Characteristics of leader/return stroke sequence along one of multiple branches of upward lightning discharges

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ABSTRACT: We performed a study on the return strokes which occurred along one of the branches of upward lightning at the instant when at least one of the remaining branches is still carrying significant currents. It was found that the rise time of the return stroke current is not affected either by the current along the branch or the height of branch joint point, which is contrary to our expectation.

INTRODUCTION

We have been conducting observation experiments on lightning discharges striking on a windmill and its standalone lightning protection tower located at Uchinada town of Japan during winter seasons for nearly 8 years (Wang et al., 2008; 2012; Lu et al., 2009). Nearly all the lightning discharges we have observed are of upward lightning usually with multiple visible upward branches. Among some of these upward lightning that contained multiple dart leader/return stroke subsequences, it was interesting to note that most of those dart leader/return stroke sequences occur along one of the branches at the instant when at least one of the remaining branches is still bright or is still carrying significant currents. In this study, using simultaneously-recorded high speed video, channel-base electric current and electric field change data, we have investigated in detail how the dart leader/return stroke sequences along one branch are affected by the current-carrying branches..

OBSERVATION

The high speed video camera we used is MEMRECAM GX-8. Our observation target is the lightning to a windmill and its lightning protection tower and a bridge girder which locate at Uchinada town in the northern coast area of Japan as shown in Figure 1. The high speed was set up about 1.4 km away from the windmill as shown in Figure 2 with its view shown in Figure 3. The electric currents of the lightning to the windmill and the tower were measured using Rogowski coils installed at the bases of the windmill and the

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tower. The Rogowski coils have a bandwidth from 1 Hz to 100 kHz and their outputs were sampled at either 500 kS/sec or 200 kS/sec with a amplitude resolution of 16 bit. Lightning-caused electric changes were recorded using slow and fast antenna. The time constants of the slow and fast antenna are 2.2 ms, 47 μs, respectively and their output were sampled at 100 kS/sec with a amplitude resolution of 16 bit.

Fig.1 Location of Uchinada town of Japan

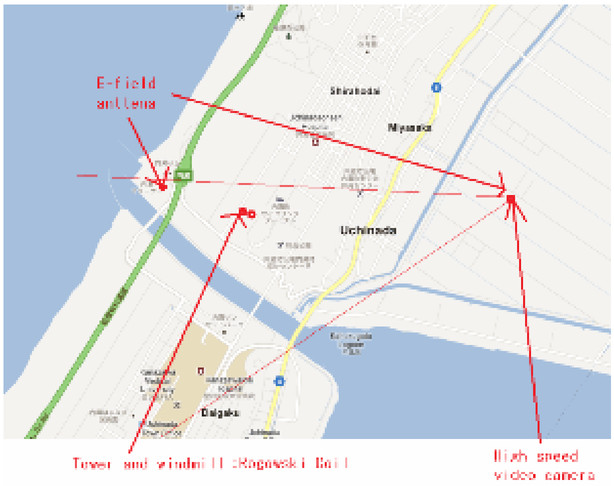

Fig.2 Arrangement of equipment

Fig.3 View of high speed video camera

RESULTS

Figure 4 shows 10 electric current pulses, numbered from ① to ⑩, and the corresponding electric field changes in an upward lightning occurred at 14:51:50, 24/12/1012, whose visible channels are shown in Fig.5. As shown in Fig. 5, this upward lightning has three main braches and along each of the branches leader/subsequent return strokes occurred. From their corresponding high speed videos, majority of the pulses were produced by a downward dart leader and a subsequent stroke. Pulses 1, 3, 4 and 5 connected to a current carrying channel at the height of 47 m above the tip of the tower, while pulses 2 and 6 at the height of 91 m, and pulses 9 and 10 at the height of 98 m. As an example, Figures 6, 7 and 8 present the 2D light intensity distribution for three successive frames of pulse 1, pulse 4 and pulse 6. From these pulse densities, those pulses are clearly produced by leader and return stroke sequences.

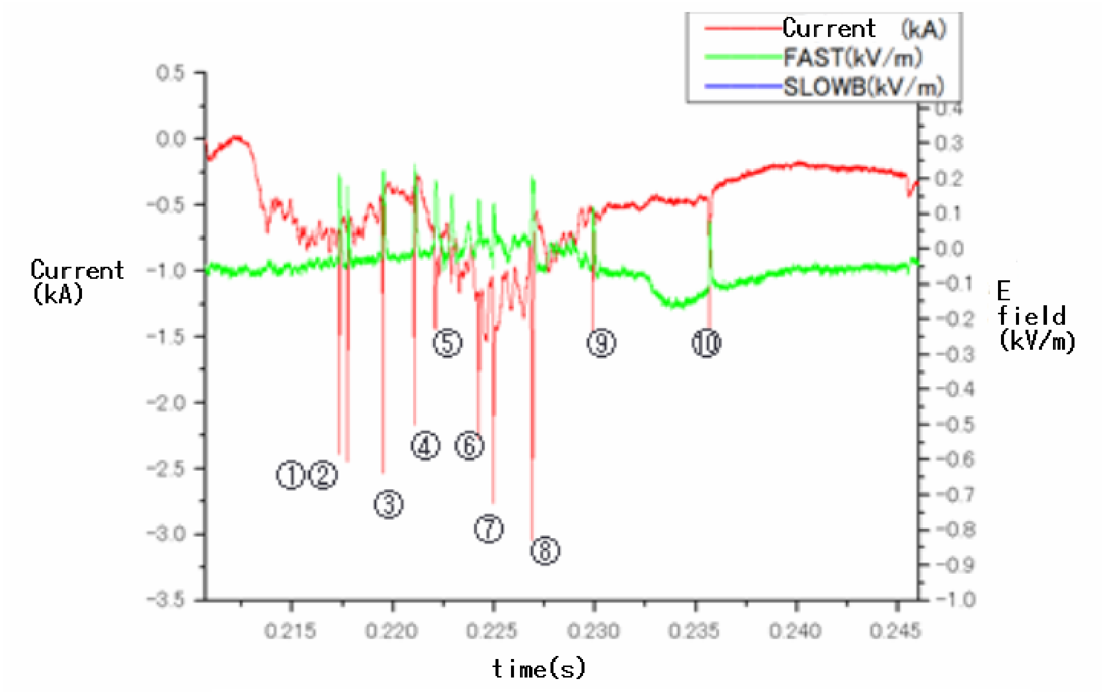

Fig.4 Synchronized wave form of current and electric field change for the lightning occurred at 2011/12/24 14:51:50 UT

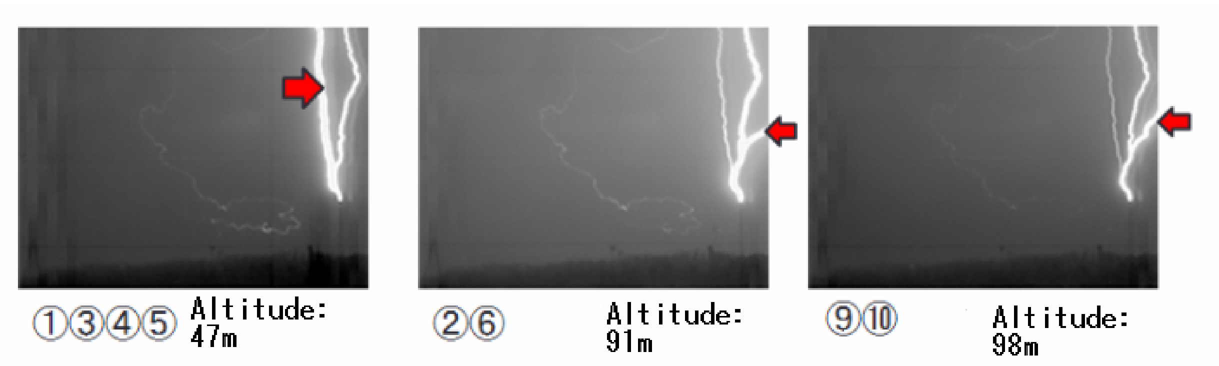

Fig.5 Altitude of connection of each pulse

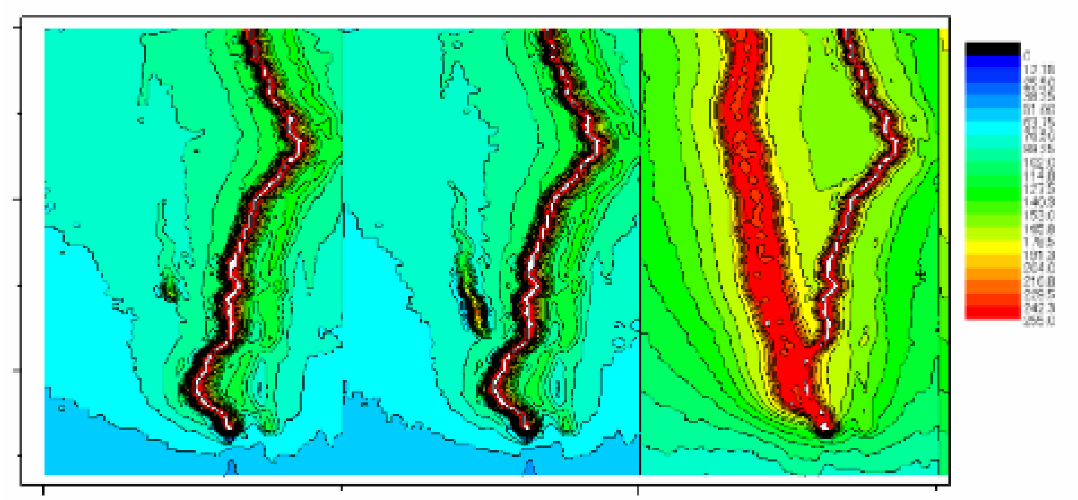

Fig.6 Analysis of light density of pulse ①

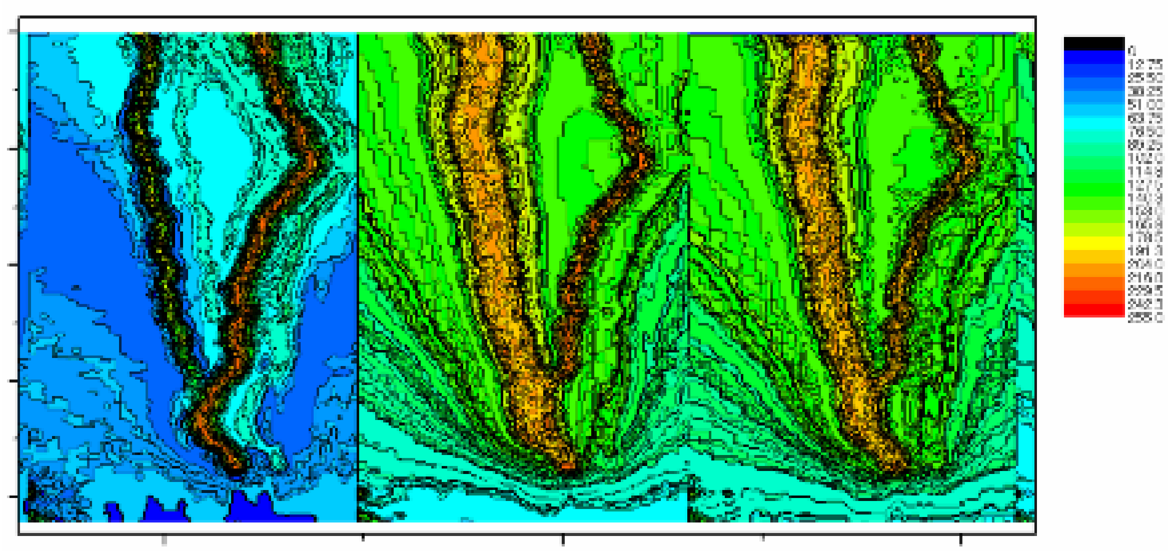

Fig.7 Analysis of light density of pulse ④

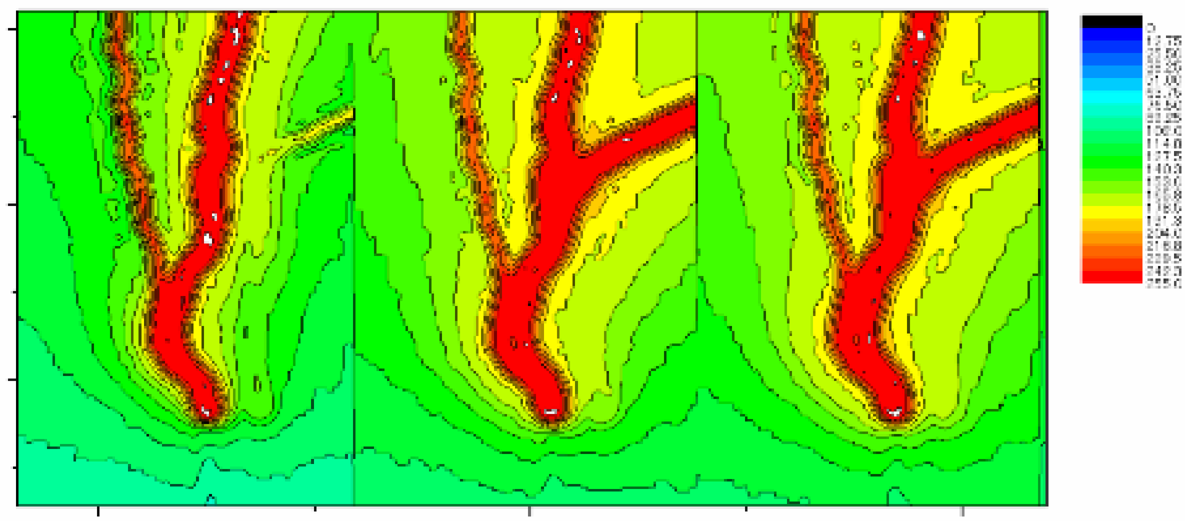

Fig.8 Analysis of light density of pulse ⑥

Figure 9 shows current waveform of pulse①,②,③. Figure 10 shows the relation between the current value just prior to each pulse and the return stroke connection heights

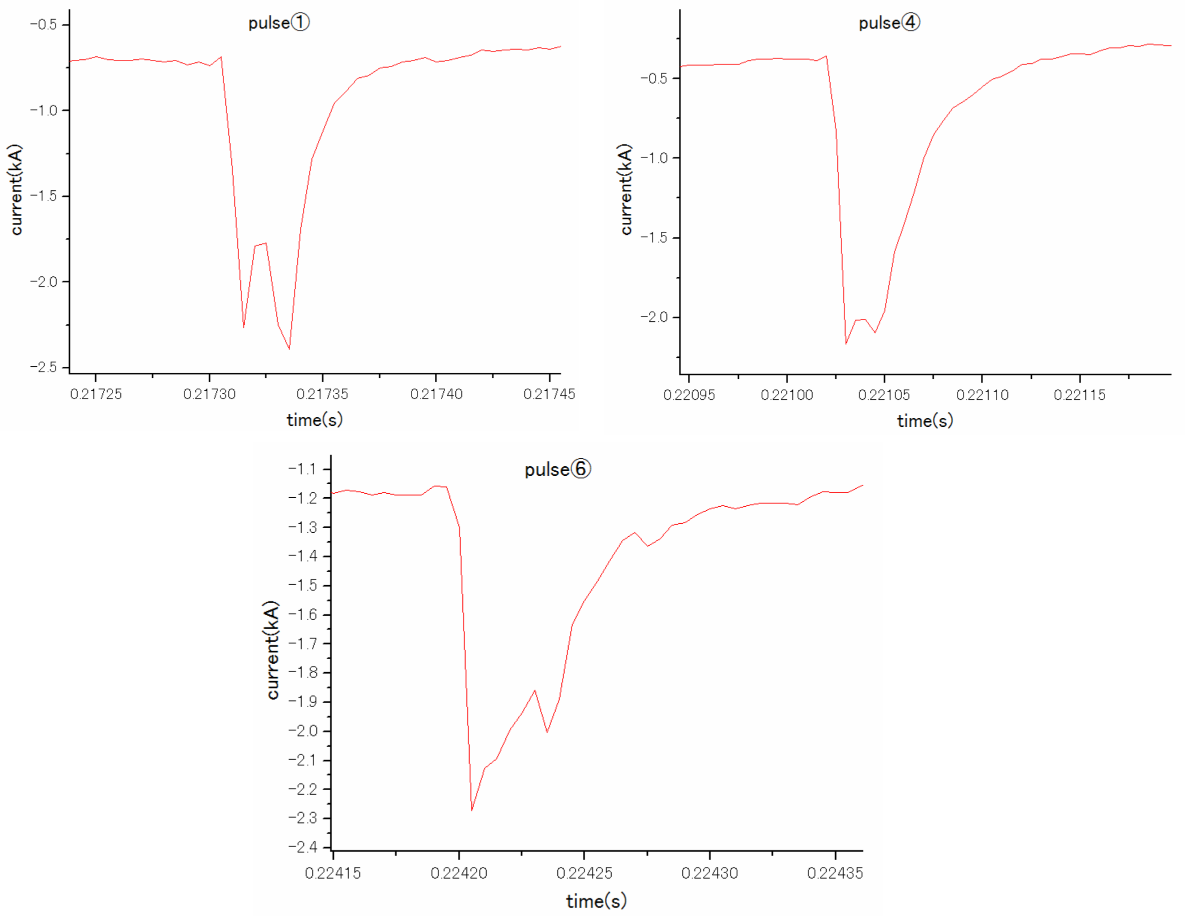

Fig.9 Current wave form of each pulse

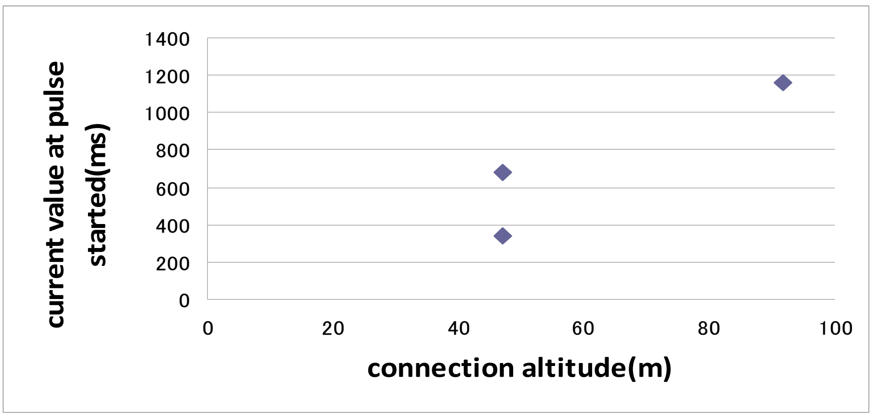

Fig.10 Relation between the current just prior to each pulse and the return stroke

From Fig. 9, the rise times of all the return stroke current are around 10 microseconds and not affected either by the current along the branch or the height of branch joint point. As shown in Fig.10, just prior to the return strokes, the currents flowing in other branches are at least several hundred amperes. It seems that when a return stroke propagates along such big current channel it will not suffer any degrading.can sustain a return stroke without any degrading. .

REFERENCES

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