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Quantitative Analysis Ageing Status of Insulation of High Voltage Motors by Polarization – Depolarization Current Measurements

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Polarization and depolarization current (PDC) technique is an effective tool to assess the condition of insulation system in high voltage motors So far the PDC behaviors of insulation have been widely investigated. This Paper presents the assessment of insulation systems for high voltage induction motor through measurement of polarization depolarization current or charging and discharging current. However, with the increasing number of Motors choosing insulation , it is important to investigate the PDC characteristics of insulation to see whether the PDC technique can also be used to assess the condition of new insulation system using PDC accurately It is considered that the insulation systems are having different types and conditions of insulation aging. It demonstrates that the insulation resistance (IR) and polarization index (PI) can't be used individually to judge insulation dryness and the combination of insulation resistance and PI. PDC analysis is better technique of insulation quality assessment than the insulation resistance alone. The PDC analysis is non destructive dielectric testing method for determining the conductivity and moisture content of insulation materials in high voltage motors. On the basis of this analysis, it is possible to take further actions like overhauling, drying process, and replacement of the winding of the motor. This paper also presents a description of PDC analysis technique with the practically and theoretical background and some results of PDC measurements on High voltage motor duration from 0–600 days.

Keywords: *Insulation system, Insulation resistance (IR), Polarization index (PI), Polarization and depolarization current (PDC), Charge storage mechanisms and Aging.*

1.0 INTRODUCTION

Large numbers of high voltage motors around the world are approaching towards the end of their design life. They are very expensive to replace; however, some of these motors are still in good condition and could be used for some more years. One way in achieving this objective is to increase the time interval between maintenance outages and reduce the time of the outage. Towards this end detecting defects at an early stage, being able to model and predict the growth of such defects, and integrating maintenance to mitigate the consequent reduction in reliability, is critical to ensure that the motors survives from one outage to the next with the desired reliability. Various industrial surveys show that problems initiated in the stator winding insulation are one of the leading root causes of High voltage motors failure. It is known that up to 70% of high voltage motors failure results from stator insulation problems. Stator insulation aging and breakdown can cause a costly, forced outage and significant loss of revenue as well as repair/ replacement costs. Therefore, prevention of such outage is major concern for both the manufacture and the end user. To this end, there has been a lot of effort towards developing reliable insulation quality assessment techniques [1–3].

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While performing insulation resistance (IR) and polarization index (PI) measurements in motors with modern day insulation systems, it is often noticed that good/acceptable IR and PI values are obtained in spite of the motor winding being excessively contaminated. This is mainly due to the fact that IR and PI measurements are largely reflective of charge transport rather than charge storage mechanisms. Charge storage analysis is useful since it is possible to identify whether charge is stored in normal "traps" within insulation or within contaminants that are likely to be present in the insulation. The PDC analysis is used to quantify and characterize charge storage mechanisms, and therefore a reliable indicator of presence of contamination [4–7].

The paper have been investigating the PDC measurement for separation of moisture and ageing impact on motor insulation degradation. One case study is presented, where the testing of high voltage motor is carried out by PDCA in one year. The test results are compared to determine the condition of insulation system of motor, and to assess the healthiness of the motor.

2.0 PDC PRINCIPLE THEORY

The measurement of the PDC following a DC voltage step is one way in the time domain to investigate the slow polarization processes of dielectrics [7–8]. When an electric field which is generated by an external voltage u(t) is applied on the dielectric material, the current through the dielectric material can be expressed as:

$$i(t) = C_0 \left[\begin{array}{l} \dfrac{\sigma}{\varepsilon_0} u(t) + \varepsilon_r \dfrac{du(t)}{dt} \\ + \dfrac{d}{dt} \displaystyle\int_0^t f(t-\tau) u(\tau) d\tau \end{array} \right] \quad \text{.... (1)}$$

Where,

C_0: geometrical capacitance of the dielectric material.

$u(t)$: the step voltage.

σ: the DC conductivity of the dielectric material.

ε_0: 8.852×10^{-12}F/mis the vacuum permittivity.

ε_r: the relative permittivity of the dielectric material.

$f(t)$: the response function of the dielectric material.

Simplified diagram of the PDC measurement for the test object is shown in Figure 1(a) [7]. Figure 1(b) shows a typical PDC due to a step charging voltage Uc [7]. Assuming that ADC step voltage u(t) with the following characteristics is applied to a totally discharged test object.

$$u(t) = \begin{cases} 0 & t < 0 \\ U_c & 0 \le t \le t_1 \\ 0 & t_{1<t} \end{cases} \quad \text{.... (2)}$$

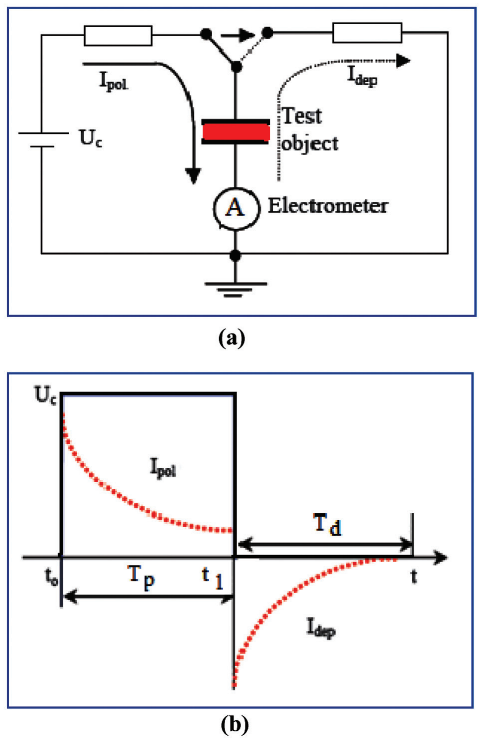

FIG. 1 (A) AND (B) PRINCIPLE OF PDC.

As shown in Figure 1(b), T_p which is from t=0 to t_1 represents the polarization duration time, and T_d the depolarization duration time. When t<0, the current through the test object is zero, and for time $0 \le t \le t_1$ the so called polarization current is generated due to the conductivity and the various polarization processes of the test object. The polarization current can be written as:

$$ipol(t) = CoUc\left[\frac{\sigma}{\varepsilon_0} + f(t)\right] \quad .... (3)$$

At time t = t1, the external voltage is removed and the test object is short circuited, the depolarization current can be expressed as:

$$idep(t) = -CoUc\left[f(t) - f(t + tp)\right] \quad .... (4)$$

The principle of PDC measurement is as follows. A DC voltage of 2500 V is applied to the winding/windings using a highly regulated electronic power supply with a stability of <1 V/s. The voltage is maintained for a time period of not less than 1000 secs. The current flowing through the insulation is monitored during this charging period. Then, the windings are discharged through a micro ammeter and discharge currents are monitored after the initial winding capacitance discharge (< 5 sec), over a total time period that will not be less than the charging time period. The charging and discharging currents are plotted on a log-log scale and analyzed in the times domains [3–4].

The schematic diagram of the PDC measuring set-up is shown in Figure 2.

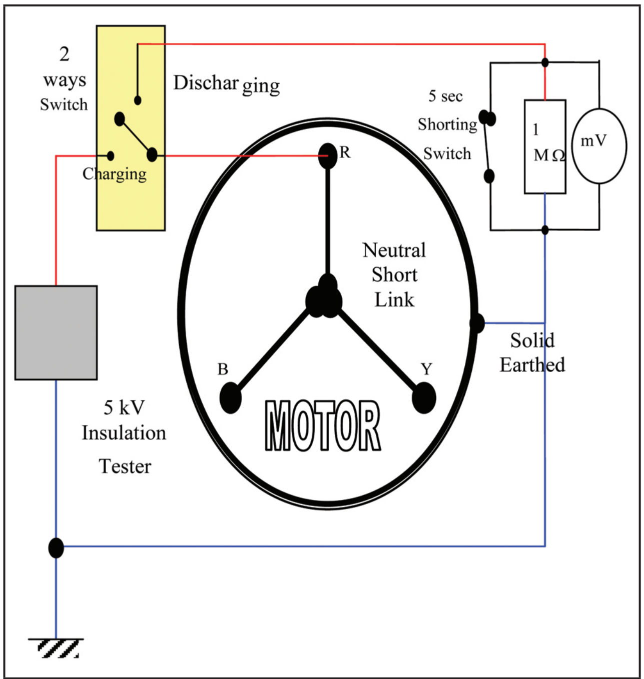

FIG. 2 PDC MEASURING SET UP.

The procedure for taking readings of charging and discharging current of insulation are as follows.

i) The setup as per circuit diagram (Figure 1) in charging mode is made.

ii) The capacitance between winding and earth (i.e. between each phase and other two grounded phases) is measured in both polarities.

iii) The initial leakage current in nA is measured with multimeter connected across MΩ resistor in both polarities.

iv) Now the winding is energize with IR Tester at 2.5 kV for 17 min and the IR values are noted down at regular time intervals. IR values are recorded with intervals of 5 sec for initial 30 sec, then with intervals of 10 sec for next up to 2 min and later with intervals of 30 sec. Thus immediately after applying the test voltage, the readings will have to be taken fast.

v) After charging for 17 min, the circuit is connected in discharging mode so that the IR Tester is not in circuit and motor terminals are connected to discharging circuit. However, during discharging, the 1 MΩ resistor is shorted for initial 5 sec to discharge high initial current. After 5 sec, the shorting link of 1 MΩ resistor is opened and the mV readings on multimeter connected across 1 MΩ resistor are noted.

vi) The above procedures are repeated for each individual cases in starting from new motor to up to one year.

For each case study in this contribution, plots of insulation resistance versus time are accompanied by the PDC analysis with the Charging current and discharging current versus time are presented. These are for better understanding of the characteristics of each aging type [6–7].

3.0 RESULTS AND DISCUSSIONS

The polarity of the depolarization current values has been changed to positive values for easy comparison. It can be seen from Figures 3(a–b) that the polarization/depolarization current of the insulation has a different pattern in the ageing process. PDC measured at different ageing intervals on the insulation of high voltage motor are shown in Figures.

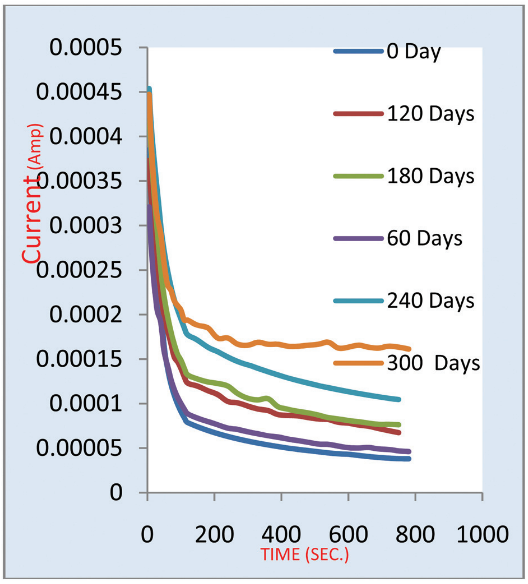

FIG. 3(A) POLARIZATION CURRENT GRAPH WITH DIFFERENT AGING CONDITION OF INSULATION SYSTEM HIGH VOLTAGE MOTOR.

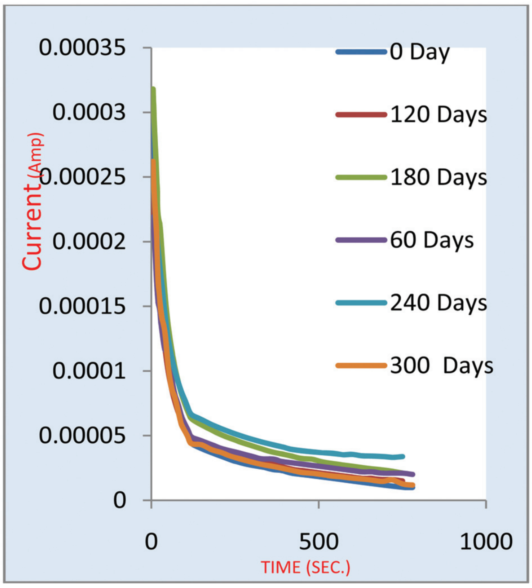

FIG. 3(B) DE-POLARIZATION CURRENT GRAPH WITH DIFFERENT AGING CONDITION OF INSULATION SYSTEM HIGH VOLTAGE MOTOR.

The polarization/depolarization current of insulation reaches a relative stable current value earlier than that of insulation testing. In addition, the polarization/depolarization current of insulation sample is higher than the same ageing intervals. For high voltage Motor insulation, the long term polarization current value increases with the ageing time increased. While the long term depolarization current of insulation increases with the ageing time all the time. The polarization/depolarization current of the insulation shows a different changing pattern in the ageing process. This is our initial attempt to use the PDC technique to assess the ageing condition of high voltage motor insulation.

4.0 CONCLUSIONS

Quantitative analysis of ageing status of insulation of High voltage motor by polarization/ depolarization current has carried out by the PDC measurement on theged at 0–300 days.

This paper describes the usefulness of PDCA technique as a modern non-destructive tool for the condition assessment of high voltage motor insulation. From the field test results, presented in this paper, it appears that both the polarization and depolarization currents are strongly influenced by the moisture contents, conductivity state of the insulation. Three diagnostic parameters, Insulation Resistance, Polarization Index and PDCA, are applied for interpretation of dielectric response results.

The long term polarization current value increases with the ageing time increased except for the sample aged for 60 days. While the long term depolarization current of mineral oil-paper insulation sample increases with the ageing time all the time.

PI is sensitive to problems caused by conductive contaminants (carbon dust, surface humidity or free water). PI can not be used alone to judge insulation dryness, since PI can still be high in case moisture in the absorbed state if no conductive contaminants are included. Moisture in the absorbed state decreases insulation resistance without changing nature of PDC. PDC shape can identify conductive contaminants.

In all case studies shown, PDCA provide the most efficient and decisive indicator in assessment of global problems in high voltage motor insulation.

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