MOISTURE ESTIMATION ON DISTRIBUTION TRANSFORMER BY FREQUENCY DIELECTRIC SPECTROSCOPY MEASUREMENTS

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Introduction

the Power transformers are one of expensive components in any power system, so that proper and continuous function is important to the system eliabilityr. However, if they fail, degradation of its insulation, as a result of increased moisture content, is one of the main reasons. A typical transformer consists of oil/paper/pressboard insulation and moisture in oil-impregnated pressboard is the dominant part in this regards. In distribution transformers, due to the sealed structure, it is practically impossible to estimate the moisture in the pressboard insulation. Different non-destructive tests are presently used to assess the condition of power transformers. Out of them, frequency dielectric spectroscopy (FDS) measurements (i.e. frequency variation of tanδ and capacitance) provide useful information compared to other time domain measurements (Ekanayake, 2006). This work proposes a method of estimation of moisture content of pressboard insulation by conducting FDS test on a distribution transformer.

Methodology

Preparation of pressboard samples

Twenty wet cylindrical pressboard samples of thickness 3 mm and diameter of 105 mm were prepared. They were kept inside in an oven (size 10 m × 4 m × 4 m) and dried for more than 48 hours at a temperature of 120 °C. After drying, they were taken from the oven and kept inside a vacuum chamber (cylindrical, 1 m of diameter & 7 m long) until cool down to the ambient temperature without absorbing any moisture. Afterwards, the samples were impregnated in side an oil bath. In order to keep different moisture contents in the pressboard samples, four of each sample was impregnated after exposing them to air under different durations. The different durations were (i) just after drying, (ii) 5 minutes, (iii) 10 minutes (iv) 1 hour, (v) 2 hours. The prepared pressboard samples were kept inside a virgin oil bath until testing.

Moisture estimation of PB samples

Moisture content of the pressboard samples were estimated by using weight measurements. A separate set of (15 samples) non-impregnated pressboard samples were dried inside the oven (size 600 mm × 600 mm × 720 mm) at 120°C for more than 48 hours to remove the moisture. Then the weights of the samples were measured using a precise scale of precision 100 μg. Then the samples were exposed to the atmosphere for different durations as listed above and the corresponding weights were measured. Finally the moisture contents (MC) were calculated and they were (i) 0.25%, (ii) 0.5%, (iii) 0.75% (iv) 1.68% and (v) 2.7%.

Test setup

A test setup was constructed to measure the capacitance (C) and loss tangent (tanδ) of the pressboard samples under oil bath. The set-up consists of three electrodes (two cylindrical for HV and LV terminals and the third as the guarding ring to remover the surface current), and a container in which the electrode system was placed. Fig.1 shows a schematic diagram of the set-up.

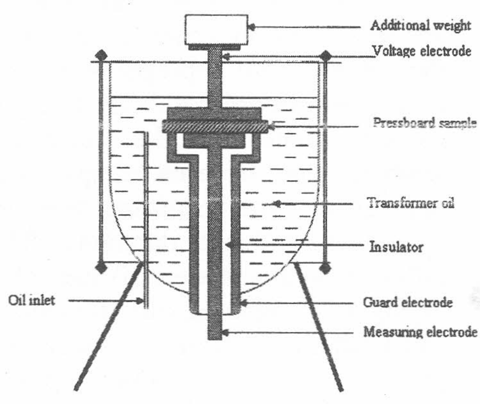

Fig.1. Schematic diagram of the test

FDS measurements

They were conducted on each sample kept in between the main electrodes of the test set up. The frequency variation of capacitance (C' and C") and loss tangent were obtained by using IDA200. The frequency range was from 1 kHz to 0.1 mHz. The applied voltage was 200V. FDS measurements were also performed on a new distribution transformer (160 kVA, 33/0.4 kV) with damaged bushing during its transportation. One could expect higher level of MC in its insulation. Here all HV and LV terminals and separately short-circuited and HV and LV terminals of IDA200 were connected to them. The measurements were obtained between HV-LV (main insulation consisting pressboard and oil) and HV-tank (through mainly oil).

Modelling

The complex capacitance of the transformer insulation was obtained using X-Y model & X model (Ekanayake, 2006), where X and Y are the ratios between thickness of pressboard barriers and width of pressboard spacers to overall insulation respectively. The obtained FDS results for pressboard and oil conductivity were used to calculate C using eqv 1 (for X model Y=0). The X and Y parameters were estimated according to transformer dimensions and were X=0.11, Y=0.12 for X-Y model and X=0.16 for X model. The geometrical capacitance C_0 was calculated as 25.54 pF. The results of X-Y and X model were in good agreement and X-Y model was used for further analysis.

$$C = C_0\varepsilon = C_0\left(Y\varepsilon_p + \frac{1-Y}{\dfrac{1-X}{2.2 - j\dfrac{\sigma(T)}{\varepsilon_0\omega}} + \dfrac{X}{\varepsilon_p}} \right) \quad (1)$$

Results and Discussion

Figs. 2 and 3 show frequency variation of C' and C" of pressboard samples with different moisture contents. Both C' and C" values increased with the moisture content confirming the higher losses at the higher MC levels.

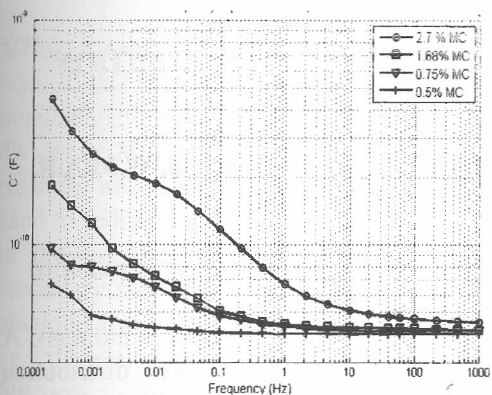

Fig. 2. C' vs. frequency of pressboard samples at 27°C

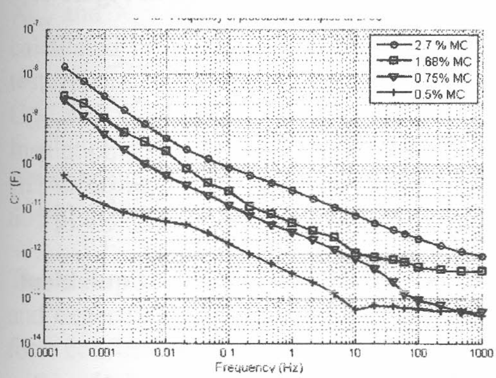

Fig. 3. C" vs. frequency of pressboard samples at 27°C

The oil conductivity of the distribution transformer was calculated using the loss tangent measurement between HV to tank (gradient -1) and it was 7.4×10^{-13} S/m. Fig. 4 shows the frequency variation of loss tangent for the distribution transformer between HV to LV terminals and HV to tank. The model loss tangent values from pressboard samples (X-Y model) with different MC levels are included in Fig. 5 for comparison. According to the figure, it is clear that the MC level of the distribution transformer is above 2.7% confirming wettable (above 2%) as expected due to moisture absorption through the broken bushing.

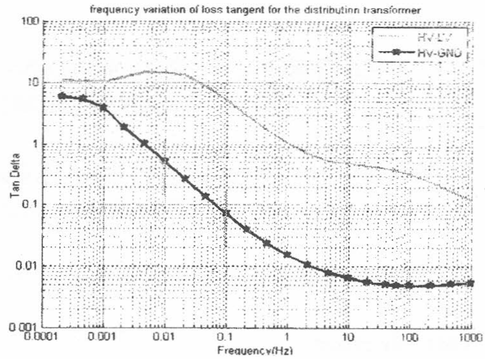

Fig.4. frequency variation of loss tangent (tanδ=C"/C')

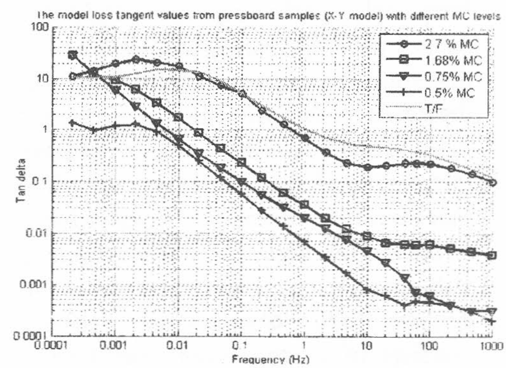

Fig.5. frequency variation of X-Y model loss tangent with Transformer

Conclusions

Frequency dielectric spectroscopy measurement can be used to estimate the moisture content of pressboard samples i.e. the wettability of a typical distribution transformer. The measurements across HV to LV and HV to ground provide the information for this estimation. However, testing on different field-aged transformers can be used for further verification.

References

Ekanayake, C. (2006), Diagnosis of Moisture in Transformer Insulation – Application of Frequency Domain Spectroscopy, PhD thesis, Chalmers, Gothenburg, Sweden.