National Lightning Location Network – an Alternative Approach

Fedosseeve Serghei, nonmember
CEPT, Faculty of Engineering, Chulalongkorn University,
Phaya Thai Road, Bangkok 10330, THAILAND
fedos@tesla.ee.eng.chula.ac.th

Samruay Sangkasaad, Member,IEEE
CEPT, Faculty of Engineering, Chulalongkorn University,
Phaya Thai Road, Bangkok 10330, THAILAND
ssamruay@chula.ac.th

Abstract: Lightning is a main cause of electric utility outages and equipment damage throughout the world. In order to base the protective measures against lightning damages on a regional data collection we propose a new approach for computer based national lightning detection and location network. In this paper the operating principles of the lightning detection and some experimental results of thunderstorm activity in Thailand are discussed.

1.Introduction

There is no doubt that the main parameters of a lightning discharge are the basis for the design of lightning protection equipment and for calculation of lightning radiation fields and their interaction with power and telecommunication lines. So the collection of the regional lightning data and its statistical processing with help of commercial lightning locating system could simplify finding of optimal solution for protecting the utilities against lightning overvoltages. The output of modern multiple-station lightning locating systems includes, besides lightning coordinates, estimates of lightning peak current, number of strokes per flash (multiplicity), and lightning polarity [1]. However a number of important lightning parameters cannot be find during the registration because of limited processing and memory capabilities of the sensor station. On the other hand the implementation of existing commercial systems at national level is limited by economical reasons.

We propose an alternative approach to national lightning location network design. The main idea is that any modern PC after simple modification represents a real lightning detecting sensor with great analyzing capabilities. Taking into account that modern PC becomes a home equipment, which cost decreases quickly and the capability (as for data acquisition and transfer) increases, we may hope that PC's based lightning detection network is more attractive for some applications.

In this paper we tried to describe the operating principle of the basic sensor unit for lightning detecting and locating network, able to supply many lightning parameters.

2.Lightning detecting and direction finding hardware and software

Computer based lightning detecting and locating unit as multifunction equipment can be divided by several separate blocks such as: signal preamplifier, GPS clock receiver, lightning locator, data acquisition hardware and software, and data transfer interface (modem) (see Fig.1). The result of the lightning data acquisition may be computer made table containing all kind of lightning parameters providing for successful direction finding and statistical treatment.

The plate electromagnetic antenna was used as a sensor for LEMP detection. It is connected via coaxial cable to signal conditioning unit, containing preamplifier and lightning protection circuit. Conditioned signal with limited amplitude (± 10 V) is coupled to analog input of fast multifunction DAQ card (PCI-DAS4020/12) installed into standard Pentium PC. The output signal of the setup is proportional to the first derivation of the electric field strength and carried the information about different lightning parameters. Direction-finding sensor represents two wide-band crossed magnetic loop antennas to measure the north-south and the east-west components of the magnetic field [2]. It is connected to the computer via the same multichannel DAQ card. GPS-clock antenna is connected to the standard GPS-clock board, which is responsible both for lightning signal synchronization and time-of-arrival lightning location with help of multiple-station system. The lightning data can be send to central server for successful position analysis and data storage via modem and telephone line. Implementation of standard equipment and software widely avaliable in the market makes the sensor unit and overall lightning detecting network very reliable and flexible.

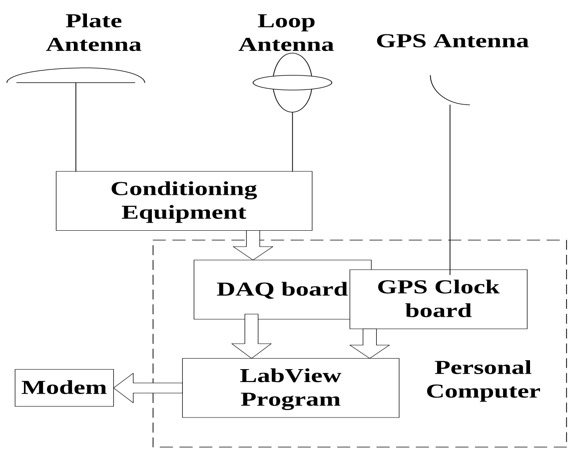

Fig.1. Block-diagram of lightning detecting and locating station.

Lightning data was processed and analyzed with help of designed LabView program [3]. Due to designed hardware and software the detection of multistroke lightning flashes becomes available, so that each separate stroke can be analyzed independently. Lightning location is based on the azimuth to the lightning strike calculation using the ratio of signals from crossed-loop antennas. It may be note that this setup allows the implementation of time-of-arrival lightning positioning too [2] if more than three stations combined into network.

Magnetic field signals are triggered by LEMP allowing the synchronization between two different antennas. This equipment provides the lightning detection in the range about 100 km around the station. One of the stations can be easily convert to position analyzer if it collect the information about lightning azimuth from additional two or more similar stations via telephone line.

The program designed for a lightning data collection and acquisition contains following base blocks (see Fig.2). Signal waveform capturing and acquisition unit (1) is represented virtual digital storage oscilloscope. GPS clock (2) provides the synchronization of the signals with the accuracy about 1 μs. Lightning locator (3) compares the amplitudes delivered by two cross-loop magnetic field antennas and calculates the azimuth to the flash. Electromagnetic signal virtual harmonic analyzer (4) is necessary for separation of ground flash from cloud one. Its operation is based on the fact that the ground lightning stroke frequency is much less than cloud one. Electromagnetic pulse waveform analyzer (5) returns main lightning pulse parameters (amplitude, rise time and so on) and is used for actual lightning signal and nose separation. Stroke number counter (6) is represented virtual peak detector with peak counting ability. Real time clock (7) shows the date and real time of each lightning event (with accuracy of GPS clock receiver). Lightning peak current and distance calculator (8) analyzes the data delivered by both electromagnetic and magnetic field antennas and calculates the distance to the lightning and its peak current. All parameters found during data acquisition are stored into the memory with help of the lightning data writer (9). Lightning data is preparing for the transferring to the central server via modem into unit 10.

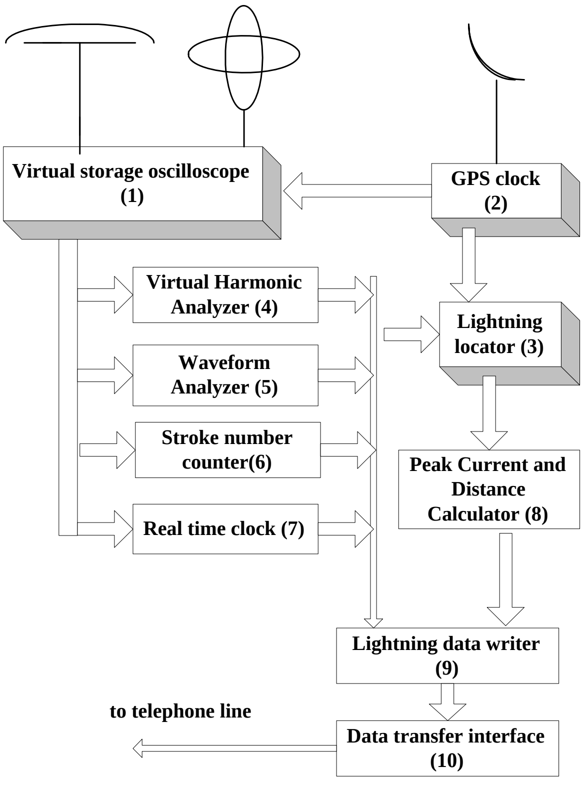

Fig.2. Lightning data acquisition algorithm.

3. Investigation of Thunderstorm Activity in Thailand

Thailand is situated in the tropical zone (latitude 5°40' – 20°30', longitude 97°20' – 105°45') where the statistical occurrence of lightning is rather high. Average annual thunderstorm-days number reported by Meteorological Service is about 90. The hardware and software shortly described above made possible the investigation of thunderstorm activity in Bangkok during few rainy seasons (June – October). The data delivered be lightning counter station was recorded everyday and allows to determine both the lightning stroke parameters and lightning statistics.

3.1. Lightning Electromagnetic Pulse Parameters

The identification of the lightning stroke nature was based on the data mentioned in [4-5]. Fig.3 shows the typical waveform of negative ground return stroke detected by station at the distance about 5 *km*. Positive first stroke waveform is presented in Fig.4. It may be note that only few waveforms of this type were registered, while the waveform specified in [4] like "narrow bipolar pulse" and mostly having positive polarity (see Fig.5) was detected very often (about 10% of total registration).

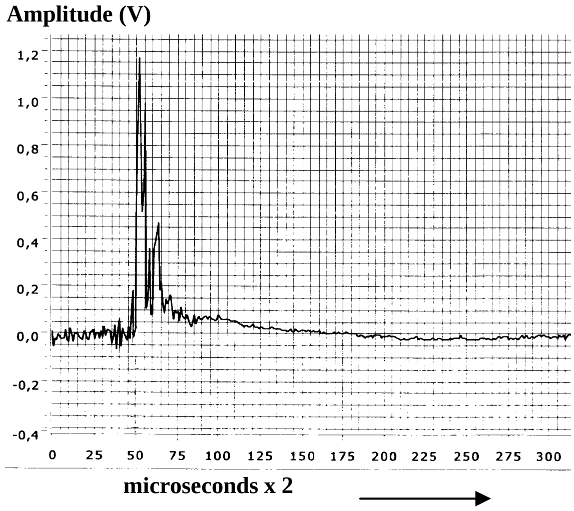

Fig.3. Typical negative ground first stroke waveform

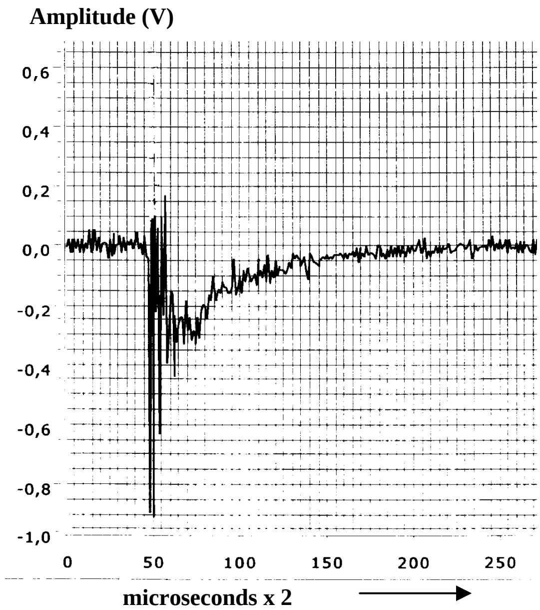

Fig.4. Positive return stroke waveform.

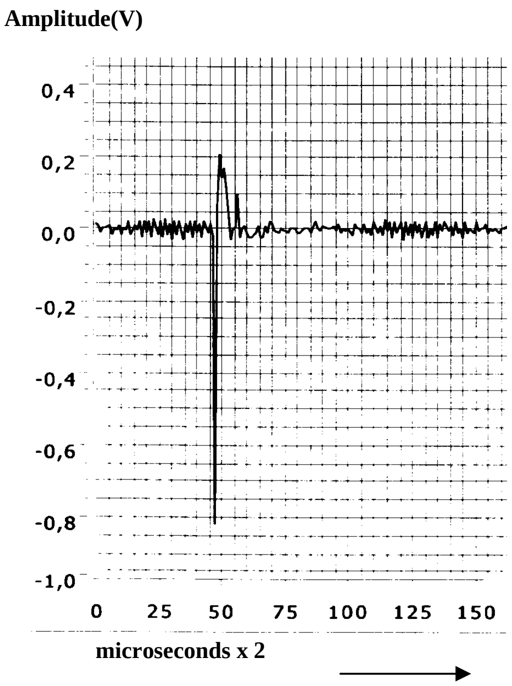

Fig.5. Typical narrow bipolar pulse waveform.

An important lightning parameter is the LEMP rise time. It is directly related to timing characteristics of lightning induced overvoltages. The analysis of data received during lightning activity investigation (stored first and subsequent strokes waveforms) gives the possibility for statistical representation of given parameter. Fig.6 represents the statistics of the first return stroke rise time and Fig.7 shows the second stroke rise time. It can be seen that in both cases the most of LEMP's has a rise time of order 8-10 μs, however the rise time distribution for the first stroke is mush larger (6-11 μs at half maximum) than for second stroke (8-10 μs at half maximum). To quantify how much the peak of the second stroke exceeds the peak of the first stroke the ratio of the second stroke peak field to the peak field of the first stroke was calculated. Fig.8 shows the frequency distribution of this ratio.

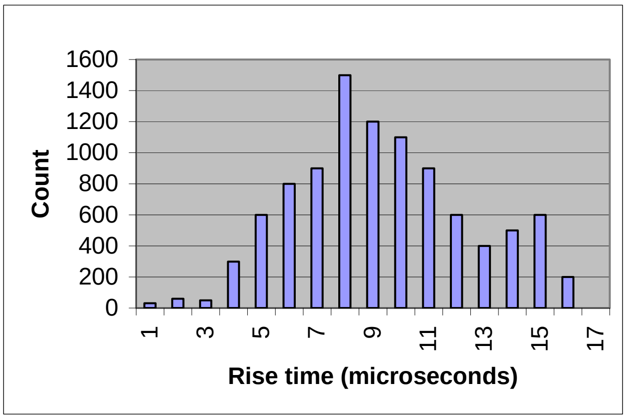

Fig.6. Statistics of the first stroke rise time.

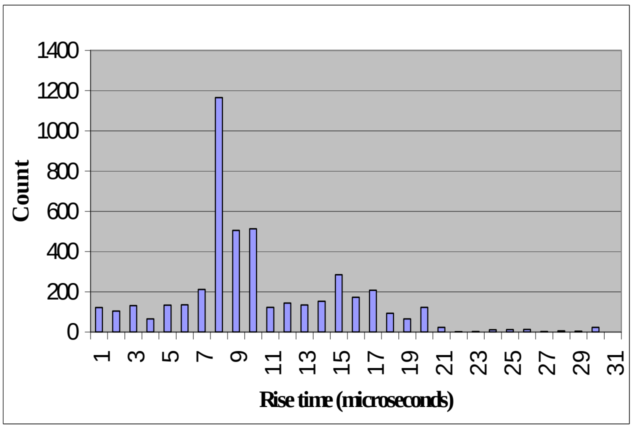

Fig.7. Statistics of second stroke rise time.

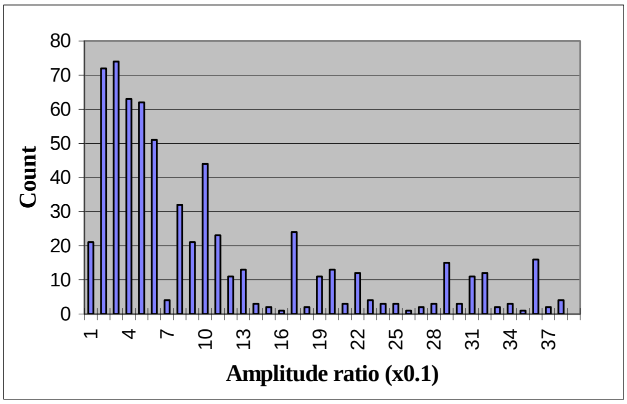

Fig.8. Amplitude ratio of second to first stroke

It can be seen that second stroke mostly less intensive than the first one and the average second/first stroke ratio is about 0.5.

3.2. Multistroke lightning detection

Fig.9 shows multistroke lightning waveform detested by station. The stroke number calculation program is based on the virtual peak detector that takes into account all strokes registered during 1 s time interval. About 40% of all flashes detected by the counter in 1997-1999 were single-stroke flashes. The percentage of single-stroke flashes varies from storm to storm and during a separate thunderstorm as seen in Fig.10, where the dynamic of typical thunderstorm is presented. Twin-stroke flashes occur very often and their percentage can reach 30% of total registration. Multistroke flashes (stroke order 3 and more) are less frequently (15-25% of total registration). Their percentage decreases exponentially with stroke multiplicity (see Fig.11).

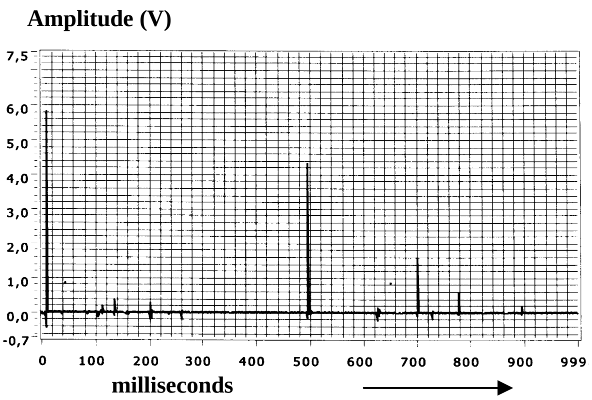

Fig.9. Multistroke lightning waveform.

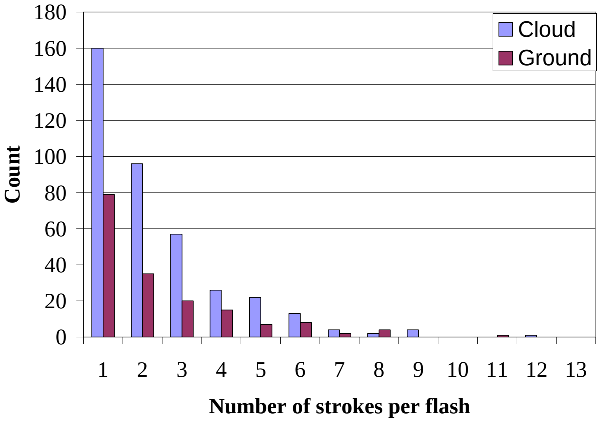

Fig.10. Typical multistroke lightning dynamics.

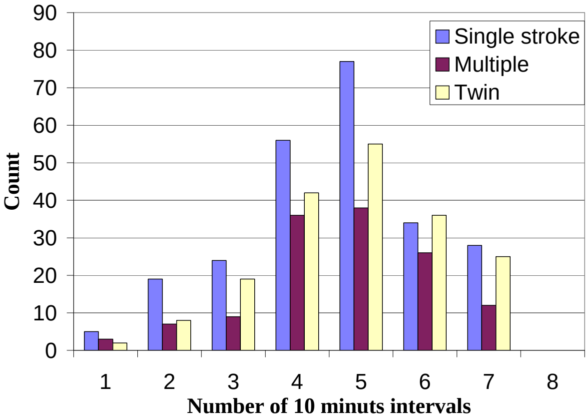

Fig.11. Distribution of flashes by stroke number.

Conclusion

There is a strong necessity for collecting and processing local and regional lightning data in order to create a real, well-founded base for lightning protection. Modern computer base technology is very useful in the study of the lightning properties. Additionally the lightning detection and location network based on this technology may be more attractive in some application because of its high reliability, flexibility, and low cost. In this paper we tried to describe the operation principles of the equipment developed for the purpose of lightning detection and location. It is consist of two antennas, conditioning equipment, and computer with DAQ and GPS cards. LabView based computer program is used for lightning data acquisition, storage, and analysis. Ability to lightning detection and location were shown on the example of single station implementation. We also discussed the lightning data collected during a few rainy seasons in Thailand.

References

[1] Kenneth L. Cummins, E. Philip Krider, and Mark D. Malone, “The U.S. National Lightning Detection Network and Application of Cloud-to-Ground Lightning Data By Electric Power Utilities”, IEEE Transaction on EMC, Vol.40, No 4, pp.465-480, 1998

[2] Gerhard Diendorfer, Wolfgang Schulz, and V.A.Rakov, “Lightning Characteristics Based on Data from the Austrian Lightning Location System”, IEEE Transaction on EMC, Vol.40, No 4, pp.452-464, 1998.

[3] Fedoseev Serguey and Samrauy Sangkasaad, “Computer based Lightning Detection and Photonic Location”. Budapest Power Tech’99 Conference (August 29 – September 3, 1999), Abstract Records, p.145.

[4] V.A. Rakov, “Lightning Electric and Magnetic Field”, in Proc. Int. Zurich Symp. On EMC, Zurich, Switzerland, pp. 561-566, 1999.

[5] V.A.Rakov, Martin A. Uman, “Review and Evaluation of Lightning Return Stroke Models Including Some Aspects of Their Application”, ”, IEEE Transaction on EMC, Vol.40, No 4, pp.403-426, 1998.