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DETERMINATION OF ELECTRICITY LOSSES IN TRANSFORMERS AND METHODS OF REDUCING THEM

The transformer is designed to convert and transmit electricity without changing its power. During the operation of the transformer, energy losses occur, which are associated with the conversion of part of the electrical energy into heat, which is heated by device and dissipated in the surrounding space. The loss of electrical energy in the transformer consists of the main components: electrical losses in the electrical windings of the transformer, magnetic losses in the magnetic circuit and additional losses.

Load losses of electric energy for a single element of the network with active resistance R according to the Joule-Lenz law are determined by the ratio [1]:

$$\Delta W = 3R \int_0^T I^2(t) dt. \quad (1)$$

The analytical function describing the law of change of current in time is often not known, therefore in practice various ways of numerical integration of this relation which define the basic methodical approaches to calculation of loading losses of the electric power in elements of electric networks are applied. One of such methods is the loss time method. According to this method, energy loss in transformers can be determined by the formula [1]:

$$\Delta W = 3RI_{av}^2 k_f^2 T = \frac{W_P^2 + W_Q^2}{U_{av}^2 T} R k_f^2, \quad (2)$$

where I_{av} is the average current value, U_{av} is the average voltage value, k_f is the graph form factor, T is the calculated time period, W_P is the active energy, W_Q is the reactive energy.

A similar approach is used according to the method of calculating electricity consumption according to the normative document of the Ministry of Energy and

Coal of Ukraine "Methodological recommendations for determining the technological consumption of electricity in transformers and power lines" [2].

In these guidelines, the technological costs of electricity include energy losses due to electromagnetic processes in the conductive parts of the electrical network and the cores of the devices during its transmission, as well as climatic losses and energy losses in the insulation of network elements.

At high voltage and low current, the transmission of electricity occurs with less loss. For the most profitable transportation of electricity in the grid, power transformers are repeatedly used: first to increase the voltage of generators at power plants before transporting electricity, and then to reduce the voltage of the transmission line to a level acceptable to consumers.

In real transformers, energy is transferred from the primary circuit to the secondary with losses. The cause of electrical losses is the active resistance of windings. When current flows through the transformer, it heats up and gives off heat to the environment. As the frequency increases, the resistance of the windings increases due to the skin effect. The causes of magnetic losses are the reversal of the core due to hysteresis and the existence of Foucault eddy currents. The alternating magnetic field in the core generates an alternating vortex electric field, which causes additional eddy currents, which also lead to heating. Part of energy is also lost due to the mechanical oscillations that occur due to magnetostriction of the ferromagnetic material of the core, as well as the interaction of the primary and secondary windings in alternating magnetic field. Additional losses occur in other steel elements of the transformer, as well as a result of current asymmetry. Losses in transformers depend on the load. Without load, the losses are due to the resistance of the windings, while at full load there is usually hysteresis and eddy currents.

Therefore, in order to reduce the loss of electrical energy, the resistance of the conductive wires should be as small as possible. Therefore, wires made of well-conducting material, there are used - mainly aluminum or copper with a fairly large cross section. To reduce Foucault currents, the core is made of thin steel plates, the surface of which is oxidized. High resistance ferromagnetic materials are used at high frequencies.

REFERENCES

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