A Review on Physico-chemical Properties of Transformer Oil

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Abstract: ***This study based on the prediction and investigation of different changes in physico-chemical and electrical properties of the transformer oil. The different five samples of transformer oils was collected from different areas of india summated for analysis. We found that some parameters of transformer oil like breakdown voltage, insulation temperature, moisture content and di-electrical strength. The measurement is based on the time or frequency response on aging of transformer oils physical, electrical and the chemical properties of insulation. Here we measure the characteristic properties of transformer oils on different load operating conditions. Through this paper we find out the is transformer fail due to copper loss or due to change of oils characteristic properties.***

Keywords: gas analysis (DGA), Frequency di-electrical spectroscopy (FDC), Physico-chemical, Break-down voltage(BDV).

1. Introduction

Mineral oils (transformer oil) are the most commonly used liquid di-electrical which work as heat transform medium in the transformer and insulating material, because of their inherent properties. Transformer oil is colour-less liquid normally mixture of hydrocarbons which consist paraffins,iso-paraffins, naphthalenes and aromatics.

The electric characteristic of liquid insulators depend on the intrinsic parameters which is related to their molecular structure and the extrinsic parameters is depend on reciprocal action with materials to which they are frequently associated, to the environment and different operating conditions of the transformer. The existence of water (moisture) dissolved in transformer oils is practically unavoidable. Measurements of breakdown voltage and other dielectric parameters of the oils are executed in the same conditions. They are observing at atmospheric temperature and pressure according to international standard [1].The long time service of oil make it darker due to presence of water content and the formation of acids and resins(sludge) in the liquid. During transformer operation, partitioning of water content between insulating oil and paper insulation in transformer is depending upon the temperature changes that affect the water solubility properties [2].This study observe the change in the dissipation factor, dielectric behavior at different operating load, finding the resistivity and permittivity according to water particle present in the oil. Experimental tests are carried out on transformers oil to find experimentally their electrical, physical and chemical properties. The long periods in service increases some particulate impurity in oil which decreasing the breakdown voltage, increase the moisture because of that oil will become non homogeneous, consequently it will decrease oil resistance, which will decrease the maximum value of the breakdown voltage of the transformer oil.

The transformer oil undergoes silent discharges due to this current lead to the chemical reactions that result in generation of acids, wax and soluble gases of hydrocarbon composition. Arc formation increase the fault gases dissolved in oil are known as a mixture of light hydrocarbons such as methane, ethane, ethylene, acetylene, propane and propane along with carbon monoxide, and carbon dioxide, hydrogen, oxygen and nitrogen, and the acidic formation through oxidation of the solid insulation, iron and copper in the liquid decrease the electrical strength of the oil.

2. Review of literature

In the experimental technique the investigated parameters are breakdown voltage, relative permittivity, dissipation factor and resistivity. The measurements are performed according to ISO 2909 standard for the viscosity, ISO 2049 for the colour (Col), ISO 6618 for the acidity number (Ia), NFT 60-103 for the flash point (Pe) and Karl Fischer titration method for water content (Wc0). The main purpose being to study the influence of water content on the different electric characteristics of the oil [1]. During transformer operation, partitioning of water content between insulating oil and paper insulation in transformer is depending upon the temperature changes that affect the water solubility properties. The water content during laboratory experiment needs to be stay constant, it means that the laboratory test cell should be free from any hydrophilic materials that may adsorb and absorb water to oil as oil temperature changes during test. The solubility for mineral oil can be calculated using Arrhenius Equation 1:

$$\text{LogS}=-A/T+B \qquad (1)$$

Where:-"S" is the solubility of water in mineral oil & "T" is the temperature in Kelvin (°C + 273) "A" & "B" are constants. Here A= 1670 & B= 7.42. Relative Saturation (RS) is the actual amount of water content measured in the insulating oil in relation to the solubility of water in oil level at that temperature. Relative saturation is expressed in units of precents & it is the concentration of water (W) in the insulating oil relative to the solubility (S) or concentration of water that the insulating oil can hold at the measurement temperature, as shown in Equation 2.

$$RS=W/S(100\%) \qquad (2)$$

Where "W" is in ppm wt. /wt. & "S" is in ppm wt. /wt.[2] Transformer oil will age rapidly at high temperatures and moisture acts as a catalyst for its aging. Transformer oil, when subjected to thermal and electrical stresses in an oxidizing atmosphere, gradually loses its stability and becomes decomposed and oxidized, its acidity increases and finally begins to produce mud. This is the degradation mechanism of the oil. In fact the aging mechanisms of oil are complicated. In general oxygen reacts with hydrocarbons by a free radical process, which generates hydro-peroxides. Hydro-peroxides was not stable and decompose to form ketones and water. Ketones can be oxidized to form carboxylic acids or cleaved to make aldehydes.

Dissolved acids may cause damage to the insulation paper and copper windings, while volatile acids corrode the top of the unit. As a result, all of the necessary conditions exist properly in a power transformer for the degradation of the oil. [3]. The distribution of moisture between paper and oil is not static, but varies depending on the insulation temperature, and thus, water migration processes take place continuously during transformers operation. a sensor is presented that allows the determination of the moisture content of the transformer solid insulation in the steady state and during the moisture migration processes. The main objective of the design is that the electrodes of the sensor should not obstruct the movement of water from the solid insulation to the oil, so the proposed prototype uses a metallic-mesh electrode to do the measurements. The measurement setup is based on the characterization of the insulation dielectric response by means of the frequency dielectric spectroscopy (FDS) method.

A sensor is proposed to determine the moisture content of solid insulation in real transformers while the equipment is in service. The sensor is based on the characterization of the dielectric response of a Kraft paper coil that would be fit inside the transformer tank and subjected to the same conditions as the transformer solid insulation. One of the electrodes has been substituted by a metallic mesh, so that it does not affect the moisture migration processes between paper and oil that continuously take place during transformer operation [4]. The sensor is not proposed to be an alternative to the off-line dielectric measurements, but to complement the information provided by them between transformer discharges. The new measuring scheme could also be used during moisture dynamics experiments, which are usually very complex and time consuming when the traditional methods based on periodical direct determinations of the moisture content of the insulation are applied [8].

3. Results

The As per the study of different paper the chemical and electrical tests especially acidity and breakdown voltage are the most important tests in the transformer oil, a technical point of view that the progressive effect of the oil is based on simultaneous combination of physical, chemical and electric stresses .Due to increasing the electrical stresses in the oil and chemical reaction with moisture, expressed by an increasing the heat losses and also acidity at long-time operation of transformer .The resistivity of the oil is decreasing because of presence of water molecule and metal practical present in the oil. According to the study the doping of the oil increased up to the limit of 100ppm. Temperature variation is one of the important parameter which affects the dialectical property of oil. At high temperature application due to fault occurrence the flash point of oil first increasing and then decreasing for a long time. such type of condition form the low weight hydrocarbons in the oil due to that flash point limit decreases. The breakdown voltage and water content capacity shown in the fig.(1) [1].

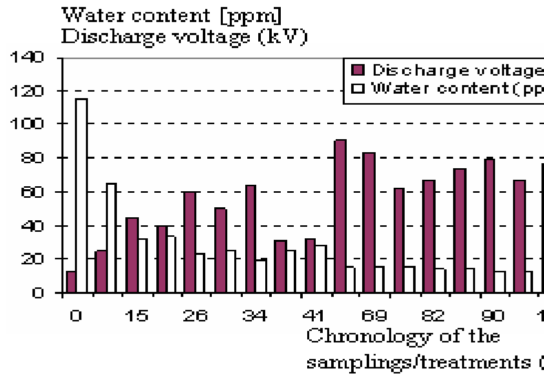

Figure 1 : Breakdown voltage and water content as a function of the delay time between samplings and eventual treatment.

We can also express that due to the high temperature the specific gravity decrease at long time application. As well as the kinematic viscosity increases. The acidity value of transformer oil is increase by mixture of different gases in oil due to oxidization. As per dissolve gas analysis (DGA), when its value is increases, fault occurs inside the transformer which affects the cooling system of transformer. In the presence of moisture in the oil with the dissolve gases at high temperature the over-all resistivity of the oil is decreases.

4. Conclusion

In this paper we have to find out the experimental evaluations of transformer oil characteristics at different operation conditions. In this study we are conclude that the combined effect of electrical , physical and chemical effect on the ageing of oil, dialectical strength, breakdown voltage and resistivity decreases due the increasing in temperature .

References

[1] T. Toudja, A. Nacer , H. Moulai , I. Khelfane and A. Debche, "Physico-chemical properties of transformer mineral oils submitted to moisture and electrical discharges ", International Conference on Renewable Energies and Power Quality (ICREPQ'12) Santiago de Compostela (Spain), 28th to 30th March, 2012.

[2] PankajShukla, Y.R.Sood and R.K. Jarial, "Experimental Evaluation of Water Content In Transformer Oil", IJIRSET,ISSN:2319-8753, Vol. 2, Issue 1, Janauary 2013.

[3] EL-Sayed M. M. EL-Refaie, Mohamed R. Salem, and Wael A. Ahmed, "Prediction of the Characteristics of Transformer Oil under Different Operation

Conditions",World Academy of Science, Engineering and Technology International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering Vol:3, No:5, 2009.

[4] Mirela Ştefania vihacencu, Alexandra ciuriuc and Laurenţiu Marius dumitran, "Experimental Study of Electrical Properties of Mineral And Vegetable Transformer Oils".ISSN 2286-3540, U.P.B. Sci. Bull, Series C, Vol. 75,Iss. 3,2013.

[5] Belén García , Diego García and Guillermo Robles, "Development of a Moisture-in-Solid-Insulation Sensor for Power Transformers ",ISSN 1424-8220, Sensors 2015, 15, 3610-3624.

[6] Guide for Acceptance and Maintenance of Insulating Oil in Equipment, IEEE Std. C57.106-2006; Institute of Electrical and Electronics Engineers: Piscataway, NJ, USA, 2006; pp.1–36.

[7] Martin, D.; Perkasa, C.; Lelekakis, N. Measuring Paper Water Content of Transformers: A New Approach Using Cellulose Isotherms in Nonequilibrium Conditions. IEEE Trans. Power Deliv. 2013, 28, 1433–1439.

[8] Li, J.; Zhang, Z.; Grzybowski, S.; Liu, Y. Characteristics of moisture diffusion in vegetableoil-paper insulation. IEEE Trans. Dielectr. Electr. Insul. 2012, 19, 1650–1656.

[9] Wang, S.Q.; Zhang, G.J.; Wei, J.L.; Yang, S.; Dong, M.; Huang, X.B. Investigation on dielectricresponse characteristics of thermally aged insulating pressboard in vacuum and oil-impregnated ambient. IEEE Trans. Dielectr. Electr. Insul. 2010, 17, 1853–1862.

[10] Baral, A.; Chakravorti, S. Prediction of moisture present in cellulosic part of power transformer insulation using transfer function of modified debye mode. IEEE Trans. Dielectr. Electr. Insul. 2014, 21, 1368–1375.

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