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EXTERNAL DESCRIPTION OF TRANSFORMERS AND THEIR EFFICIENCY

[1]Jo'raev M.Q., [2]Muzaffarov F.F., [3]Rustamov S.Sh., [4]Sharopov.F.Q., [5]Hafizov.X.I.

[1,2,3,4&5]Bukhara Engineering Technological Institute, Bukhara, Uzbekistan.

ABSTRACT

The most rapidly developing areas of society and state life are closely related to the increase in electricity consumption. Electricity consumption is also increasing due to the increase in the welfare of the population, the use of more and more electrical appliances in everyday life. This article presents an external description of the transformer and its graph, as well as formulas for determining the useful coefficient of waste.

KEYWORDS: *voltage drop, power loss, short-circuit voltage, load value, inductive properties, active power unit of the transformer, measurement uncertainty.*

DISCUSSION

The level of development of the culture of material production of mankind is determined primarily by the creation and use of a source of energy. Its use, and over the next 100 years, the use of electricity, brought a technical revolution in the development of the industry and played a decisive role in social relations.

In 2000, the monthly electricity consumption of each household consumer was 114 kWh, while in 2018 this figure increased by 57% to 200 kWh. In 1990, the share of the population in the total use of electricity was 10.3%, by 2000 this figure had risen to 13.9%, and in 2018 to 26.5%.

For information, according to estimates, the total demand for electricity in the Republic by 2030 will increase by 1.7 times compared to 2018, including 1.5 times, taking into account the growth factor of the population. With this in mind, the role of transformers in providing uninterrupted power to electricity consumers today is invaluable. In order to ensure the uninterrupted operation of the transformer, the correct choice of transformers should be fully aware of their external characteristics in order to increase their energy efficiency.

According to the state standard, the voltage drop across a given power coefficient of a two-phase transformer is the value of the difference between the voltage of the secondary winding in no-load operation and the voltage of this winding when the secondary rated current is calculated as a percentage of the secondary rated voltage. In this case, the voltage change is brought to the conditional temperature of the blanket at 75Celsius.

Thus,

$$\Delta U_2 = \frac{U_{2H} - U_2}{U_{2H}} \cdot 100 = \frac{U'_{2H} - U'_2}{U'_{2H}} 100 = \frac{U_1 - U'_2}{U_1} \cdot 100$$

Suppose that the voltage drop ΔU_2 is calculated for the nominal value of the current I_H. In this case, the vector $\overline{OA}$ of voltage $\dot{U}_1$ is divided into 100 conditional pieces (Fig. 1) and the sides of the triangle ABS are U_k, U_{ka} and $U_k \cdot r$. Since we are talking about arithmetic difference, we replace the vectors on the sides of the AVS triangle with simple straight lines.

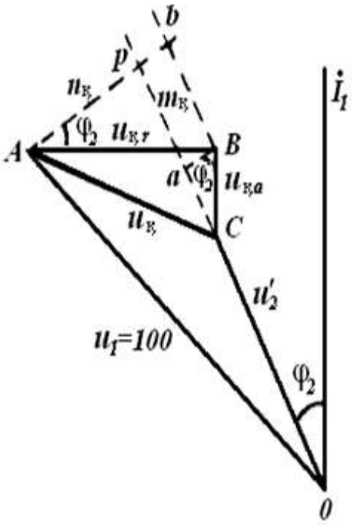

Figure 1 Vector diagram

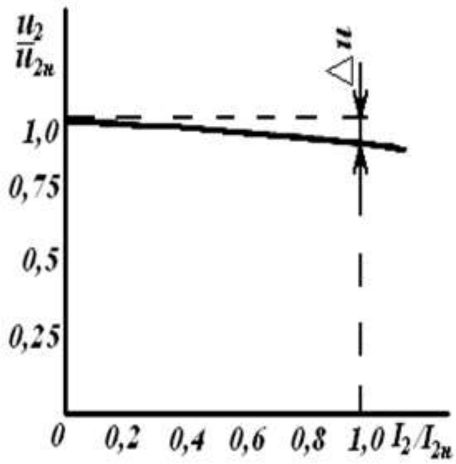

Figure 2. External characteristics of the transformer.

According to Equation (1) above:

$$\Delta U_2 = \frac{100 - U_2'}{100} \cdot 100 = 100 - U_2'$$

From point A we pass AP perpendicular to the continuation of the vector U_2'. We assume that the cross-sections SP and PA are equal to the m_k' and n_k segments.

In that case

$$U_2' = \sqrt{100^2 - n_k} - m_k = 100\sqrt{1 - \left(\frac{n_k}{100}\right)^2} - m_k$$

We spread the value under the root to the binomial row and ignore the higher than the second-order constituents.

Therefore,

$$U_2' = 100\left[1 - \frac{1}{2}\left(\frac{n_k}{100}\right)^2\right] - m_k$$

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$$\Delta U_2 = 100 - U_2' = 100 - 100 + \frac{n_k^2}{100} + m_k = m_k + \frac{n_k^2}{200}$$

To express the above values m_k and n_k through U_{ka} and $U_k \cdot r$, we move Bb perpendicular from the point B to the section CP Ba and AP to the continuation of the section. In that case,

$$m_k = C_p = C_a + aP = U_{ka} \cdot Cos\varphi_2 + U_k \cdot r \cdot Sin\varphi_2$$

and

$$n_K = A_P = AB - BP = U_{KR} Cos\alpha_2 - U_{KA} \cdot Sin\alpha_2$$

Thus,

$$\Delta U_2 = U_{K\alpha} \cdot Cos\alpha_2 + U_{Kr} \cdot Sin\alpha_2 \frac{(U_{Kr} \cdot Cos\alpha_2 + U_{K\alpha} \cdot Sin\alpha_2)^2}{200} \quad (2)$$

For the most part, the second addition of (2) is a very small number relative to the first. Therefore, in cases where there is no need for greater accuracy in the calculations, it is assumed that:

$$\Delta U_2 = U_{K\alpha} \cdot Cos\alpha_2 + U_{Kr} \cdot Sin\alpha_2 \quad (3)$$

In this case, the value of ΔU_2 is calculated for the nominal load. If the load differs from the nominal, for example, if the load differs from the nominal, for example, if the load coefficient $K_{load} = P_2 / P_H$ is not equal together, the voltage drop will change in proportion to Kload.

$$\Delta U = K_{load} \cdot (U_{K\alpha} \cdot Cos\alpha_2 + U_{Kr} \cdot Sin\alpha_2) \quad (4)$$

It can be seen from the above connections that the voltage drop depends on the value and nature of the load when the parameters of the transformer are given.
The external characteristic of a transformer is said to be the connection $U_1 = Const$ *ва* $Cos\alpha_1 = Const\ U_2 f(I_2)$ when the primary voltage and load characteristics are constant. The external description allows the detection of the voltage drop. For example, when $I_2 = I_{2H}, Cos\alpha_2 = 0.8$ *ва* $U_K = 55 - 105\%$, the voltage drop is $\Delta U_2 = 5 \div 8\%$.

Like all electric machines, the efficiency of transformers is η the ratio of the transformer's (secondary) power in the active power unit (ie, kilowatts, or watts) to P2 to the primary power (P1) supplied to it. Thus, the value of the efficiency ratio is:

$$\eta = \frac{P_2}{P_1} \quad \text{ёки}\ \eta = \frac{P_2}{P_1} \cdot 100\% \quad (5)$$

In high-power transformers, the value of the efficiency is very high (99% and higher at large capacities). Therefore, the method of direct determination of the efficiency, ie the method of calculating the efficiency by determining the P1 and P2 using measuring instruments, is not used, because inaccuracies in the measurement of P1 and P2 can lead to gross errors in determining the efficiency.

In such cases, the direct method of determining the efficiency is to determine this or that power through other power and wastes.

If PM is the power dissipation in the coils, Pp is the power dissipation in the steel, P1 + P2 + PP + PM and

$$\eta = \frac{P_2}{P_2 + P_{\Pi} + P_M} \cdot 100\% = (1 - \frac{P_{\Pi} + P_M}{P_2 + P_{\Pi} + P_M}) \cdot 100\% \quad (5.1)$$

In determining these values, some assumptions are made, which simplifies the determination of the efficiency, and at the same time results are obtained with satisfactory accuracy, because the assumptions result in errors, or second-order small values, or offsetting values. These assumptions are as follows.
The secondary power P is called the rated power of the transformer. It is defined as follows:

$$P_2 = K_{load} \cdot P_H \cdot Cos\alpha_2; \quad (6)$$

In this case, Kload is the load factor of the transformer.
The determination of power losses Pp and Pm is conditional.

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Assume that the transformer does not operate at rated primary voltage $U_1 = U_{1H} = Const$ and rated cycle speed (frequency) $f = f_H = Const$.

In no-load mode $P_П \approx P_0$. On the other hand, the steel losses at a given cycle velocity f are $P_П \equiv B^2 \equiv E_1^2$. But, $E_1 = -(U_1 - I_1 Z_1)$. Hence, the change in E1 depends on the voltage drop across the transformer primary winding; when the value of the load of inductive nature increases electromotive force E1 decreases, while E1 increases in capacitive character. This means that if the transformer load is of inductive nature, the waste in steel will be less than in the no-load mode, and in the capacitive load - more In most cases, if the change in load is in the normal range, the change in driving force will not exceed 1.5-4%. This means that steel losses do not change in the range of 3-8%. Thus, under the above conditions (excluding the change in RP), the steel losses can be assumed to be independent of the load,

$$I_1 = I_0 + (-I_2^1)$$

In this transition, if the load is inductive, the value of I1 increases more than in the short circuit, and at the same time the power dissipation in the primary winding copper increases, if the load is capacitive, the reverse occurs, i.e. I1 and with it the PM decreases. Thus, ignoring the value of the magnetic current I0, we reduce the value of losses in copper when the load is inductive (relative to the actual value), and in the case of capacitive load - by multiplying. However, since the effect of I0 is so small, this third hypothesis, like the other two, has almost no effect on the value of the useful work coefficient, on the contrary, it partially compensates for the error in determining steel wastage.

We assume $Z_1 \cdot I_1 \approx 0$ and $I_{oa} \approx 0$, i.e. we see a simplified transformer, because the decrease in forces in the windings of the transformer when the transformer is operating under load is $Z_1 \cdot I_1$ relative to the remaining voltage and electromotive forces, while the value of the active component of the magnetic current Ioa is very small to Io. Therefore, regardless of the value and nature of the current, $\dot{U}_1 \approx \dot{E}_1$. Assuming that the value of the mains voltage U1 is constant, we see that for the value of any load the same constant value of the driving force E1 is formed. Therefore, the main magnetic flux $\dot{\varphi}$, its generating current $\dot{I}_0$, and $\dot{F}_0 = \dot{I}_0 \cdot W$ the values of f are also constant and retain these values in any mode of the transformer.

The value of the short-circuit power PK at the rated current in the windings and at 75 C is given in the transformers according to the state standard.

If the load value is the Kload part of the nominal load, then the currents in the coil will also change once the Kload. This does not take into account changes in the temperature of the blanket (the blanket is heated to the desired temperature and it is assumed that it does not change). This is a waste of energy in copper

$$P_M = K_{load} \cdot P_K, \quad (7)$$

and the efficiency of the transformer for the general case is written as follows:

$$\eta = (1 - \frac{P_0 + Kload \cdot P_K}{Kload \cdot P_H \cdot Cos\alpha_2 + P_0 + K_{load}^2 \cdot P_K}) \cdot 100\%. \quad (8)$$

If there is a constant value given in the given connection, then the only variable of this equation is Kload, and at what value of this coefficient it is possible to calculate the maximum operating efficiency of the transformer. To do this, take the first product of Kload and set it to zero. After that the following is formed:

$$P_0 = Kload \cdot P_K, \quad (9)$$

that is, for the maximum operating efficiency of the transformer to be maximal, the power losses in copper must be equal to the power losses in steel.

In other words, when the variable (Pm) power losses are equal to the constant (Pp) power losses, the efficiency of the Kload reaches its maximum value.

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