International Journal of Academic Multidisciplinary Research (IJAMR)
ISSN: 2643-9670
Vol. 6 Issue 1, January - 2022, Pages:161-163

Prospects for the Use of Magnetoamorphic Materials for Energy Saving In the No-Load Operation of Transformers.

Ahmedov Abdirauf

Teacher, Jizzakh polytechnical institute
Jizzakh, Uzbekistan
umidkhudoyberdiyev1994@gmail.com

Abstract: *The efficiency of modern transformers is very high. However, power losses occur when large power transformers operate in the no-load. This power loss in no-load is a small percentage of the total power of the transformer. Continuous operation of the transformer also results in the high power losses indicated above. For this reason, in modern power transformers instead of electrical steel, magnetic materials from amorphous alloys are used. The article analyzes the prospects for the use of magnetic materials from amorphous alloys in modern power transformers.*

Keywords: amorphous magnetic material, power dissipation, power transformers, no-load losses

INTRODUCTION

The most important characteristic of electrical energy is that it can be transferred long distances from its generation unit. To transfer and distribute electric energy through power lines with high efficiency and minimal energy losses, the voltage of conducted electrical energy must be as high as possible and the current must be as low as possible. Thus, the voltage value of electrical energy must be increased where it is generated and then transformed to a low voltage at the point of supply [1]. The electrical energy generated at stations must be delivered to consumers. Transmission, subtransmission, and distribution voltage levels are factors considered by generating stations and consumers. Cheaper long-distance transmission at both high and low voltage is necessary, so voltage levels from the transmission system to the distribution system continue to decrease. Because of this, there are fewer but more powerful transformers in electrical transmission systems; however, less powerful transformers are required in large numbers in electrical distributing systems The most efficient distribution transformers, which are in service continuously except for maintenance and failure breaks, record a loss of approximately 2% to 4% of the electricity they conduct. Consequently, electric utilities and industries are searching for methods and technologies to reduce operating costs and energy losses. Electrical energy is produced using scarce resources and is becoming more expensive. New transmission and distribution technologies are being introduced to solve this problem [2]. Owing to the importance of the no-load losses in total distribution transformer losses, no-load losses in electrical steel has been studied since the invention of the transformer. No-load losses of transformers manufactured from electrical steel cores are very high compared to those recorded in the early days of transformers.However, an amorphous material discovered in the 1950s became usable as a core by the 1990s instead of the classic electrical steel core. Studies have found that no-load loss rates of 60%–70% in classic electrical steel core transformers are achievable only when amorphous laminated strips are used. Utilizing ferromagnetic materials in the production of the magnetic circuits of distribution transformers could help reduce the losses caused by Fe cores and diminish operating costs of the service providers. The scale of the gains achieved depends on the loss evaluation. Transformer design is the most important component when it comes to gains, according to optimization calculations [3]. Distribution transformers are used to distribute the electrical power in residential, commercial and industrial areas. Distribution transformers are energized for twenty four hours with wide variation in load; therefore they are designed to have low no-load losses. It is generally designed for maximum efficiency at about half full load. In order that the all-day efficiency is high, iron loss is made less by selecting a lesser value of flux density. In other words distribution transformers are generally designed for a lesser value of flux density. Two types of losses are inherent in the running of distribution transformers: no-load losses that occur in the transformer cores due to hysteresis and eddy current losses which are constant and present as soon as the transformer is energized and load losses that occur in the transformer’s electrical circuit due to resistive losses that are a function of loading conditions. The main no-load loss is core loss, which is associated with the time varying nature of the magnetizing force and results from hysteresis and eddy currents in the core materials. Core losses are dependent upon the excitation voltage and can increase sharply if the rated voltage of the transformer is exceeded. Hysteresis losses can be reduced by selecting low core losses material (such as amorphous metal), while eddy currents can be lowered by reducing lamination thickness. The problem has been overcome to some extent with the development of amorphous metal strips. This is achieved by compacting number of thin ribbons. This strip is commonly known as `Power Core'. Amorphous strips are four times harder than CRGO steel [5]. The brittleness property of amorphous metal has also made it un-friendly to the transformer manufacturers. The manufacturers of amorphous core distribution transformers are very limited in the world because of two reasons, one is its high material cost and another is its brittleness property. Because of limitation of its brittleness property, in amorphous core transformers manufacturers are using square or rectangular cross section of the core This paper primarily focuses on design of amorphous core distribution transformer. Amorphous metal core has some merits; the non-crystalline structure and random arrangement of atoms gives low field magnetization and high electrical resistivity. Due to low field magnetization, hysteresis loss is low and due to high electrical resistivity eddy current loss is suppressed. As such core losses of amorphous metal alloys get reduced by 42 per cent and magnetizing current by 53 percent.

TRANSFORMER LOSSES

Although zero power loss is expected from an ideal transformer, practically, when energized, a transformer will have some losses that occur in the windings, core, and the surrounding structures. When the transformer is energized, but no load is applied, no-load power loss occurs due to the material that is used in the core. This loss value is constant; it occurs whether or not current flows in the secondary windings. When current flows in the secondary windings, load losses occur due to the flow of the load current through the winding resistance. Thus, total transformer losses can be determined using the following expression.

$$P_t = P_0 + P_k \tag{1}$$

In Eq. (1), the first term P_0 corresponds to the no-load losses and the second term P_k stands for the load losses.

NO-LOAD LOSSES

Amorphous core transformers play an important role in reducing no-load losses. These transformers use an amorphous alloy for the Fe core, around which the transformer windings are coiled. Whether or not a load is present, there will still be power loss. This power is necessary to sustain an energized core. The losses that exist if the unit is energized are called no-load losses, or core losses. Voltage and frequency are the base factors of no-load losses, and under operational conditions they change, depending slightly on system variations. The losses stem from the magnetization of the core, dielectric losses in the insulation, and winding losses due to the flow of the exciting current and any circulating currents in parallel conductors. No-load losses are calculated using the following mathematical expression in Eqs. (2) and (3)

$$P_0 = P_{hys} + P_{eddy} + P_{ano} \tag{2}$$

$$P_0 = (k_h \times f \times B^n{}_m) + (k_g \times f^2 \times B^2{}_m) + (k_a \times f^{1.5} \times B^{1.5}{}_m) \tag{3}$$

In Eq. (2), P_{hys} represents hysteresis losses, P_{eddy} represents eddy-current losses, and P_{ano} represents anomalous losses. In Eq. (3), k_h , k_g , and k_a constants are obtained by the experimental data; f is frequency of primary voltage; B_m is the maximum flux density in the core; and the Steinmetz constant n is 1.6. When the no-load power losses are due to the microstructure of the material, the conductivity is dependent on the cross-sectional area and lamination. Eq. (3) is valid in a certain range of frequencies and flux densities. Hysteresis losses are defined as the loss equal to the area of the static magnetization loop times the cycle rate. They are the first component of the no-load power losses that are known as “core losses”. The area of the hysteresis loop times the frequency at very low frequencies is an accurate estimate of no-load losses. At low frequencies, hysteresis losses are a large part of the no-load power losses, compared to eddy-current losses and anomalous losses [4].

AMORPHOUS CORE TRANSFORMER DESIGN CONSIDERATION

A crucial aspect of transformer design is selecting the ferromagnetic material for the cross-section core and the conductor’s cross-section area. Suitable values for the peak flux density, the winding space factor, the stacking factor, and the full-load rms current density in the windings are the main factors in the determination of these areas. Ferromagnetism is the basic mechanism by which certain materials (e.g., Fe) form permanent magnets or are attracted to magnets. The strongest type creates forces strong enough to be felt. The current density depends on the transformer’s operation mode, whether in an intermittent or in a continuous form. Today, the thickness of a sheet of grain-oriented silicones has been reduced to 0.18–0.30 mm. Development of classic Fe–Si steel has led to production of a low material loss including:

-normal Si steel (0.35 mm thickness, 0.9 to 1.1 T),

-hot-rolled grain-oriented Si steel (HRGO; 1.2 to 1.4 T),

-cold-rolled grain-oriented Si steel (CRGO; 0.14 to 0.28 mm thickness, 1.4 to 1.7 T).

Transformer cores are built from thin sheets of steel. These sheets are manufactured specifically for use in transformers. Core steel has a low carbon content of 0.1%. Increased carbon content has a detrimental influence on hysteresis losses as well as the aging properties. If it is alloyed with Si, which increases the specific electrical resistance, this reduces eddy-current losses in the core and also makes the core brittle; hence, the Si content should be kept below 3%. Nowadays, grain-oriented steel produced with cold-rolled steel sheets is used. The magnetic domains in the steel sheet will tend to be oriented in the rolling direction. The material obtained has good loss properties in the rolling direction and correspondingly poor properties in the transverse direction. The grain-oriented core steel is available in several grades, depending on raw material composition, the degree of cold rolling, and different finishing treatments [6].

CONCLUSION

The significance of the amorphous core transformer gets more important when the focus is on a real electrical distribution system. Due to the load of the transformer in the real system, the total loss of the transformer decreased by 47% in an urban area and 62% in rural areas disregarding harmonic effects on the losses.

REFRENCES

[1]. Chapman SJ. Electric Machinery Fundamentals. 4th ed. New York, NY, USA: McGraw-Hill, 2004.

[2]. Bertotti G. General properties of power losses in soft ferromagnetic materials. IEEE T Magn 1988; 24: 621–630.

[3]. Alexandrov N, Schulz R, Roberge R. Amorphous alloys for distribution transformers: design considerations and economic impact. IEEE T Power Deliver 1987; PWRD-2: 420–424.

[4]. Mulder S. Loss Formulas for Power Ferrites and Their Use in Transformer Design. Laguna Hills, CA, USA: Philips Components, 1994.

[5]. Benedito Antonio Luciano, Misael Elias de Morais, and Claudio ShyintiKiminami, “Single Phase 1-kVA Amorphous Core Transformer: Design, Experimental Tests, and Performance after Annealing” IEEE Trans. Vol. 35, No. 4, July 1999.

[6]. Hasegawa R, Azuma D. Impacts of amorphous metal-based transformers on energy efficiency and environment. J Magn Magn Mater 2008; 320: 2451–2456.