Evaluation of the Dielectric Properties of Sealed and Unsealed Transformer Oil with the Effect of Moisture and Ageing

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Abstract- The transformer oil insulation will deteriorates under the effect of thermal, electrical and chemical factors and under water which is one of the by-product of ageing. In order to evaluate the dielectric properties of sealed and unsealed dissipation factor (tan delta) capacitance measurement at power frequency (50 Hz) has commonly used to diagnose the insulation integrity and condition of transformer. The main drawback of this technique is that the measurement result obtained represent the status of the complete transformer insulation system. Hence, in this paper experimental investigation has been done by studying the dielectric property change (tan delta, dielectric constant and acidity) of different transformer oil sealed and unsealed to calculate affecting parameters namely moisture and ageing of both the sample (sealed and unsealed). A simulation model of the combined transformer insulation has been used to correlate the tan delta, acidity of each insulating material differentiate the sealed and unsealed value of a transformer.

I. Introduction

The reliability of a power transformer is directly related to security and stability of power system, and its failure will significantly impact the reliability of power supply over the years. Oil- paper insulation system is widely used as insulation structure in primary electrical equipment such as transformers, instrument transformers and bushings, far its excellent insulating performance [2]

However, as the equipment run, ageing or degradation phenomenon will appear inevitably in insulating materials (oil) due to the effect of thermal, moisture, oxygen and so on.[1] Its mechanical properties and reliability of insulation will decrease leading to the increase of equipment running risk. Therefore it is very important and significant to access the condition of power equipment insulation system timely and accurately.

Diagnosis method based on dielectric response theory such as return voltage method, polarization and depolarization current, frequency domain dielectric spectroscopy are widely used in insulation diagnosis of power transformer and power cable in foreign with the gradual development of digital technology.[3]

Among these dielectric diagnosis method is the most common industry practice-dissipation factor (tan delta) and capacitance measurement at power frequency.[2] Apart from its merit of short measuring time, variation of tan delta provides useful information about the insulation quality. Most importantly power transformer separating in the field manually have a complete set of tan delta record.

The main objective of the technique is that the measurement result obtained on a transformer oil represent the insulation losses and to differentiate the sealed oil and unsealed oil of the transformer insulation system.

Involving oil as insulating material and their size and dimensions.

This paper focusing on establishing the basic relationship between tan delta of sealed and unsealed oil with the effect of moisture and ageing. Laboratory experiment were carried out to study the dielectric properties change of sealed and unsealed mineral and transformer oil due to the effect of moisture , acidity and ageing. To fit these results into the big model was used to correlate the tan delta of each sample of sealed and unsealed oil to the measured combined value.

II. SAMPLE PREPARATION

(A) Sealed transformer oil with different moisture content

The mineral oil sample used in this study is 132 kV substation transformer oil. In order to obtained sample with different moisture content, these mineral oil were conditioned in a controlled air relative humidity at room temperature. The air RH is the desiccator was controlled by the combination of glycerol and distilled water needed.

$$\text{RH air} = \frac{\dfrac{\text{Weight water}}{18}}{\dfrac{\text{weight (gly)}}{92.1} + \dfrac{\text{Weight (water)}}{18}}$$

(B) Unsealed transformer oil with different ageing level.

Sample bottles of mineral oil sample were prepared for the ageing experiment. These bottles were divided in two categories sealed and unsealed. The samples were differently aged under temperature.

In order to form a relationship between tan delta and the ageing time, the different ageing sample will be evaluated by the sealed transformer oil sample further differentiated.

TABLE 1 – tan delta and dielectric const.

SAMPLE	TEMP	SEALED		UNSEALED	
		TAN DELTA	Er	TAN DELTA	Er
1	89.8	.000231	2.014	0.000294	2.301
2	90.1	.000254	1.127	0.000386	2.205
3	89.7	.000247	1.195	0.000397	2.407
4	89.6	.000232	2.054	0.000383	2.867 T

TABLE 2

S	sample	sealed		unsealed
	Tan δ	Moisture content	Tan δ	Moisture content
1	.000231	.52	.000294	.46
2	.000254	.67	.000386	.43
3	.000247	.73	.000397	.47
4	.000232	.75	.000383	.52

III. MEASUREMENT

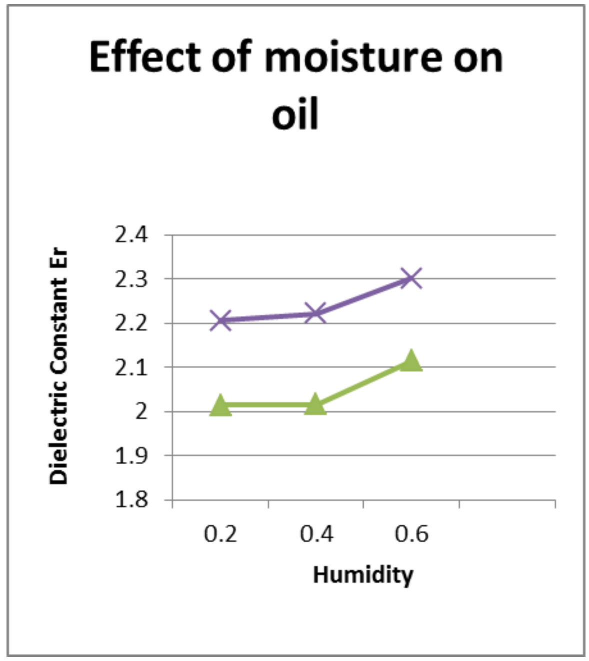
Tan delta and dielectric constant are done by using automatic dielectric constant. Tan delta and resistivity Test set model EW-188. Measurements were repeated 3 times for each for each samples and the average value was taken. All the measurement was taken at room temp. .

Oil Sample Measurement

Apart from the vessel prepared new mineral oil with a moisture content of 10 ppm was also tested for comparison purpose. When the sample was poured into the test vessel, a suitable waiting time was allowed for the air bubble to disappear. New mineral oil was used to wash the test vessel in between measurement of different sample. This step is essential to clean up the vessel from a residual liquid from previous sample which may affect the result

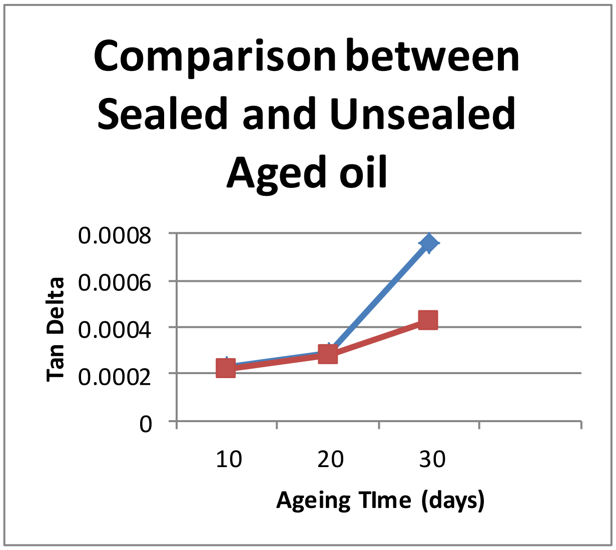
IV. RESULT AND DISCUSSION

The variation of Tan delta dielectric constant Er of sealed transformer oil as a function of moisture content. The result already demonstrate that the tan delta generally increases with the increase of oil moisture in sealed sample. When moisture content reaches a certain threshold, the increase of tan delta became significance.



Effect of Ageing on Mineral Oil – Figure illustrates the variation of tan delta of aged mineral oil as a function of ageing time. It is clear that for both sealed ad unsealed cases, the tan delta increases with the ageing days. It is observed that as ageing times increases, there is a significant difference in tanδ values between sealed and unsealed oil samples. For example, at aging time of 21 days, tanδ for sealed sample is about 3 times higher than unsealed sample. This is believed to be mainly caused by the by-products or catalysts produced during aging process. Catalysts existence was reported to help accelerating the ageing process .These major catalysts from ageing are thought to be moisture and acid. Although aged oil in unsealed bottle also produced these catalysts, the open situation allowed these by-products to be evaporated out from the sample. This evaporation is proved by the decreasing oil level at the end of ageing. As most of these ageing rate is not as fast as the sealed sample. This factor may help to explain the lower tanδ value in unsealed oil sample.

However, the colors of the aged oil samples show a contradict result. Judging from the colors, one would suggest that the unsealed oil samples are more severely aged compared to the sealed oil samples. Since unsealed oil samples are in direct contact with the air, oxidation process is more active than in the sealed oil samples.



V. CONCLUSIONS

This work focused initially on investigating how moisture and ageing affects the dielectric properties (tanδ and εr) of individual transformer insulation materials at power frequency. From the results, it can be concluded that tanδ of all tested materials increases as the ageing time or MC increases. MC affects tanδ significantly. Meanwhile, it is interesting to find out that εr of solid insulation material exhibits a sensitive variation towards moisture effect.

Practical cases are needed for further studies and more work needs to be done to clearly identify the potentials of tanδ measurement at power frequency.

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