A NEW METHOD OF DESIGNING TRANSFORMERS, PRELIMINARY COMMUNICATION

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New formulas to serve as foundations for a rational modernized design for transformers are presented as follows.

$$\Delta = k/\alpha\sqrt{\eta\ K_C/K_S} \quad \text{.......... (1)}$$

where Δ denotes the current density; α, the root-mean-square (rms) load factor; η, the core loss per pound of steel laminations; K_C, the cost of winding conductors per pound; K_S, the cost of core laminations per pound; and the value of k depends upon the average temperature of the conductor, being 715 for 80° C, 700 for 90° C, 685 for 100° C, 675 for 110° C, and 665 for 120° C.

$$A_S = C\ \alpha\sqrt{[(KVA)/4f]\ [\Delta/\eta B]} \times 10^3 \quad \text{....(2)}$$

where A_S denotes the net metallic cross-section area of the core; (KVA), the output in kilovolt-amperes; f, the frequency; B, the flux density in the core; and C is the output constant which usually varies within the limits 0.40 to 0.55 for a single-phase core-type transformer, averagely $C = 0.475$.

$$B_{\alpha'} / B_{\alpha''} = \sqrt{\alpha' / \alpha''} \qquad (3)$$

where $B_{\alpha'}$ and $B_{\alpha''}$ are flux densities for α' and α'' rms values of load factor respectively. The formula (3) may be given the particular form

$$B_{\alpha} = 93{,}500\sqrt{\alpha} \qquad (4)$$

for all practical values of α.
Where α_0 represents a usual load factor, this is the ratio of the arithmetical average load to peak load, while α represents the ratio of rms load to peak load. It is found that α exceeds α_0 by the amount $d\alpha_0$ so that

$$\alpha = \alpha_0 + d\alpha_0 \qquad (5)$$

$$d\alpha_0 = 0.08(1 - \alpha_0) \qquad (6)$$

The following formula is also useful for consideration:

$$\textit{loss ratio} = 1/\alpha^2 \qquad (7)$$

which means that the ratio of copper loss to that in the core should be correlated with rms load factor.

With the rated high and low tension voltages given and Δ, A_s, and B computed from the foregoing equations the designer is in position to find the number of turns of the windings and the size of the conductors for the desired α or α_0; in other words, the fundamental characteristics of the electric circuit will then be outlined. As to the magnetic circuit, in addition to A_s a tentative length for the mean magnetic path l_m is made determinable by following equations. For a single-phase transformer,

$$l_m = [\alpha^2/(1+\alpha^2)] \; [(1-e)/\eta e] \; [(KW)/\gamma A_s] \qquad (8)$$

For a three-phase transformer per phase,

$$l_{mph} = [\alpha^2/3(1+\alpha^2)] \; [(1-e)/\eta e] \; [(KW)/\gamma A_s] \qquad (9)$$

where e denotes efficiency and γ the specific weight of the steel laminations.

This communication concerns a further development of a method previously discussed by the writer (Oboukhoff 1942) and is a preliminary report on a continuing investigation final results of which are to be published later.

LITERATURE CITED

Oboukhoff, N. M. 1942. Emergency overloading of air-cooled oil-immersed power transformers by hot-spot temperature. Suppl. Tr. Am. Inst. Elec. Engr. 61: 993-994.