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AUTOMATIC ADJUSTMENT OF VOLTAGE CHANGES USING REACTIVE POWER

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Annotation

This article presents calculations for correcting voltage changes using reactive power in electrical networks. Before and after the introduction of an automatic reactive power compensation device.

Introduction. One of the important qualitative indicators of electrical energy is the actual value of the voltage, which can be phase or linear, depending on the connection scheme of the consumer.

Between one stage of transformation, the voltage of the network changes with a relatively small interval, therefore, in order to simplify calculations, the concept of voltage deviation is used in practice.

Literature analysis. For this network, the voltage deviation δU is expressed in the difference between the actual value U_x and the nominal value U_{nom} [1]:

$$\begin{cases} \delta U = U_x - U_{nom}\ (\text{В}, \text{кВ}) \\ \delta U = \frac{U_x - U_{nom}}{U_{nom}} \cdot 100\ \% \end{cases} \quad (1)$$

The actual value of the voltage $U_{(1)}$ is determined for single-phase electrical loads without taking into account the harmonic components of the fundamental frequency voltage, and for three-phase loads - as the values of the fundamental frequency voltage of the correct sequence $U_{1(1)}$.

According to GOST 13109-97, under normal operating conditions of electric receivers, voltage deviation by the following values is allowed [1, 2, 3]:

- ✓ on the terminals of electric motors and their starting and control devices -5... +10%;
- ✓ in the clips of lighting devices installed at workplaces of industrial enterprises and in public buildings, as well as in outdoor lighting installations -2.5 ... +5%;
- ✓ in the terminals of the remaining electrical moles "iste", a voltage deviation from the nominal to ± 5% is allowed.

In post-accident cases, a voltage drop is allowed by another 5% [3], [15].

To meet the established requirements, first of all, it is necessary to organize monitoring and measurement of voltage deviations, calculate and determine their indicators, and implement stabilization measures. These issues are discussed in detail in [3, 4]. Other indicators of electricity quality were also considered. To understand the nature of the voltage deviation, let's look at the vector diagram of currents and voltages of a simple electrical network with resistance Z = R + jX (Fig. 1) [16], [17].

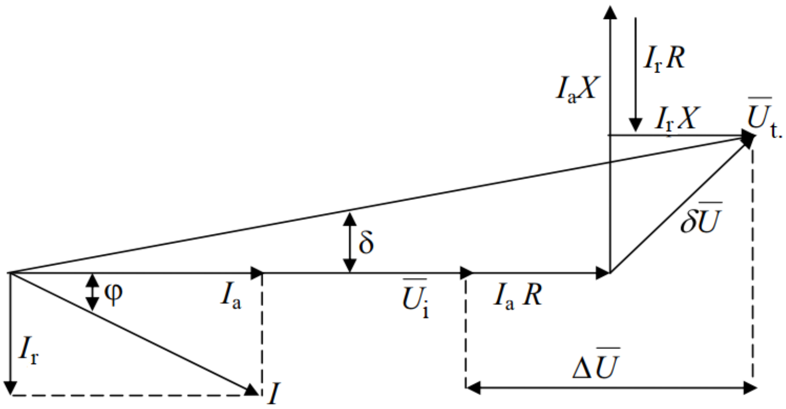

Fig. 1. Vector diagram of current and voltage for a simple electrical network

The equations of this state of the network will have the form [4]:

$$\overline{U}_n = \overline{U}_{con} + \delta\overline{U} \quad (2)$$

$$\delta\overline{U} = IZ = (I_a - jI_r)(R + jX) = I_a R + I_r X - j(I_a X + I_r R) = \Delta\overline{U} - j\Delta\overline{U} \quad (3)$$

where: $\overline{U}_n -$ is the voltage vector of the supply network; $\overline{U}_{con} -$ is the vector of the consumer voltage; Z=R+jX in the resistance line δU is the voltage drop; $\Delta\overline{U}, j\Delta\overline{U}$-are the longitudinal and transverse components of the voltage drop [18], [19].

The transverse components of the voltage drop under an active-inductive load are small, the angle between the voltages in the nodes of the power supply system is insignificant (the total angle between the voltages at different stages of transformation in practice does not exceed 10 °), therefore, for practical calculations when calculating voltage fluctuations and deviations in industries, the difference between voltage costs and voltage costs is insignificant, and is determined by according to the formula:

$$\Delta U = I_a R + I_r X \approx |\delta\overline{U}| \quad (4)$$

Given R/X=0.03 . . . 0.1 in industrial electrical networks, the equation can be written in relative magnitude as follows:

$$\Delta U_{\text{н.к}} = \frac{\Delta U}{U_n} = \frac{I_a R + rX}{U_n} = \frac{PR + QX}{U_n} = \frac{P\frac{R}{X} + Q}{\sqrt{3}U_n\frac{U_n}{X}} \approx \frac{Q}{S_{sc.}} \quad (5)$$

here: $S_{sc.}$- short circuit power (short circuit), P - active power, Q-reactive power.

From Formula (5) it can be seen that in electrical networks in most cases the voltage mode is associated with the reactive power mode [4] [14], [20].

Results. On the basis of Contract No. 53287, survey work was carried out on a 400 kVA transformer owned by JSC Ferghana Territorial Enterprise of Electric Networks. For two weeks, the determination of the quality of electricity on this transformer was carried out on the device “Malika-01” [5, 6, 7].

Figure 2 shows the voltage change on the consumption graph as of Monday 31.01.2022, obtained from the device “Malika-01". Here, the minimum voltage value was $U_{min} = 198\ V$, and the maximum value $U_{mah} = 221\ V$. This indicates a change to the limit value on demand [1]. Based on this, it is possible to see the need for reactive power compensation in a transformer (at a controlled enterprise) [3, 8, 9].

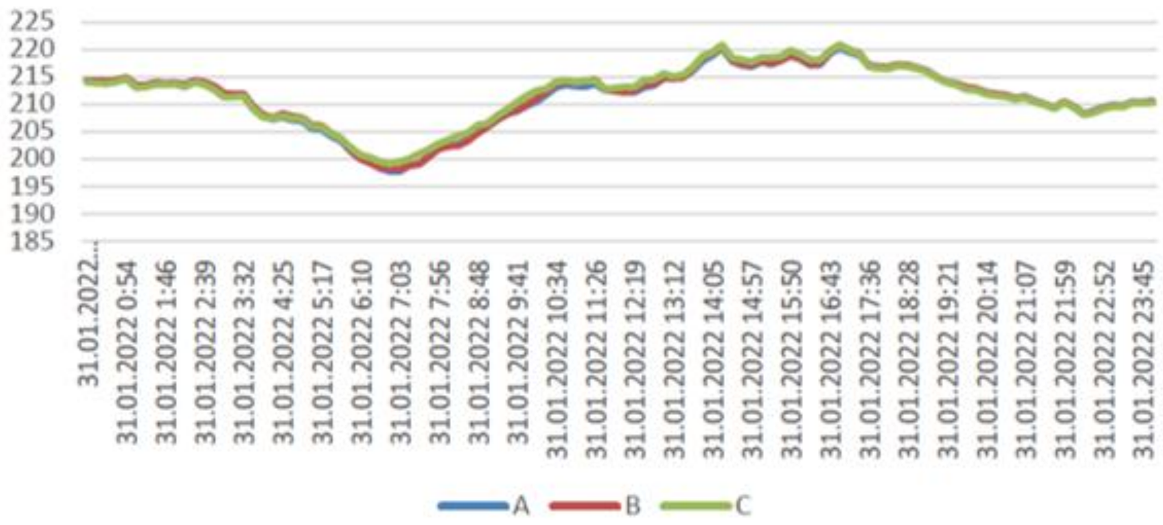

Fig. 2. Graph of voltage changes before installing the compensating device

Using [8, 9], the amount of reactive power that needs to be compensated is determined. An automatic reactive power compensation device of the PRF-12 type measures how much reactive power the consumer consumes, and automatically connects and disconnects the necessary reactive power from the network [3], [8]. The device has 12 stages, a capacitor bank is connected to each stage, and thanks to the automatic control of the stages, a smooth supply of reactive power to the network is achieved [11], [12].

Figure 3 shows the values of voltage changes obtained from the device "Malika-01" On the consumption chart of Monday 07.02.2022 after the installation of the automatic reactive power compensation device. Here, the minimum voltage value was $U_{min} = 210\ V$, and the maximum value of $U_{mah} = 228\ V$. This indicates that [1] changes within the acceptable range of values on request.

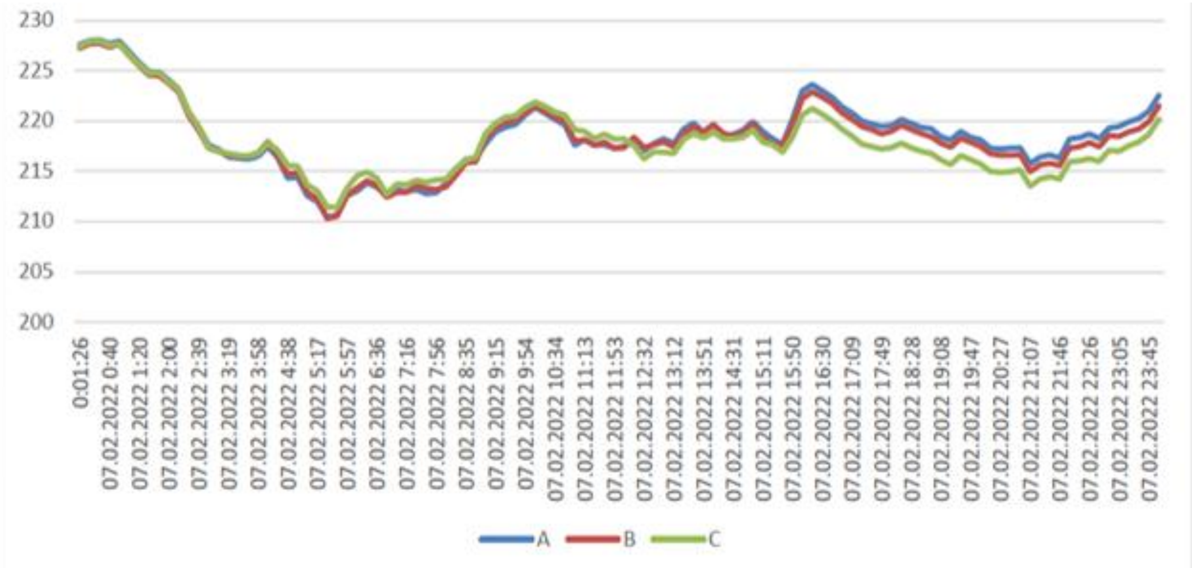

Fig. 3. Graph of measuring voltage values after installation of the compensating device

Before installing the compensating device (4.Fig.a) and after installation (4.Fig.b), a mathematical model was developed for the following cases [8], [9], [10].

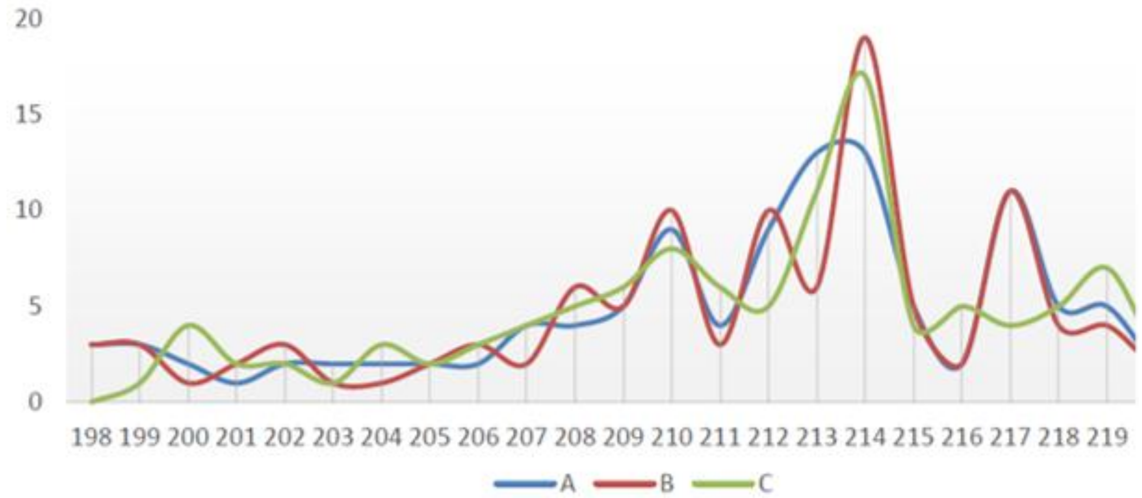

Fig.4a. Graph of voltage repeats before installing the device during measurement

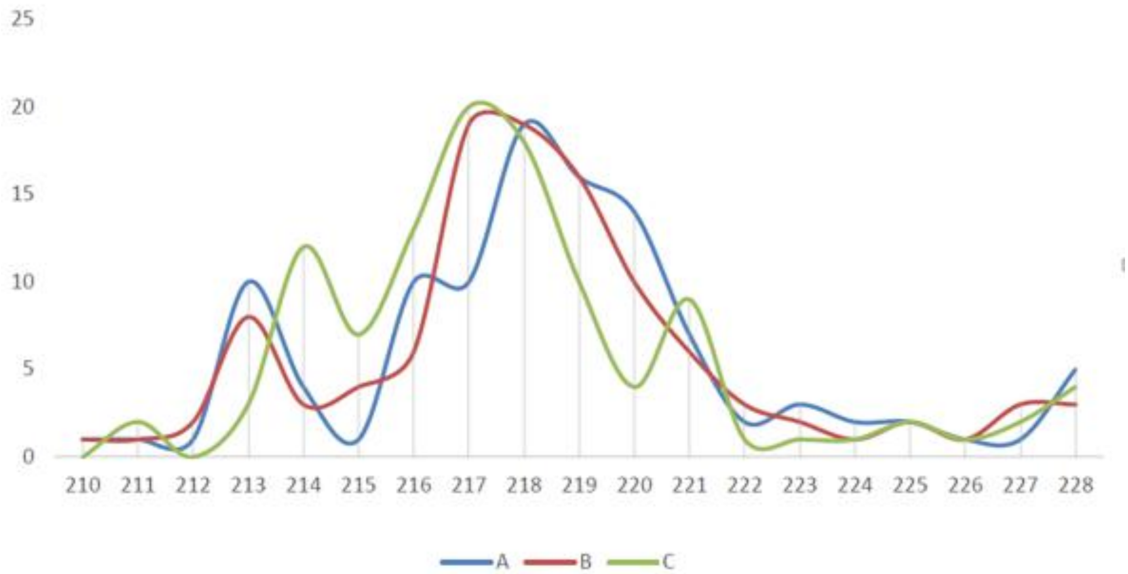

Fig. 4b. Graph of repetitions of voltage on the meter after installation of the device

Comparing the above graphs with each other, as can be seen from Figure 4a, the largest number of repetitions of measurements a day before the installation of the automatic reactive power compensation device is 214 V per phase (phase A 13, phase B 19, phase C 17). This can also be seen on the graph. It was noticed that before installing the device, the voltage value is reduced to 10% compared to the nominal state.

However, in Figure 4b, that is, in the position after the installation of the automatic reactive power compensation device, the largest number of repetitions of measurements during the day is 218 v for each phase (phase A 19, phase B 19, phase C 18). In addition, the repeatability of voltage values at intervals close to each other has increased. It was noticed that after the installation of the compensating device, the voltage value changes by less than 5% relative to the nominal state [13].

Conclusion. Summing up, we can say that after installing an automatic reactive power compensation device, the voltage in the network is reduced from 10% to 7-8% with a decrease to 2-3%.

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