High-voltage Cable Fault Analysis base on X-ray Image Processing

Ma Guoqing, Li Pengfei, Chen Zilong, Duan Yubing, Zhang Hao* and Hu Xiaoli
State Grid Shandong Electric Power Research Institute, Jinan, China

*Email: sdqzzh@163.com

Abstract. X-ray digital imaging detection technology is the use of high frequency X-ray machine to sample radiography, through the imaging detector to collect images, and the detected images after digital processing to the computer for analysis and processing technology. With the help of computer digital image processing technology, the image noise can be effectively reduced, and the contrast and clarity of the image can be greatly improved. The radiation dose and exposure time can be selected according to different materials, which greatly improves the detection efficiency. The detection can display the damage of the external force of the cable more quickly and intuitively, and provide strong support for the development of maintenance programs.

1. Introduction
With the rapid development of Chinese economy, urban construction has also achieved rapid development, and the original overhead power supply network in the city has gradually been transformed into cable power supply. Due to the small insulation distance between the cable cores, it can reduce the occupied space and land, and is not easily affected by external environments such as strong wind, lightning strikes, dirt and short-circuit of foreign objects, which greatly improves the reliability of power supply[1-4]. Due to the complicated internal structure of the cable, once a failure occurs, the disassembly and replacement work cycle is longer, thereby extending the power outage time and causing greater losses.

X-ray digital image detection technology has realized the nondestructive testing of the cable, which can analyze the internal damage of the equipment without power failure, and can reflect the internal damage of the cable more accurately and intuitively[5-7].

2. Principle of X-ray digital imaging detection technology
The basic principle of X-ray imaging is based on the penetrability, fluorescence effect and photosensitive effect of X-ray on the one hand and on the other hand, the difference in the density and thickness of the irradiated object. When the X-ray passes through the object, the X-ray measurement reaching the imaging plate is different, forming different effects of light and shade[8-10].

X-ray digital imaging detection technology is controlled by the controller ray machine produce X-ray irradiation was test sample, the attenuation of X-ray photons by imaging detector, after a series of A/D conversion and digital processing converted into digital signal, through the wireless network transmission to the computer, in processing the digital image displayed on the screen. As shown in Figure 1.
3. The Proposed Method

3.1 Cable damage caused by excavator construction
The external sheath and aluminum bellows of a 110kV cable were damaged to a certain extent during the construction of the excavator, and it is impossible to determine whether the damage to the main insulation was caused. The damage of cables on site is shown in Figure 2.

On site, the X-ray machine, the damaged part and the imaging detector are placed on the same line according to the damaged part of the cable. The emission distance of the X-ray machine is about 30cm away from the damaged part, and the imaging detector is attached to the cable. Adjust the shooting angle of the damaged part of the cable to make the X-ray tangent parallel to the damaged part. The X-ray image is shown in Figure 3. The parameter reference voltage is 130kV, the reference current is 5mA, and the exposure time is 1s.
According to the image, the upper position of the cable can be seen. In the red circle, the gap between the corrugated aluminum sleeve and the outer semi-conductive layer is small. The main insulation in the red box is caved in with obvious indentation.

To analysis the X-ray image automatically, here we use image processing method to judge the fault. The conductor is clear in Figure 3, therefore we can find the position of the cable by locating the conductor. The surrounding border created by the X-ray machine itself is cut off firstly. The binary image is shown in Figure 4, and its threshold is calculated through otsu.

Furthermore, we should find out the outer semi-conductive layer to judge whether the layer is damaged. We use the canny algorithm to find the edge and then use Hough transformation to get the inner and outer layer lines in the X-ray image.
Lines detected in Figure 5(b) is combined by the inner and outer border of the cable, with the conductor position detected in Figure (5), we can find out the outer border of the cable.

Take the $y$-position of the conductor is $[y_u, y_d]$, $y_u$ is the upper edge of the conductor as shown in Figure 6 (a). The size of the conductor and the outer layer is fixed, so with the length of $[y_u, y_d]$, we can find out the upper and lower part of the cable with $y$-position range $[2y_u - y_d, y_u], [y_d, 2y_d - y_u]$ as shown in Figure 6.

![Figure 6](image)

**Figure 6.** Exaction results for the outer semi-conductive layer

From Figure 6, the part where is damaged is quite different from other parts, with the texture pattern method like LBP (local binary pattern) and Tamura texture features, we can match the image and judge whether there is a damage.

3.2 Cable damage caused by support tip

During the construction process, a 110kV cable body is damaged, the support tip is inserted into the cable body, and the contact position between the cable body and the support is photographed by X-ray to determine whether the main insulation is damaged. The X-ray picture is shown in Figure 7. The parameter reference voltage is 130kV, the reference current is 5mA, and the exposure time is 1s.

![Figure 7](image)

**Figure 7.** X-ray picture of the contact site between cable body and bracket

For this kind of fault, we focus on the detection of the conductor and the tip. Still, the ostu segmentation result is shown in Figure 8, with the same procedure to find the outer border, the overlap between the cable and tip is easy to get.
4. The effect of parameter adjustment on image display

According to the setting of different voltages and exposure time, samples of different thickness can be photographed to achieve a trans illumination imaging. As shown in Table 1.

| Pipe diameter (mm) | Wall thickness (mm) | Double wall thickness (mm) | Voltage (kV) | Current (mA) | Focal length (mm) | Frame number (integral mode) | Window opening time (s) |
|-------------------|---------------------|----------------------------|--------------|--------------|------------------|-----------------------------|-------------------------|
| DN60 ~ DN219      | 5                   | 10                         | 150          | 5            | 600~700          | 3                           | 1                       |
|                   | 6                   | 12                         | 160          | 5            | 600~700          | 3                           | 1                       |
|                   | 7                   | 14                         | 180          | 5            | 600~700          | 3                           | 1                       |
|                   | 8                   | 16                         | 190          | 5            | 600~700          | 3                           | 3                       |
|                   | 9                   | 18                         | 210          | 5            | 600~700          | 4                           | 3                       |
| DN219 ~ DN400     | 10                  | 20                         | 230          | 5            | 600~700          | 4                           | 3                       |
|                   | 12                  | 24                         | 250          | 5            | 600~700          | 5                           | 3                       |
|                   | 13                  | 26                         | 280          | 5            | 600~700          | 5                           | 3                       |
|                   | 22                  | 44                         | 350          | 5            | 600~700          | 5                           | 5                       |
|                   | 24                  | 48                         |              |              |                  |                             |                         |
|                   | 26                  | 52                         |              |              |                  |                             |                         |

5. Conclusion

- The advantage of X-ray digital imaging detection technology lies in the digital image processing with the help of computers, which reduces the image noise, greatly improves the contrast and clarity of the image, and the image quality can be comparable to that of visible light photographic plates.
- The X-ray beam should be projected at the center of the tested sample vertically and tangent to the damaged site.
- In X-ray photographs, the intersecting contours of two objects do not indicate the contact between the two objects. But if the outlines of two objects in an X-ray image at one angle do not cross, it can be used as an argument that the two objects did not contact.
For the specimens with a wide range of thickness, one trans illumination can be achieved by changing the tube voltage and exposure time to avoid repeated trans illumination.

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