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Research on Partial Discharge State Detection in GIS Based on Internet of Things Technology

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Abstract. With the continuous development of the Internet of Things technology, the Internet of Things technology can be used in many aspects of the smart grid. Apply advanced Internet of Things technologies in substation GIS, including sensing technology, network communication technology, intelligent decision-making technology, automatic control technology, and energy and power technology, etc., and combine them closely to form a coordinated organic system. At present, partial discharge is the main cause of equipment insulation deterioration in substations. Partial discharge detection and evaluation has become an important means of monitoring insulation conditions. The monitoring of GIS partial discharge conditions in substations can help find insulation defects in GIS in time, avoid insulation failures, and improve the safe operation of GIS. It is possible to achieve GIS insulation condition maintenance, reduce power outage time and save maintenance costs. The effective application of the Internet of Things technology in the GIS partial discharge state detection system of intelligent substations can effectively improve the construction of modern intelligent substations in China.

1. Introduction

The Internet of Things technology can be used for multiple links in the generation, transmission, transformation, and distribution and dispatching of smart grids. The construction of a smart grid requires the introduction of the most advanced technologies, including sensing technology, network communication technology, intelligent decision-making technology, automatic control technology, and energy and power technologies, and tightly combining them to form a coordinated organic system. The detection methods and methods of GIS partial discharge in substations under the technology have been greatly improved [1].

2. Development of IoT Technology

The current Internet of Things technology has been widely used in power, transportation, logistics, security and other fields. Among them, the acquisition layer is mainly composed of sensors and detection front ends to realize the state recognition. The network layer is to implement data transmission through existing wireless network and communication network technologies; The application layer analyzes and

perceives the transmitted information and makes the correct processing to achieve intelligent management and human-machine interface application services. Internet of Things technology is divided into 3 levels [2].

2.1. Research on acquisition layer technology

The acquisition layer of the Internet of Things consists of a professional acquisition sensor and a detection front end. In the case of partial discharge inside the power equipment, electromagnetic wave signals and ultrasonic signals will be emitted. Professional acquisition sensors will convert these two signals into electrical signals and display them on the terminal. The system has designed UHF, transient ground voltage, and ultrasonic sensors, which are suitable for various types of partial discharge detection [3]. The UHF sensor is an electromagnetic wave receiving antenna. It receives electromagnetic wave signals in accordance with the principle of radar, converts them into electrical signals, and amplifies, filters, and compresses the circuits to finally collect valid signals. The high frequency uses the Rogowski coil principle. The ground current on the ground wire is coupled into an electrical signal through the coil, and the sensor is sleeved on the ground wire. The transient ground voltage uses the principle of capacitive coupling, which couples the electromagnetic wave signal entering the ground on the surface of the device under test into an electrical signal through a small capacitor. The ultrasonic sensor uses the piezoelectric principle to convert acoustic signals into electrical signals. When the system is testing on site, it will limit the frequency band to the corresponding signal frequency band, which can effectively detect the amplitude, phase, frequency, etc. of the signal and the relationship with the operating voltage, at the same time shield external noise, and timely reflect the insulation of power equipment such as transformer The degree and location of defects, such as partial discharge defects, floating potential defects, and loose defects [4].
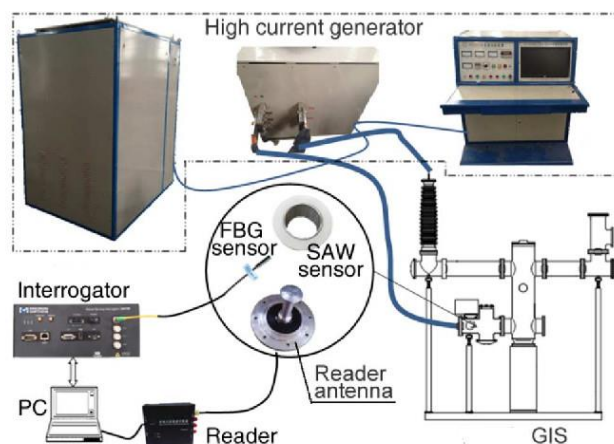

Figure 1. Detection front-end technology of GIS partial discharge sensor

The detection front-end of the Internet of Things uses a central processor of the ARM11 core to filter, amplify, and adjust the analog signals collected by the sensor, making it suitable for high-speed A / D conversion, and performing high-speed algorithm processing to extract relevant feature information. Data such as spectrum and map are encrypted at the same time and transmitted to the network layer through Ethernet or wireless network [5].

2.2. Research on Network Layer Technology

The network layer of the Internet of Things is built through Wi-Fi, 3G / 4G and other technologies, and supports 802.11b / g / n standards. According to the field test situation, the front end, server, and client terminal are detected to form an online monitoring network architecture. A dedicated network is formed in the substation. This network can transmit the detection signal data online through the network layer

of the Internet of Things during the GIS partial discharge detection process, which can improve the security of power grid communications. The system is loaded on the wireless gateway. WAN communication VPN tunnel, using the bearer function of the IP network combined with corresponding authentication and authorization mechanisms to establish a secure virtual private network, to achieve seamless connection between wirelesses LAN and wireless WAN, providing high-speed, secure, and reliable data transmission functions. For traditional optical fiber Transmission has significant advantages and significance. [6].
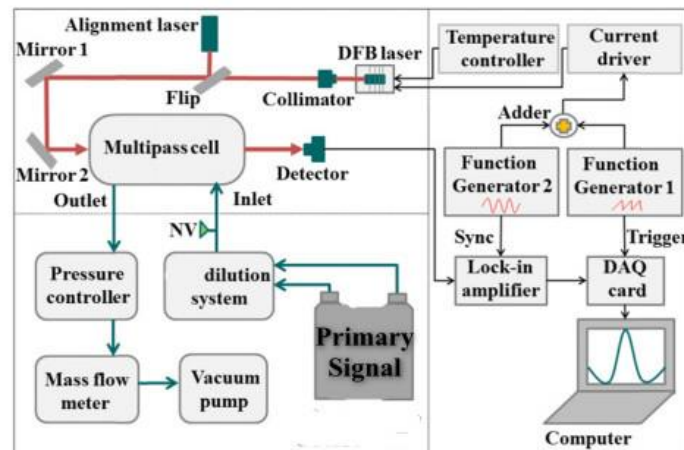

Figure 2. Classification analysis of IoT technology communication

2.3. Development of Application Layer Technology
The application layer of the Internet of Things is composed of server and client analysis software. It iThe application layer of the Internet of Things is composed of server and client analysis software. It implements the two main tasks of process control and data processing to realize intelligent management and human-machine interface application services. The main function modules of the application layer are composed of communication management, data analysis, data storage, self-test and other functional modules [7]. The Internet of Things technology breaks the bottleneck of the previous detection methods and expands the function of live detection instruments. It is a set of multi-channel detection instruments. Field test According to the material of the shell of the substation equipment being tested, banding, magnetic suction, and air suction can be used, which will not affect the mechanical characteristics of the power equipment itself, and can achieve online monitoring without construction. When the staff uses the above partial discharge detection equipment to detect the GIS equipment. The collection sensor, detection front end, server, and client of the GIS partial discharge detection system can be individually verified and maintained. It has good openness and effectively reduces the system's investment and operating costs [8]. The GIS partial discharge detection system supports long-term, short-term, and access testing after a power outage. If some of the tested equipment is found to have hidden troubles or other suspected local discharge phenomena, which needs to be monitored online for a long time to track, the system passes the external or internal network. It forms a wide-area, multi-terminal online long-term monitoring; in the short-term detection of GIS partial discharge in the field, the system uses PC terminals, wireless integrated controllers, and bracket mode operations, with good maneuverability, suitable for short-term fault detection; access after power failure Applicable, that is, after the equipment is powered off, professional sensors and detection front-ends are set up to perform GIS partial discharge signal detection. The GIS partial discharge system effectively guarantees the development of work that can detect partial discharge in all situations [9].
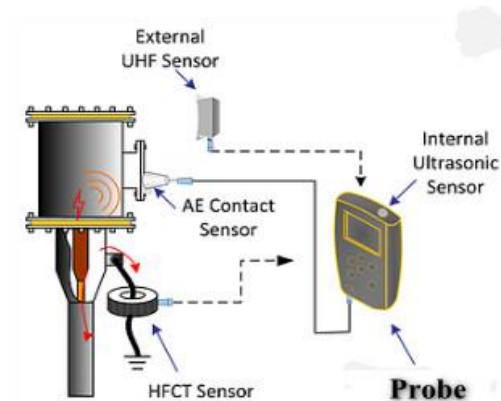
Figure 3. Application of partial discharge detection device on GIS equipment

3. Development of partial discharge state detection technology

3.1. Detection technology of partial discharge
Partial discharge measurement of electrical equipment will be performed during the factory shipment, field test and equipment operation. Accurate analysis of the test results requires accurate information on the intensity, mode and positioning of partial discharge. Detection technology is the basis of partial discharge analysis. Pattern recognition gives the cause and type of partial discharge, positioning gives the exact location of the partial discharge source, and the intensity of the partial discharge gives the intensity of the current partial discharge activity. Degree, the combination of these three aspects of information can make a reasonable and accurate assessment of the dielectric insulation state. Partial discharge detection technology has always been the focus of partial discharge research. At present, the commonly used methods are mainly the following.
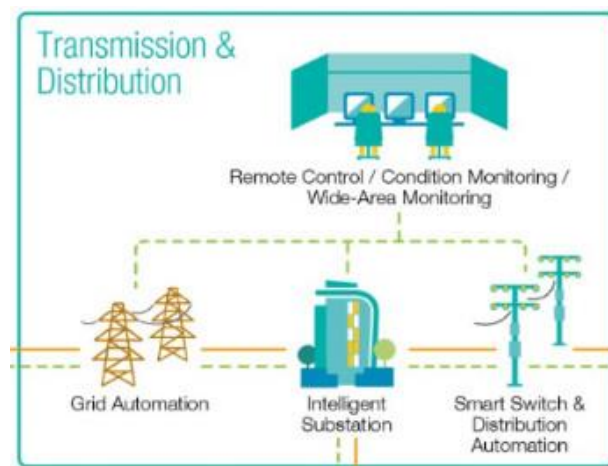

Figure 4. Analysis of Substation Technology in Smart Grid

3.1.1. Technology Development of Pulse Current Method. The pulse current method is currently the only partial discharge detection method with international standards. It measures the pulse current due to partial discharge from the neutral point or ground point of the power equipment by obtaining the measured impedance on the coupling capacitor side. In the discharge amount, discharge phase, discharge frequency and other information. The traditional pulse current method can be divided into two types: wideband and narrowband measurement. The lower limit detection frequency of the broadband detection method is between 30-100kHz, the upper limit detection frequency is <500kHz, and the

detection band width is 100-400kHz. It has high pulse resolution, relatively rich information, but low signal-to-noise ratio. The narrow-band detection method has a small frequency band width, generally 9 to 30 kHz and a center frequency of 50 kHz to 1 MHz. It has the advantages of high sensitivity and strong anti-interference ability, but it has the disadvantages of low pulse resolution and insufficient information.

In response to the shortcomings of the traditional pulse current method, in recent years, some researchers have adopted a higher detection frequency band for the detection of partial discharge pulse current, and a measurement impedance with a bandwidth of 30 MHz is used to measure the partial discharge pulse current signal. This method uses a unique waveform-based method. The data processing method of feature classification performs noise elimination, that is, the pulse is transformed in the time domain and the frequency domain according to the difference between the noise pulse and the partial discharge pulse in the pulse waveform characteristics, and the equivalent bandwidth W and equivalent of each pulse are calculated. At time T, it is projected onto a two-dimensional TW plane for cluster analysis. According to the difference between noise clustering and partial discharge signal clustering, the discharge signal and noise are separated.

This method is based on a wide-band measurement of partial discharge and uses pulse waveform characteristics to suppress noise, which is different from the previous idea of using frequency modulation for noise suppression. In recent years, it has been widely used. We use it in AC and DC. In terms of separation and identification of local discharge power sources, good results have been achieved. The pulse current method is mostly used in the factory test of electrical equipment. Some scholars have applied it to the on-line monitoring of transformers and other equipment, and used the method of polarity discrimination to suppress the discharge signal and noise signal. However, in general, the pulse current method has a low measurement frequency, a narrow frequency band, a relatively small amount of information, and a weak anti-interference ability. However, according to the IEC60270 standard, the obtained data is comparable. It is currently irreplaceable and local the most important method in the field of discharge detection.
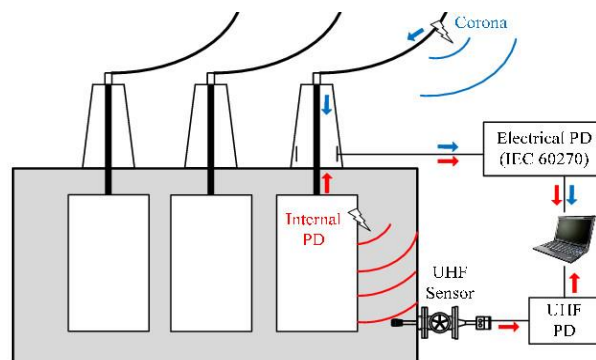

Figure 5. Analysis and research on partial discharge detection technology of transformer

3.1.2. UHF Technology Development. When a partial discharge occurs inside the oil-paper insulation, electromagnetic waves with a frequency of up to GHz will be excited. This signal will decay more slowly in the metal case than in free space, so it can propagate inside the device and pass through the connection gap between the case and the casing. Based on this, an ultra-high frequency (UHF) sensor can be used to detect the ultra-high frequency electromagnetic wave signal generated by the partial discharge inside the transformer, obtain relevant information about the partial discharge, and realize the diagnosis of the transformer insulation status.
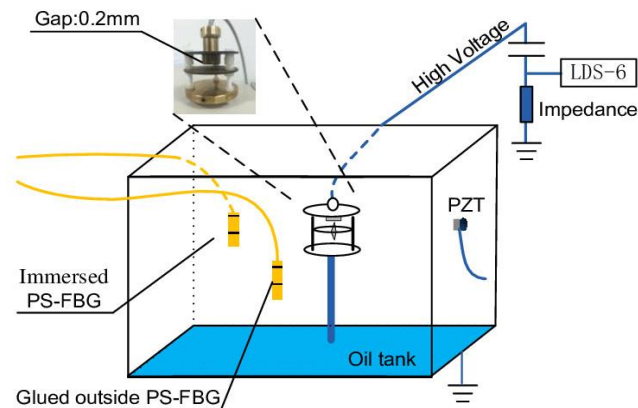
Figure 6. Partial discharge detection technology principle

The UHF method can detect partial discharge signals in the frequency range of 300-3000MHz. After reasonable band selection, it can effectively avoid field interference. In addition, UHF sensors also have the advantages of good transient response, high linearity, and high sensitivity. Although the experiments show that the pulse current parameters have the same trend as the UHF parameters, the UHF method parameters (dB) can be used to approximate the strength of the discharge, but the internal structure of the transformer is quite complicated. The UHF measurement mechanism is similar to the traditional pulse current method It is completely different. The differences in the intensity, propagation path and attenuation of partial discharge electromagnetic waves at different positions and different types of defects bring greater difficulty to the calibration of UHF discharge.

3.1.3. Development of Ultrasonic Technology. Partial discharge of a transformer is usually caused by bubbles in oil or insulation paper. Macroscopically, a pressure is generated instantly, which generates a pulse mechanical sound wave. Ultrasonic waves propagate in the oil and insulating cardboard to the transformer shell, and also generate a certain pressure on the shell. An ultrasonic sensor attached to the transformer case detects partial discharge inside the transformer.

The ultrasonic method can detect partial discharge inside the transformer with a frequency range of 20-200kHz, and has a certain anti-interference ability. The signal strength is characterized by millivolts. When the amount of discharge in the transformer is large, the measured sound pressure signal amplitude has a positive correlation with the amount of discharge, so the legality of the discharge can be judged by the ultrasonic law. In terms of partial discharge type identification, ultrasonic parameters such as arrival time, number of discharges, amplitude, energy, and duration were extracted and calculated, and it was pointed out that different discharge types have different phase distribution characteristics and different spectral characteristics; based on partial discharge ultrasound Characteristic parameter statistics, the typical map of the ultrasonic signal was established, and the partial discharge pattern recognition could be initially realized. However, due to the extremely complicated propagation process of the ultrasonic signal inside the transformer, accurate discharge type determination and quantitative analysis cannot be achieved at present, and the ultrasonic method is still an auxiliary measurement method at the scene.

3.1.4. Development of Optical Inspection Technology. In the transformer oil, a pulse current is generated by the discharge, and the phenomenon of light emission and heat generation is accompanied. Photoelectric detectors are used to detect the optical radiation signals generated by partial discharges, including ultraviolet, visible, and infrared spectral bands. The intercepted optical signals are converted into electrical signals, which are amplified and sent to the detection system, which is an optical detection method with high sensitivity and strong anti-interference ability. The optical detection method is used. After the photoelectric signal conversion, the voltage signal amplitude obtained is approximately linear

with the discharge detected by the conventional pulse current method. Therefore, the voltage signal measured by the optical detection method can be used to reflect the strength of the discharge. Based on this principle, we use a UV optical camera to perform a video inspection of the internal and external discharge conditions of the device. We have developed a discharge UV light pulse signal detection system. If a built-in optical sensor is placed inside the transformer, the transformer can be well tested. Internal insulation discharge is detected. Since ordinary optical sensors cannot penetrate into the device to monitor the key positions of the device, fluorescent fiber detection technology was born. With this technology, the low-light signal generated by partial discharge can be received from a large space without being limited by the numerical aperture of its end face. Recently, the Technical University of Munich, Germany, has successfully developed a pure optical passive sensor for partial discharge. Comparing the light measurement method with the signal measured by the traditional current pulse method, it was found that the light pulse signal detected by the light measurement method can better reflect the transformer the number of discharges and the strength of the partial discharge in the oil can obtain a more realistic partial discharge condition inside the transformer. Partial discharge live detection of power transformers using photometry is a new method for fault diagnosis of power equipment.
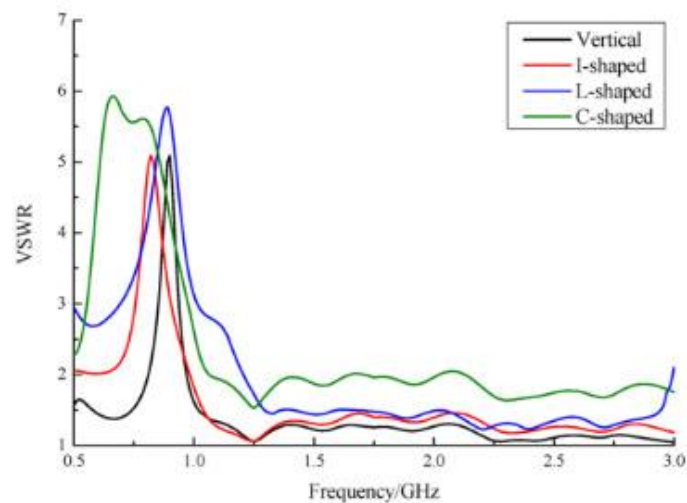

Figure 7. Partial discharge detection technology measurement data analysis

3.2. On-line monitoring and live detection technology development

With the maintenance of equipment from regular maintenance to conditional maintenance, the detection of GIS partial discharge has also undergone the process of factory inspection, live detection, and online monitoring. Back to the trend of live detection, the pros and cons of live detection and online monitoring have also been discussed from time to time. Neither on-line monitoring nor live detection is an objective. The fundamental purpose is to detect and eliminate partial discharges in a timely and accurate manner. The form of detection is only a means. From the perspective of technological development, it is a general trend to implement on-line monitoring of partial discharge of important GIS equipment in substations. From the perspective of economic operation, it is a more reasonable way to use HF and ultrasonic methods to conduct live detection of GIS equipment in the substation, and to conduct short-term online monitoring of suspected partial discharge equipment. Equipment, such as 220KV isolation switches, circuit breakers, transformers and other primary equipment, continuous online monitoring is an important part to ensure its safety.

Regardless of online monitoring or live detection, our view is to ensure the reliability, accuracy and sensitivity of the device itself. This requires continuous and in-depth research on sensor technology, data acquisition technology and signal analysis technology, especially research more sensitive, stronger anti-jamming sensors are the focus. In this way, it can be ensured that the partial discharge detection

device does not make a wrong judgment, a good judgment, and a non-missing judgment. On the other hand, we must strengthen the comprehensive utilization of GIS equipment partial discharge technology, establish a standard GIS partial discharge detection device testing link, strengthen its quality control, and use a combination of two or more GIS partial discharge detection technologies to fundamentally Solve various problems in partial discharge detection at present, and ensure the effectiveness of partial discharge detection in GIS equipment.

4. Conclusion

With the continuous development of the Internet of Things technology is of great significance to China's power industry, the Internet of Things technology will play an important role in ensuring China's energy security and optimizing the effective allocation of energy resources in the new era. The development of smart grids is an important part of smart substations as a smart grid, and an important aspect of daily work in smart substations is the GIS partial discharge state detection of equipment in the substation. This method can effectively improve the substation transfer and provide high efficiency. Auxiliary role. By using the Internet of Things technology, we can achieve the ideal goal of giving full play to the advantages of the Internet of Things technology, improving the economic and social benefits of smart substations, strengthening the state detection and analysis of non-GIS partial discharges, and continuously applying the Internet of Things technology, making our country Automation technology has taken to a new stage.

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