EXPERIMENT OF ARTIFICIALLY TRIGGERED LIGHTNING TO LIGHTNING ROD AND SEMICONDUCTOR LIGHTNING ELIMINATOR

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ABSTRACT: In the summer of 1998 and 1999, the experiments of triggered lightning aimed at testing and comparing the function of conventional type of lightning rod and so-called Semiconductor Lightning Eliminator (SLE) were conducted in Guangzhou, southern China. The results clearly showed the attachment process between lightning rod and downward leader. The parallel discharges between two or three SLE rods were observed. When the SLE rods were struck by triggered lightning, the flashover occurred and the lightning current measured on the bottom of lightning channel was more than 6kA for one case. The lightning current-limiting function of SLE was not observed.

INTRODUCTION

In recent years, various non-conventional lightning protection facilities have been deployed in China. However, there has been controversy about their working principle as well as their effectiveness in practice superior to conventional lightning rods claimed by manufacturer. Among these facilities the so-called Semi-conductor Lightning Eliminator (SLE) might be a typical example. SLE is a kind of non-conventional lightning rod composed of special material having high resistance [Chen et al., 1998]. The manufacturer of SLE claims that SLE can eliminate upward going lightning discharge and lighten the damage of downward going lightning discharge due to its current-limiting function. The artificially triggered lightning technique, especially triggered lightning in altitude provides an unique means for investigating the function and effectiveness of lightning protection facilities. In the summer of 1998 and 1999, the experiment of triggered lightning aimed at testing and comparing the function of conventional type of lightning rod and SLE was conducted in Guangzhou, southern China. The experiments and some phenomenon were described briefly in this paper.

INSTRUMENTATION AND MEASUREMENT

In 1998, altitude triggering technique was adopted for lightning rod (the height being 3.5m) in which steel wire trailing by rocket connected through nylon line 100m in length to ground. In 1999, the experiment was conducted to test SLE. Figure 1 shows the deployment of experiment. The SLE was composed of 9 rods arranged orthogonally in two directions and mounted on a 8.5m steel tower. The serial numbers of SLE rods in two directions were 1, 2, 3, 4 ,5 and letters a, b, c, d, e respectively. Each rod was made of a special material, being 5m in length and 35kΩ in resistance, and had 4 metal tips with 20cm in length on its top. In order to assure the SLE of being struck by triggered lightning the steel wire trailing by rocket was connected, through a piece of nylon line 6m in length, to the rod tip of SLE. The rockets used to trigger lightning were placed around the tower on the ground. A Rogowski coil and a shunt with 5.47mΩ were installed in a metal box placed in the tower center on the ground and used to measure lightning current. The signal from Rogowski coil was recorded directly by an oscillograph with 400kS/s sampling rate and 150ms recording length in the metal box. The signal from the shunt was transmitted through the optical fibre to recording room, being 90m far from the tower, and recorded by an oscillograph with 5MS/s sampling rate and 3.2s recording length. The electric field and field change on the ground were measured simultaneously. The optical characteristics of lightning channel were recorded by still camera and video camera in two orthogonal directions. A high speed video camera with 1000frames per second was placed 1.3km away from the tower to observe the propagation of leader.

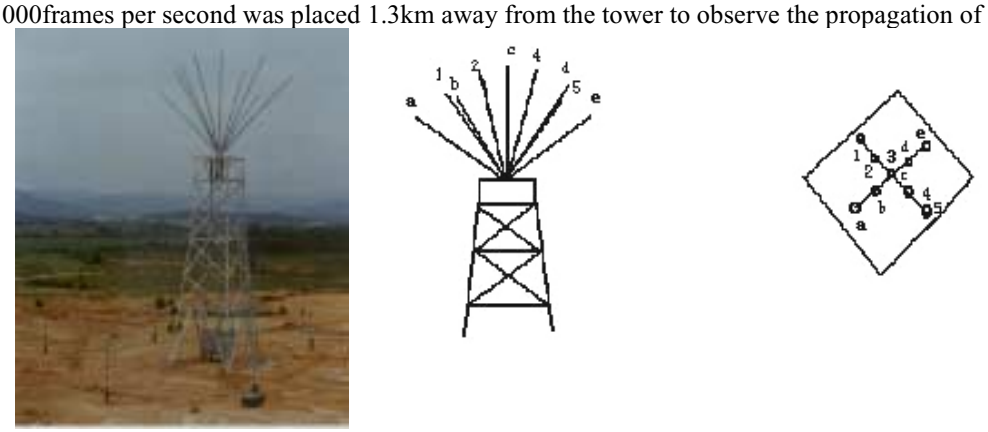

Figure 1. The deployment of experiment in 1999. SLE rod 3 and c were same one

ANALYSIS AND RESULTS

In 1998, Total of 5 successfully triggered cases were obtained, among them two struck the rod. In the experiments, the rocket first spooled out about 100m of electrically insulting nylon line from the bobbin attached to the rocket tail, and then 500m conductive steel wire. When this wire was unreeled over a sufficient length, a bi-directional leader initiated from its extremities. A positive leader initiated from the top of wire and propagated toward the cloud negatively charged, while a downward negative leader initiated from the bottom of wire and propagated toward the ground. When the downward negative leader approached the ground, an upward connecting positive leader was stimulated from lightning rod or other object on the ground. Return stroke occurred eventually after two leaders met. Figure 2 (a) shows a still picture of case 9804 taken at the distance of 1.3km away from the rod. The straight and bright line represented the trace of vaporized steel wire, while the tortuous lines showed the lightning channels in the air. It is worthwhile to mention that SLE was at 5m away from the rod on the ground and its top was taller than that of the rod, but the triggered lightning would rather choose the rod to strike. Figure 2 (b) shows the still picture of case 9802 taken 60m away from the rod. It can be seen that when lightning path was approaching to the ground, it changed direction from vertical to slant towards the rod at the horizontal distance of 14m away, while it was at the height of 15m above the rod top. The direction of lightning path changed when it was at the height of 6m above ground and connected to the rod eventually. The change of lightning path near the ground was due to the attachment process between lightning rod and downward leader. It can also be seen from figure 2(b) that the first, second and forth return strokes struck to the lightning rod. However, the third one did not propagate downward along previous channel and struck a rocket launcher 2m away from the rod.

(a) (b)

Figure 2. The sill pictures of case 9804 (a) and 9802 (b)

In the summer of 1999, the experiment of triggered lightning was conducted to test SLE. Eleven meaningful data sets or photographs were obtained and the SLE or some of its rods were struck by triggered lightning in 8 cases, among them main channel of lightning formed in 5 cases. The parallel discharges between two or three SLE rods were observed. In the case 9905, the parallel discharge between SLE rod 3 and 4 lasted 3.42s. Figure 3 shows the video pictures of case 9902 taken at 60m away from the tower. The parallel discharge firstly occurred between the rod 4 and 5 (Fig. 3a). One second later, the main lightning channel formed and struck another rod and the base of SLE (Fig.3b). The phenomenon revealed that the SLE rods can be parallel connection through the discharge between rods under the condition of high voltage. Unfortunately the current of the discharge was not obtained.

(a) (b)

Figure 3. Video pictures of case 9902

For the case of 9910, main lightning channel did not form but the current with small value was recorded by the Rogowski coil system, indicating that SLE responsed to the lightning triggering attempt. There were three

impulses in the current waveform as shown in figure 4. The peak current value of pulse A was 3.8A. The pulse B occurred 100ms later, with a peak current value of 4A. The pulse C was a continuous current lasting 25ms with a peak current value of 18A. It can be inferred that along with the rocket rising, the negative charge was accumulated at the bottom of wire spooled by rocket and local electric field was intensified. The spark discharges occurred on the tip of SLE rods and flashover discharge along the surface of rod "e" was observed by the video camera at 60m away.

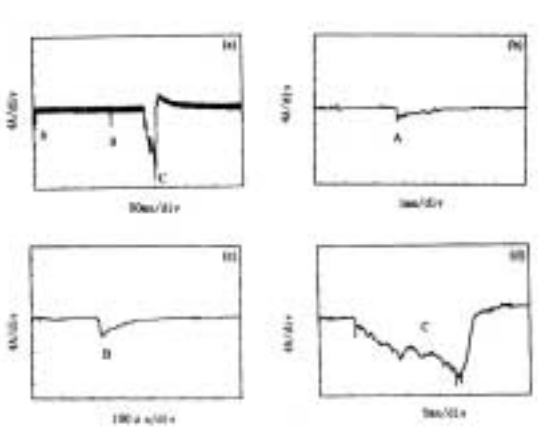

Figure 4. Current waveform of case 9910

Flashover occurred in 5 cases in which main channel formed. The lightning current-limiting function of SLE when it was struck by triggered lightning, claimed by its manufacturer, was not observed. Figure 5 shows the expanded current waveform of case 9911. The triggered lightning discharge struck the SLE rod "c". Flashover occurred as seen from the record of video camera. The lightning discharge lasted 500ms and composed of a mini-return stroke, continuous current and two return strokes. The mini-return stroke with peak value current of 914A occurred when negative leader from the bottom of wire connected with the tip of SLE rod. Zhang et al. (2001) analyzed the characteristics of the process. After mini-return stroke occurred, the positive leader on the tip of wire continued to propagate upward to cloud. The continuous current occurred 100ms later and lasted 435ms. Some pulses occurred in the continuous current process were M components and the largest pulse current of M components was 300A. There was a current quiet period of 36ms in time after the continuous current stopped. Then two return strokes occurred with the interval time of 21ms as if natural lightning. The peak value current was 6kA for first return stroke. The second return stroke was saturated with the peak current more than 6.6kA. The characteristics of the return strokes were agreement with that in natural lightning (Uman, 1978).

CONCLUSION AND DISCUSSION

The results of the experiments clearly showed the attachment process between lightning rod and downward leader. Eleven meaningful data sets or photographs were obtained in experiment for SLE. The SLE or some of its rods was struck by triggered lightning. The parallel discharges between two or three SLE rods were observed. When the SLE rods were struck by triggered lightning, the flashover occurred and the lightning current measured on the bottom of lightning channel was more than 6kA for one case. The lightning current-limiting function of SLE was not observed. However the initiations of upward leader from the tip of SLE are restrained in some extent and some characteristics of triggered lightning discharges might be influenced due to the high resistor of SLE. The triggered cases are not enough to obtain a certain answer for the effectiveness of SLE. More experiments and researches are needed to conduct in order to obtain statistical results.

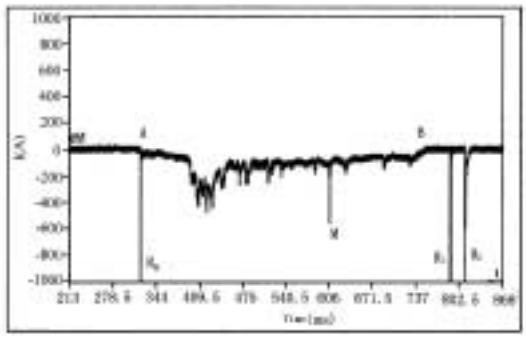

Figure 5. Expanded current waveform of case 9911

Most of lightning protection facilities are tested in high voltage laboratory. However, the high voltage discharge differs from natural lightning. The function and effectiveness of lightning protection facilities should be tested by using the artificially triggered lightning technique, especially triggered lightning in altitude.

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