Indonesian Journal of Electrical Engineering and Informatics (IJEEI)
Vol. 13, No. 3, September 2025, pp. 679~688
ISSN: 2089-3272, DOI: 10.52549/ijeei.v13i3.5754

Partial Discharge Source Identification Using Pulse Height Distribution for Diagnosis in High Voltage Rotating Machines

Amol Deshpande[1], Priya Chimurkar[2], Kiran Rathod[3], A. N. Cheeran[4], H. A. Mangalvedekar[5]
[1,2]Department of Electronics and Telecommunication Engineering, Sardar Patel Institute of Technology, India
[3]Department of Electronics and Telecommunication Engineering, KJ Somaiya Institute of Technology, India
[4-2]VJTI-Siemens HV Lab, Veermata Jijabai Technological Institute, India

Article Info

Article historys:

Received Jul 23, 2024
Revised Sep 2, 2025
Accepted Sep 17, 2025

Keywords:

Partial Discharge (PD)
PD Height Distribution (PDHD)
Pulse Height Analysis
High Voltage (HV) Rotating Machines
PD Source Identification

ABSTRACT

Electrical discharges that are localized in nature and do not completely bridge the electrodes are called as Partial Discharge (PD). PD is the major cause of insulation degradation, and it may eventually lead to system breakdown. Therefore, monitoring of such discharges is important considering efficient diagnosis of high voltage insulation systems. Depending on the source of discharge, there are types of discharges generally occurring in rotating machines viz. Slot Discharge, Delamination, void discharge etc. The plot of count of PD pulses versus the PD magnitude is called the PD height distribution (PDHD) plot or Pulse Height Distribution (PHD) plot. This plot is derived from the actual measurement data on high voltage (HV) rotating machines and the results thus obtained are discussed in this research work. This plot is used to identify the presence of individual PD source or simultaneous occurrence of PD sources in the HV rotating machine. This is the novel contribution of this research work. Phase Resolved PD (PRPD) patterns are used to validate the results. The results for individual discharges and simultaneous discharges are discussed in this paper. The significance of pulse height analysis for diagnosis of HV rotating machines is discussed in this paper.

Copyright © 2025 Institute of Advanced Engineering and Science.
All rights reserved.

Corresponding Author:

Amol Deshpande,
Department of Electronics and Telecommunication Engineering,
Sardar Patel Institute of Technology,
Mumbai, Maharashtra, 400058, India.
Email: amol_deshpande@spit.ac.in

1. INTRODUCTION

Partial Discharge is one of the main reasons for deterioration of the health of insulation. The discharges which take place at the defects or voids present in the insulation are called as partial discharges [1].

Even though the intensity of such discharges is low, they may lead to de-gradation of insulation over a period of time [2]. Thus, it is crucial to monitor PD activity in any High Voltage (HV) insulation system. PDs occur at different locations inside the HV rotating machine. Based on the location of PD, the PDs are categorized as Slot Discharge, Surface Discharge, Delamination etc.

Before discussing different ways in which PDs cab be analyzed, it is imperative to have in-depth exploration of the mathematical modelling of the PD phenomenon.

The discharge initiating voltage V_s and the apparent charge Q due to PD is given by equation (1) and (2) [3]:

$$V_s = \left(1 + \frac{d-t}{\epsilon_s t}\right) \mathrm{v_g}(t) \tag{1}$$

$$Q = \frac{\epsilon_0 \epsilon_s S}{d-t} \sqrt{2 v_g(t)} \tag{2}$$

Here [3], it is assumed that the voids are flat and parallel to conductor surface, t = gap spacing, s = discharge area, dielectric constant of insulation is $\epsilon_0\epsilon_s$, thickness of insulation d.

The PD repetition rate N0 can be expressed in terms of applied voltage V as follows:

$$N_0(V) = (2V / V_s - 1)u(V - V_s) \tag{3}$$

Where u(x) denotes unit step function.

An equivalent circuit for a single void/fault within an insulation is shown in Figure 1. The physics behind the amount of charge transfer can be further explored as a function of material dependent parameters using this equivalent circuit and the mathematical modeling.

Figure 1. Equivalent circuit of single void insulation [4]

Whenever a void gets discharged, charge transfer takes place across it. This charge transfer is given by [4]:

$$\Delta Q_v = (V_v - V_x)\left(C_g + \frac{C_s C_p}{C_s + C_p}\right) \tag{4}$$

Where V_x – voltage across the void immediately after breakdown, C_s – capacitance in series with void, C_g – void capacitance, C_p – capacitance of insulation in parallel with series combinations of C_s and C_g.

This charge transfer can further be simplified as [4]

$$\Delta Q = (V_b - V_r)\, C_s \tag{5}$$

This equation shows that, the amount of charge transfer is determined by the series capacitance and the difference of the two voltages i.e. void-breakdown voltage-V_b and residual voltages-V_r.

Thus, number of discharges per half cycle as given as.

$$\overline{N} = \frac{2\gamma V_p}{V_b - V_r} - \frac{V_b + V_r}{V_b - V_r} \tag{6}$$

Where V_p – peak value of applied voltage and γ is $\left(C_s / C_s + C_g\right)$.

PD occurrence in insulation also results in energy dissipation. Equation 7 is the energy relationship and equation 8 is the relationship of PD charge with size of defect [1].

$$P \approx 0.7(q\, V_i) \tag{7}$$

$$q = \epsilon A \Delta V \left({}^{1}/_{d}\right) \tag{8}$$

where P - energy dissipated by a discharge, q - apparent charge, V_i - Inception voltage at which the sample starts to discharge, ϵ - permittivity, A - area of the discharge site, ΔV = ignition voltage and d = thickness of the dielectric.

This shows that apparent charge (q) is directly related to energy in discharge and to the size of the defect. This makes 'q' as an attractive parameter for the measurement of discharges.

But these expressions do not consider other random variables which make PD phenomena a random phenomenon. This encourages further discussion about recent advancements in analysis of PD.

PD is analysed using various feature extraction and classification methods and assessed using Fuzzy analysis, Digital Signal Processing, Statistical Tools [5, 6]. Identification of types of PD is achieved using Weibull Distribution [7, 8]. Fractal analysis and Neural networks are also used along with Weibull distribution for PD detection [9, 10].

Several statistical parameters are used for PD Source identification [11, 12]. PD is also analysed in terms of energy dissipation [13, 14]. The PD pulse sequence and Weibull parameters are used along with Neural networks to monitor tree growth with aging of insulation [15].

Thus, it can be said that identification of PD is achieved by using various PD patterns / mathematical models. Each type of discharge can be described by specific PRPD pattern. PRPD pattern is most popular pattern to identify the source of discharge [16]. For example, there is dominance of discharges occurring in negative half cycle as compared to that in positive half cycle in case of slot discharge [17-18].

It is also important to review recent advances in this field. Considering the context of this paper, the authors have given emphasis on pulse-height distributions (PHD) and phase-resolved partial discharge (PRPD) patterns. Pulse Height Analysis (PHA) for multi-source PD was conceptualized using different electrode geometries [19] opening the doors for researchers in this field. Review of on-line PD sensing with PRPD rotating-machine [20] also supports the capabilities of PHA and its automated interpretation. Torstein Aakre et. al. [21] showed temperature and frequency dependence of PD activity in generators. The PD-echo (PDE) method augments PRPD by extracting decay attributes (time-constant, duration, maximum charge) during chopped, voltage-less gaps—offering severity and aging indicators that PRPD and PHA alone do not provide [22]. In the context of electric motors, the application of feature selection through classifiers (mRMR + RF) utilizing PRPD and pulse features resulted in an accuracy of approximately 99.875% across various insulation defects [23]. This demonstrates that carefully selected features can facilitate the automation of expert analyses of PRPD. Deep learning with data augmentation improves PD vs noise discrimination particularly at low SNR, bridging the gap where PRPD alone is noise-limited [24]. Template-matching applied to PRPD images (excluding deep learning) successfully replicated expert classifications in approximately 4 seconds, providing a streamlined approach to standardized and reproducible PRPD interpretation [25].

Overall, these studies suggest reporting PHA metrics (charge distributions, source mixing) alongside PRPD features (ϕ–q–n, image/texture), incorporating PDE attributes, and explicitly noting test conditions. In addition, ML and DL baselines provide useful benchmarks for classification. In comparison with this research, the authors propose PHA method to analyze PDs occruing in HV rotating machines. The results are also validated with the help of well accepted standard PRPD signatures for each of these discharges.

Section 2 elaborates the technique of Pulse Height Distribution (PHD) and some preliminary work carried out by researchers. This section also mentions the motivation towards the technique used and the novel contribution by author in this paper. Section 3 discuss the results of pulse height distribution and its inferences for different types of discharges generally occurring in rotating machines viz. Delamination, void discharge, surface discharge towards analysis and identification of type of PD. Section 3 also describes the results on how individual discharge and simultaneous discharges are identified using pulse height distributions for PD.

2. RESEARCH METHOD – PARTIAL DISCHARGE HEIGHT DISTRIBUTION

Figure 2. PD Measurement Circuit [1]

The PD measurement system at VJTI-Siemens-AICTE High Voltage Laboratory consists of the PD measuring equipment. It has a bandwidth of 300 kHz to 30 MHz, sensitivity of 1 pC, sampling rate of 40000 samples per second; the coupling capacitor of 1000 pF; the external calibrator and the measuring impedance of 50 Ohm. PD detectors record three parameters related to PD activity viz. Apparent charge (Q), Number of pulses (N) and Phase angle (Ø). These parameters are recorded during whole measurement time. The PD detector also provides PRPD patterns. The standard PD measurement set-up is shown in Figure 2. The experimental setup is traced through this Figure 2.
Partial discharges are pulse type discharges i.e. every discharge can be observed as a group of pulses of different charge magnitudes [19]. The pulse height analysis approach is applied to study the distribution curves in this paper. Such distribution curves are described by general relation

$$N = f(Q) \tag{9}$$

where N is the pulse repetition rate and Q is the PD magnitude i.e. apparent charge in Coulombs. The source / type of PD, count of PD and intensity of PD, influence the Pulse Height Distribution (PHD) curves i.e. N vs. Q curves [19, 26].

Thus, PHD curves can be a potential tool to detect the possible sources of PDs in practical insulation systems [19, 26, 27]. B Florkowska et. al. [19] has used pulse height distributions for analysis of different types of discharges obtained through simple experimental arrangements like needle-plane, needle-needle etc. It is interestingly observed in needle-plane experimental arrangements that, the PDs originating from several sources acting simultaneously have pulse height distributions that are equal to the superposition of pulse height distributions of the component PD sources acting alone. In such cases, it is observed that PHD curves show more than one peaks-like (and valley-like) signature, when more than one discharges act simultaneously [26-27]. This motivates the author to use approach of pulse height distribution to identify the number of PD sources in HV rotating machines. This is the motivation, objective and novelty of this paper.

Weibull function can be applied for simultaneous discharges to identify multiple sources of discharges [28] and to segregate the percentage contribution of one discharge over the other.

The results from the literature discussed above lay the foundation towards the use of pulse height analysis (PHD curves) for PD source identification. However, PHD curves have not been used for analysis and identification for types of PDs occurring in HV rotating machines. In this research work, pulse height distribution has been applied to the actual measurement data obtained from HV rotating machines which is the novel contribution of this research work. PHD curves are used for analysis and identification of different types of PDs generally occurring in HV rotating machines viz. delamination, void discharge and detection of simultaneous discharges acting in rotating machines. Results and analysis of PD sources in HV rotating machines using PHD curves (discussed in next section) form the major contribution of this paper.

3. RESULTS AND DISCUSSION - PULSE HEIGHT DISTRIBUTION FOR PDs IN HV ROTATING MACHINES

This section provides description of the experimental results and their interpretation towards source identification and ultimately towards diagnosis of HV Rotating Machines.

3.1. Delamination (Discharge)

Delamination occurs at the separation of adjacent layers of insulation during the machine operation. It may occur due to improper impregnation too [29]. It can also occur between the copper conductor and the groundwall insulation. The nature of delamination discharge is that it spreads radially on the surface of insulation [16]. It can be categorized as one of the internal PD i.e. the discharge area is surrounded by insulation. Phase window analysis of delamination shows symmetry of discharge activity in positive and negative half cycles [14]. The phase window analysis and the PRPD patterns can be used to confirm the presence of delamination discharge [30, 31].

The pulse height distribution for delamination type of discharges is obtained. Figure 3 shows NQ curve for delamination type of discharge. This figure shows the N-Q curve for PDs occurring in positive half cycle, in negative half cycle and the overall PDs occurring (considering both the half cycles) denoted as NQ+, NQ- and NQ respectively. The inference from Figure 3 is that, the PD activity in two half cycles is approximately similar. The symmetry of PD activity can be confirmed from the PRPD pattern shown in Figure 4. Another inference, particularly important considering the aim of this paper, is that, the PHD curve does not show any multiple peaks (or valley like region). Thus, it can be concluded that the data (which is plotted) comes from single source of PD. PHD plot obtained indicate the existence of single source of PD. The PD source type can be identified from the PRPD pattern (refer Figure 4) as delamination [14, 16].

Figure 3. Pulse Height distribution of delamination type of discharge.

Figure 4. PRPD Pattern for delamination discharge.

Careful observation of Figure 4 shows that PD activity is higher between 0° - 30° in positive half cycle and 180° - 210° in negative half cycle. To understand more about this, the physics of PD i.e. the breakdown process needs to be relooked. A PD pulse occurs when the electric field across the fault exceeds its breakdown value. This voltage is called as PD inception voltage (E_{inc} shown in Figure 5 below [32]). Since the applied field (AC Sinusoidal voltage) is increasing, the field within the fault continues to build up again and this results in the subsequent discharges. If the voltage across the void still increases negatively, the void again gets discharged and this process repeats.

Figure 5. Regular Pulse Patterns for void discharges [32]

There are two types of PRPD patterns viz. Regular and Random patterns. When the initial electron availability is abundant then the PD occurs without much time lag and the patterns thus obtained are the regular PRPD patterns. Whereas, when there is scarcity of initial electrons then the PD occurrence is delayed and the

pattern obtained is the random pattern. Initial electrons affect the count and magnitude of PD. When the electrons are abundantly available then higher magnitude of PDs occur but less frequently.

The PDs do not increase sharply near the inception phase angle and do not continue beyond 90° and 270° phase angles because of low PD occurrence probability and when the effect of surface conductivity is taken into consideration. Along with surface conductivity, the turtle-like patterns are obtained when residual field and the probability of PD occurrence both are stochastic in nature. The change in probability of occurrence and magnitudes of discharges is related to the density of electronegative molecules in the void and related to two parameters like gas detachment & surface electron emission.

If there are many faults in the insulation, each of them may break down giving rise to pulses which are random with respect to magnitude, phase of occurrence and number of occurrences. This makes 'q' as an attractive parameter for the measurement of discharges.

3.2. Void Discharge

The discharges which occur in the voids/cavities which are bounded by dielectric are termed as Internal Discharges or void discharges [33-35].

Figure 6 shows pulse height distribution curve for another type of discharge. Two curves are showing PD activity in positive half cycle (blue colour) and negative half cycle (red colour) respectively. It can be concluded from Figure 6 that the PD activity is symmetric in two half cycles. This symmetry is confirmed from the PRPD pattern shown in Figure 7. Another observation from Figure 6 is that the PHD curve does not show multiple peaks (or valley like region). This depicts the presence of single source of discharge. This single source of discharge can be characterized and identified as void discharge using the PRPD pattern [16] and the phase window analysis.

Figure 6. Pulse Height distribution of void discharge data.

Figure 7. PRPD Pattern for void discharge.

3.3. Simultaneous Discharges

When an HV machine is in operation, many times, the discharges are occurring simultaneously at different locations. Such discharges are called as simultaneous discharges. The PD activity recorded by the PD detectors in such scenario, shows the superposition of the each of the PD source which is acting simultaneously at that instant. It is interesting to observe the PHD patterns for such simultaneously occurring discharges in HV rotating machine. The result of pulse height distribution in case of simultaneous discharges in HV rotating machines is discussed below.

The pulse height distribution (refer Figure 8) in case of simultaneous discharges shows superposition of pulse height distributions of different PD sources. These distributions show separate single sources or multiple peaks or a valley like region as shown in Figure 8. PHD plot obtained indicate the existence of multiple sources of PD.

The task of identifying the type of PDs (which are occurring simultaneously) can be carried out by observing the PRPD pattern shown in Figure 9. The discharge activity of surface and gap discharge is confirmed from the PRPD pattern [14]. The discharges taking place along the surface of the winding insulation in case of rotating machines are termed as surface discharges. The gap discharge show PD activity in the form of fissure like portions in the PRPD pattern. Such portions, generally observed at higher magnitudes, depict the characteristics of gap type of discharge [16]. Thus, Figure 8 shows the PHD curve of simultaneous surface and gap discharge.

Figure 8. Pulse Height distribution of simultaneous surface and gap discharge.

Figure 9. PRPD pattern of simultaneous surface and gap discharge.

3.3. Discussion

The key contribution and results are the PHD plots obtained for the PDs with single source and PDs when two sources are acting simultaneously. This paper quotes that the presence of single or multiple sources can be easily observed and identified from PHD plots. The key aspect to be observed in PHD plots is whether

the trend is continuously falling or whether the trend has valley and mountain like trends (i.e. decreasing trend and followed by increasing and then decreasing again). This key aspect interprets the presence of single and two sources of PD respectively. Once the number of sources is identified, then the type of PD can be interpreted by observing the PRPD patterns. The interpretations from Figure 3, Figure 6 and Figure 8 are validated by studying the PRPD patterns from Figure 4, Figure 7 and Figure 9 respectively. The peculiarities of PRPD patterns are mentioned by several researchers as cited in respective sections in this paper. This seems an interesting approach to quickly identify the physical location of the PD and then the diagnosis of the rotating machine would become more efficient by inclusion this additional methodology with the existing ones. Similar studies can be carried out for other HV assets too.

4. CONCLUSION

It is possible to analyse the PD phenomena using the pulse height distribution curves, that is, number of PD pulses (N) versus magnitude of PD (Q). These curves are obtained by plotting the raw data from the actual measurements on HV rotating machines. The significant contribution of this research work is that these N-Q curves have been used for identification of single or multiple PD sources in the HV rotating machines. The pulse height distribution in case of single PD source does not show multiple peaks (or valley like region) whereas in case of simultaneous PD sources the pulse height distribution is the superposition of the PD sources, therefore shows multiple peaks (or valley like region). The symmetry of PD activity in positive and negative half cycle is also interpreted using the PHD curves and the same can be clearly inferred from PRPD patterns. The source of PD is confirmed by observing the PRPD pattern. Such analysis is carried out for the PD types generally occurring in HV rotating machines like delamination, void discharge and surface discharge. Thus, pulse height distribution is an important tool for PD analysis and PD source identification which is ultimately beneficial for improved diagnosis of HV rotating machines.

It would be interesting to study more PD sources in HV rotating machines using the pulse height distribution curves. Also, this tool can be applied to the PDs occurring in other HV assets.

ACKNOWLEDGMENTS

The authors are very grateful for valuable insights into Partial Discharge and Rotating Machines provided by Mr. Abhijit Patil, Mr. Cajetan Pinto, Mr. Ameet Choughule, Dr. Amit Paithankar.

REFERENCES

[1] F. H. Kreuger, *Partial Discharge Detection in High Voltage Equipment*, Temple Press, 1989.
[2] S. Mohanty, S Ghosh, "Modeling of breakdown voltage of White Minilex Paper in the presence of voids under ac and dc conditions using fuzzy logic techniques", *International Journal of Electrical Power & Energy Systems*, Vol. 32, Issue. 5, pp. 518-523, 2010.
[3] Shoji Hirabayashi, Yoshikazu Shibuya, Taketoshi Hasegawa and Yoshio Inuishi, "Estimation of Size of Vois in Coil Insulation of Rotating machines", *IEEE Transactions on Electrical Insulation*, Vol.EI-9, No.4, pp. 129-136, Dec.1974.
[4] K.G. Burnley and J.L.T. Exon, "Relationship between various measurement techniques for void discharges", *IEE Proceedings*, Vol. 129, Pt. A, No. 8, pp. 593-606, Nov. 1982.
[5] Sahoo Sahoo, N.C., Salama, M.M.A., R. Bartnikas, "Trends in partial discharge pattern classification: a survey", *IEEE Transactions on Dielectric and Electrical Insulation*, Vol. 12, Issue. 2, pp. 248–264, 2005.
[6] M. Nafar, T. Niknam, A. Gheisari, "Using correlation coefficients for locating partial discharge in power transformer", *International Journal of Electrical Power & Energy Systems*, Vol. 33, Issue 3, pp. 493-499, 2011.
[7] A.Contin, E. Gulski, M. Cacciari, G.C. Montanari, "Applications of the Weibull Function to Partial Discharge Data coming from Different sources Typologies", *Electrical Insulation and Dielectric Phenomena*, pp. 335-338, 1995.
[8] M. Cacciari, A. Contin, G. Rabach, G.C. Montanari, "Diagnosis of Practical Insulation Systems by Partial Discharge Measurements in the Presence of Multi-discharge Phenomena", *International Conference on Electrical Insulation and Dielectric Phenomena*, Pennsylvania, USA, pp. 414-419, 1993.
[9] B. Freisleben, M. Hoof, R. Patsch, "Using Counter propagation Neural Networks for Partial Discharge Diagnosis", *International Journal of Neural Computing and Applications*, Vol. 7, Issue 4, pp. 318-333, 1998.
[10] R. Candela, G. Mirelli, R. Schifani, "Partial Discharge Recognition by Means of Statistical and Fractal Parameters and a Neural Network", *IEEE Transactions on Dielectric and Electrical Insulation*, 2000, Vol. 7, Issue 1, pp. 87-94, 2000.
[11] A.Contin, A. Cavallini, G.C. Montanari, C. Hudon, M. Belec, N. Nguyen, "Searching for Indexes Suitable for Rotating Machines Diagnosis", *IEEE Intational Symposium on Electrical Insulation*, pp. 101-105, 2006.
[12] M. Mansor, P.S. Ghosh, A.B. Abdul Ghani, "PD Patterns Recognition in XLPE Cable Under Various Thermal Conditions Using Statistical Technique", *International Journal Research and Reviews in Applied Sciences*, Vol. 5, Issue 2, pp. 171-181, 2010.

[13] S. Biswas, D. Dey, B. Chatterjee, S. Chakravorti, "An approach based on rough set theory for identification of single and multiple partial discharge source", *International Journal of Electrical Power & Energy Systems*, Vol. 46, pp. 163-174, 2013.
[14] A.S. Deshpande, H.A. Mangalvedekar, A.N. Cheeran, "Partial Discharge Analysis using Energy Patterns", *International Journal Electrical Power Energy Systems*, Vol. 53(C), pp. 184-95, 2013.
[15] M. Noel, P. Basappa, V. Lakdawala, V. Nimbole, "A Neural Network Based System for Prediction of Partial Discharge Pulse Height Distribution Parameters", *IEEE International Symposium on Electrical Insulation*, pp. 331-335, 2008.
[16] C. Hudon, M. Belec, "PD Signal Interpretation for Generator Diagnostics", *IEEE Transactions on Dielectric and Electrical Insulation*, Vol. 12, Issue. 2, pp. 297-319, 2005.
[17] M. Boltze, S. Markalous, A. Bolliger, "Insulation Condition Assessment of Generators Based on On-line and Off-line Monitoring", *8th IndiaDoble Power Forum*, Ahemdabad, India, 2010.
[18] G.C. Stone, T. Goodeve, H. Sedding, W. McDermid, "Unusual PD Pulse Phase Distributions in Operating Rotating Machines", *IEEE Transactions on Dielectric and Electrical Insulation*, Vol. 2, Issue. 4, pp. 567-577, 1995.
[19] B. Florkowska, Romuald Wlodek, "Pulse Height Analysis of Partial Discharges in Air", *IEEE Transactions on Dielectric and Electrical Insulation*, Vol. 28, Issue. 6, pp. 932-940, 1993.
[20] Jonathan dos Santos Cruz, Fabiano Fruett, Renato da Rocha Lopes, Fabio Luiz Takaki, Claudia de Andrade Tambascia, Eduardo Rodrigues de Lima & Mateus Giesbrecht, "Partial Discharges monitoring for Electric Machinery: A Review", *Energies, MDPI*, vol. 15(21), pp. 1-31, October 2022.
[21] Torstein Aakre , Emre Kantar , Espen Eberg . Partial Discharge Activity in Rotating Machine Type II Insulation Systems as a Function of Temperature and Frequency, *IEEE Transactions on Dielectrics and Electrical Insulation*, TechRxiv, pp.1-8, January, 2023.
[22] Marek Florkowski, "Measurement of Partial Discharge Echo and Extraction of Decay Attributes", *Measurement*, Vol. 238, pp.1-9, 2024.
[23] Hassan, W., Hussain, G.A., Wahid, A., Safdar M., Khalid H.M and Mohd Jamil M K, "Optimum feature selection for classification of PD signals produced by multiple insulation defects in electric motors", *Scientific Reports, nature portfolio,* Vol.14:23446, pp. 1-17, 2024.
[24] Andreas Rauscher, Johannes Kaiser, Manoj Devaraju, Christian Endisch, "Deep learning and data augmentation for partial discharge detection in electrical machines", *Engineering Applications of Artificial Intelligence*, Vol.133, 108074, Part A, pp. 1-17, 2024.
[25] Abubakar, A.; Zachariades, C., "Phase-Resolved Partial Discharge (PRPD) Pattern Recognition Using Image Processing Template Matching", *Sensors*, Vol. 24, 3565., pp. 1-15, 2024.
[26] A.Contin, G.C. Montanari, C. Ferraro, "PD source recognition by Weibull processing of Pulse Height Distributions", *IEEE Transactions on Dielectric and Electrical Insulation*, Vol. 7, Issue. 1, pp. 48-58, 2000.
[27] R. Bartnikas, "Use of a Multichannel Analyzer for Corona Pulse-Height. Distribution Measurements on Cables and Other Electrical Apparatus", *IEEE Transaction on Instrumentation and Measurement*, Vol. 22, Issue. 4, pp. 403-407, 1973.
[28] M. Cacciari, A. Contin, G. Rabach, G.C. Montanari, "Use of Mixed-Weibull Distributions for the Identification of Partial Discharges Phenomena", *IEEE Transactions on Dielectric and Electrical Insulation*, Vol. 2, Issue. 4, pp. 614-627, 1995.
[29] L.M. Rux, S. Grzybowski, "Detecting Delaminated Stator Winding Insulation Using the Ramped High Voltage DC Test Method", *High Voltage Engineering Symposium*, pp. 331-334, 1995.
[30] B. Fruth, D. Gross, "Modelling of Streamer Discharges between Insulating and Conducting Surfaces", IEEE 5th *International Conference on Conduction and Breakdown in Solid Dielectrics*, England, pp. 350-355, 1995.
[31] B.M Reddy, "Insulation Condition Assessment Techniques on Rotating Machines with a Case Study", *8th IndiaDoble Power Forum*, Ahemdabad, India, 2010.
[32] B. Fruth and L. Niemeyer, "The Importance of Statistics Characteristics of Partial Discharge Data", *IEEE Transactions on Electrical Insulation*, Vol. 27, No. 1, pp. 60-69, Feb. 1992.
[33] T. Ijichi, "A study on the ageing mechanisms of insulating materials by observing Ø – q – n pattern and current form of PD", Master Thesis, Nagoya University 2001.
[34] K. Wu, F. Komori, Y. Suzuoki, "Effects of oxygen on the formation of Rabbit-like PD pattern in a void between metal surfaces", *International Symposium on Electrical Insulating Materials*, pp. 37-40, 2001.
[35] Suwarno, Suzuoki Y., T. Mizutani, "Pulse Sequence Analysis of Partial Discharges in a void and Electrical Treeing", *IEEE Symposium on Electrical Insulation*, Montreal, USA, 1996.

BIOGRAPHY OF AUTHORS

Amol S Deshpande was born in Aurangabad, India, in 1984. He received the B.E and M.Tech degrees in Dr. Babasaheb Ambedkar Marathwada University, India. He received the Ph.D. degree in Electrical engineering from Veermata Jijabai Technological Institute (VJTI), Mumbai University in 2014. He has worked as Post Doctoral Fellow in Institute for Plasma Research (IPR), Gandhinagar, India. He is currently working as Assistant Professor in Sardar Patel Institute of Technology (S.P.I.T). His research interests include Partial Discharge, High Voltage Engineering, Image Processing, Pulsed Electric Fields.

Priya Chimurkar is currently working as Assistant Professor in Sardar Patel Institute of Technology. She is pursuing doctoral research from IIT Bombay in the Area of Embedded System. She has completed her masters from VJTI and achieved a Gold Medal. She has worked in the domain of Embedded systems in Photo Voltaics with Flareum Technologies (Solar panel based company). She has been actively involved in research in the domain of Embedded Systems, IoT, Biomedical, Microcontrollers & Microprocessors since 11 years.

Kiran Ramesh Rathod was born in Yavatmal (India) in February 1978. He received his graduation in electronics and telecommunication engineering in 2002 from Sant Gadge Baba Amravati University, then he obtained his master degree in Digital Electronics in 2011 from Sant Gadge Baba Amravati University. Since March 2003, he has been with Hitech Electronix and 2006 onwards till date associated with KJSIT. Recently (July 2022) got his Ph. D in Technology (EXTC).

Alice Cheeran has completed B. E in Electrical Engineering in 1984 from Kerala University. She joined V J T I, Mumbai as a lecturer in 1987. She completed Masters in Electrical Engg with specialization in Control Systems and in Electronics respectively in 1994 and 1996 from Mumbai University. Further she did Ph. D. from IIT Bombay in 2005 in the topic of "Speech Processing for the Hearing Impaired. She was working as an Associate Professor in the Electrical Engineering department, VJTI, Mumbai.

Harivittal A. Mangalvedekar received the BE degree in 1979, the ME degree in 1984, and the Ph.D degree in 1995 in electrical engineering from Bombay University, India. He has been with VJTI for the last 25 years and was a Professor in the Elec. Engg. Dept. He has played vital role commencement of VJTI-Siemens HV Lab and developing the ecosystem of R&D in the area of power systems and High Voltage.