METHODS FOR REDUCING POWER LOSSES IN TRANSFORMERS

Utkirbek Akramjonovich Axmadaliyev
Senior Teacher, Department of Alternative Energy Sources,
Andijan State Technical Institute, Uzbekistan.

This thesis analyzes power losses occurring in transformers, their main types, and methods for improving energy efficiency. The study scientifically explains the causes of copper losses, core (magnetic) losses, stray flux losses, dielectric losses, and mechanical losses. It is shown that transformer load conditions, operating state, and design features directly affect power losses.

In addition, based on practical observations conducted in the electrical distribution networks of Khonobod city, it was found that transformers are unevenly loaded, with excessive loads in some lines and inefficient use of available capacity reserves in others. The research results indicate that optimal transformer loading, network reconfiguration, the use of modern energy-efficient transformers, and the implementation of monitoring systems are important factors in reducing electrical energy losses.

Transformers serve as a key technological component in power transmission and distribution systems. Their technical condition and energy efficiency have a direct impact on the overall reliability and economic performance of the power supply system. Recent scientific studies and practical observations show that more than one-third of total technical losses in transmission and distribution networks are attributed to transformers.

Modern power transformers typically have an efficiency (η) of about 97–98%. Despite this high efficiency, even a 2–3% power loss on a large scale—at the level of a national energy system—results in thousands of megawatt-hours of wasted energy. This, in turn, leads to economic losses, increased operational costs, and, in many cases, environmental damage.

Therefore, identifying the sources of energy losses in transformers, classifying them into different types, and developing scientifically based measures for their reduction is currently considered one of the most urgent scientific and technical tasks. In particular, the low efficiency of aged transformers and their impact on electrical power networks must be thoroughly evaluated on a large scale.

Types of power losses in transformers

Transformers play a crucial role in the efficiency of electrical energy transmission and distribution systems. During their operation, a certain amount of power losses inevitably occurs. These losses are generally classified into several main groups:

1. Copper Losses

Copper losses in a transformer occur as a result of the electrical resistance of the windings when current flows through them. These losses are manifested in the form of heat generation. The magnitude of these losses is determined based on Joule–Lenz’s law:

$$P_{(cu)} = I^2 \cdot R$$

where:

I – current in the winding (A),

R – electrical resistance of the winding (Ω).

As the temperature of copper increases, its electrical resistance also increases. Therefore, when the transformer is loaded or overloaded, copper losses significantly increase.

2. Core (Iron) Losses

Core losses in a transformer occur due to the periodic variation of magnetic induction in the transformer core. They are generally divided into two main components:

Hysteresis losses – These occur due to internal friction during the magnetization and demagnetization processes of the magnetic material. The magnitude of hysteresis losses depends on the properties of the magnetic material and the operating frequency.

Eddy current losses – These arise due to circulating currents induced within the core as a result of changing magnetic flux. To reduce these losses, the core is made of special electrical steel and constructed from thin laminated sheets that are electrically insulated from each other.

3. Stray Losses

Stray losses occur due to leakage magnetic fields that extend beyond the transformer windings and interact with other structural parts of the transformer. These losses are typically induced by stray magnetic flux in metallic components such as the transformer tank, cover, bolts, and structural steel parts, leading to localized heating effects.

4. Dielectric Losses

Dielectric losses occur within the insulating materials of a transformer, such as oil, paper, and other polymer-based insulation materials, due to leakage currents under the influence of an electric field. These losses are particularly significant in high-voltage transformers. Dielectric losses increase considerably when the insulation becomes aged, contaminated, or moist.

5. Magnetostriction Losses

Magnetostriction losses arise due to periodic changes in the physical dimensions of the core material under the influence of a magnetic field (magnetostriction effect). These vibrations result in acoustic noise and mechanical oscillations in the transformer structure. A portion of the electrical energy is thus converted into mechanical vibrations, which is considered an undesirable energy loss.

6. Mechanical Losses

Mechanical losses are mainly associated with the operation of auxiliary transformer components such as cooling systems, fans, oil pumps, and other moving parts. In addition, vibrations, friction, and wear of mechanical fastening elements (such as rubber seals and joints) also contribute to these losses. Although these losses are not directly electrical in nature, they reduce the overall efficiency of the transformer system.

In some areas, transformer capacity reserves remain underutilized, which increases core (iron) losses;

In other areas, excessive load leads to higher power losses and accelerates the degradation of transformer lifespan.

These analyses indicate the need to ensure optimal loading of the electrical network. In order to improve energy efficiency, it is necessary to reconfigure transformers, balance the load distribution, or modernize the power distribution network.

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