Research on main insulation defect of cable fusion joint based on IDIP-DR detection technology

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Abstract. The cable connector is the weak link of the electrical part of the cable. Most of the cable breakdown accidents occur at the connector, which will have a huge impact on the safe power supply of the city. In recent years, with the development and maturity of 10 kv cable fusion joint technology, high-voltage cable fusion joint technology is gradually applied in the field, but the key process problems in the production process lack of effective control means. In order to solve such problems, this paper use IDIP - DR digital radiographic testing technology. The key technology of high voltage cable melting joint detection, effectively detect the main insulation problems bubble construction technology. Through the anatomical, proved the accuracy of the test results, for the subsequent company to carry out the weld joint process control provides an effective means of. The causes of defects were analyzed and the corresponding process control suggestions were put forward.

1. INTRODUCTION
In recent years, the scale of high voltage cable lines of 110 kV and above has been increasing with an annual growth rate of about 12% [1]. Due to the influence of cable length and construction, it is necessary to make cable joints every 500m or so for connection. Cable joints are the weak link of the electrical part of the cable, and faults often occur here [2-3]. Traditional prefabricated mechanical joints have some process risks [4-5] :

Due to fasteners loosening, node corrosion and other reasons, the electrical conductivity of mechanical pressure connection resistance will change with the growth of time. If the pit is deformed after mechanical crimping, local electric field distortion will be caused, which is easy to cause the serious result of joint breakdown.

At the point of mechanical connection, the tensile strength is greatly reduced. Due to the tension of the cable line itself and other reasons, the connection point will become the weak link of the tension of the wire. Under long-term stress, it is easy to cause the loosening of the connection point and affect the electrical connection of the joint.

The connection point of the cable connector is the weak place to withstand the impact of large current. There is a resistance difference between the connection point and the conductor.
As a kind of cable fusion joint technology which is fundamentally different from the traditional prefabricated mechanical joint, the joint manufacturing is in. Therefore, in view of the key manufacturing process control of the weld joint of high voltage cable, this paper proposes to use idiP-DR digital radiographic detection technology to fill the technical gap of the field control of the weld joint of cable.

2. HIGH-VOLTAGE CABLE FUSION JOINT TECHNOLOGY
Cable fusion splicing technology is to use strong aluminum, active in the flame ignited reagents to produce high temperature in an instant, through the displacement reaction, will came out of the copper oxide copper displacement, reaction process will release a lot of heat on both ends of the conductor and the displacement of copper melting together, finish on both ends of the conductor of welding, and gradually restore cable structure of each layer, as shown in figure 1.

![Fig.1. Cable weld joint](image)

Compared with traditional prefabricated mechanical joints, high-voltage cable fusion joints have the following characteristics in field applications:

1. The joint is not affected by the instantaneous high current. When the short-circuit current is affected, the melting speed of the welding joint is slower than that of the general electric conductor, so it is not easy to be damaged.

2. Strong corrosion resistance and integrity. The welding at high temperature belongs to the intermolecular connection, and there is no mechanical stress. After welding, the joint at both ends of the conductor becomes a complete part with strong integrity.

3. The resistance of the fusion point is low. After the same metal is used for welding, the connection points are of the same material as the conductors at both ends of the cable body, and the resistance value is small.

Compared with traditional prefabricated mechanical joints, welded joints have certain advantages. However, because welded joints are made on site and affected by the production environment, their construction technology is prone to problems. So far, there is no effective process control means. Therefore, the following digital detection method based on IDIP-DR is proposed in this paper to strengthen the process control of welding joint of high voltage cable in the field production.

3. IDIP-DR digital radiographic detection technology
Because of the obvious density difference between conductor and main insulation after recovering by fusion technology, X-ray digital imaging technology can be used to detect and distinguish between conductor and main insulation.

Figure 2 shows the schematic diagram of the testing equipment in this paper, in which 1-X-ray machine; 2- plate detector; 3- Portable power module; 4- Wireless communication components; 5-X-ray machine control system; 6- Cable grayscale image receiver; 7- Cable grayscale image display tablet computer; 8- Special fixed bracket; 9- Cable body.
X-ray that penetrates the inspected workpiece is received by flat plate detector, and then the crystal circuit inside the flat plate detector converts it into current signal according to the dose intensity of X-ray, and finally presents it on the terminal computer in the form of digital image [6].

Fig. 2 The fundamentals of digital X-ray imaging

As the gray scale of the DR device reaches 16bit=65536 gray scale, and the difference between the defects and the surrounding images is small in gray scale, the human eye in the original image cannot clearly identify the defects, as shown in FIG. 3(a).

The gray value range of the gray image is compressed to the gray range that can be recognized by the human eye, and the redundant components in the image are removed, so that the gray value of the image is more concentrated in the recognition range of the human eye. In this paper, sparse transformation and projection measurement are implemented for images based on compressed sensing principle [7-8].

The image is sparse and reconstructed. After image in-depth processing [9], the gap between the defect and the surrounding images increases in gray scale and can be clearly identified, as shown in Fig. 3(b).

Fig. 3 Cable X-ray image like original image and depth-processed image

4. Application Case analysis
This paper has tested and applied the welding joint of 110 kV high voltage cable in a city, as shown in Figure 4 and 6. Idip-dr testing was performed after the cable was restored to primary insulation. Figure 4 and 6 are the original images of detection. Without in-depth image processing, the human eye cannot directly recognize the defects. After the advanced treatment proposed in this paper, the bubbles on the left and right interfaces of the main insulation are clearly displayed, as Figure 5 and 7 show.
Fig. 4 Check original picture on the right side of weld joint

Fig. 5 Inspection processing diagram of the right side of the fusion joint

Fig. 6 Check original picture on the left side of weld joint
In order to further verify the accuracy of the test results, after the position calibration of the above detection points, the section was cut parallel to the axial direction for dissection. As shown in Figure 8 Zeyu and 9, the dissected cable main insulation has different sizes of smile bubbles with diameters from 0.5 mm to 2.6mm.

In this paper, the causes of bubbles are analyzed: for the production of ultra-high voltage XLX cable, the nitrogen pressure in the pipeline should not be less than 1.2mpa. To maintain such a high pressure, the main reason is to reduce the number and diameter of microholes in the insulating layer and reduce the local discharge value; The temperature of the cross-linked pipe should match the
nitrogen pressure. When the pipe temperature is high and the nitrogen pressure is low, micro-pores and obvious bubbles will be generated [10]. In the process of XLPE crosslinking, the pressure and temperature inside the mold have a direct influence on the number and size of microholes inside the insulating layer [11]. During the cross-linking process of the main insulation at the production site, the power was cut off for 15 minutes due to the unstable power supply of the generator. As a result, the pressure and temperature in the grinding tool did not meet the cross-linking conditions, resulting in the bubble defect mentioned above.

5. Conclusions and Suggestions
In this paper, the IDIP-DR digital radiographic detection technology was used to detect the key manufacturing process of the weld joint of high voltage cable, and the bubble construction process problem of the main insulation was effectively detected. Through on-site dissection, the accuracy of the detection results was proved, which provided an effective means for the subsequent companies to carry out the control of the weld joint manufacturing process. It provides a new control method for the weld joint technology of high voltage cable in engineering application. In addition, in the process of restoring the main insulation, it is necessary to ensure the reliability of the whole power supply and voltage supply, otherwise similar defects are likely to occur.

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