



Bipolar Lightning Flashes Observed at the Sântis Tower

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Abstract— We present and discuss current waveforms associated with bipolar flashes recorded at the Sântis Tower during the period from June 2010 to January 2015. During the considered period, a total of 427 flashes were recorded, of which 58 flashes (13.5%) were classified as positive flashes and 13 (3.0%) as bipolar flashes. The majority of the recorded flashes in this study (8 out of 13) feature a polarity reversal during the initial continuous current, therefore belonging to Category 1 according to the classification proposed by Rakov [1]. Two of them were characterized by different polarities of the initial stage current and of the following return strokes (Category 2). One involved return strokes of different polarities within the same flash (Category 3). Two flashes did not meet the characteristics of any of these 3 categories.

Keywords-component; Upward lightning; bipolar lightning; lightning currents.

I. INTRODUCTION

Bipolar lightning discharges transfer both negative and positive charge to ground. They are usually initiated by upward leaders from tall structures but they can also be downward flashes. Current waveforms associated with bipolar flashes were first reported by McEachron [2] from his studies at the Empire State Building. The overall percentage of bipolar lightning discharges is relatively low but their probability of occurrence is believed to be about the same as that of positive lightning [3].

The types of cloud structure and discharge processes involved in the formation of bipolar flashes are still not clearly understood, even though some models have been suggested in the literature (e.g., [4-6]).

In this study, we present current waveforms associated with some of the bipolar lightning flashes recorded at the

Sântis Tower during the period of June 2010 to January 2015. More details on the characteristics of recorded bipolar flashes at the Sântis Tower can be found in [7].

II. INSTRUMENTATION

The data presented in this paper were obtained at the 124-m tall Sântis Tower, located on the top of the Sântis Mountain in the northeast of Switzerland. The Sântis Tower has been instrumented since May 2010 with a current measurement system to record lightning currents with high sampling rates (50 and 100 MS/s) and long record length of 2.4 or 1.2 s. The lightning current and its time derivative are measured at two different heights, 24 m and 82 m above the base of the tower, using Rogowski coils and B-dot sensors. More details on the Sântis tower lightning current measurement system and recent upgrades can be found in [8, 9].

III. OBSERVED DATA

During the considered period (June 2010 to January 2015), 427 flashes were recorded at the Sântis Tower, out of which 58 flashes (13.5 %) were classified as positive flashes and 13 (3.0 %) as bipolar flashes. In 2014, 7 bipolar flashes were recorded from a total 100 recorded flashes, a fraction that is considerably larger than in previous years (a total of 6 bipolar flashes were recorded in the time period from June 2010 to December 2013).

Rakov [1] classified bipolar flashes into three categories: (1) polarity reversal during the initial continuous current; (2) different polarities of the initial-stage current and the following return stroke or strokes; and (3) return strokes of opposite polarity.

Among the 13 recorded bipolar flashes of this study, 11 could be classified into one of the three categories introduced in [1]. Two flashes did not meet the characteristics of any of these 3 categories. These flashes are thoroughly discussed in [7].

A. Category I

This category of bipolar flashes is characterized by a change of polarity of the current during its initial stage [1]. The majority of recorded bipolar flashes (8 out of 13) belong to this category. Figure 1 shows the current waveform of a flash of this category recorded on July 4th, 2012. The waveform is characterized by an initial continuous current (ICC) associated with an upward negative flash. This flash contained no return strokes. Several pulses are superimposed on the ICC, including one positive pulse which resulted in a polarity reversal of the current. An expanded view of the positive pulse is presented in the inset. The positive current pulse is characterized by a peak value of 3.6 kA and a risetime of 0.94 ms.

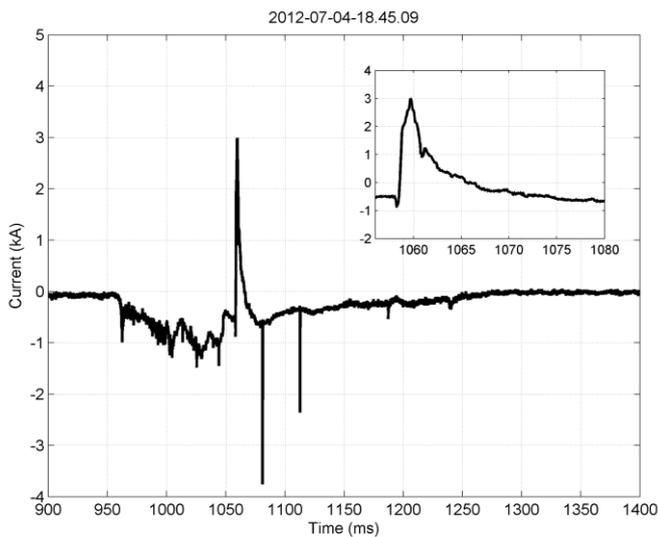


Figure 1. Bipolar flash of category I that occurred on 4 July, 2012, 18:45:09 local time. An expanded view of the positive pulse is presented in the inset (Adapted from [7]).

B. Category II

Category II is characterized by different polarities of the initial stage current and the following return strokes [1]. Two out of 13 bipolar flashes of this study were classified in this category. In both cases, the initial stage current waveform is indicative of type-2 positive flash [10]. Type-2 positive flashes are defined in [10] as “classical” upward flashes characterized by millisecond-scale waveforms with a large oscillatory pulse train on their rising portion, which are inferred to be due to the upward negative stepped leader.

Figure 2 presents one of the two waveforms belonging to this category recorded on 27 August 2011.

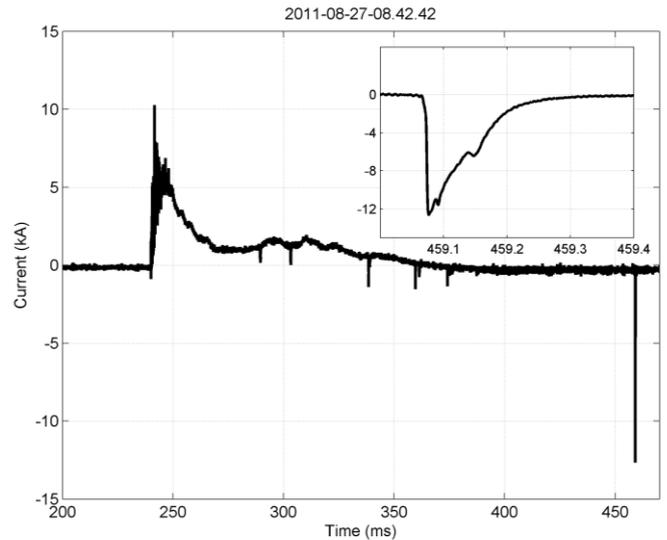


Figure 2. Bipolar flash of category II that occurred on 27 August 2011, 8:42:42 local time. An expanded view of the negative-stroke pulse associated with the only return stroke of this flash is presented in the inset. The negative return stroke pulse is characterized by a peak value of 12.6 kA and a risetime of 5.1 μ s (Adapted from [7]).

The peak of the initial positive pulse train is about 10 kA. The long relatively steady current following the peak features several M component-like superimposed pulses of negative polarity. After the extinction of the steady current and a no-current interval of about 100 ms, a negative return stroke occurred (12.6 kA peak and 5.1 μ s risetime).

C. Category III

This category involves return strokes of different polarities within the same flash. Only 1 out of 13 bipolar flashes in our dataset could be classified as a category III bipolar flash. The current waveform for this flash is presented in Figure 3a. Note that the pre-trigger time of this record was not long enough to capture the whole initial stage process. We can see, however, the late part of the initial continuous current associated with positive upward charge transfer followed by a negative return stroke. Expanded views of the negative and positive pulses are presented in Figures 3b and 3c, respectively. The negative pulse had a peak value of 7.1 kA and a relatively long risetime of 75 μ s. The positive-stroke current pulse has a peak value of 11 kA and a risetime of 0.88 μ s. Similar waveforms from this category have been reported in [11-13].

IV. CONCLUSION

We presented and discussed current waveforms associated with bipolar flashes recorded at the Säntis Tower during the period from June 2010 to January 2015. During the considered period, a total of 427 flashes were recorded at the Säntis Tower, of which 58 flashes (13.5%) were classified as positive flashes and 13 (3.0%) as bipolar flashes.

Most of the the recorded flashes in this study (11 out of 13) belong to one of the three categories introduced by Rakov [1]. Eight of these 11 flashes feature a polarity reversal during the initial continuous current, therefore belonging to Category I. Two of them were characterized by different polarities of the initial stage current and the following return stroke or strokes (Category II). One involved return strokes of different polarity within the same flash (Category III).

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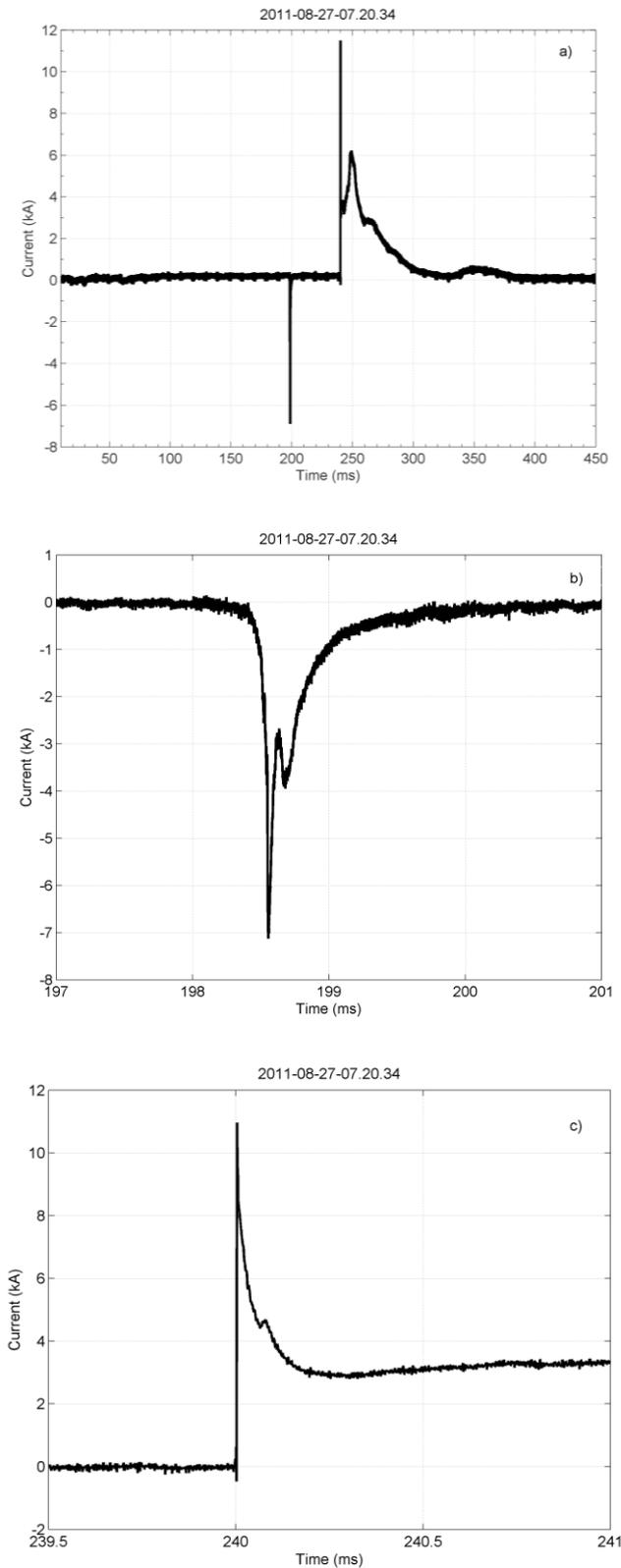


Figure 3. (a) Bipolar flash of category III that occurred on 27 August 2011. (b) Expanded view of the negative current pulse (peak value of 7.1 kA and a risetime of 75 μ s). (c) Expanded view of the positive pulse (peak value of 11 kA and a risetime of 0.88 μ s), (Adapted from [7]).

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