ASPECTS OF THE OPERATION IN CHARGE OF ELECTRICAL TRANSFORMERS

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ABSTRACT: Electrical transformer represent the crucial electrical device in the process of converting electricity to different voltage level in electrical transformer and power distribution stations that are part of the National Energy System.

1. Introduction

Electrical transformers can have two or more windings, electrically insulated between them, for changing levels of tension in the transport, distribution and use of electricity. Of the electrical transformers used in power stations and posts, one of the largest use represents the two-winding transformers. This category with two windings has the characteristic that high voltage winding has a greater number of turns and winding low tenisune has a smaller number of turns. At the free ends of the windings of transformers are different voltage lines connecting. Between them, the power transformer transfer is done by induction, due to the magnetic coupling between windings. The power transferred by induction between windings is called internal power transformer. This paper aims to explain the electrical system which has connected to secondary winding a consumer with the impedance $Z_s$.

2. Operation analysis of a transformed electric load

When at the terminals of the secondary winding transformer is connected ZS-facilitates consumer, it passes through the current $i_2$, which is phase-uncle to the secondary voltage $u_2$ angle (fig.1). It is now our attention the transition process from electrical transformer load operation to load operating system. When the transformer is operating under load $i_2 = 0$, and about known it can be assumed that the voltage $U_1$ is fully balanced by fear $e_1$, $U_1 \approx -E_1$.

ZS consumer connect through the transformer secondary winding current $i_2$ passes, which creates t.m.m. $w_{2i}$, which carries the Lenz principle of reverse magnetic action. T.m.m $w_{2i}$ tends to create magnetic flux in magnetic core mutual induction, directed opposite to the basic magnetic flux, $\Phi_0$ the current $i_0$ excited. Reverse the effect of magnetic action, in the first stage of operation of the processor load, the basic magnetic flux $\Phi_0$ is reduced. Due to this reduction in flow $\Phi_0$, is reduced the t.e.m. induced $e_1$. Then for this reason, the primary winding current increases from $i_{10}$ to $i_1 > i_{10}$.

$i_1$ creates t.m.m. $w_{1i}$, which offsets the action of reverse magnetic of t.m.m. $w_{2i}$ on the secondary winding. Therefore, the operating system load of the transformer, each secondary current $i_2$ causes properly the variation change of the primary current $i_1$.

If it is agreed that under load, $U_1 \approx -E_1$ by neglecting the active and reactive voltage drops on the primary winding resistance and reactance, the movement from the no-load operating system to the operating system load, the primary winding current increases such a way as to offset entirely the secondary winding opposite magnetic action.
Fig. 1 Schematic diagram of the transformer operating power under load

However, the magnetic flux $\Phi_0$ is restored to the size that was operating under no-load operating mode, $\Phi_{0\text{m}} = \text{const.}$ In this case, it is resulting the equality between the resultant t.m.m. $w_{10}$ that creates the flow $\Phi_0$ of no-load operating system and the t.m.m resultant of primary and secondary windings $w_1 + w_2$, which creates the same magnetic flux $\Phi_0$ in operating system task:

$$w_{10} = w_1 + w_2 \quad \text{(1.1)}$$

When using the symbolic method, equation (1.1) assumes the form

$$w_{10} = w_1 + w_2 \quad \text{(1.2)}$$

Equation (1.17) is equation t.m.m. in the operating system task processor. After solving it in relation to the current $I_1$ is obtained:

$$I_1 = I_{10} + \left( -\frac{w_2}{w_1} \right) I_2 \quad \text{(1.3)}$$

From expression (1.3) it results that the conventional load current $I_1$ can be decomposed in two components:

- An independent load component $I_{10}$ is equal to no load current and excites the main magnetic flux $\Phi_0$;

- The second component $\left( -\frac{w_2}{w_1} \right) I_2$ depends on the load and overcome the current $I_2$ magnetic response. This component is the secondary current reported and is noted $I'_2$. In this case, equation (1.3) assumes the form:

$$I_1 = I_{10} + (-I_2)' \quad \text{(1.4)}$$

Operating under load, the current through primary winding is $I_1 > I_{10}$, due to which the flow $\Phi_{01}$ increases, so the rated load is around 5% of basic magnetic flux. This leads to the growth of t.e.m. He induced dispersion $E_{01}$. Is amplified the voltage drop $R_1 I_1$. In this case, for the primary winding of the transformer under load, the force is equal:

$$U_1 = E_{11} + R_1 I_1 + j X_{01} I_1 \quad \text{(1.5)}$$

As $U_1 = \text{constant}$, the increase of the voltage drop $R_1 I_1$ and $j X_{01} I_1$ under load demonstrates the reducing of t.e.m. $E_{01}$ and $R_1 I_1$ respectively of the $\Phi_0$ flow. More detailed analysis shows that contrary to increase their load voltage drop, they remain substantially lower than.

More detailed analysis shows that contrary to increase their load voltage drop, they remain substantially lower than $E_{01}$. Consequently, with the known approximations it is acceptable to the load variation, that the $\Phi_0$ flow remains constant. In this case, equation (1.4) is about character:

$$I_1 = I_{10} + (-I_2)' \quad \text{(1.4)}$$

In the equations (1.2) and (1.4) phasor diagrams of t.m.m. current transformer and load are constructed (fig. 2 a, b).

Fig. 2 a, b Phasor diagrams of t.m.m. in current transformer and load

Far examined the response to magnetic secondary winding under load, the influence of that part of the magnetic flux, which closes by magnetic circuit and secondary winding is created by $I_2$ current crossing. The other side of the stream is created by the secondary winding, closes through air and is called leakage flux $\Phi_{02}$.

He only cuts the secondary winding and induces in her t.e.m. dispersion $E_{02}$. And here as in examining primary winding we can admit that the $\Phi_{02}$ flow does not exist, and in its place in the secondary winding circuit is connected in series the inductance with the coil $L_{02}$ in which appears the inductive collapse voltage $-j \cdot X_{02} \cdot I_2$ equal in magnitude and opposite t.e.m. $E_{02}$. $E_{02} = -j \cdot X_{02} \cdot I_2$. By $X_{02} = \omega \cdot L_{02}$ is denoted the Inductive reactance of dispersion-release secondary winding.

In addition to inductive reactance, the secondary winding has also active resistance $R_2$. In this case, the total complex impedance of the secondary winding is
\[ Z_2 = R_2 + j \cdot X_{\sigma 2} \] If it is known the active resistance and inductive reactance it can be established equivalent circuit of the transformer secondary winding fig.3 task.

![Image of transformer equivalent circuit](image)

**Fig.3** The equivalent scheme of the secondary winding of the transformer load

By the second law of Kirchhoff's for the momentary values of the t.e.m. and the voltage drops of the equivalent circuit (fig.3.) it can be established the equation:

\[ e_2 + e_{\sigma 2} = u_2 + R_2 i_2 \tag{1.6} \]

Equation (1.6) acquires the complex form as:

\[ E_2 + E_{\sigma 2} = U_2 + R_2 I_2 \tag{1.7} \]

After the substitution in equation (1.7) of \( E_{\sigma 2} = -jX_{\sigma 2} I_2 \) and the solve in report with \( E_2 \) it is obtained:

\[ E_2 = U_2 + R_2 I_2 + jX_{\sigma 2} I_2 = U_2 + I_2 (R_2 + jX_{\sigma 2}) = U_2 + Z_2 I_2 \tag{1.8} \]

The equation (1.8) characterize the electrical state of the secondary winding of the transformer under load. If considering equations (1.3) (1.4) and (1.8) which is operating under load equations of single phase power transformer, written in complex form (all sizes are considered sinusoidal electric and magnetic) it can be build the transformer phasor diagram under load.

![Image of transformer phasor diagram](image)

**Fig.4** Transformer phasor diagram under inductive load character

Diagram construction starts at secondary voltage phasors \( U_2 \). Phasors \( U_2 \) of phase angle \( \Phi_2 \) there are built the current phasors \( I_2 \) and \( I_2' = \frac{W_2}{W_1} I_2 \). In phase with the \( I_2 \) current is the secondary winding leakage flux \( \Phi_{\sigma 2} \). At 90° from the flow phasors \( \Phi_{\sigma 2} \) it is built the t.e.m. phasor \( E_{\sigma 2} \).

In agreement with equation (1.8) to obtain the t.e.m.phasors \( E_2 \)at the secondary voltage \( U_2 \) it is added the voltage drops phasors \( R_2 I_2 \) and \( X_{\sigma 2} I_2 \) (phasors voltage drop \( Z_2 I_2 \)). The angle between the current phasors and t.e.m. is denoted with \( \Psi_2 \).

The direction of phasors \( E_2 \) t.e.m. coincides with that of phasors t.e.m. \( E_2 \). The difference between the sizes of the two phasors depends on numbers of turns of primary and secondary windings of the transformer. 90° before t.e.m. phasors \( E_1 \) and \( E_2 \) it is built the magnetic flux phasors \( \Phi_0 \).

Because of losses in magnetic core the current phasors \( I_{10} \) the flow \( \Phi_0 \) phasors is phased with angle \( \alpha_1 \).

In agreement with equation (1.4) the \( I_1 \) current phasors is obtained if is made the sum between current phasors \( I_{10} \) with the current phasors built in reverse which is:

\[ I_1' = \frac{W_1}{W_2} I_2 \] in phase with current \( I_1 \) is \( \Phi_{\sigma 1} \) flow. 90° behind him is phased t.e.m. \( E_{\sigma 1} \). To obtain voltage phasors \( U_1 \) is needed the continuation of the construction which represents the graphical solution of the equation (1.4). To this end, phasors t.e.m. \( E_1 \) is traced in reverse and it is added to it the voltage drops phasors \( R_1 I_1 \) and \( X_{\sigma 1} I_1 \) (\( Z_1 I_1 \) voltage drop).

### 3. Conclusions

The angle between \( I_1 \) and t.e.m. \( -E_1 \) current phasors is denoted by \( \Psi_1 \) and the angle between current phasors \( I_1 \) and voltage \( U_1 \) with \( \Phi_1 \). Transformer is inductive load. Active power consumed by the processor is \( P_1 = U_1 I_1 \cos \Phi_1 \) and active power is transferred to \( P_2 = U_2 I_2 \cos \Phi_2 \) consumer. Phase difference for the case examined the nature inductive load is greater than the current \( \Phi_2 \) due to the influence of the no-load current operation, which is almost purely inductive nature.

Phasor diagram reports give a clear picture for characterizing amplitude and phase variables transform processes. Phasor dia-gram construction work and capacitive load is done similar to the inductive operating.

Operating regime is normal work procedure for transformer and within it is given the power with the parameters converted to consumers.

### 4. References

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