Study on Partial Discharge Detection of 10kV Power Cable

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Abstract

Partial discharge is a main factor which causes cross-linked polyethylene (XLPE) cable damaged. In order to research the Partial Discharge detecting methods of 10kV XLPE power cable, the electrostatic field is firstly simulated in order to analysis the electric filed at the distortion of the cable. According to the simulation mode, portable thermal infrared imager and ultraviolet imaging instrument is utilized to detect partial discharge of power cable terminals. The experimental results demonstrate that the use of ultraviolet imaging instrument to detect the location of defects is efficient and can observe corona photons; and thermal infrared imager can detect the temperature rising caused by Partial discharge. And this result also verified the simulation result that electric field concentration resulted in partial discharge. Test results also show that in short period of time partial discharge changes not much. This is mainly because the energy caused by PD does not accumulate so much in short time. That is contributing to the discovery of potential defects.

Keywords: XLPE cable, thermal infrared, ultraviolet imaging, ANSYS simulation

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1. Introduction

Insulation performance of power cable is a main factor to impact safely running, especially the cable joints with improper making accounted for a large proportion in cable operation failure. The domestic and foreign research discovery shows that partial discharge detection is an effective means to determine the cable insulation performance[1-3]. But on the field test of high environmental requirements and it is generally very difficult to do so. How to use partial discharge to determine the cable insulation performance, found a potential defect is the domestic and foreign scholars and producer concerns.

Good insulating performance is mainly depended on the safe operation of Cross-linked polyethylene(XLPE)cable. Partial discharge is a main factor to damage the performance of cable insulation. Partial discharge is often accompanied by heat and luminous, this way we can use thermal infrared imager to detect the local temperature rise. Some foreign scholars have given a statement about the relations between temperature and the residual life of cable[4]. If the operating temperature is rising 6 0C, the residual life of cable decreases a half. Thus, the operation state of cable can be diagnosed by detecting its temperature.

Partial discharge standards of 35kV voltage grade and below of XLPE power cable-partial discharge is given by the China national standard GB/T12976-2008, which is less than 5 pc at the voltage of 1.73 $U_0$. The insulation of XLPE cable could be damaged by various reasons when it was running, but the final performance is the electric field concentration and partial discharge[5-6]. In order to diagnose operation state of cable, we can detect partial discharge by using ultraviolet imaging instrument[7-8]. Detection method and wiring diagram of partial discharge of XLPE cable at the voltage level of 35kV and below is given by the GB/T3048-2007.

In this paper, the electrostatic field is firstly simulated in order to analysis the electric filed at the distortion of the cable. According to the simulation mode, portable thermal infrared imager and ultraviolet imaging instrument is used to detecting partial discharge, in order to find an effient methods to evaluate insulation condition.
2. Simulation Analysis

Regardless of alternating magnetic field on the influence of electric field, Maxwell’s equations can be written as

\[ \nabla \times \vec{E} = 0 \]  
\[ \nabla \cdot \vec{D} = \rho \]  

And the relationship between electric field and electric displacement vector and potential follows the two formula

\[ \vec{D} = \varepsilon \vec{E} \]  
\[ \vec{E} = -\nabla V \]  

In the electrostatic field analysis, consideration is also to meet (1), (2), (3) and (4) type, use of ANSYS software is convenient to satisfy these constraints, and also can calculate insulation electric field energy distribution. In order to analysis the electric filed at the distortion of the cable, in this paper, ANSYS software is used to do the electrostatic field simulation.

The cable terminal model is built by the Figure 1, and the parameters used are listed in Table 1. After meshing the model, applying loads as Table 1, and then processing the finite element calculation. The distribution of electric field has shown by the Figure 2.

<table>
<thead>
<tr>
<th>Table 1. Table of Parameters Used in ANSYS Model</th>
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<tbody>
<tr>
<td>Element type</td>
</tr>
<tr>
<td>Smart size</td>
</tr>
<tr>
<td>Conductor U=15.050kV</td>
</tr>
<tr>
<td>Copper shelter and outer surface of air U=0kV</td>
</tr>
</tbody>
</table>

As can be seen from Figure 2, at the location of air gap defection resulted in field concentrated. Some nodes value reaches $0.12 \times 10^{-7} \text{ V/mm}$ and this value have exceeded the insulation tolerance of 10kV cable. Partial discharge with light and heat appears during the process of applying voltage. So ultraviolet imaging instrument is used to detect partial discharge (PD), and the temperature rising due to PD can also be observed by infrared thermal imager.

Take a further analysis we can find at the location of defection we made, the electric field is not as large as electric field between copper shied and semi conductive layer. This phenomenon also occurs when we set the defection at the internal location of the cable. This would give us an advice that in the process of cable terminal making, copper shielding layer should be cutting smoothly, and the location between copper shielding layer and outer semi conductive layer should be made very well. This also explains from another angle that stress cone should be installed at the contact position of this two layer.
3. Testing Program

It is caused by cable manufacturing of the void defects or installation process lead to electric field concentration, so as to make the cable partial discharge occurring which causes the cable insulation damage. In the laboratory, a cable section running for a period of time-YJV-22, 3*70mm, and 30m long is utilized. The thickness of main insulation is about 4.5mm. A nail hole is set in the main insulation to simulate void defect -the nail hole is about 4mm deep. The nail hole is made in the position of outer semiconducting layer of cable terminal, to imitate the actual defect caused in manufacturing or installation process, as shown in Figure 3.

![Figure 3. Nail hole in semiconductor](image1)

![Figure 4. Wiring diagram](image2)

After setting the defect, the infrared and ultraviolet imaging instrument for temperature and PD detection are used. According to the standard required by GB/T12976-2008, voltage slowly increases to $2U_0$ and keeps ten seconds, and then slows down to $1.73U_0$. In this experiment, every once in a while with ultraviolet and infrared shooting, the purpose is to make sure that weather the temperature and PD would change in a short period of time. Laboratory wiring diagram as shown in Figure 4.

4. Results Analysis

4.1 Infrared (IR) Detection Results

The rise of cable temperature has mainly two reasons. One reason is due to the heat effect of electric current, and with the passage of time there will be a accumulation of heat, which cause temperature rising. Another is because the electric field is too concentrated, the occurrence of local discharge. In this experiment, no current flows through the conductor of the cable, thus we can judge, cable terminal temperature rise is caused by partial discharge. The thermal imager photo at 10min is get as Figure 5.

![Figure 5. Infrared detection results](image3)

![Figure 6. Ultraviolet detection results](image4)
The maximum temperature is 24.3 °C and ambient temperature is 20 °C is obtained from the Fig.5, which is indicated that the defect at cable terminal has caused temperature rising. Because there is no current flowing, it is conclude that the location of discharge has occurring and leading to elevated temperatures.

Comparing with thermal imager photos taking per 5 minutes, it is concluded that temperature risen caused by partial discharge will not change in a short period of time. This is different from current thermal effect, which as time accumulated, also accumulated heat, temperature change with time.

4.2 Ultraviolet (UV) Detection Results

When the insulator has gas void defection and the air gap under electric field exceeds the tolerance of electric field intensity, gas ionization is occurred, the ionization of charged particles in electric absorption and release energy also emits ultraviolet light. So it can be through ultraviolet technique for the detection of partial discharge. In this experiment, the detected results are shown by the Figure 6.

From the Figure 6, it can be obviously seen the location of partial discharge, namely, the location of setting air gap defection. From the screen we can read out discharge capacity. According to the compression of time UV image display board volume, do as shown in the board volume changes with time chart (contrasting with not setting artificial defect).

As can be seen in Figure 7, in 30 minutes time, partial discharge of the phase with nail hole has increased, but the increase is not much. According to the result of this experiment, another phase without manmade defection was also detected partial discharge. And the discharge was increasing with time, but the change is not too much. The phenomenon is probably because of the cable has run for a certain number of years. From the UV image we see some point of light. This is also the presence of a small amount of discharge. Comparing with the phase without defection, the discharge of “nail hole” phase is lager.

5. Conclusion

Partial discharge is a mainly factor for the damage of cable insulation property of XLPE cable. In order to analyze electric field distribution of cable, in this paper, finite element calculation is done by using the emulation. According to the simulation, electric field distortion is the most powerful across the copper shelter, and may be this is a main factor of which causes the insulating property decrease.

PD is detected by using infrared thermal imager and ultraviolet imaging instrument. This is because Partial discharge is often accompanied by heat and luminous. The temperature shift is detected to determine partial discharge point. And by using portable ultraviolet imaging instrument, the point of partial discharge is also observed. It can be found that in short period of time the PD will be changed a little.

By compared the experiment result and the simulation we can find, in laboratory experiments with ultraviolet imaging instrument and the ANSYS simulation reach an agreement - that the electric field distortion is most serious at the location of the contact of insulating shielding layer and insulating layer. And also this location of the partial discharge ratio is much larger than the location of “nail hole”. This also gives us a requirement, in the production of
cable connection, it must be installed stress cone (used to balance the electric field), and the installation position should be correct, otherwise the distortion of the electric field of the insulation shield will be great. That is very harm for cable.

References