A Literature Review on Analysis of Transformer Cooling System

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Abstract— Transformer plays an important role in electrical power system. Ever since the invention of a transformer, we have been facing the trend of increasing its nominal power. Together with the increase of nominal power, losses in transformers increase as well, while a transformer's own capability of cooling decreases. According to generally adopted estimate states that if a transformer’s maximum operating temperature is reduced by 6°C, the thermal life of insulation system is approximately doubled. As a part of this, many authors have presented different methodologies to provide an efficient cooling of transformer. The purpose of this paper is to provide a literature review on new technology of cooling system of transformer and its effect on transformer’s life.

Key words: Transformer, Arrhenius Equation, Microcontroller, LM35-Sensor, PLC (Programmable Logical Controller)

I. Introduction

Energy is a priority nationally as well as internationally, regarding electricity both transmission and distribution system. Electrical transformers include the huge amount of main investment in transmission and distribution electrical systems .Since power transformers are key element in power equipment operation. The different types of faults occurring inside a transformer are overload, short circuit, over excitation, oil level fault, insulation breakdown etc. All these faults increase the heating and thereby increase the temperature of the transformer resulting in local hotspots and even the insulation failure .When the temperature of the transformer goes high, oil level in the tank decreases due to heating effect. If the oil level goes beyond marked level, it will affects the cooling and insulation of transformer. The main two parameters of cooling optimization of a transformer are the temperature and losses of the cooling system of a transformer. The temperatures in oil and windings define the loading capacity of the transformer. Large transformers thus need more intense cooling to remove thermal losses. Power losses raise the temperature of a transformer to the point whereby an equalization of cooling power with the power of losses is reached.

Cooling of Transformer is the process by which heat generated in the transformer is dissipated or treated to the safe value. This is achieved by various cooling methods of transformer available. The major factor for the generation of heat in the transformer is the various losses like hysteresis, eddy current, iron, and copper loss. Among all the various losses the major contributor of the heat generation is the copper loss or I^2R loss. The principle of cooling the interior of a transformer is based on convection, i.e. heat transfer with the movement of a cooling medium which in contact with thermal sources in a transformer transfers the thermal energy and releases it through cooling systems into its surroundings.

A. *Methods of Cooling of Transformer*

Transformer is cooled by the following methods given below-

1) Air Natural (AN)
2) Air Forced (AF) or Air Blast
3) Oil Natural Air Natural (ONAN)
4) Oil Natural Air Forced (ONAF)
5) Oil Forced Air Forced (OFAF)
6) Oil Natural Water Forced (ONWF)
7) Oil Forced Water Forced (OFWF)

II. Literature Survey

A complete review of experimental approaches to the cooling of transformer coils by natural convection method performed by By E. D. TAYLOR [1]. By Wenhao Niu performed the experimental study of a novel cooling system of a power transformer in an urban underground substation [2]. Eleftherios I performed a Distribution transformer cooling system improvement by innovative tank panel [3]. PLC based transformer cooling control system performed by Shreenivas Pai [4]. The transformer fault detection and protection system performed by Kowshik Sen Gupta [5].D.V. Pushpa Latha control the temperature based on millienium 3 PLC by using LM 35sensor, [6]. Based on microcontroller the transformer cooling control performed by the Bhushan S. Rakhonde[7]. M. Anand worked on microcontroller based transformer monitoring and controlling system by using Zigbee[8]. By V. M. Monsinger performed bridgement of loading transformer [9]. Kamil Dursun performed the oil and winding temperature control in power transformers [10]. Armando Guzmán performed A current-based solution for transformer differential protection [11]. Numerical study of cooling solutions inside a power transformer by Nelu-Cristian Cherechesa [12].New development in transformer cooling calculations performed by K. Eckholz. [13]. Transformer hotspot temperature calculation performed by Mohd Taufiq Ishak [14]. Study on simulation test device of transformer split type cooling system performed by Wei Bengang[15] . By O.E. Gouda performed the predicting transformer temperature rise and loss of life in the presence of harmonic load currents [16]. By L. Pierrat the Power transformer life expectancy under distorting power electronic loads performed [17].M. Srinivasan performed the prediction, of Transformer Insulation Life with an Effect of Environmental Variables [18]. Analyzing the impact of ambient temperature indicators on transformer life in different regions of Chinese Mainland performed by Cui-fen Bai[19]. Determination of thermal life expectancy of overhead distribution transformers by Donald o Chaghead [20].Eva Müllerová performed the Life cycle management of power transformers [21].The thermal aging factor for life expectancy of 550 kV transformers with a Preventive test performed by Xiang Zhang [22]. K. S. Kassi performed the aging effect on oil cooling capacity of a non-guided disc windings power transformer [23]. Surien Sermsukeoongsakul performed an estimation of remaining life expectancy of generator step up transformer based on strength analysis of insulation paper [24]. Jianpeng Bian worked on Probabilistic Analysis of Life Cycle Cost for Power Transformer [25] . The transformer life expectancy performed by PAUL MANN, [26]. A. M. LOCKIE performed the Functional-Life Expectancy tests for liquid-filled distribution transformers [27].Insulation aging a historical and critical review by E. L. Brancato [28]. F. Husnayain performed the transformer oil lifetime Prediction Using the Arrhenius Law based on Physical and Electrical Characteristics[29].Hot spot temperature and grey target theory-based dynamic model for reliability assessment of transformer oil-paper insulation systems performed by Lefeng Cheng [30]. Tim Gradnik performed the cooling system optimization and expected lifetime of large power Transformers [31].

III. NEED OF TRANSFORMER COOLING

Transformer cooling is one of the most important factors for transformer to work properly. If the temperature of the transformer will continue to increase rapidly, it will result in the degradation of the insulation used in the transformer resulting in the damaging of the various parts and hence the failure of the transformer. Thus, proper removal or treatment of heat is necessary for the efficient working, longer life and higher efficiency of the transformer. The basic purpose of a cooling system is to limit the temperature of a transformer. Most of the transformers are designed for 55°C or 65°C rise. In each case, it is extremely important that proper temperature transfer take place. The design of the transformer relies on a specific heat transfer between the windings, oil and the radiator or cooler for heat extraction. Any increase in heat generation or any heat transfer reduction results in higher winding temperatures and shorter insulation life. Cooling system can increase the load carried by a transformer without heat damage when the critical limit of the temperature is reached, there are chances of failure of transformer as there is aging of the transformer's insulation. Thus the role of cooling system is to increase the capacity of the transformer to carry load without reaching hotspot temperature.

IV. WORKING TEMPERATURE V/S LIFE OF TRANSFORMER

The life of a transformer depends on the life of its insulation system. The temperature has a major impact in the life of transformer. According to generally adopted estimate states that if a transformer's maximum operating temperature is reduced by 6°C, the thermal life of the insulation system is approximately doubled. Conversely, if the total operating temperature is raised by 6°C, the thermal life expectancy of the insulation system is reduced by halved (based upon the Arrhenius Equation of chemical reaction time v/s temperature can be adapted to approximate relationship between insulation life and total operating temperature). Arrhenius equation is used to enhance the life expectancy of insulation system. It is the backbone to enhance the life of the insulation system. The Arrhenius equation is a formula for the temperature dependence of reaction rates. Arrhenius' equation gives the dependence of the rate constant of a chemical reaction on the absolute temperature, a pre-exponential factor and other constants of the reaction.

– $k = Ae^{-Ea/RT}$

Where

– k = Rate constant
– T = Absolute temperature (in kelvin)
– A = Pre-exponential factor, a constant for each chemical reaction. According to collision theory, A is the frequency of collisions in the correct orientation
– Ea =Activation energy for the reaction (in the same units as R*T)
– R = Universal gas constant. [29]

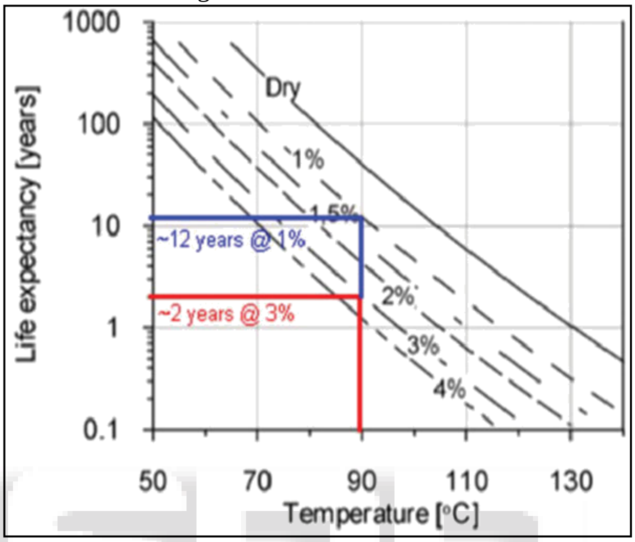

Fig. 1: Dependency on Temperature & Humidity in the Life Expectancy of Insulation of Transformer

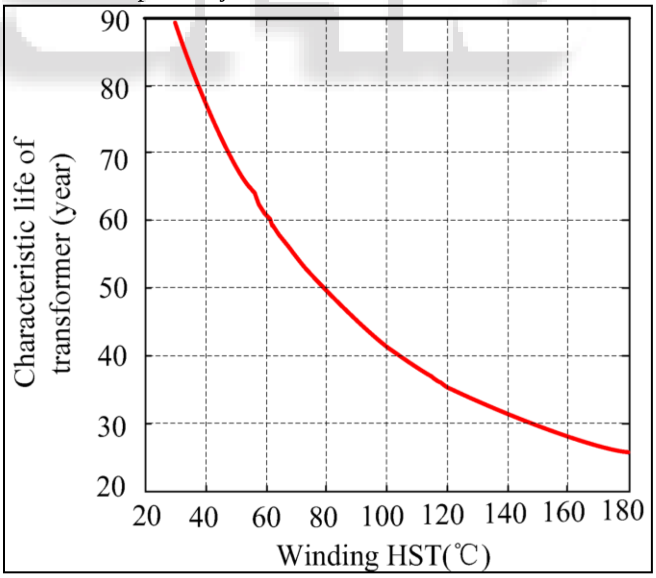

Fig. 2: Expected Life Vs. The Winding HST

Figure.1 and Fiure.2 is showing the relation between working temperature v/s life expectancy of transformer. According to all of these, if the temperature of paper insulation or oil insulation is decreases, the life expectancy of transformer is approximately doubled [30] [31].

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