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Diagnosis Of Stator Winding Of Induction Machine Using Hystresis Curves Based On Maximum Partial Discharge Magnitude

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Abstract

Insulation system in rotating machines plays a vital role. Degradation of the insulation system leads to premature failure. Partial Discharge is not considered as the main cause of the failure of insulation but it is considered as the initial cause of the failure of insulation. This paper proposes a method to diagnose the condition of the insulation. A copper bar conductor with varnish impregnated cotton tape, used in large rotating machines is considered as test specimen. High Voltage in steps is applied to the specimen first in increasing order and then in decreasing order. For a particular voltage the maximum magnitude of Partial Discharge pulses was recorded. A graph relating voltage and PD magnitude was plotted and it was observed that a curve similar to hysteresis curve was obtained. An idea about the insulation condition and residual life can be predicted from the area enclosed by the up curve and down curve. A larger area can be inferred to as a bad condition of insulation which may require corrective action and a comparatively smaller area can be inferred to as good condition of insulation. PD measurement being a non destructive method can be efficiently used for insulation condition assessment of rotating machines. In this work an attempt is being made to measure the PD occurring in an insulated copper bar specimen. The experiment was repeated with simulated faults in the insulation and hysteresis curves were plotted. It was observed that area enclosed by the curves was different for good specimen from that of a fault simulated specimen.

Index Terms — Hysteresis curve, Partial Discharge (PD), rotating machine insulation

I. INTRODUCTION

Insulation system in rotating machines plays a vital role[1,7]. Degradation of the

insulation system leads to premature failure [1]. Insulation of the rotating machines is subjected to various stresses like electrical, mechanical and thermal [1,3]. The condition of the insulation system depends upon the type of stresses[1]. The applied voltage also determines the condition of the insulation. Generally the insulation system of a rotating machine is made of epoxy resin, mica. The insulation used in this experimental work is fabricated using varnished impregnated cotton tape. Cotton tape which is highly porous in nature was wound tightly over the conductor and initially tested. Due to the presence of pores the specimen invited a high leakage current and hence it was decided to impregnate the cotton tape with varnish. An attempt is being made in this work to propose a simple non destructive method which can reasonably predict the healthiness of the insulation. It requires maximum Partial Discharge magnitude for a particular voltage. Maximum Partial Discharge is recorded while the voltage is applied in increasing and decreasing order to the specimen under test.

A. PD Insulation damage

Partial Discharge occurs in the insulation of the machine due to many reasons like enclosed cavities in the insulation, imperfections in the insulation surface, enclosed foreign particles etc.,[1] A good insulation of a machine should offer a reasonably higher resistance to the P.D. During the operation, a rotating machine experiences various stresses such as electrical, mechanical and thermal. Such stresses may be continuous on rotating machines during the life time. Such stresses applied to the machine enhance the probability of PD occurrences in the insulation of a rotating machine. PD occurrence depends not only on the stresses applied, but also on the type and quality of the insulation which is used in the machine. Small capacity rotating machines are generally not checked for PD occurrences. Even the presence of a minute cavity may initiate PD. Such regular PD occurrences along with ageing due to continuous exposure of stresses will enhance the possibility of a premature failure of the machine.

II. FLOW CHART

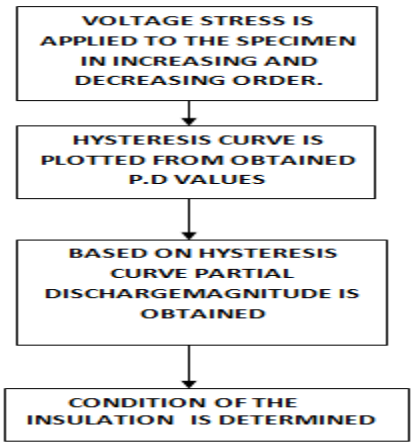


Fig.1 Test sample

Fig.2 Connection in laboratory

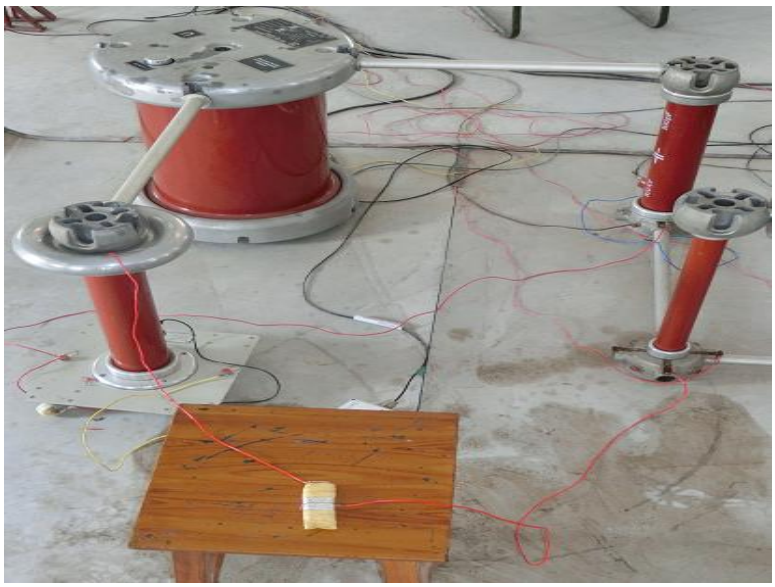
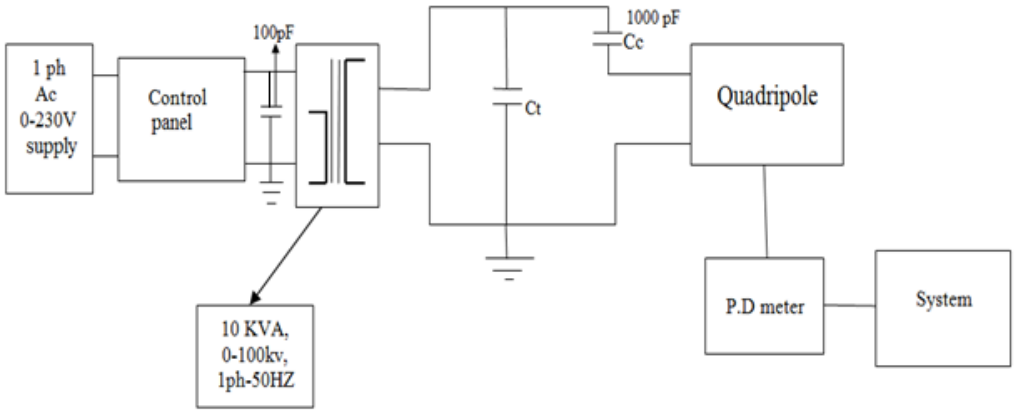


Fig.3 Laboratory setup

III. Experimental setup



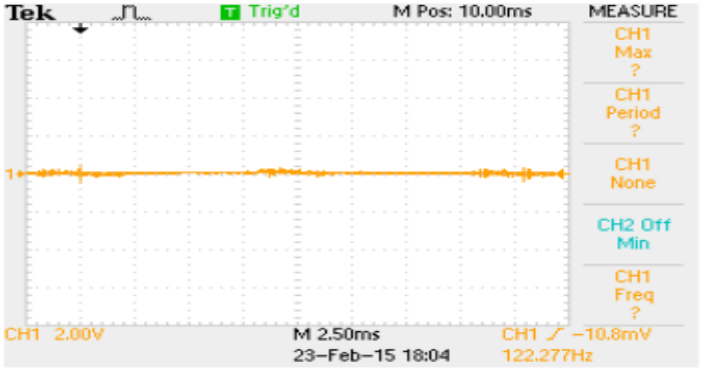
Where, Cc-Coupling capacitor, Ct-Test object

Copper bar wound with cotton tape was used as test specimen. Cotton tape inherently is porous in nature. Initially approximately eight turns of a cotton tape was wounded on the copper bar. When tested due to high content of pores it invited a huge leakage current. Hence cotton tape was impregnated with insulating varnish and dried for one day. A conducting aluminum foil is wound over the cotton tape to be connected to ground. Copper bar was connected to HV electrode and aluminum foil was connected to ground so that applied voltage falls across the insulation. Four different samples with simulated faults were made. The healthiness of the insulation can be checked by applying high voltage across the insulation and measuring the PD magnitude. From the control panel the voltage was applied to the test transformer and from the test transformer the voltage was applied to the test specimen. Initially the Discharge Inception Voltage DIV was noted for the healthy specimen. Then voltage applied was increased in steps and each time the maximum peak value of PD was measured. This process was continued till the PD data in PD meter exceeded out of range limit.

As depicted in the flowchart, the test procedure was repeated for all the four samples. Voltage was applied to the test specimen first in increasing and then in decreasing order. The maximum P.D magnitude was recorded for the different voltages. For the different samples DIV was noted. It was observed that for a healthy specimen without any simulated fault, the DIV starts usually at 3kV. The obtained readings were plotted with voltage in x axis and PD in y axis. Two curves were obtained one for increasing voltage and another for decreasing voltage [1].

IV. Experimental Results

For good specimen



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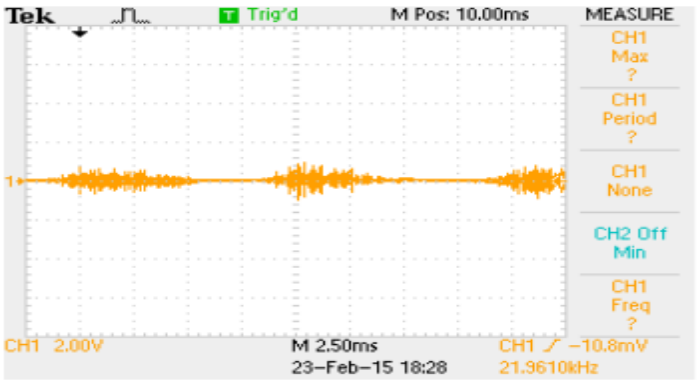
P.D recorded at 3.9kv

Fig.4



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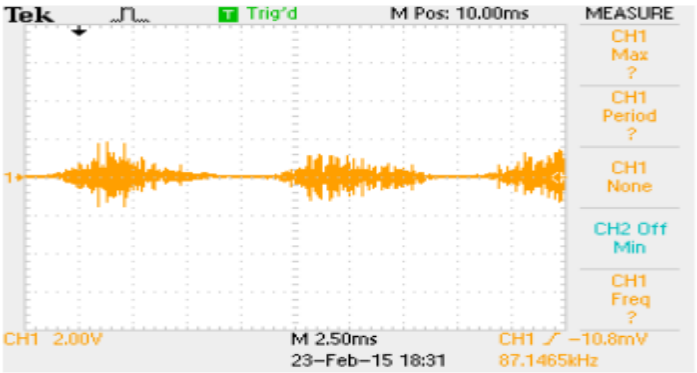
P.D recorded at 6.92 kv

Fig.5



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P.D recorded at 10kv

Fig.6

Above results were tabulated as obtained from the P.D meter[2]. P.D first occurred for good specimen at 3.9kV. Then the P.D recorded at 6.92kV, where the Partial Discharge magnitude was high when compared to result obtained at 3.9kV. For each voltage applied to the specimen the maximum Partial Discharge magnitude was recorded in Pico Coulombs. In PD meter the range was set at 50 pC. Voltage was increased up to 10kV, above which the PD magnitude went out of range. PD patterns observed from meter showed significant difference for different defects[6].The results obtained at 10kV showed dense crowded PD compared to previous readings.

Tabulation for good specimen

s.no	Voltage (kV)	Maximum P.D magnitude(pC)	
		Increasing order	Decreasing order
1	3.59	48.3	40
2	4.63	80.3	69.2
3	5.43	101.2	92.4
4	6.92	137.6	118.7
5	7.73	150	136.8
6	8.43	166	152
7	9.28	191	186
8	10	Out of range	Out of range

Tabulation for thermal aged specimen

s.no	Voltage (kV)	Maximum P.D magnitude(pC)	
		Increasing order	Decreasing order
1	2.34	7.2	6.8
2	2.6	8.6	8.2
3	3.12	15.2	13.3
4	3.79	63.5	42.7
5	4.67	105	83.4
6	5.36	Out of range	Out of range

Tabulation for void specimen

s.no	Voltage (kV)	Maximum P.D magnitude(pC)	
		Increasing order	Decreasing order
1	1.8	12	12
2	2.2	22	27
3	2.78	72	98
4	3.36	102	122
5	4.29	162	179
6	4.6	182	182
7	5	Out of range	Out of range

Tabulation for surface glaze off specimen

s.no	Voltage (kV)	Maximum P.D magnitude(pC)	
		Increasing order	Decreasing order
1	1.5	4	4
2	1.8	9.3	7.9
3	2.2	24	20
4	2.79	83	70
5	3.38	145	123
6	4	180	180
7	4.43	Out of range	Out of range

Output graph:

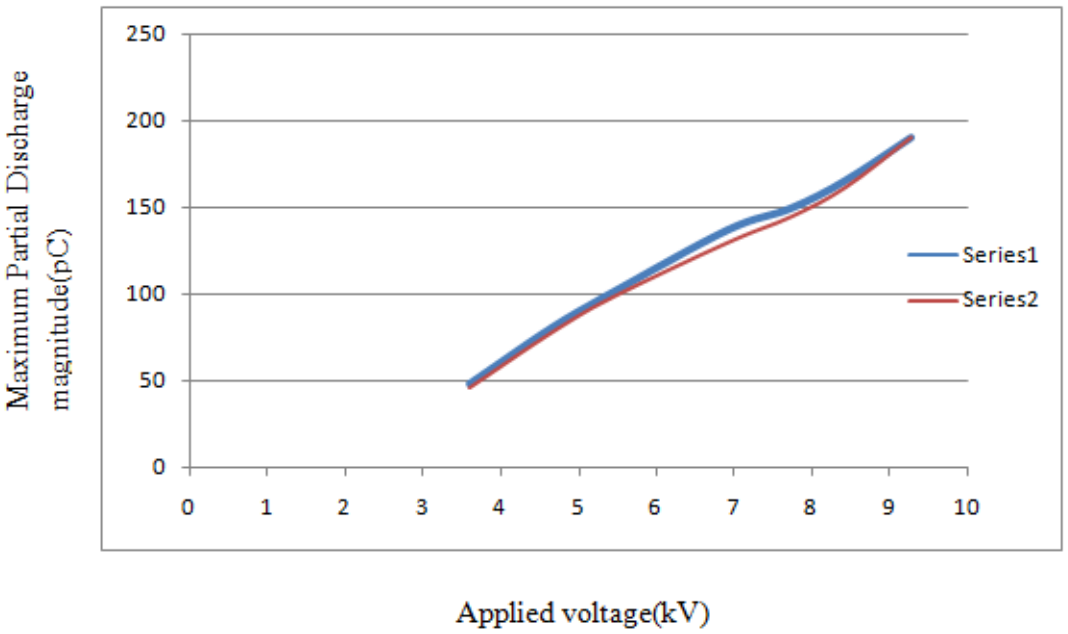

Fig.7 for good specimen

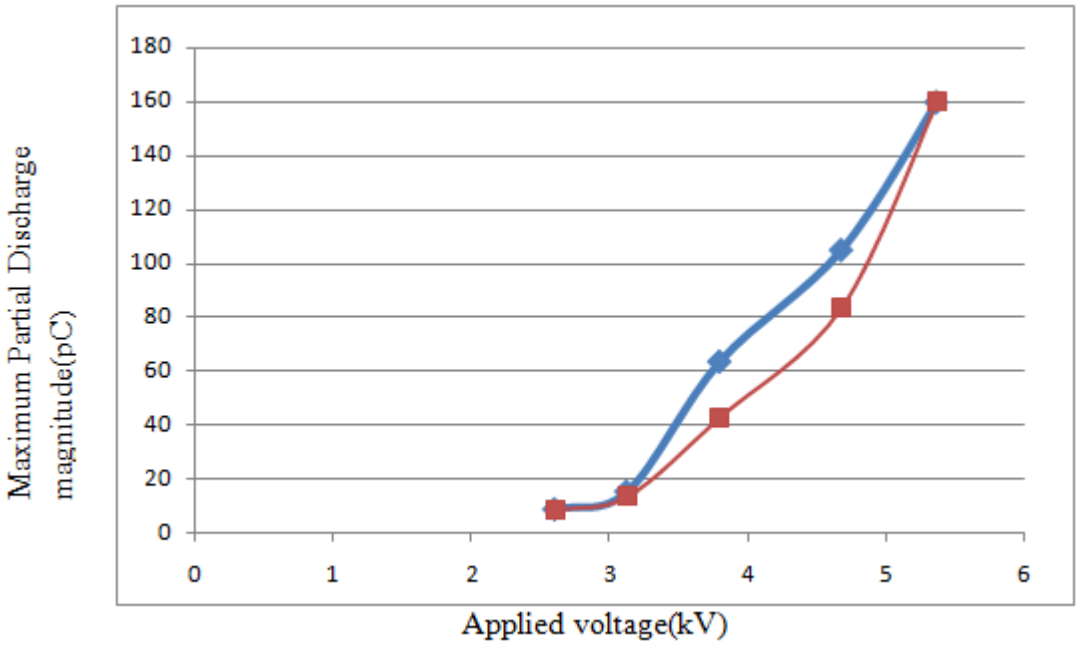

Fig.8 thermal aged specimen

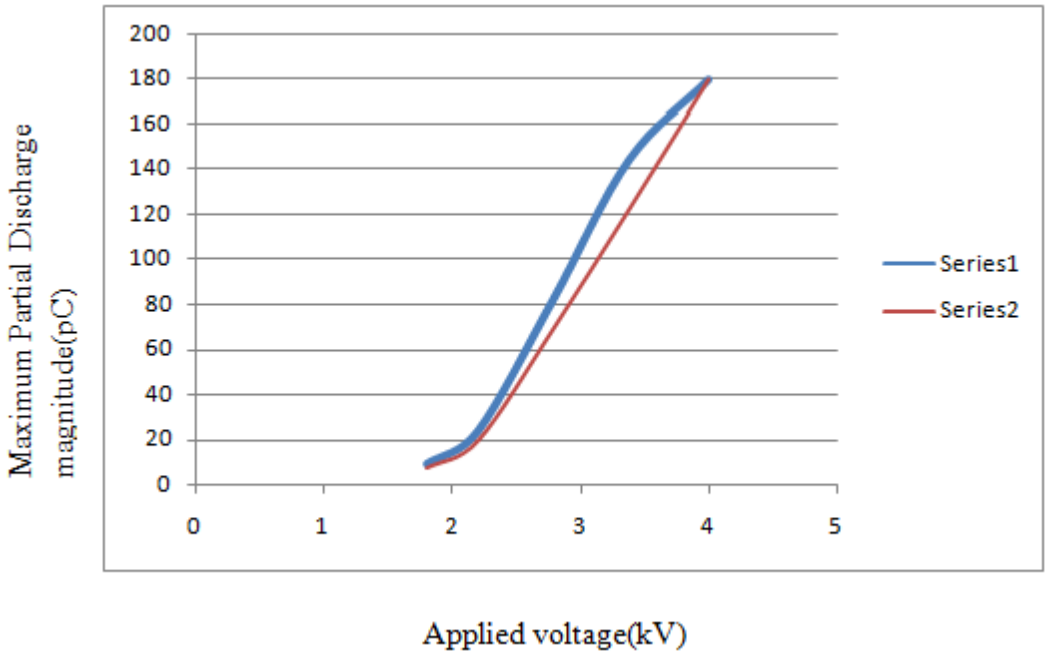

Fig.9 Void specimen

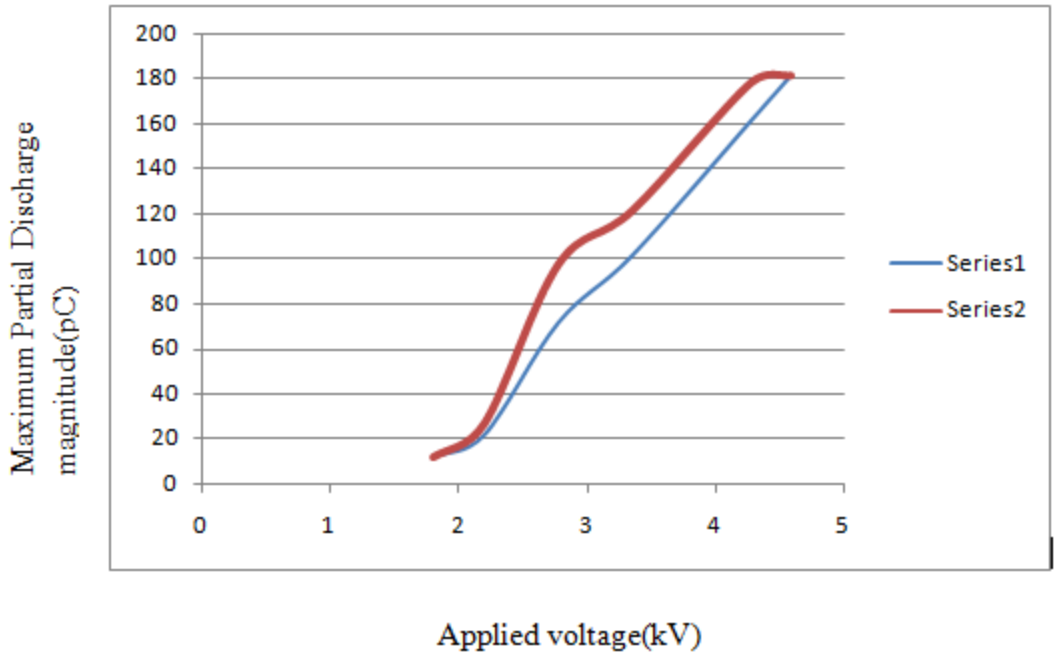

Fig.10 for surface glaze off specimen

From the plotted graph it was observed that area between the up curve and down curve was found to be comparatively small for the healthy specimen[1]. Partial Discharge is a statistical phenomenon, so the curve obtained while the voltage is decreasing may go upward than the curve obtained while increasing the voltage, there is no usual behavior in this case[5]. The gap between two curves decides the quality of insulation. It is also clear that specimen which is stressed more shows more discharges than the healthy one. Experimental arrangement and measurement is comparatively easier in this method. This method is applied to the model copper bar specimen.

IV. CONCLUSION

Tests have been performed on good specimen without any simulated faults, and on specimens with simulated faults such as thermal ageing, a void in the insulation, fault due to surface glazing. All the three faulted specimens on test showed larger areas in hysteresis curves developed compared to good specimen. But the areas were found to be different for different faults. If the area between two curves is large then the condition of the insulation of the bar is in bad state, Whereas if the area between two curves is small then the condition of the insulation is in good state. This method can be applied for rotating machine stators and the healthiness of insulation and its residual life can be reasonably predicted.

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