

MOISTURE ESTIMATION OF ASPHALT MICA GENERATOR WINDINGS BY FREQUENCY DIELECTRIC SPECTROSCOPY MEASUREMENTS

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Introduction

Generators of hydropower stations are considered as the most important equipment of a power plant. Out of different failure modes of a generator, about 56% are due to failure of the insulation of stator winding (Brutsch *et al.*, 2008). In early generators manufactured before 1960s, asphalt mica was used as the generator insulation of stator winding. Due to increase of temperature class of the generator insulation design and due to invention of new insulation material which have better resistance to temperature ageing and partial discharges, asphalt mica is rarely used in present day generators. However, it is still used in some of the older hydro generators in Sri Lanka i.e. Laxapana complex and Iniginiyagala power station, having an average age of 50 years. It has been found that deterioration of asphalt mica insulation is mainly due to moisture absorption to the bulk of insulation and deposition of moisture on the surface of the insulation during long shut downs and water leakages from the generator coolers. With the aim of assessing the condition of such insulation, this paper proposes a method of estimating the moisture content of asphalt mica stator windings using Frequency Dielectric Spectroscopy measurement (FDS) (Farahani *et al.*, 2006).

Methodology

Two sets of samples were prepared by cutting 5 cm long pieces taken from asphalt mica insulated winding. In the first set, the ground-wall insulation was separated from copper conductors with a cut and tied together with the conductors. These samples were used for moisture measurements. The second set was used as it is for FDS measurements with three electrode configuration i.e. (High Voltage) HV, (Low Voltage) LV and guarding. The Copper conductor of the sample was connected to the HV terminal whereas 1.5 cm wide Aluminum foil strip was tied in the middle of the ground wall for the LV terminals. A guardian ring was formed on both ends of the ground wall in order to remove surface leakage current from measurements. Initially the samples were considered as naturally fully wetted since it had been exposed to atmospheric condition for long time. All the samples were dried inside an oven (size 60x60x60 cm³) at a constant temperature of 70 °C in order to get different moisture contents. (70°C is a typical temperature of a generator winding in a loading condition). During different drying periods (i.e. different moisture contents), the first type of samples were taken out, the conductor was removed, weight was measured by using precise scale (minimum value

0.01g) and after the measurements, conductor was tied and samples were kept inside the oven for further drying. FDS (Frequency variation of real part of capacitance (C') and imaginary part of capacitance (C''), $C' - jC''$) measurements were performed on the second set of samples inside the oven at 70°C using IDA200. The frequency varied from 1 kHz to 1 mHz. The above drying process was continued until negligible change of weight was observed at which point it was assumed that the insulation sample was fully dry. The moisture percentages were calculated with respect to the last weight at fully dry condition. After the samples were fully dried, they were kept at room temperature 28 °C and RH of 75% for naturally wetting for 15 days the moisture contents were calculated similar to drying process.

Results and Discussion

From Fig.'s 1 - 4, C' and C'' increase with increase of moisture percentage confirming higher losses in wetted samples. The dependency of temperature also shows increased capacitance (C' and C'') at higher temperatures for a similar level of moisture contents (see Figures 1 and 3 with 2 and 4).

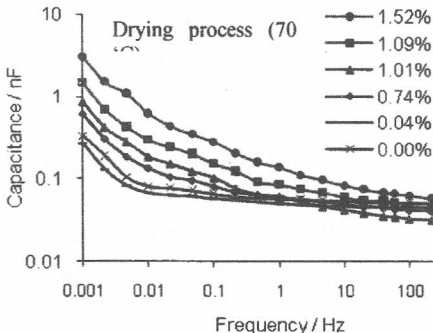


Fig. 1. C' variation with frequency at moisture percentages in 70 °C

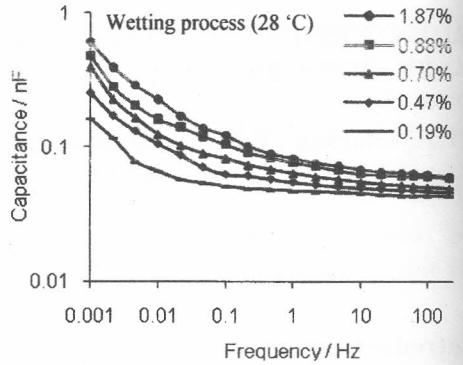


Fig. 2. C'' variation with frequency at moisture percentage in 70 °C

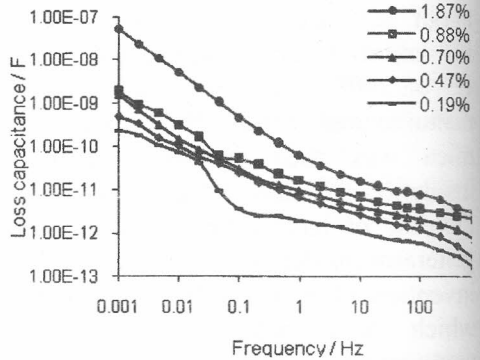


Fig. 3. C' variation with frequency at moisture percentages in 28 °C

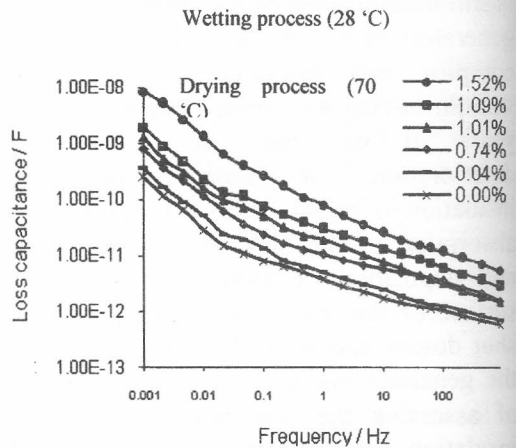


Fig. 4. C'' variation with frequency at moisture percentages in 28 °C

The influence of RH during the drying process is less than in the wetting process. The increase of the loss tangent ($\tan \delta$) with increasing humidity is influenced by the increased surface leakage current.

Moisture Estimation in Winding
 FDS results on samples were used to estimate the moisture content of asphalt mica windings at 70 °C. The $\tan \delta$, due to geometric independence, was used to compare the results of samples and the full winding.

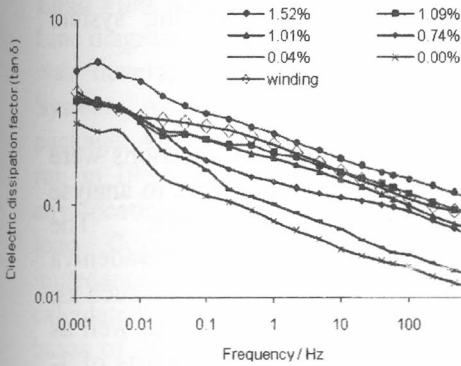


Fig. 5. Loss tangent ($\tan \delta$) with frequency at moisture levels in 70 °C

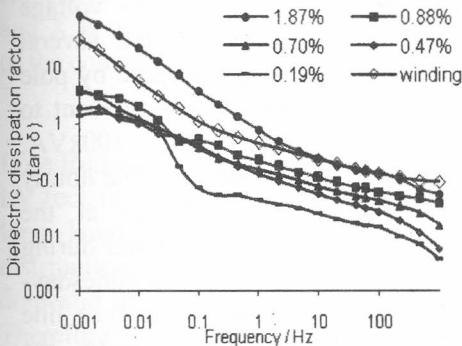


Fig. 6. Loss tangent ($\tan \delta$) with frequency at moisture levels in 28 °C

Fig. 5. shows the loss tangent results for samples and the full winding. According to the results it is clear that the moisture content of the winding

was in between 1.52 % to 1.09 %. In the same manner, the FDS test was carried out on asphalt mica winding at 28 °C and plotted with the test results of samples as in the Fig. 6. The moisture content of the asphalt mica winding lies in between 1.87 % and 0.88 %. The moisture content of the winding was high indicating remedial actions to be taken.

Conclusions

The loss tangent and capacitance results obtained from the sample measurements can be effectively utilized to estimate the moisture percentages of the asphalt mica winding insulation with the respective temperatures. With the estimated moisture values the necessary recommendation can be made about the condition of the winding insulation. The accuracy of the final results depends on the proper calibration of the equipment and impedance matched connecting cables. It is also possible to calibrate the results of other tests such as DC Ramp test to evaluate the absolute moisture content of the winding insulation.

References

M., Frohlich K., Weiers T. and Vogelsang R. (2008). Insulation Failure Mechanisms of Power Generators, IEEE Electrical Insulation Magazine, Vol. 24, pp 17-25.
 Farahani M., Borsi H. and Gockenbach E.(2006), Dielectric Response Studies on Insulating System of High Voltage Rotating Machines, IEEE Transactions on Dielectrics and Electrical Insulation, Vol.13, pp 383-393.