CALCULATION OF ENERGY WASTE OF A TRANSFORMER OPERATING AT THE 110/6 KV SUBSTATION DARKHAN.

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Annotation. This article presents an analysis of energy losses in operating transformers at the "Darxon" 110/6 kV substation located in Andijan, Uzbekistan. The study explores both no-load and load losses in transformers, their causes, and strategies for reducing these inefficiencies. Special attention is given to the physical and electromagnetic principles underlying transformer operation, including core losses, hysteresis, eddy currents, and copper losses. The paper emphasizes the importance of optimizing transformer design to improve energy efficiency and reduce long-term operational costs. Based on the findings, the authors recommend replacing outdated transformers with modern energy-efficient models to minimize energy waste and enhance reliability.

Keywords. Energy loss, transformer efficiency, hysteresis, eddy currents, core loss, copper loss, Darxon substation, power distribution, transformer design, energy saving.

Introduction

Today, electricity is widely used in the development of mankind. It is widely used in industry and agriculture to drive various mechanisms, directly in technological processes, transport, and in cultural and domestic life. Energy is the main sector of the Complex Economy of our Republic. The total installed capacity of Uzbekistan is 11,043 MBt, including 37 thermal power plants and hydroelectric power plants, including thermal power plants - 9,644 MBt, hydroelectric power plants - 1,399 MBt, which provide Uzbekistan with uninterrupted energy.

There are 115 substations with a total capacity in Andijan region. Of these, 6 are 110/35/6 kV, 14 are 110/35/10 kV, 20 are 110/10 kV, 12 are 110/6 kV, 13 are 35/6 kV, 48 are 35/10 kV, and 1 is 10/6 kV. The Darkhon 110/6 kV substation, located in the Khakan MFY in Andijan, was commissioned in 1977. The Darkhon 110/6 kV substation is equipped with T-1 TDN-16 MVA 110/6 kV and T-1 TDN-10 MVA 110/6 kV transformers. The purpose of the diploma project is to calculate the energy losses occurring in the transformer.

Main part

The Darkhon 110/6 kV substation is an important electrical installation that converts, distributes and transmits electrical energy from high voltage to low voltage to consumers. At this substation, electricity is supplied from external power networks via 110 kV overhead or cable lines. The incoming high-voltage energy is reduced to 6 kV by power transformers. Transformers increase the efficiency of the energy transmission process and provide the consumer with the required voltage level.

When idle, the transformer does not transmit electricity to the consumer. The power consumed by it is mainly spent on compensating for power losses due to currents in the magnetic circuit and hysteresis. These losses are called steel losses 〖ΔP〗_st or no-load losses. The smaller the cross-section of the magnetic circuit, the greater the induction in it and, as a result, the more it will idle. They also increase significantly with an increase in the voltage applied to the primary winding above the nominal value. During operation of powerful transformers, no-load losses are 0.3-0.5% of its nominal power. Nevertheless, they try to reduce them as much as possible. This is explained by the fact that steel losses do not depend on the transformer being idle or under load. Since the total operating time of the transformer is usually very large, the total annual energy loss during idle is a significant value.

Electrical losses in winding wires under load, no-load losses

$$\Delta P_{ез} = \Delta P_{ел1} + \Delta P_{ел2}$$

(losses in copper) are added proportionally to the square of the load current. These losses at the rated current are equal to the power consumed by the transformer during a short circuit when the voltage Uk is applied to its primary winding. For high-power transformers, they are usually 0.5-2% of the rated power. To reduce total losses, it is necessary to correctly select the wire cross-section of the transformer windings (reduce electrical losses in the wires), use electrical steel for the manufacture of the magnetic circuit (reduce losses from magnetization reversal), and divide the magnetic circuit into a number of sheets separated from each other (reduce losses from eddy currents).

Transformer efficiency equation:

$$\eta = \frac{P_2}{P_1} = \frac{P_2}{P_2 + P_{эл} + P_{ст}}$$

The efficiency of the transformer is relatively high and reaches 98-99% in high-power transformers. In low-power transformers, the efficiency can decrease to 50-70%. When the load changes, the efficiency of the transformer changes, since the useful power and electrical losses change. However, it remains significant over a fairly wide range of load changes (Fig. 2.1). With a large load, the efficiency decreases, since the useful power decreases, and the losses in the steel remain unchanged. A decrease in efficiency is also caused by overloads, since electrical losses increase sharply (they are proportional to the square of the load current, and the useful power is equal to the current only in the first order). The maximum value of the efficiency is at such a load, when the electrical losses are equal to the losses in the steel.

When designing transformers, they strive to achieve maximum efficiency at a load of 50-75% of the nominal; this corresponds to the most likely average load of the operating transformer. Such a load is called economic.

The proposed material discusses the principles and some subtleties of the process of converting electrical energy, how to avoid some mistakes when designing transformers, and also why the transformation ratio is not always a constant value.

Transformer - a static (without rotating parts) electromagnetic device that converts electrical energy of an alternating current with one voltage (current) value into electrical energy of another voltage (current) value of the same frequency. The simplest transformer consists of a core made of electrical steel, on which two windings I and II are installed (Fig. 2.2). The windings that, when connected to a network with a certain voltage, receive alternating current from it, for example, winding I, are called primary, and the other winding that supplies alternating current to another network or load, for example, winding II, are called secondary.

When an alternating current of a certain frequency is passed through the primary winding, the magnetic flux that appears in the magnetic circuit crosses the turns of the secondary winding, inducing an electromotive force (EMF) in it, which, when the winding is short-circuited to any circuit, causes the appearance of an alternating current of the same frequency in the load.

Since the magnetic flux in its change simultaneously crosses the turns of the energized primary winding, an electromotive force is induced in it, which is in phase with the electromotive force induced in the secondary winding. As for the losses in both copper coils, they depend on the specific load. In this case, the resistance of the primary winding is equal to the sum of its active and inductive resistances. According to Kirchhoff's second law, the voltage applied to the primary winding is equal to the sum of the voltage drops in the two emfs due to the active resistance of the winding and the magnetic fluxes associated with the primary winding. This means that one magnetic flux is wound through the core of the transformer, and the other through the air. Since these magnetic fluxes have different "stickiness", they are described differently in Kirchhoff's law. The resistance of the secondary winding also consists of active and inductive resistances. Active resistance only plays a role when the load is connected to the secondary winding, and inductive resistance

$X_D = w \times L_D$ characterized by leakage inductance $L_D = w \cdot F_D \cdot I$ and, in turn, depends on the magnetic flux F_D, which, in addition to the magnetic circuit, is closed through the air, bypassing the primary winding.

As for the losses in the magnetic core of the transformer, this should be discussed in detail. The alternating magnetic flux in the core, induced by an alternating voltage in the primary winding, induces eddy currents in the magnetic circuit, depending on the frequency, permeability of the magnetic circuit material and its shape. In addition to losses, eddy currents shift the magnetic flux to the surface, demagnetizing the magnetic circuit. To reduce the effect of these eddy currents (Foucault currents), the magnetic circuit is assembled from separate electrically insulated thin plates. In this case, the magnitude of the eddy currents is significantly reduced (up to 1% of their magnitude in a monolithic core). The inherent losses in the transformer core have one feature - the nonlinearity of the magnetization process. As is known, ferromagnetic bodies consist of regions of spontaneous magnetization. The magnetic state of each region is characterized by a magnetization vector. The direction of the magnetization vector depends on the internal elastic stresses and the crystal structure of the ferromagnetic body.

The magnetization vectors of individual regions of a ferromagnetic body that is not affected by an external magnetic field are equally directed in different directions. Therefore, in the space outside this body, the magnetization of the body does not manifest itself. If it is placed in an external field, under its influence the magnetization vectors of individual regions rotate in accordance with the direction of the field. In this case, the induction of the resulting field in the body can be many times greater than the magnetic induction of the external field before placing the ferromagnetic body in it. During the reversal of the periodic magnetization of the ferromagnet, irreversible processes occur in it, for which energy is consumed from the magnetization source. In general, losses in a ferromagnetic core are associated with hysteresis, Foucault currents, and magnetic viscosity. The degree of manifestation of various types of losses depends on the rate of magnetization reversal of the ferromagnetic material. If a core made of transformer steel is slowly remagnetized over time, then core losses are practically only due to hysteresis (macroscopic eddy current and magnetic viscosity losses are zero).

Physically, hysteresis losses are caused by the inertia of the growth processes of the magnetization reversal nuclei, the inertia of the displacement processes of the domain walls, and the irreversible rotation processes of the magnetization vectors. The specific energy loss from hysteresis for 1 cycle of magnetization reversal is equal to the area of the hysteresis loop. Reducing the maximum induction, of course, reduces the loop height, but even at low values of induction and in the presence of bias, for example, with direct current, the width of the partial loop for low-quality steels. remains significant. In other words, reducing the induction in the magnetic circuit to reduce the area of the hysteresis loop has limited meaning.

Analysis and results

The main scheme of electrical connections of power plants (substations) is a set of interconnected main electrical equipment (generators, transformers, lines), busbars, switching and other primary equipment in a natural form, as well as all connections made between them in a natural form.

The choice of the main scheme is the main criterion in the design of the electrical part of a power plant (substation), since it determines the complete composition of the elements and the connections between them. The selected main scheme is the initial information for drawing up the principle scheme of electrical connections, the scheme of own needs, the scheme of secondary connections, the assembly and other schemes.

The main schemes are depicted in the drawing as a single line, in which all elements of the system are disconnected. In some cases, it is allowed to show some elements of the scheme in working condition.

In operating conditions, along with a full description of the scheme, simplified operational schemes are used, which show only the main equipment. The shift supervisor completes the operational scheme and makes the necessary changes to it in the state of the switches and disconnectors during the shift.

When designing electrical systems, before drawing up the main scheme, a structural scheme for supplying electrical energy (power) is drawn up, which shows the main functional parts of the electrical system (distribution device, transformers, generators) and the connections between them. Structural schemes serve for the subsequent more complete and detailed development of the principle schemes, as well as for a general acquaintance with the operation of the electrical system.

Conclusion

The electrical energy losses in transformers at the Darkhan substation were calculated. During the calculation, measures to save energy losses in transformers were considered and the most optimal option was selected. Considering that the transformer at the substation has been operating for many years and that over the years the losses increase, the transformer's transformation coefficient decreases, and energy losses increase, the option of replacing it with modern and energy-efficient transformers was considered. Modern transformers are an alternative option because they are energy-efficient and have low losses, are compact, and have high reliability and safety.Foydalanilgan adabiyotlar

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