A Study on the Pattern Recognition Rate of Partial Discharge in GIS using an Artificial Neural Network

Yoon-Sik Kang† , Chang-Joon Lee*, Won-Jong Kang*, Hee-Cheol Lee* and Jong-Wha Park*

Abstract - This paper describes analysis and pattern recognition techniques for Partial Discharge (PD) signals in Gas Insulated Switchgears (GIS). Detection of PD signals is one of the most important factors in the predictive maintenance of GIS. One of the methods of detection is electro magnetic wave detection within the Ultra High Frequency (UHF) band (300MHz ~ 3GHz). In this paper, PD activity simulation is generated using three types of artificial defects, which were detected by a UHF PD sensor installed in the GIS. The detected PD signals were performed on three-dimensional phi-q-n analysis. Finally, parameters were calculated and an Artificial Neural Network (ANN) was applied for PD pattern recognition. As a result, it was possible to discriminate and classify the defects.

Keywords: PD, UHF, GIS diagnostic system, pattern recognition

1. Introduction

In the last thirty years, GIS have proven to be very reliable. Moreover, many GIS are installed at important nodes in the electricity grid. However, it is known that faults cannot completely be excluded and that the majority of faults that might lead to GIS failure demonstrate PD activity. Therefore, techniques to diagnose GIS failures are definitely required [1]. Condition evaluation of GIS can be performed by measuring its PD activity. One of the main advantages of the conventional PD detector is its very broad scale of experience and recently also the presence of digital tools related to phase-resolved PD recognition. However, due to external noise that is frequently present within the field, the use of a conventional PD detector is quite difficult. Therefore, UHF signal detection techniques that remain unaffected by background-noise have begun to receive wide recognition. In this experiment, IEC 60270 and UHF signal detection techniques were performed simultaneously. PD data was acquired by using an oscilloscope and data acquisition unit (DAU).

In this paper, we performed PD pattern recognition based on ANN technique, and presented the above pattern recognition rate.

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2. Experiments

2.1 Experimental setup

Fig. 1 shows the 362kV model GIS and internal type UHF PD sensor used in this experiment. This sensor was mounted on the hatch cover using a zeolite cover. This GIS has two inspection windows and two spacers. Also, the diameter of the inner conductor is 120mm and the diameter of the enclosure is 490mm. The UHF PD experiment system was composed of an AC 100[kV] transformer, a 1000:1 voltage divider, three kinds of artificial defects, a CT type PD sensor, a spectrum analyzer (Agilent 4402, 9kHz-3 GHz), an internal type UHF PD sensor, a pre-amplifier, a digital oscilloscope (Lecroy WM8300A) and PC, etc.

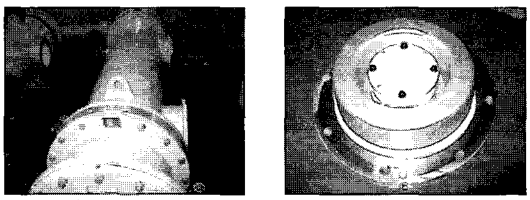
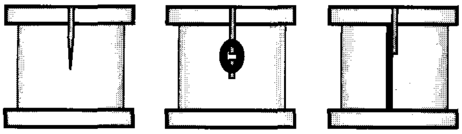


Fig. 1 362kV model GIS & internal type UHF PD sensor

2.2 Artificial partial discharge sources

To simulate partial discharge in the GIS, the following three types of PD sources were constructed. These artificial defects were recommended by CIGRE. Floating particles in the GIS enclosure can stick to an insulator if the HV conductor is not perfectly clean. To simulate this situation, a metallic particle of 10mm in length and 0.5mm in diameter was used. Protrusion with a length of 30mm was fixed to the HV conductor at the same location. Lastly, to simulate surface discharge, a metallic particle was placed on the insulator.



(a) (b) (c)

Fig. 2 Artificial defects used in the experiment:
(a) A protrusion fixed to the HV conductor.
(b) A floating particle using insulation material between HV conductor and enclosure.
(c) A fixed metal particle on the insulator surface.

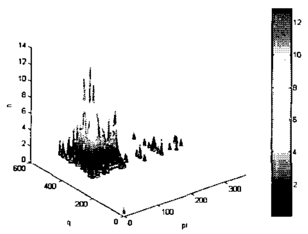
2.3 Measuring methods

The measurement frequency range of the UHF method extends up to about 1.5GHz, and detection methods can be distinguished between narrow and wide band measurement. In the case of narrow band measurement, bandwidth is 3MHz.

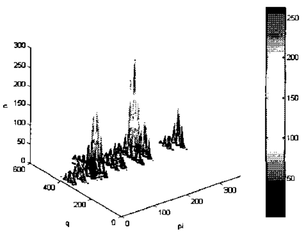
In this paper, we performed phi-q-n analysis using narrow band measurement, which has a center frequency of 490MHz and a frequency range from 300MHz to 1.5GHz.

3. PRPD pattern analysis

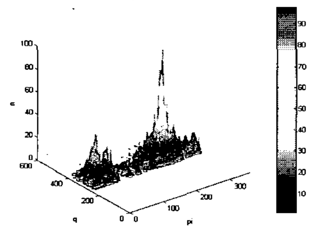
Fig. 3 shows the phi-q-n analysis examples of each signal source. Phi-q-n was performed for 60s and X, Y, Z axes in a three-dimension express phase angle [degree], magnitude [dBm] and pulse number [n]. Each of the phi-q-n parameters was stored in PC. These parameters were used for the pattern recognition of PD signals.

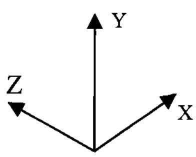


(a) Floating particle discharge



(b) Needle to plane discharge





(c) Surface discharge

Fig. 3 Examples of PD pattern made by three-dimensional phi-q-n analysis

4. PD pattern recognition methods

4.1 Detection parameter

Important parameters used to characterize the PD signals are selected as follows;
- Phase angle in degree
- Magnitude in q
- Repetition number in n

Patterns of PD signals were distinguished from these parameters, such as phi-q, q-n, phi-n patterns, etc. They are used for pattern recognition.

Table 1 shows the parameters that were used in phi-q-n analysis (back-propagation algorithm).

Table 1 Detection parameters (phi-q-n)

2D patterns	*Phi-q*		*q-n*	*phi-n*	
Skewness	+	-	.	+	-
kurtosis	+	-	.	+	-
Standard deviation	+	-	.	+	-
mean	+	-	.	+	-

+; positive half cycle, -; negative half cycle, . ; no polarity

20 parameters were used for phi-q-n analysis. These parameters were used for input of the back-propagation algorithm.

Each parameter of phi-q-n data was calculated as

$q_{\max}$: Peak of discharges

q_j : Magnitude of discharges

n_j : Number of discharges

$N_t = \sum_{j=1}^{I} n_j$: Total number of discharges

$\bar{q} = \sum_{j=1}^{I} q_j \cdot n_j / N_t$: Mean of discharges

$\delta_q = \sqrt{\sum_{j=1}^{I} (q_j - \bar{q})^2 \cdot n_j / N_t}$: Standard deviation

$S_q = \sum_{j=1}^{I} (q_j - \bar{q})^3 \cdot n_j / (N_t \cdot \delta_q^3)$: Skewness

$K_q = \sum_{j=1}^{I} (q_j - \bar{q})^4 \cdot n_j / (N_t \cdot \delta_q^4)$: Kurtosis

4.2 Artificial Neural Networks

The ANN has been explained in numerous other literatures. Therefore, only a brief outline of the ANN is given here.

Fig. 4 shows the schematic description of the ANN.

Each layer is fully connected to the succeeding layer. It is consisted of the input layer, at least one hidden layer and the output layer. The learning process used in this work was the back-propagation algorithm. This is a very commonly used learning method for ANN. The perceptron type of ANN was used, with three layers consisting of 15 to 20 units in the input layer, 20 units in the hidden layer and 3 units in the output layer.

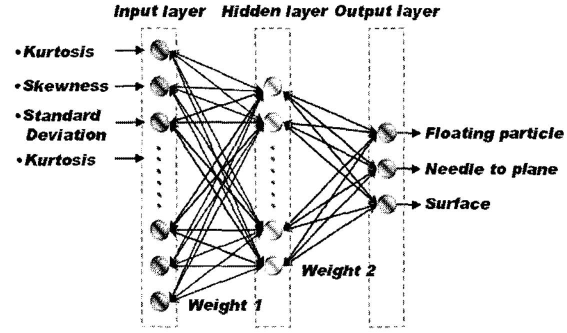


Fig. 4 Structure of the back-propagation learning algorithm

4.2.1 Pattern learning

There are several important parameters that determine the learning characteristics of the ANN besides the number of neurons in each layer. They have the initial connection factor and the learning factor. The former is a uniformly distributed random number from -0.5 to 0.5, and the latter is 0.001. The Sigmoid function was used as an Activation Function (AF). Also, pattern learning of the phi-q-n data was performed by the learning option that is shown in Table 2 and Table 3. This learning algorithm has three layers. The input layer for the phi-q-n data has 20 neurons, which represents the number of parameters for PD pattern recognition. The output layer has 3 neurons, which represents the number of PD sources.

Table 2 A list of learning options (a)

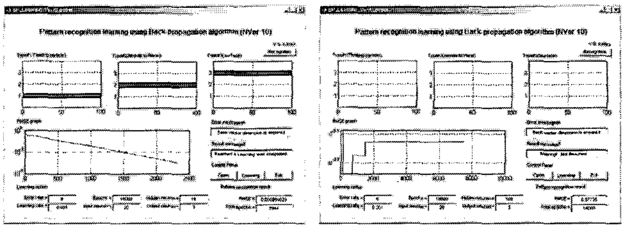
Learning option	*phi-q-n*
Error rate	*0*
Input/Hidden/Output layer	*1 / 1 / 1*
Input/Hidden/Output neuron	*20 / 10 / 3*
Learning rate	*0.001*
RMSE	*0.0001*
Default epochs	*10000*

Table 3 A list of learning options (b)

Learning option	*phi-q-n*
Error rate	*0*
Input/Hidden/Output layer	*1 / 1 / 1*
Input/Hidden/Output neuron	*20 / 100 / 3*
Learning rate	*0.001*
RMSE	*0.0001*
Default epochs	*10000*

Fig. 5(a) shows the result of pattern learning according to Table 2 for phi-q-n parameters. Learning results for the artificial defects were learned very definitely, and these results could be made by hundreds of trial and error processes.

Fig. 5(b) indicates the result of pattern learning according to Table 3. This ends in failure because of too many hidden neurons.



(a) Example of table 2 (b) Example of table 3

Fig. 5 Example of the learning result

4.3 Pattern recognition

Fig. 6 shows the structure of a recognition algorithm, which is similar to that of the learning algorithm.

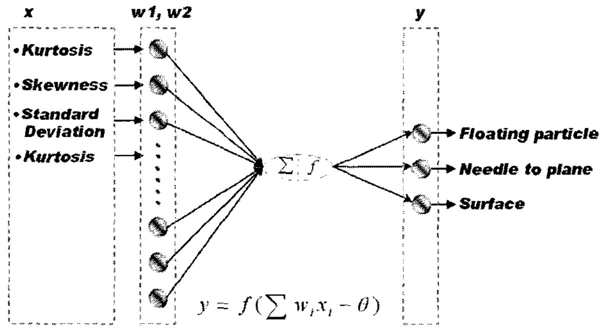
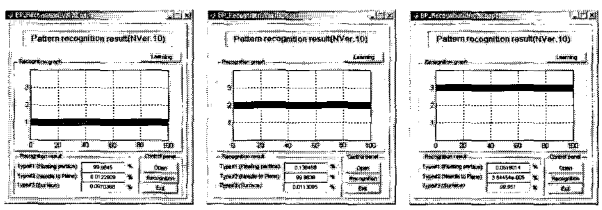


Fig. 6 The structure of recognition algorithm

Fig. 7(a) shows an example of pattern recognition result for a fixed protrusion discharge. Fig. 7(b) shows an example of pattern recognition result for a floating particle and Fig. 7(c) shows pattern recognition result for a surface discharge. All results were very good.



(a) (b) (c)

Fig. 7 Example of pattern recognition result

More than 300 PD signals were processed for pattern learning and recognition. Satisfactory results were obtained as presented in Table 4.

5. Conclusion

It was demonstrated that the back-propagation algorithm ANN technique could be applied effectively to precisely distinguish defect from PD signal data. It was also shown that pattern recognition technique using the ANN is another effective method for PD signal analysis.

Table 4 Recognition rate of phi-q-n analysis

Defect type	Recognition rate (%)	Average (%)
Floating particle	100	
Needle to plane	86	95.33
Surface	100	

Acknowledgements

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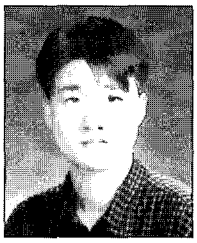

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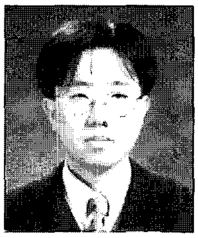

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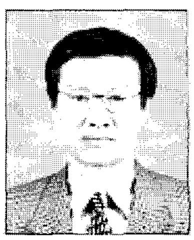

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