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## **METHODS OF REDUCING LOAD LOSSES IN TRANSFORMER WINDINGS**

In contrast to idle losses, the reduction in load losses was not accompanied by a significant improvement in materials. Load losses in the wire consist of direct current losses in the ohmic resistance of windings ( $I^2R$  losses), eddy current losses in the wire and additional losses in the tank walls and metal parts of the structure. The main way to reduce load losses was to reduce the current density in the wire by increasing its cross section. However, this had two negative consequences: firstly, the dimensions of the core, its weight, and idle losses increased; secondly, losses caused by eddy currents increased. The use of a compact transposed wire, consisting of a large number of insulated from each other and transposed conductors with common insulation, partially removed the first drawback and to a greater extent the second.

Currently, large transformers use a transposed wire in which the number of elementary conductors can reach 80.

The wire may have insulation with epoxy resin, which after polymerization during the drying process gives greater rigidity to the wire, which increases the strength of the windings when exposed to short circuit currents.

The additional losses in the metal parts external to the windings are caused by the scattering flux generated by the windings, which depends on the configuration of the windings and is independent of the current density. As the loss in the wire in the load loss decreases, the proportion of additional losses outside the windings increases, especially in transformers with a large value of short-circuit resistance. As ratings of transformers increase, the proportion of stray losses in their load loss may increase significantly. These losses in structural components may exceed the stray losses in windings in large power transformers (especially autotransformers). A major portion of these stray losses occurs in structural components with a large area (e.g., tank plates) and core clamping elements(e.g.,

frames). The high magnitude of stray flux usually does not permit designers to disregard the nonlinear magnetic characteristics of steel elements.

Previously, control of the scattering field was carried out primarily in order to avoid unacceptable heating at individual points on the walls of the tank and other metal parts, especially in transformers of high power or having a high value of short-circuit resistance. Today, such control is also carried out to reduce additional losses. To reduce additional losses, conductive screens are used, which serve to deflect the magnetic flux from the surface to be protected, or electromagnetic shunts that collect and direct part of the magnetic flux in the desired direction.

The advantage of electromagnetic conductive screens is their simplicity and the ability to give them the necessary shape to protect the surface of a complex configuration. Their disadvantage is that in the screen itself there are losses that must be estimated, and the screens themselves must have cooling. In this case, it is necessary to control the scattered flux deflected by the screen, which can induce losses in other parts made of magnetic material.

Electromagnetic shunts direct magnetic flux along paths where there can be only small losses, preferably outside the walls of the tank and other metal parts. The advantage of electromagnetic shunts recruited from electrical steel is the better control of the scattering field and losses created by this field. The disadvantage is the difficulty in giving the shunts the necessary shape when protecting parts of complex configuration.

Shielding allows you to reduce additional losses in the protected parts by more than 50 %. In modern transformers, the additional losses can be from 10 to 50 load.

Existing calculation methods to determine the most favorable location: protective devices (shields or shunts), losses created by the scattering field, and the temperature at the site of the greatest losses.