Tropical Lightning Stroke Data Collected and Analyzed by Computer Based Lightning Detecting Station

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Abstract: Lightning is a main cause of electric utilities outage and equipment damage throughout the world. We propose a flexible and reliable lightning detection and location system in order to take protective measures against lightning damages. The system is based on standard PC hardware and software. We discuss several tropical lightning stroke characteristics found with help of the described equipment. We show that lightning flash duration and inter-stroke interval as the negative lightning peak current measured by the station are similar to the data collected by alternative lightning location systems. We also discover parameters of so called “isolated pulse” and irregular negative stroke. Good agreement of determined stroke parameters with data found in the literature demonstrates great capabilities of presented lightning counter station both as lightning detection and location network unit as well as lightning physics investigation system.

1. Introduction

Lightning parameters based on the regional data are of great interest for both electrical power utilities and telecommunication authorities.

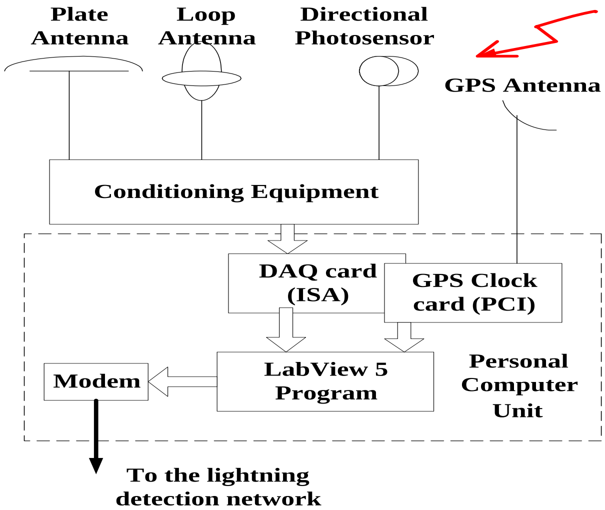

Fig.1. Block-diagram of Advanced Lightning Detecting and Locating Station.

As we reported earlier [1,2], the computer based lightning detecting and locating system (CLDLS) represents a powerful instrument for natural lightning investigation. Figure 1 shows the block-diagram of the basic station unit.

It consists of several antennas and sensors, capable of delivering lightning electromagnetic field and optical irradiation parameters, conditioning and protection equipment, and a standard desktop PC with DAQ and GPS cards. The collection and analysis of lightning characteristics is conducted with help of original LabView program.

The station is ready to be combined with lightning detection and location network, which is capable of collecting, storing, and analyzing the lightning data on the regional and national levels. Implementation of standard hardware and software makes the system inexpensive, reliable and flexible. The station setup was used for lightning stroke data collection during few rainy seasons (August-November) in the central Bangkok region (Thailand). All lightning parameters presented here are taken from flashes located in a circular area of about 20 km radius around the central station.

In this paper we analyze and compare various tropical lightning stroke parameters measured by CLDLS with those found in the literature.

2. Multi-stroke Flash Duration

About 40% of all flashes detected by the station in 1997-2000 were single-stroke flashes. Twin-stroke flashes occur very often and their percentage reaches 30% of total registration. Multistroke flashes (stroke order 3 and more) are less frequent (15-25% of total registration). Their percentage decreases exponentially with stroke multiplicity [1-2].

Flash duration data was analyzed due to waveforms received from both electromagnetic antenna and directional photosensors. As an example Fig.2 shows the six-stroke lightning registered by photosensor. Optical lightning detection is more convenient for flash duration calculation because of very low noise level and single polarity waveforms. We limited the investigation to maximum flash duration time of 1 s. Only multi-stroke lightning (stroke order 2 and higher) were examined. The result is presented in Fig.3. As long as we did not take into account single stroke lightning, the median flash duration (τ = 200 ms) is slightly higher than the value mentioned in [3].

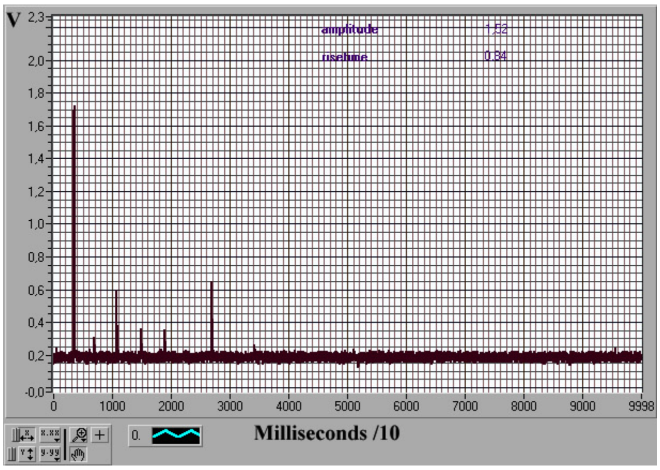

Fig.2. Six-stroke ground lightning registered by photosensor.

We also investigated flash duration distribution for separated stroke orders. Fig.4 shows the range and median values of flash duration vs. stroke order. It can be seen that flash duration time is increasing almost linearly relative to stroke order. Unfortunately investigation of lightning having stroke order higher than 7 was limited by low data set.

3. Inter-stroke Intervals

As reported in [6] the inter-stroke interval geometric mean is 60 ms and slightly varies for different stroke order. We determined inter-stroke time interval statistics using the same data set of multi-stroke lightning detected by CLDLS. The geometrical mean inter-stroke interval was estimated to 58 ms for the sample of 307 subsequent strokes. No dependence on the stroke number was registered.

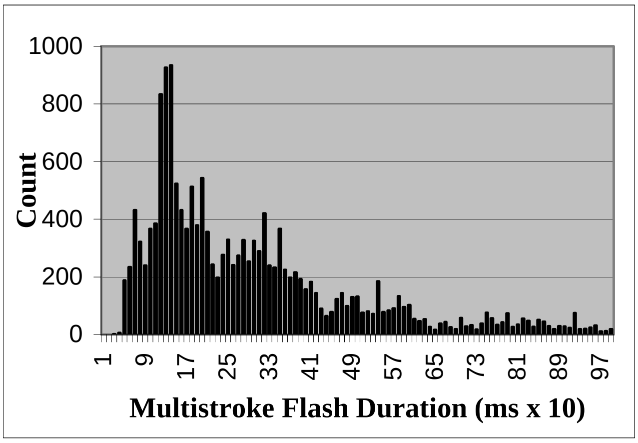

Fig.3. Multi-stroke flash duration distribution (stroke order 2-12).

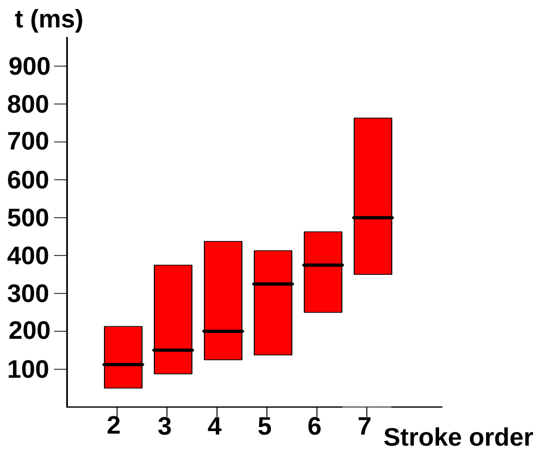

Fig.4. Lightning flashes duration vs. stroke order.

This result is in good agreement with data collected by Austrian Lightning Location System [3] and shows that the lightning ground flash parameters in different geographical regions are very similar.

4. Negative Stroke Peak Current

Lightning peak current is one of the most important parameters. We estimated the negative lightning peak current using statistical software and the combined analysis of optical and electromagnetic waveforms registered from the same first strokes of negative lightnings [1]. Really both the electromagnetic signal and the photoresponce registered simultaneously are functions of two variables – peak current and distance to the lightning strike. Assuming linear dependence of signals amplitude on mentioned variables and solving both equations together it is possible to determine the peak current for given lightning discharge. We provided computer statistical analysis of the data about more then 13 000 waveforms identified as first negative strokes for the ground multistroke lightnings (stroke order 2 and higher). The results are presented in the Table 1 and Fig. 5.

Table 1. Negative first stroke peak current

Minimum (kA)	Maximum (kA)	Mean (kA)	Std. Deviation
9.00	50.00	19.0163	6.472

We compared thoroughly our data with the results published in [4] and based on lightning current measurements in Switzerland, which became the real source of international standard on lightning protection. In spite of the different technique of peak current estimation the comparison shows a good agreement of peak current distribution with mentioned data. Really, a value of 14 kA mentioned in [4] as 95% of registrations justly corresponds to the maximum count in Fig.5.

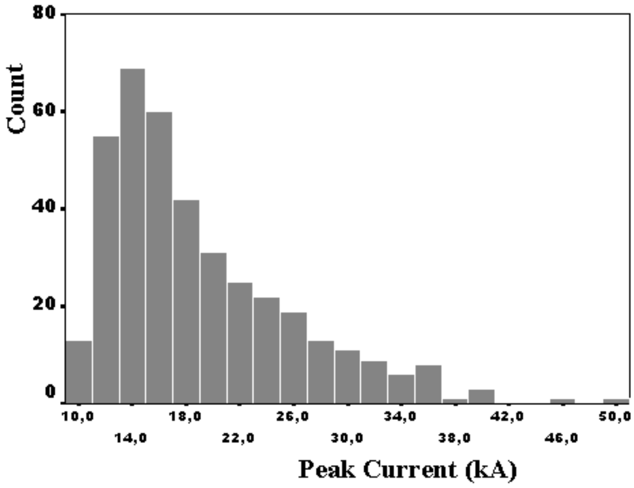

Fig.5. Negative stroke peak current distribution

5. Isolated Pulse Detection

As we reported in [2] about 10 % of total registered waveforms are related to type, which can be identified as “isolated pulse” (or narrow bipolar pulse) (see Fig.6). The majority of the registered discharges of given type occur in the period of thunderstorm termination, when the average number of atmospheric discharges is only 1-2 per minute. This poorly known short pulse is characterized by a high frequency (f_{mean} ~ 130 kHz) and is apparently bound to the electrical phenomena inside a cloud. Using the technique mentioned above we attempted to estimate a peak current of such type of discharge. The result is represented in the Table 2 and Fig.7.

Table 2. Isolated pulse peak current

Minimum (kA)	Maximum (kA)	Mean (kA)	Std. Deviation
2,10	29,70	9,1112	3,3452

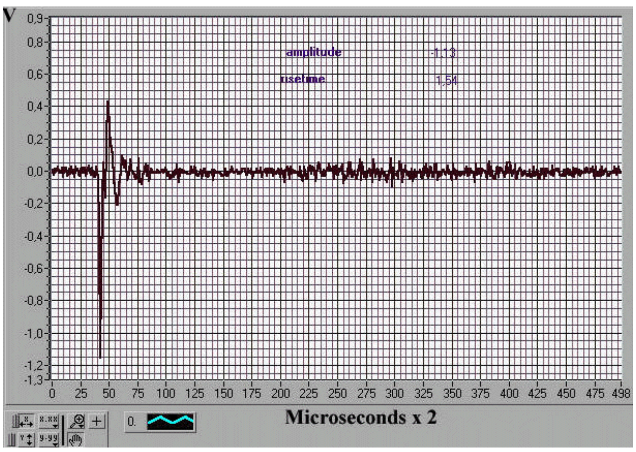

Fig.6.Typical isolated pulse waveform.

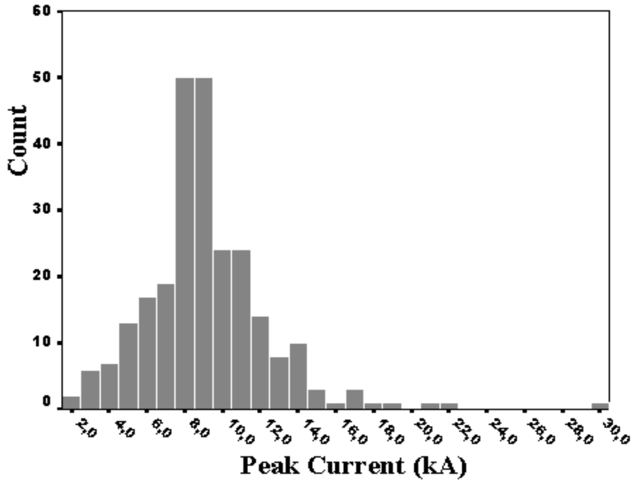

Fig.7. “Isolated pulse” peak current distribution.

6. Irregular Negative Lightning Stroke Waveforms

We reported earlier [1,2] about main parameters of negative lightning stroke detected by CLDLS, which as a whole corresponds to the results presented in [3-6]. However, about 1 % of registered negative strokes have an unusual waveform. As a rule this waveform consists of two consecutive negative strokes separated by a short time interval (see Table 3) and cannot be identified as the set of two separate strokes. Typically such negative stroke waveform is observed in the single stroke lightning registrations. Nevertheless it sometimes appears between strokes of double-stroke lightnings (see Fig.8.). It can be assumed that this type of negative stroke waveform is associated with double channel lightning stroke.

Table.3. Inter-peak time delay

Minimum (μs)	Maximum (μs)	Mean (μs)	Std. Deviation
70,00	800,00	318,9583	179,1063

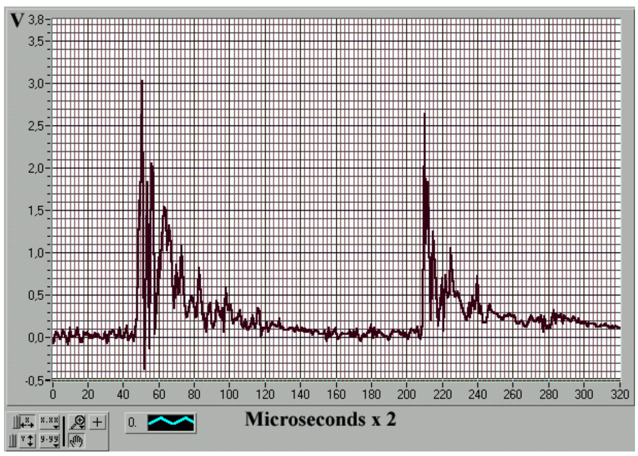

Fig.8.Typical twin-peak ground negative stroke.

7. Conclusion

The collection of regional lightning data and its statistical processing with help of modern lightning detecting and locating systems could simplify finding of optimal solution for protecting utilities against lightning overvoltages. In this paper we discussed several tropical lightning stroke parameters found with help of original computer based lightning detecting station. Especially we examined and analyzed the multistroke lightning duration and defined the average flash time for different stroke orders. We estimated the peak current distribution for the first stroke of negative lightning and discussed insufficiently explored lightning waveforms, such as isolated pulse or twin-peak first stroke. A good agreement of determined parameters with data found in the literature demonstrates great capabilities of the described station both as a lightning detection and location network unit and as a lightning physics investigation system.

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