PARTIAL DISCHARGE AMPLITUDE DISTRIBUTION FOR THE EVALUATION OF INSULATION AGEING

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ABSTRACT

During preventive maintenance programs of high voltage apparatus, diagnostic tests are performed to estimate the likelihood that apparatus can remain in operation without experiencing outages until the next planned maintenance, or must be taken out of service immediately. Such an evaluation procedure requires the detection of the degradation phenomena and identification of the defects causing the damage. The diagnostic test can be destructive or non destructive. A non destructive test could be a partial discharge (PD) test where the life is defined to end when the insulation has a partial discharge magnitude above a specified threshold level. In this study, PD tests on cast epoxy resin specimens were introduced and the variations of the maximum discharge amplitude and ageing test time were observed under several test conditions.

I.INTRODUCTION

Breakdown of insulation while in service can cause considerable damage of the equipment and the system to which it is connected. It has been recognized that failures of this type often may be related to the occurrence and the severity of PD's within voids and /or on surfaces of the insulation [1-3]. Discharge within cavities in solid insulation systems has been associated with gradual degradation and dielectric failures. The correlation between cavity discharge and degradation has been established for rotating machines, power cables, transformers and many other electrical insulation systems. Gass-filled cavities can originate in a wide range of solid dielectric systems through many mechanisms including differential thermal expansion (composite systems), incomplete impregnation or excessive mechanical stress, or improper process control (Epoxy casting).

Many studies have been devoted to the defining parameters which express the harmfullness of PD. Several international organizations have recommended certain parameters as being representatives of discharge damages. General agreement seems to be emerging concerning the validity of criteria based on the maximum amplitude of discharges (Qmax) [4].

II. EXPERIMENTAL SETUP AND PARTIAL DISCHARGE TESTS

Partial discharges in high voltages systems are local electrical discharges within the insulation of these systems. If the PD is above a certain level, it can cause permanent damage to the insulation systems. For this reason, a correlation was established between the magnitude of partial dischage and the life expectancy of the insulation.

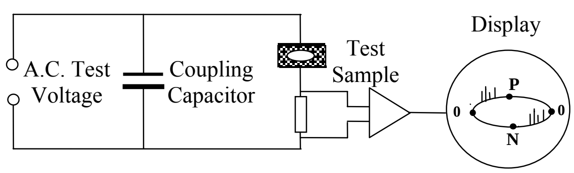

Figure 1**.** Basic Discharge Detection [5]

The magnitude of partial discharges can be measured with the help of sensitive instruments. Figure 1 shows a conventional PD measuring test setup. Internal discharges in a solid insulating structure having internal voids give the different discharge patterns on the display/or measuring instrument that the discharges occur in advance of the voltage peaks on both the positive and the negative halves of the waveform.

Details of our experimental setup used for partial discharge tests are as follows:

1. A shielded test laboratory which is suitable for partial discharge and radio interference voltage tests. Walls, ceiling and floor of the test room were covered with copper of 0.5 mm,
2. Test transformer with special isolation, 100 kV, 20 kVA test transformer partial discharge free,
3. 100 kV, 226 pF measuring capacitor,
4. 120 kV, 1007 pF coupling capacitor,
5. Epoxy resin test samples,

6. Double traces PD dedector 70 kHz – 400 kHz measurement range.

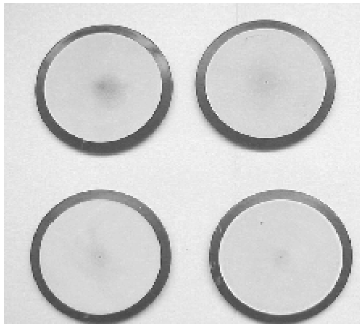

Figure 2. Epoxy resin test samples

Epoxy resin test samples, see Fig. 2, having the diameter of 10 cm and the thickness of 6.5 mm were used as test specimens in accelerated ageing tests based on partial discharge measurements. During PD tests, test samples were fixed simetrically between Rogowski electrodes where the electrical field distribution is uniform (see Fig. 3).

Figure 3.Rogowski electrode profile and a test sample

Electrode profile and test samples were put in a clean transformer oil in order to minimize the probable surface discharges that are not desired during PD measurements.

III. EXPERIMENTAL RESULTS ON AGEING EPOXY RESIN TEST SAMPLE

It is a well known fact that solid insulating materials can age under high electrical stresses [6]. In this study, ageing is accelerated by means of increasing the voltage levels. Using conventonal PD dedection, maximum partial discharge magnitude (Qmax) was measured during the short term ageing tests. Normally, the test voltage is chosen so that it will be high enough to ensure a significiently large number of punctures occur. In contrast to the constant ageing test voltage, the ageing voltage was gradually increased from 6 kV to 10 kV with the steps of 1 kV. Each test voltage with this range was applied for 288 hours (12 days), see Fig. 4.

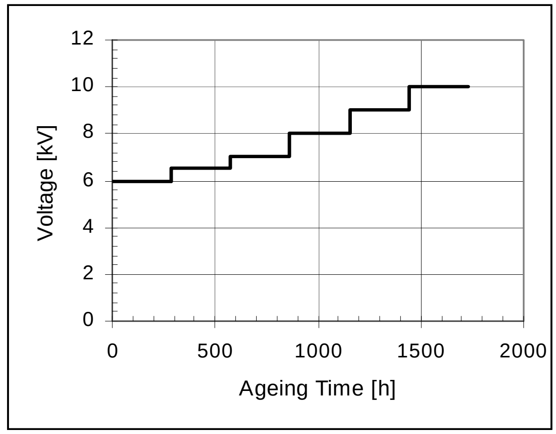

Figure 4**.** Step by step increasing the ageing test voltage levels

Test setup was first calibrated by means of an external calibrator before the PD measurements. Calibrations were conducted for several PD levels in order to minimize the measurement errors.

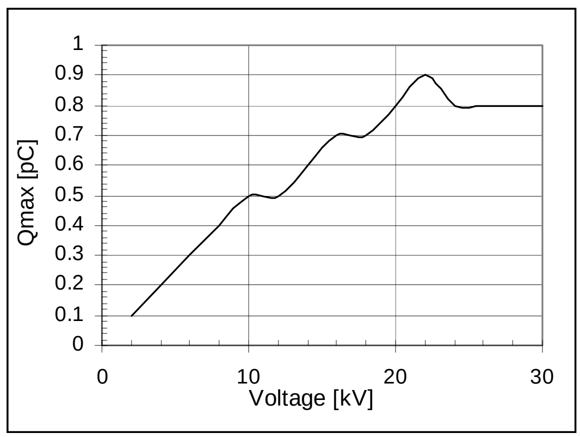

Figure 5. Maximum discharge magnitude measured during idling situation up to 30 kV.

In addition to the calibration process, in case of idling, partial discharge magnitude must be less than a specified value. PD values for the idling phase are illustrated in Fig. 6 up to 30 kV test voltage levels.

Epoxy resin specimens, see Fig. 2, were continuously aged during a period of 1440 hours by step by step increasing the alternative test voltage levels (Fig. 4). During the entire ageing process, discharge dedection was carried out in regular intervals where one such PD measurement was performed three times and the last cycle measurements were recorded. Test results are illustrated in Fig. 6 and 7.

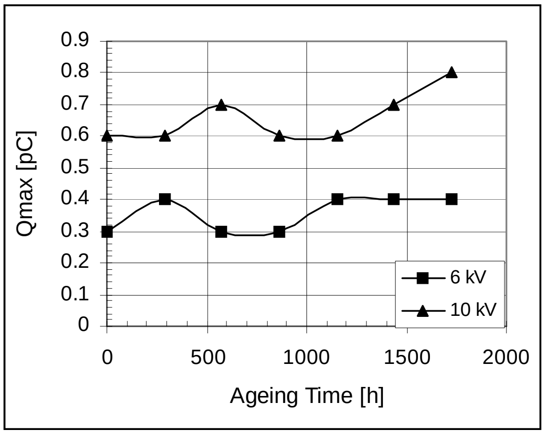

Figure 6. Maximum discharge magnitude measured during 1440 h of ageing under 6 kV and 10 kV test voltages.

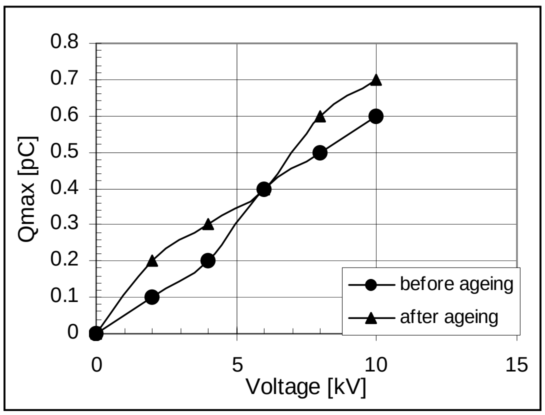

Figure 7. Maximum discharge magnitudes measured before and after ageing process up to 10 kV

It can be concluded from Fig.6 and Fig.7 that, after 1440 h of ageing, no remarkable variations in the PD magnitudes were observed. Actually, there was a small increase in the maximum discharge magnitude with time. However, these variations were not high enough to ensure over an economically and practically feasible test period. This was the first part of our ageing test program.

Following the first case, PD measurements were conducted for the test voltages above 10 kV in order to achieve significiant changes in discharge magnitudes. Test samples were continuously subjected to gradually increased test voltages. Initial voltage, final voltage and voltage step were chosen as 15 kV, 25 kV and 1 kV, respectively. PD measurements were carried out following a 24 -hour ageing with each voltage step. PD magnitudes versus test voltages are illustrated in Fig. 8 both for before and after the ageing process.

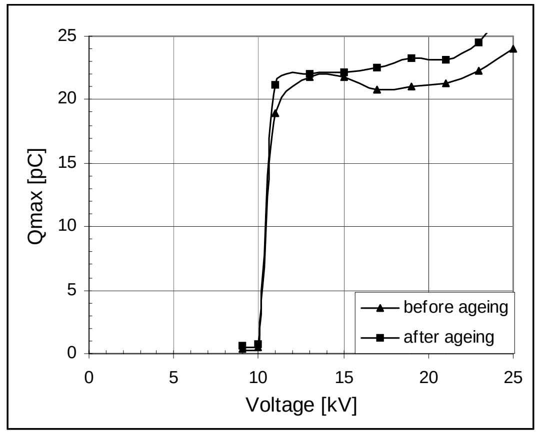

Figure 8. Maximum discharge magnitude measured during 24 h ageing time up to 25 kV test voltage.

A quick glance at Fig. 8 shows that, after 24 hours of ageing period which is very short test time compared with the previous ageing times, significiant increases in the discharge magnitudes have been observed. Studies on ageing tests are still going on.

IV.DISCUSSION

In order to establish a realtionship between the applied voltage, maximum PD magnitude and the ageing time, fistly lower test voltages (6-10 kV) were chosen as representative ageing voltages. Then, voltage levels were increased to get significiant variations in PD magnitudes and to reduce the total test time. There were some restrictions upon conducting the test program with 30 kV and higher test voltages since the surface discharges starts at that voltage levels. Besides this limitation, transformer oil mut be renewed or vacummed in some test intervals in order to obtain reliable test results. Our test program will continue until a time when the insulation/or test samples have PD values above a specified level.

V.CONCLUSIONS

Measurement of partial discharges occuring within the insulation structures can be used to detect the weakness and the quality before they lead to catastropic failures. If all the test specimens show failure threshold levels given a defined quanity with ageing times, these times can be defined as “time-to-failure” of the insulation under the defined test conditions, such as applied accelerated voltage levels and exposure of ageing times. In order to establish a corrolation between the PD magnitudes and life expectancy, a great number of test samples produced in the same manner and tested under the same conditions must be evaluated in the accelerated ageing tests. After getting these test data, selecting suitable failure model and using appropriate statistical distribution that represents the ageing life data best, life at normal operating conditions for the insulation can be estimated for some confidence intervals.

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