

## NEURAL NETWORK BASED RECOGNITION OF PARTIAL DISCHARGE PATTERNS

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### ABSTRACT

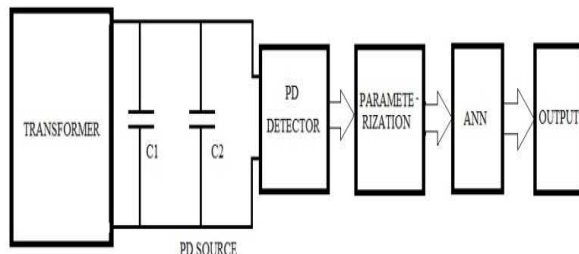
Partial Discharge (PD) monitoring and analysis has become imperative for utilities as well as for equipment manufacturers as it causes deterioration of insulation systems in high voltage (HV) electrical equipment. The analysis of PD includes detection, recognition & classification of PD using various advanced mathematical tools & techniques. In the artificial intelligence, Neural network methodology is one of the most popular and widely used for the analysis of PD. This work represents the generation of the partial discharge like signal using the MATLAB 7.9 software and the recognition of generated signals by artificial neural network technique. The obtained PD pattern represents the characteristics of Partial discharge signal and the discrete spectrum interference signal with it. The variants of these signals are taken as samples for the training of the neural network. The offline recognition of the PD signal has been done.

**KEYWORDS** Partial Discharge, Artificial Neural Network, Pattern recognition.

### 1. INTRODUCTION

The care of insulation is the primary need for any electrical system, even, for almost all technical systems we are using now days. One of the major reasons for deterioration of insulating system failures in high voltage power equipment ascends from Partial Discharges (PD). This phenomenon is usually found in the high voltage systems and they are more hazardous, which may result in to big loss of lives and money. Hence it is extremely essential to monitor such cases.

A large number of patents/research papers has been published on the subject of partial discharge analysis with experiments performed on equipment such as transformers, capacitors, cables, motors/ generators etc., under direct and alternating voltage stresses as well as impulse conditions, these things are in action from early 19<sup>th</sup> century [1]. The progress is remarkable, because of the techniques developed for measurement, detection and classification of partial discharge came to such a great extent, where, at hand plenty of techniques are available for its investigation. Here in this work we are presenting a review of efforts made in the field of PD recognition using artificial neural networks which will focus on the basics of PD, its occurrence, various techniques applied in conjunction with neural networks.



**Fig.1: Block diagram of PD recognition system**

### 2. PARTIAL DISCHARGE

Partial Discharge may be defined as the electrical breakdown incident which occurs when some form of electrical activity within the system results in a rapid

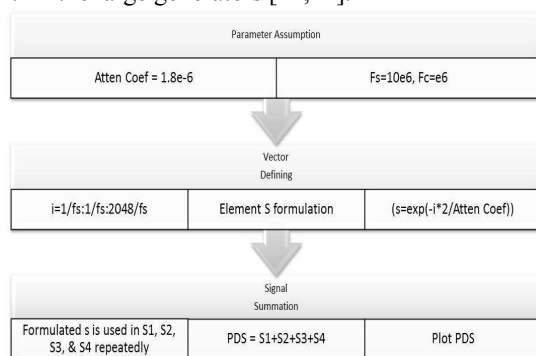
change of the electric field configuration that causes a current to flow in a conductor connected to external world [2]. This phenomenon may start from a number of ways like (1) from void in a solid dielectric, (2) due to surface discharges, (3) from a bubble in gas insulation, (4) as corona in air and liquids, (5) as floating discharge, etc. Partial discharge can be generated artificially also, by many different methods for the purpose of its analytical study, in the high voltage laboratories by research scholars.

To detect insulation faults, non –destructive test methods are applied as PD identification techniques. The basic block diagram of PD identification system is shown in fig.1, which tells the story of different stages of this process. In this block diagram C1 is a capacitor, and C2 represents the source of partial discharge from where any type of PD will enter the system. This generated PD is detected by PD detector which consists of a sensor and transduction stage. For this task of sensing, acoustic emission technique [3], ultrasonic effect sensors [4], HFCT (high frequency current transformer) as sensor [5], etc. are used. As the classification of partial discharge is a complicated task which completely depends on procedure and standard of technique used for its measurement. The measured data may be in the form of pulse which can be displayed on the CRT screen. All the received PD configurations from PD detector are having unique characteristic information for each type of fault or PD. The initially measured values will be given to next stage where the conditioning or preprocessing of the measured data occurs. This preprocessing includes the extraction of characteristic information from measured PD pulses. For this ample of techniques are available, one of the mostly used is the feature decomposition, in which features are considered as  $(\Phi-q-n)$  [6], where  $\Phi$  is phase angle of obtained discharge pulse or waveform,  $q$  is discharge magnitude, and their number densities or discharge rates is denoted by  $n$ , they are

also famous as statistical operators. These statistical operators are then changed into different forms acceptable by the system which is taken as classifier, here in this paper we are going to have a view of various such systems that are explained in further sections.

### 2.1 Sources of PD generation

Sources of partial discharges are mainly those systems or apparatuses, operate at high voltage. The defect of PD has been observed in transformers, motors, generators, in case of gas insulated substations, XLPE cables, etc. and crash at these sites can cause an interruption in electricity supply and result in a loss of considerable profits. The location of PD is determined at different places within the transformer windings which are classified by Fuzzy ART technique [7]. Many times the experiments are performed in the shielded laboratories by generating these defects. There may be the circumstances when discharge can arise in the transformer oil such discharges can be detected by acoustic techniques [8, 9]. The occurrence of PD in case of motors is deliberated in [10]. It is not comfortable to get the signal of discharge, perhaps the presence of noise, stochastic pulse interference etc. are there and their suppression is more important aspect within the large generators [11,12].



**Fig.2 Flow chart of PD signal formation**

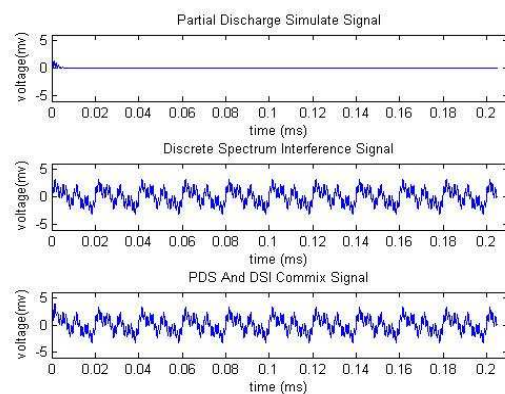
PD in gas insulation systems is more dangerous than in the solids, it could result catastrophic failures, SF6 (Sulphur hexafluoride) is mainly used for these insulations. It could be initiated in the GIS (Gas Insulated Substations) due to (i) roughness of electrodes (ii) free moving particles (iii) a fixed protrusion on the surface of the insulating barrier [13]. Outside the GIS a form of stochastic pulse shape noises occur is called as corona discharge. There is very much similarities to PD (of corona) in the time domain and frequency domain so it is difficult to distinguish. In case of XLPE (cross linked polyethylene) cables the experimental study is reported higher in number than online monitoring case. This is due to the many complications in the doing the task. The study reveals that PD can be discriminated in XLPE cables by producing the defects in fully shielded laboratories. It is being performed with the 115 kV/12kV distribution substations [18-20].

### 2.2 Measurement of PD

There are plenty of techniques available for the measurement of the partial discharges. It has got many efficient methods for its detection and measurement, like acoustical, ultrasonic effects instruments, ultra high frequency methods, radio frequency instruments, and many more. The selection of the measuring technique depends on the environment of occurrence, of partial discharge. The various conditions where a PD could happen are already discussed [21-26].

#### 2.2.1 Generation of PD Signal

The generation of partial discharge signal has been done here simple algorithm fig 2 and the obtained results are shown in the fig 3.



**Fig. 3 PDS and DSIS signals**

Here the waveform of Partial discharge signal and discrete spectrum signal has been obtained. As it is well known that PD signal is an impulsive response and occur in the systems for a small time, so it is very difficult to trace it. Hence, making a step ahead in this study can be useful to test the PD signal. The attained signal is shown in the fig.3. Here the first block represents the partial discharge signal which can be there in high voltage systems, this signal will not come in existence lonely i.e. there is always the presence of interference signal which is shown here as discrete spectrum interference signal (DSIS). The signal which is received by the primary sensor for partial discharge detection will be the combination of both of the signals (PDS & DSIS). This obtained commix signal of PDS & DSIS can be used for the study of parameterization and classification of partial discharges.

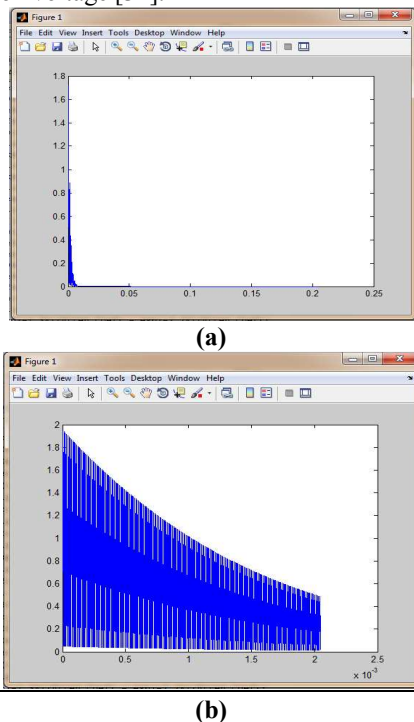
PDS (Partial Discharge Signal) is the combination of four different amplitude signals defined as s1, s2, s3, & s4. It uses the simple mathematical equations for the waveform representation of the signals with varying amplitude, they are like step signals.

DSIS (Discrete spectrum interference signal) is the combination of four different zigzag signals which ultimately forms an interference pattern shown in results. The two types of patterns are shown in fig.4, PD Pattern 1 & 2 represents the cases of PD occurrence due to voids and corona.

### 2.3 PD Pattern Classification

Pattern recognition is a process in which the given set of information is compared with some standard data. The decision will be taken on the basis of the matching of the standard data and the input data. The pattern which has to be recognized is already given to the system (recognizing tool). For this task, the input information is changed into many different forms which are acceptable to the recognition tool. For example, a picture has to be recognized or classified, that picture will be changed into its image components (pixels, color intensity, or any electrical quantity) and these values are kept as target for the recognizing tool. Then at the time of experimentation the target values are compared with the input values and simultaneously the output is presented [27-28].

For this PD pattern recognition, the signal of partial discharge is decomposed into various parameters. After the study of many papers it is observed that many times PD is measured and decomposed into  $(\Phi, q, n)$  three basic parameters. There are few more elements which are treated as statistical parameters for the study and classification purpose. Few of the statistical parameters are kurtosis (Ku), the discharge asymmetry- Q, the phase asymmetry-  $\alpha$ , cross-correlation factor-cc and so on. Total 37 operators form a characteristic vector, namely the PD fingerprint are used to detect the various PD signals. The fingerprint could be the input for pattern recognition system to identify the PD fingerprints.[29-31]. Sometimes the PD signal is modeled into PDIV and PDEV which stands for partial discharge inception voltage and partial discharge extinction voltage [32].



**Fig.4 (a) PD Pattern 1(b) PD Pattern 2**

### 3. ANN FOR PD RECOGNITION

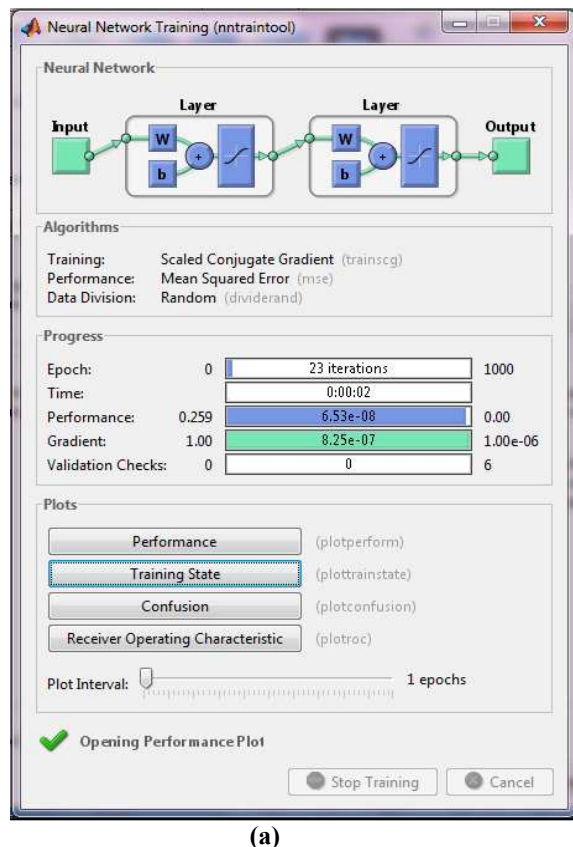
From the childhood, we are being taught many things, much stuff we learned intentionally or accidentally. We learn to speak, behave, write, calculate, etc. and this is all due to the learning ability of our brain. Our brain consists of thousands of biological neurons those are extended in all body parts making a nervous system. As this system works, it carries an electrical impulse which act as some information to brain, and on the basis of that information brain takes required action. In the same way we learned to recognize the various things like notebook, car, pen, etc.. The concept artificial neural network is completely based on the functioning of biological neural network which is not as complex as human nervous system but eligible to solve the various difficult and composite problems.

There are very much similarities in the signals of various partial discharges, corona discharges, and other noise signals, so, it is quite difficult to detect them with greater accuracy. Hence, there is a need of such a technology which can easily classify the various PD patterns. Artificial neural networks have the ability to learn from the examples so the purpose has been served and many destinations of it are achieved. The various studies have been made in this respect are mentioned here. As PD is a stochastic phenomenon it has its several types. They all are tested for their recognition like 11 well designed models are presented, in which 8 internal insulation model and they are collected by DJYC-1 digital recorder. They are classified by using Back Propagation Network [33]. The discharge in case of surface PD patterns relevant to the endurance of polymer films, are classified by the same technique [34]. After the measurement of PD by acoustic emission technique BPN is eligible to give 97% identification rate in a case study [35]. Phase resolved PD analysis, PHPD, FFT and many other techniques are applied and data is being fed into the Back Propagation network which delivered the profitable results [36-40]. Wavelet transforms is again a good technique which is used individually and sometimes in conjunction with NN techniques. There are two different approaches are available 1. 2-D wavelet transforms 2. Cross wavelet transforms (CWT) [41, 42]. The other famous techniques are Adaptive Resonance Theory (ART) [43, 44], Self organizing maps (SOM), Support vector machine (SVM) [45, 46], Probabilistic neural networks (PNN)[47, 48], Radial basis function (RBF) [49], Fractal image compression (FIC) [50], Fuzzy neural networks (FNN) [51], and Pulse Sequence analysis (PSA).

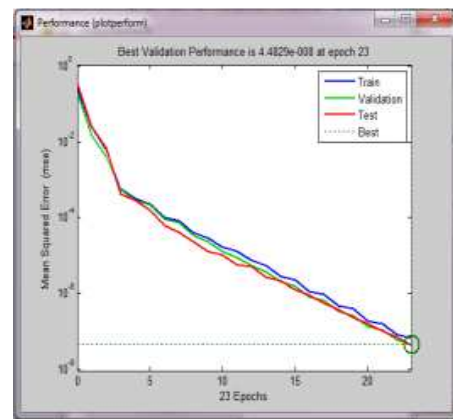
#### 3.1 Neural Network Training

For the recognition of partial discharge patterns the training of the neural network has to be done. As we know that the neural network learns from examples and this learning process is named as training of the neural network. For this purpose we already have obtained the 20 samples of each PD pattern(PD pattern1 & PD

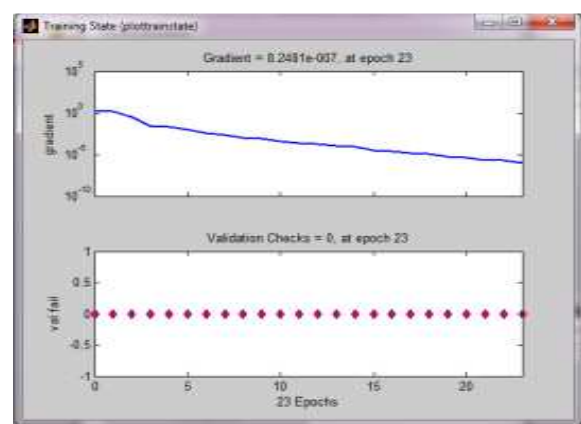
pattern 2). By using the Matlab actions we are able to get the mathematical values or features of the PD patterns. All these features are arranged in a matrix form named as Input matrix and test matrix. The data will be trained and it is compared with the allocated target values. Then the status of the training can be seen in nntool with its various facilities of plots. Thereafter a set of test signals (test matrix) is applied for the evaluation of the trained network which will again give the confusion matrix (explained below) of final output (tested data). The level of neural network training can be determined by examining the results shown in fig 5. For the training of the samples nntool uses the two layer feed forward network with sigmoid hidden and output neurons. The network is trained with the scaled conjugate gradient back propagation algorithm. As the confusion matrix shows that a 100% training of the network has been achieved, the 70% of the input data is used for the training, 15% of the input data is for the validation and the remaining 15% is for the testing of the network on the same time while training. This is the training of the network, but for the task of recognition the testing of the network has to be done. The testing of the network is obtained by applying the test matrix into the trained network and if the target response is matched with the output response then with the examination of confusion matrix shown in fig.6 it is observed that 100% of the recognition is done for the two different kinds of partial discharges.



(a)



(b)

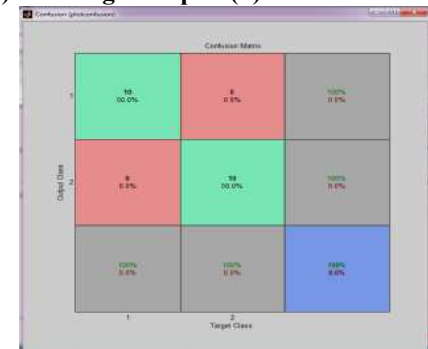


(c)



(d)

**Fig.5 Results after training of Neural Network**  
**(a) NN Training Tool (b) Performance plot**  
**(c) Training state plot (d) Confusion Matrix**



**Fig.6 Confusion matrix of the tested data**



#### 4. CONCLUSION

Partial discharge monitoring is key task for the long life of the plant or high voltage systems, so its level of performance should be as accurate and successful as possible. Pattern classification with efficient parameterization plays a good role in making the 100% satisfying results and all the discussed techniques are capable for the classification purpose but the efficiency is varied with all. This made some techniques widely usable, BPN is one the mostly used techniques till now. This work may be helpful for the basic introduction of the field of PD recognition with respect to ANNs.

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