Distributed Partial Discharge Detection Technology for High Voltage Cable Based on Ac Withstand Voltage

Liu Dawei, Liu Yi, Li Fang, Wang Chen
State Grid Weihai Power Supply Company, Weihai, 264200, China
Xd2199@Sina.com

Abstract. With the Development of Urbanization, It is More and More Urgent to Improve the Reliability and Stability of Power Supply. Due to the Consideration of Municipal Planning, Environment, Personal Safety and Other Factors, the Utilization Rate of Power Cables in Urban High-Voltage Transmission Channels Has Increased Dramatically. Accidents Such as Fire, Large-Area Power Failure and So on, Which Are Caused by Internal Insulation Defects of Cables, Defects in Joint Position Fabrication and Installation Process, Occur from Time to Time. This Paper Studies the Detection Method of Potential Insulation Defects in the Cable Interior and Joint Position Based on the Ac Withstand Voltage Partial Discharge Detection Technology, and Designs a Set of Distributed Partial Discharge Test System Based on the High Frequency Pulse Method to Detect the Interior, Middle Indirect Head and Terminal Head of the Cable. In the Field, the Distributed Pd Detection Technology Based on Ac Withstand Voltage Designed in This Paper Can Effectively Detect the Internal and Joint Insulation Defects of Power Cables, and Realize Fault Location, Which Has the Value of Practical Application and Promotion.

1. Introduction
With the development of urbanization, it is more and more urgent to improve the reliability and stability of power supply. The high-voltage transmission channel in the urban area is widely used in the transmission line due to the consideration of municipal planning, environment and personal safety. With the increase of cable rate, the capacitance current of the system also increases[1]. The arc of ground fault caused by insulation defect is not easy to extinguish, and then the fault range is expanded, leading to serious accidents. The cables are mostly laid in the tunnel or under the ground, and the distance is long, so it is difficult to check the internal insulation defects. In recent years, accidents such as fire and large-area power failure caused by internal insulation defects of cables, defects in joint position fabrication and installation process occur from time to time[2]. Therefore, the cable should be thoroughly tested before putting into operation to avoid the equipment with insulation defects entering the network for operation. Before leaving the factory, the high-voltage power cable shall be tested according to the regulations to check the possible internal insulation defects. The factory AC withstand voltage test can purify the tiny defects existing in the insulating medium to a certain extent. At the same time, the small defects that originally had little influence on the insulation performance are amplified after withstand voltage. Therefore, in the equipment handover test stage, it is necessary to conduct another AC withstand voltage test to check the important defects inside the cable. Voltage withstand test can not effectively detect the small defects inside the equipment, which will produce partial discharge in the process of voltage withstand. Therefore, the partial discharge detection at the
same time of withstand voltage can detect the insulation defects caused by the transportation and installation process more thoroughly[3].

The completion voltage withstand test before the power cable is put into production can discover the obvious defects and hidden dangers of the cable in time, including the damage of the cable body in the process of transportation and laying and the major defects in the production of the field joints. It is very important for the long-term safe and stable operation of the cable line to find out the minor defects of the cable in time. A large number of studies show that PD test is an important technical means to detect cable defects in time. The cable line has the characteristics of distributed parameters, and the inner and outer semiconducting layers of high-voltage cable have strong attenuation and distortion to the high-frequency partial discharge signal[4]. The detection of partial discharge can find about 5-10pc small discharge defects. This characteristic determines that PD detection of HV, UHV cables and accessories can only be carried out near the defective parts. In order to study the synchronous distributed partial discharge test technology of cable withstand voltage and provide effective support for the cable completion withstand voltage test, this paper carries out simulation and test research on some technical problems in the distributed partial discharge test, and finally realizes the engineering application in Guangzhou power grid. The relevant results have important reference significance in the cable engineering of China Southern Power Grid.

2. Related Works
Under the action of high voltage, if there are defects in the insulation of power cable, partial discharge will occur at the defects. The energy of partial discharge is very small, usually it will not affect the insulation strength and normal operation of the cable in a short period of time, but it may cause slow damage of the internal insulation of the cable for a long time, leading to insulation breakdown[5]. Based on the characteristics of cable partial discharge, such as small energy and wide spectrum, several common measurement methods are based on ie60270 pulse current detection method, differential detection method, electromagnetic coupling detection method, capacitance coupling detection method, etc.

2.1 Pulse Current Detection Method
When there are defects in the cable, the internal discharge generated after power on will trigger a high-frequency pulse current, which will enter the ground from the high potential core to the intermediate joint or terminal ground wire. By placing current transformer at the joint or terminal to collect and analyze the pulse current signal generated by discharge, the final test results are obtained[5]. Figure 1 is a schematic diagram of partial discharge test by pulse current method. Because of the low frequency, narrow frequency band, low amount of information and other factors, the signal extraction effect of the conventional pulse current method can not meet the test requirements, resulting in the low detection rate of partial discharge phenomenon in the cable. The wide-band pulse current method improves the conventional pulse current method. By expanding the test bandwidth, we can collect as many pulse current signals as possible, remove the interference signals in the pulse signals by classification, and classify and analyze the discharge signals. The frequency band of conventional pulse current method is mostly 40-400khz, while the frequency band of broadband pulse current method is generally 1khz-50mhz, the amount of data collected is much higher than that of conventional method.
2.2 Differential Detection

Differential detection method is a partial discharge test method proposed by Tokyo Electric Power Company and calendar cable company, which is suitable for power cables with voltage level above 110kV. Figure 2 is the structure diagram of the differential detection method. Two pieces of foil electrodes are pasted on both sides of the metal shielding layer of the cable intermediate joint through the coupling agent[6]. When one side of the cable joint is discharged, the other side is the pulse current signal coupled to the discharge by the detection impedance through the equivalent capacitance. This method is simple to realize, and the effect is best when the frequency of pulse signal is 5-10mhz. If the frequency of pulse is greater than 20MHz, the sensitivity of detection will be greatly reduced.

3. Distributed Pd of High Voltage Cable Based on Ultrasonic

When ultrasonic wave propagates in the medium, there are only two kinds of medium interfaces with different acoustic impedance, i.e. heterogeneous interface, such as gas / liquid interface, gas / solid interface, liquid / solid interface and different solid interface. Because of the different acoustic impedance of the two kinds of medium, reflection, refraction and diffraction will occur. Combined with the high-voltage cable studied in this paper, when the insulating material is extruded on the cable core, the interface from the steel mold to the insulating material is one, and the interface from the insulating material to the copper core is another. When ultrasonic wave incident on a smooth interface, it will produce reflection; if it occurs on a rough interface, it will produce wave scattering. When ultrasonic wave passes through the interface of two kinds of media, one part will be reflected back to the first medium by the interface, which is called reflected wave; the other part will enter the second medium through the interface, which is called transmitted wave. Therefore, it can be seen that whether the emission or scattering occurs, or with the increase of the propagation distance, the energy of ultrasonic will weaken, which is called the attenuation of ultrasound. Many factors, such as the expansion of sound velocity, the scattering of sound waves and the absorption by the medium, may lead to the attenuation of ultrasonic energy[7, 8]. Therefore, in practical application, it should be avoided that the ultrasonic attenuation is too much to cause the detection is not ideal or can not be detected. When high-voltage power cable generates partial discharge, it not only radiates...
electromagnetic wave to the surrounding, but also generates many other non electrical signals, such as acoustic wave, temperature, luminous and other information. Through the collection and analysis of these non electrical signals, we can also judge the internal insulation defects of the cable. The ultrasonic detection method uses the ultrasonic sensor to detect the ultrasonic generated by the partial discharge of the cable, and converts it into an electrical signal. The working mechanism of the ultrasonic sensor is to transmit the ultrasonic wave to the piezoelectric crystal sheet made of the magnetic conducting material. Under the action of the ultrasonic wave, the piezoelectric crystal will stretch and deform to obtain the corresponding electrical signal. Fig. 3 is the structure diagram of ultrasonic sensor.

Figure 3 Structure Diagram Of Ultrasonic Sensor.

In the process of partial discharge of power cable, in addition to the transfer of electric charge and the loss of electric energy, it also produces a variety of non electric information, such as sound wave, light, heat and new products. When partial discharge occurs, there is a violent impact between molecules in the discharge area, which produces a kind of pressure on the macro level. Because the discharge is formed by a series of pulses, containing various frequency components, the generated sound wave also contains a very wide frequency band. The principle of ultrasonic partial discharge detection is to diagnose the defect according to the ultrasonic signal generated by the detection of partial discharge, which is transmitted from the internal discharge through the insulation layer to the external surface. In this paper, the non-contact detection method is used to detect the partial discharge. The ultrasonic sensor is of open structure, high sensitivity and light weight. The transmitting sound pressure of the ultrasonic probe used for transmitting can reach 118db; the receiving sensitivity of the probe used for receiving is at least - 46db. The center frequency of the ultrasonic sensor used for transmitting and receiving is 40KHz. Because the ultrasonic signal is a kind of signal quantity related to frequency and changing with time, when analyzing the ultrasonic signal, first of all, the acoustic signal obtained from the ultrasonic sensor should be converted into the corresponding electrical signal. Because the ultrasonic signal is usually weak at this time and will be interfered by the external and internal boundaries, the acoustic signal must be amplified to a certain extent through amplification, detection, filtering and other links. The level of the transducer is then measured, so the transducer is used with a preamplifier with a gain of 40dB.

4. Partial Discharge Experiment and Result Analysis
Partial discharge is a phenomenon of repeated breakdown and extinction in the insulation. In the manufacturing of insulation, there will always be more or less residual impurities in it; in the operation of equipment, due to the aging and decomposition of insulation, there will also be some dispersive foreign matters. The conductance and dielectric constant of these impurities and foreign matters are very different from that of the insulating materials. When the applied voltage acts on them, the field strength of the parts where these impurities and foreign matters are located will be significantly higher than the surrounding field strength. With the increase of the applied voltage, when the field strength of the impurity and the place where the foreign matter is located exceeds the ionization field strength of the matter there, the matter there will produce ionization discharge, that is, partial discharge. There are
many reasons for partial discharge of power cable, which are mainly caused by the quality of cable itself, improper technology during installation and construction, external force of machinery or aging caused by long-term operation of cable. In this paper, according to the characteristics of XLPE Cable Partial discharge, several typical discharge models are designed. The voltage is applied to these models respectively, the phenomenon of partial discharge is observed and the discharge signal is measured.

Among the main causes of power cable insulation failure, electrical tree is a common one, and the existence of bubbles, impurities and metal burrs can lead to the generation and development of XLPE insulation electrical tree, which will eventually lead to insulation breakdown. When there is burr in the metal shielding layer or conductor core, the discharge is often caused by the uneven electric field at the tip, so we can use the pin plate discharge model to simulate it in the laboratory; for the partial discharge caused by the tiny bubbles in the insulation, we can use the internal discharge model to simulate it; in addition, because of the manufacturing quality of cable accessories, the installation quality of cable laying, etc, the reason is that there are suspended electrodes in the cable joints, which can cause partial discharge, and then lead to insulation deterioration, and finally lead to insulation breakdown. This situation can be simulated by the suspended discharge model.

Figure 4 Pd Test Of High Voltage Cable Based on Ultrasonic

5. Conclusion
The application of power cable in urban high-voltage transmission system is more and more extensive. The insulation defects in the internal and joint parts of power cable (including intermediate joint and terminal head) are the important hidden dangers of system operation, which easily lead to large-scale blackout. In this paper, for the problem that the internal insulation defects of long-distance power cables are not easy to find, the distributed PD detection technology of high-voltage cables based on AC withstand voltage is used to detect and locate the internal insulation defects of cables. The distributed PD detection technology of high-voltage cables based on AC withstand voltage designed in this paper can effectively detect the internal insulation defects of power cables and joints Edge defect, and the realization of fault location, has the value of practical application and promotion. It is not easy to find the insulation defects in the internal and joint parts of power cable in the process of AC withstand voltage. It is feasible and necessary to carry out partial discharge detection at the same time of AC withstand voltage. The distributed PD detection method designed in this paper has been verified in practice, which has played a good role in the field test of high-voltage equipment. Because of the different defect types and fault locations, the signal strength and characteristics of PD signal are complex and changeable, and the existing detection methods have their limitations. How to use a small number of detection units to quickly and accurately identify PD signals is one of the development directions of detecting internal defects of high-voltage equipment. In addition, AC withstand voltage belongs to destructive test, which has certain damage to the equipment itself. If repeated, it will greatly
reduce the service life of the equipment and increase the frequency of equipment maintenance. It will be a new milestone in the field test of high-voltage power equipment to reduce the repeated withstand voltage of equipment and even to find a reliable alternative to AC withstand voltage.

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