Analysis and countermeasures of the tilt of lightning rod in transformer substation

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Abstract. The lightning rod is an important lightning protection facility in transformer substations, which has a good protective effect for the compact equipment, while its safety performance is often neglected. The lightning rod in the 220kV transformer substation is up to tens of meters, the collapse of the lightning rod results in not only serious damage to the equipment, but also severe power failure. In this paper, the causes of the tilt of the lightning rod were analysed, and the installation requirements for the new lightning rod was proposed, which could effectively ensure the safety of the lightning rod.

1. Introduction
As a variety of equipment is stored in the substation, lightning rod, as a direct, simple and effective lightning protection method, has played a good role in protection for the substation equipment. However, the safety of the lightning rod itself has been neglected for a long time. After the old lightning rod is in operation for a long time, it has obvious inclination due to various reasons. In the process of operation, if it is affected by the strong wind load, the collapse of the lightning rod may occur, thus causing a major power failure accident. In a substation with the power of 750kV, there have been accidents of 750kV side independent lightning rod fracture and 330kV side frame lightning rod fracture [1-3]. However, in the process of installation for the new lightning rod, there is no clear technical requirement, and all sorts of installation operation are not very normative, leading hidden later trouble [4-5]. In the present work, reasons for the tilt of lightning rods in old substations are analysed, and the corresponding installation requirements and acceptance indexes are proposed to ensure the safe operation of lightning rods in the future service process, so as to prevent the collapse of lightning rods effectively and ensure the safe operation of substation equipment and power grid.

2. Detection and analysis

2.1 Lightning rod inclination measurement
In February 2015, power operations staff found that substation lightning occurred obvious tilt, then reported this phenomenon to Hunan Electric Institute. Then the experts went to the scene the next day, and measured two apparent-tilt 220 kV side lightning rod and two 110 kV side tilt of the lightning rod, using the total station and the lift car up homework to inspect the lightning rod.
Table 1. Lightning rod inclination measurement

| Lightning rod No. | Total inclination | Inclination (tangent value) | Standard request |
|-------------------|------------------|----------------------------|------------------|
| 1                 | 0°37'45"         | 0.0107                     | Q/GDW183-2008    |
|                   |                  |                            | 《110KV~1000kV》  |
|                   |                  |                            | The regulations  |
|                   |                  |                            | for acceptance   |
|                   |                  |                            | and evaluation   |
|                   |                  |                            | of civil         |
|                   |                  |                            | engineering      |
|                   |                  |                            | construction     |
|                   |                  |                            | quality of       |
|                   |                  |                            | substation       |
|                   |                  |                            | (converter)      |
|                   |                  |                            | stipulates that  |
|                   |                  |                            | the vertical     |
|                   |                  |                            | deviation of     |
|                   |                  |                            | lightning rod    |
|                   |                  |                            | shall not exceed |
|                   |                  |                            | 1‰               |
| 2                 | 0°32'55"         | 0.0096                     |                  |
| 3                 | 0°26'18"         | 0.0076                     |                  |
| 4                 | 0°28'34"         | 0.0082                     |                  |

2.2 Lightning rod height check

After the inclination of the inclined lightning rod was measured by the total station instrument, the elevator was used for the climbing operation, and the obviously inclined lightning rod was checked. The following problems were found:

(1) The gap between the upper and lower parts of the lightning rod was large. Metal gaskets, rubber, and other fillers were used to fill the gap between the upper and lower parts of the lightning rod during installation. After operation for a couple of years, the metal gaskets and rubber became thinner or more aged, as shown in Fig. 1. In addition, according to the introduction from provincial maintenance company technical personnel, they installed the lightning rod in order to prevent the large gap between the upper and lower sections, leading to the tilt problem, the lightning rod joint parts for spot welding or welding were fixed and strengthened.

(2) The base of the lightning rod was not leveled. The level of the lightning rod was adjusted by filling the metal sheet when mounting. After a long-term operation, the metal sheet was corroded and thinned to form a void (see Fig. 2), which affected the perpendicularity of the lightning rod.
(3) The bolt connecting rod between the lightning rod segment and the segment was not installed correctly, the flat gasket and spring gasket were missing, as shown in Fig. 3. Since the point of force of rod wearing connection bolt was the outer arc surface of the lightning rod, the place of force was not a plane, but a line of the outer arc surface [6]. After a long-term operation, rod wearing connection bolt would become loose due to insufficient tightening torque, thus affecting the verticality of the lightning rod. Although the bolts of No. 1 and No. 4 lightning rods were installed correctly, the bolts, plain washers, and elastic washers were severely corroded, and the plain washers and elastic washers have been deformed, as shown in Fig. 4. The deformed gasket would cause the nut to loosen, which also affected the lightning rod perpendicularity.

3. Conclusion and treatment measures

(1) Materials used to fill the gap between the upper and lower sections of the lightning rod were corroded and aged after a long-term operation, resulting in an excessive gap between the upper and lower sections;

(2) The lightning rod base was not plain, and the filling metal sheet formed a void after corrosion after a long-term operation during installation;
(3) The bolt part of the connecting rod was not installed correctly, there was a lack of flat washers and spring washers, or the washers were corroded and deformed. After a long-term operation, the fastening torque of the connecting bolt of the connecting rod was insufficient.

Based on the above situation, it is recommended to replace the 220kV transformer lightning rod.

The site installation quality of the new replacement lightning rod shall be supervised, and the key points of supervision are as follows: 1. In addition to connecting the upper and lower sections of the lightning rod with rod bolts, spot welding or full welding method shall be adopted to fix and strengthen the lightning rod to ensure that the joints are fixed between the joints. The welding part shall not have cracks. Anticorrosive paint shall be applied to the welding position and the 100mm area nearby; 2. The lightning rod base shall be plain before installation. It is forbidden to adjust the level by filling the metal sheet; 3. Wear rod connection bolt assembly should be correct, it should not be lack of flat gasket and spring gasket. 4. During the overall acceptance, the total station shall be used to measure the vertical deviation of the lightning rod. The vertical deviation shall be no more than 0.1% of the length of the lightning rod and no more than 35mm.

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