

PARTIAL DISCHARGE PULSE SEQUENCE ANALYSES - A NEW REPRESENTATION OF PARTIAL DISCHARGE DATA

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Abstract:

Computer-based Partial Discharge (PD) data acquisition and analyses are common in use. Over the last two decades, there has been tremendous growth in PD data processing to extract information. There are efforts made to make data banks of different PD signature patterns based on ϕ - p - n measurements on insulation models. Problems related to standard PD measurements and quantification has resulted into ambiguous interpretations. This paper presents an alternative representation of PD data which includes the PD pulse time characteristics and its phase position. The representation is indicative of PD phenomenon and will be useful for PD diagnosis.

1 Introduction

Partial Discharge (PD) measurements are performed with computer-aided analysers which record the charge magnitude and the time position of the PD pulses. Numerous statistical and digital signal processing techniques are applied on PD data to interpret the results. Some of the research topics relates to the understanding of the phenomenon and diagnosis include:

- Stochastic nature of PD: (PI) phenomenon is studied on a pulse to pulse basis to correlate the charge magnitude and the time difference between pulses. Memory propagation effects are investigated to characterise the discharge phenomenon /1-3/.
- Discharge mechanism: PD can exist as pulsating and non-pulsating discharges. The change from pulsating to non-pulsating discharge occurs due to change in mechanism from spark discharge to pseudo-glow or glow discharge. The non-pulsating discharges elude detection /4/.
- Fingerprint analyses: Distribution parameters and ϕ - p - n patterns are obtained

for various artificially created defects. Recognition of the discharge source by computer algorithms are attempted which will help insulation defect diagnosis /5/.

- Measurement techniques: PD detector and analyser characteristics affect the measured data. Correct and universal quantification of data is possible only with well defined standard systems /6/.

The present paper is an attempt to identify the PD fingerprint indicative of the stochastic properties of the discharge independent of the measuring instrument.

2 Pulse Sequence Analyses

Pulse sequence analyses are performed to obtain the characteristic time involved in the discharge process which is dependent on local field conditions /3/.

PD experiments were performed with a point-plane electrode system and the pulse records were obtained for corona discharges at different applied voltages. The PD measurement setup consisted of a resistive measuring impedance (50Ω), conventional PD detector and an analyser. The output of the measuring impedance was fed to the detector and also monitored on the channel one of the digital storage oscilloscope (DSO). The detector was interfaced with the analyser and the detector's output was connected to channel two of the DSO.

The analyser stored the PD pulse information in form of PD records on the computer. A sample extract from a PD record is shown in Figure 1(a). It can be observed that the pulses occur in bursts. Burst is a cluster of pulses characterised by small time interval between them.

Figure 1(b) gives the distribution of the time between pulses obtained from the record at 110% of the inception voltage. The distribution shows a large number of pulses with small time differences.

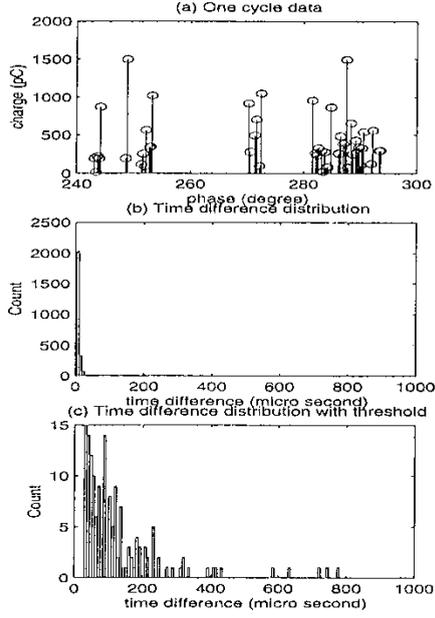


Figure 1: Corona discharge (a) PD phase-charge plot for pulses in one half cycle (b) time difference distribution (c) time difference distribution with threshold.

Pulses with large time differences are negligible compared to the pulses with small time differences and therefore, they are not visible in Figure 1(b). The distribution primarily give the time difference information of pulses within the clusters (intra-cluster time information). The distribution shows significant contribution of pulses having less than $30\mu s$ time interval.

To study the inter-cluster spacings (time interval between clusters), a threshold of $30\mu s$ is considered on the time difference distribution and another distribution is obtained (Figure 1(c)). It can be seen from the figure that the inter-cluster time varies upto $800\mu s$.

Analyses were performed on intra-cluster and inter-cluster pulse behaviours with the help of distributions. From the record obtained at 110% of the inception voltage, the pulse data were arranged to give $\phi - q - n$ distribution (Figure 2(a)), $\phi - t - n$ (phase-time difference-number) distribution (Figure 2(b)) and the charge distribution (Figure 2(c)). These distributions were used to investigate the dependence of the charge magnitude and the time interval between pulses on the applied stress. Since, the dependence is studied on a pulse to pulse basis, the instantaneous stress comes in play. The study on the intra-cluster pulses and the inter-cluster pulses are treated separately and are given below:

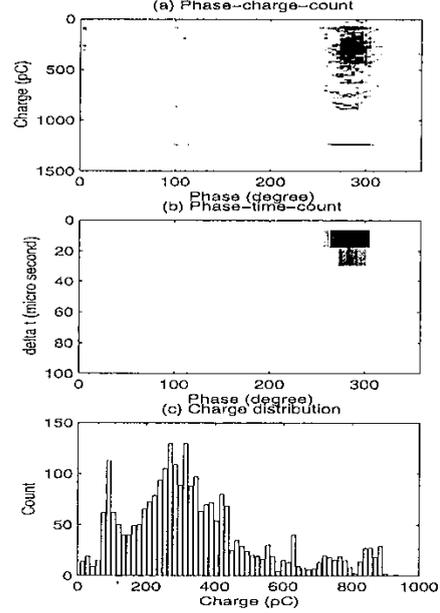


Figure 2: Corona discharge (a) $\phi - q - n$ distribution (b) $\phi - t - n$ distribution (c) charge distribution

2.1 Intra-cluster pulses

- Intra-cluster charge magnitude $\phi - t - n$ distribution show pulses with small time differences to appear at all active phase windows. To study the charge distributions at different phase angles, conditional charge distributions were obtained as shown in Figure 3. Figure 3(a) is the charge distribution at 275 degree phase angle and Figure 3(b) is the charge distribution at 300 degree phase angle. These conditional distributions can be compared with the unconditional charge distribution (Figure 2(c)) and it can be concluded that the discharge magnitudes do not show significant dependence on the phase position of the pulse. This brings out an important conclusion that intra-cluster pulse magnitudes do not depend on the instantaneous stress.
- Intra-cluster time interval Variation of pulse time interval were studied along with the phase of the AC voltage. The time between pulses were observed maximum at the start and the end of the pulse sequence in any half cycle, minimum being at the peak stress. Figure 4 gives the oscillogram of detector's output obtained with the DSO at 200% inception voltage. It can be seen that the PD detector shows a DC shift (no pulse) at the negative peak of the applied voltage. The pulse magnitude also decreases with increase in the stress. The analyser made no measure-

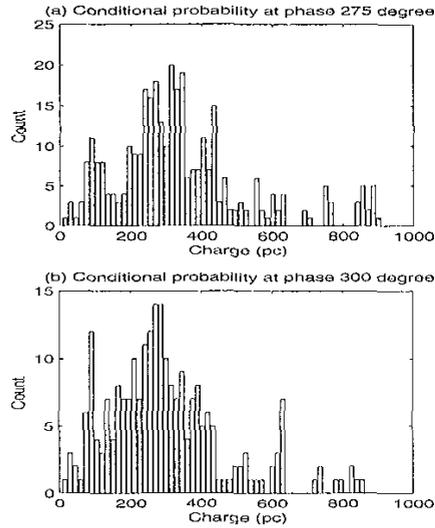


Figure 3: Conditional distribution of charge magnitude with (a) 275 degree phase angle (b) 300 degree phase angle

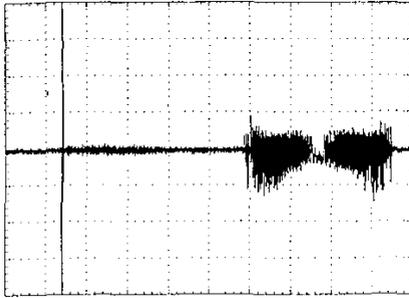


Figure 4: PD Detector's output, 1V/div (ver), 2ms/div (hor)

ments around 270 degree phase angle

Oscillograms of pulses developed across the measuring resistance were captured at the negative peak of the applied voltage for six different voltages in the range of 110% to 200% inception voltage. Figure 5 gives the oscillogram obtained at the applied voltage of 200% inception voltage. The periodic variation of the pulses can be clearly seen from it. The time between pulses were found to vary from $35\mu s$ at 110% inception voltage to $2\mu s$ at 200% inception voltage.

As the time interval between pulses decreased along the phase and at the same phase with different applied voltages, it can be concluded that the intra-pulse spacing decrease with increase in the instantaneous stress.

The time difference between some pulses were found to be less than the resolution time and

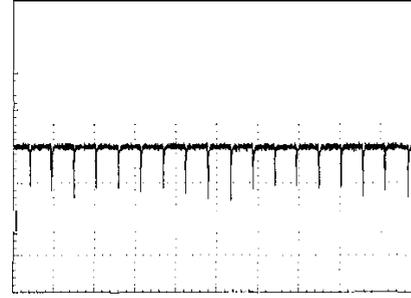


Figure 5: PD pulse oscillogram, 50mV/div (ver), $4\mu s$ /div (hor)

the dead time limits of the detector and the analyser respectively, and hence no measurement of pulses at some phase angles (near 270 degree) were observed. The output of the detector can show decrease in the pulse magnitude along the phase upto 270 degree phase due to superposition errors caused by the overlapping of pulses. However, it is difficult to comment on the discharge magnitude trend at very high applied stress as the mode of discharge may change due to the strong local field.

2.2 Inter-cluster pulses

To study the inter-cluster pulse characteristics, a set of distributions (Figure 6) were obtained by conditioning the distribution set shown in Figure 2 by the threshold value of $30\mu s$. The 4-4-71 (Figure 6(a)) distribution shows a positive correlation with instantaneous stress, the charge magnitude increasing with increase in the stress.

It can be seen in the $\phi-t-n$ distribution (Figure 6(b)) that the clusters are distributed with different inter-cluster time, the largest inter-cluster time occurring at around the negative peak of the applied voltage. This is possible because of sinusoidal variation of the stress, the rate of change in the stress decrease in the phase range of 180 degree to 270 degree and same delta change in stress near 180 degree will occur at a lesser time as compared to that near 270 degree. However, the probability of finding clusters at higher stress decreases with increase in stress as then the cluster spans for larger time.

The charge distribution is found to be different from the unconditional distribution (Figure 2(c)) exhibiting dependence of charge magnitude on time characteristics of pulses.

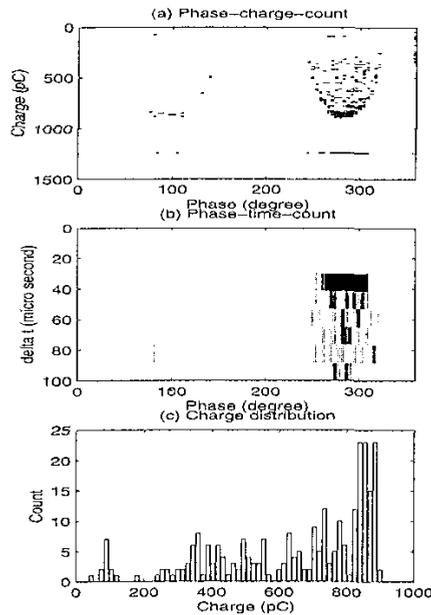


Figure 6: Corona discharge with threshold of $30\mu s$
 (a) $\phi-q-n$ distribution (b) $\phi-t-n$ distribution
 (c) charge distribution

3 $\phi-t-n$ Representation

Figure 7 gives $\phi-t-n$ patterns for internal discharge (Figure 7(a)), surface discharge (Figure 7(b)) and corona discharge in presence of a dielectric (Figure 7(c)). It can be observed that the patterns are distinct and will be useful for discharge recognition. As has been discussed above, the $\phi-t-n$ can be used to explain PD pulse time characteristics. Implementation of the $\phi-t-n$ analyser is simple as only measurement of time position of the pulse is required. The detection of the pulse can be done using logic comparators which will make the $\phi-t-n$ analyser very fast overcoming the resolution limitations of conventional analysers. $\phi-t-n$ analysers are also independent of measuring instrument characteristics and experience of the user.

3.1 Conclusions

Pulse sequence analyses are shown to be useful to interpret PD distributions. Intra cluster and inter cluster time intervals indicate the stress condition around the discharge source. The characteristics of PD are represented by $\phi-t-n$ patterns which can be used for discharge source recognition. The $\phi-t-n$ analyser is simple to implement and use.

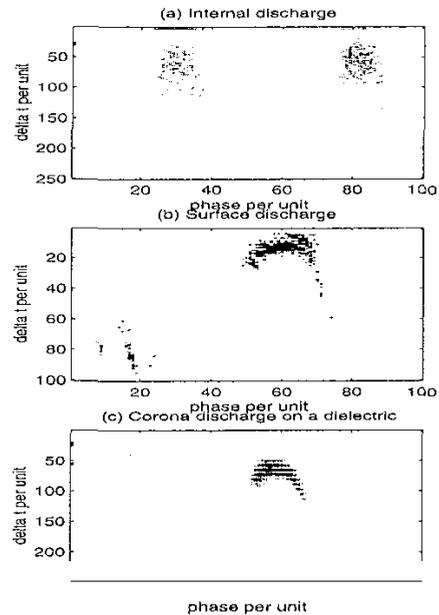


Figure 7: $\phi-t-n$ patterns for (a) Internal discharge (b) Surface discharge (c) Corona discharge in presence of a dielectric.

4 References

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