Review on Cooling Performance of Transformers

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Abstract: A power transformer is connected that converts electricity from one wired circuit to the next until maintaining a steady frequency. A transformer is characterized as static equipment because it does not rotate or transform into something new. This study discusses the concept, classifications, and operating procedures of transformers. The fundamental operation of transformers is seen below.

Keywords: Transformers, step up, step down, cooling , coolants

I. INTRODUCTION

A power transformer is an electrical machine that converts power from one circuit to another and then maintaining the same frequency. A transformer is categorized as a static device because it has no rotating as well as moving components. Transformers are powered by an alternating current (AC). Mutual induction is the basis for transformer operation.The cost of generating electrical power at a low voltage level is very limited. This low voltage level power can methodologically be transferred to the receiving end. If this low-voltage power is transferred, it implies a higher line current, that also ultimately resulted in much more line losses.

The basic mechanism of a transformer is quite straightforward. Faraday's law of electromagnetic induction governs this. The transformation activity in an electrical transformer is usually triggered by mutual induction among two or more windings. "The induced EMF in a conductor or coil is directly proportional to the rate of change of flux linkage with respect to time," according to Faraday's laws.

However, as the voltage level of a power is continued to risen, the current of the power is mitigated, leading to a minimization in ohmic or I2R losses in the system, as well as a minimization in the cross-sectional area of the conductor, lowering the system's capital expenses and enhancing voltage control. Low-level power should be stepped up as a result of these factors for effective transmitting power.

At the transmitting section of the power system network, a step up transformer is used to accomplish this. Because this high voltage power cannot be straightforwardly divided up to users, it must be stepped down to an acceptable level at the receiver section using a step down transformer. As a result, the electrical power transformer is critical in power transmission.When the ratio of high voltage to low voltage is more than 2, two winding transformers are usually employed. When the ratio of high voltage to low voltage is less than 2, using an auto transformer is competitively priced.In a three phase system, a single entity three phase transformer is much more economically efficient than a bank of 3 single-phase transformers. However, a single three-phase transformer unit is hard to manage and must be taken out of service when one of the phase windings fails.

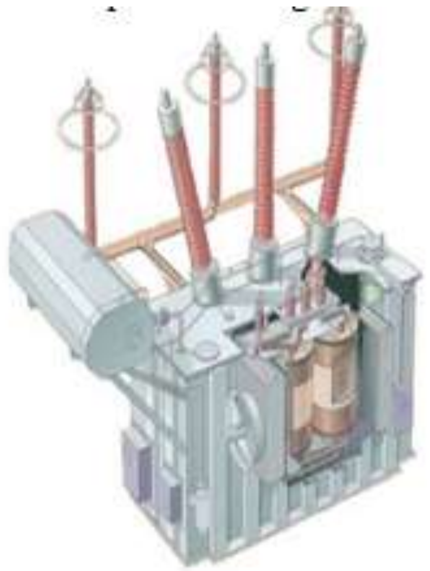

Figure 1 Structure of disc winding transformer

The process of dissipating heat generated in a transformer to the environment is known as transformer cooling. The heat generated by the losses in the transformer is converted into heat, raising the temperature of the windings and core. Cooling should indeed be accomplished to dissipate the heat produced. The transformer can be cooled in two ways:

The heat is transferred entirely from the windings and core to the tank walls by the coolant circulating inside the transformer, and then it is dissipated to the surrounding medium. Second, in addition to the first method, heat can be transferred by coolants within the transformer. The method chosen is determined by the size, type of application, and working conditions.

Air and oil are used as coolants in the transformer. Air coolant is used in dry type transformers, while oil is used in oil immersed transformers. The heat generated in the first case is conducted across the core and windings and dissipated to the surrounding air from the outer surface of the core and windings. The heat is then transferred to the oil surrounding the core and windings, and then to the transformer tank's walls. Finally, radiation and convection transfer the heat to the surrounding air.

Air Natural **-** In this mechanism, the cooling medium is ambient air. The heat generated by natural convection is dissipated using natural air circulation. By enclosing the core and field winding in metal, the core and windings are protected from breakages. This method works for transformers with a rating of up to 1.5 MVA. This method is used in areas where fire is a significant threat.

The transformer is cooled using this procedure by circulating a consistent blast of cool air through to the core and windings. External fans are used for this. To avoid dust particles accumulating in the ventilating ducts, the air supply must be filtered. Heat is transferred to the oil surrounding the core and windings and then conducted to the walls of the transformer tank in this method. Finally, radiation and convection transfer the heat to the surrounding air.

II. Literature Review

(Hasan, 2017) [1] The impact of external temperature on the cooling performance of an electrical distribution transformer was analysed mathematically in this paper. The temperature range investigated encompasses hot climate zones. The research framework is a 250 KVA distribution transformer. To enhance the cooling performance of this transformer, a new cooling cooling fluid is recommended: transformer oil depending microencapsulated PCM suspension with a volume concentration (5–25%) percent is often used as a cooling fluid rather than pure transformer oil. Paraffin wax is used as a PCM in the suspension, and additionally to the ability to absorb heat due to melting, it is also a good electrical insulator. The findings demonstrate that employing

(Córdoba et al., 2019) [2] The goal of this study is to prove the accuracy of a numerical model that simulates convective heat transfer in a distribution transformer. The model focuses on gathering the temperature and velocity domains in the oil volume using an oil natural air natural (ONAN) transformer. A segment model formed for a preceding experimental investigation is replicated in the virtual environment domain. The heating element, that also comprised of a series of parallel heating channels, was standardised into a permeable medium in the numerical method. The mathematical research was performed out by utilising the in-house established FEM strategy to address the 3D Navier-Stokes as well as thermal equations GPFEP code (par-GPFEP).The computational results simulated and measured have been validated with the observed data measured from the actual experimental machine in order to justify the model. Notwithstanding the the mathematical model's simplifying assumptions, researchers found a good match among experimental and numerical results in terms of heat transfer rates, temperature distribution, and total flow conditions. The heating element's simplicity creates discrepancies in the behaviour of the thermal plume directly above it, but the effect appears to be local and does not appear to have a huge effect on the overall convection flowing pattern.

(Rodriguez et al., 2017) [3] Semi-analytical assessments, CFD simulations, and experimental data on a pretty standard 30 MVA power transformer are reported in this section. The exploratory test were performed out on an improvised workbench. This feature allowed for the estimation of various significant determinants engaged in heat dissipation well within radiator, such as process of convective heat transfer coefficients, oil flowing rate, air circulating speed among radiator fins, and overarching dissipated heat, to name a few.The original study main goals are to assess the cooling efficiency of the current radiator architecture in ONAN mode, as well as to verify mathematical modelling and performance will affect for future design optimization techniques. Owing to the increase computational effort of the resulting models, the coupled thermo-hydraulic mathematical simulations were conducted on a distributed architecture. The modelling findings are in agreement with the experimental measurements values and those acquired with the semi-analytical model, indicating that this model, in combination with Computational fluid dynamics, is a reliable analytical technique.Heat transfer coefficients in oil, radiator panels, and air are calculated. Rate of heat transfer from the board to the air is discovered to be about ten times smaller than heat transfer in the oil. There is a brief discussion of enhancement opportunities to the current radiator configuration.

(Meyer et al., 2021) [4] Numerous implementations, including oil-filled power transformers, require simulation studies of fluid flowing through a complicated geometries with heat transfer. A greatest difficulty here is that high resolution is required to resolve the fluid flow behavior, but this tends to make modelling of the entire geometry extremely difficult. In this paper, researchers propose a simulation methodology that integrates a porous-medium strategy for simulating a few really context regions with optimum system simulation studies in those zones deemed most fascinating to investigate in depth.The settlement in these components can be magnitudes coarser because flow characteristics like thermal boundary layer thickness are not resolved in the porous methodology. Through use of optimum system simulation studies in the entire site, as well as analytical solutions to the elongated Graetz issue, are used to substantiate this multiscale method. The method is then applied to the study of oil flowing and heat transfer in huge electric power transformers, demonstrating a huge cost savings over an optimum system methodology.

(Garelli et al., 2021) [5] This paper presents a combined electromagnetic, heat, and fluid circulation interpretation of an

ONAN distribution transformer in order to ascertain the differences in thermal dissipation achievement whenever a biodegradable ester replaces mineral oil as the cooling medium. The transformer has a voltage ratio of 13.2kV / 0.4kV and a rated power of 315kVA. The heat losses in the magnetic armature are calculated using the ANSYS® Maxwell software and then transmitted as volume heat source terms for heat flow calculations. A temperature-dependent density is used to account for the fluid flow's convective heat transfer. Effective thermal conductivity through solid walls and radiator panels is also taken into account. The software Code Saturne is used to remedy the thermo–hydraulic issue. The simulation studies are validated using data from laboratory investigation with mineral oil. To modify the heat conducting fromework in the active parts, comparable and anisotropic thermal properties in the core and windings are determined by calculating using a semi-analytic procedure and FEA simulations. After achieving a steady state, the ester-cooled transformer has an elevated temperature variable between specific places at the underside than that of the mineral-cooled transformer. Once ester is employed, the magnetic core and copper coils work extremely hot as well. Eventually, an examination of the circulation via windings' refrigerating ducts reveals that the oil velocity is on average 25% greater than the ester velocity.

(Meitei et al., 2021) [6] In whatsoever power system network, the power transformer is one of the most important high voltage apparatus. The insulation condition of certain equipment is frequently used to determine its life expectancy. Partial discharge is the most common cause of insulation failure. Partial discharges (PDs) are electrical discharges that occur in the transformer insulation system. The presence of PDs causes the transformer insulation system to deteriorate. To avoid complete transformer failure, it is essential to compare and recognise the Partial Discharge at an early stage. For Partial Discharge monitoring in power transformers, numerous PD identification and evaluation techniques, including such electrical, chemical, acoustic, Ultra High Frequency, and optical methods, are probably currently have been using. Traditional PD detection methods, such as electrical or chemical, have some drawbacks. To address these issues, the optical Fiber Bragg Grating (FBG) Sensor was used as a PD sensor for PD tracking in the power transformer. This paper examines the use of FBG sensors as a PD monitoring sensor in an oil-filled power transformer. This area's issues and future prospects are also mentioned.

(Cudok et al., 2021) [7] The use of waste heat or low-exergy heat sources represents a strategic opportunity to reduce the environmental footprint and operation cost of industrial processes. The absorption heat transformer, also known as absorption heat pump type II, is a thermal machine which can boost the temperature of a heat flow by using a negligible amount of electrical power. However, owing to the lack of established technical knowledge and the absence of comprehensive recordings of successful heat transformer applications, the feasibility and reliability of absorption heat transformers have been questioned and the diffusion of this technology remained limited. Therefore, in this paper, all the industrial applications of the absorption heat transformer that are recorded in previous literature and yet unpublished reports are presented and discussed. In addition to literature research, intense knowledge exchange with three leading manufacturers of absorption heat transformers gave an accurate perspective on the technological level of commercial products and operative installations. It is shown that between 1981 and 2019, 48 absorption heat transformers have been installed in 42 plants with a total capacity of ≈134MW. Two main implementation periods, separated by 25 years of infrequent heat transformer installations, have been recognised. More than 74% of the installations were in Asia. Approximately 61% of the heat transformer installations were applied into the chemical industry. Therefore, through the analysis of the technical challenges and their solutions, along with related economical aspects of heat transformer installations, the effective state-of-the-art of this technology is presented and discussed.

III. TRANSFORMER'S WORKING PRINCIPLE

Mutual inductance among two circuits connected by a common magnetic flux is the underlying principle of operating condition of a transformer. A fundamental transformer is made up of two inductive coils that really are electrically distinguishable but magnetically connected by a reluctance route

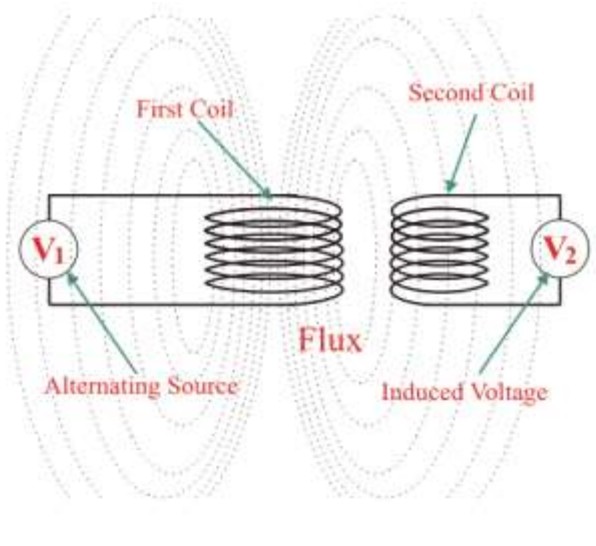

Figure 2 Operating principle of transformer

The electrical transformer consists of primary winding and secondary windings, as seen above in figure. The core laminations are merged in the pattern of strips, and we can observe few narrow disparity running the length of the cross-section of the core. 'Imbricated' refers to the staggered joints. The mutual inductance of both coils is very high. The alternating flux that is established in the laminated core, due to the coil that is hooked up to an alternating voltage source, induces a mutual EMF (electromotive force) in the transformer.

The mutual induced electro-motive force is generated when the majority of the alternating flux produced by this coil is connected with another coil. Faraday's laws of EMI (electromagnetic induction) can be used to describe the electromotive force that has been created

$$e = M\left(\frac{dI}{dt}\right) \qquad (1)$$

. A current passes through the second coil circuit when it is closed, and electrical energy is transmitted magnetically from the first coil to the second coil. The primary winding receives an ac supply, and thus is referred to as the primary winding. The energy is extracted from the second coil, which is referred to as the secondary winding.

IV. TYPES OF TRANSFORMERS

Transformers are classified in a variety of ways based on their objective, application, and design. Remember that these categorizations sometimes can coincide – for example, a transformer can still be a three phase and a step up transformer simultaneously.The following are the various categories of transformers:

a) Step Up Transformer

A Whenever the value of voltage increases from primary winding to secondary winding by maintaining the similar power in both windings at the rated frequency, then this type of transformer is termed as step up transformer. The primary side of a this type transformer transforms low voltage (LV) and high current to high voltage (HV) as well as low current on the secondary side.

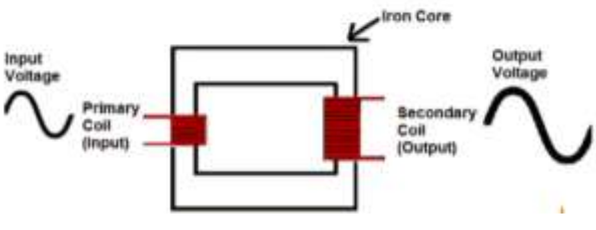

Figure 3 Step-Up Transformer

b) Step- down Transformer

In step down transformer, its primary side transforms high voltage (HV) and low current into low voltage (LV) and high current on the secondary side. A step down transformer transform a higher primary voltage to a lower secondary voltage.The primary winding of a coil in a Step Down Transformer has much more rounds s compared to the secondary winding.

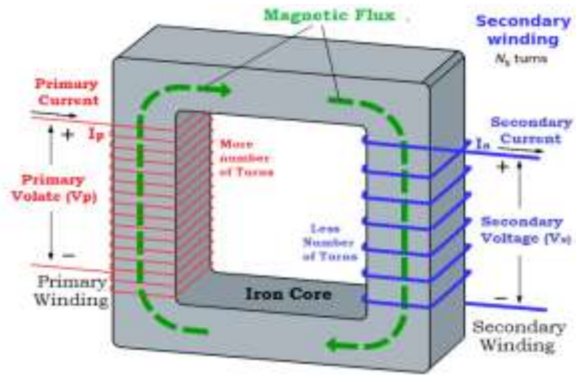

Figure 4 Step Down Transformer

c) Three Phase Transformer and Single Phase Transformer

Seeing as three phase transformers are more expensive and effective than single phase transformers, they are commonly employed in three phase power systems. Whenever space is limited, however, it is desirable to utilize a bank of three single phase transformers instead of a single three phase transformer because it is convenient to carry.

V. CONCLUSION

A power transformer is an electrical device that transforms electricity from one wired circuit to another while keeping the frequency constant. Since this lacks both rotating and transformed into a new, a transformer is classified as a static equipment. This paper discuss the theory about transformers, types and its working procedures. Here we indicate the foundational working of transformers.

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