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The Performance of Lightning Rod Arrester and Its Effect on the Top Potential of Tower for 500 kV Transmission System

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Abstract

When the tower overhead is struck by the lightning impulse, the lightning current flows into the earth through the impedance of tower and the grounding resistance, which heightens potential of the tower overhead and possibly induces insulator flashover. Lighting rod arrester is used to shield the tower and provide another routine for lightning current, decreasing the potential of tower overhead. In this paper, the performance of a 500 kV lighting rod arrester is tested used in AC transmission system under the current impulse. Besides, the influence of the lightning rod arrester performance on the top potential of tower is also studied. The results show that, when the rod arrester is connected to the tower, the top potential of tower can be obviously limited under the lightning strike.

Keywords

Lightning Impulse, Grounding Resistance, Lightning Rod, Top Potential of Tower, Insulator Flashover, Lightning Protection

1. Introduction

With the incessant increase of social electrical power demands, more and more Extra-High Voltage (EHV) and Ultra-High Voltage (UHV) AC/DC power transmission lines are under planning and construction. Because the energy supply entered in China is far away from the power load district, the transmission line corridors are unavoidably through the regions with the complex terrain, including the mountains with frequent lightning activi-

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ties [1]-[5]. Once the lightning impulse strikes the tower overhead, the lightning current flows into the earth through the impedance of the tower and the grounding resistance, which heightens the potential of the tower overhead and possibly induces insulator flashover. When the lightning rod arrester is installed on the tower overhead, it can shield the electric field of the tower overhead and can provide another routine for the lightning current, which directly limits the potential of tower overhead and protects the safety of insulator [6]-[8].

In 500 kV AC transmission system, a large number of lightning rod arresters have been used to protect the transmission line. To guarantee the stability and reliability of the lightning rod arresters, the performance test of the lightning rod under pulsed current waveform is necessary. Besides, when the lightning current flows through the lightning rod connected by the down lead, the potential of the tower overhead will also change. With different connection method of the lightning rod, the potential of tower overhead varies. Thus, it is also important to investigate the connection method of the lightning rod.

In this paper, the performance test of the 500 kV lightning rod arrester under current impulse is conducted. Besides, the potential of the tower overhead is tested when the lightning rod is installed in a 500 kV tower and connected to the center of the tower by the down lead while different current waveform is applied.

2. Property Test under Lightning Current Impulse

To obtain a current impulse with variable rise time and duration, a capacitor bank, including six 30 kV 8 μF capacitors and equipped with a resistor and inductance to adjust the waveform, is employed. The schematic diagram of the discharge circuit and the picture of the 500 kV lightning rod are shown in **Figure 1**. The current of the discharge circuit is measured by a Rogowski Coil (Pearson 101, 4 MHz, 50 kA) while the voltage on the lightning rod is monitored by a High Voltage Probe (Tek-6015A, 75 MHz, 40 kV).

When six capacitors are connected parallel to each other and discharge to the lightning rod, both the current and voltage waveforms with different charged voltage U, are measured and shown in **Figure 2**. The current is with a rise time (10% - 90%) of 17 μs and a duration (full width at half maximum, FWHM) of 40 μs. Due to the high inductance of the lightning rod arrestor, the voltage waveform of lightning rod under current impulse has an overshoot, as shown in **Figure 2(b)**. Both the overshoot U_o and the peak U_p of the waveform platform are recorded and shown in **Figure 2(c)**.

With a fixed charged voltage of 17.5 kV, different capacitor is used to generate the current waveforms with different rise time and duration. Five kinds of current waveforms are generated, and the waveform parameters are 17.4/39.6, 15.2/36.6 s, 14/32.6, 13.1/28.9 and 9.7/25.1 μs respectively. Under the current waveforms, the voltage waveforms are monitored and shown in **Figure 3**.

3. The Effect of Lightning Rod Arrester on the Top Potential of Tower

To study the effect of lightning rod on the potential of tower, the lightning rod is installed on the top of an actual 500 kV tower, as shown in **Figure 4**. The bottom of the lightning rod is fixed by an insulated support and connected to the center of the tower by a down lead while the top of lightning rod is directly connected to the current pulse generator for current injection. The current waveform produced by the current generator has two sets

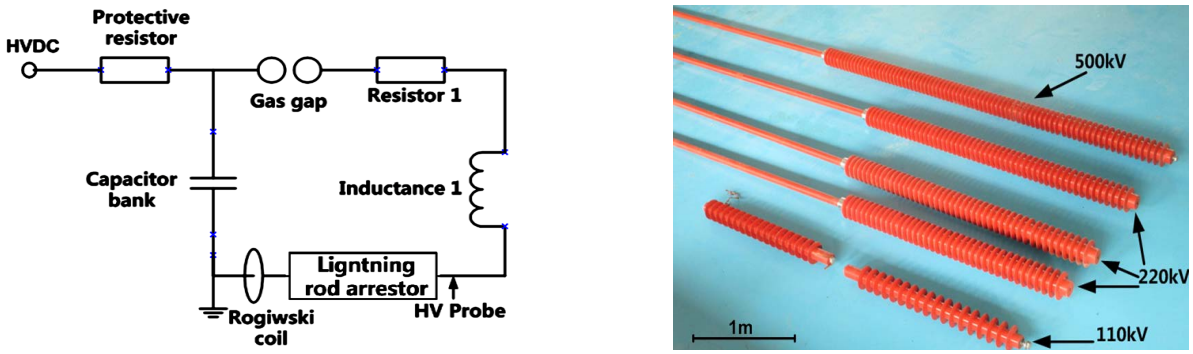

Figure 1. The schematic of the test circuit and the picture of lightning rod arresters. (a) test circuit; (b) lightning rod arresters.

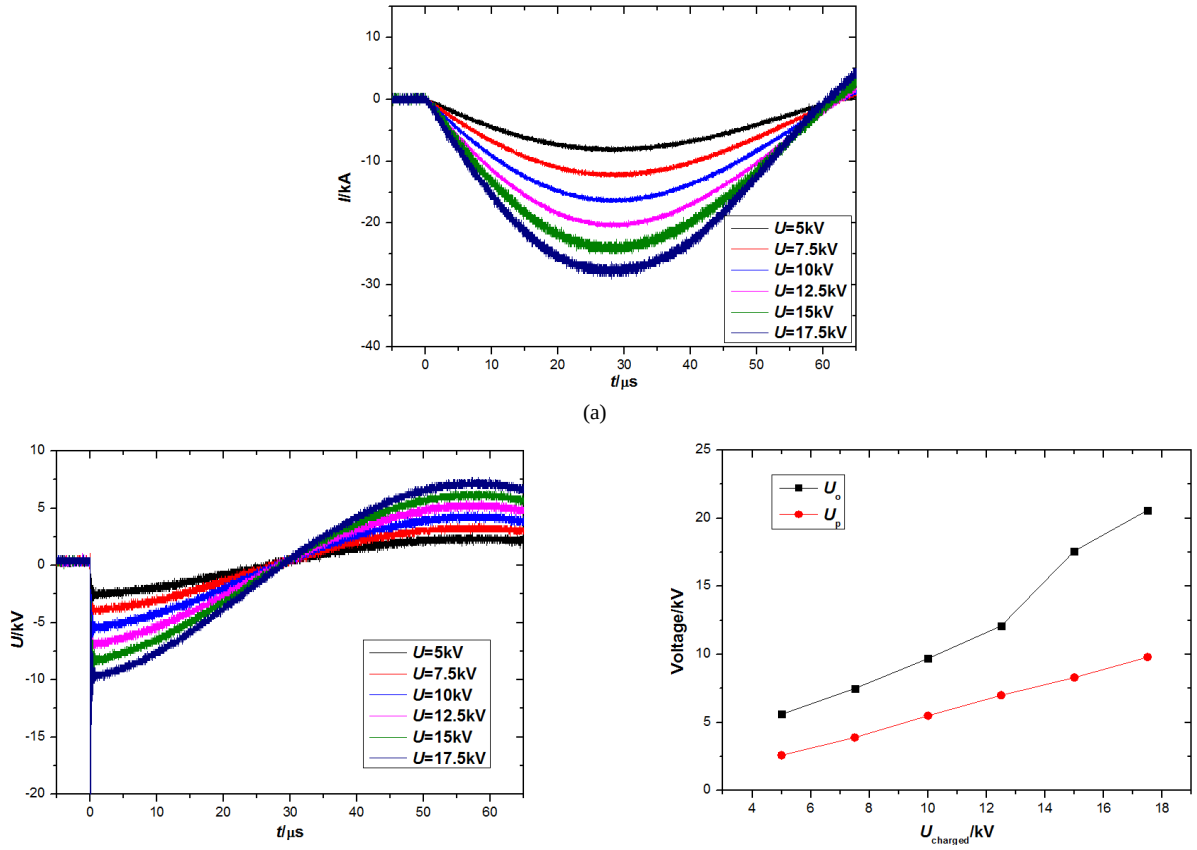

Figure 2. Current and voltage waveforms with different charged voltage. (a) current waveform; (b) voltage waveform; (c) the overshoot and peak of voltage waveform.

Table 1. The current parameter and potentials in different locations.

Applied current	I_{peak} (kA)	Rise time (μs)	FWHM (μs)	U_1 (kV)	U_2 (kV)	U_3 (kV)
4/10 μs	18.42	15.3	34.5	17.6	5.2	5.3
8/20 μs	17.24	17.5	38.5	13.6	4.2	4.4

of parameters, 4/10 μs and 8/20 μs respectively. When the current is applied to the lightning rod, the potential of three points, including the top of the lightning rod and both the top and center of the tower, are measured. The equivalent circuit is shown in **Figure 4(b)**. The current waveform and the potentials in different locations are recorded and shown in **Table 1**.

According to the data in **Table 1**, the potential of the top of the lightning rod is far higher than that of the overhead of the tower, and most of the voltage are applied to the lightning rod and the down lead. Under both current waveform, the potentials in different locations have the similar trend. In this way, the potential of the tower overhead can be greatly limited by the lightning rod, which can directly decrease the voltage on the insulator and reduce the probability of insulator flashover.

4. Conclusion

In this paper, the performance of the 500 kV lightning rod under lightning current impulse is studied. Besides, when the lightning rod arrester is installed in a 500 kV tower and connected to the center of the tower, the potential of different locations is investigated. When the lightning current impulse flows through the lightning rod, the rise time and duration of current waveform increase and an overshoot will be generated on the lightning rod. Once the lightning strikes the lightning rod, the current will flow through the down lead and greatly limit the

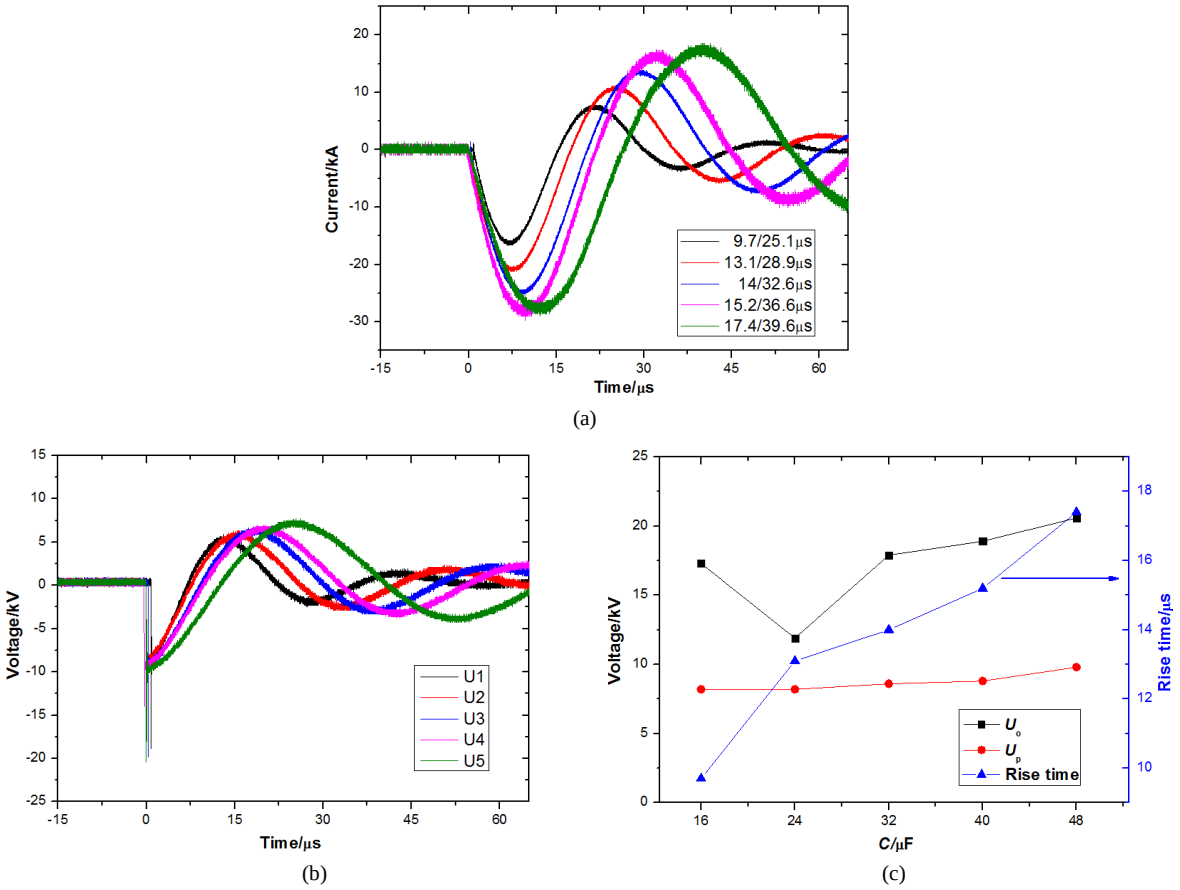

Figure 3. Current and voltage waveforms under different waveforms. (a) current waveform; (b) voltage waveform; (c) the overshoot and peak of voltage waveform.

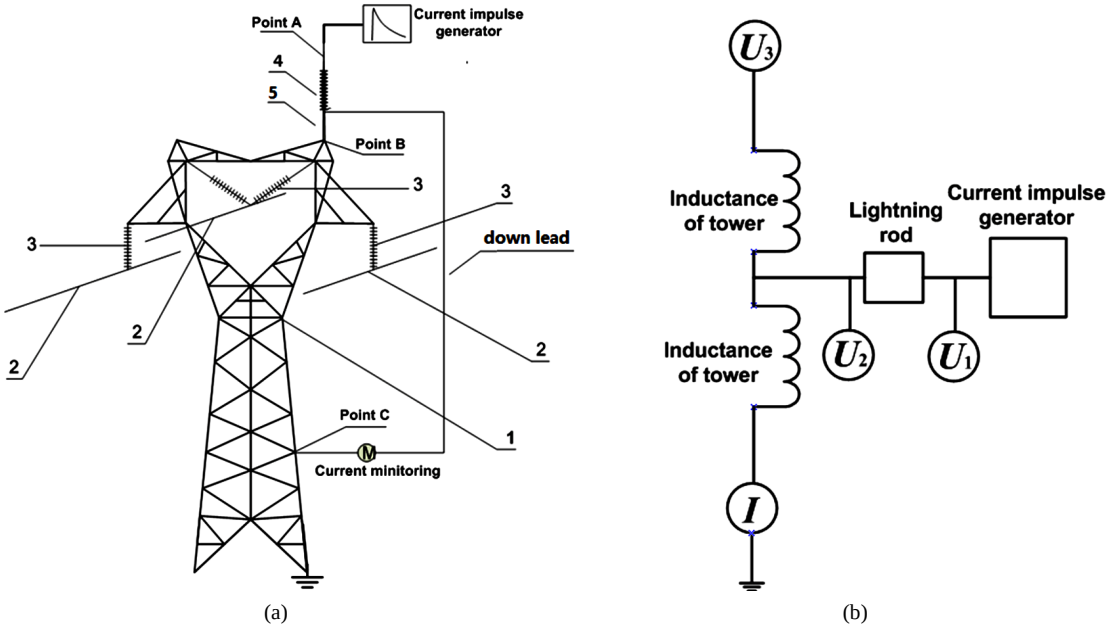

Figure 4. The test circuit (1—the tower; 2—transmission lines; 3—the insulators; 4—the lightning rod; 5—the insulated support). (a) the 500 kV tower; (b) the equivalent circuit.

potential of the tower overhead. In the future research, investigating the influence of connection method of lightning rod on the potential of tower overhead would be the main focus.

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