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Application of Lightning Optical Path Monitoring System on 500kV Transmission Lines in Mountain Area

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***Abstract*—In order to obtain optical path photographs of lightning strike with a higher resolution, providing the necessary technical means for the accurate identification of 500kV transmission line lightning fault in mountain area, we developed an embedded, low-power remote online Lightning Optical Path Monitoring System based on 3G communication technology. Then, a case containing a lightning which struck the transmission line was analyzed in this paper combined with the results of the Lightning Optical Path Monitoring System, State Grid Lightning Location System and the Transmission Line Distributed Fault Diagnosis System.**

Keywords-500kV Transmission Lines; Lightning Optical Path Monitoring System; Mountain Area;Online;Remote

I. INTRODUCTION

In order to minimize the loss of lightning fault of transmission line, the transmission line management department has been trying to find a method of positioning the point of lightning strike quickly, judging lightning fault character accurately, and analyzing the process and reason of transmission line fault. Two types of lightning information can be obtained for power system in China, One is lightning activity information of transmission line corridor, and two is information of transmission line ontology being struck by lightning. At present, for the first kind of lightning information acquisition is mainly rely on the State Grid Lightning Location System. Construction and operation of the State Grid Lightning Location System, provides lightning activity information for monitoring and analyzing of lightning failures of transmission Line, with the aid of this, lightning fault character have been able to distinguish between parts. However, the State Grid Lightning Location System is a kind of indirect wide-area telemetry device, it can't monitor lightning information of transmission line directly and the lack of direct correspondence between its monitoring information and actual fault information of transmission line. For the second type, we use the Transmission Line Distributed Fault Diagnosis System to obtain lightning information of transmission line ontology being struck by lightning. The system relies on monitoring terminal installation of every 20~30km in transmission line, lightning information on the body of the transmission line is obtained by monitoring of fault traveling wave. By means of this system, it can obtain lightning information of transmission line ontology more accurately. These two systems are relying on monitoring lightning electromagnetic wave to achieving the presumption of lightning strike point information, and then, to judging lightning failure reversely, lacking intuitive, accurate and reliable evidence to help draw conclusions.

In fact, the optical image information is the most direct and most scientific basis for determining lightning information [1-10]. *Katsuhiro Ouchi et al*. [11] made use of the still camera and lightning current monitoring device installed on the 12.7km-long 500kV transmission line of 31 towers, get a lot of observation optical image data from 1984 to 1993.*Hiromitsu Taniguchi et al.* [12] used the still camera to observe distribution line lightning optical image information, beginning in 1993. *Philip Barker et al.* [13] employed four sets of still cameras and camcorders to gain the lightning optical image information of 13.5kV distribution lines. With the continuous development of science and technology, *Gu Shanqiang et al.* [14] and *Zhang yijun et al*. [15] applied high-speed video system to observe the optical image of the lightning tall buildings, getting more detail information about the process of lightning.

The lightning optical observation system based on the traditional still camera and high-speed video system, requiring higher storage capacity and power consumption, and cannot achieve real-time online to send and receive image data, resulted in a greater difficult to the maintenance of the system, data acquisition, and long-term stable operation of the system. *Bo Huang et al.* [16] developed a set of Remote Online Observation System of Power System of Lightning Stroke installed on the top of distribution lines, using the video recording lightning process. 500kV transmission lines are mostly located in the remote mountainous areas in China, traffic conditions and wireless communication signal quality is poor, large amount of real-time video data to send and receive will lead to the emergence of problems. At the same time, higher data traffic costs also limit the widespread application of the system. Therefore, we rely on new technology to establish a more advanced, more targeted observing systems has important significance. This article describes an embedded, low-power lightning remote online optical path photograph monitoring system based on 3G communication technology, obtain high-resolution lightning optical path photograph data real-time, providing the necessary technical means for 500kV transmission line lightning fault discrimination in mountain area.

II. SYSTEM STRUCTURE AND WORKING PRINCIPLE

The Lightning Optical Path Monitoring System is mainly composed of monitoring terminal and central server, as shown in Fig.1. Monitoring terminal is usually installed on the tower of the 500kV transmission line (Fig.2), including camera modules and energy supply module. sc2410 chip as a control processor of camera module, when lightning strike occur, lightning optical trigger export trigger signal to the control processor (sc2410), control processor module will capture photograph data through CCD module at this moment, and storing in the internal SD card of camera module, at the same time, sent to a central server for users to browse through 3G signal access internet. Time service of this system through network.Tab.1 is the basic system parameters of the Lightning Optical Path Monitoring System.

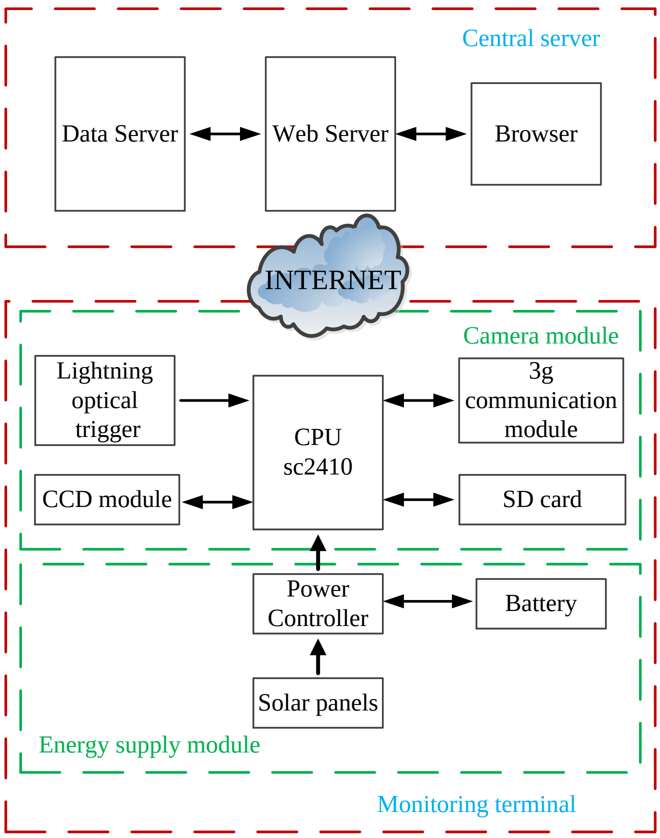

Figure. 1 System Diagram of the Lightning Optical Path Monitoring System

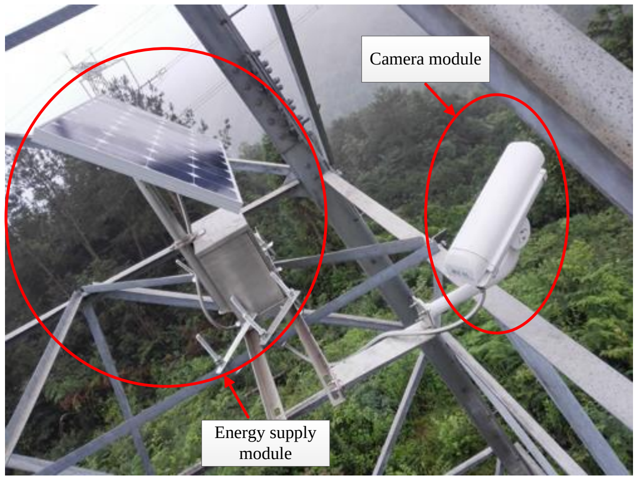

Figure. 2 Monitoring terminal is usually installed on the tower of the 500kV transmission line

Table. Ⅰ Basic system parameters of the Lightning Optical Path Monitoring System

Photo resolution	1600x1200
Viewing angle	70°
Data transmission	3g communications technology
Storage	SD card，32GB
Input voltage	5V，1A
Energy Consumption	Average:2W Max:5W
Solar panel	80W
battery capacity	80AH 12V
Maximum working time without illumination	20d
Ambient temperature	-30～+65℃
Environment humidity	10～90%RH

III. ANALYSIS OF THE OBSERVATION RESULTS

A. Typical observation image data

We adopted long-term lightning data statistics of the State Grid Lightning Location System, 25 lightning observation points selected in 5 provinces of the 500kV transmission line in the mountain area, from 2014. 25 sets of terminals of the Lightning Optical Path Monitoring System have been installed. Between 2015, a total of 134 cloud lightning flashes and 41 ground lightning flashes were obtained, the first occurrence of a thunderstorm on March 12, observation point located within the Sichuan Province, the latest one occurred on November 8, located in Fujian Province observation points. Here show some typical observations, which occurred in Fig.3 is a cloud lightning over the line, Figure 4 is a typical image of lightning stroke on nearby ground of transmission line, Figure 5 is a ground flash stroke on transmission line.

Figure. 3 Cloud lightning over 500kV transmission line

Figure. 4 A typical image of lightning stroke on nearby ground of 500kV transmission line

Figure. 5 A ground flash stroke on 500kV transmission line

B. A comparative analysis of the process of lightning

Lightning image captured by the Lightning Optical Path Monitoring System shown in Fig.6. This photograph captured by the Lightning Optical Path Monitoring System which installed on no.123 tower, the Dong-Jin line. View of this system towards the south, facing the Xi-Jin III line on the opposite hill. After a preliminary judgment on this photo, lightning strock the overhead ground wire between no.146 tower and no.147 tower, the Xi-Jin III line.

Figure.6 A ground flash stroke on 500kV transmission line

According to the GPS position of the Lightning Optical Path Monitoring System installed on no.123 tower of the DongJin line, and the time when the photograph was obtained by this system, we obtain the accurate information of this lightning strike by the Lightning Location System of the State Grid as shown in Fig.7. This lightning was detected at 03:44:15.290 on June 25, 2015, which was negative lightning and its current amplitude was 25.9kA. From the lightning location result we can determine the distance between lightning strike point and the Lightning Optical Path Monitoring System installed(no.123 tower, DongJin line) is 640 meters and the location point is just near no.146 tower of XiJin III line. The lightning result was calculated by the electromagnetic signals from 12 sub-stations.

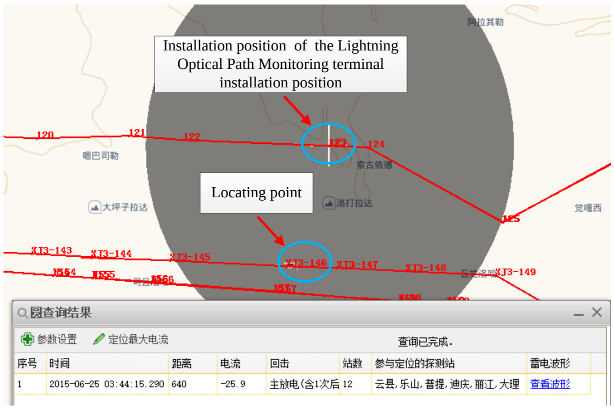

Figure.7 Locating results from Lightning Location System of the State Grid in China

We are also query the lightning strike from the Transmission Line Distributed Fault Diagnosis System. 500kV XiJin line length is 82.427km. Terminal of the Transmission Line Distributed Fault Diagnosis System installed on the no.1, no.82, no.120, and no.163 towers, shown in Fig.8.

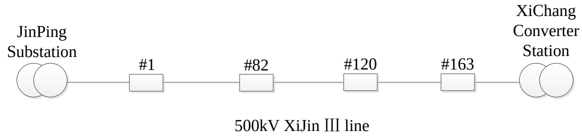

Figure.8 Terminal of the Transmission Line Distributed Fault Diagnosis System installation

Lightning stroke overhead ground wire occurred at 2015-06-25 03:44:15 290, the XiJin III line ,using the XiChang Converter Station reflected wave to position the lightning strike point, location of lightning stroke point near no.146 tower, the XiJin III line. The positioning process is as follows:

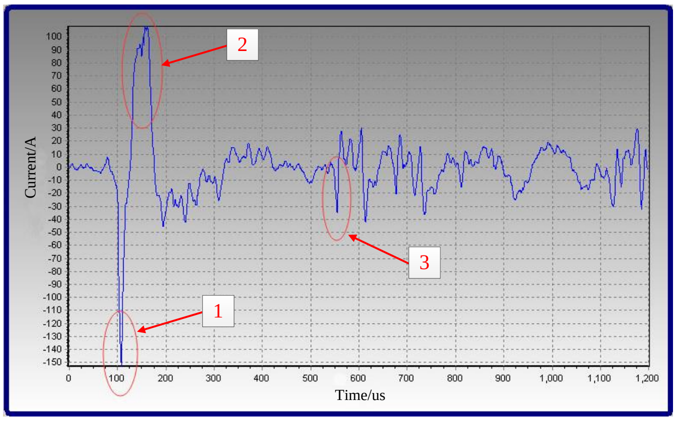

Figure.9 Lightning traveling wave record by terminal of the Transmission Line Distributed Fault Diagnosis System installed on no.120 tower C Phase(1: Lightning traveling wave entering terminal no.120 from lightning strike point.2: Lightning traveling wave through the XiChang Converter Station reflected entering terminal no.120 again. 3: The lightning wave passed through the terminal no.120 firstly and then it was detected by the terminal no.120 again after reflected by the JinPing Substation)

Lightning traveling wave shown in Fig.9.Fig.10 is illustrating the time differences between the reflexions in the waveform. The waveform record caused by lightning traveling wave reflection off between the substation, lightning traveling wave entering terminal no.120 from lightning strike point, at the same time, lightning traveling wave through the XiChang Converter Station reflected entering terminal no.120 again.Fig.9 shows that the lightning traveling wave transmitted from lightning strike point to the XiChang Converter Station about 26 microseconds, the distance between the point of lightning stroke and the XiChang Converter Station is about 7.49 kilometers, equivalent to that from no.146 tower to the XiChang Converter Station. Therefore, the point of lightning stroke was on no.146 tower nearby. The wave tail time of lightning surge less than 20us, in line with lightning strike ontology feature.

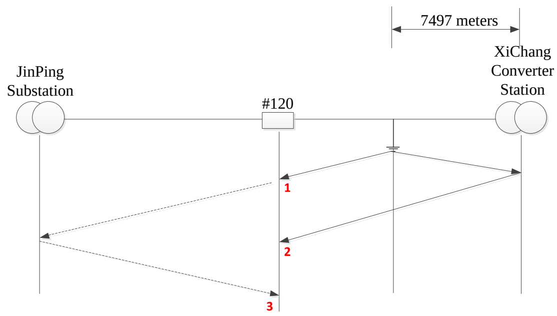

Figure.10 Positioning method schematic of the Transmission Line Distributed Fault Diagnosis System(1: Lightning traveling wave entering terminal no.120 from lightning strike point.2: Lightning traveling wave through the XiChang Converter Station reflected entering terminal no.120 again. 3: The lightning wave passed through the terminal no.120 firstly and then it was detected by the terminal no.120 again after reflected by the JinPing Substation)

The Lightning Optical Path Monitoring System shows photo of lightning strike overhead ground wire between no.146 and no.147 tower, the XiJin line. Straight-line distance about two towers is 230 meters. Visual distance is about 40 meters left from no.146 tower. Query result of the State Grid Lightning Location System just on the no.146 tower, here we can think of location error of the State Grid Lightning Location System is about 40 meters, in this process.

IV. CONCLUSION

- This paper developed an embedded remote online observation system of the Lightning Optical Path Monitoring System with low power consumption, based on 3G communication technology and obtained lightning photographs with high resolution.
- A lightning which struck the transmission line was analyzed in this paper combined with the results of the observation system of the Lightning Optical Path Monitoring System, State Grid Lightning Location System and the Transmission Line Distributed Fault Diagnosis System. The Lightning Optical Path Monitoring System could reveal the lightning channel photograph is more intuitive and obtain more accurate location information compared with the State Grid Lightning Location System and the Transmission Line Distributed Fault Diagnosis System.
- In the future, we would set up more observation station to provide more reliable first-hand information for the lightning protection of the transmission line in the mountains through accumulating the lightning data further.

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