Use of reactive power sources in improving the quality of electricity

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Abstract. The losses of power and electricity have sufficiently negative and significant impact on air transmission networks. In the supply of electricity and power to electricity consumers the power supply must be reliable and of high quality without interruption. In recent years the process of uninterrupted reliable and high-quality supply of electricity has become extremely complicated. Currently measures are being developed to calculate the solution of this issue as much as possible. The problem of reactive power compensation and the quality of electricity is directly related to the immediately consumer loads, voltage and frequency. It is also a process associated with increasing the value of the system's active power coefficient to balance the total power from the ac network, not decreasing the voltage value, and reducing the harmonic components of large fluctuations in nonlinear industrial consumer loads. Voltage storage is usually required to reduce voltage changes in the power line.

1 Introduction

Reactive power compensation improves the reliable performance of the system by increasing the maximum active power that can be changed. The main consumers of electricity in our economy are naturally production and industrial enterprises. The most important requirements for designed and existing power supply systems of industrial enterprises are reliability and efficiency in providing them with electricity. This primarily requires rational and economical use of capital costs in the process of building power supply systems and annual costs for their operation. The most accurate way to calculate the losses of electricity is to determine the electric charge graphs by section. Measures to reduce power losses are always carried out. The active and reactive power of consumers has caused changes even with an increase in the number of consumers.

Therefore, it is necessary to constantly monitor the level of losses, since they determine the economical operation of the entire network. A systematic approach to the problem of managing the level of losses is a complex issue, and only with the help of modern economic and mathematical models and exposures can it be solved in a complex way. The main difficulty in this is the collection and processing of messages in network modes, since they are constantly changing with the change of downloads, and the three-phase system is quite

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common, since in this system there is less power losses compared to a single-phase system at the same power and voltage [1]. Loading graphs are divided into daily and annual loading graphs. One of the main indicators of the functional effectiveness and economy of electrical networks consists in the loss associated with electricity in the technical composition and use of electrical equipment and devices. Failure to continuously supply active electricity to various seemingly operational processes and electrical networks leads to excessive electricity loss [2].

The amount of active, reactive, and full capacities transmitted to consumers over overhead power lines must be essentially equivalent in value with the capacities commonly used by consumers. The voltage on the elements of the network in this case should not exceed 5% of the total visibility of the losses. The losses of power are mainly in the current state active and reactive capacities transmitted to consumers, as well as depending on the rated voltage, asset and reactive resistance over the length of the conductors. Standards should be scientifically based, progressive and dynamic, that is, regularly revised as organizational and technical changes in production [3].

2 Results and discussion

Although, as mentioned above, it is common in dictionaries for material resources, it fully reflects the requirements for the normalization of losses of electricity and power. Normalization is a procedure for determining the optimal (normal) level of losses (level of damage) according to economic criteria, the value of which is determined based on the calculation of losses, by analyzing the possibilities of reducing each component of their actual structure during the planned period. As a standard of losses in the report, we can see styles that each have an independent nature and, as a result, require an individual approach to determining its optimal (normal) level for the period under consideration.

At present, issues of uninterrupted, reliable and high-quality electricity supply of production enterprises remain relevant. In this case, it is an important process in the transmission of electricity mainly through air power lines, along with active and reactive power losses, to calculate voltage losses, to develop measures to reduce them. Also, improving the quality of electricity with the use of reactive power sources also constitutes one of the main tasks of the energy system today. It was found that it is economical and structurally convenient to compensate for direct reactive power with transverse and longitudinal static capacitor batteries in improving the quality of electricity. Over the years, voltages and power losses in Substations and air power lines have been analyzed. In such cases, the place of installation of capacitor batteries should be in the section of the network with a voltage of 0.4 kV [4]. In this case, the cross-section surface of the cables and the losses of electrical energy in the distribution network are reduced. An analysis of the operating mode of electric networks refers to the analysis of the operating modes of existing electric networks and transformers, and the losses of power and electricity in air power lines was carried out from the calculation

The technical losses of reactive power and the ratio and dynamics of electricity transmitted through the network made it possible to assess the reliability of reactive energy accounting. If we connect the technical losses of power with the reactive power transmitted through the network, then it makes it possible to consider the reliability of economic calculations [5].

During the supply of electricity and power, losses occurs in each element of electrical networks. To assess the need for one or another measure aimed at studying the components of losses in various elements of the network and reducing losses, the structure of losses of electricity and power was analyzed.

Standards refer to the accounting values of the expenditure of material resources used in the planning and management of the economic activities of enterprises. Currently, technical, organizational and economic measures are being developed to reduce losses of power and energy. This resulted in statistical analysis. Statistical analysis is carried out in the following sequence:

1. The ratio of reactive losses in power lines is analyzed.
2. Load dynamics and conditional constant losses are studied.
3. Reactive power coefficients and load factors of a power transformer.

The thesis of the proposed methodology for the structural analysis of reactive losses is presented in the example used in the analysis of the state of the electronic regime. The dynamics of the ratio of technical losses from the power supply is necessary to assess the effectiveness of measures to reduce losses. This must be determined for each class of rated voltage. Longitudinal compensation of reactive power provides for consistent additional input by sequential loading of capacitors through voltage-increasing or separating Transformers.

Longitudinal compensation of reactive power-indicates a more economical way of achieving the goal set even for Inter-systemic, internal systemic relations. The existing cases of technical losses of electricity, reactive and active power in networks with a voltage of 35 kV and 110 kV are shown in (Figure 1)

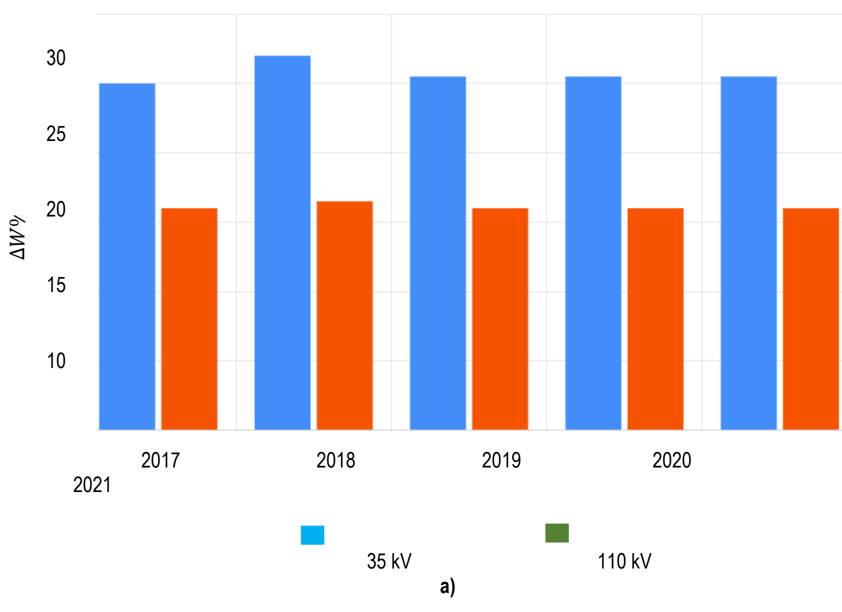

Fig 1. The ratio of technical losses of power in the supply of electricity by years: a – losses of active power; b – losses of reactive power.

In recent years, there has been a steady increase in load-free losses in power transformers, which indicates a decrease in reactive power load, since the number of connected consumers has not changed, and the active power fluctuates within negligible limits. Over the years in this case, the air power lines and power are changing in different manifestations in Transformers [6]. The fact that air power lines and power transformers mainly contain total active power, reactive power and rated voltages in the calculations of active and reactive power losses is shown in (Figure 2)

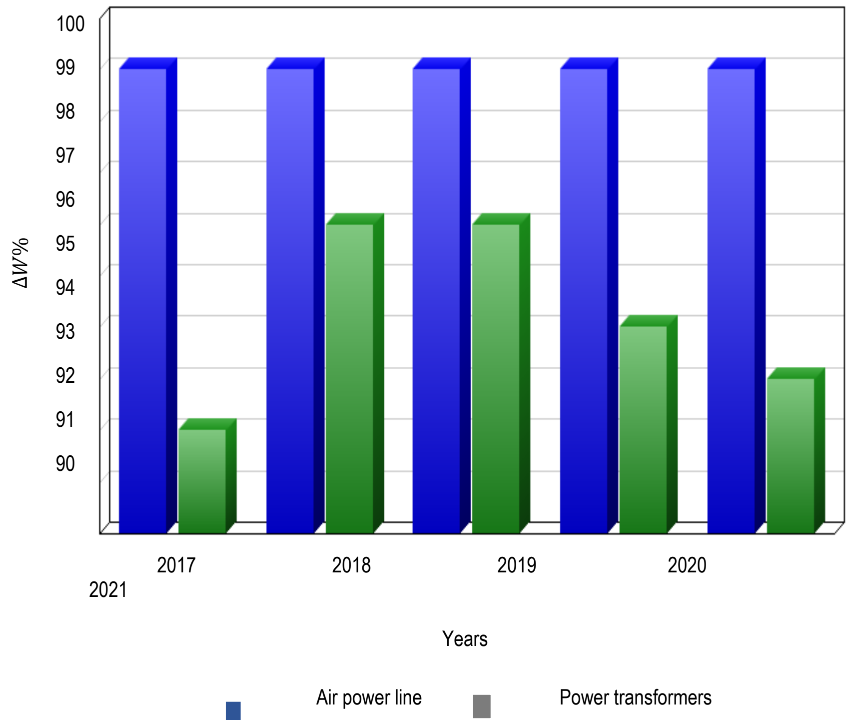

Fig 2. The appearance of technical losses in the network with a voltage of 35 kV of the reactive power being sent through the power transformer and the air transmission line.

Due to the fact that long-distance electrical voltage is transmitted on air transmission lines, active and reactive power losses will be present in them. These losses are determined by the following formulas.

Losses of active power on the line:

$$\Delta P = 3I^2 R = 3\left(\frac{P^2}{3U^2} + \frac{Q^2}{3U^2}\right)R = \frac{P^2 + Q^2}{U^2}R = \frac{S^2}{U^2}R \tag{1}$$

Losses of reactive power on the line:

$$\Delta Q = 3I^2 X = 3\left(\frac{P^2}{3U^2} + \frac{Q^2}{3U^2}\right)X = \frac{P^2 + Q^2}{U^2}X = \frac{S^2}{U^2}X \tag{2}$$

This will also include the active and reactive power values of the power line in expressions 1 and 2, as well as the nominal voltage values transmitted at the same time.

In current existing electrical networks, i.e. general losses on existing voltages in high-voltage power lines are notable for the fact that the losses in high-voltage networks in the following electrical network elements are less than losses in relatively low-voltage power transmission networks. Since the transverse cross-sectional surfaces of the conductor in low-voltage electrical networks are slightly larger, the losses in them have a high indicator. Measures to reduce the losses of electrical energy in the electrical network can be divided into the following groups:

1. Continuous control of consumer loads by increasing the length and operating time of electrical networks. To study the features of the work of electrical networks in this case and whether the performance indicators depend on the available capital funds.
2. Control over the working condition of the elements of the electrical network, and carry out scheduled repairs on time.
3. Control of consumer operating modes directly through condenser batteries.

It is known that when transmitting reactive power through conductors, it allows a significant increase in the current strength in the sections of electrical networks, thereby creating restrictions on the transmission of active power. When the longitudinal compensation capacitor current I is equal to the full load current, and the capacity of the battery of the Q capacitors is a variable value dependent on the load at each specific moment in time. This reactive power can be calculated by the following formula:

$$Q_k = \frac{I^2}{\omega c} \tag{3}$$

Where I-is the full load current; ω-is the angular frequency; c-is the capacitor capacity.

The main economic advantage of using longitudinal compensation is energy saving [7].

Advantages of transverse compensation of reactive power:

1) The use of transverse compensation radically reduces reactive power and associated energy losses through power lines,
2) Helps to maintain the required voltage level in electrical networks
3) Increase the amount of voltage and power coefficient
4) The content of high voltage harmonics decreases
5) Helps to increase the quality indicators of electricity.

Disadvantages of transverse compensation of reactive power:

In compensation, mainly static condenser batteries are used. Reducing the reactive power efficiency in the network due to the use of static capacitor batteries leads to a significant reduction in active power losses in networks with a voltage of 6-220 kV, which reduces the load on power lines and network Transformers. The increase in power in the main and distribution power grids allows transformers to increase their power without increasing their power and without the construction or modernization of power lines [8].

Another of the main functions of static capacitor batteries is voltage regulation. The permissible voltage deviation from the nominal should not exceed 5%, and the maximum permissible-no more than 10%. The share of voltage surges in energy transmission in networks can reach 8-12%.

Considering the presence of voltage losses in the quality indicators of direct electricity and their current indicators, we can see that the losses in such cases are somewhat higher. In this case, the voltage losses and their values vary in different networks. The process of calculating the losses of power and voltage is considered complex. During the period under consideration, individual values were considered, determined on the basis of determining the optimal level of losses according to economic criteria, calculating definitions for electricity, studying the operating modes of electric networks, taking into account the length of air transmission lines, schemes of electric networks, acceptance and supply of electricity. In this we can see an increase in the losses of active power in recent years.

Table 1. Zarafshan-Uchkuduk Energy Center Networks at the intersection of 2017-2021.

Years	2017	2018	2019	2020	2021
Maximum power consumption of the line with a voltage	437	451	442	460	466

Consumption of a substation with a voltage of 220 kV	386	393	396	414	418
Asset power losses	51	58	46	46	48

Loss values in Zarafshan-Uchkuduk energy networks in 2017-2021 depending on the consumed load. In some substations, active power loss can be reduced by up to 16.8% to reactive power loss by up to 20%. Minimizing reactive power transmission can reduce operating costs associated with the cost of active energy. For example, only the adoption of measures for the 5 substations considered allows reducing excessive infestations of active power. If we determine the systemic effect of reducing the transmission of reactive power in electrical networks as a whole and the complex effect, it will be at a much higher level [9]. We can see the losses of electricity transmitted from substations through transformers in different seasons of the year.

Table 2. Normative and technical indicators of losses on power lines with a voltage of 6-10 kV.

№	October-November 2022					
	Electricity sent to the network kW*h	Useful used electricity kW*h	Power electricity day	%	Power electricity night	%
N1	7717091	6200564	379671	17	1516527	99
N2	880325	743931	65032	33	136421	15
N3	598334	487127	6402	14	111207	18
Total	16457458	13643955	979199	42	281350	12

The level of Optimal losses changes from year to year, as occurs due to network loads and dependence on changes in equipment prices. If the standard of losses is determined by the promising loading of the network (for the estimated year), taking into account the effectiveness of the implementation of all economically feasible measures, it can be called a promising standard. Due to the gradual improvement of the data, the promising standard should also be revised from time to time. As reactive power supplies, we can see synchronous compensators, voltage adjustment, static capacitor batteries, reactors controlled using shunt.

The disadvantages of synchronous compensators include increased costs. The specific value and asset power losses of synchronous compensators increase significantly with a decrease in their rated power [10]. In the control parts of the power supply system under study, the main factors affecting the decrease in the values of voltage and active power were identified, and the existing indicators of the quality of electricity were analyzed. This resulted in the determination of the dependence of voltage and reactive power on the current strength and the power supply network (Figure 3)

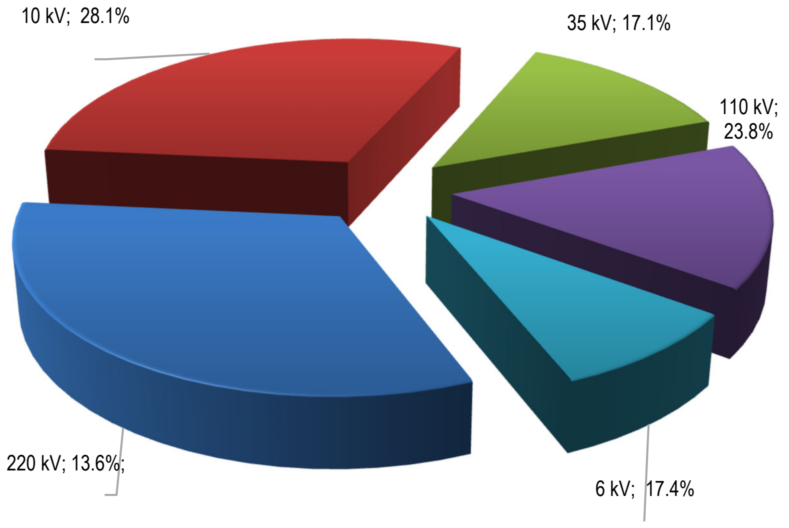

Fig 3. The appearance of normative, technical and general lossess of electricity transmitted to consumers through Transformers.

By controlling the production, transmission and consumption of reactive power at appropriate levels of the power supply system, controlling the voltage and keeping it within acceptable limits can reduce its losses.

Increase in active power losses:

$$\Delta P = \frac{P^2 + Q^2}{U^2} R \tag{4}$$

Where P- is the active power kW, Q- is the reactive power kVar, R is the active resistance of the line kOm, U-is the rated voltage kV.

Increasing voltage losses:

$$\Delta U = \frac{PR + QX}{U} \tag{5}$$

Where P is the active power kW, Q is the reactive power kVar, R is the active resistance of the line kOm, U is the rated voltage kV, X is the reactive resistance of the line kOm.

Reducing constant losses:

$$S = \frac{\rho l P^2}{\Delta P U^2 \cos\phi} \tag{6}$$

Where p=specific resistance, cosφ=active power coefficity.

The main criteria for the organization of reactive power supplies are to reduce the reactive power coefficient, provide adjustable voltage values for consumers, and reduce network losses [11].

Table 3. Aluminum steel conductors at ambient temperature, the permissible long-term Season cross-section power values.

Cross-sectional surface of the conductor mm^2	$t=25^0C$ k=1	For the winter season $t=0^0C$ k=1.24	For the summer season $t=40^0C$ k=0.81	For the autumn season $t=18^0C$ k=0.65	For the spring season $t=25^0C$ k=0.72
AS-300	255	316	206	185	195
AS-240	219	272	177	160	165

Analysis of cases of reducing active power losses and improving the quality of electricity is carried out with the solution of the following tasks. Determination and assessment of the reserves of the energy supply system and electricity generating enterprises to reduce asset power losses [12].

Identification and ranking of the main factors determining the level of active power losses. By saving electricity, their efficient use. Expansion of the construction and maintenance of capital requirements necessary for the development of power supply. Optimization of the voltage level of electrical networks, power losses by reactive power distribution. Calculation of the height of the power transformer positions that adjust the voltage under load.

Taking into account changes in the resistance of the autotransformer, which adjusts the voltage under load. Analysis of the permissible current load of power lines and Transformers, including taking into account the dependence of the permissible current on temperature. Taking into account the experience of designing and operating electrical networks, the following permissible values voltage losses are assumed [13].

The reliability of the power supply and the ever-increasing modern requirements for the quality of electricity supplied (fast, reliable, long-term application) force the use of devices [14].

To monitor the stability of reactive power and voltage, the correct selection and coordination of their values is one of the main tasks in the design of energy systems. These problems led to reactive power compensation [15]. Both the capacities specified in the calculation and the values of the currents corresponding to these capacities can be used. On lines with a length of several kilometers, in particular with a voltage of 6-10 kV, it is necessary to take into account the effect of the inductive resistance of the wire on the voltage loss in the line. For calculations, the inductive resistance of copper and aluminum wires can be taken as 0.32-0.44 ohm/km, and a lower value should be obtained at cross-sections 10-25 mm2 at small distances between conductors (500-600 mm) and conductor transverse cross-section surfaces, and a higher value-at distances of 1000 mm and above [16].

One of the main solutions is the use of devices that improve the quality of electricity, the use of a filter to block the harmonica, as well as the correct installation of electrical installations [17]. Since the installation of reactive power supplies partially or completely solved several problems, it made it possible to stabilize and increase the voltage level at the control points of the power unit, thereby improving the quality of electricity, improving the static and dynamic stability of the power grid by discharging networks from reactive power, while increasing power, stabilizing modes in case of an accident.

Minimizing reactive power transmission can reduce operating costs associated with the cost of active energy. For example, only the adoption of measures for the above substations considered allows reducing excessive inflows of active power and changing the existing parameters of voltages and line resistances.

Table 4. We will also consider in with the available cases of networks with a voltage of 35 kV.

Conductive cross-sectional surface	Voltage losses %				Electricity losses kW*h
	Day		Night		
AS 35/6.2	0.822	17.73	1.34	19.6	5038.15
AS 35/6.2	3.03	16.91	3	18.26	45311.27
AS 35/6.2	3.82	13.88	4.34	15.22	39269.25
AS 35/6.2	1.96	12.01	2.38	13.56	14516.25
AS 35/6.2	1.85	15.01	2.01	12.57	18256.59

If we determine the systemic effect of reducing the loss of reactive power in electrical networks as a whole and the complex effect, it will be at a much higher level. In the process of supplying electricity and power to consumers, losses occur in each element of electrical networks. To assess the need for one or another measure aimed at studying the components of losses in various elements of the network and reducing losses, the structure of losses of electricity and power was analyzed. Reactive power supplies may change the active power before and after installation. Analyzing the data, we can draw conclusions that the amount of active power losses in the network has significantly decreased.

The conclusion is that the implementation of all economically feasible measures to reduce existing losses requires a certain amount of time. Therefore, when determining the norm of losses for the next year, it is necessary to take into account the effectiveness of activities that can be increased in practice during this period. This standard is called the current standard. The degree of losses was determined at the specific values of the network load. Before the planning period, these downloads were determined based on analysis calculations. Since the definitions for three categories of consumers who receive power from voltage networks of 0.4kV, 6-10kV, 35kV and 110 kV were determined differentially, the general standard of lossess was divided into several components. This division should be carried out taking into account the degree of use of networks of different voltage classes of each category of consumers. The temporarily permissible commercial losses included in the definition were evenly distributed among all categories of consumers.

Also, the analysis of the operating modes of existing electrical networks and transformers at the time of analysis of the operating Order of power networks and power on air power lines was carried out. It was mathematically substantiated by familiarizing yourself with the existing parameters of capacities (active and reactive) in air power lines.

Recommendations were made to reduce the impact on power transmission networks, considering the feasibility and implementation of measures aimed at reducing the losses of reactive and active power. Also, as a result of research, we will cite the following. The loss of reactive power has a serious impact on the efficiency and reliability of electrical networks, the degree of their increase leads to a decrease in the loss of distribution network complexes.

3 Conclusion

Through the use of reactive power sources, explanatory and training measures have been developed on active chelate and voltage. Based on the results of the work, the following main conclusions can be drawn. Electricity transmitted through electrical networks consumes part of it for use. Part of the electricity generated is used in electrical networks to generate electrical and magnetic fields, and technological costs are required to transmit it. and in all directions or in each of them, as well as when the foci of loss are detected. The process of calculating the consumed electricity and power takes a lot of time. In the period under consideration, an important issue is the determination of the permissible level of losses according to economic criteria, as well as the determination of electricity, the rationing of losses. The difference between high voltage and low voltage capacitors is as follows 6-10 kV voltage-up to 15%; A method of circuit analysis has been proposed in the case of a situation that allows you to determine the influence of the parameters of the proposed electrical networks on the amount of reactive power loss. For a structural analysis of electrical energy and reactive power losses in distribution networks, a statistical method has been developed, which is recorded in the operating conditions of the data used to determine energy losses.

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