Research on the Application of Phased Array Detection Technology in Composite Insulator Interface Debonding Detection

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Abstract. The main reasons for the failure of composite insulator are the fracture of core rod and the breakdown of interface. However, due to the particularity of composite insulator, the traditional insulator detection method is not fully applicable to it. In this paper, phased array detection technology is used to detect the interface debonding defects of composite insulator sheath and core rod, and clear interface debonding signals are obtained. The research results can provide research basis for the application of phased array detection technology in the field of composite insulator defect detection.

1. Introduction

The insulator is one of key devices for safe operation of the power system. It can hang conductors and isolate the support and high-voltage conductors. Its performance is closely associated with safe operation of the power system. Since successful manufacture in the 1950s, the composite insulators have been widely applied due to their advantages such as small volume, small weight, high mechanical strength, excellent resistance to contamination and high insulation strength [1-4]. The composite insulator mainly consists of umbrella sheath, FRP core rod and end metallic fitting. In the past 15 years, the quantity of used composite insulators with silicone rubber insulation is increasing, and the composite insulator has been used in more than 30 countries and regions in the world. More than 4 million composite insulators have been applied in transmission cables in China, especially in medium and heavy pollution areas[1]. In the manufacturing technology of composite insulators, the bonding quality of the interface between the umbrella sheath and core rods is an important factor to guarantee the internal insulation strength. The poor bonding or bubbles existing in the interface between umbrella sheath and core rod of the composite insulators due to technique or materials may bring threats to the safe operation of power grids. The electric field of the defective insulators is distributed unevenly, and distorted electric field may be caused in the defective area. The long-time influence of high field strength may facilitate local discharging of sheath, core rod and metallic fitting, etc. of composite insulators, worsen the performance of insulators, even penetrate and break insulators.
in the severe cases, affect the safety of cables. These concealed defects may cause hidden risks of safe operation of power grids[2].

The ultrasonic wave is the elastic vibration wave whose frequency is larger than 20 kHz. The most common frequency is 0.5～10 MHz. When the ultrasonic wave is disseminated among heterogeneous materials, it will return an interface reflection wave in the heterogeneous interface when it enters another material from one material due to the different acoustical properties of heterogeneous materials, i.e. characteristic reflection wave of heterogeneous materials. The reflection degree of the ultrasonic wave in the interface depends on the acoustic impedance difference of two media (the acoustic impedance of media is media density multiplied by acoustic velocity). The larger the acoustic impedance difference is, the larger the reflection degree will be. The dissemination speed of the sonic wave in the air is 340m/s. The speed in the FRP core rod is 2,570 m/s. The speed in silicone rubber sheath (the density is 1.56 g/cm3) is 1,060 m/s. The ultrasonic testing is widely applied in crack detection of materials, and it is one of the approaches that are widely applied in non-destructive evaluation of composite materials. As regards its principle, it detects the defects inside and on the surface with the influence of acoustical properties of the composite materials and their defects on the dissemination of ultrasonic wave, such as bubble, layering, crack, debonding and lean glue, etc. This thesis detects the artificial debonding defects of composite insulators by phased array.

2. Detection experimental methods

Doppler Phascan II phased array is adopted to detect debonding defects of sheath and core rods of composite insulators. This test adopts a 64-matrix element probe. The frequency of the probe is 5MHz. This test adopts water as the coupling media in order to guarantee the coupling effects between the probe and workpieces.

The test workpiece defect is artificial debonding in the interface between sheath and core rod of composite insulators. The defect is 4mm, 3mm, 2mm, 1mm wide respectively. The macroscopic form of the sample defect can be seen in Figure 1.

![Figure 1 Artificial defect of debonding in the interface between sheath and core rod of the composite insulator](image)

3. Results and Analysis

3.1. Intact sample test results

At first, the phased array probe is used to detect the intact interface of sheath and core rod. The following figures show the interface without defects. The background noise of workpiece material can be detected in the area where the probe contacts with the workpiece. And an intact and even background wave can be seen below, which indicates that when there is no defect in the interface between the sheath and core rod, the sonic wave can penetrate the interface of both sides, reach the sheath in the opposite side and form the reflection wave.
3.2. Detection of the defect which is 4mm wide
When the debonding defect in the interface between the sheath and core rod is 4mm wide, the detection result of defective samples can be seen in Figure 3. In the probe detection area, the strength of the background wave significantly decreases, and it even disappears in some areas. The background noise can be detected, indicating that when the defect is 4mm wide, this waterlogging phased array can effectively detect the debonding in the interface between the sheath and core rod.

3.3. Sample detection of the defect which is 2mm wide
When the defect is 2mm wide, the detection result of the defect can be seen in Figure 4. In the defective area, the strength of background wave significantly decreases, but the background wave can be still observed, indicating that some sonic waves penetrate the interface between the core rod and sheath, which may be related to the defect fabrication.

3.4. Sample detection of the defect which is 1.5mm wide
When the debonding defect in the interface between the sheath and core rod is 1.5mm wide, the detection result of the defective sample can be seen in Figure 5. When the defect is 24mm long, the strength of background wave significantly decreases in the whole defect area, and it even disappears in some areas. The background noise can be detected. When the defect is 15mm long, it can be...
intuitively observed that the background wave strength with defect is lower than that without defect, indicating that the existence of defect can lower the display strength of the background wave, i.e. the existence of defect makes the sonic wave energy reflected in the defect, and it cannot reach the interface between the sheath and the air in the opposite side of the insulator. It forms reflective background wave, so the energy of the background wave is remarkably attenuated. This is significantly different from phased array images of defective insulators with intact interface.

![Figure 5 Detection results of the defect which is 1.5mm wide](image5)

3.5. Detection of the defect which is 1mm wide
When the defect is 1mm wide, the detection results indicate that the phased array cannot effectively recognize the defect. In the end, as there exist squeezing and tearing in the interface during preparation of the defect, the defect in the end is more than 1mm wide. The detection figures indicate that the strength of the background wave in this area remarkably decreases, but in the sample deep area where the width of the defect approximates to 1mm, the reflection strength of the background wave is still high. The discontinuity exists. However, it cannot be used as the effective signal to recognize the defect. Therefore, this approach cannot recognize the defect which is 1mm wide.

![Figure 6 Detection result of the defect which is 1mm wide](image6)

3.6. Detection of the defect which is 0.5mm wide
When the defect is 0.5mm wide, the detection results indicate that the phased array cannot effectively recognize the defect. In the end, as there exist squeezing and tearing in the interface during preparation of the defect, the defect in the end is more than 0.5mm wide. The detection figures indicate that the strength of the background wave in this area remarkably decreases, but in the sample deep area where the width of the defect approximates to 0.5mm, the reflection strength of the background wave is still high. This approach cannot recognize the defect which is 0.5mm wide.
4. Conclusion

In this test, the defects of five workpieces may display different results with the background wave, but the display effects of different defective areas differ due to the technique of artificial defects. In this test, it is difficult to ensure that the probe and detection surface of workpieces are tangential. The detection is difficult.

This detection approach can achieve effective qualitative recognition of defects. The reflection wave energy in the defective area and intact area differs, which can be effectively recognized. However, this detection approach cannot characterize the defective size. The detection results of defective samples with different width are similar because the coupling interface of the probe and the sample is small, and all defects may not be detected once. This problem can be solved by improving the coupling interface of the probe and the insulator sample and increasing coupling area.

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