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Development of Insulation Degradation Diagnosis System for Electrical Plant

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Abstract

Insulation aging diagnosis system provides early warning regarding electrical equipment defects. Early warning is very important in that it can avoid great losses resulting from unexpected shutdown of the production line. Since relations of insulation aging and partial discharge dynamics are non-linear, it is very difficult to provide early warning in an electrical equipment. In this paper, we propose the design method of insulation aging diagnosis system that use a electromagnetic wave and acoustic signal to diagnose an electrical equipment. Proposed system measures the partial discharge on-line from DAS(Data Acquisition System) and acquires 2D patterns from analyzing it. For filtering the noise contained in sensor signals we used ICA algorithms. Using this data, we design of the neuro-fuzzy model that diagnoses an electrical equipment and is investigated in this paper. Validity of the new method is asserted by numerical simulation.

Key words : ICA(Independent components analysis), IDDS(insulation Degradation Diagnosis System), Neuro-fuzzy model, Ultrasonic waves, Electromagnetic waves, Acoustic emission(AE)

I. Introduction

Since every system in industrial fields becomes autonomous by using FA and CIM technology, electrical machinery is in increasing demand and capacity is growing powered. Insulation breakage due to overload and insulation degradation in high- voltage electrical equipment such as PT, CT and transformers can cause fatal accidents in working autonomous systems. Insulation degradation occurs due to uneven distribution of electrical fields and the existence of internal voids oriented from poor production technology in insulation and molding. As insulation material deteriorates, electrical and mechanical characteristics are no longer controllable, which may result in accidents. It is well known that partial discharge is closely related to insulation degradation that is the main cause of failure in high-voltage electrical equipment. many researchers report that the persistent observation of partial discharge is effective in insulation degradation diagnosis[1-5]. Detection for partial discharge in electrical equipment has been suggested by many researchers-detection of electrical current pulse produced by partial discharge using the Rogowski coil, measurement of electromagnetic waves, and detection of Acoustic waves. Even in practical diagnosis by observing partial discharge, it is difficult to define the standard for insulation degradation steps and to classify degradation status according standards due to the complex mechanisms involved. 3D patterns(phase, magnitude, count) of partial discharge have been used to for the evaluation of the relationship between partial discharge and insulation degradation status, but its direct application needs expert knowledge. Thus, it is necessary to investigate parameters for automatic recognition inference.

The study of diagnostics for insulation degradation has concentrated on the investigation of new analysis method in PD(Partial Discharge) and its application to the development of practical diagnosis.

First, the literature reported the 3D pattern. In 1992, L. Satish suggested 3D pattern of partial discharge by the acquiring current waves produced by PD. This is the first pattern recognition method applied to PD. This method made analysis more complex but provided more information about PD, thus expanding the scope of analysis[6-9]. In 1992, M. Kosaki suggested a new parametric method and in 1993, G. Zingales proposed the standardization of 3D pattern of PD. Second, the literature focused on the design of dedicated digital system. In 1993, E. Gulski reported the computerized method dealing PD in high-voltage equipment and announced computer-aided systems[10-12]. Third, the literature suggested estimation methods for the insulation breakage point based on accelerated experiments. In 1992, H. suzuki at Hitachi Cable Company reported diagnostic results predicting the insulation breakage point in transformers. In 1993, J. Fuhr investigated the recognition of insulation defects in transformers. Fourth, the literature tried artificial intelligence in the study of PD evaluation, many researchers applied back-propagation learning algorithms in artificial neural networks to get optimal inference instead of using complex mathematical equations. Recent literature studied diagnostics that measured Acoustic

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waves and electromagnetic waves generated by PD correlated data to known insulation degradation[13-5]. Previous methods had difficulties in field testing since dynamic characteristics of insulation degradation are highly nonlinear and not easily modeled. Further more, they need more complex, precise, costly hardware. To remedy of the problem, this paper suggests a neuro-fuzzy diagnostic model for insulation degradation of 2D trend data pattern of Acoustic and electromagnetic waves signal based on load current in electrical plant.

In this paper, we propose diagnosis system that define abnormal status of objective power plant on site, and we propose ICA algorithms to filter the noise signals.

II. The framework of experiment equipment

The framework of signal measurement equipment, is shown in Fig.1, consists of wide broad antenna and Acoustic sensors, pre-AMP, signal analyzer, main computer(PC). Wide band antenna is used to measure wide frequency ranges from 10KHz to 500MHz. The signal is sent to analyzer through cable-net after the weak signals received in antenna is amplified in wide band pre-amp. This signals are analyzed in analyzer, and then analyzed data is sent to main computer through LAN-cable. Characteristics data are classified in main PC. In Fig.1, experiment equipment is constructed at 3M the front of the transformer for measuring electromagnetic and acoustic waves .

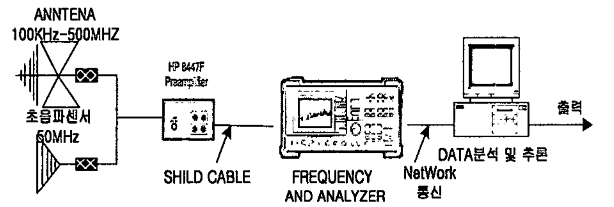


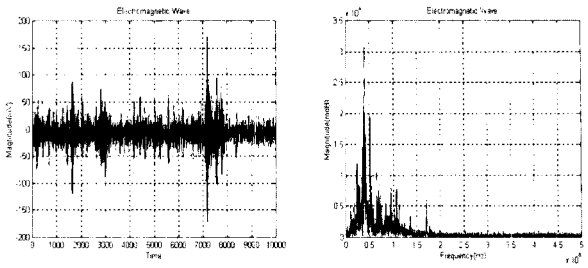
Fig. 1. Structure of Electromagnetic and Acoustic measurement system

In this experiment, we analyze the distribution status of signals on frequency band and classify the distribution patterns. This results is used to make configuration sheets of diagnosis system.

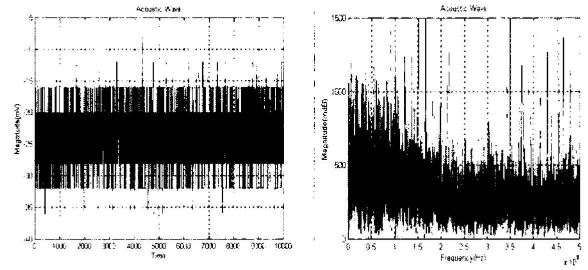
III. Experiment and consideration

3.1 Quantitative analyzation of signals

Experiment results are shown in Fig.2. Sampling Time is 5 second. Unit is [dB](RMS) in electromagnetic waves signals and it is [mV] in Acoustic waves signals. We show that these signals are distributed on frequency band from 10[KHz] to [500MHz] and can find that hard variation in data trend is appeared. The signals value of Acoustic waves is sensitive of mechanical vibration. In particular, it is sensitive of a variation of power plant load and an air condenser vibration. To solve this problem, we take moving average and ICA algorithms the signal data. This result is shown in Fig.3. and Fig.4.



a) Electromagnetic Wave Signals



b) Acoustic wave Signals

Fig. 2. Row Data trends

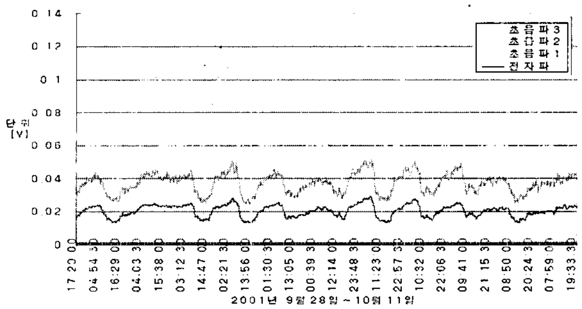


Fig. 3. Trend after Moving Average

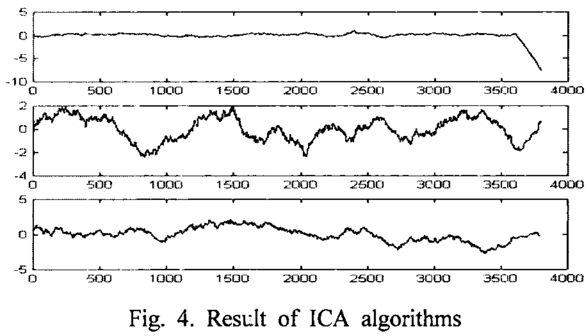


Fig. 4. Result of ICA algorithms

In Fig.3, the trends of acoustic signals coincide with the trend of electromagnetic signals. To filter off noises in partial discharge signals radiated from PD, source signals were analyzed by using ICA algorithms and moving average. Fig.3 is trend of source signals analyzed by moving average and Fig.4 is it's results.

In Fig.4, first trend data is selected for insulation degradation diagnosis. Fig. 5 and 6 show the trend of data for one week and 3 weeks.

Fig.7 shows the trend of data from 22-Feb-2001/15:13:21 to 09-Mar-2001/09:29:18 that is analyzed by using

ICA algorithms. We can find out noise data that is second line.

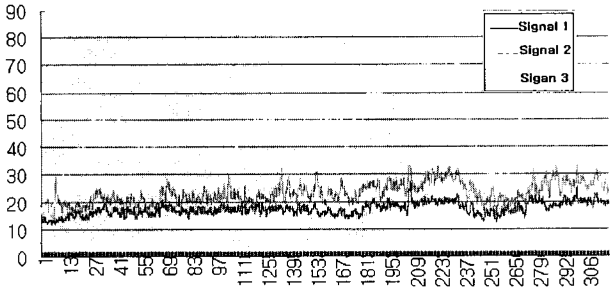


Fig. 5. Trend from 22-Feb-2001/15:13:21 to 26-Feb-2001/ 09:27:58(Acoustic Signal)

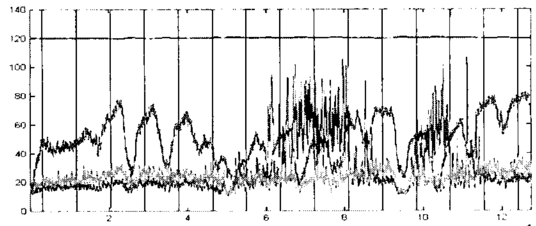


Fig. 6. Trend from 22-Feb-2001/15:13:21 to 9-Mar-2001/ 09:29:18

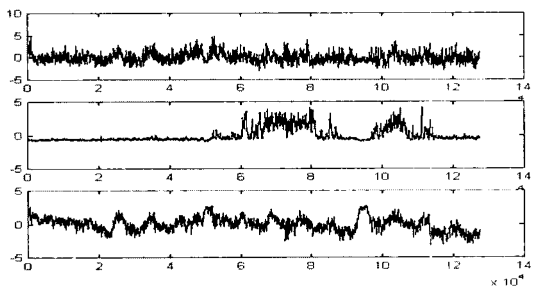


Fig. 7. Analyzed Signal by using ICA Algorithms

If we can compare the acquired data with operating condition(load current), in conclusion, we meet with good results that we can diagnose the power plant. Fig.8, shows 2D characteristic data(Frequency band, Radiation magnitude) that can be used to diagnose the power plant.

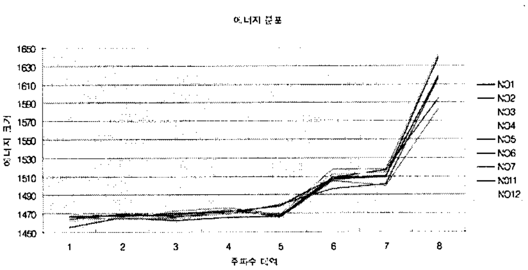


Fig. 8. 2D characteristic data of transformers

Fig.8 is 2D characteristic data of transformers. Frequency band is divided 8 separation range from 10[MHz] to 1[GHz]. We can see that every 2D Characteristic data of 9 transformers has different characteristics.

3.2 Design of IDDS

Fig.9 is a flow diagram of IDD(Insulation Degradation Diagnosis) algorithms that is the flow of analyzing algorithms of characteristic data and inference model. As Fig.9, input interface device is data acquisition system, input data of inference system(Diagnosis Fuzzy model) is quantitative data and expert's knowledge.

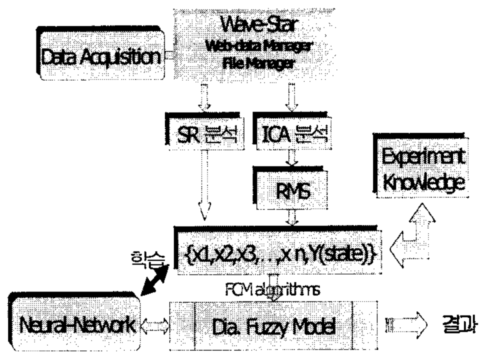


Fig. 9. Flow-Diagram of Insulation Degradation Diagnosis algorithms

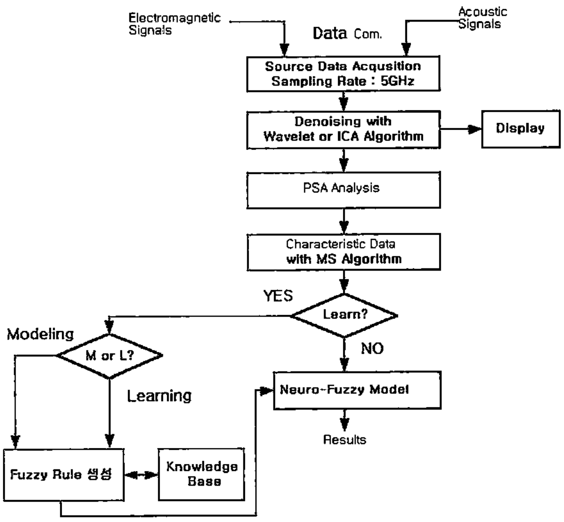


Fig. 10. Flowchart of Diagnosis Algorithms

We get the input vector in quantitative analysis that is X([x1,..,x9],x1:SR (square root) value, x2-x9:2D data). We learned the diagnosis model with the input vectors. Diagnosis algorithms is as fallow

1 step. start algorithms
2 step. calculate the square root value of signals.
3 step. analyze the signal with ICA algorithms

4 step. analyze the signals with PSA(power spectrum analysis) to acquire 2D data.
5 step. infer ID status with neuro-fuzzy model.
6 step. stop algorithms

Fig.10 shows the flow-diagram of diagnosis algorithms. If you are interested in ICA algorithms, then you can refer the reference papers[16,20].

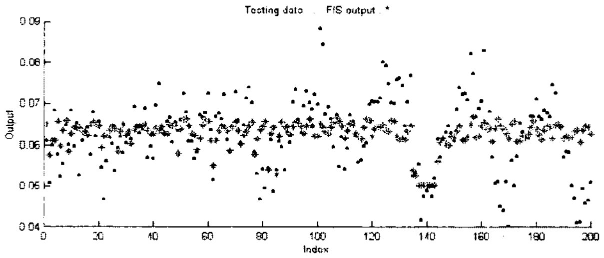


Fig.11 Results of Diagnosis simulations

IDD model is constructed by using ANFIS(Adaptive Neuro Fuzzy Inference System)[12].

This model is evaluated with experiment data, and this result is shown as Fig.11. As a result, inference error is there about +,-10%.

IV. Conclusion

In general high-voltage electricity handling, it is difficult to reliably manage the status of insulation degradation. There are many problems applying conventional methods since they are offline methods that shut down power, stop production lines and still need positioning measuring devices properly. In previous methods, the system configuration is complex to measure many variables and costly. Many researchers suggest solution to these problems and come up with almost practical systems using 3D methods, frequency-analysis, and tree analysis based on fractals. These methods still have problems because phase variable measurement needs more complex systems, PD is discontinuous, frequency(10 KHz-10GHz) is too broad to measure reliably, and systems are costly. To solve these problems, this research suggests the possibility of diagnosis based on 2D trend data based on load current in electrical plant, with experiment results verifying usefulness, and develop the diagnosis systems based on this method.

This proposed system combines the result of this research with electromagnetic waves and acoustic waves that can give a more practical system for commercial purpose. This system overcomes the discontinuity of PD signal and produce general reference patterns for diverse environments and can be used to diagnose on-site the power plant in live.

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