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Experimental Investigations On Surge Pd In Low Voltage Ac Motors Due To Influence Of Rotor And Its Position

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Abstract

Switching devices such as relays and circuit breakers in power systems create voltage surges. Implementation of power electronics devices also creates repetitive voltage surges. Such repetitive fast rise time voltages of relatively higher magnitude upon reaching the stator winding of rotating machines tend to degrade the insulation of such machines. The voltage surges created by the switching devices may lead to excess electrical and thermal stresses on the stator winding insulation leading to premature failure. In this work a surge generator circuit along with PD measurement circuit incorporating direct detection method was implemented. Partial Discharge was measured for four different stress levels on stator insulation of a low voltage induction motor with and without rotor. It was observed that PD measured without the rotor was less when compared to the PD measured with the rotor inserted. Hence it was inferred that the PD test without the rotor will result in under qualification of the motor for operation under transient surges. Further the rotor was positioned at 3 different positions with reference to stator and was tested for PD. Significant changes were observed in the PD pulse patterns.

Keywords— surge PD, direct detection method, PD on rotating machines.

I. INTRODUCTION

Recent developments in semiconductor switching devices have encouraged an increase in the use of low voltage drives for induction motor applications. These fast switching devices cause short rise time pulses with rise times in the order of hundreds of nanoseconds[2], and magnitudes as high as twice or even more. Hence motors manufactured to work on 50 Hz frequency of power, will be experiencing electrical and thermal stress in excess of what it is designed for, causing premature failure. In addition to this the manufacturing defects such as voids or impurities that may be present in the insulation will lead to premature failures. In addition to the above effects the electrical stress due to switching devices will behave like a surge voltage with short raise time in repetition superimposed on the supply voltage. In addition to this, the capacitance effect present in the cable used aids the terminal voltage magnitude causing a surge.

The windings present in the stator are mostly random wound for motors less than 700 V[10]. The raised terminal voltage and uneven distribution of voltage with higher voltage in the terminal end can give rise to PD due the voids present in the system. This is prevalent in low voltage motors below 700 V and causes degradation in turn to turn, phase to phase and ground wall insulation leading to premature failure in the motor. The random wound stators insulation is made of organic materials which are vulnerable to PD.

In this work a surge voltage having short raise time similar to that created due to switching is generated using a Marx Impulse generator circuit and it is injected to the insulation of a low voltage induction motor.

II. PARTIAL DISCHARGE

Definition: Localized electrical discharge that only partially bridges the insulation between conductors and which can or cannot occur adjacent to a conductor. Partial discharge is also the consequence of local electrical stress concentrations in the insulation or on the surface of the insulation. such discharges appear as pulses having a duration much less than 1 µs [1].

Researchers have inferred that Partial discharges occur in solid insulations mainly due to the manufacturing defects present in the insulation. The presence of gas or air pockets due to these defects enhances the PD process. As the name itself suggests these discharges do not short circuit the insulation system but instead bridges the insulation partially. PD detection test circuits are listed in the standard IEC 60270:2000 in which they are classified into four types. In this work direct detection method is implemented. In low voltage motors the materials used are varnish and cotton tapes for the phase and inter turn insulations, plastic sheets are used to separate the phase winding from the ground. Hence PD can occur in any of these insulations.

In the figure 1 the Ck is the coupling capacitor which is connected to the quadripole CD from the quadripole a connecting cable is used to connect to the PD measuring instrument. Ca is the test object of which one end is earthed. During the occurrence of PD the PD will be measured through the coupling capacitor and a quadripole. The corresponding data will be recorded in a computer for analysis.

III. SURGE PD TESTING

(a) TEST SETUP

To conduct the test on a low voltage induction motor, off-line test was considered. A single stage Marx impulse generator circuit was implemented to generate a surge voltage[2]. The figure 3 shows the test setup, where a three phase induction motor was used as a test object. The rotor of the induction motor was removed to test the stator winding alone for its phase to ground, phase to phase, and turn to turn insulation[12][7]. The designing of wave shaping components of the test circuit were decided based on the available facilities. The stepped up voltage from test transformer was fed to two diodes in series each rated at Peak Inverse Voltage (PIV) of 140kV. A current limiting resistor (10 MΩ) was added to protect the diode and transformer. To reduce the ripples in the rectified DC voltage a capacitor (25000pF) was charged and considered as a DC source. The sphere gap arrangement was appropriately positioned for generating surge voltages of various peaks. During this discharge the front time resistance and tail time resistance of 122 Ω (Two 245 Ω resistors in parallel) and 98K Ω respectively. For the purpose of reducing the peak value of applied voltage to the motor, a 1200 pF capacitor was connected in the circuit as a potential divider.

The method used to measure the Partial discharge was direct detection method set up in SASTRA University HV laboratory. The test equipment included 1000pF coupling capacitor, test transformer of (230V / 100kV 10kVA), a sphere gap, oscilloscope and PD measurement kit. This equipment allows off-line measurement of PD to be carried out.

(b) MOTOR UNDER TEST

The motor used for the test had class B insulation in it with inter-turn insulation as varnish and Plastic sheet for phase to ground insulation. In the hang over region where the winding is exposed to other phases, cotton tape along with varnish was present as insulation between them. It was inferred from records that the motor was operational for 4 years in the university laboratory and its specifications are 1 HP, 415 V, 3 Phase, Star connected winding with class B as insulation, closed slot rotor and random wound. The figure 4 shows one end of winding present in the motor under test.

The stator terminal U1 was connected as the HV terminal of the Marx circuit, and terminals V1 and W1 were shorted with motor body and grounded finally. Surge voltage applied will be stressing all the coils but initially the coil U1 will experience higher stress than the other two coils and the applied voltage stress will pass though the neutral point of the machine. By connecting the motor in this way, phase to ground and phase to phase and turn to turn insulation will be tested.

IV. MECHANISM OF INSULATION DEGRADATION

In type 1 insulation system which are generally random wound the insulation present in the conductor is very thin or small in thickness and mostly air surrounds the conductor. It is also observed that the initial and final turns of the coils present in the motor may be present side by side. The air present between the conductors or the ground will experience electrical stress and more possibilities of PD to occur. The insulation used in type 1 motors is generally organic film, and this thin organic insulation may easily be eroded by PD which will enhance the insulation failure rate or may lead to inter turn short in the winding[9][10]. In addition to this, a dielectric heating which may result due to presence of higher frequency components of voltage superimposed on the fundamental waveform that are generated from power electronic switching devices may also play a vital role in enhancing the insulation failure rate.

V. EXPERIMENTAL RESULTS

To test the motor in different levels of stress four different voltages were applied namely 1.755kV, 2.86kV, 4.86kV and 5.07kV as peak values of surge voltage from the Marx generator circuit [4].

Stress level 1:
Initially 2.1 KV was generated in the secondary of the test transformer and applied across the sphere gap. The peak value of surge voltage generated was measured as 1.755 kV. After recording the PD waveform the time scale was altered to have a clear idea about the pattern of PD pulses.

Stress Level 2:
The surge voltage generated from the Marx circuit was increased to 2.86kV. The following figure shows PD pattern obtained for the voltage of 2.86 KV. The magnified wave form show the RPDIV pulses

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Stress level 3:
The surge voltage generated from the Marx circuit was increased to 4.08kV. The following figure shows PD pattern obtained for the voltage of 4.08kV. The RPDIV concentration is more figure 13 shows The magnified image of number of peeks present in the PD.

The output shows that there is a change of RPDIV pattern and the prolonged appearances of the pulses show that the insulation present in the motor has week insulation. With this insulation it can be inferred that if the motor is exposed to surge voltages near the magnitudes of 4kV it may lead to premature failure.

Stress Level 4:
The surge voltage generated from the Marx circuit was increased to 5.07kV. The following figure shows PD pattern obtained for the voltage of 5.07kV. I was observed that the PD occurrence was very intense when compared with the lower voltages and further increase will damage the insulation.

The magnitude of the PD was also high when compared to the previous tests proving the presence of defects in the inslation and not qualifying the motor for operation under this stress levels. The expanded view of the PD measurement shows the continous RPDIV through out the surge voltage. the figure 14 shows the RPDIV which is coutinous and there are more number of pulses observed.

V. INFLUENCE OF ROTOR ON SURGE PD TEST:

To check the influence of rotor on surge PD initially The rotor of the machine was removed from the machine and the stator winding alone was tested for PD under short raise time pulse voltages. Later the same voltage was applied with the rotor in its inserted position the PD was measured and changing the position of the rotor to three different positions with reference to a particular stator position approximately 0°, 90°, and 180°.

A considerable change is present in PD pattern observed in figure 16 and figure 17,18,19. The wave shape of the applied voltage also changes when the rotor is inserted. This is due to the short circuited coil of the rotor which has an influence on the applied voltage.

It is also to be noted that the rotor winding is insulated with the ground hence the PD observed will also have the influence of the induced voltage from the rotor winding which is responsible for the change in the wave shape of the applied voltage[12]. The figure 18 and figure 19 shows the PD observed for the rotor position of 90 degree and 180 degree. This also shows that there is a change in the PD pattern observed when the position of the rotor changes. A combined image of all the PD measured was plotted on a common time scale which shows the differences clearly.

DIRECT DETECTION

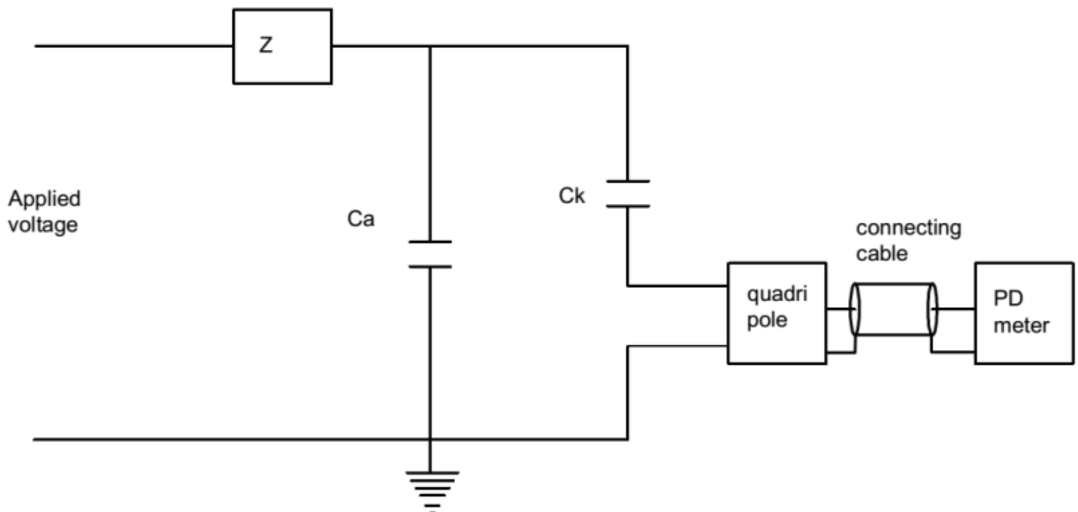


Fig.1

CIRCUIT DIAGRAM

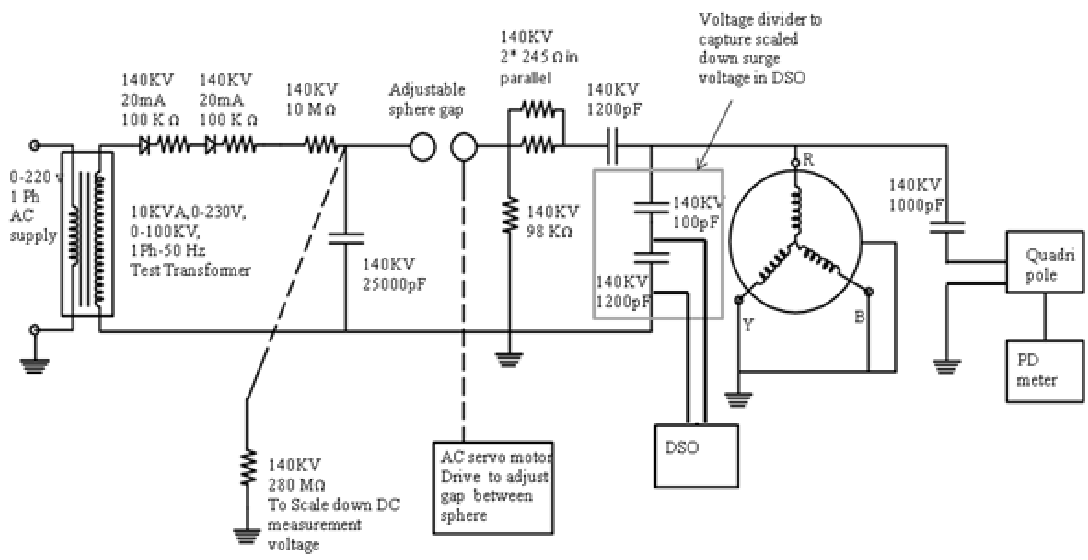


Fig.2

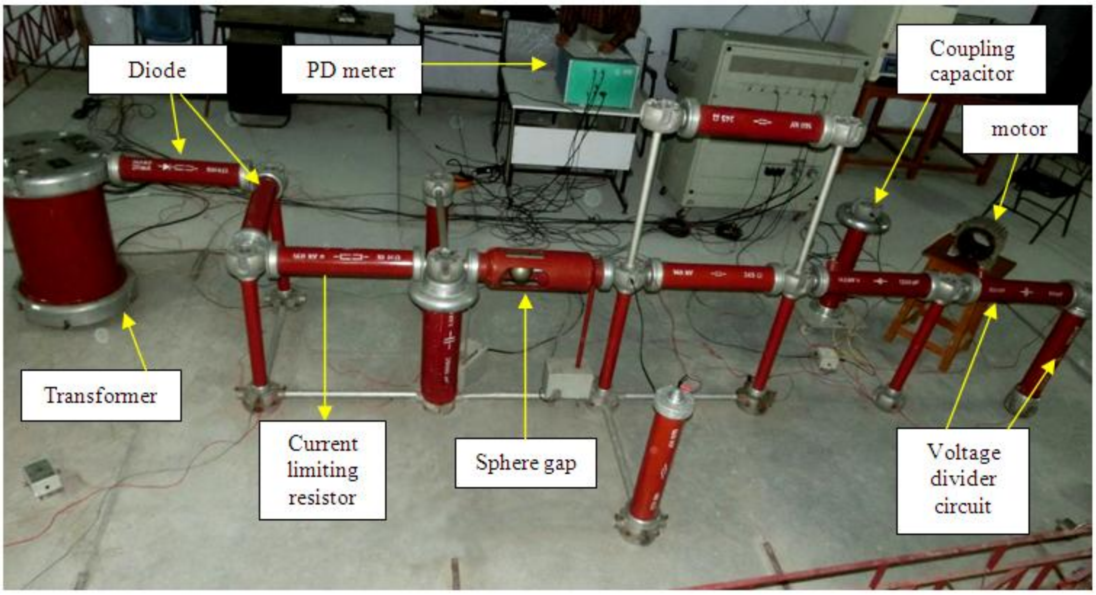


Fig.3

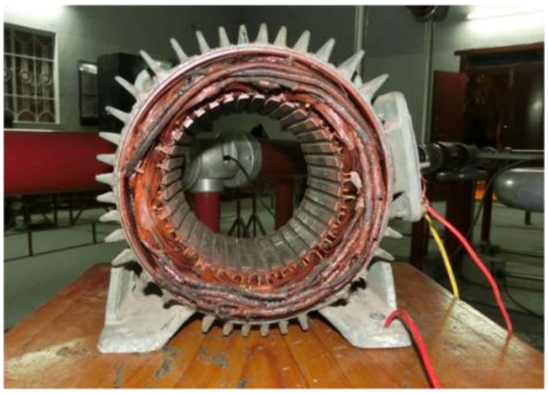


Fig.4

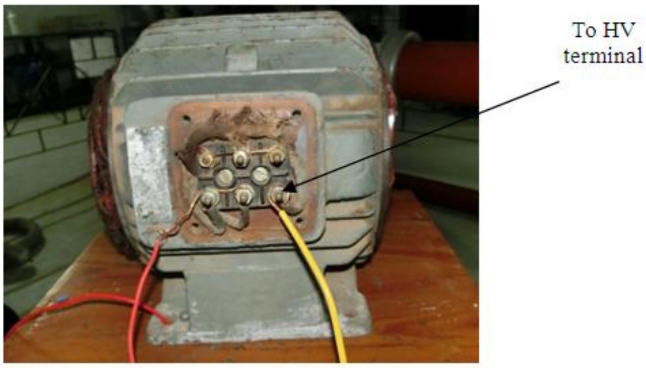


Fig.5

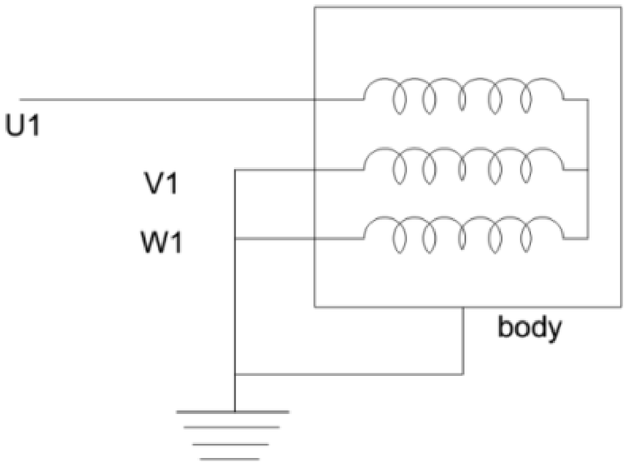


Fig.6

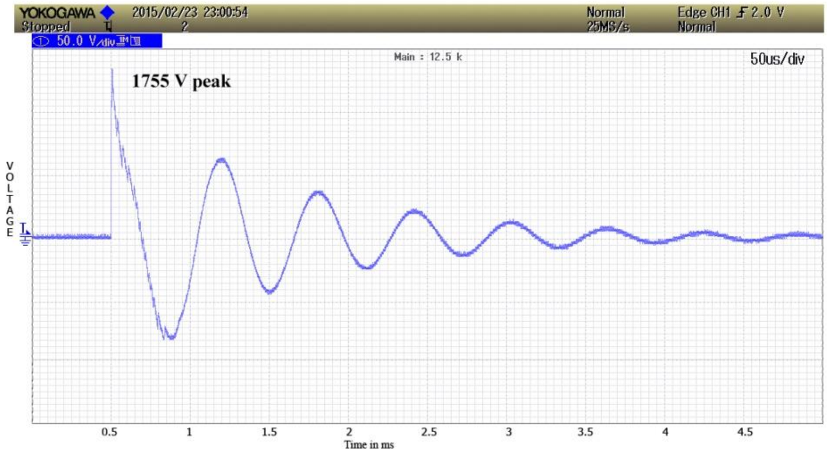


Fig.7

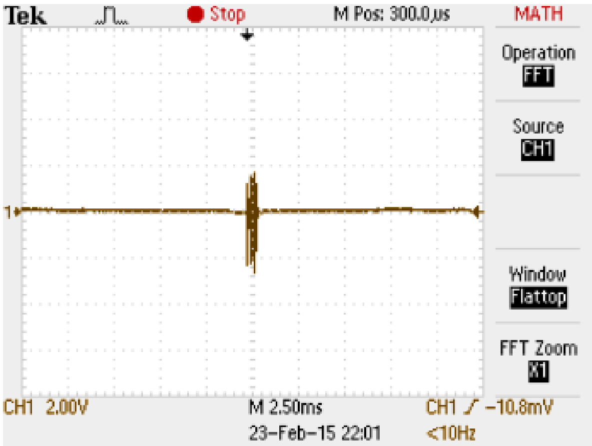


Fig.8

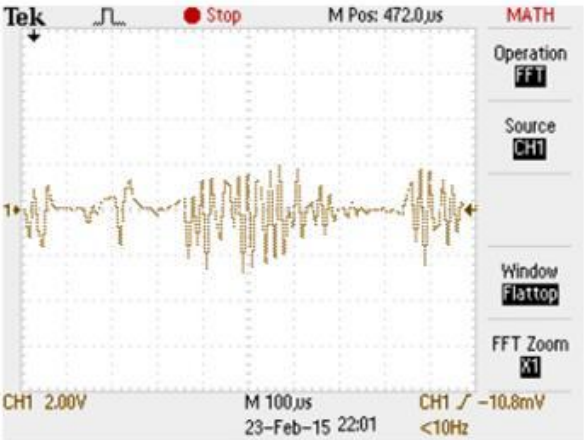


Fig.9

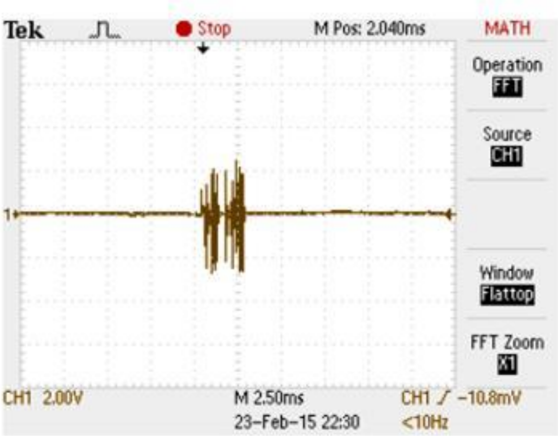


Fig.10

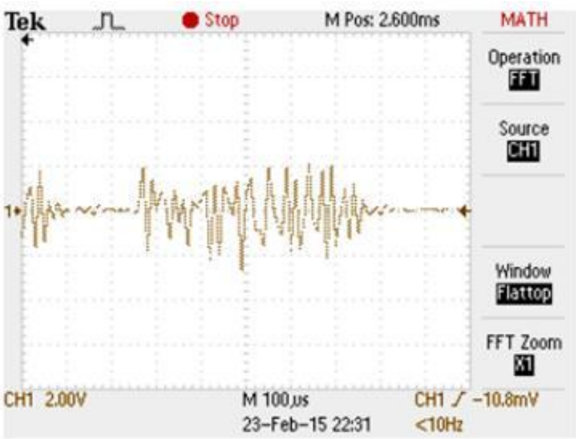


Fig.11

Fig.12

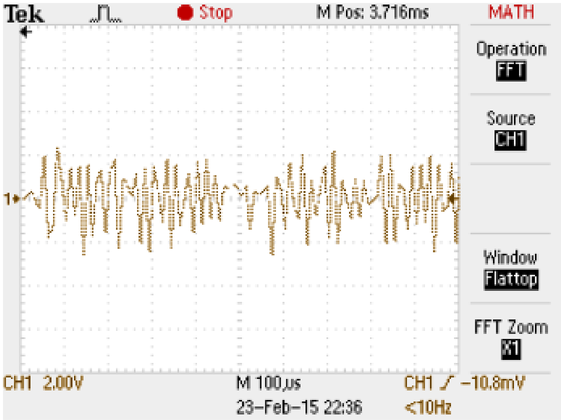


Fig.13

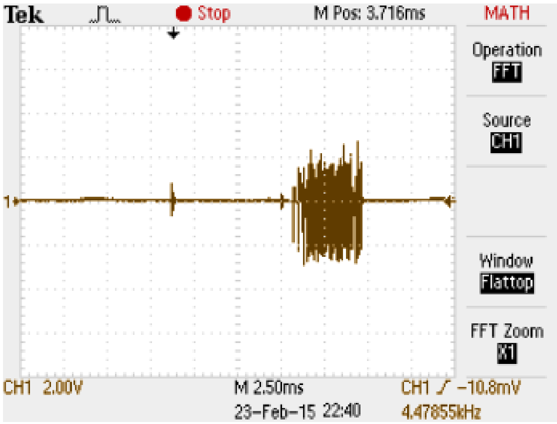


Fig.14

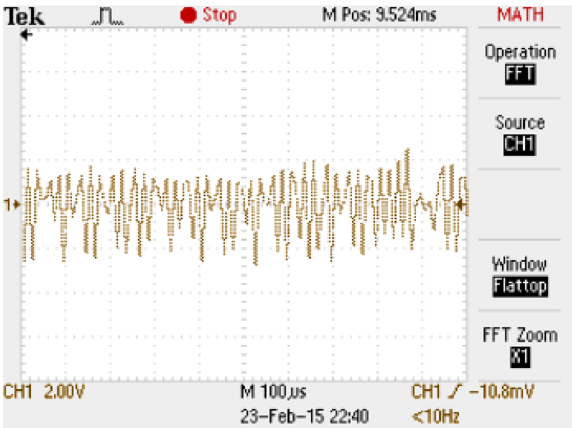


Fig. 15Magnified RPDIV for 5.07 KV

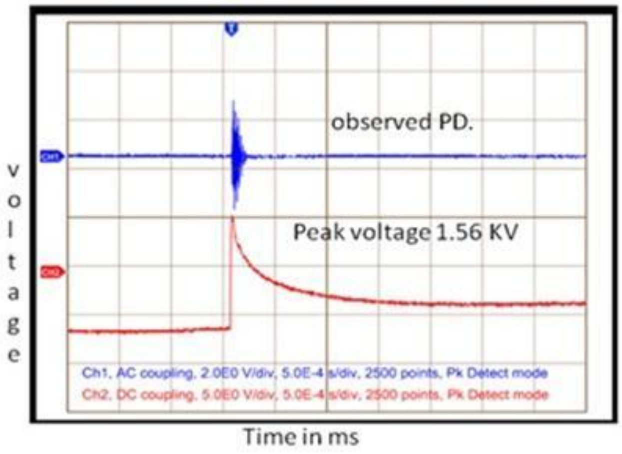
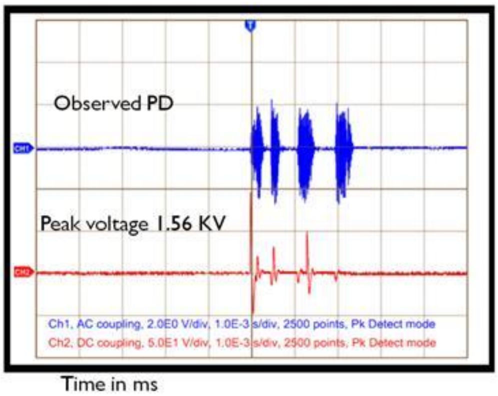


Fig.16 PD measured with out rotor for 1.56KV peak



Rise time - 3 micro sec (time taken to reach 90% of peak)
Fall time - 18 micro sec (time taken to fall 50% of Peak)

Fig.17 PD measured with rotor position at 0˚

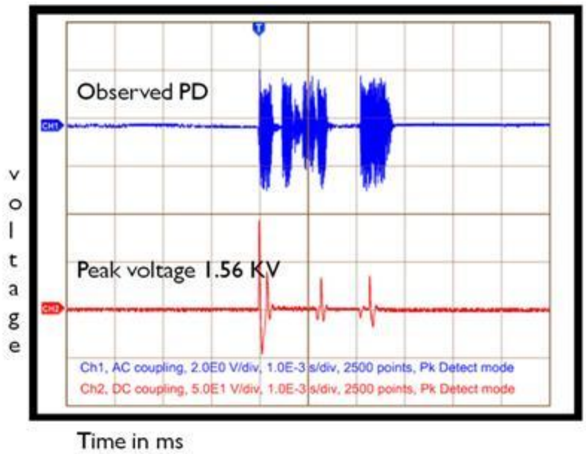


Fig.18 measured with rotor position at 90 ˚

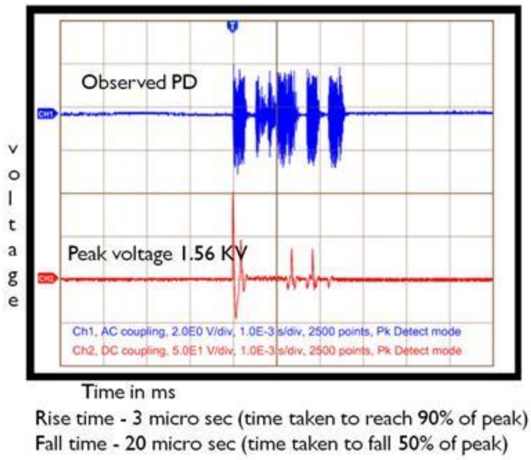
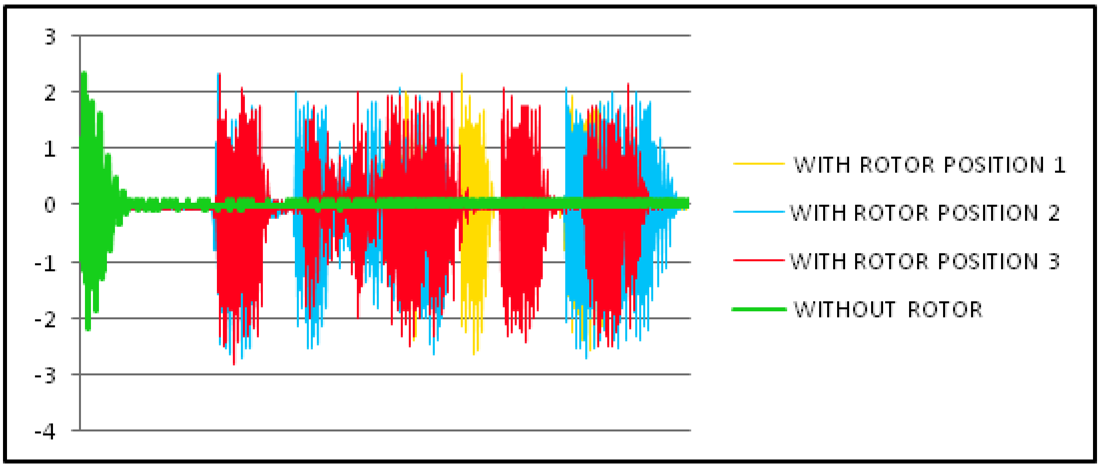


Fig.19 measured with rotor position at 180 °



Comparison of the all the PD measured on a common time scale.

CONCLUTION:

A single stage Marx impulse generator circuit was implemented to create a surge with short raise time pulses of the order of 200 ns, and the corresponding Partial Discharge pulses were measured using the direct detection method under different voltage stress categories. This measured PD shows that as the voltage stress is increased the PD occurring across the insulation also increase and if the surge voltage peak is near 5kV the RPDIV is highly concentrated that further increase will cause a break down. For voltage stresses in the range of and up to 3kV the PD measured had only slight difference but if surge voltage peaks reach a level of 4kV or above the magnitude of the PD measured was very high. Hence it is inferred that motors of type 1 insulation can be operated in power systems which may generate surge voltages of peaks less than 3kV and if operated under severe conditions where surge voltages of peaks around 4 to 5kV, premature insulation failure may occur.

It was also observed that while testing the motors for off-line PD, the magnitude and crowding of PD pulses measured without the rotor is less when compared to that measured with the rotor inserted. Hence it is clear that the PD test without the rotor will result in under qualification of the motor for operation under transient surges created by fast switching devices. To avoid under qualification of a motor to operate under surge voltage conditions the rotor was fixed at 3 different positions 0,90,180 degrees with reference to stator and PD was tested. A significant change was observed in the PD pattern proving the weakest position in which Maximum PD has occurred. By precisely fixing up the relative rotor position the weaker portion of the insulation can be approximately identified by performing the above discussed surge PD testing.

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