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Original Article

Comprehensive Analysis of Transformer Losses-Merging Experimental Insights with Simulation Techniques

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Abstract

The transformer in electrical power system plays a vital role for increasing the voltage for transmission and reducing for distribution and utilization. The continuous operation, over loading and poor selection of core material produces losses which badly affect the efficiency of transformer and may result in burnt out the winding. The students of electrical department conducted the survey at 132 kV grid station Larkana and physical understand the parts of transformer and execute the hand on experiments in the laboratory for the understanding of losses effect on transformer. The practical results are also authenticating through MATLAB Simulink software. The aim of this study to find out the causes and effects of losses in the transformer.

Keywords: Power Transformer, Grid station, Power Transformer, Instantaneous Over-current Relay

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INTRODUCTION

The transformer in electrical power system plays a vital role for increasing the voltage for transmission and reducing for distribution and utilization [1]. The continuous operation, over loading and poor selection of core material produces losses in which badly affect the efficiency of transformer and may result in burnt out the winding [2] and [3]. The aim of this study to find out the causes and effects of losses in the transformer by experimental and simulation approach [4] and [5] due to vital role in power engineering [6]. The conventional methods which are applying is on assumption made and the results in this research paper may lack of in accuracy during practical application [7]. The open, short circuit tests and simulation results are conducted to facilitate the researcher to analyze the losses of transformer [8] and [9], and [10]. Conversely, simulation results can complement experimental findings by providing insights into phenomena that may be challenging to observe directly. Overall, the integration of experimental and simulation methods offers a promising approach for analyzing transformer losses and optimizing transformer design and operation [11]. This approach bridges the gap between theoretical models and practical applications, enhancing our understanding of transformer performance and facilitating the development of more efficient and reliable power systems. Two types of losses occurred in the transformer, iron and copper losses. The iron losses occurred in the core of transformer which covers the performance and efficiency. During operation of transformer proper magnetization and demagnetization is essential even at no load [12]. It is essential to reduce the iron losses in avoid poor operation and efficiency of [13]. The iron loss is divided into two parts hysteresis and eddy current losses [9]. The selection of core material is important for reducing the hysteresis loss because it is more dependent on magnetic

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properties of core material [14]. The eddy current loss is also known as circulating current loss in the transformer tank and depend on the thickness and conductivity of core material [15]. The combination of both losses is referred as tank losses and measured through no load condition [16]. It is essential to reduce these types of losses to improve the efficiency of transformer [17]. These losses can be reduced by adding good core material and lamination of core [18]. The copper loss are another type of transformer losses which occurred in winding and mainly depend on the load of the transformer. The selection of good core material and avoiding overloading of transformer pushes transformer with higher efficiency

TRANSFORMER

Transformer is a static device which transfer electrical power from primary side to secondary side in shape of higher or lower voltage [19]. The principle of operation is based on induction. The primary and secondary windings are separated electrically but coupled magnetically and wound around the core [20]. Transformers are utilized for higher voltages to reduces the losses and the material required for installation and also selected for lower voltages for industrial, commercial and residential purposes [21]. The transformer also provide good isolation between input and output circuits and helps impedance matching for maximum power transfer efficiency [22]. Finally, transformers are essential devices for the transfer of electrical power from generation to distribution network for maintaining power quality [23].. Figure 1shows the internal and external assembly of transformer [21]. The selection of good core material and avoiding overloading of transformer pushes transformer with higher efficiency

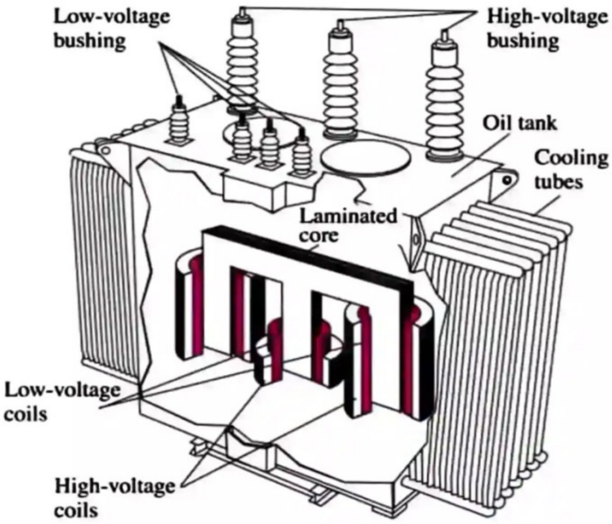

Fig. 1. Electrical Power Transformer

METHODOLOGY

The investigation was conducted at the Electrical Machines Laboratory within the Department of Electrical Engineering at the University of Larkano. The purpose was to assess the core and copper losses of a transformer. A range of equipment was utilized to evaluate these losses, employing both open circuit and short circuit tests, as illustrated in Figures 2(a), 2(b), 2(c), and 2(d).

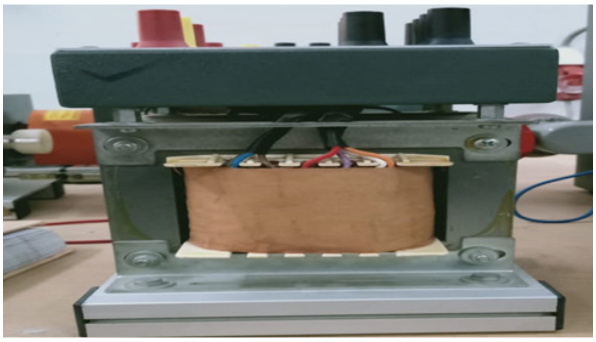

Fig. 2(a) Internal view of transformer

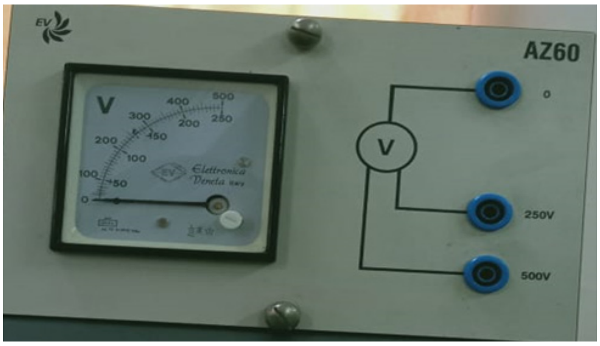

Fig. 2 (b) Voltmeter

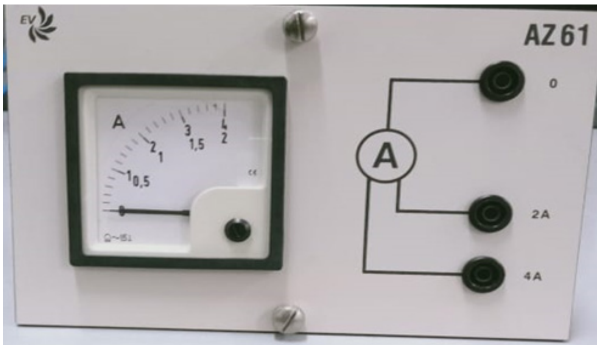

Fig. 2(c) Ammeter

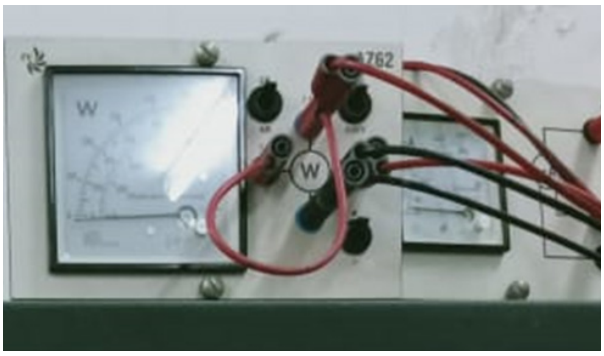

Fig. 2(d) Wattmeter

Core losses Test

Understanding the losses incurred by transformers is vital for evaluating their efficiency and operational performance. The open and short circuit tests are conducted to evaluate the both iron and copper losses. The open circuit diagram is shown in in Figure 3 and enlist the results in Table I.

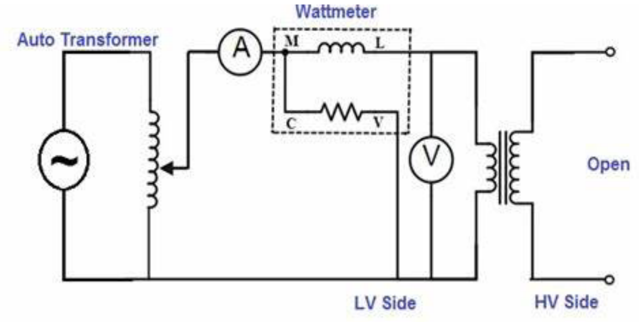

Fig. 3. Connection diagram of core loss test

Table I

Experimental results of core losses

S.No	Item	Result (Losses)
1	Voltage (220 volts) Current (0.12 ampere)	12.2 Watt
2	Voltage (200 volts) Current (0.094 ampere)	10.2 Watt
3	Voltage (180 volts) Current (0.073 ampere)	8.4 Watt

Copper loss Test

The copper loss test is proposed to analyzes the copper losses, in this test one winding (low voltage) is short circuited and other winding (high voltage) is open circuited. The Figure 4 represent the connection of short circuit test [24]. The results based on experiment are given in Table II.

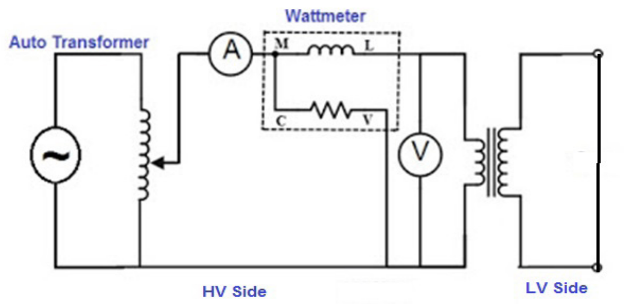

Fig. 4. Connection diagram of copper loss test

Table II

Experimental results of copper losses

S.No	Item	Result (Losses)
1	Voltage (10.4 volts) Current (2.088 ampere)	21.5 Watt
2	Voltage (8 volts) Current (1.612 ampere)	12.8 Watt
3	Voltage (7 volts) Current (1.189 ampere)	7 Watt

SIMULINK SOFTWARE RESULTS

A MATLAB simulation model has been devised to analyze the core losses and copper losses experienced by transformers. Figures 5(a) and 5(b) depict the open circuit and short circuit tests, respectively.

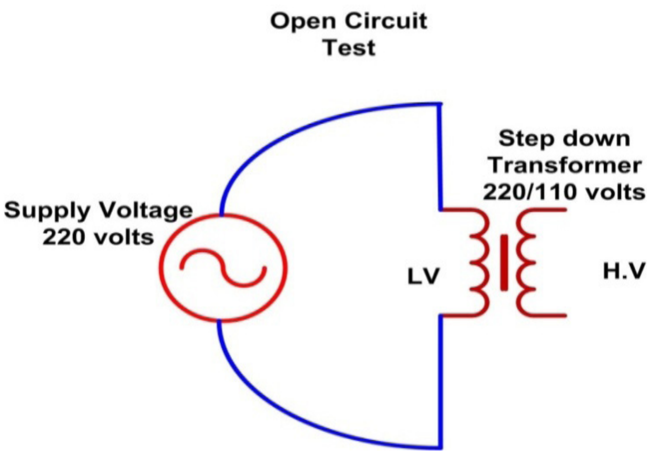

Fig. 5(a). Open circuit test simulation diagram

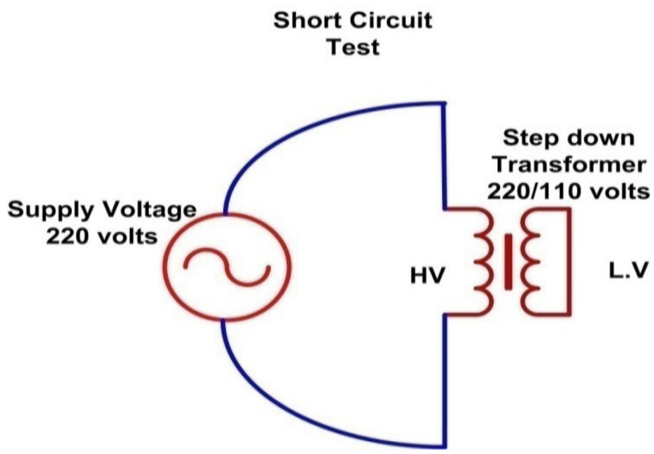

Fig. 5(b). Short circuit test simulation diagram

Results and Discussions

A. Open Circuit Test

It has been seen in simulation results that the core losses are decreased at 150 Volts and shown in Figures 6(a), 6(b), and 6(c), the RMS values of current, voltage, and power and tabulated in Table III.

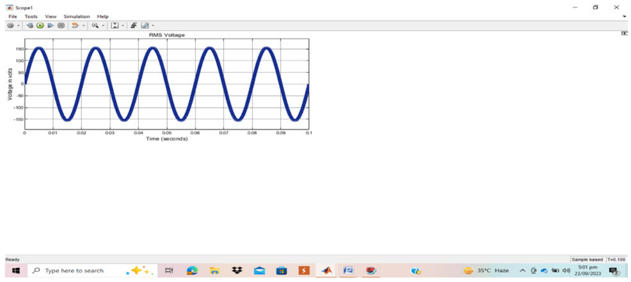

Fig. 6(a). Normal Voltage

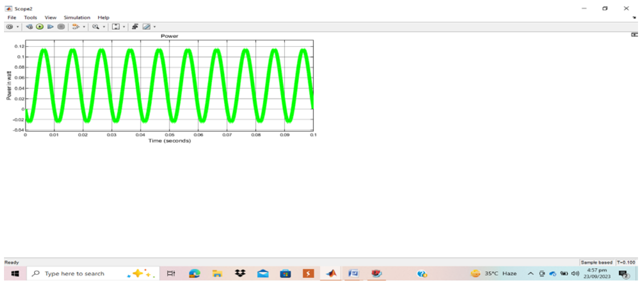

Fig. 6(b). Core losses measured

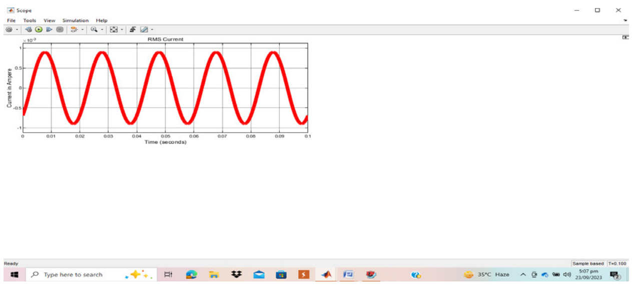

Fig. 6(c). Current during core losses

B. Short Circuit Test

It has been seen in simulation results that the copper losses are 50 Watt at 150 Volts and shown in Figures 7(a), 7(b), and 7(c), the RMS values of current, voltage, and power and tabulated in Table III.

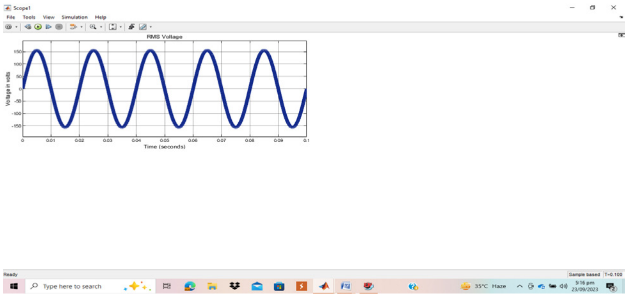

Fig. 7(a). Normal Voltage

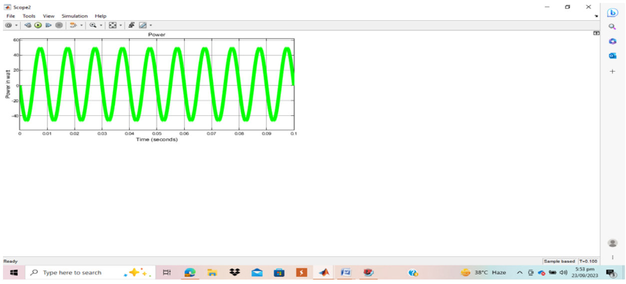

Fig. 7(b). Copper loss measured

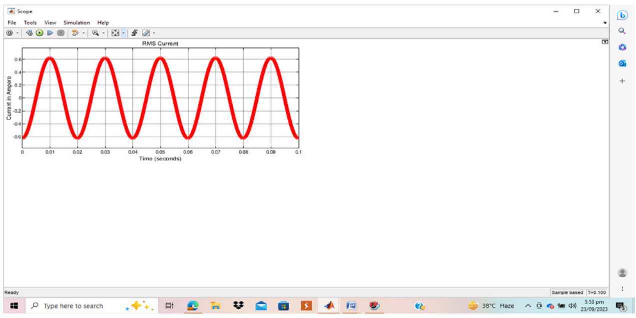

Fig. 7(c). Current during copper loss

Table III

Simulation results of core and copper losses

S.No	Test	Item	Result (Losses)
1	Open Circuit Test	Voltage (150 volts) Current (0.9 milli ampere)	0.11 Watt
2	Short Circuit Test	Voltage (150 volts) Current (0.6 ampere)	50 Watt

CONCLUSIONS

The experiment and Simulink software approach is employed to analyze the transformer losses and their effect on the performance. It is essential to reduce these types of losses to improve the efficiency of transformer. These losses can be reduced by adding good core material and avoid overloading, result in higher efficiency. It is concluded that that the iron losses decreased at 0.11 watt during supply voltage of 150 volts and during short circuit test the losses were 50 watt.

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Competing Interests

The authors did not declare any competing interest.

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