Analysis Of Voltage Regulation Methods in Low-Voltage Electric Networks

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ABSTRACT

This article examines the scientific basis of voltage adjustment methods to ensure reliability of power supply. The purpose of this is to provide continuous, high-quality electricity supply to modern enterprises with complex technological processes and existing energy system networks. Through the proposed methods, it is possible to control the voltage loss and drop between the generation and consumption of electricity.

Keywords: Quality indicators of electric power, voltage losses, methods of voltage adjustment, supply of industrial enterprises with electric energy, reliability indicators

An important indicator of the quality of power supply is the stability of the voltage. The problem of maintaining it at the required level in any part of the electric power system remains relevant at the present time [1]. Modern large industrial enterprises (production of oil and oil products, chemical industry, mining industry, metallurgy, etc.) are the first-class consumers, and continuous supply of electricity in technological processes remains a priority task [2]. For such enterprises, a power outage of a few seconds, even a tenth of a second, not only endangers human life, but also causes disruption of the technological process and production stoppage. The majority of low-voltage power networks belong to 2nd and 3rd category consumers. We must provide uninterrupted, high-quality and reliable electricity to consumers of this category. In the winter season, voltage drops are observed in consumers of categories 2 and 3. Eliminating and preventing this is the duty of every power supply company [3].

The stability of the voltage can be understood only in a limited sense. None of the existing technical solutions can maintain guaranteed power flows at normal voltage levels. Ideally, the reliability of power flow should be fully protected from external disturbances. But in practice, there are many problems in ensuring this situation. It is known [4] that voltage values at any node are constantly changing. According to GOST 13109-97, the permissible limit values for voltage changes in networks up to 1 kV are given. The following formula is used to determine these values:

$$\delta U\% = \frac{U - U_{nom}}{U_{nom}} \cdot 100\% = \pm 5\% \quad (1)$$

here;

$\delta U\%$ - permissible value of voltage deviation (%);

U_{nom} - installed nominal voltage (kV);

U - network voltage (kV);

In addition, according to GOST 13109-97, there are permissible values for the maximum voltage of the equipment [5]. These values are determined by the reliability of the insulation of electrical devices. Because exceeding the high value of the voltage leads to rapid erosion of the insulation and short circuits in the network. If there are electric motors with a voltage of 6-10 kV in the network, the maximum voltage of the network should not be higher than the nominal [6].

There are several ways to adjust the voltage. In 0.4 kV power networks, the voltage is mainly adjusted through the PBV device. PBV is also known as "Pereklyuchenie bez vozbujdeniya" non-excited rectifier transformer - (QRT). Figure 1 shows the principle scheme of PBV.

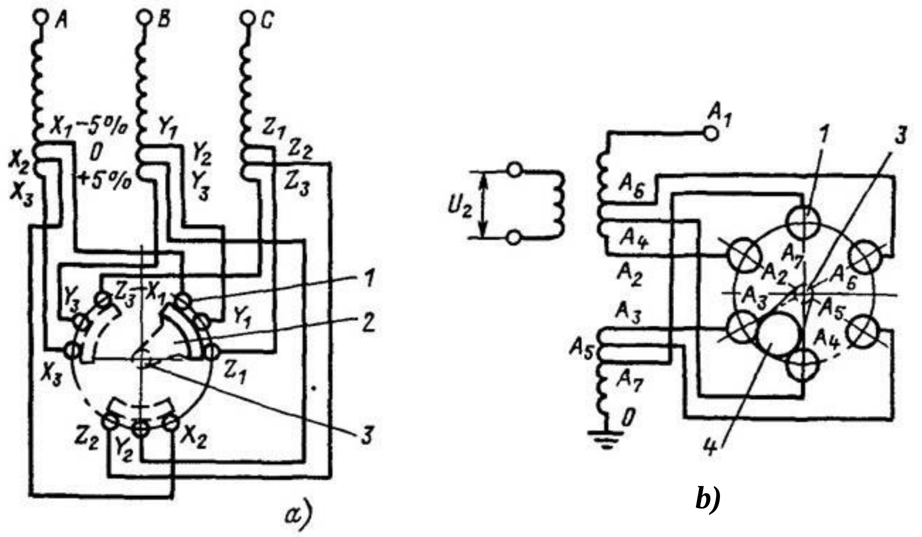

Figure 1: PBV voltage regulation circuit.

a) - branches near the zero point of the winding ± 5% with a three-phase switch for three positions,

b) - branches in the middle of the winding ± 2x2.5% with single-phase switches for five positions (phase A); 1 - fixed contact, 2 - contact segment; 3 - switch shaft, 4 - slip rings.

We used a PBV device to adjust the voltage under laboratory conditions. For the first case, the PBV device was checked in neutral mode, i.e. in position 0. Active resistance R=1000 Ohm, inductive resistance L=1 Hn was obtained. The nominal voltage entering the network was $U_{kir}=U_{B1}=228$ V, the incoming current was $I_{kir}=I_{B1}=0.075$ A.

A table of all values obtained from the network. Table 1.

Time t/s	U_{B1} V	I_{B1} A	ΦB_1 I*	P_{B1} kW	U_{D1} V	I_{D1} A	Φ_{D1} I*	P_{D1} kW
0,1	228,2	0,075	13,5	0,015	207,3	0,351	78,0	0,014
0,2	228,3	0,074	12,4	0,015	207,3	0,352	78,0	0,014
0,3	228,3	0,074	12,2	0,015	207,4	0,352	78,0	0,014
0,4	228,4	0,074	11,9	0,015	207,4	0,352	78,0	0,014

0,5	228,4	0,074	11,9	0,015	207,5	0,352	78,0	0,014
0,6	228,5	0,074	11,9	0,015	207,5	0,352	78,1	0,014
0,7	228,5	0,074	11,9	0,015	207,5	0,352	78,1	0,014
0,8	228,6	0,074	11,9	0,015	207,6	0,353	78,0	0,014
0,9	228,6	0,074	12,1	0,015	207,6	0,353	78,1	0,014
1	228,5	0,074	12,3	0,015	207,6	0,353	78,1	0,014

From the values given in Table 1, it can be seen that the output voltage drops to 207 V when the input voltage is 228 V. The reason for this is that the load of the consumer exceeds the nominal load. We can see this situation in the graph of Figure 2.

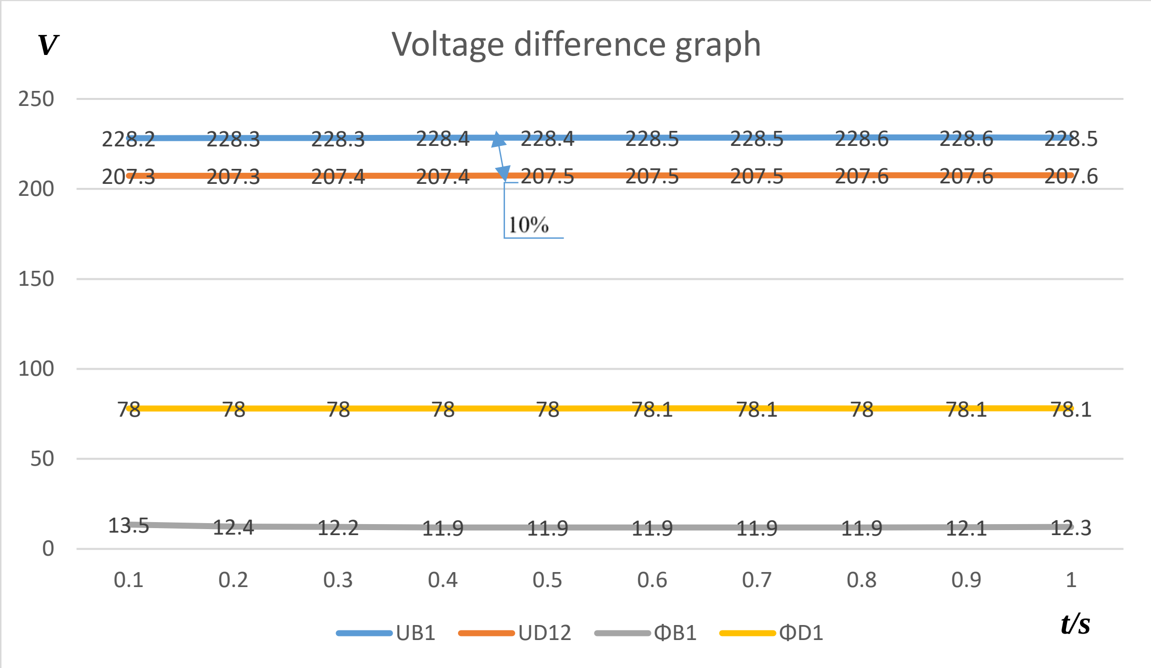

Figure 2; All values in the network, the graph of U_{kir} and U_{chiq} voltage drops.

As can be seen in this graph, network consumers are increasing from the value set by GOST 13109-97. We can use the voltage drop in this case for 6-10 kV electric networks. But we cannot accept this value for the 0.4 kV network [7]. So the mode of the PBV device in state 0 did not meet our standard. We will check the width by raising it from 0 to +5. In this case, the input voltage U_{kir} = 235 V, the output voltage Uchik = 218 V. The remaining values are listed in Table 2.

A table of all values obtained from the network.

Table 2.

Time t/s	U_{B1} V	I_{B1} A	ΦB_1 I^*	P_{B1} kW999	U_{D1} V	I_{D1} A	Φ_{D1} I^*	P_{D1} kW
0,1	241,0	0,083	14,0	0,016	218,1	0,373	78,0	0,016
0,2	241,1	0,083	14,1	0,016	218,1	0,373	78,1	0,016
0,3	241,1	0,083	14,1	0,016	218,1	0,373	78,1	0,016
0,4	241,1	0,083	14,4	0,016	218,1	0,373	78,1	0,016
0,5	241,1	0,083	14,4	0,016	218,1	0,373	78,1	0,016
0,6	241,1	0,083	14,4	0,016	218,1	0,373	78,1	0,016
0,7	241,2	0,083	14,5	0,016	218,1	0,373	78,2	0,016

0,8	241,2	0,083	14,5	0,016	218,2	0,373	78,2	0,016
0,9	241,2	0,083	14,8	0,016	218,2	0,373	78,2	0,016
1	241,2	0,083	14,6	0,016	218,2	0,373	78,2	0,016

The indicators given in Table 2 show the value of the output voltage close to the nominal value. When we set the PBV device to +5 without changing the consumer load, the voltage drop came close to the standard value. We can also see in Figure 3 how close our values are.

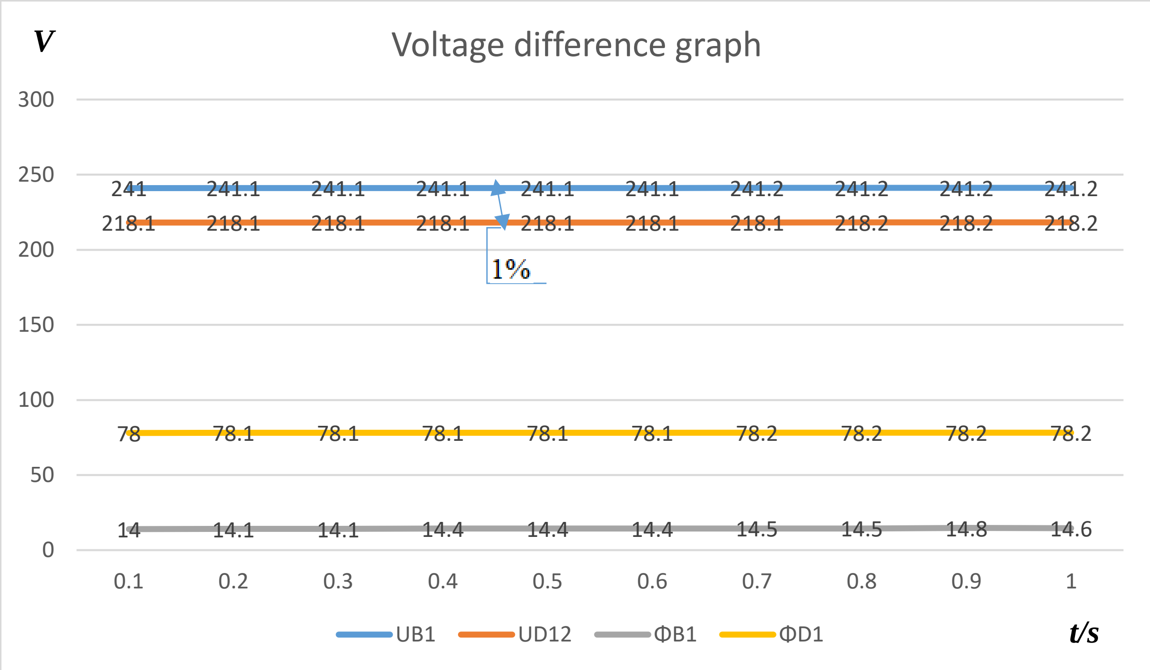

Figure 3; All values in the network, the graph of Ukir and Trip voltage drops.

The obtained values are input voltage and output voltage drop of 1%. For 0.4 kV electrical networks, these indicators satisfy the voltage deviation $\delta U\%$ [8].

Conclusion: We have analyzed through the above tables that the voltage deviation is a condition related to the increase of the load. Voltage deviations of electric networks are often observed in the winter season. The input voltage of the network was U_{kir}=228 V, and the output voltage received by the consumer was U_{chiq}=207 V. If the deviation of our obtained result is 10%, it is considered a non-standard value for 0.4 kV power networks according to GOST 13109-97, and this has a negative impact on the quality of electricity.

After the above values did not give us the desired result, we adjusted the PBV device to +5 steps. In this case, the voltage entering the network was U_{kir}=241 V, and the output voltage received by the consumer was U_{chiq}=218 V. This value, i.e. the voltage deviation indicator, showed 1%. According to GOST 13109-97, this value is a positive indicator close to the nominal value.

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