REPUBLİC OF AZERBAİJAN

On the right of the manuscript

ABSTRACT

of the dissertation for the degree of
Doctor of Philosophy

INCREASING THE EFFICIENCY OF ENERGY SUPPLY IN THE ASYMMETRIC MODE OF DISTRIBUTION NETWORKS

Specialty: 3341.01 - Power plants (electrical part) and power systems

Field of science: Technical sciences

Applicant: **Naib İsmixan Hacıyev**

BAKU – 2022

The dissertation work was carried out on the basis of The results of research and experiments developed by the "Azerenergy" power system, and plans for 2012-2021 years implemented and included in the reports of the "Power system" department.

Scientific supervisor: Doctor of Technical Sciences, professor
Ashraf Balamat oglu Balametov

Official opponents: Doctor of Technical Sciences, professor
Abdulla İlyasovich Abdulkadirov

Doctor of Technical Sciences
Elchin Jalal Gurbanov

PH.D. in technical sciences
Elshan Faxraddin Sultanov

Dissertation council ED 2.04 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at Azerbaijan State University of Oil and Industry

Chairman of the Disertation council: Doctor of Technical Sciences, professor
Nurali Adil Yusifbeyli

Scientific secretary of the Disertation council: PH.D. in technical sciences
Shukur Nariman Nasirov

Chairman of the Scientific seminar: Doctor of Technical Sciences, professor
Asker Mammedgulu Kuliyev

İMZANI TƏSDİQ EDİRƏM
ADNSU-nun elmi katibi
dosent N.Əliyeva

GENERAL DESCRIPTION OF THE DISSERTATION

The actuality of the topic. Energy has the greatest impact on our lives of all areas of human activity. Our civilization is dynamic, and all the changes that take place in our lives require, first of all, energy consumption.

Power supply is determined by two factors - the quality and reliability of electricity. Its price, shape and frequency are characterized by a constant sinusoidal voltage. These parameters may vary within the small limits specified in the regulatory documents for power supply and do not impair the operation of electrical equipment. Even the best energy production and distribution systems cannot be completely reliable. There is a long way from the power plant to the end user through power lines, transformer substations and distributors. The further away from the source, the problems resulting from the quality and reliability of the power supply, as a result of malfunctions in the operation of electrical equipment, will manifest itself in both household electrical appliances and office and industrial electrical equipment.

Problems with power supply occur in the following cases:

Density in the transmission line; short circuit or lightning strike; availability of industrial and household electrical appliances with high pulse energy consumption in the supply line: argon welding equipment, heaters, electric motors, laser printers, copiers, etc .; poor quality electrical wiring in the building; breakdown or malfunction of power substation equipment; power line breakage; other reasons.

The above causes of power supply problems are manifested by a significant change in the parameters of the mains voltage: instability of its price, shape and frequency, insufficient current strength, unreliability, ie, its complete disappearance; pulse voltage, ie a short-term voltage increase of not more than one or two cycles of 100 percent or more of the rated voltage; voltage - a sharp short-term decrease (up to several hundred milliseconds) during which the voltage decreases by 15-100%;
overvoltage (overvoltage in the network) - an increase in voltage by more than 110% of the nominal value, in which case there may be a

sharp drop in load, low voltage in the network when connecting powerful devices or changing network switches; Because harmonics can pass through an electrical network, electrical equipment hundreds of miles away can be a harmonic source; frequency oscillations, which manifest themselves in less network power sources, are more common in backup power systems, such as generators operating in backup mode; noise (electromagnetic accumulation) - the reception of weak voltage from other power and signal lines, strong radio communication or between the "ground" contacts of electrical outlets in different places.

Asymmetric modes are caused by three reasons: unequal phase loads of network elements caused by the operation of a consumer with an unstable phase load (for example, electric stoves) and single-phase electrical consumers (this is especially noticeable in 0.4 kV networks). operation of lines caused by a short-term shutdown of one of the phases of the line during short circuits or longer breaks during phased repairs, the presence of reactors not on all phases of the line, etc. inequality of the phase parameters of the lines.

Thus, the asymmetry of currents (voltages) leads to an increase in power losses in all elements of the electrical network, which is associated with the flow of reverse and zero sequence currents.

The deterioration in the quality of electricity occurs through the fault of both power supply organizations (voltage trend) and consumers themselves (coefficients of non-sinusoidality, negative and zero sequence).

Currently, individual houses are being built far from the centers of settlements. Connection is carried out according to previous standards without verification. Tension is rising, norms are being broken. The level of design, connection and operation of HVAC 0.4 kV shows that the design, connection and level of operation of this network must be developed in accordance with the requirements of the day.

In rural power networks at low levels of operation, these losses are greater due to the increase in the low specific load and the asymmetry of phase loads along power lines. The specificity of low voltage electrical networks is especially evident in industrial and municipal rural EPS.

The main reason for the occurrence of long-term asymmetric modes of electrical systems is the asymmetry of the distribution of electricity consumers over the phases of the network.

A great contribution to the development of methods for calculating the quality and losses of electricity, as well as methods and means of reducing these losses due to current asymmetry in 0.4 kV networks I.A. Budzko, V.E. Vorotnitsky, I.V. Zhezhelenko, Yu.S. Zhelezko, F.D. Kosoukhov, V.G. Kuznetsov, given by M. S. Levin.

CIS scientists I.A. Budzko, V.E. Vorotnitsky, I.V. Zhezhelenko, Yu.S. Zhelezko, F.D. Kosoukhov, V.G. Kuznetsov, M.S. Levin and Azerbaijani scientists N.R. Rakhmanov, O.S. Mamedyarov, A.K. Guliyev, A.B. Balametov.

Power losses in the electrical networks of the UES range from 4 to 10%. Most of the EE losses are in distribution networks.

One of the key issues is the development of measures to reduce POWER ENERGY losses and the establishment of its standards for checking technical and economic indicators.

Improvement of methods for accounting for POWER ENERGY losses in asymmetric modes of operation of the 0.4 kV electrical network is relevant.

The dissertation is devoted to the issues of ensuring the quality of electricity and the calculation and reduction of additional losses of electricity due to current asymmetry in 0.4 kV networks.

Goal of the dissertation. The purpose of the dissertation is the development of algorithms for increasing the efficiency of power supply to consumers in the distribution networks of the power system.

In accordance with the purpose of the research, the dissertation is mainly aimed at solving the following questions:

-Carrying out experimental work on the phase distribution of voltage and active power in the unbalanced load mode;

- Using the wavelet transform to obtain experimental data on the distribution of voltage phases,

- analysis of known methods for calculating power losses in unbalanced load mode;

- identification of areas of application of circuits for connecting the windings of power transformers in three-phase distribution electrical networks with a voltage of 10/0.4 kV;

- Development of methodology and software based on the calculation of current and voltage asymmetries, as well as additional energy losses.

Research methods. When solving the problems of the dissertation, the theoretical foundations of electrical engineering, electrical measurements, wavelet transform for processing experimental data, numerical methods of applied mathematics, and the matrix method for analyzing electrical circuits were used.

Main highlights, brought forward for dissertation defence:

1. Application areas of power transformer winding connection schemes in three-phase distribution electrical networks 10/0.4 kV;

2. Results of experimental work to determine the asymmetry of currents and voltages in 0.4 kV networks;

3. Methodology and software based on the calculation of current and voltage asymmetries, as well as additional energy losses.

Scientific value of the thesis. Development of methods for calculating the quality and losses of electricity, as well as methods for reducing losses due to current asymmetry in 0.4 kV networks.

The scientific novelty of the work

The main scientific results obtained in the dissertation are as follows:

1) Registration of regime parameters of electric power quality indicators in 0.4 kV distribution electric networks was performed with the application of modern digital measurement and reporting complexes, experimental results were processed, EE KG deviations were determined and appropriate measures were proposed [1, 2, 59].

2) Violation of EEGG norms in 0.4 kV electric networks, 10 ÷ 80% change of current asymmetry in phases, voltage level in consumers is less than the allowable limit (5 ÷ 10%) and it is recommended to take more detailed measures [59].

3) Analysis of existing measures to reduce losses in 0.4 kV networks and normalize the quality of EE, based on which proposed schemes of connection of windings of three-phase power

transformers, which are more cost-effective in three-phase distribution power networks with voltage 10 / 0.4 kV [4,5];

4) it is proposed to install or replace new decentralized 0.4 and 0.66 ÷ 1 kV distribution networks with new ones in order to ensure the efficiency and quality of electricity supply to consumers;

5) taking into account the asymmetry of currents and voltages in distribution networks, developed methodology and software that allows to determine the normative characteristics of power losses [12].

Theoretical and practical significance of the thesis. . The results obtained in the dissertation have both theoretical and practical significance.The theoretical significance of the work lies in the fact that the proposed methods and algorithms can be used to study the asymmetry of voltage and current in distribution networks and to distribute technical losses.

The practical significance of the study lies in the fact that the results of the study can be used to improve the quality of energy efficiency sold to domestic and industrial consumers, use in the workflow of experimental and theoretical information obtained by Azerbaijani electric power companies, bachelor's and master's programs of technical universities.

Approbation and implementation. The content of the research is reflected in 14 research papers. Among them: 5 articles and 9 Conference proceedings published in scientific collections and journals of Azerbaijan, and 2 articles were published abroad in journals recommended by the Russian Supreme Attestation Commission. 4 works are co-authored, 4 conference materials are published abroad.

Case application. The software developed on the basis of the developed methodology and algorithms was used to study the non-sinusoidality and asymmetry of voltage in the distribution networks of Azerenergy OJSC and to calculate technical losses.

The results of the dissertation work were used in reports on research work for Azerenerji OJSC.

The name of the organization in which the dissertation work is being carried out. The results of R&D were carried out on the basis of plans studied by the Azerenerji Power System and included in the reports of the Power System Modes Department for 2012-2021.

The volume of structural units of the dissertation separately and the total volume with a sign. The dissertation used introduction (15 pages), chapter I (27 pages), chapter II (40 pages), chapter III (15 pages), chapter IV (27 pages), result (2 pages) and 100 titles. bibliography (10 pages). The total volume of the dissertation consists of 21 tables, 45 figures and 3 graphs, consisting of 185,660 characters on 167 pages.

MAIN CONTENT OF THE WORK

The first chapter of the dissertation shows the need to correct the quality of electricity, analyze the main and additional indicators of the quality of electricity, study the quality of electricity.

The main function of the power system is the production, transmission and supply of electricity to consumers in accordance with the standards of efficiency, sustainability and quality of electricity.

The quality of electricity is the degree to which the parameters of electricity correspond to the set prices. The parameters of the EE indicate the voltage, frequency curve, shape of the electric current.

They distinguish between basic and additional indicators of electricity quality.

According to GOST 13109-99, the 11 main indicators of power quality include: frequency slope -f; Stabilized voltage trend (increase and decrease in nominal value) - Home; voltage change amplitude - Ut; flicker dose - Pt; the distortion factor of the sinusoidality of the voltage curve - KU; coefficient of organization of the n-th harmonic of the voltage of the KU (n); negative sequence voltage asymmetry coefficient -K2U; zero sequence voltage asymmetry coefficient -KoU; duration of a sharp drop in voltage -tn ; impulse voltage Uimp; transition coefficient of limit stress - KigU.

Chapter I analyzes the main indicators of power quality, in particular, the non-sinusoidal ratio of the voltage waveform, voltage asymmetry, electrical characteristics, ECG, the most likely causes of

ECG abnormalities, additional power quality indicators, studies of power quality indicators.

Ensuring the quality of electricity in electricity consumers can be explained by the following reasons:

- Measurement technique: Poor quality of electricity can affect the accuracy of electrical measurements.

- Delay of relay protection: Poor quality of electricity affects the operation of relay protection.

- shortening the service life of electrical equipment: Poor quality of electricity causes the equipment to expire quickly, which is accompanied by production costs.

- costs: Poor quality of electricity leads to increased production costs.

- electromagnetic compatibility: poor quality of electricity affects the joint operation of different types of electrical equipment.

The MATHCAD MKS package was used to simulate power quality indicators.

The main results of the first chapter are reflected in the author's works [1, 2].

In the second chapter of the dissertation work Spectral analysis and Fourier transform, Fundamentals of the wavelet method, Application of the wavelet method to non-sinusoidal voltage, reactive power in non-sinusoidal systems, comparative analysis of modeling by various methods of reactive power, power quality of an agricultural PES feeder The results of experimental studies on registration are given.

Distribution networks with voltages up to 35 kV are associated with increased control of operating modes due to distributed generation, modern switching equipment and flexible reactive power compensation devices, technical and information support within the concept of "smart networks" (Smart Grid).

Currently, distribution networks are actively implementing and developing technologies and other solutions to optimize smart homes and offices, energy storage systems, including the use of electric vehicles to adapt consumption schedules.

There is a growing need for finer control of network constraints due to the increase in modal and topological diversity, as well as the fact that they did not initially meet the operating conditions for which they were designed.

New opportunities are opening up for managing distribution networks, operating modes, so it is necessary to create control systems in accordance with the complexity of the facility.

The number of distribution network elements is greater than that of backbone networks, and the management of distribution networks requires a high degree of automation in managing operating modes. Such a control system seems impossible without an online calculation of the operating mode of the power grid based on the measurement of current electrical parameters.

Recently, the process of updating the measurement infrastructure both on local and foreign computers has begun, which has been significantly expanded and updated.

In table. 1 shows a fragment of the change in the phase of the current in field measurements carried out in the distribution ne

Table 1.

Current phase change in field measurements made in the distribution network

t	A	B	C
16:20:00	12,58	16,74	17,07
16:30:00	12,91	20,16	14,53
16:40:00	20,66	21,05	14,87
16:50:00	21,5	20,34	13,47
17:00:00	19,97	18,64	11,74
17:10:00	20,36	14,07	12,28
....	....	....	....

The Fourier transform is based on the following integral transformations:

$$F(v)=\int_{-\infty}^{\infty} f(x)\cdot e^{i\omega x}dx\,,\ F(x)=\int_{-\infty}^{\infty} F(v)\cdot e^{i\omega x}dv$$

Fourier analysis is suitable for stationary signals and cannot be applied to non-stationary signals whose parameters change over time or exist for a certain period of time.

The problems of spectral analysis and synthesis of time-limited experiments are partially solved by the Fourier transform with windows. Thus, the Fourier transform with a window allows you to take into account the changes in harmonics over time.

The other disadvantages of Fourier transform methods are as follows: Fourier conversion requires knowledge of the signal not only in the past but also in the future, even at a given frequency, which is a theoretical abstraction; the obligatory limitation of the number of harmonics or the spectrum of oscillations is not possible, both theoretically and practically (due to the Gibbs effect), after a straight Fourier transform; In Fourier series, the basic function is a harmonic oscillation that is mathematically defined in the time interval (-∞; ∞) and has parameters that do not change with time; individual characteristics of the signal (for example, interruptions, peaks) (-∞; ∞) cause a change in its frequency description in the frequency range and propagate to the entire frequency axis, which makes it virtually impossible to see them in the spectrum; it is impossible to determine the time-dependent properties of the signal and their nature due to the composition of the higher spectral complexes.

Given the difficulties of the Fourier method, the Wavelet analysis method, which is considered to be a modern and promising method in the process of data processing of stationary and non-stationary signals, has recently been used. The results obtained with the help of wavelet analysis in various fields have increased interest in this area and led to its development.

Wavelet analysis leads to finding the wavelet coefficients W (a, b). Spectrum W (a, b) allows one to describe the non-sinusoidal voltage in the time-frequency scale in three-dimensional space.

Fourier analysis shows the composition of higher harmonics and their levels, but it is difficult to determine the intervals of their existence in time and the nature of the change. Wavelet analysis clearly shows high-frequency harmonics, their location on the time axis, the nature and degree of change. Thus, wavelet analysis makes it possible to determine its non-sinusoidal distortions with high accuracy for any voltage fluctuations (stationary, non-stationary) under any conditions. This can be used to effectively control non-sinusoidal voltage readings in real time.

The above is reflected in the Fourier and Wavelet spectra of a specific non-sinusoidal signal, consisting of harmonics 1, 5, 7, 11 and 13.

The histogram of the initial stress values based on the results of level 5 analysis using the Haar wavelet is shown in Figure 1.

We also present some statistical estimates. For example, the average phase voltage was 218.4 V, and the maximum and minimum values \u200b\u200bof 221.5 and 216.1 V.

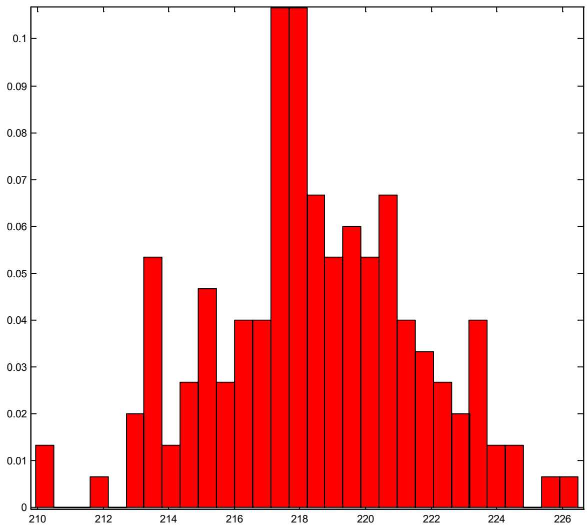


Figure 1. Histogram of voltage values

Reactive power of sinusoidal mode in a linear circuit

$$P = \frac{1}{T}\int_0^T u(t)\cdot i(t)dt = UI\cos(\psi_u - \psi_i) = UI\cos\phi,$$

$$Q = UI\sin\ \ ,\ S^2 = P^2 + Q^2$$

In electrical engineering, the concept of reactive power is accepted as an analogue of active power for a non-sinusoidal mode in a linear electrical circuit:

$$Q = \sum_{n=0}^{\infty} Q_n = U_1 I_1 \sin\ _1 + U_2 I_2 \sin\ _2 + \ldots$$

In non-sinusoidal modes, the circuit apparent power and distortion power are calculated as follows:

$$\mathrm{S} = \mathrm{UI} = \sqrt{\mathrm{U}_0^2 + \mathrm{U}_1^2 + \mathrm{U}_2^2 + \ldots} \times \sqrt{\mathrm{I}_0^2 + \mathrm{I}_1^2 + \mathrm{I}_2^2 + \ldots}$$

$$\mathrm{D} = \sqrt{\mathrm{S}^2 - \mathrm{P}^2 - \mathrm{Q}^2}$$

According to Budean, reactive power is calculated using the following formula:

$$\mathrm{S}^2 = (\sum \mathrm{P}_k)^2 + (\sum \mathrm{Q}_k)^2 + (\sum \mathrm{D}_k)^2$$

According to Budian, the reactive power for a harmonic signal K is defined as follows:

$$\mathrm{Q} = \sum \mathrm{Q}_k = \sum_{k=1}^{K} \mathrm{U}_k \mathrm{I}_k \sin\varphi_k$$

In addition, this formula $\mathrm{S}^2 = \mathrm{P}^2 + \mathrm{Q}^2$ does not agree with the formula, so for the total power, determined by the square root of voltage and current, one can write:

$$s^2 = \sum_n \mathrm{U}_n^2 \cdot \sum_n \mathrm{I}_n^2 \geq (\sum_n \mathrm{U}_n \mathrm{I}_n \cos\varphi)^2 + (\sum_n \mathrm{U}_n \mathrm{I}_n \sin\varphi)^2$$

In addition, Budyanu introduced the concept of distortion force, defined by the following formula:

$$D^2 = S^2 - P^2 - Q^2$$

Sharon's total reactive power is in the following expression:

$$S_Q = U\sqrt{\sum_{n\in N} I_n^2 \sin^2\varphi_n}$$

While the remaining extra power

$$S = \sqrt{S^2 - p^2 - S_Q^2}$$

is in the formula.

According to the IEEE standard, reactive power in the non-sinusoidal mode of the voltage and current equation is divided into two components: fundamental and harmonic:

$$u = u_1 + u_H, \mathrm{i} = \mathrm{i}_1 + i_H$$

$$u_1 = \sqrt{2}U_1 \sin(\omega t - \alpha_1)$$

$$i_1 = \sqrt{2}I_1 \sin(\omega t - \beta_1)$$

$$u_H = u_0 + \sqrt{2}\sum_{h\neq 1} U_H \sin(h\omega t - a_h)$$

$$i_H = i_0 + \sqrt{2}\sum_{h\neq 1} I_H \sin(h\omega t - \beta_h)$$

The harmonic distortion of the voltage and current curves is determined by the ratio of the RMS harmonics to the fundamentals:

$$P = \frac{1}{KT}\int_{\tau}^{\tau+KT} pdt = P_1 + P_H, \mathrm{P}_{11} = U_1 I_1 \cos\theta_1,$$

$$\mathrm{P_H} = \mathrm{P} + \mathrm{P_1} = \sum_{\mathrm{h}\neq 1} \mathrm{U_h I_h} \cos\theta_{\mathrm{h}}$$

According to Zarnetsky, the instantaneous values of voltage and current are determined by the Fourier order:

$$i = \sqrt{2}\sum_{k=1}^{K} U_k (G_k + jB_k)\cos(2\pi k f_0 t - \psi_k)$$

The effective value of current and active power can be found as follows.

$$I^2 = I_a^2 + I_S^2 + I_r^2 = \frac{P}{U^2} + \sum_{k=1}^{K} (G_k - G_e)^2 U_k^2 + \sum_{k=1}^{K} B_k^2 U_k^2$$

$$S^2 = P^2 + D_S^2 + Q_r^2$$

where D_s and *D*r are the scattering and reactive forces, respectively.

According to O. A. Mayevsky, the slip power should be calculated from the area of the current-voltage characteristic:

$$Q = -\frac{1}{\omega T}\int_0^T i\frac{du}{dt}dt = \frac{1}{\omega T}\int_0^T u\frac{di}{dt}dt;$$

In the definition proposed by Fourier, the current is divided into two parts. The phase angle of the first part is equal to the voltage and equal to the active power as Ia · U. The second part consists of the error and is called Ir. Then the two currents are defined by the following equations::

$$i_a = \frac{P}{U^2} u, \; i_r = i - i_a$$

This definition of reactive power for a sinusoidal signal is the same as for conventional reactive power.

On the other hand, the current IR error is very well defined and often used for this purpose.

The IEEE and Budeanu approaches were analyzed for two different cases using numerical examples. Basic speed f1 = 50 Hz. Table 2 shows the Budean reactive power values and Table 3 shows the IEEE power definition.

Table 2.

Determination of reactive power according to Budeanu

	Case 1	Case 2	Case 3	Case 4
S	9120	9696.4	6328.5	10042.
P	8272.2	8272.2	5196.2	9154.1
Q_b	3839.8	3839.8	3000	3839.8
D_b	0	3293.2	2012.5	1514.3

Table 3.

IEEE Power Determination

	Case 1	Case 2	Case 3	Case 4
S	9120	9696.4	6328.5	10042
S_{11}	9120	9120	6000	9120
S_H	0	0	0	886.7
S_N	0	3293.2	2012.5	4202.6
P	8272.2	8272.2	5196.2	8243.7
P_{11}	8272.2	8272.2	5196.2	8272.2
P_H	0	0	0	-28.54
Q_{11}	3839.8	3839.8	3000	3839.8
D_I	0	3293.2	0	3293.2
D_U	0	0	2012.5	2455.6
D_H	0	0	0	886.2
N	0	3293.2	3612.5	4202.6

The software was developed in the MATHCAD environment to simulate reactive power in various ways. Non-sinusoidal voltage and current were taken into account:

$$u(t) = 400 + 200 \cdot \sin(2\omega t) + 100 \cdot \sin(3\omega t)$$

$$i(t) = 3.75 \cdot \sin(\omega t - 55\frac{\pi}{180}) + 0.75 \cdot \sin(2\omega t - 70\frac{\pi}{180}) +$$
$$0.5 \cdot \sin(3\omega t - 75\frac{\pi}{180})$$

As a result of modeling reactive power by different methods, the values of reactive power determined in different theories can differ significantly.

The current-voltage characteristic of the sample under consideration is shown in Fig. 2.

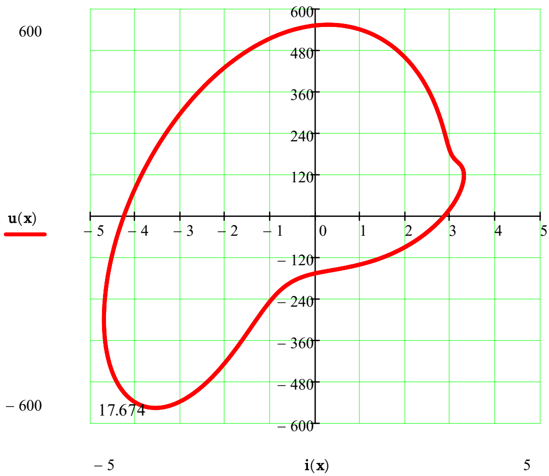


Figure 2 .Current-voltage characteristic of the sample

In order to determine the level of electricity quality indicators in a sample of the 0.4 kV electric network, regime registration of parameters was carried out on the 0.4 kV side of the 63 kVA transformer substation in the summer season and the experimental results were processed.

The results of modeling reactive power by various methods are given in Table. 4.

Table 4.

Results of modeling reactive power by various methods

Reaktiv power					
Budeanu	Sharon	Kusters-Moor	Shepherd-Zakikhani	İliovisi	Mayevskiy
1417	1461	1457	1461	828	828

From Table. 1 it follows that the simulation of a given reactive power by different methods can lead to different results.

The power loss reporting methodology and the MAHTCAD program were developed for unevenly loaded 0.38 kV three-phase fourth wire systems. The program is based on the principle of the so-called method (principle of superposition) for breaking down a complex scheme and evaluating its impact separately.

From Table. 4 it follows that this leads to the possibility of modeling this reagent by various methods.

It is shown that the distortion of the shape of the load current curve affects the magnitude of the voltage associated with the load.

In modern conditions, a significant increase in the weight of nonlinear current-voltage operators of electric current in the total load of electrical networks has led to a further increase in the level of higher harmonic complexes of voltage and current in supply networks. This situation requires that this factor be taken into account when implementing certain technical measures to improve the efficiency of electricity distribution in the distribution networks of the power system.

The main results of this chapter are reflected in the author's papers [3, 7, 8, 9, 13].

In the third chapter of the dissertation, the application of power transformer winding connection schemes in three-phase distribution electrical networks with a voltage of 10 / 0.4 kV, features of a decentralized energy saving scheme, a comparative analysis of low-voltage distribution electrical networks, economics of traditional ones are considered, and calculations of an energy-saving power supply system are performed.

The current traditional 0.4 kV distribution networks have a number of disadvantages: low transmission capacity of 0.4 kV networks; limiting the length of the allowable voltage, usually at a cost of 200-600 m, from the distribution substation to the consumer; excessive voltage drop and power loss on 0.4 kV lines; Commercial losses in networks 0.4 kV; Low quality indicators of electricity.

Combined distribution network 0.66-1 kV The advantages of a mixed distribution network 0.4 kV and 0.66-1 kV according to the concept of electrical networks 0.4 kV are as follows:

1. Reducing the length of 0.4 kV lines due to the input of 0.66 kV;
2. Excellent conductivity;
3. Reducing the area for the construction of distribution networks by reducing the number of transformer substations and security zones of overhead lines;
4. Reducing commercial losses;
5. Saving land for the construction of a distribution network, reducing the number of transformer substations, reducing costs by reducing the length of overhead lines;
6. ECG rise.

The third chapter also gives the reasons for the deterioration of the technical and economic performance of the distribution network, lowering the quality of electricity and leading to serious accidents due to the lack of accurate information on the characteristics and fundamental differences between the different circuits of power transformer windings.

Priority measures have been proposed to reduce technical losses in traditional power supply systems.

In order to determine the power losses, the network modeled the consumption modes for both power supply systems via Multisim (Figure 3). while saving energy, the losses amounted to 61.32 kW / h.

It was noted that the introduction of a decentralized energy saving scheme will allow abandoning 0.38 / 0.22 kV distribution networks, as well as overhead lighting networks passing through residential development.

A comparative analysis of low voltage distribution networks has been carried out.

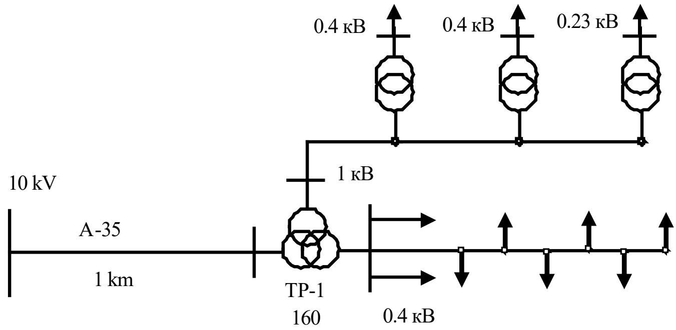


Figure3. Combined distribution networks 0.4 kV with a network of 0.66 -1 kV

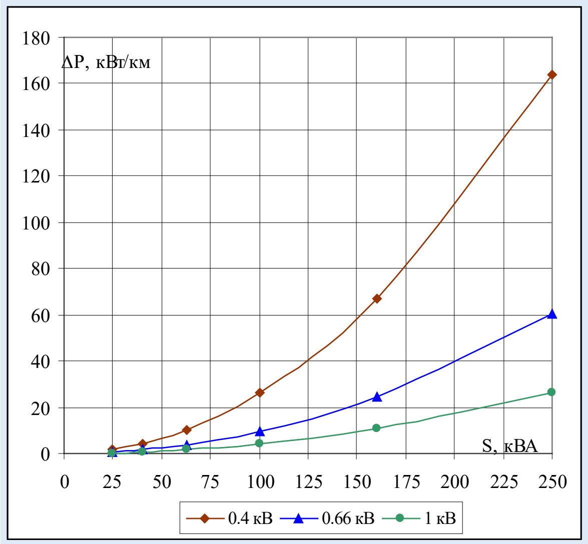
Economic calculations of the traditional and energy-saving power supply systems were carried out.

For an overhead line with a cross section of 35 mm, the dependence of the voltage drop on the transmitted power, the dependence of specific power losses on the transmitted power, and the dependence of the transmission line capacity on voltage were determined. On fig. 1 shows one of these relationships.

The calculation results show that the loss of electricity in the 0.66 kV network leads to an increase in the service range of energy consumers by 1.65 times compared to the 0.4 kV network. When using a voltage of 1 kV, the service range of energy consumers increases by 2.5 times.

As a result of the calculations, it was obtained that the power loss on a line 1 km long with a voltage of 0.66 kV is 2.7 times less than on a line of 0.4 kV. Power losses on a 1 km line with a voltage of 1 kV are 6 times less than on a 0.4 kV line.

Electricity is the only product that consumes part of its electricity when moving it from the place of production to the place of consumption, therefore losses are inevitable, and the task is to determine their economically justified level.



Graph 1. Dependence of specific power losses on transmitted power

Reducing electricity losses in electrical networks to a level that meets reasonable standards is one of the important areas of energy saving.

In the technical literature, the term "losses necessary for the normal, i.e. optimal operation of electrical networks" is usually used as "technological costs necessary for the transmission of electricity." The term power loss is usually applied to the part that exceeds the technological costs and can be reduced by organizational measures. However, in most cases, the term power loss is used.

Different literature sources use different approaches to calculate the additional losses of the active load.

To calculate the power loss norms for known circuits in 0.4 kV networks, the average load method used for 6-10 kV networks, or algorithms for the number of hours of maximum energy losses, are used.

Active power load losses are calculated by a known formula.

$$\Delta P = 3I^2 \cdot R = 3\frac{P^2 \cdot R}{U^2 \cdot \cos^2 \varphi}$$

where ΔP - are active power losses, Vt;

I- current intensity, A;

R- resistance, Om;

P-transmitted active power, Vt;

U-network voltage, V;

cosφ is the power factor.

The conventional power factor is calculated for sinusoidal current and voltage in a symmetrically balanced system as follows:

$$\cos\varphi = \frac{P}{S} = \frac{P}{\sqrt{P^2 + Q^2}}$$

where S- transmitted full power, VA;

Q - is the reactive power taken.

The conventional power factor is the cosine of the angle between the fundamental frequency voltage and the current and is related to the flow of reactive power. In foreign literature, it is sometimes called the displacement power factor. Thus, the power losses due to reactive power can be calculated as follows.

To estimate additional load losses in an asymmetric load, a power loss coefficient equal to the ratio of power losses in the asymmetric mode to losses in the symmetrical operating mode is used.

For power transformers and power lines where the forward and reverse resistances are equal

$$k_p = 1 + k_{2I}^2 + k_{0I}^2 \cdot \frac{R_0}{R_1}$$

k_P - coefficient of power losses in asymmetric load;

R_1-straight-line resistance, Ohm;

R_2 - reverse sequence resistance, Ohm;

R_0-zero sequence resistance, Om.

Then the active power losses in asymmetric mode are calculated by the following formula:

$$\Delta P = \Delta P_1 \cdot k_p = 3 \cdot I_1^2 \cdot R_1 \cdot k_p$$

ΔP_1 - active power losses in symmetrical mode, Watts.

At the same time, the existing methods are equipped with special estimation methods that determine the procedure for calculating losses in low-current networks.

0.4 kV power grids are the last stage in the process of transmitting EE from power plants to consumers. The accuracy of the detection of commercial losses depends on the accuracy of the calculation of technical losses of EE in 0.4 kV power networks. The difficulty of calculating the technical losses of EE in such networks is due to the following factors:

- large amounts of information with low accuracy;
-distribution of networks over large areas;
-dynamics of changes in the scheme and especially the mode parameters;
- four, three, two-wire stations;
-unequal loading of phases;

EE losses - power grid is one of the main economic indicators of the enterprise. Its price applies to all transmission systems, recording devices, etc. characterizes the efficiency of metrological support of measuring devices, energy sales activities, as well as technical and operational condition.

According to international practice, EE transmission and distribution can be considered economical if the level of relative losses of EE is 4-5%.

Loss of electricity at the level of 10% can be considered the maximum allowable from the point of view of the physics of its transmission through the networks.

If this level is less than 10%, then, as a rule, there is a commercial organizer in the losses.

The main results of this chapter are reflected in the author's papers [5, 6, 7, 8, 11].

The fourth chapter shows that the asymmetry of currents and voltages leads to an increase in power losses in power distribution elements in networks.

In the fourth chapter of the dissertation, the existing approaches to the calculation of EE losses in 0.4 kV distribution networks and methods for calculating EE losses in 0.4 kV distribution networks are studied.

A decrease in the quality of electricity leads to a deterioration in energy performance, a decrease in the reliability of the network and an increase in active energy losses, which leads to the consumption of active and reactive power.

In industrial networks, there are many unbalanced and non-linear loads that are sensitive to voltage fluctuations.

As the voltage quality decreases, the operating conditions of electrical equipment worsen, which leads to an increase in active power losses.

Features of agricultural power networks, a wide dispersion of EE consumers, a significant length of 10 (6) and 0.4 kV networks, small consumption prices at each node.

Electricity distribution networks with utility loads use transformers with a star-to-zero winding connection scheme with a high zero-sequence resistance, a resistance higher than the approximate positive-order resistance. With an asymmetric phase load in these transformers, a significant zero sequence voltage is generated, which causes an asymmetric voltage in the second side windings of the transformer. For a zero-sequence transformer, the voltage asymmetry coefficient is often greater than the allowable value.

Simeas Q devices were used to measure the ECG on the low voltage side of 10 / 0.4 kV transformer substations.

When the asymmetry coefficients of the reverse and zero sequence currents in the network are equal to 0.25-0.30, the power and power losses in the lines and transformers increase by 30-50% compared to the symmetrical operation mode.

Over the last ten years, technological losses of energy efficiency in rural networks have increased almost 3 times and reached 30%. This is due to the increase in the share of single-phase load in 0.4 kV networks compared to three-phase symmetrical load. This is facilitated by the use of particularly powerful (up to 50 kW and more) single-phase voltage stabilizers.

A significant reduction in power losses in 0.4 kV networks can be achieved by reducing the current balance in these networks.

At the present stage of energy development, the issue of switching to energy-saving technologies is very relevant, which is associated with an increase in energy consumption and a decrease in the quality of energy efficiency for emerging agricultural consumers. Software has been developed in the DELPHI environment for calculating asymmetric modes of a four-wire power supply network with a neutral wire, the results of calculating EE losses in 0.4 kV networks for the total length of the line, and voltage losses.

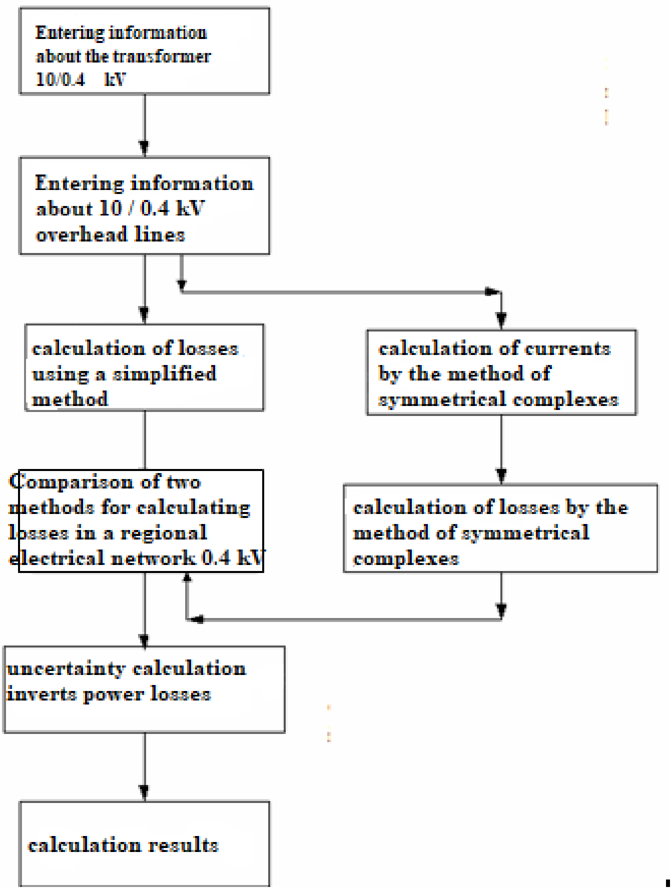


Figure 4. Unbalanced feeder 0.4 kV block diagram of the program for calculating power losses due to unbalance

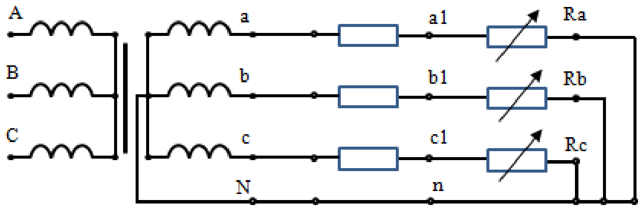


Figure 5. Scheme of distribution network distribution 0.4 kV

Flowcharts of programs and substitution schemes in which reports are executed are shown in Figures 4 and 5.

The program covers the following stages:

- calculation of power losses in each line and in a symmetrical load transformer;

-calculation of power losses due to asymmetry of currents in each part of the lines and in the transformer;

- calculation of EE losses with a system of asymmetric currents in each line and one transformer coming out of a certain transformer.

A distinctive feature of the program is its complex nature: along with the calculation of EE losses at the 0.4 kV network junction, the asymmetry of voltages and currents in all lines running from this transformer is calculated.

Table 5 shows the results of single-phase unbalanced modes with a Y/Z0 transformer.

Table 5

Single-ended with Y/Z0 connected transformer mode calculation results

№	Transformator, TL	Parameter	Unit of measurement	Asymmetric single phase
1	Transformator, TL	Z_a	Om	Z_y=7+j3 Ом
2		Z_b	Om	0
3		Z_c	Om	0
4		I_A	A	20.23
5		I_B	A	0
6		I_C	A	0
7		I_1	A	9.45
8		I_2	A	9.45
9		I_0	A	9.45
10		K_2	n.v.	1
11		K_0	n.v.	1
12	Transformator Y/Z_0	ΔP_1	Vt	54.11
13		ΔP_2	Vt	54.11
14		ΔP_0	Vt	728.54
15		ΔP_ε	Vt	782.65
16		K_ε	n.v.	14.46
17	TL 0.38 kV	ΔP_1	Vt	64.28
18		ΔP_2	Vt	64.28
19		ΔP_0	Vt	204.10
20		ΔP_ε	Vt	332.67
21		K_ε	n.v.	4.175

The main results of this chapter are reflected in the works of the author [12, 15, 16].

GENERAL RESULTS

1. A significant increase in the share of electric operators with distorting characteristics in the total load of electric networks in modern conditions of development has led to an increase in the level of electricity quality indicators. This leads to an increase in power losses in the distribution networks of the power system.

2. A significant increase in the share of electric operators with distorting characteristics in the total load of electric networks in modern conditions of development has led to an increase in the level of electricity quality indicators. This leads to an increase in power losses in the distribution networks of the power system.

3. The results obtained on the basis of different approaches to determining the unsymmetrically loaded reactive power of PES are compared, and it is shown that there is no single approach in this area.

4. It is proposed to replace Y/Y0 transformers with power 25 ÷ 100 kVA in distribution networks and Y/Z0 transformers.

5. Software has been developed for calculating EE and EECG losses, taking into account the load asymmetry in 0.4 kV networks. As a result of the reports, a significant reduction in EE losses and an increase in ECG was achieved with asymmetrically loaded PES.

6. Software has been developed for calculating EE and EECG losses, taking into account the load asymmetry in 0.4 kV networks. As a result of the reports, a significant reduction in EE losses and an increase in ECG was achieved with asymmetrically loaded PES.

7. It is proposed to build new distribution networks 0.66÷1 kV and replace old ones with new ones to supply agricultural consumers with electricity and ensure its reliability, efficiency and quality. This transition increases the capacity of networks, expands the range of customer service, and reduces power and electricity losses.

THE MAIN RESULTS OF THE DISSERTATION ARE PUBLISHED IN THE FOLLOWING WORKS

1. Fərhadzadə, E.M., Quliyev, H.B., Hacıyev, N.İ., Səfərəliyeva, S.M., Hacıyeva, K.R. Veyvlet-analiz üsulunun gərginliyin qeyri-sinusoidallığının tədqiqinə, tətbiqinə dair // Energetikanın müasir elmi-texniki və tətbiqi problemləri Beynəlxalq elmi konfransının materialları, - Sumqayıt: - 27-28 oktyabr, - 2015, -s. 76-79.

2. Анализ эффективности смешанных распределительных электрических сетей низкого напряжения. Sumqayıt Dövlət Universiteti, Elmi xəbərlər, Sumqayıt, 2017, №4, cild 17, s. 79-85

3. Balametov, Ə.B., Hacıyev, N.İ. Gərginliyi, 0,4 kV olan paylayıcı elektrik şəbəkəsində elektrik enerjisinin keyfiyyət göstəricilərinin tədqiqi // Tətbiqi fizika və energetikanın aktual məsələləri Beynəlxalq elmi konfransın materialları, - Sumqayıt: 24-25 may, - 2018, - s. 232-234.

4. Balametov, Ə.B., Hacıyev, N.İ. Gərginliyi 10/0,4 kV olan üçfazlı paylayıcı elektrik şəbəkələrində güc transformatoru dolaqlarının qoşulma sxemlərinin tətqiqi sahələri haqqında // - Sumqayıt: Sumqayıt Dövlət Universiteti, Elmi xəbərlər, - 2018. №3, cild 18, - s. 84-90.

5. Баламетов, А.Б., Гаджиев, Н.И. Области применения разных схем соединения обмоток трансформаторов 10/0,4 кВ в распределительных электрических сетях // XLVIII международная научно-практическая конференция с элементами научной школы, - Москва: -14-16 ноября, - 2018, - с. 252-253.

6. Баламетов, А.Б., Салимова, А.К., Гаджиев, Н.И. Анализ эффективности смешанных распределительных электрических сетей низкого напряжения // Материалы IV Национальной научно-практической конференции, - Казань: - 6-7 декабря, - 2018 г., -с . 92-100

7. Balametov, Ə.B., Səlimova, A.K., Hacıyev, N.İ. Yaşayış evlərinin elektrik təchizatında bir fazlı və üçfazlı qidalanma sxemlərinin müqayisəli təhlili // Energetika ixtisasları üzrə kadr hazırlığının aktual məsələləri Respublika elmi konfransının materialları, - Sumqayıt: - 2019, - s. 183-186.

8. Gadjiev, N.İ. İncreasing of working efficiency of three-phase 10/0,4 kV distribution networks with asymmetric loads // - Istanbul:

International Conference of Technical and Physical Problems of Electrical Engineering, -14-15 October, 2019, - p. 33-36.

9. Balametov, A.B., A.K.Salimova, E.A.Balametov, N.İ.Gadjiev. About measures to reduce power losses from current asymmetry in 0,4 kV networks // Technical and Physical Problems of Electrical Engineering, - Istanbul: - 2019, Turkey, page 17-21

10.Balametov, Ə.B., Səlimova, A.K., Hacıyev, N.İ. Qeyri-sinusoidal sistemlərdə reaktiv güc // - Sumqayıt: Sumqayıt Dövlət Universiteti, - 2020. №8, -s. 223-228.

11.Balametov, Ə.B., Hacıyev, N.İ. Üçfazalı elektrik şəbəksində yüklərin qeyri-simmetrik paylanmasının ölçü kompleksi əsasında eksperimental tədqiqi // İnformasiya sistemləri və texnologiyalar nailiyyətlər və perspektivlər. Beynəlxalq elmi konfransın materialları, - Sumqayıt: Sumqayıt Dövlət Universiteti, - 2020 - s. 42-44.

12.Баламетов, А.Б. О программном обеспечении для планирования мероприятий по снижению потер мощности от несимметрии токов в сетях 0,4 кв. / Баламетов, А.Б., Салимова, А.К., Гаджиев, Н.И. [и др.] // Программные продукты и системы, - Тверь: - 2020. том 33, №2, - с. 328-334.

13.Hacıyev. N.İ. Aşağı gərginlikli 0.4 kV paylayıcı elektrik şəbəkələrində texniki itkilərin hesablanması metodları // - Sumqayıt: Sumqayıt Dövlət Universiteti, - 2021, cild 21, №2, - s. 82-88.

14.Гаджиев, Н.И. Методы моделирования реактивной мощности. Нефтегазовое дело ФГБОУ ВО «Уфимский государственный нефтяной технический университет» 2021. Том 19. № 6

Personal contribution of the applicant in the works published in co-authorship.

[8, 13, 14] the author did the work freely.

[1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12] in scientific works, the author participated in the formation of the problem, the conduct of experimental studies, and the analysis of the results..

The defense of the dissertation will be held 29 june 2022- nd at PM 15.00 at meeting of the Dissertation Council ED 2.04 operating under the Azerbaijan State Oil and Industry University

Address: Az 1010, Baku Azadlig Avanue 34
Azerbaijan State Oil and Industry University

The dissertation is available in the library of the Azerbaijan State University of Oil and Industry.

Electronic versions of the dissertation and abstract are posted on the official website of the Azerbaijan State University of Oil and Industry.

Abstract sent to the required addresses 27 may 2022