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Investigation of the Modes of Electrical Networks in Terms of Reactive Power and Voltage

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Abstract: The article is devoted to the study of the behavior of reactive power flows through overhead lines and transformers of distribution electric networks and voltage in nodes, analyzes ways to reduce losses, and the possibilities of improving basic modes.

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1 INTRODUCTION

The distribution of electric energy (EE) from substations of the backbone network to power centers for industrial, urban and transport consumers is provided by electric distribution networks (EDN). EDN power centers represent substations with a secondary voltage of 6-110(220) kV, including generator voltage buses of power plants. The role of the distribution zone is reduced to the transportation of electricity to consumers of 0.38-10 kV, the distribution of electricity – 6-110(220)/0.38-35 kV between substations of the area of power consumption and the collection of power stations.

From 8 to 15% of the total electricity generated in Uzbekistan is transferred to consumers of various categories through distribution networks. These electric networks are characterized by a variety of schemes for the construction of operated electrical equipment, materials and structures, and a significant number of interacting participants in the electric energy market.

The structure depends on the purpose of the distribution network, thus, medium-voltage 110-220 kV networks are carried out by overhead power lines, contain district-level electrical substations, including low-power power plants. Low voltage networks of 0.38-35kV are carried out by cable and air for power supply to individual enterprises, cities, etc.

The operating characteristics of EDN depend on their configuration, which is determined by the relative location of power supply centers, receiving substations and the requirements for ensuring reliable power supply, whether they are open or closed. The advantages of open-circuit networks include a simple configuration, low cost, low cost of conducting materials and equipment, and the ability to connect substations using the simplest schemes. The advantages of closed circuits are the independence of the distribution flow from high voltage flows, the absence of short–circuit currents in adjacent networks, and high reliability. In such conditions, special attention is paid to the problem of providing improved EDN modes (Nikolaeva, 2018).

The methods and directions for controlling reactive power flows and voltage control in open-circuit 0.4-35 kV and closed-circuit 110-220 kV distribution zones are different. In open-circuit networks, the optimization task is reduced to loading electrical networks with reactive power to reduce active power losses and ensure normalized voltage levels at power supply points, and economic efficiency depends on the locations of the compensating device (CD). In 110-220 kV closed-circuit electric networks, compensation means are used to ensure system reliability, control the capacity of main power transmission lines, maintain voltage at nodes, and reduce power losses while ensuring technological requirements and operating restrictions (Gracheva, 2018; Makhoshev, Gavrina, Klyuev, 2023).

2 MATERIALS AND METHODS

Improvement of electrical network modes by choosing the configuration and composition of the included equipment; control of network operating mode parameters; creation of an optimal distribution voltage system.

The study showed that improving the modes of the electric grid in terms of voltage and reactive power (RP) is one of the effective means of achieving an increase in its energy efficiency (Gerasimenko, Neshataev, 2012).

Since the elements of electric energy distribution systems are maximally loaded with reactive power flows due to its consumption from the grid, there is a need to compensate for reactive power. Efficient distribution of reactive power flows is ensured by loading existing reactive power sources and installing new compensating devices in 0.38-6.10 (20) kV networks of most electric energy consumers and the most problematic voltage nodes of 35-110 (220) kV. network companies. The production of RP locally makes it possible to reduce EE losses, normalize voltage levels, increase the operational controllability of the EDN and connect new consumers. Thus, it is possible to solve the urgent problem of the republican electric power industry for effective economic regulation of reactive power flows, taking into account the introduction of new regulatory documents regarding RP consumption.

The value of electricity losses and the dynamics of its changes is a key indicator of the technical condition of distribution electric networks and the level of their operation. The main factors influencing the value of electricity losses in Uzbekistan's distribution networks are: suboptimal operating modes; technical parameters and configuration of networks; insufficient number of regulatory means; lack or unsatisfactory compensation of reactive power; uneven schedules of electrical loads; inefficiency of electricity metering systems (Abdurauf Sattarov Kudenov, I Karimov, 2024).

Causes of increased overflows from reactive power values in the electrical network:

1) Increasing the total current value:

$$I = \frac{P\sqrt{1+tg^2\varphi}}{\sqrt{3}U}. \quad (1)$$

There is a need to increase the cross-sections of wires and cable cores, replace the transformer with a higher power.

2) Increased additional voltage losses:

$$\Delta U = \frac{(PR-QX)}{10U_n^2} = \frac{P(R-tg\varphi\cdot X)}{10U_n^2}. \quad (2)$$

In this case, the sliding of asynchronous motors increases, the voltage on the tires of substations and load units decreases, and the stock of static stability of power supply units and load units decreases as a result of the occurrence of a “frequency avalanche”.

3) Increased losses of active power and electric power in electric networks:

$$\Delta P = \frac{P^2+Q^2}{U^2}R \text{ and } \Delta W = \int_0^T \Delta P(t)dt. \quad (3)$$

It causes overspending of electricity, an increase in electricity tariffs, and a deterioration in technical and economic efficiency.

All means of reactive power compensation in power supply systems are conditionally divided into passive and active, and the implementation of passive means leads to a decrease in the amount of reactive power consumed, and active means generate reactive power and are integrated into electrical networks in accordance with the optimal compensation method (Myasoedov, 2013).

Passive means of reactive power compensation include:

-organizational and technical measures to optimize technological processes to ensure the improvement of the energy mode of operation of energy receivers-equipment, devices, systems. These are the replacement of outdated low-energy efficient equipment, modernization of lighting systems, monitoring and process management, not simultaneous, but distributed (non-symmetrical) activation of reactive loads, optimization of the operating mode of divisions, etc.;

-reducing the amount of reactive power consumed by turning off asynchronous motors running at idle, as well as decommissioning (or disconnecting) transformers with a load of less than a third;

-application in projects and replacement of asynchronous motors in existing drives with synchronous ones, where this is acceptable in technical and technological aspects;

-modernization of drives using thyristor voltage control, converters with replacement with models with a large number of rectification phases;

-integration into electrical networks of systems with artificial switching of valves or restrictions on the generation of currents of higher harmonics.

Active means of reactive power compensation include:

-single cosine capacitors and capacitor banks used in individual and group reactive power compensation methods;

-capacitor banks with switching equipment, protection and control devices – complete installations for increasing the power factor – unregulated and automatic with relay contactors;

-synchronous motors and their type – synchronous compensators operating without load on the shaft and used to stabilize the voltage at the connection point within the range of ± 5% of the nominal value;

-multi-stage power factor correction units on capacitor banks and with thyristor switches;

-static thyristor reactive power compensators - bridge reactive power generators with inductive storage, saturation reactors with nonlinear or linear voltage characteristics, as well as serial connection of counter-parallel controlled valves – operating on the principle of direct and indirect compensation.

-thyristor reactive power compensators for networks with alternating loads of 6-10 kV, thyristor reactor groups for power lines, etc.

Among the popular methods, centralized (on the side of higher and lower voltage), group, individual and combined reactive power compensation are distinguished, and centralized in combination with group or individual compensation is usually used as a combined compensation (Figure 1).

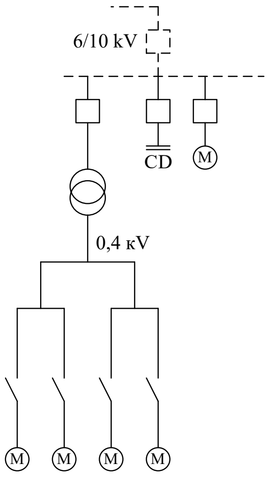
Regulation of voltage and reactive power is reduced to ensuring:

– voltage levels at electric power facilities acceptable for the equipment of electric power plants and networks;

– stability of generating equipment and load of electric power consumers;

– the quality of electrical energy in accordance with the mandatory requirements.

It is shown that power systems use regulation of reactive power flows through lines, transformers, autotransformers, and voltage levels in nodes of 0.4-220 kV electrical networks.



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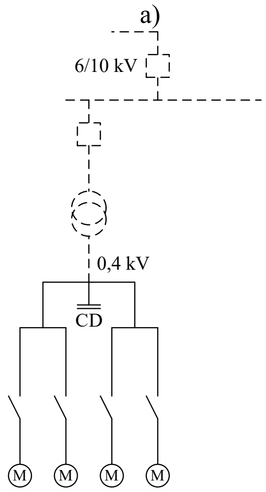

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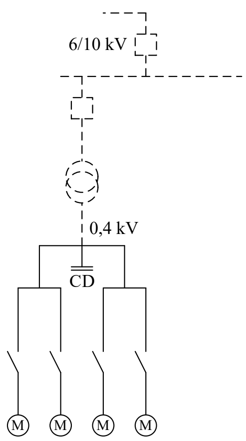

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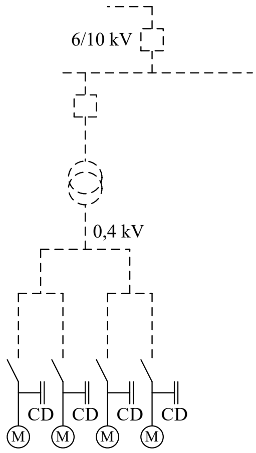

d)

Figure 1: Methods of reactive power compensation: a – centralized on the high–voltage side, b – centralized on the low-voltage side, c - group (sectional), d – individual, where the dashed symbol shows electrical networks unloaded from reactive power overflows.

3 RESULTS AND DISCUSSION

Significant differences from the optimal values of reactive power flows in electrical networks cause the network to be loaded with additional current, which leads to increased losses of voltage, power and electricity, to a decrease in the throughput and load capacity of lines and transformers, i.e. affect operating modes and voltage levels (Figure 2).

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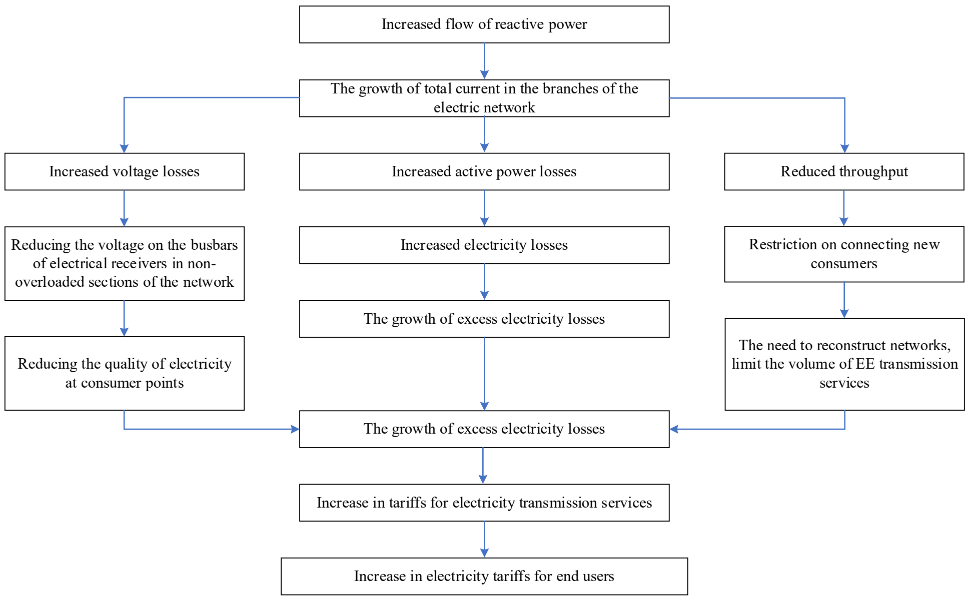

Figure 2: Causes of increased reactive power overflows in the electrical network.

1) Reducing the capacity of power transmission lines, it is necessary to provide for the construction of new highways, which requires financial costs.

2) The shortage of active capacity in a number of nodes and areas of power systems causes restrictions on connecting new consumers and increasing existing production capacity.

In order to improve the modes of supplying consumers with electric energy with acceptable parameters of electricity quality, it is necessary to ensure a balance of reactive power by compensating for reactive power (CRP) in electric networks (Voronin, Gadzhiev, Shamanov, 2012; Myasoedov, 2013; Jurayeva, Rustamova, 2019).

In this regard, in the context of modern energy conservation policy and improvement of power supply indicators, voltage regulation and improvement of electrical network modes using all available means of compensation and regulation of reactive power are of great technical and economic importance.

The choice of means and method of reactive power compensation, installation of devices and maintenance is carried out by a specialized company based on the results of an energy audit of the facility, which eliminates the risks of overcompensation and minimizes the amount of overcompensated power for a specific electrical network with reactive loads.

4 CONCLUSION

It has been established that the main indicator of reactive energy consumption is the coefficient (cosφ), numerically determined by the ratio of active power to total power, and not the coefficient of reactive power (tgφ), equal to the ratio of reactive power to active power.The value of the reactive power coefficient (tgφ) consumed during the hours of the highest daily loads, depending on the rated mains voltage for: 110 kV (150 kV), 6-35 kV below 1 kV tgφ=0.35.

The problem of reactive power compensation is caused by the high load of elements of electric power distribution systems by reactive power flows as a result of its significant consumption from the grid.

It is shown that improving the modes of distribution electric networks in terms of reactive power and voltage levels is an important energy–saving task, the solution of which will reduce electric energy losses, normalize voltage levels, and increase the operational controllability of distribution networks. It has been established that an effective solution to this problem should be based on improving and managing the operating modes of distribution electric networks and equipping them with modern means of reactive power compensation, taking into account the parameters (tgφ) of the point of its connection to the network, and developing the selection of algorithms for optimal power and locations of the CRP installation, CD loading based on a set of network conditions, It is mainly determined by the factor of multimode and the stochastic nature of the initial information, taking into account their integral characteristics, determined with a given accuracy and reliability.

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