Study on insulation performance optimization of EMU high-voltage equipment box

Chao Li*a, Lin Linb*, Weidong Qu*c

1Skills Training Center of State Grid North Hebei Electric Power Co., Ltd, Baoding 071051, China
a*731817442@qq.com, b*15933930851@163.com, c39400920@qq.com

Abstract—The EMU high-voltage electrical equipment on the roof not only bears the erosion of various harsh and extreme environments, but also bears the impact of various over-voltage, and the insulation performance of the electrical equipment on the roof is seriously threatened. This paper studies the insulation optimization design method of EMU high-voltage electrical equipment, puts forward the method of adding a certain length of insulating sheath on the electrical equipment to improve the insulation performance of high-voltage equipment box, and tests the insulation optimization measures on high-voltage circuit breaker and EMU high-voltage cable. The result shows that the installation of insulating sheath is feasible to improve the insulation performance of EMU high-voltage equipment box.

1. Introduction

With the development of high-speed railway, the running speed of high-speed EMU has reached 385km / h. In addition, the temperature difference of railway lines is large and the operating environment is poor, the insulation problem of EMU high-voltage electrical equipment is becoming increasingly prominent. In addition to environmental factors, insulation problems are also closely related to insulation design. Therefore, it is necessary to strengthen the research on insulation design and improve the insulation performance of EMU high-voltage electrical equipment[1].

At present, a lot of investment has been made at home and abroad to improve the insulation performance of EMU high-voltage equipment. Part of the research is devoted to the selection of insulating materials. In the emerging research on electrical equipment insulation, outdoor insulating sheath is widely used, and its application in other devices needs to be further explored. After the test operation of "anti flashover insulating sheath", there was no flashover accident on the connected line [2]. Literature [3] introduces the use of insulating metal sheath. The advantages of insulating sheath are introduced in literature [4]. Literature [5] proposed a method to install a certain length of insulating sheath on the transmission line at the end of high-voltage composite insulator to improve the electric field strength at the high-voltage end. Literature [6] concluded that the pollution flashover characteristics of composite insulators can be improved by optimizing sheath parameters. Through the power frequency withstand voltage test in literature [7], it is proved that the installation of insulating sheath can reduce the voltage borne by insulators. Based on the above research, this paper explores the application of insulating sheath in EMU high-voltage equipment. The paper adds a certain length of insulating sheath on EMU high-voltage equipment, and tests the lightning impulse withstand voltage of the equipment. The results prove the feasibility of adding insulating sheath to improve the insulation performance of EMU high-voltage equipment box.
2. Insulation optimization method

The insulation level of electrical equipment refers to the test voltage (withstand voltage) that the equipment insulation can withstand. Under the action of this voltage, flashover and breakdown or other damage will not occur.

(1) Selection of insulating materials

According to different insulating materials, high-voltage cables can be divided into high-voltage oil paper cables, high-voltage plastic cables and rubber insulated cables. Insulators can be divided into porcelain insulators, glass insulators, silicone rubber composite insulators and epoxy resin composite insulators.

(2) Shielding

By improving the electrode shape, the potential distribution along the surface of solid medium is homogenized, the maximum potential gradient is reduced, and the surface flashover voltage can also be increased. This method is called shielding. There are many kinds of shielding, including shielding cover, shielding ring, shielding layer and insulating sheath. The function of shielding ring and shield cover is to control corona on electrical equipment. The insulating sheath is made of silicone rubber material by high-temperature molding, which has excellent electrical performance, aging resistance, high and low temperature resistance. Installing the insulating sheath on the high-voltage electrical equipment can improve the electric field strength at the high-voltage end, increase the effective leakage distance of the equipment, improve the corona voltage and improve the pollution flashover characteristics of the equipment.

(3) Barrier

The barrier is a solid insulating medium placed in the electric field and has prominent edges in the equipotential plane direction of the electric field. The barrier can significantly improve the electric field distribution and increase the surface flashover voltage.

3. Verification of impact withstand voltage test

The insulation level of high-voltage electrical equipment is determined by the most serious one of lightning over-voltage, operating over-voltage and maximum working voltage acting on the insulation. Since the system voltage is lower than 220kV, it is uneconomical to limit the lightning over-voltage to lower than the operating over-voltage in the EMU high-voltage electrical system. Therefore, the insulation level of the EMU high-voltage equipment box is determined by the lightning over-voltage. The EMU high-voltage electrical equipments include circuit breaker, high-voltage cable, insulator, high-voltage transformer, lightning protector, isolating switch and traction transformer. Taking CRH380 EMU as an example, the lightning impulse withstand voltage test of high-voltage circuit breaker and high-voltage cable of EMU is carried out to obtain the insulation performance of the equipment in this paper. Through the impact withstand voltage test of EMU high-voltage circuit breaker and high-voltage cable before and after the installation of insulating sheath, the influence of insulating sheath on the insulation performance of EMU high-voltage equipment under over-voltage is explored.

3.1 Test operation instructions

This paper tests the impulse withstand voltage of the high-voltage circuit breaker and high-voltage cable respectively. The test object sequence is circuit breaker, circuit breaker with insulating sheath installed on the head, cable and cable with insulating sheath installed on the terminal. The test operation process is as follows:

(1) Conduct wiring according to the experimental schematic diagram, select appropriate wave head and wave tail resistance, and make the impulse voltage generator output lightning impulse voltage;

(2) After confirming that the wiring is correct, all personnel shall leave the experimental area;

(3) Remove the grounding rod from the impact body capacitance, determine that there is no one in the experimental area, and close the experimental area;

(4) Turn on the power supply of the impulse voltage generator experimental console, and set the
charging voltage of each stage as the design value on the control operation interface;

(5) Press the charging button;

(6) Record the waveform after synchronous discharge of the impact machine;

(7) Click the grounding button on the console, turn off the power supply, and hang the grounding rod on the non-grounding end of the first stage capacitor of the impact generator;

(8) Gradually increase the voltage applied to the test object, repeat steps 5-7, and observe the change of output voltage waveform until the test object is broken down;

(9) Replace the test object and retest;

(10) Disconnect the main power supply of the experiment and restore the experimental site clean and tidy after the experiment.

The field physical drawing of the equipment before and after the installation of insulating sheath is as follows. The left side of Fig.1 is the head of the circuit breaker in the initial state and the right side is the head of the circuit breaker after the installation of insulating sheath. The left side of Fig.2 is the cable terminal in the initial state and the right side is the cable terminal after the installation of insulating sheath. Fig.3 is the holistic model of CRH380 EMU high-voltage equipment.

---

**Fig.1** Circuit breaker head before and after installing insulating sheath

**Fig.2** Cable terminals before and after installing insulating sheath

**Fig.3** The holistic model of CRH380 EMU high-voltage equipment

In this paper, the measured wave voltage waveform is selected as the injury indication method in lightning impulse voltage test. Whether the tested object is broken down can be determined by the dynamics of the waveforms. The voltage divider with oscilloscope, peak voltmeter and digital recorder
are used to measure the voltage peak and waveform. The tested voltage waveform is output after being reduced in a certain proportion.

3.2 Test results

3.2.1 High-voltage circuit breaker
First, the impulse withstand voltage test is made on the circuit breaker before installing the insulating sheath, and then on the circuit breaker after installing the insulating sheath. The impulse voltage applied to the circuit breaker before and after installing the insulating sheath is recorded in Tab.1. Fig.4 shows the voltage waveform before installing insulating sheath. Fig.5 shows the voltage waveform after installing insulating sheath.

| Test voltage 1 | Test voltage 2 | Test voltage 3 | Test voltage 4 | Test voltage 5 | Test voltage 6 |
|----------------|----------------|----------------|----------------|----------------|----------------|
| Initial state  | 139.2kV        | 145.6kV        | 150.4kV        | 163.2kV        | 179.2kV        |
| After installing the insulating sheath | 182.4kV | 185.6kV | 192kV | 212.8kV | 220.8kV | 228.8kV |

![Fig.4 Voltage waveform before installing insulating sheath](image)

![Fig.5 Voltage waveform after installing insulating sheath](image)

3.2.2 High-voltage cable
Firstly, the impulse withstand voltage test of high-voltage cable before installing the insulating sheath is conducted. The waveform recorded is shown in Figure 6. Next is the cable installed with insulating sheath. The waveform is shown in Figure 7. The impulse voltage applied to the high-voltage cable before and after installing the insulating sheath is recorded in Table 2.

| Test voltage 1 | Test voltage 2 | Test voltage 3 | Test voltage 4 | Test voltage 5 | Test voltage 6 |
|----------------|----------------|----------------|----------------|----------------|----------------|
| Initial state  | 122.4kV        | 139.2kV        | 177.6kV        | --             | --             |
| After installing the insulating sheath | 168kV | 176kV | 187.2kV | 195.2kV | 201.6kV | 243.2kV |
3.3 Analysis of test results

It can be seen from the test results that the installation of insulating sheath for EMU high-voltage equipment does improve the insulation performance of the equipment. For the high-voltage circuit breaker, the installation of insulating sheath increases its impulse withstand voltage value from 163kV to 213kV. For the high-voltage cables, the installation of insulating sheath increases the impulse withstand voltage value from 178kV to 243kV.

4. Conclusion

Due to the existence of insulating sheath, the withstand voltage on the circuit breaker and cable is lower than that added by the impulse voltage generator to the tested object, and the reduced part of the voltage is borne by the insulating sheath. The insulating sheath plays a role in sharing the impact high voltage during the test. By changing the equivalent capacitance of the insulating sheath, the improvement degree of the insulation performance of the equipment installed with the insulating sheath can be changed. But first of all, the voltage shared on the insulating sheath cannot exceed its puncture voltage. And the different of installation positions has different effects on the optimization of insulating performance. Therefore, it is necessary to reasonably configure the parameters of insulating sheath to achieve the best effect.

References
[1] Guo Chenxi. Discussion on high voltage insulation design of electric locomotive / EMU [J]. China Academy of Railway Sciences. 2010.
[2] Wang Jianhong. "Anti flashover insulating sheath" fills the gap in China [n]. Ningxia daily, December 17, 2008 (006).
[3] Popovic, Ljubivoje. M. Comparative analysis of grounding systems formed by feeders in one case with uninsulated and in the other case with insulated metallic sheath [J]. 2005, 1-5.
[4] Lu Zhigang. Application of insulating sheath in oilfield power system [J]. Instrument electrical, 2012, 31 (4): 51-51.
[5] Mei Hongwei, Chen Jinjun. Study on installing insulating sheath on high voltage transmission line of composite insulator [J]. Chinese Journal of electrical engineering, 2011, 31 (1): 109-116.
[6] Mei Hongwei, Peng GONGMAO. Pollution flashover characteristics of composite insulator suspension conductor after installing insulating sheath [J]. Chinese Journal of electrical engineering, 2011, 31 (31): 189-195.
[7] Ma Kui, Wang Hailong. Analysis of flashover protection effect of anti flashover insulating sheath on bird droppings [J]. Ningxia electric power, 2012, (2): 20-24.
[8] Ma Limin, Cui Wei, Yu Demai. Analysis and research progress of three insulator materials [J]. New chemical materials, 2011, 39 (12): 28-30.
[9] Wang Shuqin. Analysis of insulators for CRH2 EMU Roof [J]. Shanghai Railway Science and technology, 2009, (4): 43-44.
[10] Zhang Zhaohui, Wu Mingli. Common fault analysis of high voltage electrical system on the roof of EMU [C]. International Academic Conference on rail transit electrical and information technology, 2013.