Comparison of Classification Rate Between BP and ANFIS with FCM Clustering Method on Off-line PD Model of Stator Coil

Seong-Hee Park† , Kee-Joe Lim*, Seong-Hwa Kang**, Jeong-Min Seo* and Young-Geun Kim***

Abstract - In this paper, we compared recognition rates between NN(neural networks) and clustering method as a scheme of off-line PD(partial discharge) diagnosis which occurs at the stator coil of traction motor. To acquire PD data, three defective models are made. PD data for classification were acquired from PD detector. And then statistical distributions are calculated to classify model discharge sources. These statistical distributions were applied as input data of two classification tools, BP(Back propagation algorithm) and ANFIS(adaptive network based fuzzy inference system) pre-processed FCM(fuzzy c-means) clustering method. So, classification rate of BP were somewhat higher than ANFIS. But other items of ANFIS were better than BP; learning time, parameter number, simplicity of algorithm.

Keywords: Partial discharge, BP, ANFIS, Clustering, Classification

1. Introduction

Recently, railroad system is attract public attention because of opening KTX and the current of the times higher reliability, safety and accurate on time. Stop operation of traction motor system occur variable path and these results caused the suspension of operation and delay on time of railroad system. But, traction motor of EMU(electric multiple unit) for high capability and high speed have some problem of insulation reliability caused by transient surge and partially over heating. Because these problems can make the degradation of insulation, finally, insulation failure can caused. This insulation failure can be occurred by PD from some defects of insulation of stator coil of traction motor.

PD(partial discharge) can give information on insulation degradation problem in stator winding of traction motor, since PD is a symptom of the most insulation failure mechanisms. Therefore as recognizing accurately a type of PD sources, we can obtain a great amount of information related maintenance and repair the train system[4,5,6].

Recently, diverse methods are introduced to distribute some PD patterns. This paper describes comparison of classification result BP and ANFIS performed preprocessing clustering method.

And this paper was made three defected PD occurrence models; void discharge of insulator, surface discharge, slot discharge. PD data acquired from PD detecting method(IEC 270) and calculated statistical distributions. And then we studied on PD distribution characteristics between three defected PD models. We used these characteristics as an input data of diagnosis algorithm for classification.

† Corresponding Author: School of Electrical and Computer Engineering, Chungbuk National University, Korea. (shpark1975@chungbuk.ac.kr)
* School of Electrical and Computer Engineering, Chungbuk National University, Korea. (kjlim@cbnu.ac.kr)
** Dept. of fire prevention Engineering, Chungcheong University, Korea .(shkang@ok.ac.kr)
*** LS industrial system .
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2. Comparison Architecture

2.1 Architecture of BP

BP algorithm is based on the MLP(multi layer perceptron). The MLP is a feed-forward network composed of organized topology of interconnected PE(processing elements). The architecture of the BP is shown Fig. 1. It consists of an input layer, output layer and one or more hidden layer Learning constitutes the means by which the neural network adapts itself to the desired output[1,5,6]. This adaptation is performed through a change in the weights, which gradually converge to values ensuring that each input vector produces the correct output. There are different learning procedures that dictate the neural on how to modify its weight in response to a certain stimulus. MLP's architecture is composed to forward propagation but BP learning method is composed to backward propagation. BP is an adaptive network whose nodes(or neurons) perform the same function on incoming signals; this node function is usually a composite of the weighted sum and a differentiable nonlinear activation function, also known as the transfer function. This network is trained in a

supervised learning method; it is provided with both input pattern and desired response. It then runs through a series of iterations. It compares its own output with the desired response. And then a match is computed; if then is match, no change is done to the network, otherwise the weights are modified using the gradient search technique to minimize the mean square error between the desired response and the actual output.

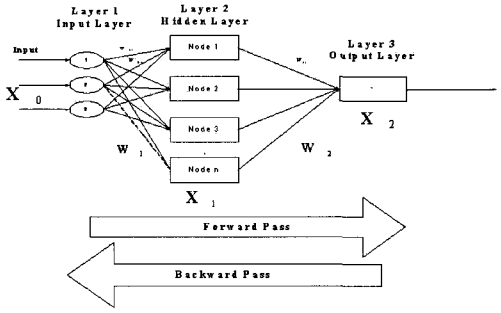


Fig. 1 Architecture of BP

2.2 Architecture of ANFIS preprocessed FCM clustering

The architecture and learning procedure underlying ANFIS(adaptive-network-based fuzzy inference system) is presented, which is a fuzzy inference system implemented in the framework of adaptive networks. By using a hybrid learning procedure, the proposed ANFIS can construct an input-output mapping based on both human knowledge and stipulated input-output data pairs. An adaptive network is a multilayer feed-forward network in which each node performs a particular function on incoming signals as well as a set of parameters pertaining to this node. The formulas for the node functions may vary from node to node, and the choice each node function depends on the overall input-output function which the adaptive network is required to carry out[3,6].

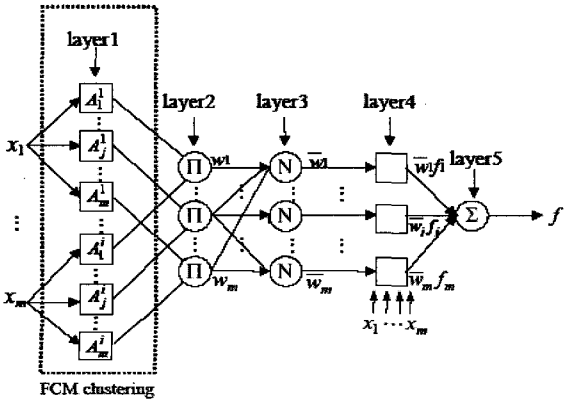


Fig. 2 Architecture of ANFIS

Fig. 2 shows the architecture of ANFIS used in this paper. It is important that FCM clustering was adapted before ANFIS learning process. Using the rule of clustering can maximize learning process and result.

3. Experimental

3.1 PD model

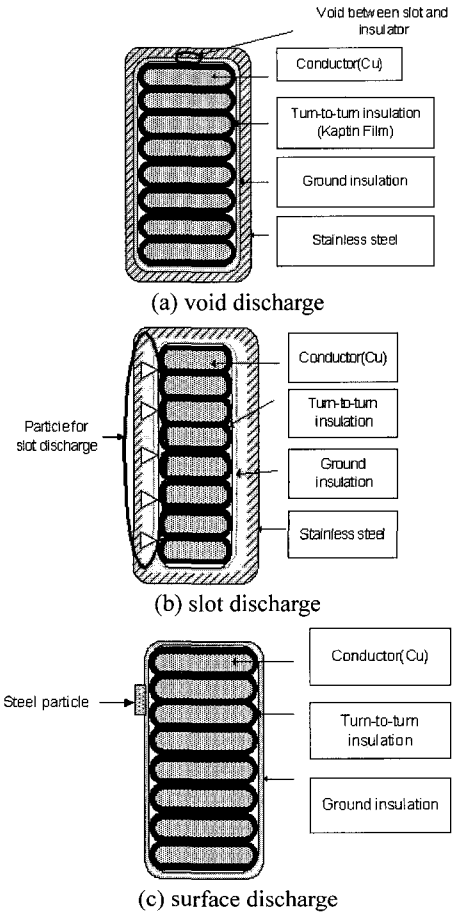


Fig. 3 PD model

Fig. 3 shows the stator coil shape of traction motor and cross sectional view of specimens on three models. Specimens are made with resin of polyamide and silicon and processed by VPI(vacuum pressure impregnation).

3.2 Test procedure and data processing

PD signals were collected with the PD detector system(Biddle instrument, AVTM 662700Ja), which is a computer controlled system for PD data acquisition and analysis. According to IEC 270, the PD pulses are integrated where the maximum value of the integrated signal is proportional to the apparent charge. Fig. 4 shows block diagram of PD data acquisition.

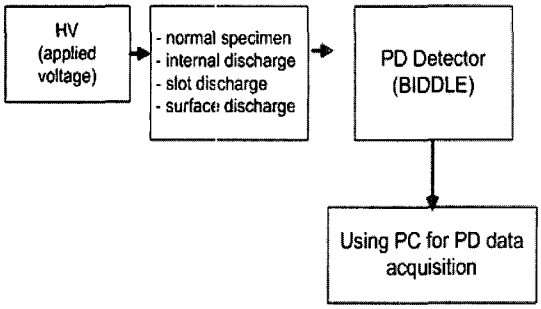


Fig. 4 Block diagram of test procedure for acquisition of PD data

This paper used calculated statistical distribution from original PD signal as input data of BP and clustering scheme. So, Fig. 5 shows procedure of PD data for acquiring statistical distribution.

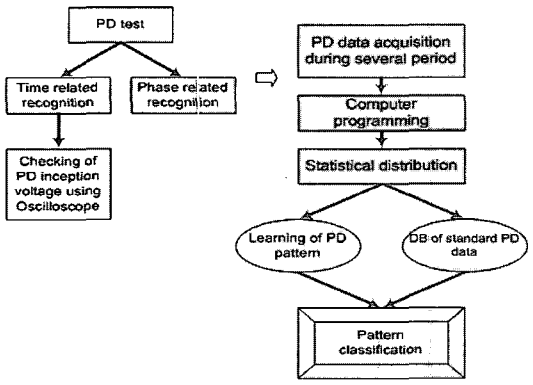


Fig. 5 Block diagram of PD data process

4. Experimental

4.1 Distribution of PD signal

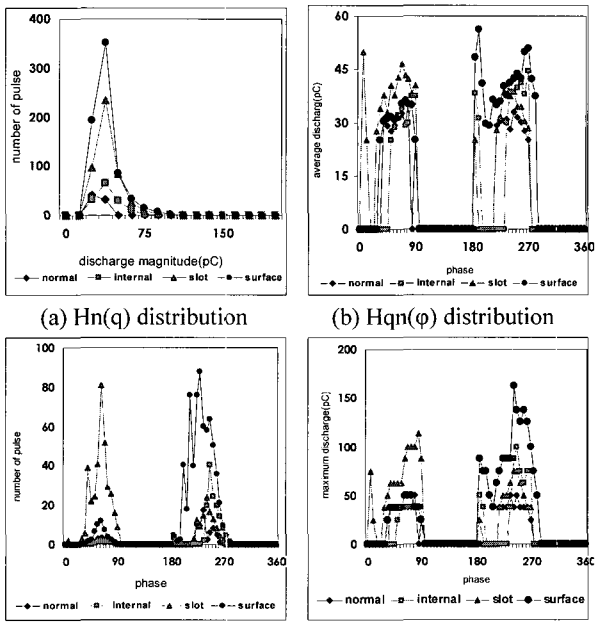
The relationship between PD magnitude and intensity as related to PD phase angle can be displayed using two or three dimensional pattern. In general, for convenience of comparison, two dimensional distributions have chosen to use. In this paper two dimensional distributions are used to recognize PD. And BP network is applied to learning scheme. These distributions were derived from statistical distributions of individual PD events by taking appropriate averages. Three dimensional distribution is ϕ(phase) - q(discharge magnitude) - n(number of pulse). And two dimensional distributions are q-n, ϕ-q_a(average discharge magnitude), ϕ-n, ϕ-q_{max}(maximum discharge magnitude) distributions. Two dimensional distribution can be presented by four types; Hn(q), Hn(Φ), Hqn(Φ) and Hq(Φ).

Hn(q) distribution is present pulse count distribution which represents the number of observed discharges in each discharge magnitude.

Hn(Φ) distribution is present pulse count distribution which represents the number of observed discharges in each phase window as a function of the phase angle.

Hqn(Φ) distribution is present the mean pulse height distribution which represents the average amplitude in each phase window as a function of the phase angle

Hq(Φ) distribution is present the maximum pulse height distribution which represents the maximum amplitude in each phase window as a function of the phase angle. Fig. 6 is present two dimensional distribution from Φ-q-n distribution.



(a) Hn(q) distribution (b) Hqn(φ) distribution

(c) Hn(φ) distribution (d) Hq(φ) distribution

Fig. 6 Distribution of PD signal

Hn(q) distribution is present surface discharge characteristic bigger than other discharges.

Hqn(φ) distribution is similar to all discharge sources, but surface discharge little more than other discharge in the negative period.

Also, Hn (φ) distribution is in negative period surface discharge presented remarkably than other discharge. But, in positive side, slot discharge remarkably big value presented.

Finally, Hq(φ) distribution is similar characteristic to Hn(φ) distribution.

Surface discharge and slot discharge are remarkably presented on PD magnitude and number of PD pulse. Void discharge has very small value than two discharge sources. In this paper we used q-n, ϕ-n distributions as an input data of BP learning algorithm because these distributions have good information on PD phenomena.

5. Comparison of two methods

5.1 Classification result of BP

The patterns of the surface discharge and slot discharge remarkably are differed from those of other discharge sources as PD characteristics. This is readily discernible from Fig. 7 and 8. Fig. 7 shows RMSE(root mean square error) variation value during processing learning discharge pattern. And Fig. 8 shows training result and classification result among four patterns. During the training process, this output is forced to be equal to '0', '0.3', '0.5' and '0.8' for the case normal discharge, internal discharge, slot discharge and surface discharge. Between these total pattern, 50 patterns have been used in the training data, the remaining 50 patterns are used in classification data. At the end of the learning process, the network is successful in dis-criminating between four different discharge sources of the coil with success rate of 100% on both the training and classification data. As a result of learning process, the learning capability of the NN with BP is excellent in this case.

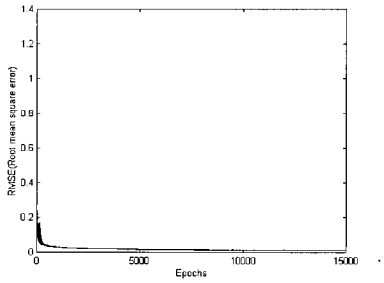
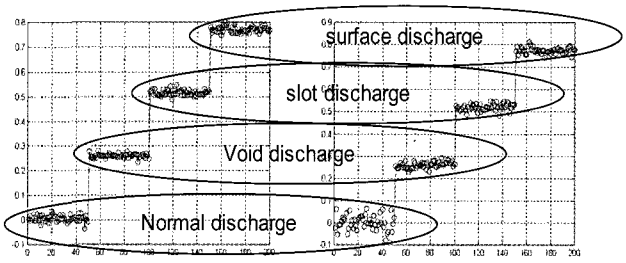


Fig. 7 Distribution of PD signal



(a) training result (b) classification result

Fig. 8 Distribution of PD signal

5.2 Classification result of ANFIS with FCM clustering

Fig. 9 shows the classification result of ANFIS with FCM clustering. This scheme performed clustering method before learning process. Also, input data was used statistical distribution. This output is forced to be equal to '0', '0.3', '0.5', and '0.8' for the case normal discharge, internal discharge, slot discharge and surface discharge same BP learning process. Between these total pattern, 50 patterns have been used in the training data, and the remaining 50 patterns are used in classification data. ANFIS with clustering method is successful in discriminating among four different discharge sources of the coils with a success rate of 98% on classification data.

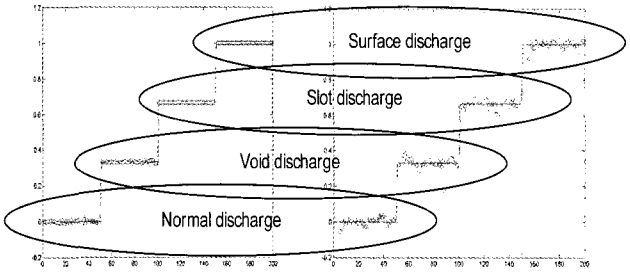


Fig. 9 Classification result of ANFIS with clustering

The most difference of two systems is division method of data sets. As method of division, BP used the linear range between data sets, and ANFIS with FCM clustering use their characteristics of data sets. That is, ANFIS with FCM clustering is superior to BP as a view application.

Classification result is present almost same rate of 100%. So, for the comparison of two methods need another items; learning time, parameter number, application capability on field, simplicity of algorithm, and so on. Table 1 shows comparison result of these items. In conclusion, ANFIS with clustering have more merits than BP. It is that clustering before learning system can make comparably clear data set. Because of these results, learning algorithm the ANFIS is more simply and speedy when learning process than BP.

Table 1 The caption must be followed by the table

	BP	ANFIS with clustering
Classification rate	100%	98%
Learning cycle (Learning time)	Above 1,000	Need just one time
Parameter number	Many	Many (need if – then rules)
Application capability on field	Good	Good
Simplicity of algorithm	complexity	simplicity

6. Conclusion

In this paper describes comparison of BP and ANFIS with FCM clustering. As a result we meet the following conclusion.

1) Classification result is BP better than ANFIS; BP is 100% and ANFIS is 98%.

2) Other items for the comparison, ANFIS with FCM clustering is superior to BP network.

But, these results are not absolutely standard as a application of classification PD sources. Application on field is more difficult and needs many consideration thing. So, it is important that research on these applications will perform now.

Acknowledgements

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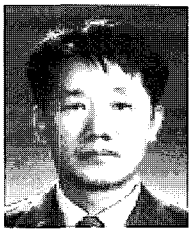
Seong-Hee Park
He received the B.S and M.S in the department of electrical engineering from Chungbuk National University in 2000 and 2004, respectively. He is currently process of doctor's degree in the electrical engineering from Chung buk National University. His research interest is high voltage, electrical equipment and PD phenomena.



Seong-Hwa Kang
He received the B.S, M.S and ph. D. degree in the department of electrical engineering from Chungbuk National University in 1987 and 1989 and 1997, respectively. He worked as a researcher at KAITECH(Korea academy of Industrial Technology) in 1991 to 1993. And also, he worked with Prof. M. Zahn as a visiting scientist of high voltage laboratory of MIT in US in 1998 to 1999. He has now worked as an associate professor at Chungcheong College.

Kee-Joe Lim
He received his B.S., M.S., and Ph.D. degree in electrical engineering from the College of Engineering in Hanyang University. From 1977 to 1981, he was with the Agency for Defense Development, Korea, where he designed airborne telemetry system. He joined the School of Electrical and Computer Engineering at Chungbuk National University in 1981. He is currently working on insulation diagnostic technique in power apparatus, piezoelectric ceramics and its applications, and flat panel displays including OLED and backlight for LCD. Professor Lim is a member of the KIEE, KIEEME and IEEE. He is vice-president of KIEE.

Jeong-Min Seo
He received the B.S in the department of electrical engineering from Hanyang University in 1982. And he received the M.S in department of electrical engineering from Chungbuk National University in 2000. He have been worked as a researcher at LS industrial system from 1982 and he is currently process of doctor's degree in Chungbuk National University.

Young-Geun Kim
He received the B.S in the department of electrical engineering from Hanyang University in 1988. And he received the M.S in department of electrical engineering from Chungbuk National University in 2000. He have been worked as a researcher at LS industrial system from 1988 and he is currently process of doctor's degree in Chungbuk National University.

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