Pulse Sequence Studies on PD Data

S.Senthil Kumar, M.N. Narayanachar and R.S. Nema
Department of High Voltage Engineering,
Indian Institute of Science,
Bangalore, INDIA

Abstract: Partial discharge (PD) pulses are measured to assess the condition of the insulation under test. The pulse magnitude and its phase position are the most commonly measured parameters. The PD pulse magnitude is used as an index to the quality of the insulation under test. The phase information is used to identify the type of PD. The most common method of PD analysis is statistical analysis on PD distributions. The representation of PD data as distributions all though convenient for representation of magnitude variations, loses the PD pulse sequence information. Recent studies have shown that PD pulse sequence contains information useful for understanding of PD phenomena. The paper presents pulse sequence studies with PD data obtained from model insulation systems representing different types of discharge models. The study brings out different characteristics of discharges and their variations with the applied voltage. The paper discusses the changes in the charge magnitude, the time between pulses and their relation with the phase of occurrence of PD. The use of time information for simple measurement and recognition of PD is also discussed.

Introduction

Modern PD analyzer provides a complete record of PD events obtained during the time of observation. The PD record contains charge magnitude and phase position data for all PD pulses measured. The time between PD pulses can be computed from the phase data. A variety of analysis techniques can be applied on the data to extract characteristic information. Figure 1 gives a schematic block diagram that shows different approaches used for analysis and interpretation. The distribution analysis follows probabilistic models and is popularly used for ageing characterization, the pulse sequence analysis method characterizes temporal behavior of data and thirdly, the group for various analysis based on transforms or state based techniques (eg. Fourier transform, Neural analysis etc.) are mainly used for classification.

The paper presents pulse sequence studies. This approach for analysis is selected for the following

Figure 1: Block diagram of various schemes for PD analysis

reasons.

1. It can reveal information useful for understanding of the physical process involved with the system [1].
2. Characterization based on time information has measurement advantage [2, 3].
3. Pulse sequence analysis can lead to instrument independent characterization. Narrow band and wide band detector differ in their resolution ability and therefore the data collected using them may vary [3].

A new compositional technique for pulse sequence analysis is developed to characterize PD. The technique identifies and characterizes structural information present in the data.

The New Compositional Technique

The pulse sequence data obtained from a PD record can be viewed as a train of PD pulses with varying magnitude and time intervals accumulated over number of ac cycles. PD pulses can be distinguished based on time interval between pulses and grouped together as clusters. Grouping PD pulses allows group level treatment for the entire sequence and also individual treatment for pulses within a group. Figure 2 gives the composition followed for PD pulses in a PD record.

Figure 2: PD data structure

A cluster can be characterized and represented with its structural parameters as shown in Figure 3. The definitions of terms used in the representation are given below.

- Inter-cluster charge magnitude (Q_I): Inter-cluster charge magnitude is the charge magnitude of the first pulse in a cluster.
- Inter-cluster time (T_I): Inter-cluster time is the time between two clusters.
- Intra-cluster charge magnitude (q_i): Intra-cluster charge magnitude is the charge magnitude of pulses within a cluster except for the first pulse.
- Intra-cluster time (t_i): Intra-cluster time is the time between pulses within a cluster.
- Cluster size (N): The cluster size is given by the number of pulses in a cluster.

Analysis with clusters

PD data collected with experiments performed for corona discharge, barrier discharge, surface discharge and internal discharge at multiple overvoltage levels with wide band detector (resolution- $6\mu s$) and analyzer system (dead time - $10\mu s$) are used for analysis. Corona discharges were obtained with a point-plane ($265\mu m$ tip diameter) separated with 8mm gap distance. The same arrangement was used for barrier discharges with a PMMA sheet used as barrier at 8mm distance. For surface discharge experiment, the point rested on the dielectric surface. Internal discharge was created with a sample made by having a PMMA sheet with a void of 6mm depth and 10mm diameter sandwiched between two

Figure 3: A cluster representation of PD data

PMMA sheets of 1.5mm thickness and placed between plane electrodes.

The study is made with $\phi-q-n$ and $\phi-t-n$ distributions. $\phi-t-n$ distribution is a 3D distribution of time interval between pulses and phase position. It shows phase resolved time interval distribution obtained by representing n th pulse in a sequence by time interval (At_n) and phase position (ϕ_n) where $At_n = \phi_{n+1} - \phi_n$. The $\phi-t-n$ distribution therefore contains pulse information present in natural sequence of occurrence of pulses along its phase angle. All 3D distribution patterns are presented as images with gray scale intensity representing the count.

$\phi-t-n$ distributions are used to obtain threshold values to separate clusters from the pulse sequence data [2]. Threshold values of $60\mu s$ for corona discharges and of $100\mu s$ for barrier, surface and internal discharge are selected for analysis.

The analysis is performed to study dependence of PD pulse charge magnitude and time intervals on the applied voltage. The study is made at two overvoltage levels of $1.3V_i$ and $1.5V_i$. The results are expressed as observations from the 3D distributions and numerical values of cross-correlation coefficient between charge distributions.

Results

Figure 4 and Figure 5 show unconditional (all pulses) and inter-cluster $\phi-q-n$ distributions respectively for corona, barrier, surface and internal discharges at $1.5V_i$. Intra-cluster $\phi-q-n$ distributions were very similar to the unconditional distributions and therefore not shown. Comparison of inter-cluster and intra-cluster charge distributions with

Figure 4: $\phi-q-n$ distributions: (a) corona discharges, (b) barrier discharges, (c) surface discharges and (d) internal discharges

unconditional distributions ($q-n$) are made with help of cross-correlation coefficient, the values of which are given in Table 1. A cross-correlation factor of '1' means 100% correlation and '0' means no correlation. A value of '-1' means negative 100% correlation between distributions.

From the table it can be noted that the inter-cluster pulses show varying levels of correlation, with very poor correlation (less than 15%) for corona discharges compared to other type of discharges (around 90% correlation). For corona, barrier and surface discharges correlation factors decrease with the increase in the applied voltage. However, for the case of internal discharges (each half cycle considered separately) the correlation factors increase with the increase in the applied voltage. For corona discharges, the inter-cluster charge magnitude appear directly proportional to the applied instantaneous voltage (observation from phase angle) [2]. No inter-cluster pulses are present at around 270 degree phase angle indicating that a single cluster spans around the negative peak of the applied voltage. Similar trend is observed for barrier discharge but with a difference. The inter-cluster charge distribution is found to correlate very well with the unconditional distribution indicating that the nature of pulse magnitude variation is same for all pulses. This may be interpreted as caused by surface influence of the dielectric. Surface and internal discharges show a higher degree of such influence exhibited by high degree of correlation between inter-cluster and unconditional distributions. Intra-cluster charge distributions correlate very well for all types of discharges.

Figure 5: Inter-cluster $\phi-q-n$ distributions: (a) corona discharges, (b) barrier discharges, (c) surface discharges and (d) internal discharges

Figure 6 gives the $\phi-t-n$ distributions for corona, barrier, surface and internal discharges. It can be seen from the figure that for corona and barrier discharges the time intervals are small and they appears to be uniformly distributed along the phase angle. The distribution for surface discharges show presence of pulses with large time intervals. These pulses also show a decreasing trend in the time interval with increase in the instantaneous voltage (observation from phase angle). For internal discharges pulses have time interval of more than $100\mu s$ and are uniformly distributed indicating very little influence of the applied instantaneous voltage. Uniform distributions of pulses in case of corona and barrier show up due to limited phase detector resolution and very large number of pulses with small time intervals masking the pulses with large time intervals. To some extent the dead time of analyzer also matters (contributed mainly by ADC digitization time). Results with a $\phi-t-n$ analyzer [2] having a dead time of $1\mu s$ for corona and barrier discharges are shown in Figure 7. The variations in time interval between pulses can be easily seen to be dependent on the applied instantaneous voltage. Barrier discharge show an increased scatter compared to corona discharges indicating the influence of the dielectric surface.

Conclusion

The paper can be concluded with the following comments:

1. A new compositional treatment of PD data is presented for pulse sequence analysis. The anal-

Table 1: Cross correlation factors for charge distributions

Type	voltage	q-n	inter	intra
Corona discharge	1.3 V _i	1	-0.072	0.998
	1.5 V _i	1	-0.141	0.999
Barrier discharge	1.3 V _i	1	0.900	0.997
	1.5 V _i	1	0.880	0.999
Surface discharge	1.3 V _i	1	0.939	0.883
	1.5 V _i	1	0.924	0.836
+ve Internal discharge	1.3 V _i	1	0.881	0.997
	1.5 V _i	1	0.948	0.991
-ve Internal discharge	1.3 V _i	1	0.827	0.983
	1.5 V _i	1	0.996	0.998

ysis treats PD data as clusters which exhibit characteristics of PD type.

2. $\phi-t-n$ distributions represent pulse sequence and can be used for characterization and recognition of PD.
3. A high resolution $\phi-t-n$ distribution is captured with the $\phi-t-n$ analyzer which are simple to implement and use.

References

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Figure 6: $\phi-t-n$ distributions: (a) corona discharges, (b) barrier discharges, (c) surface discharges and (d) internal discharges

Figure 7 $\phi-t-n$ distributions from $\phi-t-n$ analyzer: (a) corona discharges and (b) barrier discharges

Authors address:

S. Senthil Kumar

Dr. M.N. Narayanachar

Prof. R.S. Nema

Department of High Voltage Engineering,
Indian Institute of Science,
Bangalore, INDIA- 560 012,

Email: senthil@hve.iisc.ernet.in

URL: <http://hve.iisc.ernet.in/~senthil>

Email: mnn@hve.iisc.ernet.in

URL: <http://hve.iisc.ernet.in/~mnn>

Email: rsnema@hve.iisc.ernet.in

URL: <http://hve.iisc.ernet.in/~rsnema>