Classification of GIS Based on Adaptive Neural-Fuzzy Reasoning System

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Abstract. Partial discharge (PD) measurement is one of the most important diagnostic methods for the insulation system of high voltage equipment, which is convenient to evaluate the insulation state. Partial discharge activity may originate from various defects and exhibit different behaviors accordingly. Here, three PD patterns generated by different laboratory models representing GIS defects are recorded and analyzed. The purpose of this study was to conduct PD test with three GIS devices including prefabrication defects, statistical features are extracted from PD pattern data and reduced by linear discriminant analysis (LDA). The adaptive neural fuzzy inference system (ANFIS) was used to train the fuzzy inference system (fis). The proportion of trained fis used for ANFIS classification was as high as 95.83%.

1. Introduction

Partial discharge (PD) is an omen and the main reason for the deterioration of the insulation of gas insulated switchgear (GIS)[1]. Different types of GIS defects produce different partial discharge marks, and the degree of damage to GIS is different. Discharge detection is therefore essential for the reliable evaluation of insulation systems and the identification of defects in these components. Therefore, the trend towards automatic detection and identification in the testing of cables, transformers, and other insulating devices is obvious: an undoubted advantage of computer-aided measurement systems is the ability to process large amounts of information and translate that information into understandable outputs [2]. A new method of using adaptive neural fuzzy inference system to identify discharge power is proposed. ANFIS uses discharge fingerprints containing 74 statistical parameters to identify PD defects. In addition, the contribution of each feature to the classification was analyzed by linear discriminant analysis (LDA). This suggests that not all features have the same discriminatory power [3].

In other words, the original feature is transformed into a new feature without loss of accuracy, thus an ANFIS classifier with a simplified structure can be obtained. Thus, the total number of input features after the linear discriminant analysis was reduced to 5. Then use samples to train and test PD recognition, finally, the performance of ANFIS classifier is evaluated.

2. Partial discharge import

In modern society, electricity is regarded as the most important energy source to enable many power facilities to operate correctly. To maintain these facilities, the power quality from the grid should be as stable as possible to meet the requirements of electrical equipment. Especially now there are many factories and buildings that need constant power supply to run, and when the power fails, the cost can be high. In this sense, the proper monitoring and protection of power system is one of the important
problems in the development and monitoring of power system. Despite growing attention to the issue, power systems have remained fairly similar over the past few decades. This has led to a disastrous chain reaction of several blackouts around the world in recent years. These events illustrate the importance of protecting and monitoring the power system, the most complex human system ever. Compared with many protection methods in power systems, PD is considered as one of the most promising solutions to monitor and detect possible failures in the system prior to possible failures. Protection systems are becoming cheaper, more robust and more sensitive because of developments in other fields of engineering such as radio communications, computer science and signal processing. Partial discharge is able to find possible fault symptoms in the system in the most basic and simple way [4].

Partial discharge may be defined as an electrical pulse or discharge in a gas-filled void or on the dielectric surface of a solid or liquid insulating system. This pulse or discharge only partially connects the gap between the phase insulation and the ground, and the relative phase insulation. Full discharge will be a complete fault between line potential and ground. These discharges may occur in any void between the conductor and the ground. Voids can be located between the conductor and the insulation wall, or within the insulation itself, or between the external insulation wall and the ground frame. Pulses occur at high frequencies, so they decay rapidly as they pass through short distances. These discharges are actually small sparks occurring within the insulation system. Thus, deteriorating insulation and may eventually lead to complete insulation failure [5].

3. Partial Discharge in GIS

The high reliability, less maintenance and compact size of GIS make it a major option for many utilities. However, sometimes insulation defects within GIS may seriously threaten the safe operation of GIS and may lead to expensive supply disruption. Since insulation failure usually begins with PD activity, this section investigates differences in PD characteristics in SF6 gas between different types of defects. The defect types considered in this study were metal protrusions, free metal particles and contamination including paint. Different experiments on PD analysis [6]. Since 1960, GIS has been widely used in high voltage insulation. Compared with air, GIS has higher insulation characteristics and higher breakdown voltage, which makes the structure of substation more compact and reliable. In a recent paper, PD detection techniques in GIS are traditional, asymmetric, or combined. Typically, the sensor should be located within the appropriate distance so that the sensor can detect the PD signal from the GIS. The UHF method in GIS was first used in the 1980s [7].

PD experiments were carried out according to the standard IEC 60270. In the laboratory, applying over voltage significantly changes the rate of insulation aging. Figure 1 shows the test wiring method used in this paper. Apply AC test voltage between high voltage winding and ground. The GIS test equipment is grounded through a measuring device. The right half of the figure shows the PD measurement circuit [8]. The test object is powered by a non-PD transformer with an AC voltage up to several kilo-volts. When the voltage applied to the defect model exceeds the threshold of PD onset voltage (PDIV), the PD phenomenon occurs in electrical weakness. Discharge-induced PD current flows through the test object and capacitor, then the PD pulse can be detected. The PD signal is transmitted to the measuring device, which samples the signal and processes the data. All measured analog signal data are converted to digital data stored in a personal computer.
The test circuit consists of AC high voltage test equipment, current limiting resistor, voltage divider capacitor, PD test object, circuit protector, attenuator, measuring device, data acquisition card and computer. The high-voltage portion containing the test model requires special attention so that the measurement system has no source of partial discharge. The high voltage part consists of a boost transformer, a potential divider, a coupled capacitance and a test object. The voltage of the variable transformer is controlled by the bench knob. AC high voltage test equipment gradually increases the test voltage for PD measurement. The AC high voltage test equipment consists of two booster transformers. Series booster transformers provide up to 200 kV voltage. During the voltage boost of the PD experiment, the rising voltage generated by the high voltage generator increased by 2 kV from 18 kV, every 12 hours until the insulation breakdown. Record 40 electrical CAL cycle data every 5 minutes at a sampling rate of 20 MHz at the A/D interface of the computer, 144 times a day. Records are stored in computers, and PD's signals and test voltage signals are recorded at the same time. Every record including voltage signal and current signal is difficult to process and store.

4. Performance analysis

The classification results of the ANFIS model are shown in Figure 2. The classification performance of the proposed ANFIS model is determined by the total classification accuracy as follows.

![Figure 2. Total classification accuracy of different ANFIS models](image)

The total classification accuracy values of the 5-input ANFIS classifier proposed with ANFIS system are 94.44%, 95.83% and 94.44%, respectively. The results of the input ANFIS classifier are almost similar to that of the 5 input ANFIS classifier. Compared the throughput of the three models, the 74 input ANFIS classifier identified the defects at 87.5%, 86.11%, and 84.72%, while the other...
models identified more than 90%. It can be clearly seen that the 5 input ANFIS classifier provides the best accuracy than other classifiers, and the 12 input ANFIS classifier is slightly better than the 74 input ANFIS classifier. The maximum total classification accuracy from 38 kV is 95.83%, and the minimum total classification accuracy of 46 kV is 84.7222%. From the results of the study, the ANFIS algorithm has a significant effect on the classification accuracy of more than 90%. The proposed accuracy is very encouraging, which means that the ANFIS classifier has a good classification ability [9].

5. Conclusion
This paper presents an ANFIS system for partial discharge defect classification in GIS. The importance of PD diagnosis and feature extraction is discussed. The results show that using feature extraction, redundancy can be eliminated, thus eliminating redundancy in a simpler final model, not only with less fuzzy rules of input and output neurons and classification processes, but also with relatively accurate and accurate systems. The PD defect classification system consists of three main components. On the basis of the preprocessing stage, responsible for collecting the ANFIS database from the PD test of 26kV, 38kV and 46kV, and equipped with three kinds of GIS equipment including prefabricated defects. The phase-resolved pd data were successfully evaluated and processed. The data collected from the selected database is connected to the MATLAB software, where the data is processed. The second part is based on feature extraction algorithm. This uses linear discriminant analysis (LDA) as a medium to process PD data.

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