A STUDY OF MEMORY EFFECT OF PARTIAL DISCHARGES

YL Madhavi and MN Narayanachar

Abstract : From the computed conditional pulse amplitude and phase distributions it is shown that, as the gap spacing is reduced the charging of dielectric surface affects the corona pulse-time distribution which becomes significant at lower gap spacings. **Most** probable **values** are **found** to be the best statistical indicators for interpreting the results.

Introduction

Partial discharge (PD) phenomena which occur both in the presence and absence of solid dielectrics are inherently stochastic processes that exhibit significant statistical variability in such characteristics as pulse amplitude and phase of occurrence. The statistical behaviour of PD is governed primarily by memory effects such as associated with charge deposited by PD on the dielectric snrfacc. When ac generated PD occur near thc dielectric surface the predominant memory effect may be due to surfacc charge deposition [1-3].Much work has been done in interpreting the stochastic nature of PD phenomena. It is shown that the sum amplitude of the discharges on the positive half cyclc Q^+ affect the phase of occurrence ϕ^- of the first pulse in the negative half cycle. This is shown to be true in the case of sccontl negative pulse too. The unconditional PD amplitude and phase distributions are shown to be sensitive to relatively small physical or chemical changes occuring in the gap spacing, such as might result from interaction of the discharge with the surface. The sensitivity to non-stationary behaviour is much less evident in conditional distributions. In the present work the relative effect of the first negative pulse q_1^- on the second negative pulse q_2^- has been studied by considering their magnitude and the time separation At distributions.

Experimental arrangement and procedure

Experiments wcre performed in a controlled environment using point-planc configuration, with and without a perspex dielectric at various voltagc levels and at different gap spacings: Straight detection method of PD detection was used: The sample was placcd in a normal oven wherein standard ambient conditions were maintained following the methods given in IS : 2260-1973, Appendix A, (Clansc 3.1.1). The temperature was 27 ± 2^0C and the humidity $70 \pm 5\%$ during the course of experiments.

The high voltage 50Hz ac setup was found to be discharge free upto 10kV. Voltages of 1.05, 1.1 and 1.2 times the inception voltage were applied. The gap spacings varied from 1mm to 5 mm with perspex dielectric. Phase resolved pulse height analyser was used for measuring the amplitude and phase of the discharge pulses. Each record was taken for a time duration of 1 min and 10 such records were taken at 2 min interval. The procedure was repeated for point-planc at 5 mm spacing without the perspex dielectric.

Experimental results and analysis

In ordcr to understand the basic phenomena, it is essential to study the stochastic nature of the PD behaviour at different gap spacings and at different voltage levels. **As** very few pulses occurred at inception **voltagc** level, the experiments were condrictcd at overvoltages and data collected for a sufficient time duration so that a proper statistical analysis could be made. In the case of perspex dielectric surface there wcrc a small number of pulses in the positivc hall cycle followed by a large number of pulses in the negative half cyclc, whereas in the case of point-planc, the pulses in the positivc half cyclc wcre negligible. From the recorded distributions it was found that the magnitude and phase of occurrence of all the pulses occurring in the negative half cycle are distributed quantities. For the purpose of analysis only the distributions of the magnitude and phase of occurrence of the first and second pulses in the negative half cycle were considered. From the computed conditional amplitude and phase of occurrence distributions the correlations between successive pulses can be determined. The paramctcrs chosen in the present work arc q_1^-, q_2^- and At. From the data obtained the following conditional distributions were computcd,

$P1(q_2^-/q_1^-)$: gives the probability of occurrcrice of q_2^- given q_1^-.

$P1(\Delta t/q_1^-)$: gives the probability of occurrence of q_2^- in a time At given q_1^-.

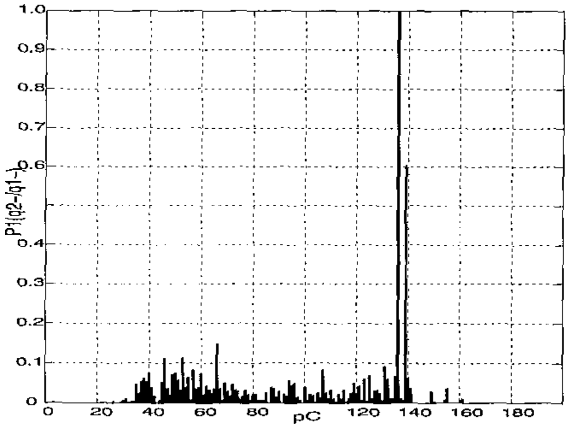

Fig. 1. $P1(q_2^-/q_1^-)$ for Point-Plane 5mm GAP, 1.1Vi

$P1(q_2^-/\Delta t)$: probability of q_2^- occurring, following a given At.

A number of distributions were computed for all the gaps and at all levels of vpltages. Typical distributions are presented in Figures 1-9. The probabilities are normalised with respect to the maximum occurring in the particular distribution. The distributions are best characterised and explained by considering only the most probable values. Figures 1-3 and Figures 4-6 show the conditional distributions $P1(q_2^-/q_1^-)$ and $P1(\Delta t/q_1^-)$ respectively, for the most probable value of q_1^-. Figures 7-9 show the conditional distributions $P1(q_2^-/\Delta t)$ for the most probable At. We get a number of distributions $P1(q_2^-/q_1^-)$ and $P1(\Delta t/q_1^-)$ for different windows of q_1^-. Similarly we obtain a number of conditional distributions $P1(q_2^-/\Delta t)$ for different windows of At. From Figures 1-6, we can pick out the most probable q_2^- and the most probable At given the most probable q_1^-. These values are given in Table-I for all the cases. From the distributions shown in Figures 7-9 one can find the most proabable q_2^- for the most probable q_2^-. The product of $P1_{max}(q_2^-/\Delta t)$ and $P(\Delta t)$ is a joint probability which indicates the probability of the most probable q_2^- occurring in a particular window At where, $P(\Delta t)$ is the unconditional distribution. Such joint probabilities were worked out for all the gaps and at all voltage levels. Table-I1 gives a typical case where joint probabilities are given for gap spacings of 1 mm and 5 mm with perspex dielectric and for 5 mm without dielectric at the same voltage level(1.1Vi). Table-I11 gives only the maximum of the joint probabilities and the respective window At. Note that **At** of μ s corresponds to 3.14 x 10^{-4} rad.

Discussion

Interpretation of the results obtained from the analysis forms an important part of this discussion. From Figures 1-6 it can be seen that; following a most probable discharge q_1^-, there is a most probable q_2^- and

TABLE I

V_{5pl}=3.92KV , V_5=3.69KV , V_4=4.12KV , V_3=3.32KV , V_2=3.84KV , V_1=2.55KV

gap mm	q_1^- pC	q_2^- pC	Δt μs
5, pt-plane			
1.05 V_{5pl}	65	70	80
1.1V_{5pl}	135	140	80
5, pt-pspx			
1.05 V_5	115	110	160
1.1V_5	165	175	80
1.2 V_5	165	170	80
4, pt-pspx			
1.05 V_4	95	90	160
1.1 V_4	115	120	120
1.2 V_4	115	120	80
3, pt-pspx			
1.05 V_3	115	120	160
1.1V_3	115	120	120
1.2 V_3	105	110	120
2, pt-pspx			
1.05 V_2	125	130	120
1.1 V_2	125	130	120
1.2 V_2	125	130	120
1, pt-pspx			
1.05 V_1	135	130	440
1.1 V_1	115	130	320
1.2 V_1	125	130	440

TABLE II

gap ,mm →	1 pcrspex	5	5 pt-plane
joint probability x10^{-2} ↓	0.33	2.1	2.5
	1.4	1.8	1.3
	3.1	0.43	0.72
	3.6	0.25	0.4
	2.6	0.17	0.55
	1.3	0.24	0.4
	0.37	0.18	
	0.13	0.33	
	0.01	0.23	
	0.073	0.28	0.15
	0.056	0.16	0.076
	0.04	0.14	[illegible]

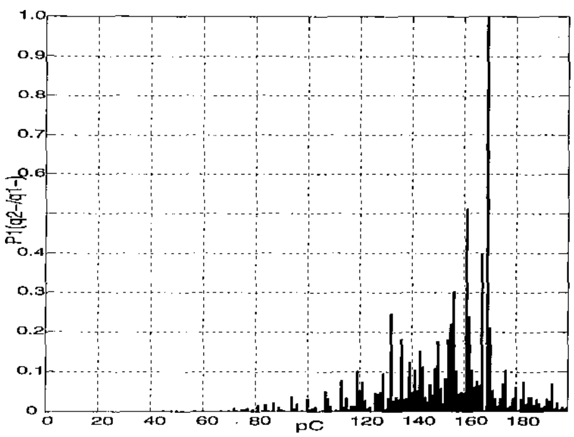

Fig. 2. $P1(q_2^-/q_1^-)$ for Point-Perspex 5mm GAP, 1.1Vi

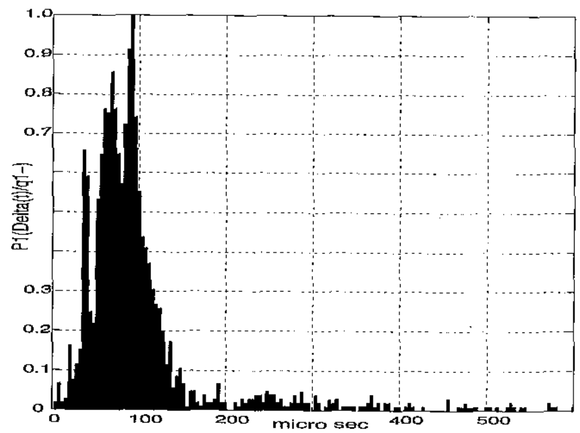

Fig. 5. $P1(\Delta t/q_1^-)$ for Point-Perspex 5mm GAP, 1.1Vi

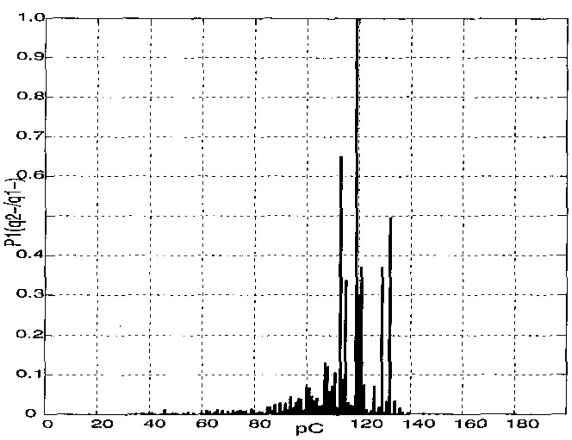

Fig. 3. $P1(q_2^-/q_1^-)$ for Point-Perspex 1mm GAP, 1.1Vi

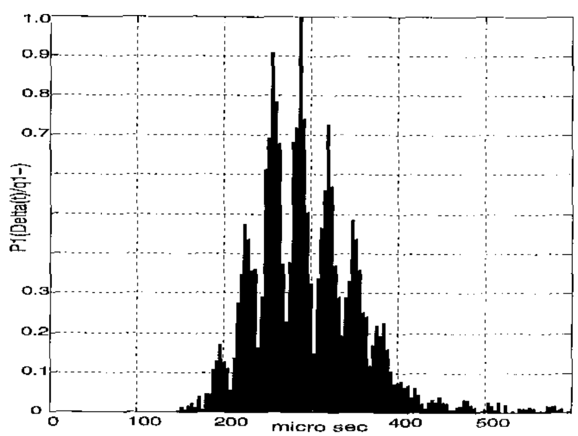

Fig. 6. $P1(\Delta t/q_1^-)$ for Point-Perspcx 1mm GAP, 1.1Vi

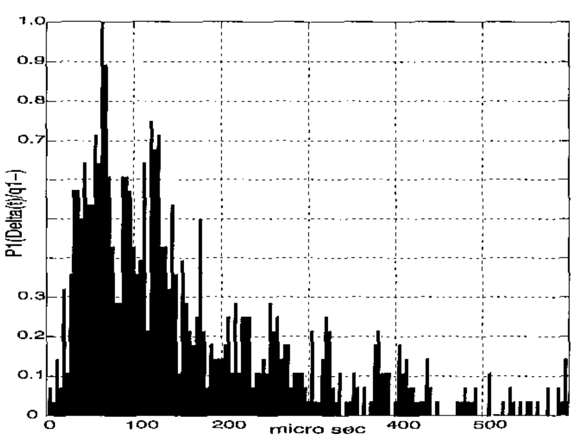

Fig. 4. $P1(\Delta t/q_1^-)$ **for** Point-Plane 5mm GAP, 1.1Vi

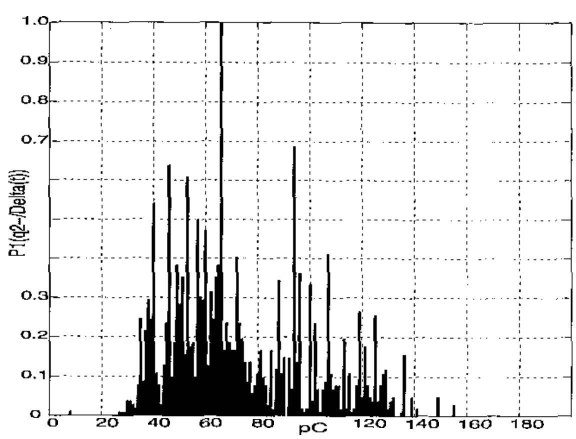

Fig. 7. $P1(q_2^-/\Delta t)$ for Point-Plane 5mm GAP, 1.1Vi

TABLE III

	bili	window μs
1		400-440
		80-120
		160-200
		120-160
		50-120
		40-50
		280-320
2	1.5	120-160
3	4.9	120-160
4	2.3	80-120
5	2.1	40-50
5pt-pl	2.5	40-50
1.2 V_i,		
1	4.6	160-200
2	1.2	120-160
3	**3.1**	80-120
4	2.1	40-50
5	2.2	40-50

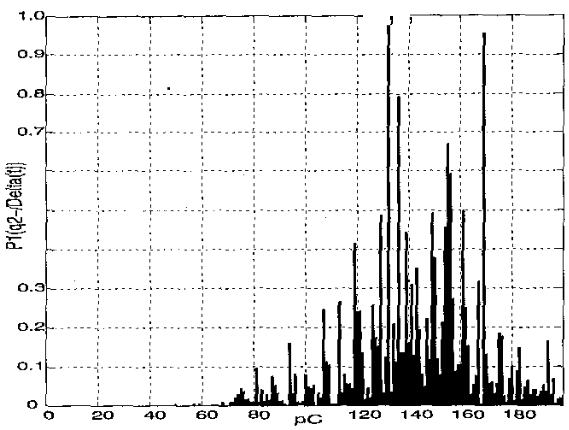

Fig. 8. $P1(q_2^- /\Delta t)$ **for** Point-Perspex 5mm **GAP,** 1.1Vi

a most probable At. However the most probable q_2^- need not always follow the most probable At. But if one works out a joint probability, one can find out the most probable q_2^- and At, following q_1^-. This is when the joint probability $P1(q_2^- / At)$ x $P(\Delta t)$ is a maximum. This value is 3.6×10^{-2} for 1mm gap (Table-11). It can be seen from Table-I1 that,

1. the time lag increases with decrease in the gap spacing at all voltage levels. This reflects the increasing effect of spacing on the gap characteristic s that might occur due to the interaction of the discharges on the surface of the dielectric.
2. the overstressing of the gap tends to decrease the time lag in the range 1 to 3 mm of the gap spacing.

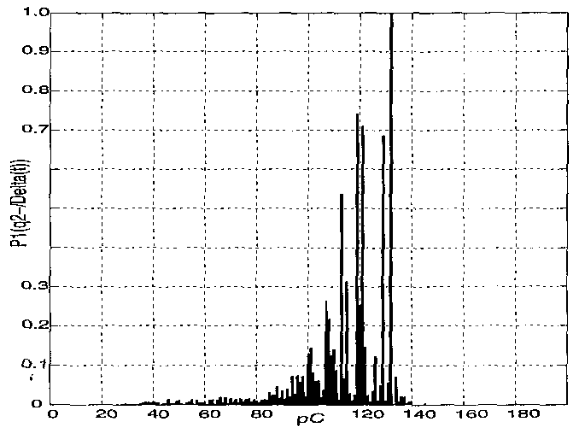

Fig. **9.** $P1(q_2^- /\Delta t)$ for Point-Perspex 1mm GAP, 1.1Vi

At higher spacing **(4** and 5 mm) the effect is not pronounced which fairly reflects the ineffectiveness of the dielectric surface at higher spacings.

From Table-I we can infer that,

1. the most probablc q_1^- increases with decrease in gap spacing.
2. there is positive correlation between q_2^- and q_1^-.
3. the value of At increases with decrease in gap spacing.
4. the time lags seem to stabilize to thier characteristic values for lower gap spacings even at overvoltages.

Conclusions

It is shown that the effect of dielectric on the recurrence of corona pulses can be studied by considering the conditional distributions of the first two pulses in the negative half cycle and the time difference between them. The analyses of the parameters show the effect of the previous discharges on the following events.

References

1. R.J.Van Brunt, E.W.Cernyar, P.Von Glahn, "*Importance **of** Unravelling Memory Propagation Effects in Interpreting Data* on *Partial Discharge Statistics*" , IEEE transactions on Elec.Insul., Vol.28, pp.905-916, 1993.

2. R.J.Van Brunt, M.Misakian, S.V.Kulkarni, V.K.Lakadawala, *"Influence **of** a Dielectric Barrier* on *the Stochastic Behavior **of** Trichel-pulse Corona"*, IEEE transactions on Elec.Insul., Vol.26, pp.405-415, 1991.

3. P.Von Glahn and R.J.Van Brunt, *"Continuous Recording and Stochastic Analysis **of** PD"*, IEEE transactions on Dielectrics and Elec.Insul., Vol.2, No.4, pp.590-601, 1995.