Linear Discriminant Analysis and Adaptive Neuro-fuzzy Inference System Development of Gas Insulated Substation

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Abstract. In this study, a PD defect identification system based on linear discriminant analysis and adaptive neural-fuzzy inference system is developed. The partial discharge signs of the typical defects of GIS were measured with a measuring device. The corresponding characteristic parameters extracted from the GIS were then filtered according to the optimization algorithm and stored in the form of three-dimensional discharge mode (q-φ-t). After that, the 3D discharge mode is transformed into statistical parameters. Statistical PD features can be used for defect classification purposes, but are obvious. Processing such a large database would be inefficient for that purpose. Therefore, it would be very helpful to select those features that are more effective and more efficient to identify and distinguish potential PD defects through their relevant statistical parameters. Select feature extraction techniques for dimensionality reduction. In solving pattern classification problems, feature extraction methods are usually used as pre-processing techniques, which can not only reduce the computational complexity, but also achieve better classification performance by reducing irrelevant and redundant information in the data.

1. Introduction
The feature extraction process uses a linear combination of all measured values. The selection methods for these linear combinations are determined by the dimensionality reduction algorithm used, while the number of combinations to be used is determined according to the dimension of the new feature. In the research process, the dimensionality is reduced by LDA [1], which attempts to improve the success of the classification method. Considering the ANFIS-based classification method, we first use lda to extract features from statistical parameters, and then use fuzzy if-then classification rules, which are obtained from the training process of the ANFIS model. Finally, the training system automatically completes the classification of PD defects. Test samples are used to verify the performance of the identification system. The ANFIS results focused on the classification of three PD defect types. In order to classify the defect types according to the feature vector obtained in feature extraction, the ANFIS toolbox of MATLAB is used [2].

2. Effect of Partial Discharge of Insulation System
The appearance of partial discharge is the main reason for the degradation of insulating materials, and also the cause of breakdown. The occurrence of discharge repetition rate is the cause of mechanical and chemical degradation of insulating materials. The effect of discharge on high voltage power equipment is serious insulation system. Insulation damage occurs due to the emergence of PD. The electrical conductivity of insulating materials rises due to chemical changes in the medium. Media are divided into several types, such as inorganic media and organic media. In general, the immunity of
inorganic media is high. Porcelain, glass, and mica belong to such dielectrics. Polymer dielectrics belong to organic dielectrics. Generally, PD produces energy in the form of heat. Thermal energy is the main reason for the degradation of insulating materials. This effect is called the thermal effect on the insulating material used. For high voltage power equipment, the deterioration of insulation can be known by monitoring PD activity. At manufacturing, pd activity shall be monitored from time to time by the power engineer or power manager. PD can be prevented by careful design and selection of suitable insulation materials. Therefore, its prevention and detection are essential for the safe, long-term operation of high-voltage equipment [3].

Electrical detection method is one of the most commonly used partial discharge measurement methods in high voltage power equipment. In this work, electrical detection methods have been used to simulate the measurement of PDs in model transformers. It focuses on current and voltage pulses generated by current streamers in voids and impurities. The pulse is less than 1 second, the frequency component changes in the KHz range, and the shape of the pulse and the occurrence of the phase position during the ac cycle give information about the pd type and insulation failure. This detection method uses a time-domain recording device to observe partial discharge pulses. Various signal processing methods are suitable for PD signal identification / detection. This method is also suitable for on-line PD detection. In the operation of high voltage power equipment, there are both broadband noise and narrow band noise. To separate these electrical noises from PD is not easy. The pulse received by this detection method depends on the geometry of the high voltage transformer. This method has certain disadvantages, but it is widely used in power plants. It helps power engineers and technicians by providing necessary important information on the characteristics, appearance and insulation failure of high voltage power equipment such as transformers and cables for different types of partial discharge [4].

3. PD experimental setup
The occurrence of PD in GIS can make the electromagnetic transient reach 2 GHz, which can be propagated in the coaxial and symmetric structure of GIS. Compared with the structural diameter, the wave propagation at lower frequencies has the characteristics of the electric and magnetic field of the wave completely transverse to the direction of wave propagation, which is called transverse electromagnetic wave [5]. This wave can not pass through the open contact switch chamber. However, at higher power frequencies, the electric and magnetic fields of the emitted waves are not entirely transverse, i.e., transverse electric (te), transverse magnetic (tm). Compared with TEM, the wave has short-wave length, both electric and magnetic fields can have the same components that propagate to the wave in the same direction. These components can pass through the open contact in GIS [6]. The test circuit consists of AC high voltage test equipment, current limiting resistance, voltage divider capacitor, PD test object, circuit protector, attenuator, measuring device, data acquisition card and computer. Various test equipment are described below.

(1) AC High Pressure Testing Equipment
The high voltage section containing the test model requires special attention to make the measurement system without a 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 increased the test voltage for PD measurement. AC high-voltage test equipment consists of two booster transformers. Series booster transformers can provide voltage up to 200 kV.

(2) voltage divider capacitor
The voltage divider is a pure capacitor divider and is a commonly used coupling circuit for PD measurement. The voltage divider capacitor plays two main roles in the test system. The voltage divider capacitor makes the voltage measurement a voltage divider and the partial discharge measurement a coupling capacitor. Open closed defect type 1(with an oil point) defect type 2(metal particles) defect type 3(prominent) load side source side

(3) Current limiting resistance
Current limiting resistance is an indispensable part of the metal cladding, gas insulation HVAC test system for two reasons. They protect test transformers or reactors from high voltage, test the case of the object crash. They block the PD measurement loop of partial discharge from the noise signal through the power supply and high voltage generator [7].

(4) PD test object

In this study, the circuit breaker was used as PD test object for PD monitoring. PD test object filled with SF6 gas. PD test subjects were subjected to various PD monitoring tests. The three related defect types on the PD test object are shown in Figure 1.

![Figure 1 Typical defects in GIS](image)

4. Test procedure for experimental setup

During the voltage boost of the pd experiment, the high voltage generator generates a rising voltage of 2 kV from 18 kV, every 12 hours until the insulation breakdown. 40 electrical cycle data were recorded in the A/D interface of the computer with a sampling rate of 20 MHz every 5 minutes and 144 times per 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. Because if the measured data is completely recorded as a power cycle, then the original measured data amount will be very large, which will extend the data calculation time [8].

Therefore, the original records must be further filtered and simplified. Signal processing units mainly use signal processing technology and statistical methods to reduce the amount of data. Figure 2 shows the applied test voltage process for defect type 2. The test voltage began to increase gradually, and breakdown occurred from 18 kV to 58 kV.

![Figure 2 Test voltage boost procedure for defect type 2](image)
5. Conclusions
This paper puts forward the method and conclusion of establishing GIS defect identification system. However, there are a number of research topics worth considering and, as a way forward, some suggestions are listed below:

1. The classification accuracy of ANFIS model combining neural network adaptive ability and fuzzy logic qualitative method can also be improved by combining several ANFIS classifiers in the training stage of input data.
2. The accuracy of PD defect classification widely used in MATLAB software and the performance of training time can be improved by other software.

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