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Voltage Regulation Devices and Calculation Methods in Power Transformers

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Abstract. *Two and three-phase transformers and autotransformers can be installed at various points in electrical networks and perform the functions of increasing or decreasing the network voltage class. The voltage regime at transformer installations is usually not known in advance; in addition, it may change due to changes in the structure of electricity consumption or changes in the parameters of the electrical network.*

Keywords: *power transformers, load, on-load tap-changer, voltage regulation, electricity.*

INTRODUCTION

To maintain the voltage level required by GOST 13109-97 on consumer buses and ensure economical operating modes of the electrical network, it is necessary to change the transformation ratios of transformers for successful voltage regulation. Therefore, step-down transformers and autotransformers are produced with the ability to change the transformation ratio within 10...20% [1-2]. Regulatory taps are usually made on the supply side, that is, on the high voltage side of step-down transformers (HV), if the highest rated voltage class does not exceed 220 kV. In high classes of rated voltage, autotransformers are installed in networks; their regulating branches are performed on the middle side or neutral of the common winding [3-4].

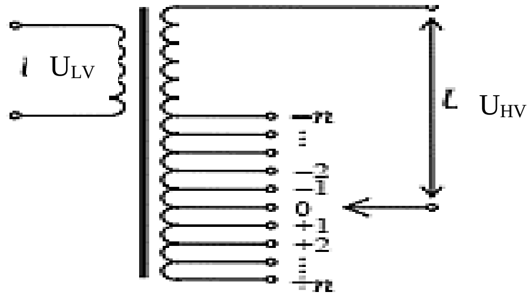

Figure 1. Voltage regulation location

The nominal transformation ratio k_{tn}corresponds to "0" and is found as follows.

$$k_{tr} = \frac{U_{VH}}{U_{LV}} \qquad (1)$$

When changing the number of turns of the transformer winding by changing the control taps, the transformation coefficient changes and can be written as [3].

$$k_{tr} = \frac{U_{HV} \pm n \cdot k\%}{U_{LV}} \qquad (2)$$

Here n is the total number of adjustable branches in the direction of increasing or decreasing the number of turns of the transformer winding, k% is the percentage of one branch in relation to the internal voltage of the highest rated voltage.

Figure 2. State of the substation and its consumer .

2. Research methodology

When placing consumers directly on the substation busbar, U_{tr}it is recommended to maintain the required voltage equal to the rated voltage of the consumer: $U_{tr} = U_{n.пот}$. If the consumer is located at a certain distance from the substation buses, then the voltage on its $U_{пот}$power buses differs from the voltage on the substation buses by the amount of voltage loss in the line ΔU. Therefore, the required voltage U_{tr}must exceed the rated voltage of the consumer $U_{пот}$by ΔU [5-6]:

$$U_{tr} = U_n + \Delta U \qquad (2)$$

The possible coefficient in the OLTC limit is found as follows:

$$k_{tn} = \frac{U_{HV} \pm x \cdot k\% \cdot \frac{U_{HV}}{100}}{U_{LV}} = \frac{U_{HV} \pm x \cdot k(kV)}{U_{LV}} \qquad (3)$$

In Fig. Figure 3 shows a simplified equivalent circuit of a two-phase transformer without taking into account the dependence of power losses in the steel core on the upper side voltage.

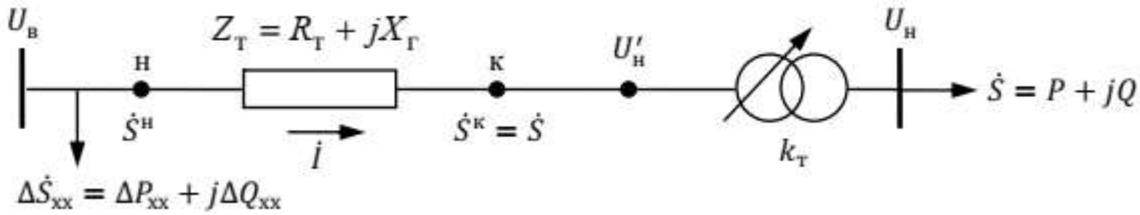

Figure 3. Equivalent circuit of a two-phase transformer.

To select a rational state, it is necessary to take into account the power losses at the transformer resistance $\Delta\,\dot{S}$and determine the power flow at the beginning of the section $\dot{S^H}$(at point " n "):

$$S^H = \dot{S} + \Delta\dot{S} = \dot{P^H} + j\dot{Q^H} \quad (4)$$

In this case, some initial estimates of the voltage value can be used $U'_H$to determine the power loss.

$$\Delta\dot{S} = \frac{P^2+Q^2}{(U'_H)^2}(R_T + jX_T) \quad (5)$$

From the found power current, $\dot{S^H}$you can determine the unknown voltage at the input of an ideal transformer U'_H:

$$U'_H = \dot{U_B} - \dot{\Delta U} = U_B - \Delta U - j\delta U \quad (6)$$

$$U'_H = \sqrt{(U_B - \Delta U)^2 + \delta U} \quad (5)$$

$$\Delta U = \frac{P^H R_T + Q^H X_T}{U_B} \quad (7)$$

$$\delta U = \frac{P^H X_T + Q^H R_T}{U_B} \quad (8)$$

The required transformation ratio is found from the condition that the transformer must provide the required voltage in the low-voltage busbars ($U_H = U_{talab}$) [1].

$$k_{talab} = \frac{U'_H}{U_{talab}} \quad (9)$$

Now, by equating the necessary (9) and possible (3) transformation coefficients, we can determine the rational number of the branch and its "x".

$$k_{talab} = k_{tn} \quad (10)$$

$$\frac{U'_H}{U_{talab}} = \frac{U_{HV} \pm x \cdot k(kV)}{U_{LV}} \quad (11)$$

$$\pm x = \frac{U'_H U_{LV} - U_{HV} U_{talab}}{U_{talab} k(kV)} \quad (12)$$

3. Conclusion

In practice, the rational use of electricity and its savings are among the pressing issues. Electrification of some devices and mechanisms, installation of reactive power compensation devices, as well as preliminary analysis of the technical condition of transformers are highly effective means of ensuring continuity of power supply [6-10].

In conclusion, we can say that the technical method of regulating voltage in electrical networks is effective. With the help of equipment placed in transformers using technical means, it is possible to increase the voltage of consumers in accordance with the requirements of GOST 13109-97 and further increase the duration of normal operation of consumers.

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