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CLASSIFICATION OF PARTIAL DISCHARGE FAULTS BASED ON SIGNAL PEAKS AND LOCATIONS

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ABSTRACT

Diagnosis of the partial discharge (PD) faults protects the insulation of the high voltage equipment from the breakdown issues. Many techniques are used to capture and analyse the PD signals that emit in the case of PD faults. In this work, a new application of the peak-finder algorithm is employed to classify among the PD faults that result from different PD sources. The artificial defects are made in different types of high voltage insulation such as mica and the cross-linked polyethylene (XLPE) insulation of the power cable in the laboratory to capture PD data using Portable PD Analyzing System (LDS-6). The high accuracy is obtained for the classification of the PD signals that developed from different PD sources, which is 93.34% of mica insulation and 86.67% for XLPE insulation for power cable. The results of the PD type classification accuracies refer to the high performance of the proposed technique to extinguish among the different sources of PD.

Keywords*: PD faults, PD sources, Fault classification, Peak-finder.*

1. INTRODUCTION

Partial discharge (PD) is considered the origin of the insulation breakdown in the high voltage apparatus and hence a variety of complex shapes and surface will be made in the insulation materials. PD detection in early stages prevents a catastrophic failure and external damage, fires to the HV equipment in addition to loss of revenue due to an unscheduled outage [1]. Recently, both automated diagnostic and condition assessment and monitoring systems are very important for the electrical utilities [2]. They help to identify the defects that take place in the equipment to prevent their failure and schedule their maintenance. In addition, these systems are required to optimize the operation of the equipment and increase their reliability [1-3]. The phase resolved discharge patterns influenced by the voltage stress. In addition, the defect type of PD has a great effect on the PD pulse reputation rate. Therefore, the visual and automated PD classification diagnosing and monitoring takes into consideration the voltage and time of the PD characteristics [4]. Partial discharge patterns develop by applying PD sources to the insulation materials with defects. These patterns should be recognized to determine the reason of the PD sources. The following main categories of the pattern recognition techniques are structural, statistical and hybrid pattern recognition systems [5]. Some techniques that are used for the partial discharge pattern recognition are,

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Expertise Methods [5], Generic Knowledge-Based Approach [3], Fractal Features [6-10], Fuzzy Logic Expert System [11], Artificial Neural Networks (ANN) [12-17], Acoustic Partial Discharge Detection [18], K-Mean Method [19], Support Vector Machine (SVM) [20], and Inductive Inference Algorithm [21]. The artificial intelligence methods were complicated and need more data and more time for training process, therefore, providing a simple technique to classify different fault sources of the PD was very valuable for saving the computation time.

The current work uses the LDS-6, which has a frequency selective PD measuring to eliminate noise, as phase resolved analyzer to measure the PD that was developed due to some artificial defects that were made in mica and XLPE cable insulation [22]. Thereafter, the peak-finder is used to classify among the partial discharge data that are developed by artificially defects in the insulation materials. The proposed technique is based on distinguishing among the measuring partial discharge data by determining their peaks and their locations. The measurement data (discharge number, N) were used as an input to the Matlab code that was drawn the relation between the number of samples and the discharge number (N) and determine the peak and its location for each fault case and then a classification process was accomplished based on the peak and its location for each fault case. The validation of the constructed code was carried out by applying a faulty case and obtaining the source of the fault. At least 15 measuring samples are collected for each PD fault to be able to construct the classification model. The accuracy of the model was measured using 5 measuring samples as test samples and the other ten measuring samples were used as training samples for the ANN model. The classification model was based on the visual inspection to determine the variation of the measuring charges based on the artificial fault type and then determine the peak's location of each fault type. The peak value and peak location are the input to the ANN model and the output of the ANN model is the fault source in the mica and XLPE insulation of the power cable.

The novelty of the current work is constructing the PD pattern recognition model based on the use of peak finder function in Matlab code to classify between the PD source of the high voltage insulation as mica and XLPE sheet of the power cable. This technique will save the time and the data needed to construct a classification model using artificial intelligence methods. The rest of the paper was organized as follows, section 2 referred to the Experiment setup, section 3 indicated the proposed classification methodology, and finally, the conclusions remarks were given in section 4.

2. EXPERIMENTAL SETUP

For PD measurements, IEC Std. 6270 [23] was adopted. The measurement system consisted on a PD analyzer (LDS-6), a high voltage control desk, a high voltage transformer. Moreover, two capacitors were utilized for coupling and calibrating purpose. The goal of the experimental work is to determine partial discharge patterns. The experimental setup is shown as in Figure 1. The electrical detection technique was adapted to measure partial discharges signal. Most partial discharge detection systems were integrated into the test circuit shown in Figure 1. Where, U is high-voltage supply, Z_{mi} is the input impedance of measuring system, cc is connecting cable, C_a is test object (mica insulators), C_k is coupling capacitor, CD is coupling device, MI is measuring instrument (the computer aided PD measuring system LDS-6), and Z_f is a filter. Figures 2, 3 and 4 show the experimental setup and the artificially designed defect in the power cable and mica. LDS-6 is a

conventional phase resolved PD analyzer that is used to measure the PD signal due to the artificially designed defects on the insulation materials. In the experiments, a healthy, one and two voids mica insulation is used as an object under test. In addition, the artificially 1 void, 3 and 5 voids are made in the insulation material of the power cable. An excess of the applied voltage results in an incipient PD voltage and at the weak point, the PD increases and hence the PD bridges the whole void causing a breakdown. PD induces a current that flows through the insulation material and the PD signal will amplify and transmitted to measuring instrument. The measuring signals are digitally converted and stored as PD data in the computer in the form of Excel sheets. These data will be collected and analyzed to determine the classifier parameters that will classify among the PD sources. By visual inspection and studying data results for all the measured data of each PD source, a threshold is determined to separate each class from the others. The peaks and locations of each PD source data are estimated using the "find peaks function" in MATLAB software and hence the threshold will be determined.

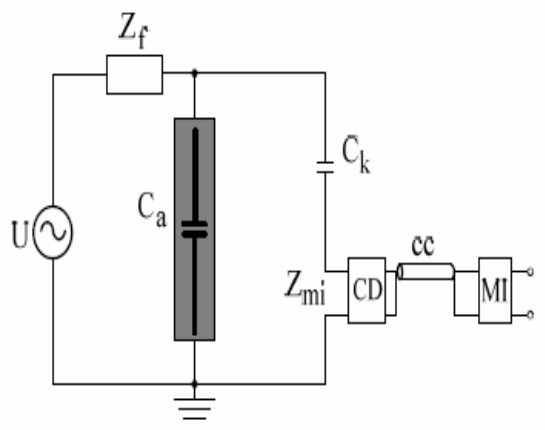

Fig. 1. Basic partial discharge test circuit



Fig. 2. Experimental test setup



Fig. 3. Cable under test

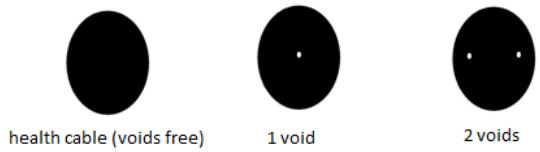

Fig. 4. Artificial defects in the mica

The experimental results were developed in Excel spreadsheet that contains the discharge number (N) versus the location points that determined at any point in the grid that expresses the charge value (q) and the phase angle (ϕ). For example, if the charge value (q) ranges from 0 to 40 and the phase angle (ϕ) from 0 to 360 degrees, therefore, the total number of q×ϕ is 14400 points. At each point of 14400, there is a discharge number. Figures 5 and 6 explain the distribution of the discharge number versus the location point on the grid for the measurement data that developed by different PD sources, i.e., from defects that made in the mica insulation as in Figure 4. Figure 5 explains the relation between the discharge number (N) and the location

point. By applying visual inspection and analysis of the data results of the images that were shown in Figure. 5(a), 5(b) and 5(c), it is clear that the discrimination between them at location point 9500 to the location point 10500 at the peak of the discharge number. Every defect of the mica insulation has 15 measuring data and all measuring data of every defect can be analyzed to construct the classification model. Figure 5 expresses the difference among the 3 defect types that made in Mica, where Figure 5(a) explains the relation between the sample number and discharge number (N) which illustrates that the peak value of the discharge number (N) is at sample number 14400 and there another peak at sample number 4500. The one void PD source in Figure 5(b) explains a peak between sample number 500 and 2500, but in case of two voids PD source, there are two peaks at sample number 500 and at 14400. Therefore, the discrimination process was based on the peaks at sample number between 9500 and 10500. Figure 6 illustrates the different PD sources that are made in the XLPE insulation for the power cable. There are three kinds of defect that were artificially made in the power cable, 1 void, 3 voids and 5 voids and the measuring data were captured by LDS-6 for 15 sample test for each defect. There is no distinct difference between the images in Figures 6a, 6b and 6c. The variation of the discharge number with the sample number is slightly different and Figures 6a, 6b and 6c illustrated that there were two peaks at the beginning and the end of the signal, therefore, two peaks with two peak location was used to carry out the discrimination process. Figure 7 represents the three dimensional plot of PD for the phase resolved partial discharge. It explains the relation between the discharge number (N), the charge value (q) and the phase angle (ϕ) for 3 voids defect that are artificially made in the power cable insulation. In the next section, the constructed methodology to classify the patterns of the PD defects based on PD sources will discuss in detail.

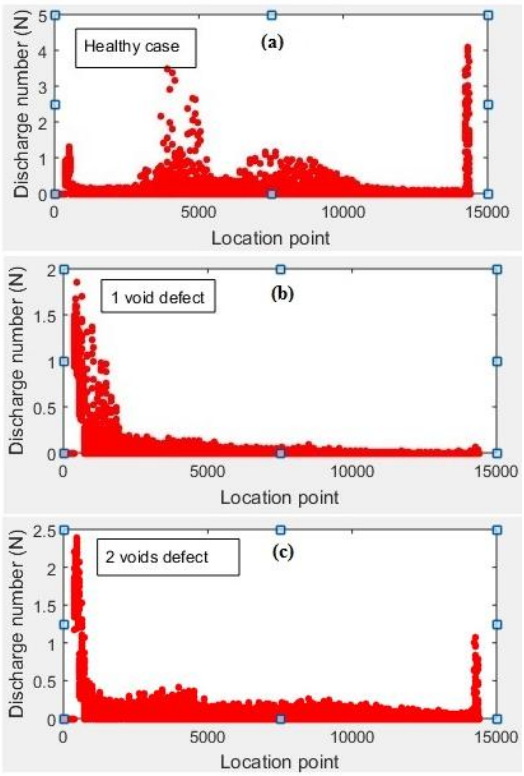

Fig. 5. PD Discharge number at different PD sources for mica insulation
(a) Healthy case, (b) 1 void defect, (c) 2 void defect.

3. THE PROPOSED CLASSIFICATION METHODOLOGY

The find-peak is a MATLAB function that able to find the local peaks and valleys of the discharge numbers which act as the local extrema. It uses with the noisy vector to determine the location of the peaks or valleys according to the data around a specified point. If the measured signal has many peaks this will lead to a great problem with the strictly derivative that based on peak finding algorithms. The large data set needs longer time and a large amount of user interaction. In addition, more complex methods for finding peaks are still giving variable results. The purpose of the peak finder function is attempting to use the alternating nature of the derivative along with the user defined threshold to locate the local maxima and

minima in a vector quickly and robustly. More than 1.5 million data point noisy sum of sinusoids can be checked to locate the maxima and minima is a second [24].

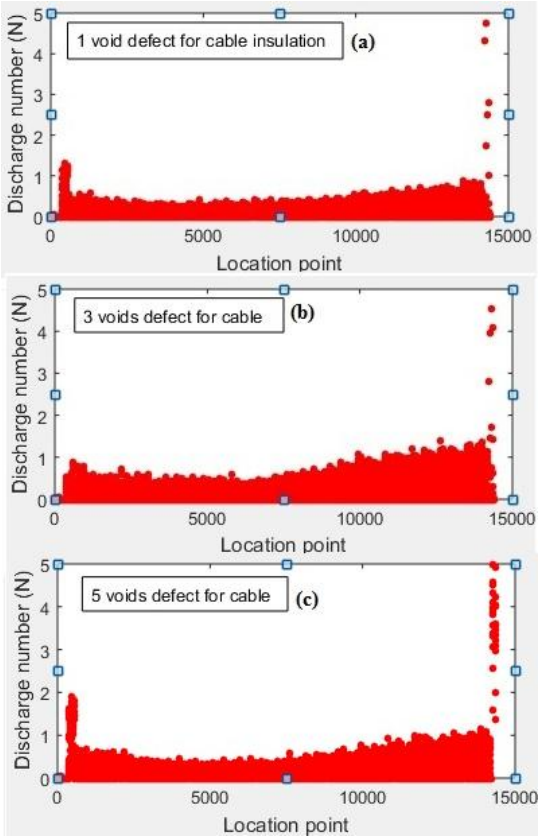

Fig. 6. PD Discharge number at different PD sources for XLPE power cable
(a) 1 void defect for cable insulation, (b) 3 voids defect for cable, (c) 5 voids defect for cable.

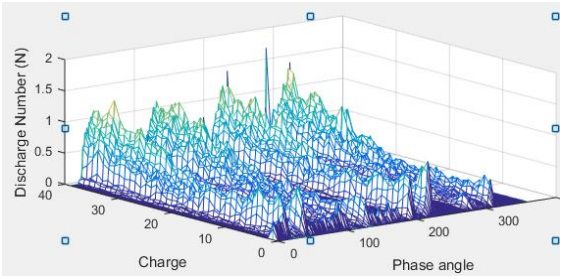

Fig. 7. 3D PD representation for phase resolved PD (q-ϕ-N)

The proposed method is based on the peak and its location of the measuring PD signals. The 15 PD signals at different defects are captured using LDS-6 equipment (phase resolved partial discharge measuring device). The accuracy is calculated as the ratio of the number of successful classifications to the total number of the measuring signals (15 samples for each defect). The threshold limits of the classifying model are estimated using data statistic of the total samples for each defect. Figures 5 and 6 refer to one sample for each defect in case of mica and XLPE insulation of the power cable. Figure 5 illustrates the peaks and their location of the discharge number and explains the differences of them based on the insulation status. Figure 5(a) shows the healthy case (No artificial fault is made in the mica insulation), there are different peaks of the signal at different location points (location point results from the product of the phase angle and the proposed charge, 360*40) and the significant peak difference between this case and the other cases for 1 void and 2 voids artificial PD sources Figures 5(b) and 5(c) are located between 9500 and 10000. This significant peak difference is observed on the 15 test cases to determine the threshold limits to distinguish between the resulted patterns of the PD (Table 1). Figures 6(a), 6(b) and 6(c) explains the PD signals at different fault cases for the power cable insulation. The situation becomes more complicated since the peaks of the studied PD pattern lie at the same location and the patterns for the different cases (1 void, 3 voids and 5 voids) are close to each other. Therefore, two peaks and their location are assigned for different PD patterns to distinguish between the resulted patterns (Table 2). Table 1 indicates the peak value (number of discharges) of the PD signals for different types of PD sources at the proposed location (at location point 9500 to the location point 10500) which clearly the distinction of the discharge number (N) among the different defects in the mica insulation. The flowchart of the constructed classification model to distinguish among the PD signals for each defect is shown in Figure 8. The proceeding of the classification method begins by reading the signal data as the

discharge number (N) with the location point (the charge range by the phase angle). By determining the peak value at the specified location (9500-10500), if the peak value is greater than 0.21, it refers to the healthy case of the mica. But if the peak is smaller than 0.07, it refers to the 1 void defect in the mica, otherwise, the 2 voids defect will be indicated. The resulting accuracy of the healthy case is 80% (12/15), while the accuracies in cases of 1 void and 2 voids defects are 100%. The overall accuracy of the classification model is 93% (42/45). In case of power cable, Table II refers to the two locations of each sample with the peak values. Three defect types are artificially made in the insulation of power cable, 1 void, 3 voids, and 5 voids defect. The flowchart in Figure 9 explains the proceeding steps to classify among the PD signals that generated due to different kinds of PD sources (1 void, 3 voids, and 5 voids). The measuring data are used as an input for the classifying model and then determine the peak and its location. The find-peaks function in MATLAB is used for this purpose.

TABLE 1: PEAK VALUE AT DIFFERENT PD SOURCES OF MICA INSULATION

Test	Peak of healthy mica	Peak for 1 void defect	Peak for 2 voids defect
1	0.57	0.05	0.2006
2	0.86	0.016	0.142
3	1.48	0.033	0.158
4	1.47	0.0251	0.1951
5	1.17	0.0255	0.1669
6	0.916	0.0167	0.1694
7	1.3527	0.0335	0.1672
8	1.41	0.0251	0.0922
9	0.75	0.025	0.0933
10	0.1	0.0167	0.9751
11	0.09	0.0334	0.0933
12	0.133	0.0417	0.1
13	0.88	0.0587	0.0919
14	0.85	0.0417	0.075
15	0.46	0.0501	0.083

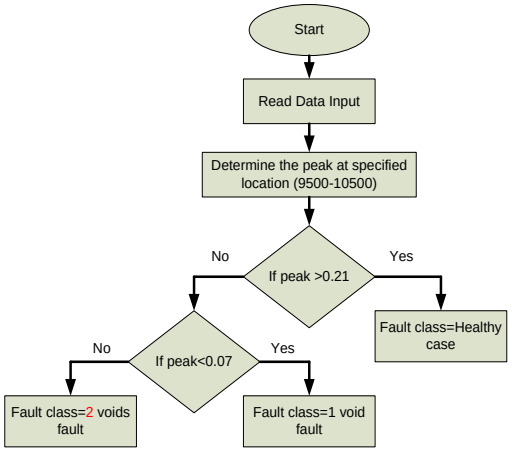

Fig. 8 Flowchart of the classifying model to classify the signals of different PD sources in mica insulation

At the first step, the model detects the location of peaks (locations 1 & location 2). If the location1 (Loc1) at 14252 or 14251 and location2 (Loc2) at 14342 are detected, then the PD signal comes from 3 voids PD source. If not, the second step will be followed as if the location 2 (Loc 2) at 14252 then the PD signal is from 5 voids PD source and if not, then the peak 2 will use to distinguish between the class of 1 void and 5 void again. If the peak 2 is greater than 168 and less than 176 then the PD signal refers to 5 voids PD source if not it refers to 1 void PD source.

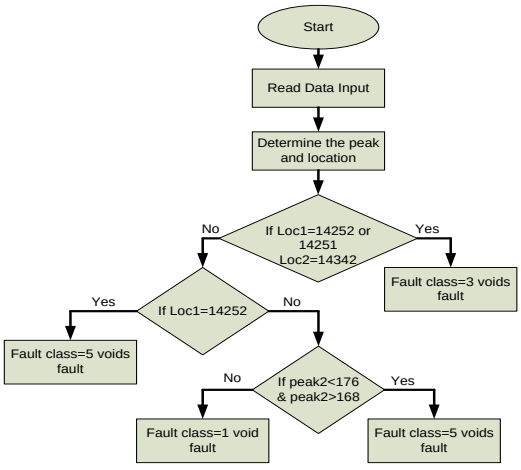

Fig. 9. A flowchart of the classifying model to classify the signals of different PD sources in power cable

The accuracy of the classification model is calculated as mentioned above (the number of correct classifying signals /total number of signals that should be classified). The accuracy in case of 1 void, 3 voids and 5

voids PD source is 80%, 100% and 80% respectively. The resultant overall accuracy is 86.67%. The reduction of the accuracy of the proposed model attributes is due to the high similarity of the PD signals which are produced for different kinds of PD sources in Figure 6. The advantages of the proposed model are, the simplicity to implement and very low consumed time compared to other artificial techniques. Compared to classification model based on the artificial neural network (ANN) and fuzzy logic, the proposed technique is competitive since, the ANN and fuzzy logic model needed large amounts of data and time to be trained to develop satisfying results.

4. CONCLUSIONS

The find-peaks function in MATLAB is used in this paper to classify among the PD measuring data that are developed by different PD sources in case of different kind of insulation materials such as mica and the XLPE for the power cable. The advantage of using the find-peaks function is its ability to identify the peaks and their locations and classify among the different data depends on these peaks and their locations. Moreover, it is not a time consuming method for the classification purpose. The accuracy of the proposed technique to classify among the PD signals that obtained due to different PD sources for the mica and XLPE insulation for power cable are 93.34% and 86.67% respectively. The reduction in the second classification model for power cable is due to the high similarity between the measuring data for different defects. The limitation of the proposed technique was appeared in the case of PD developed through the artificial defects in XLPE insulation of the power cable, where the determination of the peak and its location may be very difficult when the number of voids was increased.

TABLE 2: LOCATIONS AND PEAK VALUES AT DIFFERENT PD SOURCES OF POWER CABLE INSULATION

No	1 void		3 voids		5 voids	
	Loc1/peak1	Loc2/peak2	Loc1/peak1	Loc2/peak2	Loc1/peak1	Loc2/peak2
1	14243/163.15	14337/124.99	14252/148.45	14342/162.63	14247/156.58	14337/155.68
2	14247/166.47	14337/138.28	14252/157.05	14342/162.84	14247/170.53	14337/169.17
3	14247/167.94	14337/141.05	14251/159.58	14345/165.63	14247/170.77	14337/171.11
4	14247/170.17	14337/149.4	14252/165.38	14342/167.28	14247/173.07	14337/174.09
5	14247/174.38	14337/176.91	14252/166.77	14342/168.25	14247/172.38	14337/174.9
6	14247/172.01	14337/156.1	14252/166.06	14342/167.9	14247/171.45	14337/173.78
7	14247/171.27	14337/159.65	14252/169.73	14342/169.85	14247/170.1	14337/174.57
8	14247/171.45	14337/161.68	14252/169.18	14342/170.82	14247/166.98	14342/178.84
9	14247/171.68	14337/165.68	14252/172.98	14342/173.48	14247/160.35	14337/173.68
10	14247/172.08	14337/166.00	14252/179.09	14342/176.01	14247/151.16	14337/168.81
11	14247/170.47	14337/156.26	14252/179.51	14342/176.65	14252/148.09	14337/164.83
12	14247/171.84	14337/170.68	14252/180.67	14342/174.34	14252/164.86	14337/162.57
13	14247/171.47	14337/169.98	14252/180.05	14343/174.06	14252/148.89	14337/162.40
14	14247/171.47	14337/171.48	14252/175.34	14342/163.11	14252/148.23	14342/161.73
15	14247/175.5	14337/176.56	14252/176.05	14342/164.79	14252/151.08	14342/158.82

REFERENCES

[1] R.E. James and Q. Su, Condition Assessment of High Voltage Insulation in Power System Equipment, Institute of Engineering and Technology, London, United Kingdom, Chapter 8, 2008.

[2] Y. Han and Y.H. Song, "Condition Monitoring Techniques for Electrical Equipment – A literature Survey", IEEE Trans. Power Delivery, I.e. 18, p.4 –13, 2003.

[3] S. Rudd, S. D. J. McArthur and M. D. Judd, "A Generic Knowledge-based Approach to the Analysis of Partial Discharge Data", IEEE Transactions on Dielectrics and Electrical Insulation I.e. 17(1), p. 149-156, 2010.

[4] T. Hucker, H.-G. Kranz, "New Approach in Partial Discharge Diagnosis and Pattern Recognition", IEE Proc.-Sci. Meas. Technol., I.e. 142(1), p. 89-94, 1995.

[5] Maher Ahmed, Rabab Kreidieh Ward, "An Expert System for General Symbol Recognition", Pattern Recognition 33, p. 1975-1988, 2000.

[6] F.-C. Gu, H.-C. Chang, F.-H. Chen, C.-C. Kuo, C.-H. Hsu, "Application of the Hilbert–Huang Transform with Fractal Feature Enhancement on Partial Discharge Recognition of Power Cable Joints", IET Science, Measurement and Technology, I.e. 6(6), p. 440–448, 2012.

[7] L. Satish and w. s. Zaengl, "Can Fractal Features be Used for Recognizing 3-d Partial Discharge Patterns?", IEEE Transactions on Dielectrics and Electrical Insulation, I.e. 2(3), p. 352-359, 1995.

[8] H.-C. Chen, "Fractal Features-Based Pattern Recognition of Partial Discharge in XLPE Power Cables Using Extension Method", IET Generation, Transmission & Distribution, I.e. 6(11), p. 1096–1103, 2012.

[9] Jian Li, Caixin Sun, "Partial Discharge Image Recognition Influenced by Fractal Image Compression", IEEE Transactions on Dielectrics and Electrical Insulation, I.e. 15(2), p. 496-504, 2008.

[10] Elsayed M. Elrefaie, Mohamed K. Abd Elrahman, Sherif Ghoneim, Ahmed Bakr, "Classification of Partial Discharge Patterns Using Fractal Geometry", Journal of Engineering Research and Applications (IJERA), I.e. 2(5), p.1010-1015, 2012.

[11] S. Gopal, B. Karthikeyan, D.Kavitha, "Partial Discharge Pattern Classification Using Fuzzy Expert System", 2004 International Conference on Solid Dielectrics, Toulouse, France, July 5-9, 2004.

[12] L. Satish and W. S. Zaengl, "Artificial Neural Networks for Recognition of 3-d Partial Discharge Patterns", IEEE Transactions on Dielectrics and Electrical Insulation, I.e. 2, p. 265-275, 1994.

[13] M. M. A. Salama, and R. Bartnikas, "Determination of Neural-Network Topology for Partial Discharge Pulse Pattern Recognition", IEEE Transactions on Neural Networks, I.e. 13(2), p. 446-456, 2002.

[14] Mang-Hui Wang, "Partial Discharge Pattern Recognition of Current Transformers Using an ENN", IEEE Transactions on Power Delivery, I.e. 20(3), p. 1984-1990, 2005.

[15] Mehrdad Majidi, Mohammed Sami Fadali, Mehdi Etezadi-Amoli, Mohammad Oskuoee,"Partial Discharge Pattern Recognition via Sparse Representation and ANN", IEEE Transactions on Dielectrics and Electrical Insulation I.e. 22(2), p. 1061-1070, 2015.

[16] Hui Ma, Jeffery C. Chan, Tapan K. Saha and Chandima Ekanayake, "Pattern Recognition Techniques and Their Applications for Automatic Classification of Artificial Partial Discharge Sources",IEEE Transactions on Dielectrics and Electrical Insulation I.e. 20(2), p. 468-478, 2013.

[17] Sobhy S. Dessouky, Adel A. El Faraskoury, Waleed M. Elzanati, "Comparative Analysis and Classification of Partial Discharge Defects within XLPE Medium Voltage Cable by Using Ann and Statistical Techniques", International Journal of Electrical Engineering & Technology (IJEET), I.e. 5(6), p. 01-16, 2014.

[18] A. Swedan , A. H. El-Hag and K. Assaleh, " Enhancement of Acoustic Based Partial Discharge Detection Using Pattern Recognition Techniques", Proceeding of the 2nd International Conference on Electric Power and Energy Conversion Systems (EPECS'11), Sharjah, UAE, Nov. 15-17, 2011.

[19] X. Peng, C. Zhou, D. M. Hepburn, Martin D. Judd and W. H. Siew, " Application of K-Means Method to Pattern Recognition in On-line Cable Partial Discharge Monitoring", IEEE Transactions on Dielectrics and Electrical Insulation I.e.20(3), p. 754-761, 2013.

[20] J. C. Chan, H. Ma, T. K. Saha,"Partial Discharge Pattern Recognition Using

Multiscale Feature Extraction and Support Vector Machine", 2013 IEEE Power & Energy Society General Meeting, Vancouver, BC, Canada, p. 1 – 5, 21-25, 2013.

[21] T. K. Abdel-Galil, R. M. Sharkawy, M. M. A. Salama and R. Bartnikas, " Partial Discharge Pulse Pattern Recognition using an Inductive Inference Algorithm", IEEE Transactions on Dielectrics and Electrical Insulation I.e.12(2), p. 320-327, 2005.

[22] Ahmed Bakr Abo Sharf, " Classification of Three-Dimensional Partial Discharge Patterns", Master Thesis, Faculty of Industrial education, Suez University, 2013.

[23] IEC, High-Voltage Test Techniques-Partial Discharge Measurements, IEC 60270, 2001.

[24] Https://www.mathworks.com/help/dsp/ref/dsp.peakfinder-system-object.html", J. Nano-Electron. Phys. 8(1), 2016, 01020-1 - 01020-7.