The Journal of CPRI,
Vol. 13, No. 1, March 2017 pp. 25-30

zPulse characteristics and pattern analysis of corona discharges with different pressboard insulation barriers

Muhammed Faisal Rahman*, Nageshwar Rao B** and Pradeep M Nirgude***

Corona discharge is one of the significant problem associated with power transformer and can occur due to sharp points or free conductive particles. The existence of sharp points at joints or terminals or conducting parts is very difficult to avoid completely during the manufacturing process of the transformer. The free conductive particles can arise from manufacturing process or can be developed during service period of the transformer. These free conductive particles can adhere to paper or pressboard insulation barrier or freely move in the bulk oil. In transformers highly non uniform fields are often present due to sharp points and free conducting particles, so detecting their effect on the transformer is very critical for the life of transformer. In the present investigation, to generate a high voltage corona in air or oil, a test chamber of dimension 50cm x 50cm x 50cm made from Perspex material and fitted with removable needle plane electrode arrangement has been used. The discharge measurements are carried out using Partial Discharge (PD) measurement technique according to IEC 60270. The results obtained are presented and discussed. Discharge pulse characteristics such as magnitude, rise time and decay time of different needle plane barrier configurations are analyzed. This paper also discussing pattern analysis and dominant frequency of discharges due to different needle plane barrier configurations.

Keywords: *Corona in air, oil, pressboard barrier, partial discharge, pulse characteristics, pattern analysis.*

1.0 INTRODUCTION

Power transformer is the most vital and expensive component in a power system network. Catastrophic failures of transformers can occur without warning, resulting in serious oil spills, fires, extensive damage to adjacent equipment, and major disruption of service. The cost of failures can easily drive the total cost of a single transformer failure into the hundreds of millions of rupees [1]. The reliability and life of oil filled transformers relies basically on operating condition and by proper insulation design [2, 3].

Corona discharge is one of the significant problem associated with transformer and can occur due to sharp points or free conductive particles. During design and testing of transformers, one of the most important problems is discharge developed from a weak link, example edge of the winding or due to protrusion from the winding conductor causing corona etc. [4].

The transformer insulation is a combination of oil impregnated pressboard material and the transformer oil. The oil impregnated pressboard barriers placed between the current carrying

*Senior Research Fellow, Cables and Diagnostics Division, Central Power Research Institute, Bangalore, India
**Additional Director, Cables and Diagnostics Division, Central Power Research Institute, Bangalore, India
***Joint Director, Ultra High Voltage Research Laboratory, Central Power Research Institute, Hyderabad, India

conductor and the ground to increase the electric strength of the medium [5-7].

G.C Stone discussed, Partial Discharge (PD) measurement has long been used as a test to evaluate different insulation system designs, and as a quality control test for new equipment.[8].

In the present investigation, a study has been carried out, to understand the barrier effect by generating a high voltage corona in air or oil and insulation barrier interposed between the electrodes. The PD measurement were carried out according to IEC 60270 standard procedure, discharge inception voltage characteristics were studied for different thickness of barrier. The discharge pulse characteristics, pattern and dominant frequency were analysed.

2.0 EXPERIMENTAL ARRANGEMENT

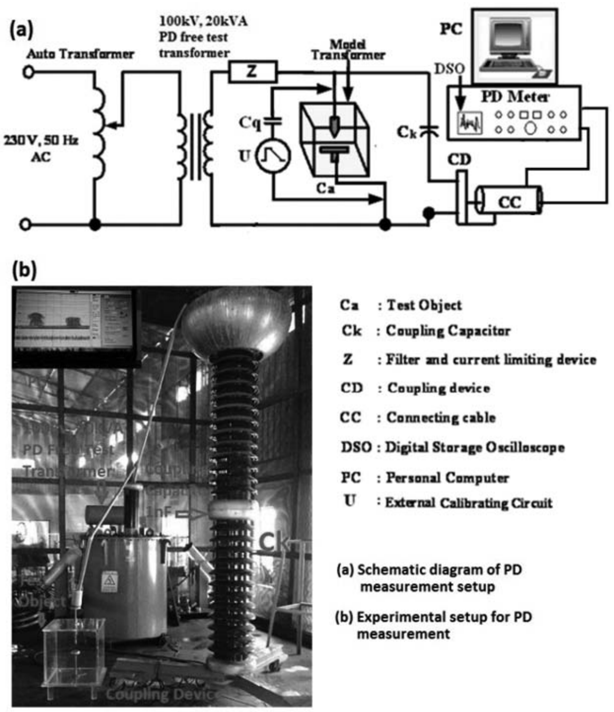


FIG. 1: PD MEASURING CIRCUIT (IEC 60270).

The experimental arrangement for investigation of corona discharge in air or transformer oil with pressboard barrier, under AC voltages, is shown in Figure 1 and were divided in to three parts viz., the AC high voltage source with coupling capacitor or standard capacitive voltage divider, test cell for corona generation in air or transformer oil and the partial discharge detection unit.

2.1 High Voltage AC Source with Coupling Capacitor.

A 100 kV, 20 kVA, 50 Hz test transformer is used for generating AC high voltage. The voltage was increased to the required level, at a rate of 0.5 kV/s. The coupling capacitor having 1000 pF is also used as a standard capacitance voltage divider for measuring voltages. The used AC source and coupling capacitor have only less than 2 pC background noise. Figure 1 shows the schematic and experimental setup of PD measuring circuit.

2.2. Test Cell for Corona Generation

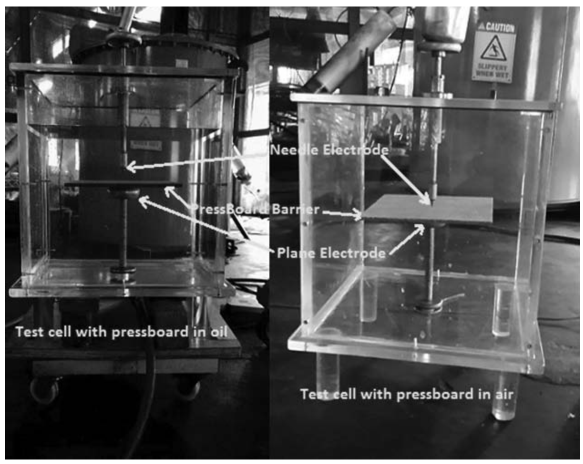


FIG. 2: TEST CELL WITH NEEDLE-PLANE ELECTRODE.

For corona generation, a test chamber of dimension 50 cm x 50 cm x 50 cm made from Perspex material and fitted with removable needle plane electrode arrangement has been used. The distance between the needle plane electrodes can be adjusted using moving seal arrangement and it can vary from 0 to 300 mm. The materials used for needle electrodes are steel and carbon. The needle electrode diameters are approximately 280 μm for steel and 220 μm for carbon. Different plane electrode of diameter 50 mm and 90mm respectively are used as ground electrode. Barrier insulation is oil impregnated pressboard insulation. Pressboard having different thickness of 1 mm, 2 mm, 4 mm and 8 mm are used to study the barrier effect on corona discharge. In this present study barrier is always keeping on bottom plane electrode (ground potential) and needle electrode (HV potential) varying from top of the barrier from 0 to 90 mm. The photograph of the test cell is shown in Figure 2.

2.3 Partial Discharge Detection Unit

The partial discharge analysis was carried out by using Omicron MPD600 PD detector. The circuit was calibrated by using PD calibrator CAL542.

3.0 RESULTS AND DISCUSSION

3.1 Corona Discharges in Air with Barrier

Figure 3(a) shows typical position of Needle-plane electrode with pressboard barrier during corona. Figure 3(b) shows variation in Corona Inception Voltage (CIV) of the Needle-plane gap with different thickness of pressboard barrier in air, under AC voltages. In the present investigation, the corona inception voltages was measured based on IEC60270. It is observed that, generally the corona inception voltage is higher with barrier than thecorona inception without barrier (clean electrode gap). Also the corona inception voltage is high when the barrier thickness is small compared to larger thickness and barrier placed on the plane electrode in a needle-plane electrode gap at which condition the needle electrode is10mm or above from top of the barrier.

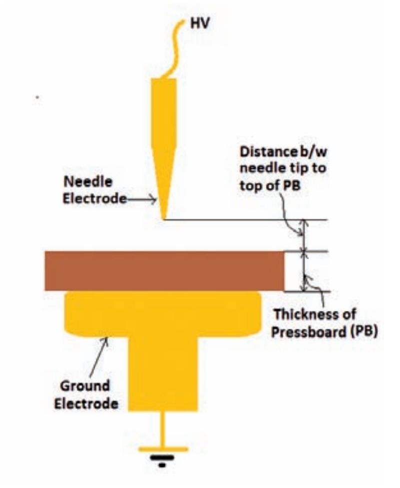
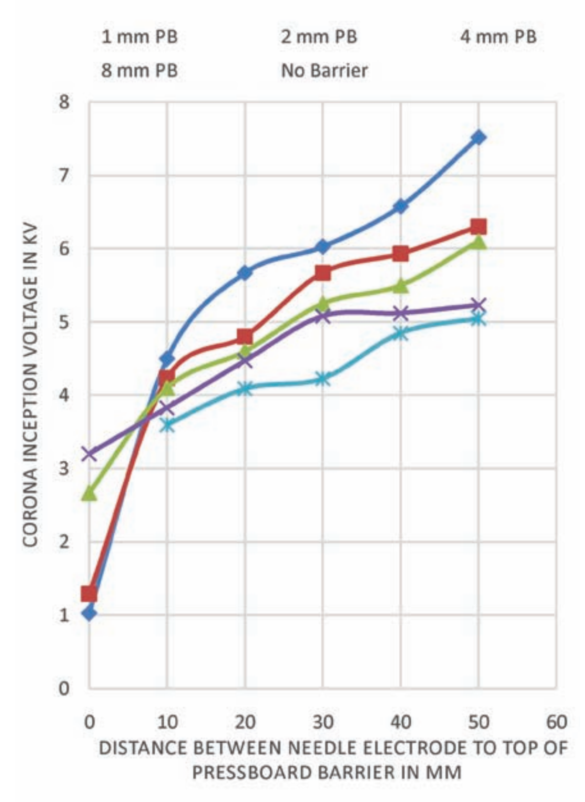


FIG. 3(A): TYPICAL POSITION OF NEEDLE-PLANE

when the barrier thickness is small compared to larger thickness and barrier placed on the plane electrode in a needle-plane electrode gap at which condition the needle electrode is10mm or above from top of the barrier.



3.2 Analysis of Discharge Pulse Characteristics

Figure 4 is the corona generated signal measured by IEC 60270 methods. It is observed that discharge signal of high and low magnitudes are formed during corona discharge process.

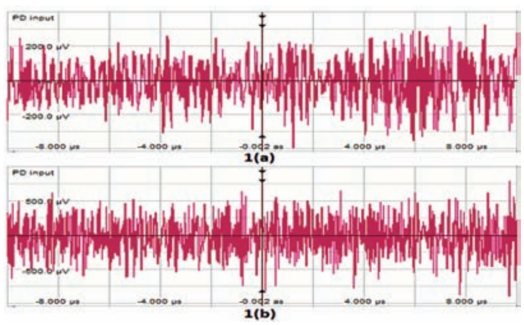


FIG. 4: TYPICAL DISCHARGE SIGNAL DUE TO CORONA WITH PRESSBOARD BARRIER IN AIR MEASURED BY IEC 60270, 1(A) AT CIV, 1(B) ABOVE CIV.

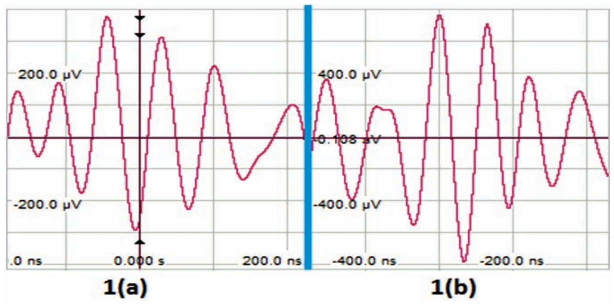


FIG. 5: TYPICAL DISCHARGE PULSE DUE TO CORONA WITH PB BARRIER, 1(A) AT CIV, 1(B) ABOVE CIV.

Figure 5 shows typical discharge pulse generated due to corona discharge with barrier in the electrode gap under AC voltage. The corona discharge pulse characteristics such as rise time (t_R), decay time (t_D) and peak magnitude ($|M_P|$) are calculated. The rise time defined as the time to rise from 10 to 90% of its peak magnitude. The decay time is the time taken for the peak magnitude of a pulse to decrease from 90% of the peak to 50% of the maximum value. Table 1 shows the pulse characteristics of discharges due to corona under 1mm, 2 mm, 4 mm and 8 mm thick pressboard (PB) barrier at 0, 10 mm, 20 mm, 30 mm, 40 mm and 50 mm gap between needle electrode and top of the barrier. 2 mm, 4 mm and 8 mm thick pressboard (PB) barrier at 0, 10 mm, 20 mm, 30 mm, 40 mm and 50 mm gap between needle electrode and top of the barrier.

TABLE 1

OBSERVED VALUES OF CORONA DISCHARGE PATTERN WITH PB BARRIER IN A NEEDLE PLANE ELECTRODE.

PB in mm	GD in mm	V_{rms} in kV	Phase (φ), deg.	Q in pC		N in kPDs/s
				Q_A	Q_P	
1	0	1.41	53-125,228-308	131.4	230.4	61.73
	10	4.50	65-114,242-300	1750	2452	64.47
	20	5.67	59-124,230-314	177.6	808.7	62.94
	30	6.97	50-131,224-318	130.1	199.5	63.88
	40	9.57	35-142,212-325	192.4	542	61.76
	50	12.76	25-30,203-331	70.31	315.5	54.14
2	0	2.25	217-307	167.5	353.4	63.22
	10	4.24	64-118,246-293	1395	2203	64.24
	20	6.72	46-136,228-315	291.4	416.7	62.12
	30	9.59	137-148,214-326	155.2	276.9	63.27
	40	12.75	149-152,206-332	192.6	272.7	68.54
	50	13.39	139-149,205-330	148	215	61.73
4	0	2.67	67-82,232-280	262	344.3	63.29
	10	4.10	68-109,246-290	1714	2162	64.68
	20	7.94	35-145,218-321	314	445.1	66.40
	30	8.10	117-138,223-318	105	280.2	62.36
	40	13.15	148-150,205-332	83.13	203.7	62.34
	50	14.90	201-333	82.61	104.2	59.67
8	0	3.25	76-99,233-302	471.7	1716	64.38
	10	5.05	53-132,232-311	2414	3722	64.08
	20	6.66	48-136,227-317	1030	1763	64.10
	30	7.19	51-132,227-316	153.1	276.4	62.74
	40	12.90	145-152,204-334	153.3	214	68.53
	50	16.96	198-338	128.8	177.6	54.44

3.3 Analysis Corona Discharge Pattern and Frequency

Figure 6 shows typical discharge pattern due to corona with pressboard barrier in the electrode gap under AC voltage. The gap maintained between needle electrode to top of th pressboard is 10mm. It is observed that CIV lowered with incraesing thickness of pressboard at 10mm or above gap between needle electrode to top of the pressboard. Table 2 shows the discharge pattern values such as phase (φ), discharge magnitude (Q) and number of discharges (N) for a given applied voltage (V_{rms}).

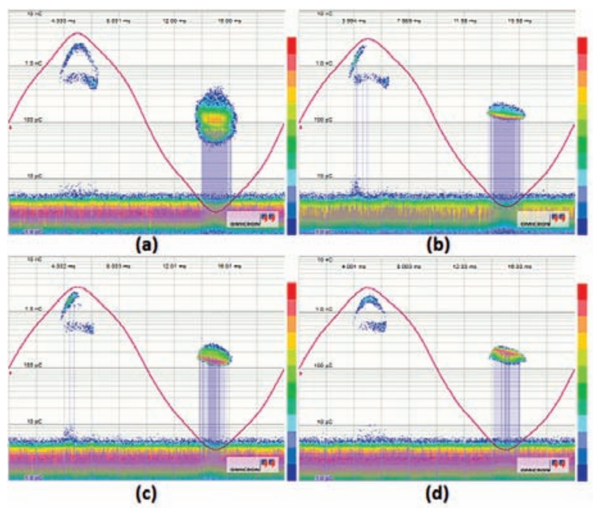


FIG 6: TYPICAL DISCHARGE PATTERN DUE TO CORONA (A) 1MM PB AT 4.50KV, (B) 2MM PB AT 4.24KV, (C) 4MM PB AT 4.10KV (D), 8MM PB AT 4.08KV.

Figure 7 (b) shows typical FFT analysis of discharge signal due to corona with pressboard barrier and histogram of frequency spectrum. The dominant frequency of discharge signal is about 9-10.5 MHz.

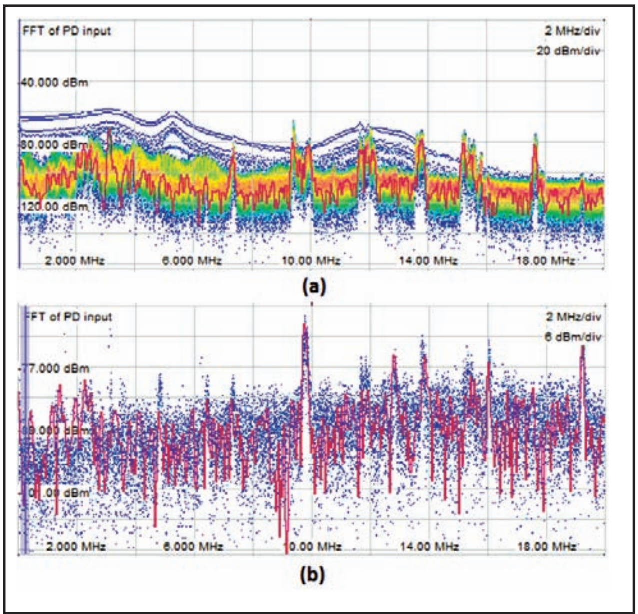


FIG. 7 (B) SHOWS TYPICAL FFT ANALYSIS OF DISCHARGE SIGNAL DUE TO CORONA WITH PRESSBOARD BARRIER AND HISTOGRAM OF FREQUENCY SPECTRUM. THE DOMINANT FREQUENCY OF DISCHARGE SIGNAL IS ABOUT 9-10.5 MHZ.

3.4 Corona Discharges in Oil with Barrier

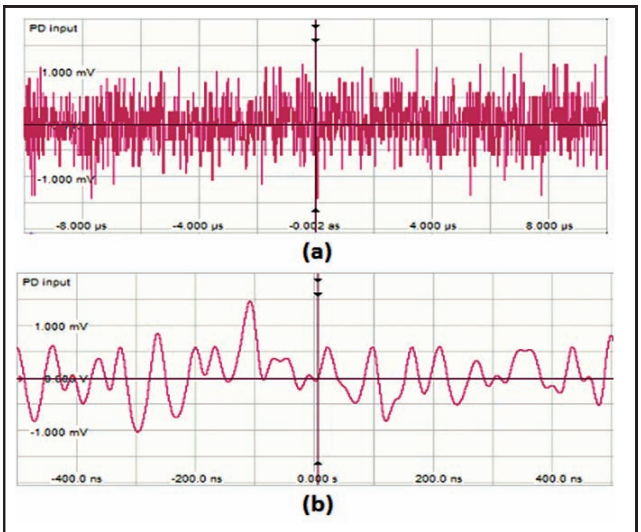


FIG 8: (A) TYPICAL DISCHARGE SIGNAL DUE TO CORONA WITH PRESSBOARD BARRIER IN OIL MEASURED BY IEC 60270, (B) DISCHARGE PULSE.

Figure 8(a) shows typical discharge signal due to corona with barrier in oil measured by IEC 60270. It is observed that discharge signal of high and low magnitudes are formed during corona discharge process.

Sahitya *et al* explained the heat generated due tocorona at the tip of high voltage electrode vaporises the liquid and forms vacuum bubble[9].

TABLE 2
CORONA DISCHARGE PULSE CHARACTERISTICS, PBT:-PRESSBOARD THICKNESS, GD:-GAP DISTANCE BETWEEN NEEDLE ELECTRODE AND TOP OF THE BARRIER

PBT in mm	GD in mm	Discharge pulse characteristics					
		At CIV			Above CIV		
		t_R in ns	t_D in ns	$\|M_P\|$ in µV	t_R in ns	t_D in ns	$\|M_P\|$ in µV
1	0	22	104	370	18	110	750
	10	14	96	900	12	104	1200
	20	15	80	850	12	90	1260
	30	20	100	320	18	108	1400
	40	20	108	600	16	100	1100
	50	16	102	500	14	94	800
2	0	24	84	480	18	96	870
	10	20	96	880	15	106	1200
	20	14	90	850	14	100	920
	30	18	88	750	16	102	910
	40	22	84	460	18	92	720
	50	22	88	580	20	102	690
4	0	18	92	930	16	88	1000
	10	16	92	1000	12	82	1400
	20	18	78	960	16	94	1080
	30	20	104	900	18	90	990
	40	20	110	660	20	104	930
	50	22	112	640	20	82	920
8	0	20	98	960	14	94	1200
	10	18	90	1050	13	88	1500
	20	18	94	900	20	92	1170
	30	20	92	660	18	88	910
	40	18	98	620	18	94	780
	50	24	118	220	28	124	300

4.0 CONCLUSIONS

The observation made by experimental study wes summarised:

- The corona inception voltage is higher with barrier than the corona inception without barrier in air.
- CIV is high when the barrier thickness is small compared to larger thickness and

barrier placed on the plane electrode in a needle-plane electrode gap in air (10 mm or above from top of the barrier).

ACKNOWLEDGMENTS

The authors wish to thank Mr. Thirumurthi, CPRI, Bangalore, India, for his kind support in carrying out the experimental study. Authors are grateful to CPRI Bangalore, Govt. of India, for the support of the work.

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