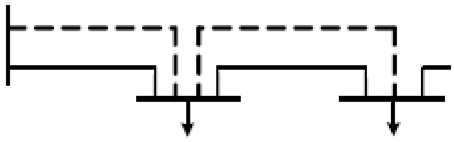

Figure 1.7 - Separate redundancy.

- mixed.

In fig. 1.8 combines two types of redundancy - general and loading. That is, mixed redundancy combines different types.

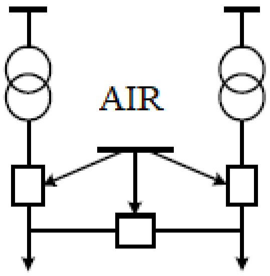

Figure 1.8 - Mixed redundancy.

AIR – automatic inclusion of a reserve.

- constant.

In fig. 1.9 shows how the lines $W1$ and $W2$ in the normal mode of the circuit reserve individual sections of the main network. That is, the backup elements ensure the operation of the object together with the main lines.

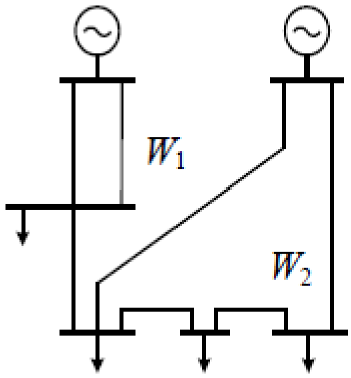

Figure 1.9 - Permanent redundancy.

- substitute.

In fig. 1.10 shows a diagram in which the functions of the main element after failure are transferred to the backup.

In fig. 1.10:

MPS – main power supply;

BPS – backup power supply.

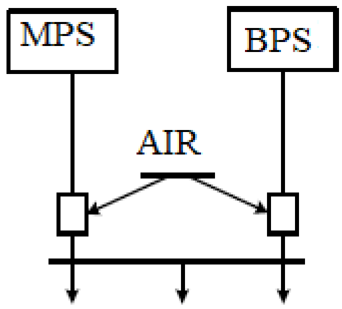

Figure 1.10 - Substitution reservation.

- sliding.

In fig. 1.11 shows a diagram in which each of the group of basic elements at random moments of failure of the main is replaced by a common backup.

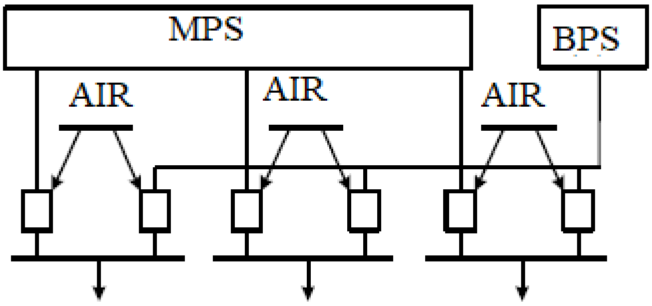

Figure 1.11 - Sliding redundancy.

2 CALCULATION AND RESEARCH SECTION

2.1 Network specifications

The specified part of the 110 kV network of "Ternopiloblenergo" OJSC (Fig. 2.1) supplies the cities of Borshchiv, Ozeriany, Bilche-Zolote, Rudky, Burdiakivtsi, Skala-Podilska, Shuparka, Ustia, Vovkivtsi, Hermakivka, Ivane-Puste, Melnytsia-Podilska, Urozhaine. Power is supplied from the substation (SS) 110/35/10 kV busbars of the city of Borshchiv.

A fragment of the map of electric power networks (750-35 kV) of Ternopil region is presented in Fig. 2.2.

The geographical location of substations of a given 110 kV electric power network of "Ternopiloblenergo" OJSC is presented in Fig. 2.3.

The list of transformers installed at substations of a given network is given in Table. 2.1., And the list of existing OHPL-110 kV and OHPL-35 kV is presented in Table. 2.2.

The task of this thesis is to develop the power supply system of 110/10 kV "Losiach" substation and optimize the modes of operation of the (given) network to ensure the quality of electricity supplied to consumers.

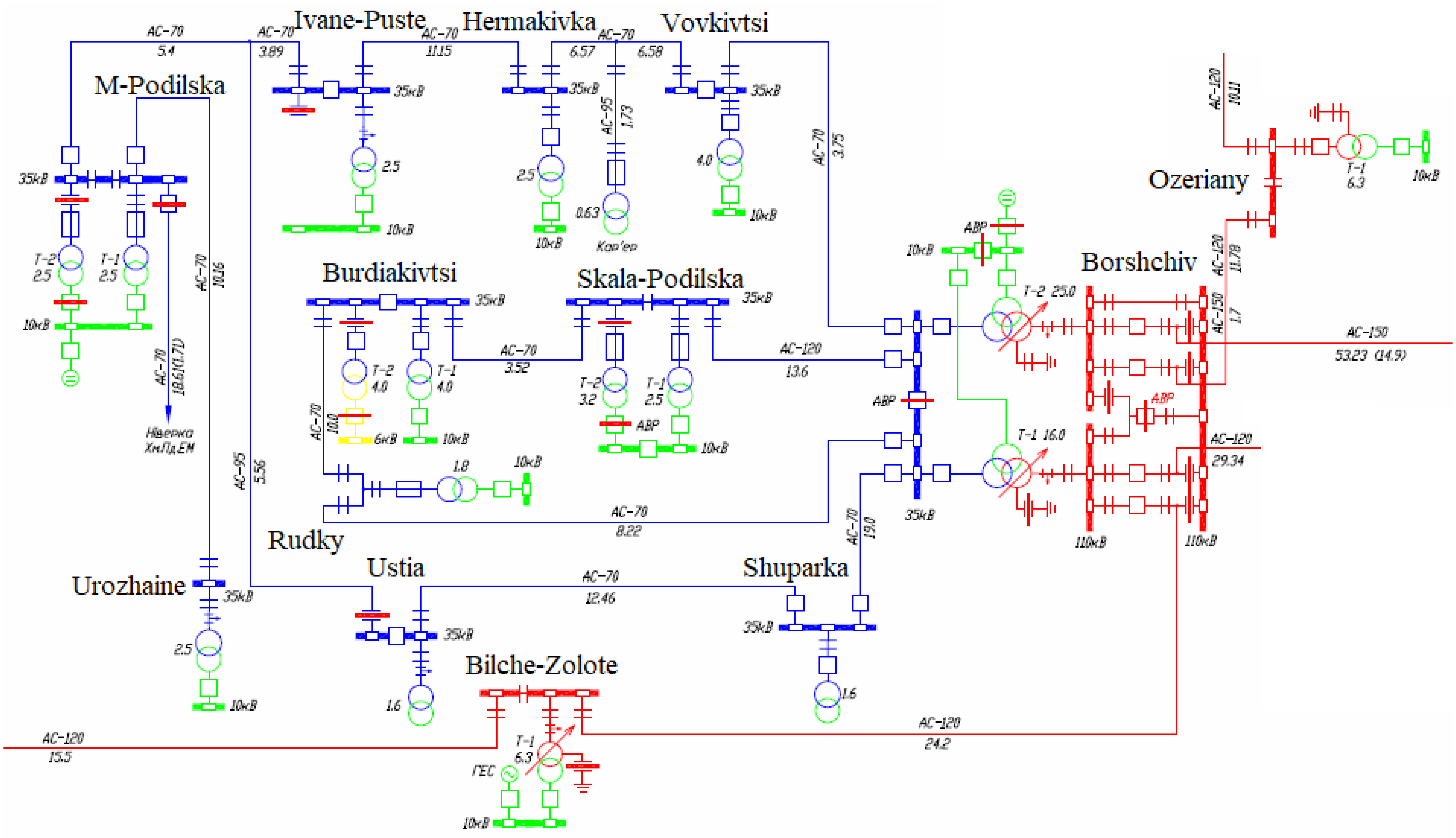

Fig. 2.1 – A fragment of the 110 kV electric power network of "Ternopiloblenergo" OJSC

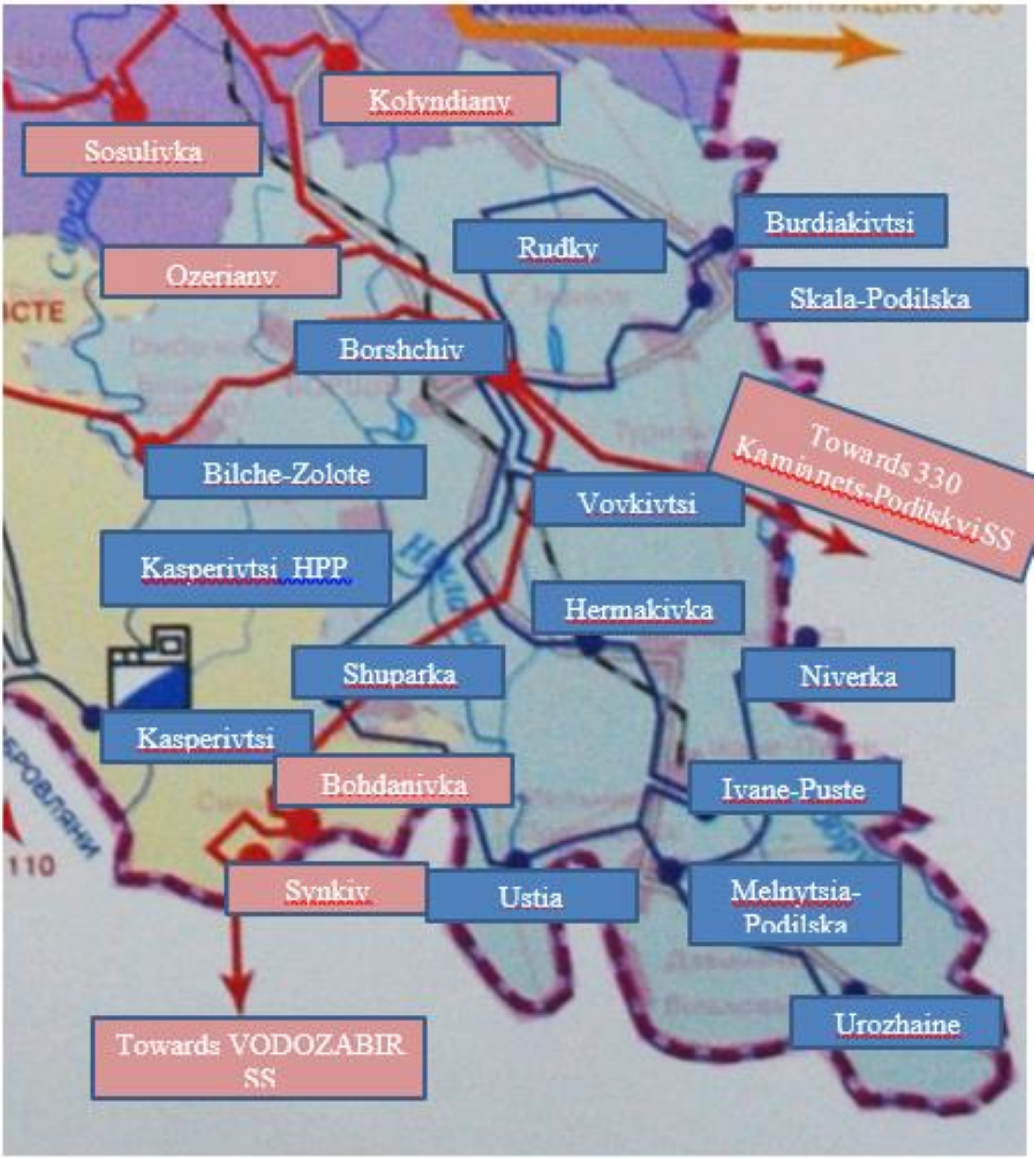

Fig. 2.2 – A fragment of the map of electric power networks (750-35 kV) of Ternopil region

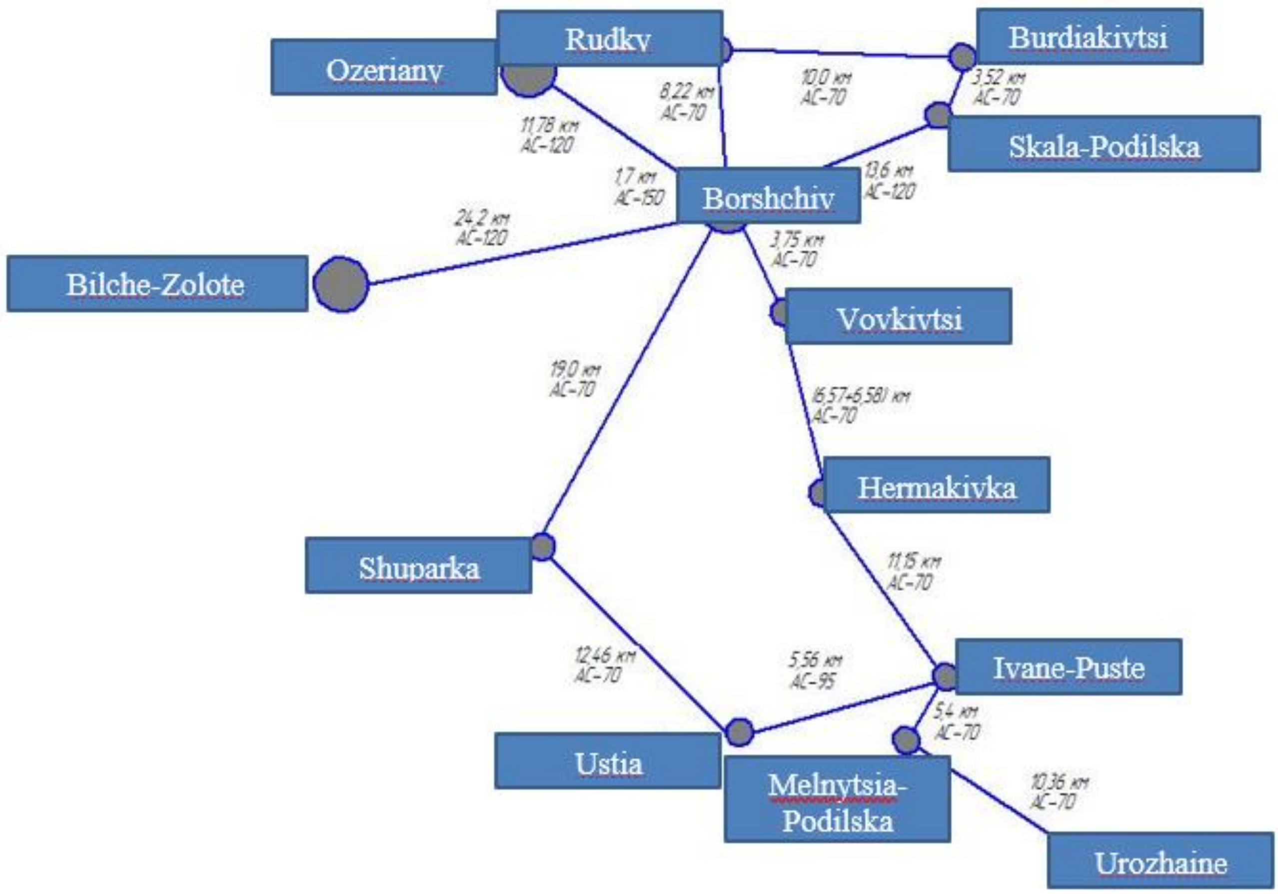

Fig. 2.3 – The geographical location of substations of a given electric power network

Table 2.1 – Transformers installed at substations of a given network

Substation	Transformer type	$S_{ном}$, MVA	$U_{ном}$, kV		
			High voltage	Medium voltage	Low voltage
Ozeriany	6300/110	6.3	115	-	11
Bilche-Zolote	6300/110	6.3	115	-	11
Rudky	1800/35	1.8	35.5	-	11
Burdiakivtsi	4000/35	4.0	35.5	-	11
	4000/35	4.0	35.5	-	6

Continued from Table 2.1

Skala-Podilska	3200/35	3.2	35.5	-	11
	2500/35	2.5	35.5	-	11
Vovkivtsi	4000/35	4.0	35.5	-	11
Hermakivka	2500/35	2.5	35.5	-	11
Ivane-Puste	2500/35	2.5	35.5	-	11
Melnytsia-Podilska	2500/35	2.5	35.5	-	11
	2500/35	2.5	35.5	-	11
Urozhaine	2500/35	2.5	35.5	-	11
Shuparka	1600/35	1.6	35.5	-	11
Ustia	1600/35	1.6	35.5	-	11
Borshchiv	25000/110	25	115	35.5	11
	16000/110	16	115	35.5	11

Table 2.2 - List of electric power transmission lines of a given network

Start node	End node	Wire brand	Length, km
Borshchiv	Rudky	AC-70	8.22
Borshchiv	Skala-Podilska	AC-120	13.6
Borshchiv	Ozeriany	AC-150 AC-120	1.7 11.78
Borshchiv	Bilche-Zolote	AC-120	24.2
Borshchiv	Vovkivtsi	AC-70	3.75
Borshchiv	Shuparka	AC-70	19.0
Rudky	Burdiakivtsi	AC-70	10.0
Skala-Podilska	Burdiakivtsi	AC-70	3.52

Continued from Table 2.2

Shuparka	Ustia	AC-70	12.46
Ustia	Ivane-Puste	AC-95	5.56
Vovkivtsi	Hermakivka	AC-70	6.57+6.58
Hermakivka	Ivane-Puste	AC-70	11.15
Ivane-Puste	Melnytsia-Podilska	AC-70	5.4
Melnytsia-Podilska	Urozhaine	AC-70	10.36

According to the initial data, the total load of the SS is P_{Sub}=9.5 MW. Load factor on the busbars of 10 kV SS is $\cos\varphi = 0,85$. Minimum load factor is $k_{\min} = 0,55$, the time of the maximum load use is $T_{\max} = 5780$ hours.

“Losiach” substation will supply consumers of the second and third categories at a voltage of 10 kV. The scope of consumers by category is provided in table. 2.3.

Table 2.3 - The scope of consumers by category

Consumer categories			
II		III	
30%	2.85 MW	70%	6.65 MW

The location of the network refers to the third category according to the wind pressure speed and the second one according to the ice crust [5]. The average annual temperature in the area covered by the network is 7 ° C, and the average annual duration of thunderstorms is 80 hours per year, according to [5].

2.2 Calculation of substation loads

We will determine the values of active and reactive load on the busbars of "Losiach" substation for the maximum and minimum load modes.

Reactive components of loads on different busbars of the substation are determined on the basis of active components and corresponding power factors:

$$Q_{\max} = P_{\max} \cdot tg\varphi,$$

in which $tg\varphi$ is reactive power factor.

$$Q_{\max 10} = 9.5 \cdot tg(\arccos(0.85)) = 5.268 \text{ MVAr}$$

The calculation of the load of the low voltage substation busbars for the mode of its lowest load is performed by the following expressions

$$P_{\min} = k_{\min} \cdot P_{\max};$$

$$Q_{\min} = tg\varphi \cdot P_{\min},$$

in which $k_{\min}$ is minimum load factor.

$$P_{\min 10} = 0.55 \cdot 9.5 = 5{,}225 \text{ MVAr};$$

$$Q_{\min 10} = tg(\arccos(0.85)) \cdot 5.225 = 3.238 \text{ MVAr};$$

The results of load calculations on the low voltage busbars of the substation are summarized in table. 2.4.

Table 2.4 - Load distribution on “Losiach” substation busbars

Total load, MW	Nominal voltage, kV	Maximum load		Minimum load	
		$P_{\max}$, MW	$Q_{\max}$, MVAr	$P_{\min}$, MW	$Q_{\min}$, MVAr
9.5	10	9.5	5.268	5.225	3.238

3 PROJECT DESIGNING SECTION

3.1 Designing the electric power network development options

According to the given input data we make three possible options of an electric power network development.

Option 1.

The network scheme for this option is shown in Fig. 3.1. In this option one two-circuit line L-1 with a length of 15 km is built with the AC-120/19 wire from “Borshchiv” substation to “Losiach” substation.

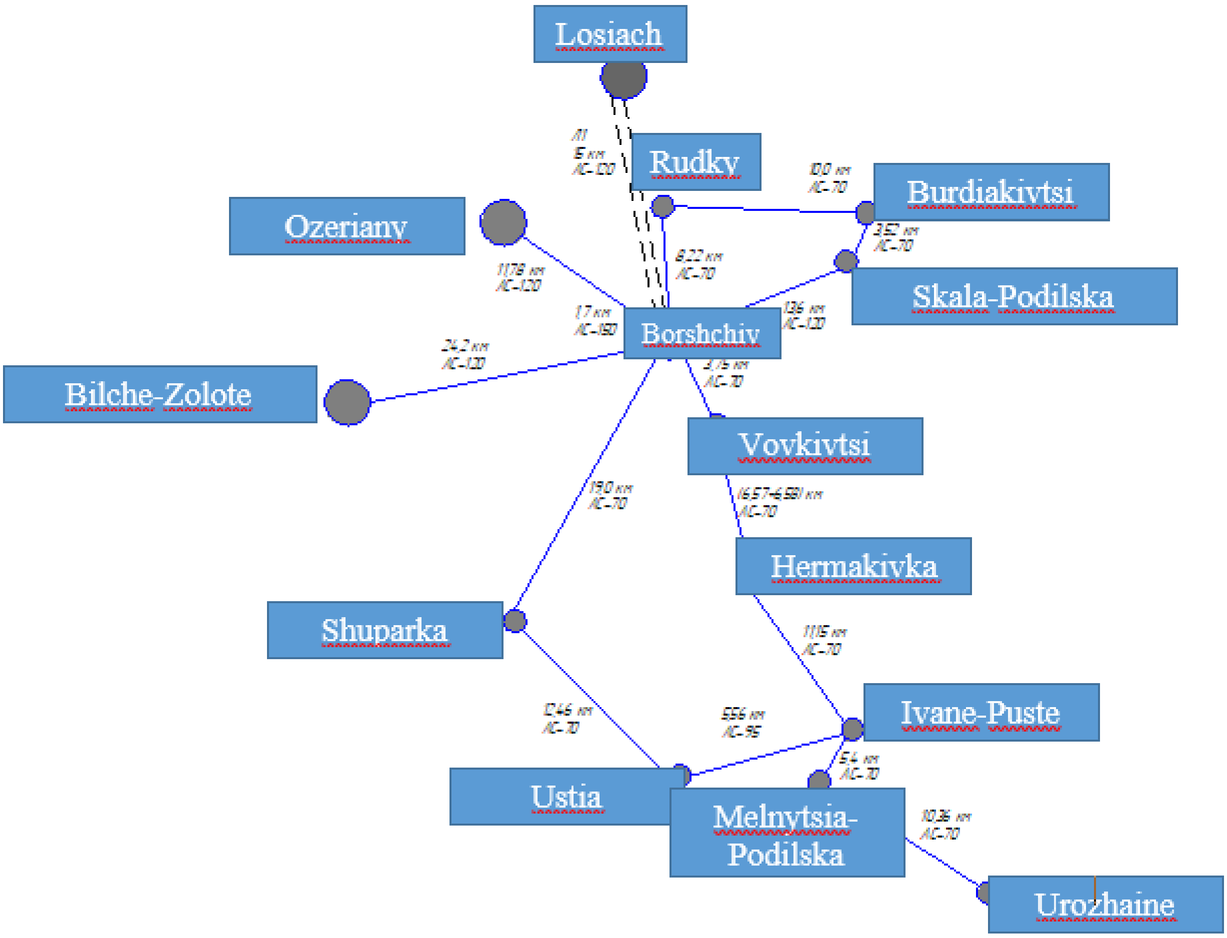

Fig. 3.1 - Option 1 of an electric power network development

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Option 2.

The network scheme for this option is shown in Fig. 3.2. In this option, a single-circuit line L-1 with a length of 15 km from "Borshchiv" substation to "Losiach" substation is built, as well as a single-circuit line L-2 with a length of 10 km from "Ozeriany" substation to "Losiach" substation.

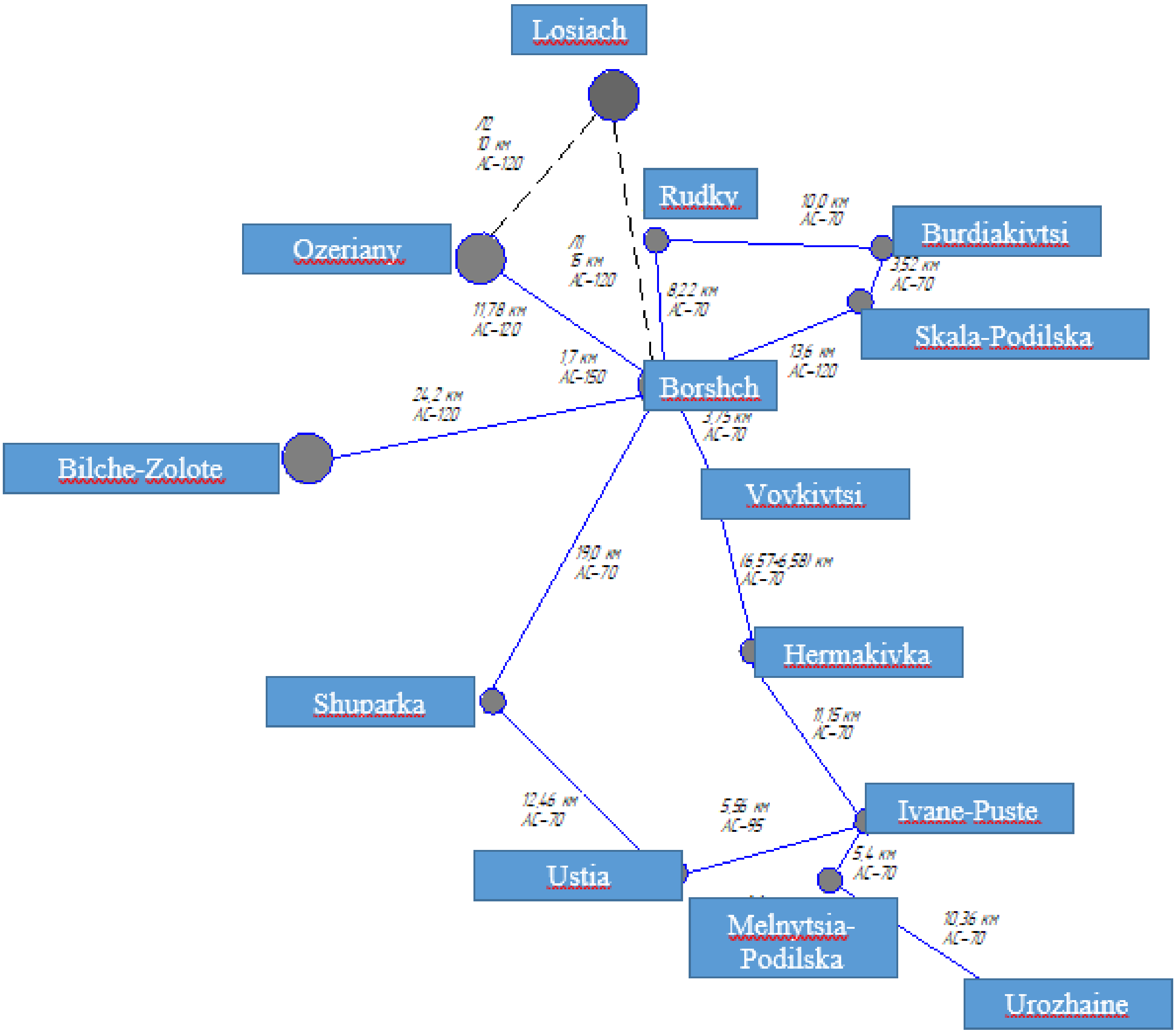


Fig. 3.2 - Option 2 of an electric power network development

Option 3.

The network scheme for this option is shown in Fig. 3.3. In this option, a single-circuit line L-1 with a length of 15 km from "Borshchiv" substation to "Losiach" substation is built, as well as a 13-km single-circuit line L-2 from "Kolyndiany" substation to "Losiach" substation.

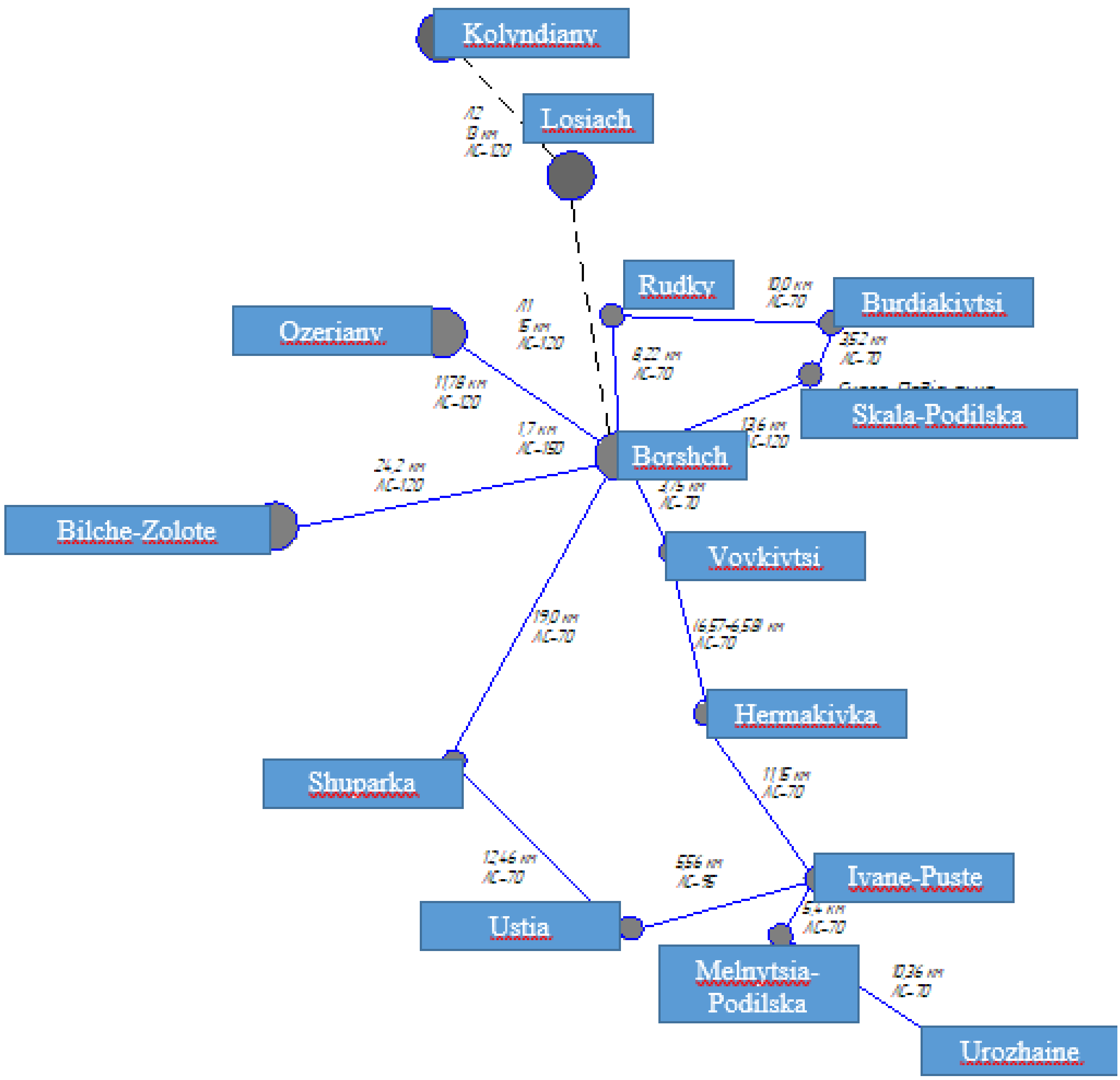


Fig. 3.3 - Option 3 of an electric power network development

3.2 Selection of substation transformers

"Losiach" substation will be built as a two-transformer substation.

When choosing transformers it is necessary to ensure:

a) the most efficient use of the installed capacity of transformers at step-down substations of all categories;

b) minimum capital and settlement costs and their distribution according to the stages of substation development;

c) reliability of power supply;

d) serviceability;

e) the possibility of expanding the substation without complex reconstructions and interruptions in the power supply to consumers.

Based on the reliability of electricity supply to consumers, we install two transformers at the substation.

The power of one transformer of a two-transformer substation is selected taking into account the allowable overload of the transformer by 40% during an emergency shutdown of one of the transformers in the maximum operating mode [6].

$$S_{nom} \geq \frac{S_{Sub}}{1,4} = \frac{\sqrt{R^2{}_{Sub} + Q^2{}_{Sub}}}{1,4} = \frac{\sqrt{9,5^2 + 5,268^2}}{1,4} = \frac{10.863}{1,4} = 7.759 \text{ MVA}$$

We select two transformers of TDN-10000/110 type with nominal catalog data:

$$S_{nom} = 10 \text{ MV} \cdot \text{A};$$

$$\text{U}_{\text{nomHV}} / U_{\text{nomLV}} = 115/11 \text{ kV};$$

$$\Delta P_{idling} = 15{,}5 \text{ kW};$$

$$\Delta P_{short\,circuit} = 60 \text{ kW};$$

$$u_{short\,circuit} = 10.5\%;$$

$$I_{idling} = 0.9\%.$$

Transformers have the OLTC device ±9 x 1.78% in the neutral of the HV winding.

As consumers of this substation belong to categories II and III according to the power supply reliability, the given "Losiach" substation will be constructed as a two-transformer substation pursuant to the requirements.

In emergency modes, the overload of one transformer by 40% (factor 1.4) is possible at the maximum load. Therefore, the power of the transformer is selected taking into account the overload factor:

$$S_{nom} \geq \frac{S_{Sub}}{1,4} = \frac{\sqrt{R^2{}_{Sub} + Q^2{}_{Sub}}}{1,4} = \frac{\sqrt{9,5^2 + 5,268^2}}{1,4} = \frac{10.863}{1,4} = 7.759 \text{ MVA.}$$

The values of short-circuit losses, no-load losses, short-circuit voltages, no-load current are selected from table. 7.3 [7]. The cost of transformers is selected from [8]:

In the first option we consider two transformers with the power of 6300 kVA.

Option 1 (O1):

For 6300 kVA oil transformer:

$$S_T = 6300\, kVA$$
$$TM - 6300/110$$
$$\Delta P_{short\,circuit} = 10\, kWt$$
$$\Delta P_{idling} = 44\, kWt$$
$$I_{idling} = 1\ \%$$
$$U_{short\,circuit} = 10,5\ \%$$
$$\text{Price} = 300\,000\, uah$$

In the second option we consider two transformers with the power of 10000 kVA.

Option 2 (O2)

$$S_T = 10000\, kVA$$
$$TM - 10000/110$$
$$\Delta P_{short\,circuit} = 58\, kWt$$
$$\Delta P_{idling} = 14\, kWt$$
$$I_{idling} = 0,9\ \%$$
$$U_{short\,circuit} = 10,5\ \%$$
$$\text{Price} = 500\,000\, uah$$

From [9] page 86 we select the change of losses factor:

$$K_{ch} = 0,02 \quad kWt / kVAr\,.$$

The losses of electric power are presented:

O1:

$$\Delta Q_{idling} = 6300 \cdot \frac{1}{100} = 63\,kVAr\ ;$$

$$\Delta Q_{short\,circuit} = 6300 \cdot \frac{10,5}{100} = 661,5\,kVAr\ ;$$

$$\Delta P'_{idling} = 10 + 0,02 \cdot 63 = 11,26\,kWt\ ;$$

$$\Delta P'_{short\,circuit} = 44 + 0,02 \cdot 661,5 = 57,23\,kWt\ ;$$

$$\Delta P'_{1} = 11,26 + 0,862^{2} \cdot 57,23 = 53,799\,kWt\ .$$

O2:

$$\Delta Q_{idling} = 10000 \cdot \frac{0,9}{100} = 90\,kVAr\ ;$$

$$\Delta Q_{short\,circuit} = 10000 \cdot \frac{10,5}{100} = 1050\,kVAr\ ;$$

$$\Delta P'_{idling} = 14 + 0,02 \cdot 90 = 15,8\,kWt\ ;$$

$$\Delta P'_{short\,circuit} = 58 + 0,02 \cdot 1050 = 79\,kWt\ ;$$

$$\Delta P'_{1} = 15,8 + 0,543^{2} \cdot 79 = 39,106\,kWt\ .$$

The losses for both transformers are given:

O1:

$$\Delta P'_{1,2} = 2 \cdot 53,799 = 107,597\ kWt$$

O2:

$$\Delta P'_{1,2} = 2 \cdot 39,106 = 78,212\,kWt$$

The switch-on time of a power transformer is:

$$t = 365 \cdot 24 = 8760 \text{ hours.}$$

Electricity losses during the year will be:

$$\Delta E = \Delta P'_{1,2} \cdot t\ .$$

O1:

$$\Delta E = 107,597 \cdot 8760 = 942549,794 \text{ kW/hour;}$$

O2:

$$\Delta E = 78,212 \cdot 8760 = 685136,102 \text{ kW/hour.}$$

The cost of 1 kW of electricity for an industrial enterprise is [10]:

$$c = 2,7515 \text{ UAH.}$$

The cost of electricity losses during the year is:

$$C_e = \Delta E \cdot c .$$

O1:

$$C_e = 942549,794 \cdot 2,7515 = 2593425,758 \text{ UAH;}$$

O2:

$$C_e = 685136,102 \cdot 2,7515 = 1885151,984 \text{ UAH.}$$

Capital costs for the two options are:

O1:

$$K_1 = 2 \cdot 300 = 600 \text{ thousand UAH;}$$

O2:

$$K_2 = 2 \cdot 500 = 1000 \text{ thousand UAH.}$$

Annual operating costs are determined according to the formula:

$$C_a = \phi \cdot K ,$$

in which ϕ is the depreciation factor on the power transformer, it is taken as equal to:

$$\phi = 0,1 .$$

O1:

$$C_a = 0,1 \cdot 600 = 60 \text{ thousand UAH.}$$

O2:

$$C_a = 0,1 \cdot 1000 = 100 \text{ thousand UAH.}$$

The total annual costs will amount to:

$$C = C_e + C_a$$

O1:

$$C_1 = 2593 + 60.0 = 2653 \text{ thousand UAH};$$

O2:

$$C_2 = 1885 + 100.0 = 1985 \text{ thousand UAH}.$$

The payback period is:

$$T_{ок} = \frac{K_2 - K_1}{C_1 - C_2} = \left|\frac{1000-600}{2653-1985}\right| = 0,6\ року\,.$$

Therefore, the calculations showed that the best selection option is 10000/110 oil power transformer. It should also be noted that the installation of a more powerful power transformer in the future will increase the load.

We will calculate the economic efficiency when installing a 10000/110 oil power transformer and not 6300/110 oil power transformers, it will amount to:

$$E = C_1 - C_2 = \left|2653 - 1985\right| = 668 \text{ thousand UAH.}$$

We choose two power transformers of 10000/110/10 oil transformer type with catalog data [7]:

$$S_{nom} = 10 MVA;$$

$$U_{nomHV} / U_{nomLV} = 110/10\, kV\,;$$

$$\Delta P_{idling} = 14\, kWt;$$

$$\Delta P_{short circuit} = 58\, kWt;$$

$$u_{idling} = 10,5\%\,;$$

$$I_{hort circuit} = 0,9\%\,.$$

This power transformer has the OLTC device $\pm 9 \times 1,5\%$ in the neutral of the HV winding.

3.3 Selection of overhead wires

Taking into consideration the fact that all existing overhead lines of a given network are made of AC-120/19 brand wire, for new 110 kV overhead lines we choose the same brand of AC-120/19 wire.

Wire line parameters [7]:

$$r_0 = 0.249 \text{ Ohm/km;}$$

$$x_0 = 0.427 \text{ Ohm /km;}$$

$$b_0 = 2.66 \cdot 10^{-6} \text{ Ohm /km.}$$

The permissible current *(I_{per})* of the wire at heating conditions is 390 A (with the air temperature of +25 C).

The maximum current that can flow along the lines corresponds to the load of "Losiach" substation.

$$I_{\max} = \frac{S_{Sub}}{\sqrt{3} \cdot U_{nom}} = \frac{10{,}863}{\sqrt{3} \cdot 110} = 57\,A\,/$$

Thus, $I_{\max} = 57A < I_{per} = 390A$, AC-120/19 wire passes full-load amperage.

3.4 Determination of parameters of elements and formation of the electric power network equivalent circuit diagram.

The calculation scheme of the electric power network is formed from the power lines and transformers equivalent circuit diagrams.

110 kV overhead power lines are represented by a U-shaped equivalent circuit diagram.

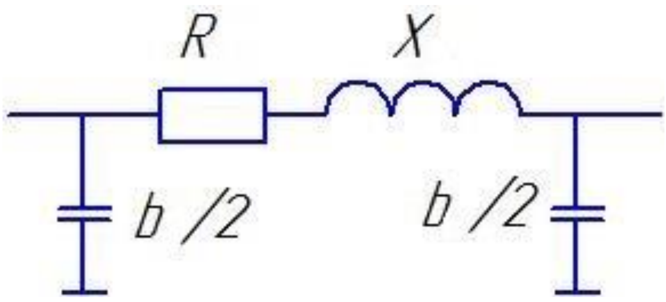


Fig. 3.4 - U-shaped line equivalent circuit diagram

Three-winding transformers are represented by a three-beam equivalent circuit diagram.

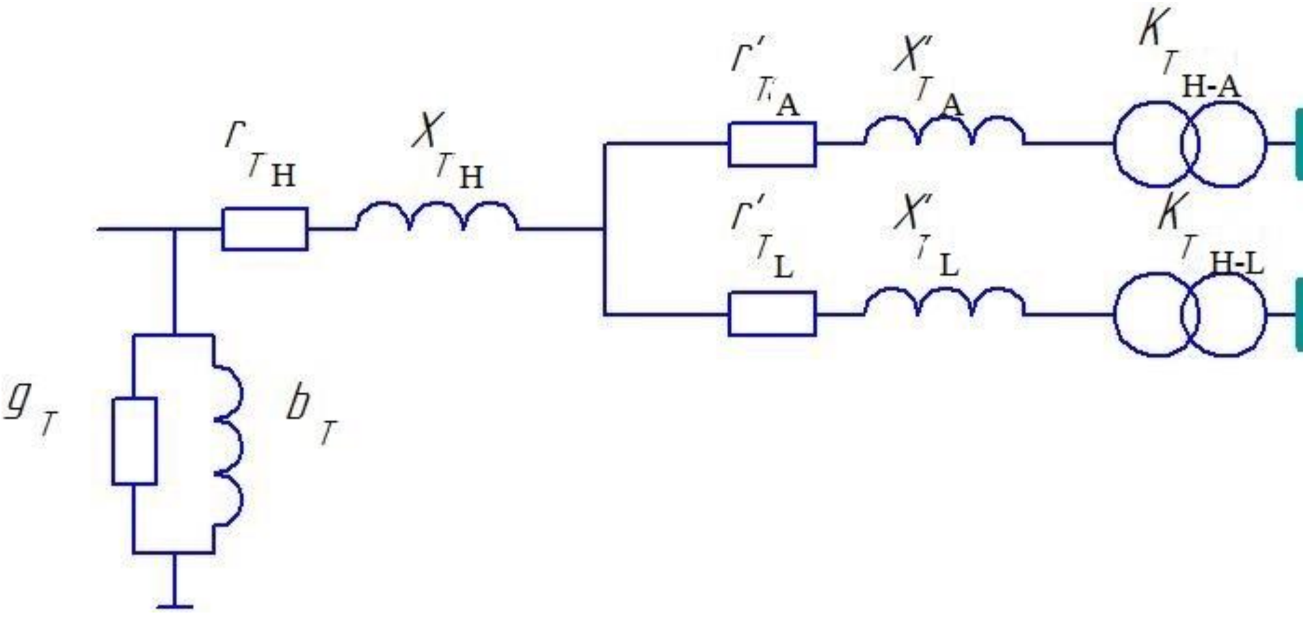


Fig. 3.5 - A three-winding transformer equivalent circuit diagram

Parameters of elements of a three-winding transformer equivalent circuit diagram are determined according to the following formulas:

$$r'_{\text{тH}} = r'_{\text{тA}} = r'_{\text{тL}} = \frac{\Delta P_{short\,circuit} \cdot U^2_{nom}}{S^2_T};$$

$$x'_{\text{тH}} = \frac{0.5(u_{\text{кH-A}} + u_{\text{кH-L}} - u_{\text{кA-L}})}{100} \cdot \frac{U^2_{nom}}{S_T};$$

Зм.	Лист	№ докум.	Підпис	Дата	GW 17-025.00.00.000 EN	Лист

$$x'_{\text{тA}} = \frac{0.5(u_{\text{кH-A}} + u_{\text{кA-L}} - u_{\text{кH-L}})}{100} \cdot \frac{U^2_{nom}}{S_T};$$

$$x'_{\text{тL}} = \frac{0.5(u_{\text{кH-L}} + u_{\text{кA-L}} - u_{\text{кH-A}})}{100} \cdot \frac{U^2_{nom}}{S_T};$$

$$g_T = \frac{\Delta P_{idling}}{U^2_{nom}};$$

$$b_T = \frac{I_{idling} \cdot S_T}{100 \cdot U^2_{nom}};$$

$$k_{\text{H-A}} = \frac{U_A}{U_{\text{H}}};$$

$$k_{\text{H-L}} = \frac{U_L}{U_H}.$$

in which $r'_{\text{тH}}, r'_{\text{тA}}, r'_{\text{тL}}$ are respectively the active resistance of windings of high, medium and low sides of the transformer;

U_{nom} is rated voltage of the main input of the transformer windings , U_{nom} *= 115 kV;*

S_T is rated power, MVA;

$P_{shotr\,circuit}$ is losses in copper, *kW*;

$x'_{\text{тH}}$, $x'_{\text{тA}}$, $x'_{\text{тL}}$ are respectively the active resistance of windings of high, medium and low sides of the transformer, *Ohm;*

$u_{\text{кH-A}}, u_{\text{кA-L}}, u_{\text{кH-L}}$ are short-circuit voltage of the respective pairs of windings;

g_T , b_T are respectively active and reactive conductivity of the transformer, *S*;

ΔP_{idling} is idling losses, *kW*

I_{idling} is no-load current, % of I_{nom}.

A double-winding transformer equivalent circuit diagram is presented in Fig. 3.6.

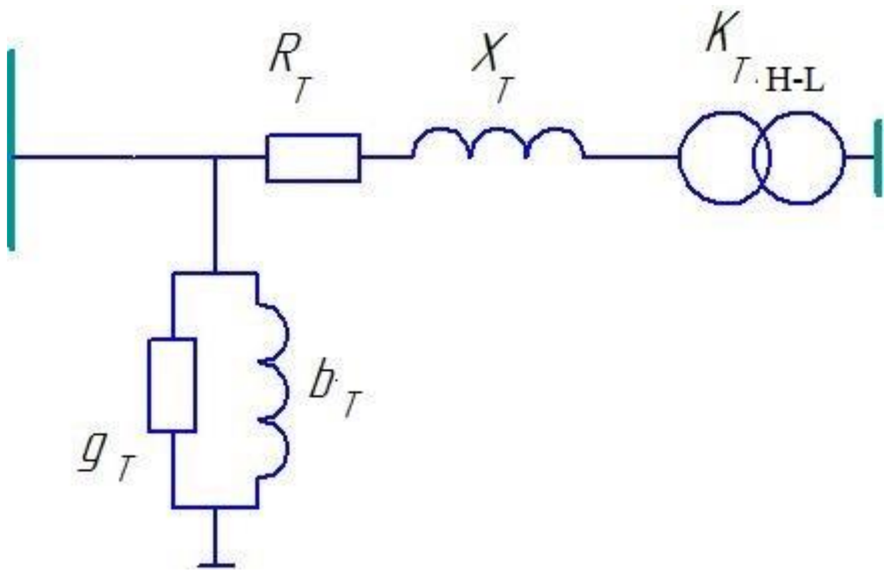


Fig. 3.6 - A double-winding transformer equivalent circuit diagram

A double-winding transformer equivalent circuit diagram parameters:

$$r_T = \frac{\Delta P_{short\,circuit} \cdot U_{nom}^2}{S_т^2};$$

$$x_т = \frac{u_{short\,circuit}}{100} \cdot \frac{U_{nom}^2}{S_т};$$

$$g_T = \frac{\Delta P_{idling}}{U_{nom}^2};$$

$$b_T = \frac{I_{idling} \cdot S_T}{100 \cdot U_{nom}^2};$$

$$k_{тH\text{-}L} = \frac{U_L}{U_H}.$$

We make the electric power network equivalent circuit diagram (Fig. 3.7). The power supply unit is “Borshchiv” substation.

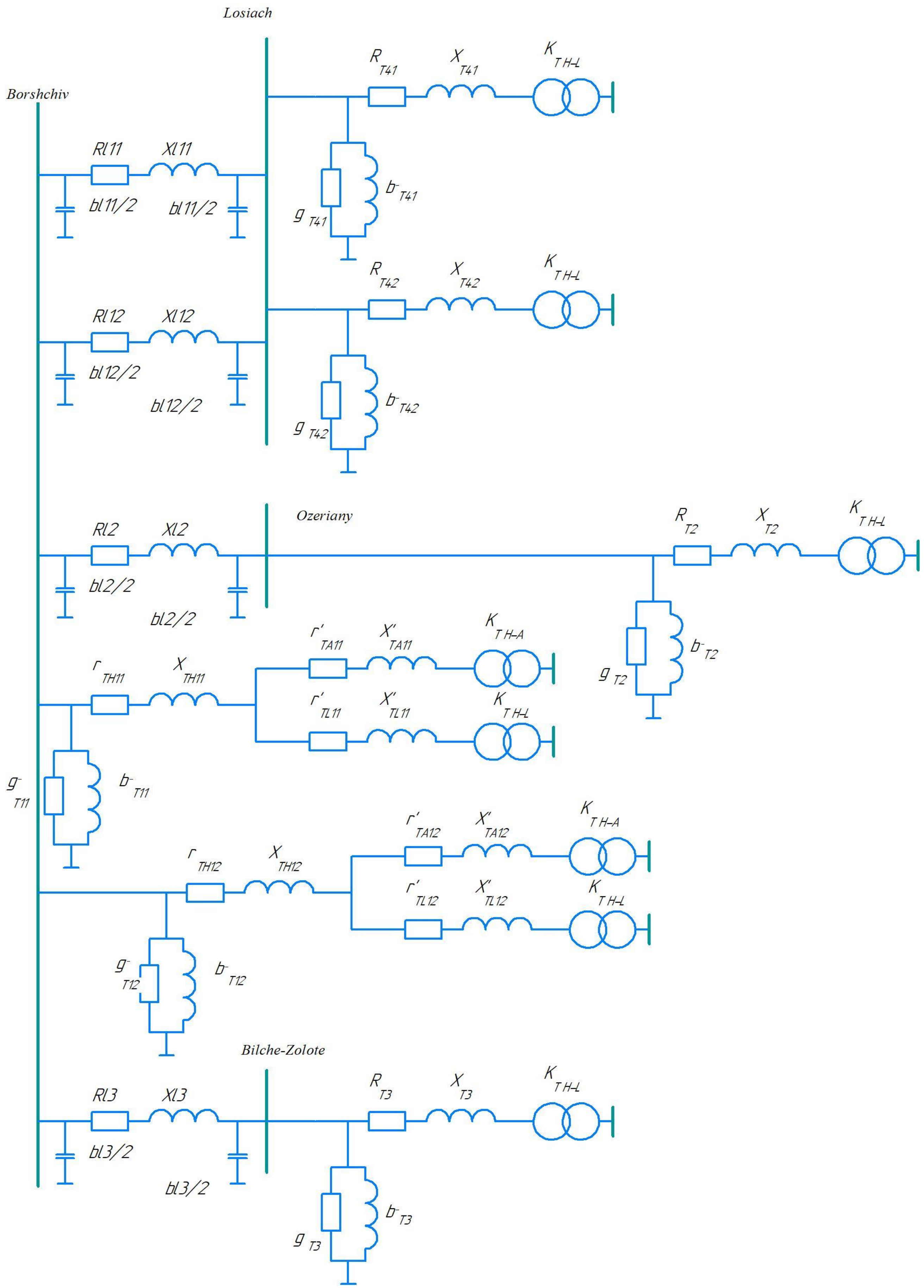


Fig. 3.7 – The electric power network equivalent circuit diagram

3.5 Typical operation modes

There are three typical network operation modes [11]:

1) the maximum mode - a mode in which consumers are characterized by maximum electricity consumption. In this mode, the network loses maximum power and voltage;

2) the minimum mode - a mode in which there is a minimum consumption of electricity. The mode is characterized by minimal power losses, voltage levels on the substation busbars increase;

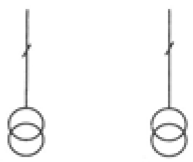
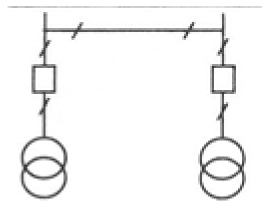
3) the post-emergency mode - this is the mode that occurs after the emergency shutdown of individual elements of the electrical power network (lines or transformers). The mode is characterized by the most difficult working conditions for the equipment.

3.6 Variants of the main scheme of electrical connections

The choice of the scheme is made using the recommended schemes of switchgear for unified substations 35-330 kV *[7, 12]*.

According to the recommended switchgear schemes for unified 35-330 kV substations, two options can be used. In the table. 3.1 shows a list and scope of 110 kV circuits that can be used for our case.

Table 3.1 - List and scope of 110 kV high voltage circuits [7, 12]

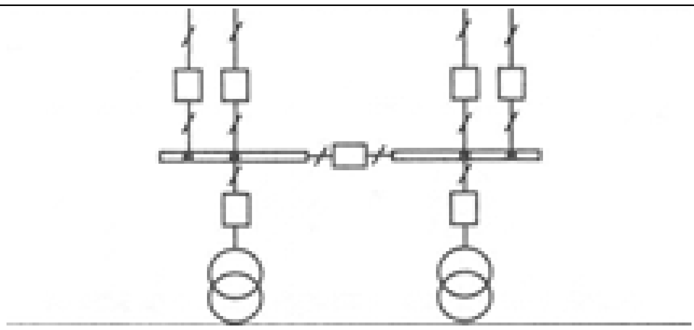
Schema code		110-1	110-2
Schema name		Two transformer line blocks with disconnectors	Two blocks line-transformer with switches and non-automatic jumper on the side of the lines
Conditional image of the scheme			
Scope	Voltage, kV	110-330	35-220
	Side	High voltage	High voltage
	Number of lines	2	2
Additional conditions		1. Dead-end substations located in areas with polluted atmosphere. substations are fed by lines without branches. 2. Coverage of the transformer with linear protection from the supply end or transmission of the tele-switching pulse	Dead-end and branch substations

In the previous section of the qualification work, the first option was proposed as the most appropriate. The construction of a dead-end Losiach substation will save money on the construction of a new power line and an open 110 kV switchgear. The second version of the connection scheme will be more appropriate.

A two-wheeled power line approaches the high side of the substation. In order to connect this two-circuit power line to the high voltage busbars of the substation, we use the second scheme of electrical connections - "Two blocks of line-transformer with switches and non-automatic jumper on the side of the lines" [7, 12]. The scheme is used for dead-end substations.

Table 3.2 shows a possible connection diagram for the low side of the substation.

Table 3.2 - List and scope of 35 kV circuits for low voltage [7, 12].

Schema code		35-5
Schema name		One partitioned busbar system
Conditional image of the scheme		
Scope	Voltage, kV	35
	Side	High voltage, medium voltage, low voltage
	Number of lines	3 and more
Additional conditions		1. For high voltage node substations of 35 kV network and medium voltage and low voltage at 110-220 kV substations 2. Allowed at the beginning of the development of the circuit

Therefore, for the 10 kV side of the Losiach substation, the following scheme must be used: One busbar system partitioned with a switch. As mentioned earlier, this circuit is used in the first stage of development of the low voltage circuit of the Losiach substation.

In fig. 3.8 shows the connection diagram of 110 kV.

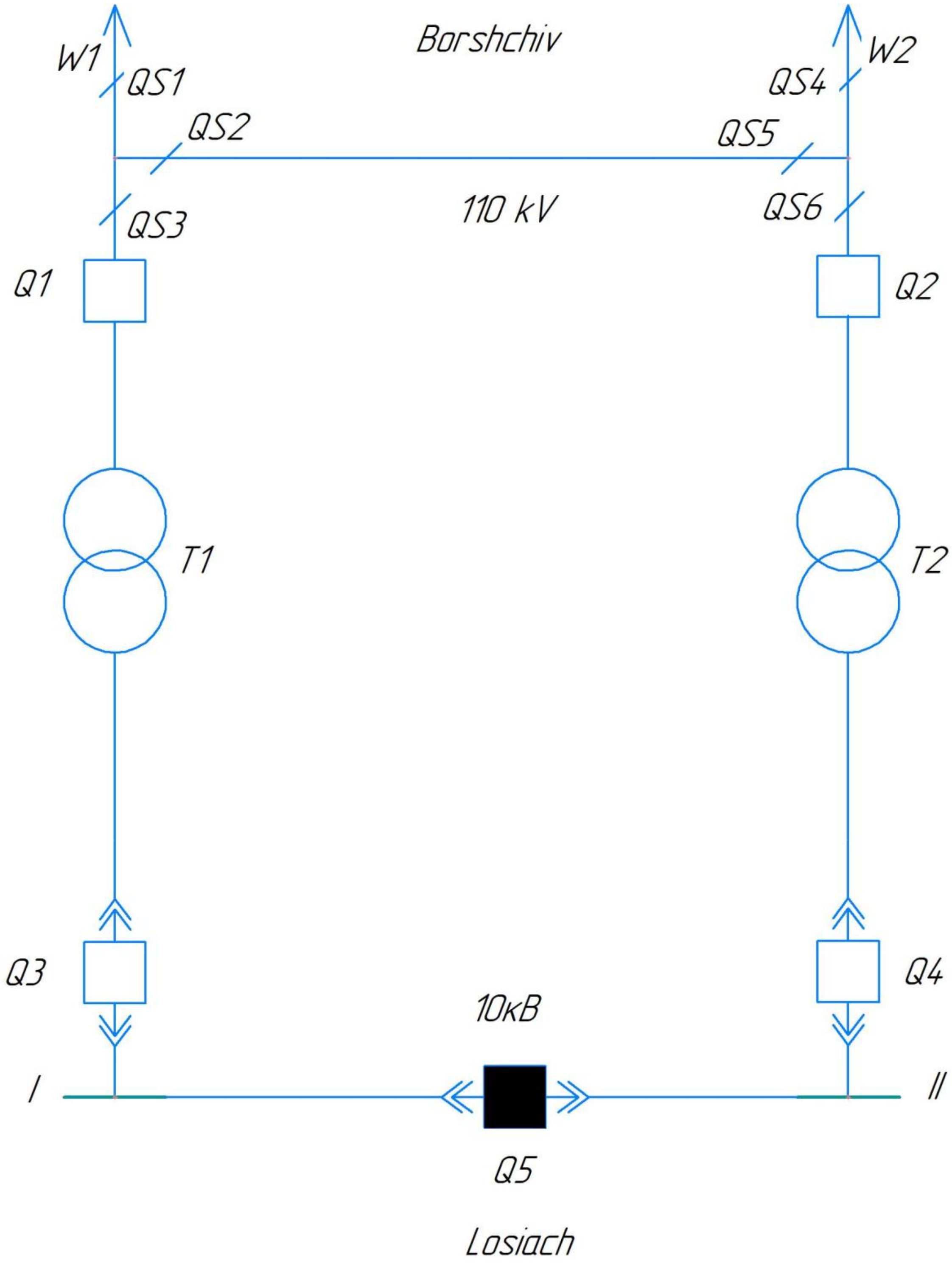


Figure 3.8. Connection scheme at Losiach substation

This diagram indicates:

- W1-W2 - overhead power lines;
- Q1-Q2 - switches on the high side;
- QS1-QS6 - disconnectors;
- T1-T2 - power transformers;
- Q3-Q4 - switches on the low side;
- Q5 - automatic reserve activation.

This scheme "Two blocks of line-transformer with switches and non-automatic jumper on the side of the lines", shown in Fig. 3.8, used on the high side of the switchgear 35-220 kV at dead-end substations or branch substations. In this case, the switchgear must be connected to the lines by a blind branch. The circuit is more flexible than the "Two-block line-transformer with disconnectors" scheme due to the use of a non-automatic jumper with two disconnectors.

The algorithm of this scheme is as follows (the scheme is shown in Fig. 3.8).

If one of the two lines W1 or W2 is switched off, a jumper with two disconnectors is used. In normal substation operation, the jumper cannot be turned on. That is, for operational reasons, one of the jumper disconnectors should be turned off and the other turned on. Accordingly, in the event of a short circuit on one of the lines, the protection will not unlock the second line.

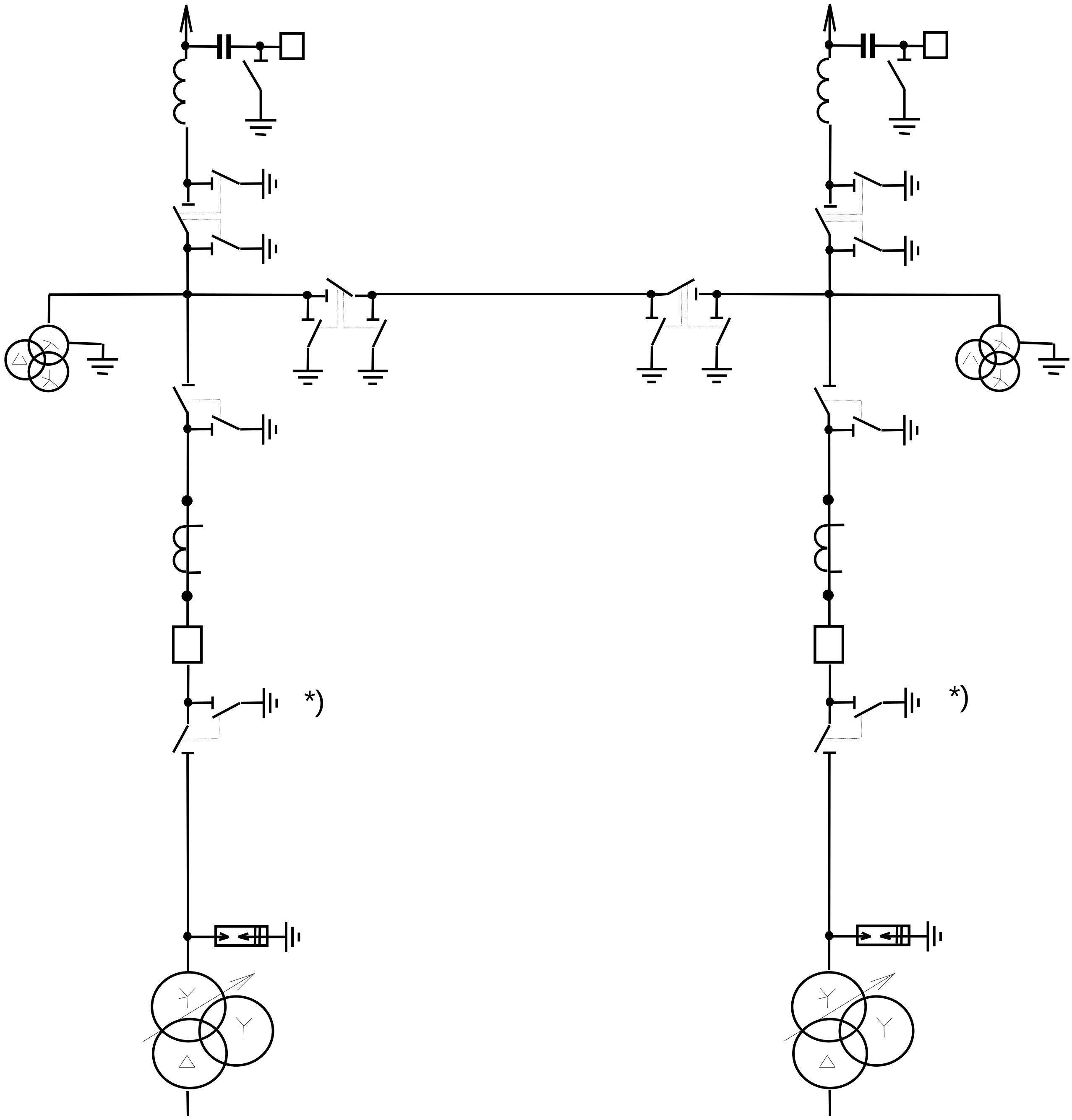


Figure 3.9. Scheme “Two blocks of line-transformer with switches and non-automatic jumper on the side of the lines”

Low side circuit "One busbar partitioned section" is used when installing transformers in which 6-10 kV low voltage windings are not split.

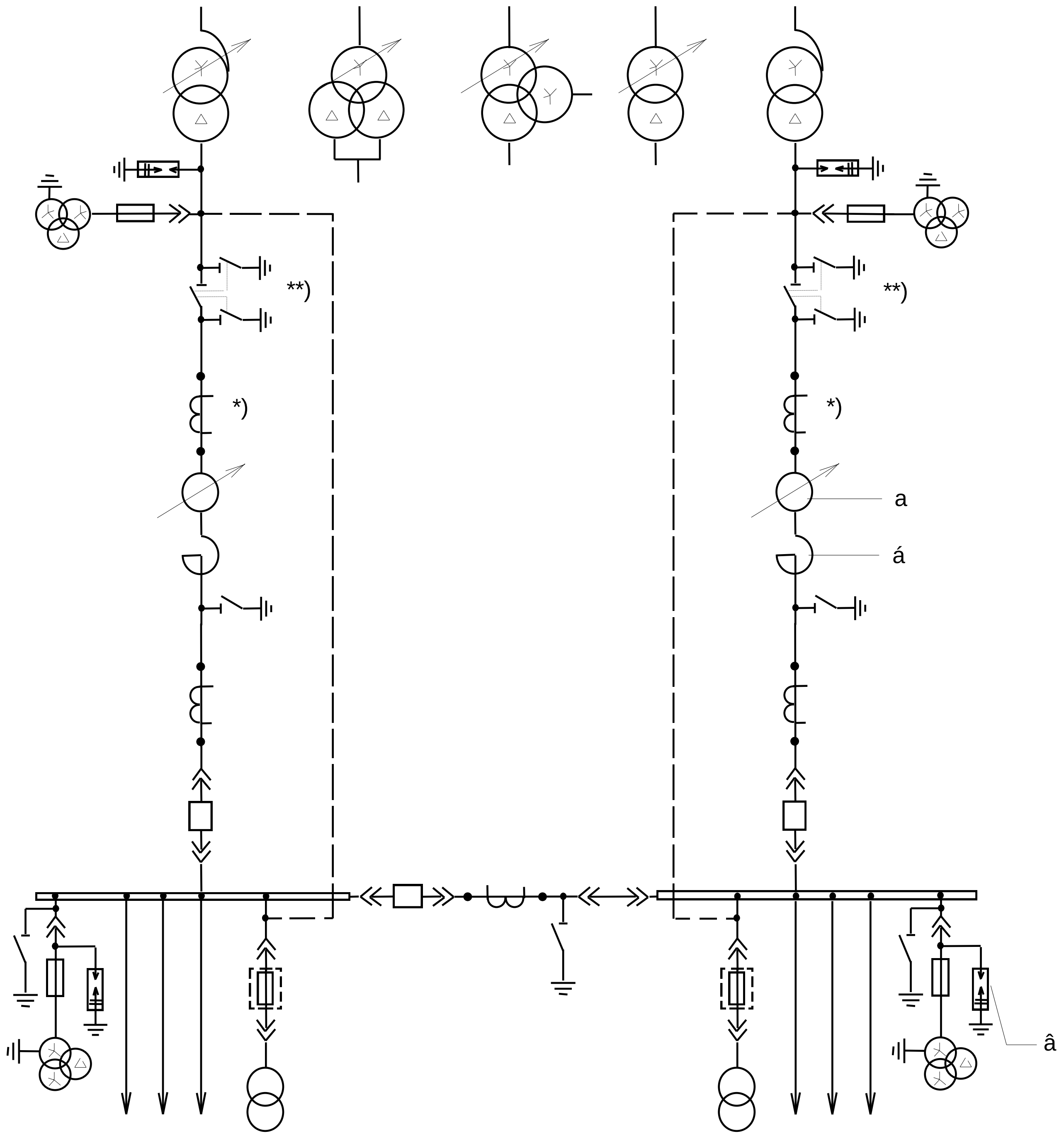


Figure 3.10. Low side diagram “One busbar partitioned system”

4 LABOUR OCCUPATIONAL SAFETY AND SECURITY IN EMERGENCY SITUATIONS

4.1 Electric shock Hazards and controls and inadvertent activation of equipment.

What is electric shock? electric shock is a sudden stimulation of the body nervous system by an electric current which can cause pain, injury, or death. although it is usually painful, electric shock is not always associated with actual damage to the body tissues. the most common sensation is stabbing and numbing pain at the points of current entry and exit and sometimes along the path of the current through the body.

Any time a person comes in contact with an energized conductor there is a potential for electrical shock. as in the example, current will flow through the human body if it becomes part of an electric circuit when the potential difference (voltage) is adequate to overcome the body`s resistance in the example, the man became part of the circuit because his body became a path of least resistance to ground.

The five principal ways that people experience electrical shock:

1. contact with a normally bare energized conductor,

2. contact with a normally insulated conductor on which the insulation has deteriorated or been damaged so that it is no longer protective,

3. equipment failure that results in an open or short-circuit, which, in turn causes the current to flow in an unexpected manner,

4. static electricity discharge,

5. lightning strike.

One common situation and a frequent cause of electrical injuries, is contact with live, overhead power lines. Examples include the boom of a crane, the boom of a cherry picker a raised dump truck bed, a metal ladder the metal mast of a sailboat, or any number of construction, maintenance, or recreational tools and vehicles inadvertently coming into contact with high-voltage, over head lines. when this happens, and a person is in contact with the tool or vehicle, the high voltage often means severe injury or death.

High-voltage sources are not restricted to overhead lines. although safety codes require high-voltage equipment to be enclosed, injuries and fatalities continue to occur. failure to secure the enclosures against unauthorized entry has led to injuries involving people from the curious to the vandal. at a minimum, such enclosures should always be designed with a locking system that can only be opened by trained and authorized individuals. other methods, such as a system that will automatically cut power when an enclosure is opened,

Electrical consumer products and appliances in the home are also potential sources of shock if protective covers are damaged or removed. typically, some conductors inside electrical equipment are not insulated because unskilled human contact is not expected. when unskilled or unsuspecting people dismantle or break through protective enclosures, there is a potential for shock.

In many cases a conductor is covered with an insulating material that keeps a current from passing to another conductor, including the human body. if, however, the insulation is defective by design, deterioration, or damage, there is a high potential for equipment failure or electric shock. deterioration or damage.

The heat may also be part of the operating environment. for example, the insulating materials used in or near equipment that produces high temperature as a normal part of operation must be capable of withstanding the heat for the designed life of the system. essentially, circuit designs that require very low operating energies or design precautions that immediately cut power when an overload occurs are good preventive measures. processes involving high temperatures as a normal operating characteristic call for cooling system to remove heat.

Cold environment can also damage insulating materials. some insulating materials may become brittle when exposed to cold environments. if you live in a cold climate, think of what happens when you leave a garden hose out for the winter. it becomes brittle and cracked. similarly, fluctuation in temperature may also effect an insulator. temperature fluctuations can expand and contract the insulating materials and possibly result in their mechanical failure and breakdown of the insulating properties.

Equipment failure that results in an open or short circuit:

Any time a conducting element in a circuit comes in contact with another conductor, whether it is part of the designed circuitry or not, a short circuit or very low impedance connection can occur. if you have ever driven behind a car on which the tail lights kept dimming or randomly blinking, you have likely witnessed the results of a short circuit. a common scenario with vehicle electrical systems as they age is the breakdown and deterioration of the insulation covering wires throughout the vehicle. if the conducting wire touches the frame or another conductor, the current will flow in unexpected paths and reduce or eliminate the current from the intended path, such as to the tail lights. similarly, if a conductor is severed, or if a path in a circuit is opened by other means, the open circuit may cause current to increase in other parts of the circuit, and to overload components, which may cause failure. although failed vehicle tail lights certainly create a hazardous situation.

Effects of shock on the human body:

If you are outside during an electrical storm, you can do several things to protect yourself from injury. if an all metal shelter or structure that has lightning protection is available, seek shelter within the structure. once inside, however, avoid contact with metal surfaces any part of a metal structure or electrical equipment that may become energized in the event of a lightning strike. the interior of the steel body of an automobile is considered an excellent shelter during an electrical storm, even if a high voltage line is touching it the rubber tires insulate the vehicle from ground. if you attempt to leave the car while the line is energized, however, you will provide the path to ground and will be severely, probably fatally, sh ocked.

In an open area or in a boat on a body of water, away from high points, it is advisable to lie down so that you are not the high point acting as the least resistance path. on land ravines or depressions are the best place to lie down.

A common error people make is to seek shelter from storms under large trees. the only tree in an area, or the highest tree, should be avoided because a lightning strike in the vicinity is most likely to hit that tree. in a wooded area, seek shelter near the smallest trees, well away from the tallest tree in the area.

5 to 25mA

Current in this range is referred to as let-go current threshold can be defined as the maximum current at which a person holding an electrode in each hand can still let them go. average let-go levels range from 9 to 16 milliamperes for men and 6 to 10.5 milliamperes for women. when a person threshold has been exceeded, the affected muscles freeze and it is impossible to voluntarily release the conductor. when this happens, the person may be exposed to current for a longer period, and the potential for injury is increased. the let-go threshold for direct currents occurs at 300 milliamperes or greater.

20 to 75 mA

Currents in this range can be very painful and injurious. prolonged contact may result in a fall always a potential source of injury unconsciousness, and death as inhibition of the respiratory muscles stops breathing. cessation of breathing can be caused by prolonged contraction of the respiratory muscles or by inhibition of the breathing control centers of the central nervous system.

When breathing stops because of respiratory muscle inhibition, it usually resumes once the current is stopped or after first aid assistance is given. death from asphyxiation will occur unless resuscitation is performed within 3 or 4 minutes maximum. respiratory arrest of a central nervous system origin is rare an requires two things: a passage of current through the brain, and a higher current.

Controlling the shock Hazard:

Equipment directly in contact eith the heart muscle. a shock hazard that would pose little danger in a normal environment can be lethal in these situations. in certain industries or situations, therefore, special precautions, through design and procedure, are needed to minimize shock hazard.

Isolation:

Enclosures or barriers should be used to isolate unauthorized or untrained personnel from shock hazards, especially from high voltage systems. the isolating barriers must be so designed and located to eliminate contact with energized equipment and must be available only to trained and authorized people.

Marking:

Warnings posted at points of access to hazardous electrical systems should be marked with appropriate hazard information. As a designer, you should design to eliminate hazards. some equipment is however, inherently hazardous, especially if other hazard control methods are bypassed, as often happens during maintenance procedures. warning information, both written and color coded, must be located so that personnel will be informed at critical points during operation, installation, or maintenance procedures.

Warning devices:

Warning devices, such as sound or light, may be connected to an electrical system to indicate when it is energized. these are important in complicated, multi-function systems for which an operator must monitor a number of system is actually energized.

Grounding:

The earth can be looked at as an infinite store for electrons. given a conductive path to earth, or ground; a charge difference will eather draw electrons from or return them to the soil. the idea that the earth is an infinite electrical sump is not true. all current must flow in loops any current that enters the earth must also leave. in fact this is often the current path in electrocution or shock incidents, the person becomes part of the circuit.

GENERAL CONCLUSIONS

The following results were obtained:

1. The 110 kV electric network of Borshchiv district of electric networks of OJSC "Ternopiloblenergo" was analyzed, which allowed to carry out further development of 110 kV networks.
2. The calculation of active and reactive load on the tires of the substation "Losiach" for the smallest and largest modes of operation of the network.
3. Three possible variants of development of 110 kV electric network of Borshchiv district of electric networks are offered and the choice of dead-end substation “Losiach” is substantiated, which will allow to save money when building a new power transmission line and open 110 kV switchgear.
4. The substitution scheme for the analysis of the established modes of operation of the 110 kV electric network of Borshchiv district of electric networks is shown, which will allow to predict the overload of power transformers and overhead power lines.
5. The construction of an overhead power transmission line using the AC-120 wire and the installation of a two-transformer substation with a capacity of 20 MVA are substantiated.
6. The main circuit diagram of the substation for the 110 kV and 10 kV switchgear has been selected.

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