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The discrimination and characteristics of continuing current in Positive CG flash in Beijing

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1、Introduction

Continuing current is usually defined as the relatively low-level current of typically tens to hundreds of amperes that immediately follows a return stroke, in the same channel to ground [1]. The duration of continuing currents is very long, typically lasts for tens to hundreds of milliseconds , therefore, it is responsible for much of the serious damage due to lightning, including forest fires, burned holes in the metal skins of aircraft and certain kinds of power line damage [2-4].

Up to now, there are many researches about the characteristics of continuing current. However, it is far from being satisfied. Only a few research pay attention to the accurate discrimination in the continuing current (CC). It is relatively difficult to discriminate a terminative point of the continuing current.

Continuing current measurements can be most precisely made by direct measurements of triggered lightning or lightning that strikes an instrumented tower [5]. In the absence of such measurements, continuing currents are most often obtained by high-speed video. In addition, continuing currents are also detected by their signature in measured ground-level static or quasi-static electric fields (called electric field slow change). In the three methods, the measurement from electric field slow change is the easiest method to implement due to the small requires of experiment environment and equipment. However , it is also difficult to discriminate the terminative point of CC in some condition only by slow antenna. In the present work, a method to discriminate the CC from electric field slow change is proposed and the CC characteristics of positive cloud-to-ground flash in Beijing are analyzed.

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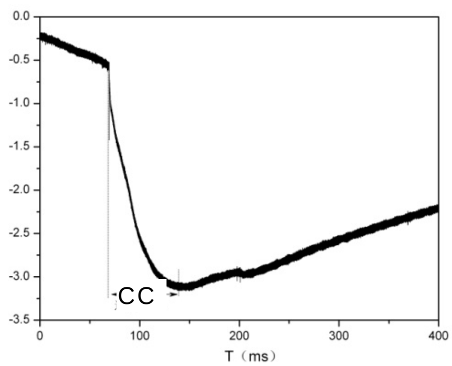
2、Instrumentation and data collection techniques

The data collection used in this study of the discrimination method is from the experimentation of triggered lightning in Guangdong province. A flat-plate slow antenna was used to obtain the electric field slow change. Its bandwidth range was from 100Hz to 5 MHz .The video records used were obtained with high-speed video, a Red-Lake Motion Pro adjusted to record 5000 frames per second (a time exposure of 0.2 ms) .The current was measured directly by coaxial shunt. The above data of electric field slow change and video record was obtained synchronously by DL750 and the sample rate used was 5 MS/s. After achieving the method, the statistical data of CC was gained from the slow antenna in Chinese academy of meteorological science in Beijing.

3、The discrimination of CC by electric field slow change



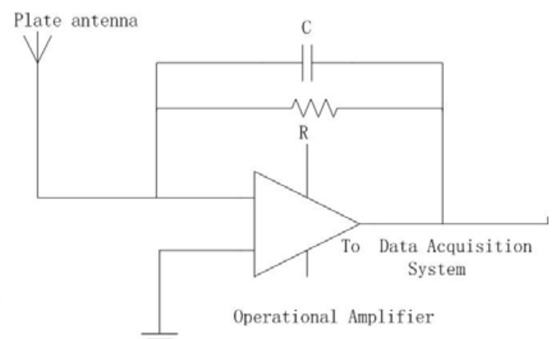


Fig.1 the slow change of electric field   Fig.2 the schematic diagram of slow antenna

Fig.1 is the curve of electric field slow change from a slow antenna. As can be seen in Fig.1, this signature is a slow increase in the magnitude of the electric field change because of the steady charge transfer in the continuing current. Usually, The CC begins from the stroke and ends when the increase rate of electric field changes. The terminative point of the continuing current is corresponding to the position with fast change. However, as can been seen from Fig.3, it is not easy to directly find the point from the curve of electric field slow change sometimes.

Fig.2 is the schematic diagram of slow antenna. It can be shown that the output of the antenna is an integrated result of charge by lightning and discharge by the resistor. The slope of the output curve can reveal the integrated discharge rate. In a process of CC, the continuous charge decreases the rate of integrated discharge. When CC ends, the rate of integrated discharge will be increased. This can be shown in the electric field slow change with a rapid change of the slope. Therefore, it is feasible to get the terminative point of continuing current from the derivative curve of electric field slow change. The terminative point is corresponding to the position of the slope with rapid change. Fig.3 is the curves of current, show change of electric field and it derivative for two triggered lightning. As shown in Fig.3, it can be found that the terminative point from the derivative is accurately corresponding to the CC current measured from coaxial shunt.

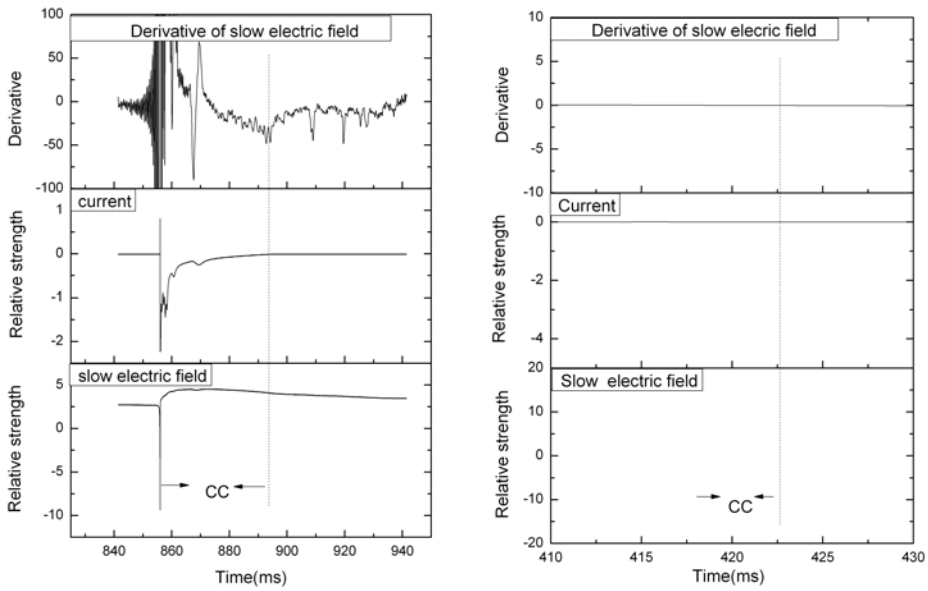


Fig.3 the curves of current, show change of electric field and it derivative

4、The method contrast of discrimination CC

As the direct measurement of CC, the coaxial shunt is the most accurate method. The reliability of high-speed video and slow antenna can be found by the contrast with the results of coaxial shunt. Table1and Fig.4 show the relationships between the duration of CC determined from high-speed video and from slow antenna for 16 strokes. An average relative discrepancy can be revealed by $CC_{E\text{-field}}/CC_{coaxial\ shunt}$ and $CC_{video}/CC_{coaxial\ shunt.}$ As can be seen from Table1, it can be found that the result of slow antenna is more precise in determining the duration of CC due to the fact that the high-speed video exist a long afterglow. The slow antenna is equally useful for short and long CC observations. The high-speed video can be only used in the long CC process. Therefore, the data from slow antenna can be widely used in the following statistics.

Table1 CC duration got from different methods in the experiment of triggered lightning

coaxial shunt （ms）C	High-speed video （ms）H	Slow antenna （ms）S	H/C	S/C
1.01	13	1	12.8712	0.9901
4.67		5.2	--	1.1134
4.95	14.2	4.86	2.8686	0.9818
5.63	15	5.52	2.6643	0.9804
9.25	28	8.97	3.0270	0.9697
13	25	12	1.9230	0.9230
23	37	21.8	1.6087	0.9478
28.9	67	27.7	2.3183	0.9584
41.3		37	--	0.8958
159	187	158	1.1761	0.9937
213.5	254	210.2	1.1897	0.9845
283.34		279.42	--	0.9861
302	350	296	1.1589	0.9801
335	354	331	1.0567	0.9880
417	470	412	1.1271	0.9880
443	476	435	1.0744	0.9819

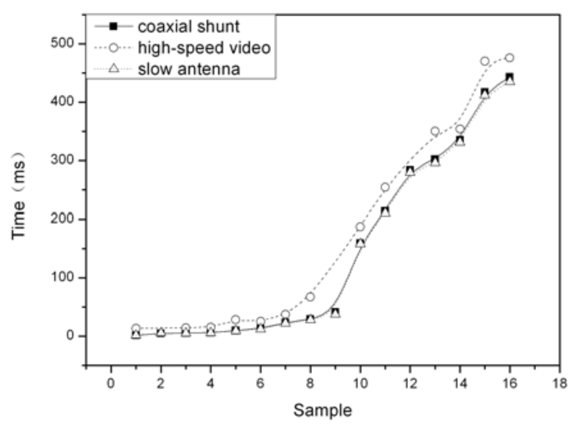


Fig.4 the curves of the CC duration from the three measurements

5、The characteristics of CC in Beijing

The CC can be classified according to the different duration. Kitagawa et al. and Brook et al. defined“long” continuing current (CC) as indicated by a steady electric field change with duration in excess of 40 ms [6-7]. Shindo and Uman [8] defined “short” CC as indicated by a similar field change with duration between 10 ms and 40 ms, and “questionable” lasting 1 to 10 ms. As can be seen from Table 2 and Fig.5, a total of 117 positive cloud-to-ground flashes were recorded by slow antenna during 7 different thunderstorm days. The statistics about the duration of

CC in positive cloud-to-ground flash showed that, in 117 flash of Beijing, 81 flashes which are 69.2 percent of lightning contain continuing current. The percentage is similar with that value of Zhongchuan in Gansu province and is larger than that value 30% of Guangzhou in South of China. The mean duration of the continuing current is 113 ms, which is larger than Zhongchuan of Gansu province with the value of 65.3ms. The long CC is 48.7 percent of the total flash with continuing current. The short duration of CC in Zhongchuan of Gansu province can be attributed to the difference in the structure of thunderstorm. According to the research of Krehbiel [9], the CC process is corresponding to a charge neutralisation along a horizontal channel; however, the area of thunderstorm is small in Zhongchuan, which is disadvantageous to the form of long CC.

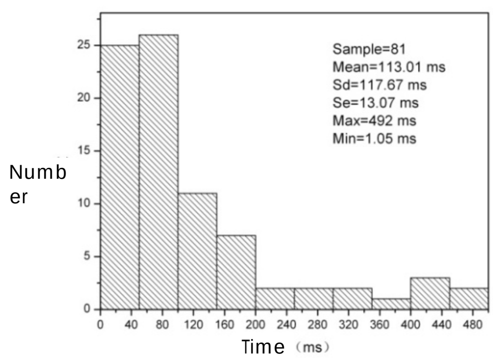


Fig.5 Distribution of continuing current in positive CG lightning

Table 2 Statistics of continuing current

	Positive CG lightning	Tcc≤1ms	1<Tcc≤0ms	10<Tcc≤40ms	Tcc>40ms
numbers	117	36	8	16	57
percentage		30.8%	6.8%	13.7%	48.7%

6、Conclusions

1）A method of discrimination the CC is proposed. The method is based on an analysis to the curve of electric field slow change. After differentiated of the curve of electric field change, the terminative point of a CC process is corresponding to the position of rapid change of the derivative curve.

2) The discrimination methods for CC are contrasted. It is found that the measurement of CC from slow antenna is more precise than that from high-speed

video. It can be equally useful for short and long CC observations.

3) It is revealed from the statistics of CC in Beijing that the continuing current with the average value of 113ms is 69.2%, thereinto, 48.7 percent contain long continuing current.

Acknowledgment

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