



RADIAL BASIS FUNCTION NEURAL NETWORK FOR PARTIAL DISCHARGE IDENTIFICATION IN HV GIS

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Abstract

Gas Insulated switchgear comprise of many devices like circuit breaker, disconnecter, Current transformer, voltage transformer, busbars and bus ducts. The insulation defects in these devices can be identified by Partial Discharge (PD) monitoring and analysis. The analysis of PD includes detection, recognition & classification of PD using various advanced mathematical tools & techniques. In the artificial intelligence, radial basis neural network methodology in MATLAB is one of the most popular and widely used for the analysis of PD. This work represents the generation of the partial discharge with known defects in GIS like cavity in epoxy bushing, particle on housing, and free particle etc. the signatures are used for training, testing and identification. The obtained PD pattern represents the characteristics of Partial discharge signal and the discrete spectrum interference signal with it. The PD signal that occur during testing and service conditions can be identified by expert RBF NN Tool. The expert algorithm will reduce the time in finding out the actual root cause that is creating PD.

Introduction

The demand for Gas insulated switchgear has been increased drastically with growing world. GIS is based on the principle of complete enclosure of all energized parts in a grounded metallic encapsulation insulated with SF₆ gas. As on today there were many GISs installed in the world, the insulation is very important factor for life of equipment. So it is important to monitor the life of GIS by expert intelligent systems. Therefore, any defects that are introduced in GIS during manufacturing or operation affect and inhibit the full potential of GIS by affecting the insulation characteristics. As insulation failure usually starts with partial discharge (PD) activity; several studies have been performed to use PD measurements as a diagnostic method for detecting defects and preventing major insulation breakdown [1, 2]. PD activity in GIS can arise from protrusions on the conductor, free conducting particles, particles fixed on spacer, floating components and spacer defects such as void and detachment [3]. Metallic particles and spacer detachment are conceived to be the most well-known defects that can exist inside GIS. The extreme field intensity caused by these defects may produce PDs and eventual failure of the system especially under lightning surge condition. In recent years, the risk assessment of defects on PD monitoring has been eagerly demanded, and many studies have been conducted.

Partial discharge measurement is a useful insulation diagnosis method which has been widely applied to HV power equipments. It is an important tool for power apparatus, such as GIS, XLPE power cables, power transformers, etc. The main purpose of an insulation diagnosis for HV power apparatus is to give operator information on the degree of dielectric deterioration for equipment [4]-[6]. Commercial PD detector is used to measure the electrical or magnetic field variations in HV equipment, and provision of the 3D (n-q- ϕ) parameters. The main parameters of traditional 3D PD patterns are number of discharges n, discharge magnitude q, phase angle ϕ , these can provision of the basis parameters for PD recognition that can identify the different defect types [7, 8]. Neural networks (NN), because of their capacity for pattern recognition are candidates for realizing an automatic classification [9]-[11]. The advantage of NN is that it can directly acquiring experience from the training data.

In recent years, the radial basis neural network (NN) has become one of the main PD recognition methods. The basic idea is that a NN may learn the required input-output mapping information from a variety of examples. Comments on aspects of certain algorithms regarding their ability to rightly recognize new inputs are given. Problem arising from the existence of multiple defects in insulations and the difficulty of the PD recognition are discussed. The most time will be utilized in identifying the problem and to bring back GIS into service.

PD detection methods

Partial discharge is localized electrical discharge that only partially bridges the insulation between conductors and which can or cannot occur adjacent to a conductor. Partial discharges are in general a consequence of local electrical stress concentrations in the



insulation or on the surface of the insulation. Generally, such discharges appear as pulses having duration of much less than $1\mu\text{s}$. More continuous forms can, however, occur, such as the so-called pulse-less discharges in gaseous dielectrics [12].

PD Measurement Methods

Two types of methods are used for, measurement and analyzing the partial discharge, that occur in Gas insulated switchgears. The first one is direct measurement and the second is indirect method of measurement.

Indirect measurement: To detect PD inside GIS few indirect methods are used worldwide, acoustic method, visual or optical method, chemical detection method, radio disturbance meter method and UHF method. UHF method is mostly used method in detecting PD in GIS. The patterns for different defects are measured in this topic are by using UHF method.

UHF PD Detection Method: UHF sensors are mounted on GIS enclosures to detect PD; the data from sensors are connected to digital measurement system where PD pulses are seen on sinusoidal wave. The pulses are plotted with apparent charge “qi”, pulse repetition rate “n” and phase angle ϕ_i . The experimental setup for UHF method is shown “Fig. 1”. PRPD Patterns from digital measurement are considered for Neural Network recognition.

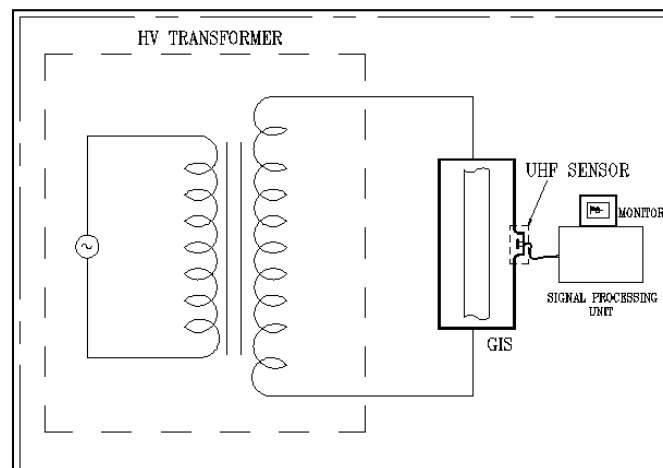


Fig. 1. Experimental setup for UHF PD detection

Direct measurement: In this method a coupling capacitor is used in parallel with test object to get the analog signal to coupling device. The data from coupling device is connected to Measuring instrument through connecting cable. The Measurement instrument displays the discharge pulses on a sinusoidal wave. The reliability of this method is high compared to other measurement methods [12].

Defects causing PD in GIS

In GIS mostly the defects occur during manufacturing of components like conductors, insulators, enclosures, and during the assembly of components. The defects in components like protruding tip on conductor, protruding tip on painted enclosure, protruding tip on unpainted enclosure, void inside epoxy insulation and during assembly the particles, foreign objects may enter inside, loose tightening of shields causes the PD inside GIS. In this topic the mentioned defects considered for PD analysis and their recognition.

Cavity inside epoxy insulation

The purpose of solid insulator in GIS is mainly to support conductors and as gas barriers between compartments. The material generally epoxy resin in moulded form. The void forms as manufacturing defect during the process of epoxy pouring. These voids generate PD during the GIS in testing or in service. Voids in solid insulation generate a confused pattern, containing pulses of both high and low amplitudes. Since a void may be thought of as an internal floating electrode, it can exhibit the phase synchronization typical of that defect. Positive identification of a void comes from the point on wave display of count rate, which appears as a wedge having a short front and long tail. If the internal discharges have sufficient energy, they will cause internal treeing in the insulation and this will eventually lead to complete internal breakdown. The PRPD pattern for cavity inside epoxy shown in “Fig.2”

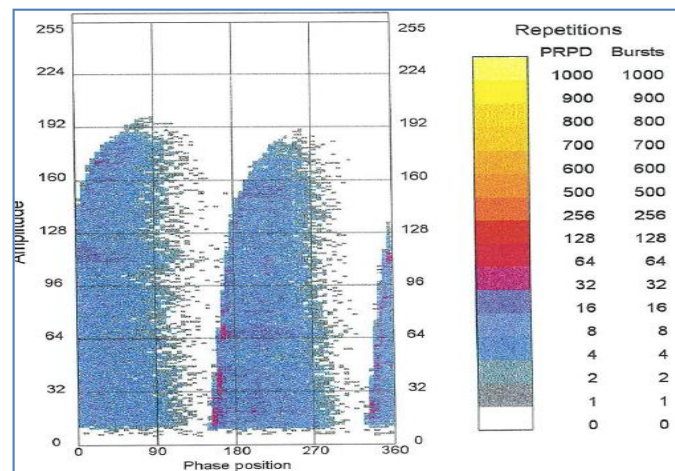


Fig. 2. PRPD Pattern for cavity inside Epoxy insulation

Floating conductors/shields

A floating electrode is a metallic component, such as a stress shield, that is not properly joined either to the HV conductor or earth. It becomes charged electrostatically by the alternating electric field and the voltage across the bad joint increases until the joint sparks over. This usually occurs at least twice per cycle; on the rising part of the positive half-cycle, and on the falling part of the negative half cycle. The typical pattern is formed because when the bad joint sparks over and then recovers, it leaves a charge trapped on the floating electrode and this determines the position of the next spark on the voltage wave. The floating electrode is very much larger than any other defect found in a GIS, and the capacitive energy stored by it, is very high. Although the high energy in the spark will not cause breakdown, it erodes the metal and many metallic particles are generated. These move around the chamber and eventually cause breakdown, especially if they become trapped on an insulating barrier. It may take many weeks or months until enough particles are formed for this to occur. The PRPD pattern for floating potential shown in "Fig. 3".

Jumping particle painted enclosure/unpainted enclosure

The particles inside GIS may be during assembly or may be generated during operation of active devices like circuit breaker, Disconnecter and earthing switches. A free metallic particle lying on the chamber floor becomes charged by the electric field, and is attracted upwards towards the HV conductor. First it stands on end, and appears to dance across the floor. Each time the particle touches the floor it assumes a new charge, which depends on the point on the voltage wave at which the contact occurs. This exchange of charge is the discharge pulse that is shown on the single cycle pattern. When the particle is dancing, it usually generates more than one pulse per cycle. However as the voltage is raised the particle jumps higher, and fewer pulses are formed. As the particle jumps higher and higher, there may be only one pulse in several cycles; and when it touches the HV conductor complete breakdown is likely to occur. The PRPD patterns for particles on painted/unpainted enclosure shown in "Fig. 4" and "Fig. 5" respectively.

Protruding tip on live conductor

The protrusion on conductors is due poor casting/machining finish. Inception corona is the first to appear. The pulses have very low amplitude, and occur on or soon after the positive peak of the voltage wave. Streamers are formed on the negative peak as the voltage is increased. They form a space charge cloud, which relieves the stress at the tip of the protrusion and prevents breakdown. This phenomenon is known as corona stabilization. Leaders are energetic streamers that become very hot and conducting. They occur at higher voltages, also on the peak of the negative wave, and are the discharges that develop into complete breakdown. These defects very rarely occur in GIS. The defects are identified as HV failure and can be cleaned or replace the conductors at the stage of manufacturing. Edge transition on outer radius causes HV failures or PD issues during routine testing or onsite testing. The PRPD pattern for protruding tip on conductor shown in "Fig. 6".

Conducting particle on spacer

The PD pulses due to particle on spacer are very low and identifying these type of defects are very critical. These particles react in lightning impulse condition or switching surge conditions[13]. The PRPD pattern for conducting particle on spacer shown in "Fig. 7".

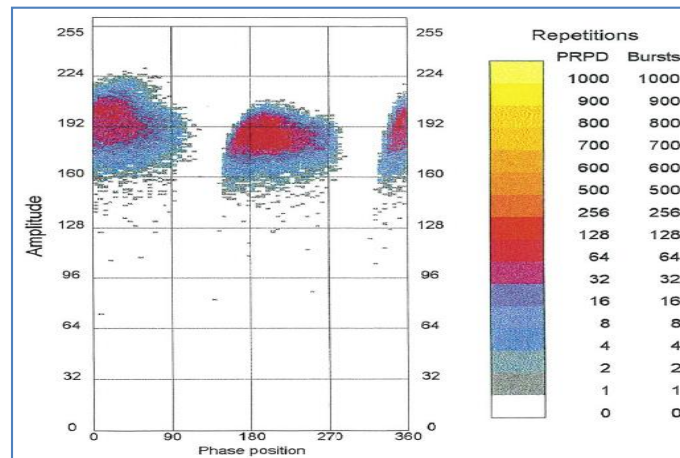


Fig. 3.PRPD Pattern for floating potential

Protruding tip on painted/unpainted enclosure

The protrusion on enclosures is due poor casting/machining finish. The PD pulses are high at positive and negative peak of wave. These defects react in lighting impulse condition or switching surge conditions. The PRPD pattern for protruding tip on painted/unpainted enclosure shown in “Fig. 8” and “Fig. 9” respectively.

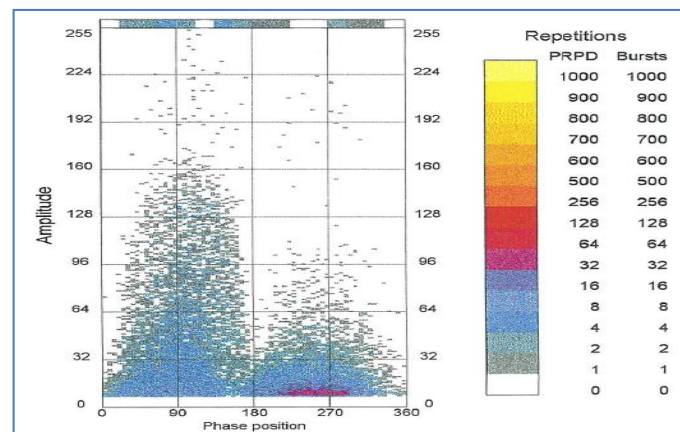


Fig. 4.PRPD Pattern for particle on painted enclosure

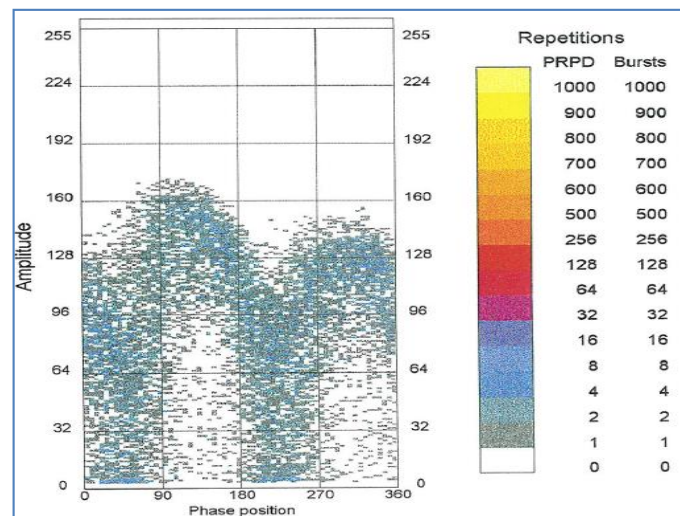


Fig. 5.PRPD Pattern for particle on unpainted enclosure

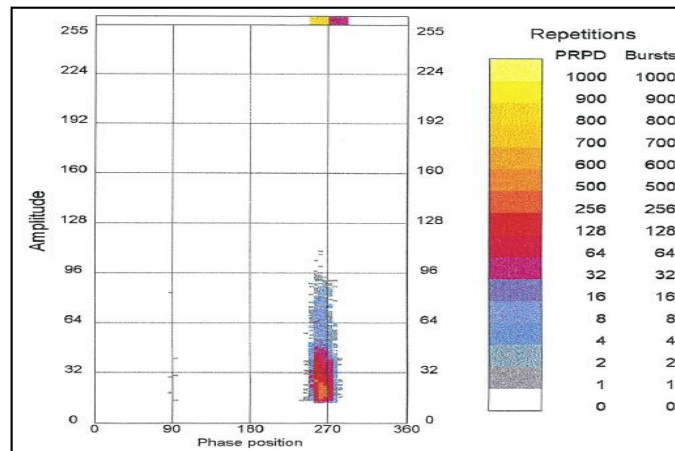


Fig. 6.PRPD Pattern for protruding tip on live conductor I.

RBFNN for a pattern 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. A total of 135 sets PD patterns for eight defects are measured for this study. We measured 12 sets of PD patterns for each GIS defect type. For PD recognition, we chose, at random, 10 sets of patterns as training data, and the remaining 5 sets of patterns were the testing data for each defect type

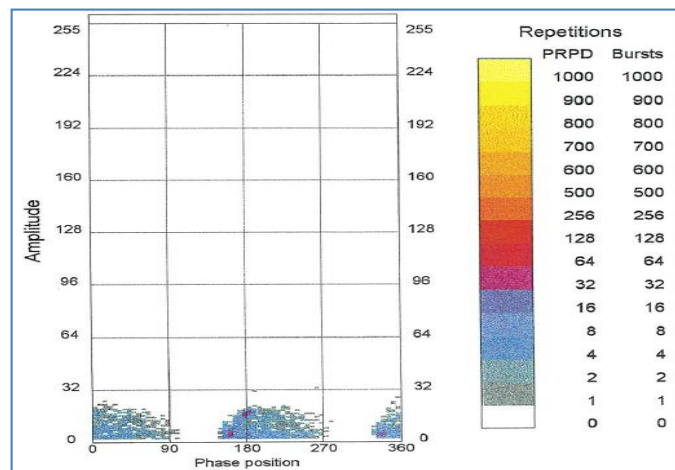


Fig. 7.PRPD Pattern for conducting particle on spacer

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 15 samples of each PD pattern. A sample two type of PD patterns uploaded in Matlab as image scanning function shown in (“Fig.10” & “Fig. 11”). 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.

Neural network validation

The trained network tested with giving input as one of the trained PD pattern and resulted in identifying the patterns with accuracy 99.99%.The results shown in "Fig. 12."

Neural network testing

Thereafter set of PD patterns are applied for the evaluation of the trained network which will give the results with identifying the applied PD pattern. The results shown in "Fig. 13."

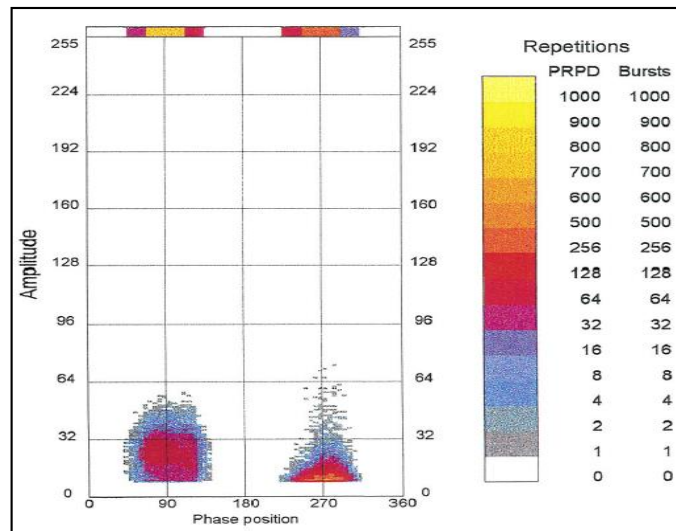


Fig. 8.PRPD Pattern for protruding tip on painted enclosure

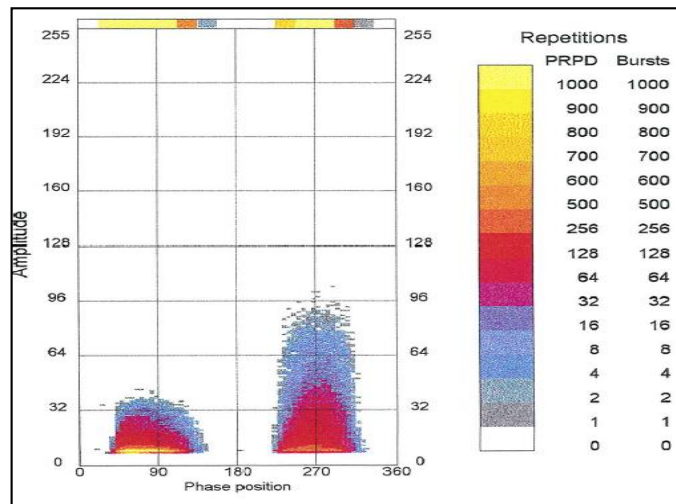


Fig. 9.PRPD Pattern for protruding tip on unpainted enclosure

data).The level of neural network training can be determined by examining the results shown in "Fig. 12". For the training of the samples nprtool 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 50% of the input data is used for the training, 50%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. 13" it is observed that 100% of the recognition is done for the two different kinds of partial discharges.

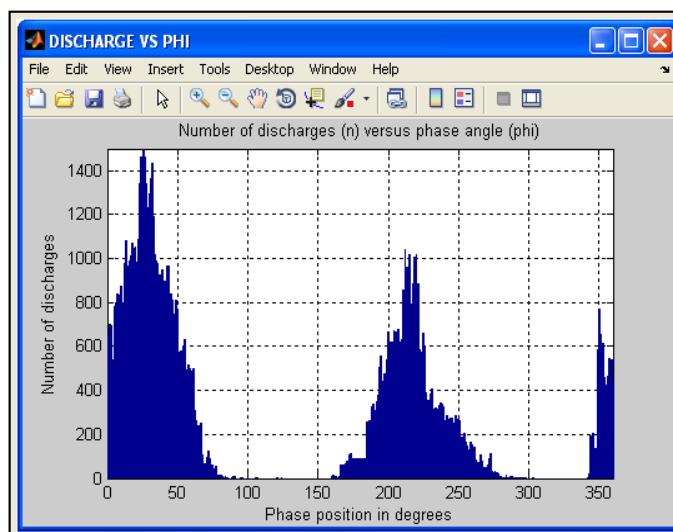


Fig. 10. Sample PD Pattern uploaded in Matlab showing (N-φ)

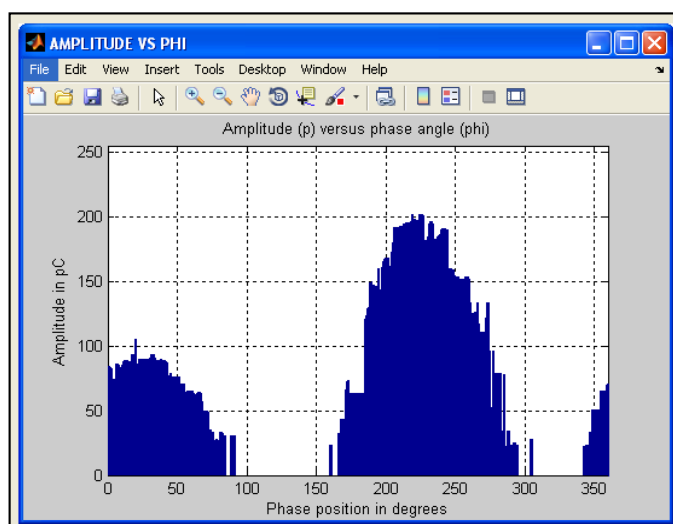


Fig. 11. Sample PD Pattern uploaded in Matlab showing (q-φ)

SAMPLE NO.1: Protruding tip on painted enclosure

Fig. 12. NN Validation result

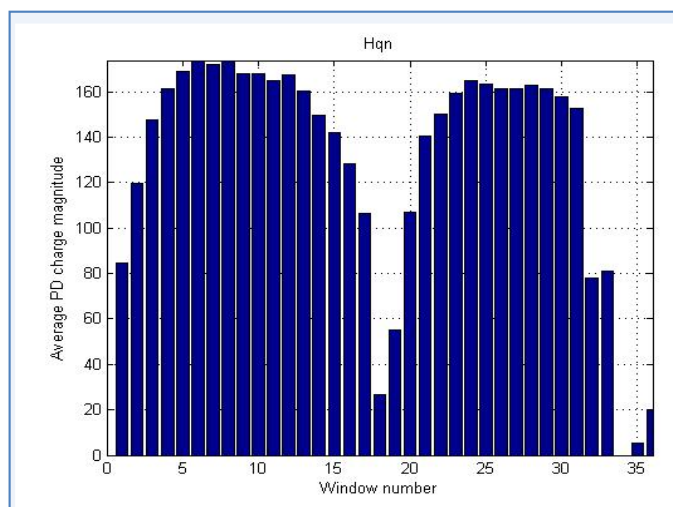


Fig. 13.a. Average PD Charge Magnitude

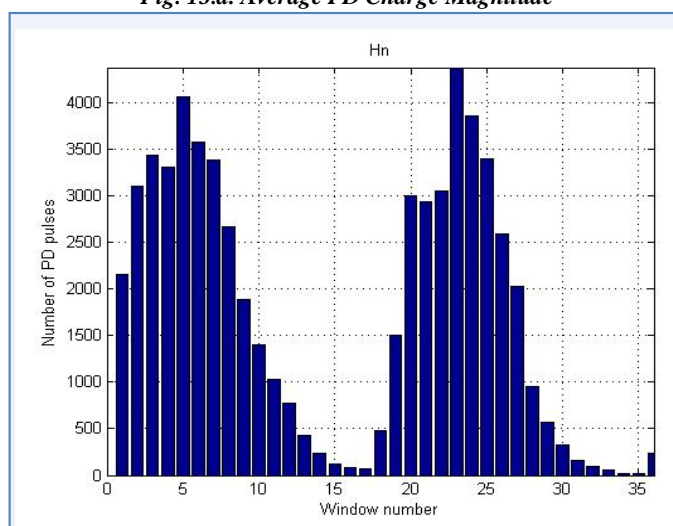


Fig. 13.b. Number of PD pulses

MEAN Hqn+ :143.4958.	MEAN Hqn- :115.6611.
VARIANCE Hqn+ :1497.6527.	VARIANCE Hqn- :3595.8488.
SKEWNESS Hqn+ : -1.7814.	SKEWNESS Hqn- : -0.90065.
KURTOSIS Hqn+ :5.677.	KURTOSIS Hqn- :2.2562.
STD DEV Hqn+ :38.6995.	STD DEV Hqn- :59.9654.
DISCHARGE ASYMMETRY :0.80602.	
CROSS CORRELATION FACTOR :0.80102.	
MOD CROSS CORRELATION FACTOR :0.64564.	

Fig. 13.c. Factors Evaluated

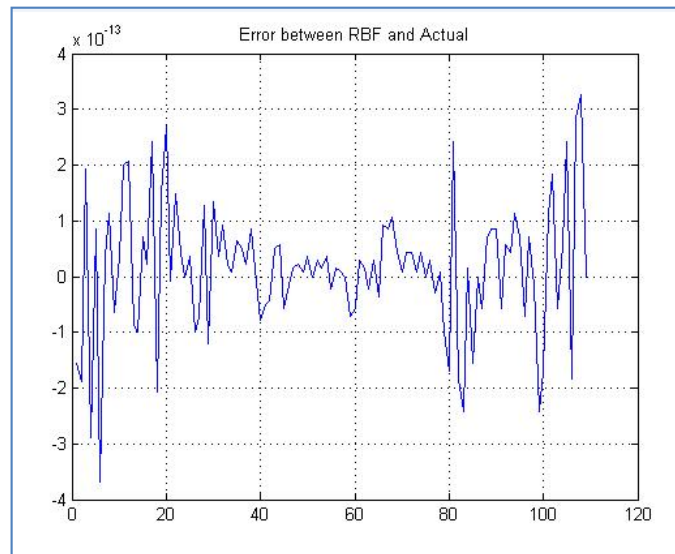


Fig.13. d. Error between Tested and Trained

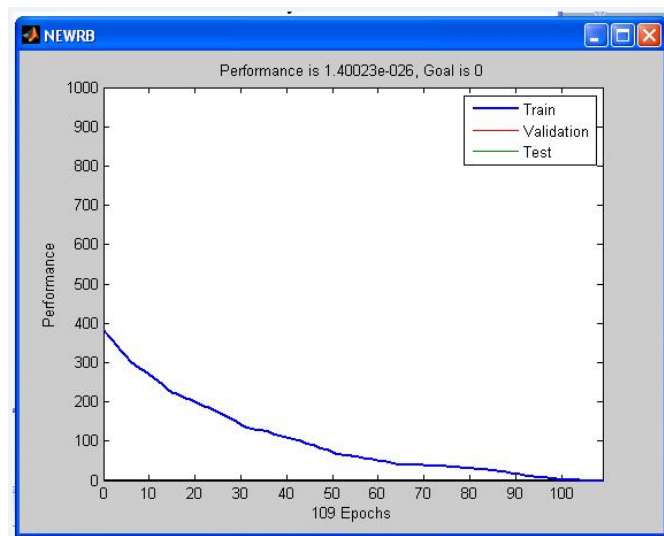


Fig.13. e. Performance plot

SAMPLE NO.1: Artificial Cavity

Fig. 13.f. Result Tested



Conclusion

This study building, defect model to simulate that may be caused by humans during GIS construction. PD measurement is a useful tool for insulation ability diagnosis. In this study, using the UHF sensor measures the current impulse cause by PD phenomenon, then transfer to 2D PD pattern. In 2D PD patterns we can found that the features difference between the defect models. Finally, PD pattern recognition based on NN method. The result shows the proposed method has high recognition rate. Moreover, this method is very simple and suitable application in other high voltage equipment, such as power transformer and power cable.

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