MODELING OF GENERATOR STATOR WINDGINGS FOR NON-DESTRUCTIVE TESTS

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Introduction

One of the mode of failures of synchronous generators in power stations are due to failure of its insulation i.e. stator winding. Different non destructive tests are performed to asses the condition of its insulation. Out of different Non-destructive tests, response measurements such as polarization depolarization current in time domain (PDC) and Frequency Dielectric Spectroscopy (FDS) measurements in frequency domain provides useful information on the response function of the stator insulation compared to conventional dc ramp and insulation resistance measurements (IR). This paper presents the modeling results of different non-destructive tests for stator windings collected from four different hydro power stations in Sri Lanka.

Samples

The selected four stator winding samples were collected from

(1) W1 – 52 years old, a "wet" asphalt mica winding from Wimalasurendra power station

(2) W2 – 40 years old a "dry" asphalt mica winding from Polpitiya power station

(3) W3 – 36 years old, a "dry" polyester mica windings from Ukuwela power station

(4) W4 – 22 years old, a "dry" epoxy mica winding from Kotmale power station

Methodology

The samples were tested using Dc ramp test, time variation of IR, PDC, and FDS measurements. In the Dc ramp test, the current was measured at elevated voltage up to 15 kV at 1kV/min ramp using a DCR50 Adwel DC ramp tester. The IR measurements was performed continuously for 1000s at 5 kV DC using a megaohm meter. In PDC measurements, first the polarization current was measured at 100V for 2500s and then the depolarization current was measured for another 2500s under short circuit condition using an electrometer (Model 6517A). The FDS measurements were performed from 1 kHz to 0.1 mHz at 200V using IDA200. In order to investigate different effects, the following treatments were adopted and measurements were repeated.

W1 & W2 windings were heated inside an oven. The oven temperature was increased from 29°C to 65°C at a rate of 5°C per hour. (Phase I). Then the oven temperature was increased to 80°C at the rate of 5°C per hour and kept for 48 hours. Finally the sample was allowed to cool naturally under closed condition of the oven for further 18 hrs (Phase II). DC ramp test and IR tests were conducted at the end of each heating process. The first measurements were taken in Phase I at coil temperature of 37°C after 23hrs. The final measurements were taken at the end of Phase II at 29°C and relative humidity of 66%, 18 hrs after shut down of the oven. After Phase II, FDS measurements were also taken for comparison.

W3 – The winding was wetted by dipping in a water bath for two weeks. Dc ramp and FDS measurements were taken. W4 – A void was created in the insulation and later the void was filled with oil. dc ramp and FDS measurements were taken.

The PDC results were used to model the response function and the parameters (A and n) of the Curie-Von Schweidler model ($f(t) = At^{-n}$) were obtained (Jonscher, 1983). Later the dc conductivity values were calculated. The IR results were modeled and relevant parameters (K and R_L) were obtained. The dc ramp results were modeled. In FDS measurements, the capacitance at ∞ (in our case at 1 kHz) and loss tangent at 50 Hz were obtained.

Results and Discussion

Fig 1a shows the polarization and depolarization current patterns for all four windings. The obtained response functions together with calculated values from Curie-Von Schweidler model is shown in Fig 1b. According to Fig 1a, the depolarization current behavior for windings W1 and W2 showed rapid decrease of the currents confirming the aged condition of the insulation (42 and 50 years in service). The calculated dc conductivity values obtained at t =2500 s were for W1- 1.02×10^{-10}, for W2 - 4.73×10^{-11}, for W3 - 2.88×10^{-11} and for W4 - 7.41×10^{-14} and the results confirmed that the W1 had high content of moisture. From the modeled results, the calculated A and n values were for W1, A=2.149 and n=0.7443, for W2, A=0.7612 and n=0.5771, for W3, A=0.6032 and n=0.4768, and for W4, A=0.4768 and n=0.002943. It is interesting to note that the wet insulation (i.e. W1) had significant values for A and n.

Fig. 2 show the time variation of IR results for W1 and W2 for with and without heat treatment inside the oven. The modeled results were in good agreement with the measured ones. The calculated K and R_L values are for W1 (without), K=3.9, R_L=0.1764 GΩ, for W1 (with), K=0.9, R_L=71.61 GΩ, W2 (without) K=0.6797, R_L=7.386 GΩ, and W2 (with) K=0.701, R_L=15.17 GΩ. Again lower R_L for W1, i.e. without heat treatment, confirms the wettability of the winding.

Fig 3 shows the dc ramp test results for W1 for with and without heat treatment. The modeled results are in good agreement with the measured ones showing significant reduction of current.

Fig. 4 shows the frequency variation of loss tangent for all windings with different treatments. The obtained capaciatcnes at 1 kHz (in nF) and loss tangent at 50 Hz (in %) were W1(initial) - 2.8 & 15, W1(drying) - 2.5 & 9, W2(initial) - 1.9 & 12, W2(drying) – 1.5 & 14, W3(initial) - 1.75 & 1.8, W3(moisture) – 1.84 & 8, W4(initial) – 1.8 &2.5 , W4(void) – 1.1 & 1.2, and W4(oil)- 1.2 & 1.2. It is clear from the results that losses reduces with drying (see W1) and losses increases with wetting (see W3).

Conclusions

The modeled curves for nondestructive tests in time domain was in good agreement with the measured results. Curie-Von Schweidler model gives good fitting in this respect. The frequency dielectric spectroscopy, despite limited accuracy in modeling, provides useful information on the status of the stator insulation.

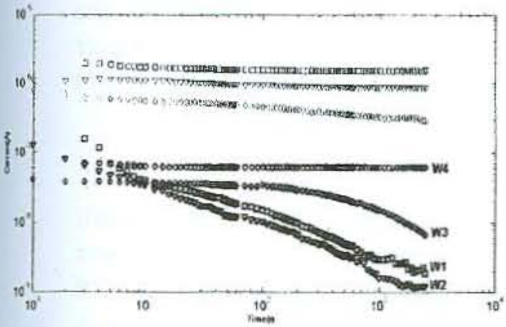

Fig 1a. PDC results for all four windings

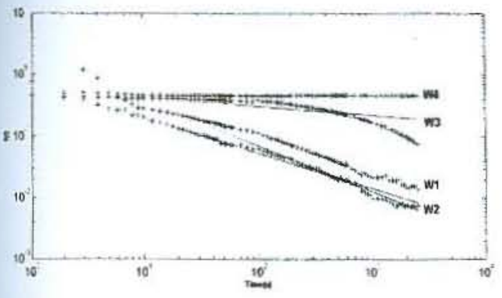

Fig 1b. Calculated and modeled f(t)

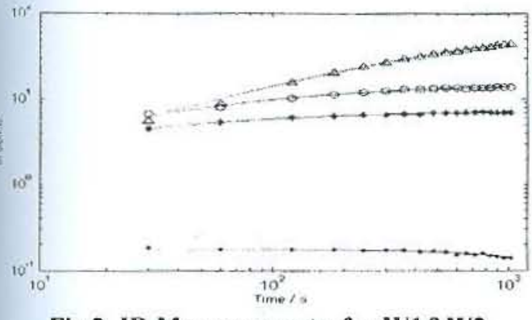

Fig 2. IR Measurements for W1&W2

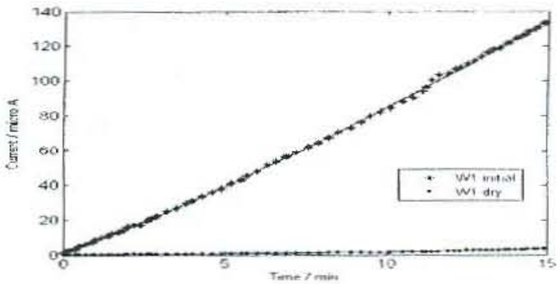

Fig 3. Dc Ramp test results for W1

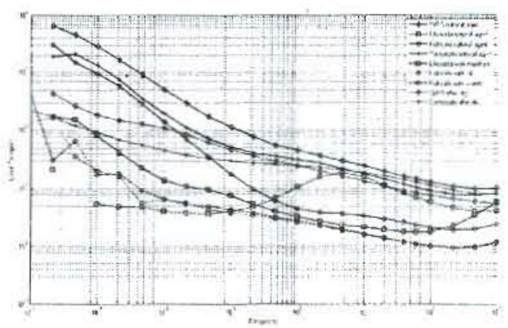

Fig 4. Tan δ for all windings

References

Jonscher, A.K. (1983). Dielectric Relaxation in solids, Chelsea Dielectrics Press, London UK, ISBN 0-9508711-0-9.