A SIMPLIFIED AND LOW COST LIGHTNING AND RECORDING SYSTEM

I.F. Gonos **L. Ekonomou** **F.V. Topalis** **I.A. Stathopulos**

National Technical University of Athens
Department of Electrical and Computer Engineering, High Voltage Laboratory
igonos@softlab.ntua.gr ekonomou@power.ece.ntua.gr topalis@softlab.ece.ntua.gr stathop@power.ece.ntua.gr

Abstract: A simplified low-cost system for automatic observation and recording of lightning was developed at the High Voltage Laboratory of the National Technical University of Athens. The system includes two pair loop-antennae for the measurement of the magnetic flux density caused by the lightning current, an electronic integrator of the signal, a data acquisition system and a personal computer with a software package, which was developed for the analysis of the measurements. The developed system was tested experimentally by recording impulse lightning currents applied on a vertical rod by an impulse current generator. The system gave very reliable results during its experimental application. The main advantage of the presented system is its low cost that can greatly facilitate scientific projects and applications, in the area of research of the effects of lightning strokes.

Keywords: lightning location system, lightning observation system, lightning current, shielding.

1. INTRODUCTION

The main systems, which have been developed for the localization of position, recording and warning of electrical discharges and oncoming thunderstorms are the following:

- Wide zone antenna system
- Observation and recording system of variation of electromagnetic field
- Observation and recording system of values of electromagnetic field
- Atmospheric radar.

A low-cost, wide zone antenna system for automatic recording of lightning was developed at the High Voltage Laboratory of the National Technical University of Athens. The system includes two pair loop antennae for the measurement of the magnetic flux density caused by the lightning current, an electronic integrator of the signal, a data acquisition system and a personal computer with a software package which was developed for the analysis of the measurements.[1-3]

2. MEASURING APPARATUS

The basic arrangement of the developed system [1], which has been used for the experimental measurements (Fig. 1), is consisting of:

- Loop-antenna (coaxial cable RG – 58 A/U 50 Ohm).
- Electronic integrator of the signal
- Arrangement for collecting and analysing of received signals

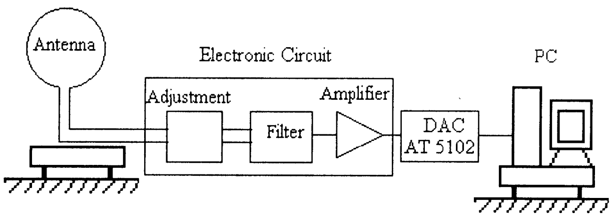

Fig. 1: Diagram of the measurement system.

2.1 Loop-antenna

The normal operation of the used loop-antenna was secured by shielding it. This has been considered necessary since the loop-antenna was near to the ground surface something, which could affect the normal operation of it due to stray capacities (Fig. 2).

If the distributed capacities C_1 and C_2 in between the earth and the opposite sides of the antenna were inequal then the resulting output voltage in the antenna's sides (as far concerning ground, due to the existence of the field) would produce inequal currents. This could distort the results since a considerable amount of these currents would flow through C_1 and C_2 to the earth.

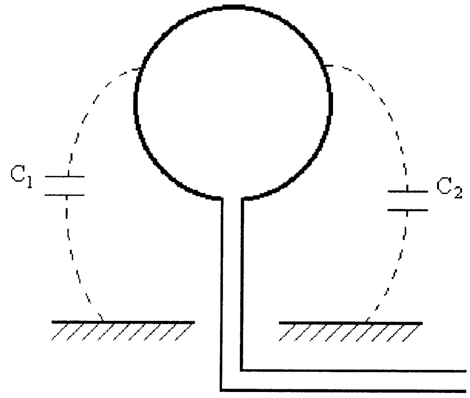

Fig. 2:.Loop antenna

To avoid this desirable situation the loop-antenna was enclosed in a metallic shield, which provides equal capacities to the earth.

This grounded metallic shielding could also protect effectively the loop-antenna from accidental interference caused by the existence of electrical current carrying cables. The shielding was symmetrically placed to the top of the antenna to avoid the accidental flow of circle current inside the metallic shield. So this gap secures the metallic shield to work as a short circuit turn.

Another reason for applying shielding to the antenna was the correct alignment. It was important the imaginary straight line, which was passing from the gap at the top of the loop-antenna and the output at the base of the loop-antenna to be in the same plane with the changing electric field of the spreading electromagnetic wave which existed in the spreading direction.

This plane coincided with this that was defined from the vertical electrode and the direction, which connected the centre of the discharge to the centre of the loop-antenna. In case that a correct alignment like this had not be done, it was observed a non-negative signal for $\varphi=0^{\circ}$ or $\varphi=180^{\circ}$. This was undesirable since with that way the range of values of possible signal between maximum ($\varphi=90^{\circ}$) and minimum ($\varphi=0^{\circ}$ or $\varphi=180^{\circ}$) is reduced with an obvious result the reduction of the ability of the vertical antennae's to locate the direction of the signal.

2.2 Electronic integrator

An electronic integrator is necessary to be used in order a magnetic field caused by lightning to be able measured from distance. The LF 411 electronic integrator has been used in these measurements and has provided an output voltage proportional to the resulting field [4-6].

2.3 Arrangement for collecting and analysing of received signals

It has already mentioned that for these measurements a PC equipped with a special card for collecting and analysing the receiving signals (AT-5102 National Instruments) has been used.

This particular card combined the advantages of an A/D converter and an oscilloscope. More specific it has got the following characteristics.

- Two 8-bit resolution analog input channels
- Real time sampling of 20MS/sec
- Two digital triggers
- 663.000 samples on board memory

2.4 Impulse current generator

For the formation of artificial electrical discharges and the resulting production of magnetic fields an impulse current generator must be used. This paper presents measurements performed by two different generators. The first one was the impulse current generator PC 6-288 manufactured by ASEA-HAEFELY and the second the impulse current generator EMC 2004 manufactured by HILO TEST.

When PC 6-288 is operating as a current generator, it can produce peak current of 0.25-3kA. The waveform of the impulse current in the short circuit is 8/20 μs ±30%.

When EMC 2004 is operating as an impulse current generator, it can produce maximum current value setting the charging voltage at 2-25KA ±5% and energy of 1500 J. The waveform of the impulse current in the short circuit, according the IEC 60 [7] is 8/20mms ± 20%.

3. LIGHTNING DETECTION AND LOCATION PROCEDURE

A simple way of measuring a magnetic field from distance is by using a loop antenna. The inductive voltage at the terminals of a loop antenna is equal to the loop area multiplied by the magnetic flux density's derivative, which is vertical to the loop's surface. So the signal in a vertical placed loop-antenna is proportional to the cosine of the angle which is formed from the direction of the lightning and the surface of the loop-antenna [1, 3].

The induced voltage to the loop antenna, that is proportional to the time-derivative of the magnetic flux density B, is integrated differentially by the electronic circuit connected in series to the antenna. The output of this circuit is proportional to the magnetic flux density and the azimuth angle to the lightning location. The waveform is recorded by a data acquisition system connected to the output of the integrator and is transferred to the computer [1].

An effort was made to avoid the existence of stray signals in the receiver's system and also in the arrangement for collecting and analysing of received signals. In addition was aimed the reduction (control) of the emission of electromagnetic radiation from the involving parts of the generator, leaving as the only emission source the electrode, which was going to assimilate as the lightning, when the impulse current was passing through it.

The avoidance of the existence of stray signals in the receiver system was achieved by twisted together the two co-axial cables which were started from the base of the loop-antenna and ended in the entrance of the electronic integrator. With this way it was tried the reduction of the inductive currents which would developed on the co-axial cables due to the emitted electromagnetic signal and would change the real signal produced by the loop-antenna. The rest part of this measurement system (arrangement for collecting and analysing of received signals) was enclosed in a chamber Faraday.

Based on the same reason, attempting to reduce the emission of electromagnetic radiation from undesirable sources, we twisted together impulse current generator's cables.

Finally was attempting the non-existence of considerable metallic objects next to the electrode, the impulse current generator, the loop-antenna and the imaginary line that connected the electrode with the loop antenna. This happened because it could re-emit interference, causing changes in the results which concerned the direction of the antenna.

The computer programme has calculated the azimuth angle of the direction from the integrated output signals of the vertical antennae. On the other hand, the distance was obtained by using two or more separate systems. Finally, the polar co-ordinates were defined and the lightning stroke was geographically located on the digital map of the covered area. Further analysis of the obtained data leaded to the analytical definition of the lightning current waveform. Moreover, the developed software has calculated the parameters (peak current, charge, front duration, maximum slope, stroke duration, energy, flash duration and polarity of the lightning current). An analysis of these parameters, based on determined values of the respective parameters from the literature, permits the estimation of the probability to be the recorded signal a lightning stroke [8].

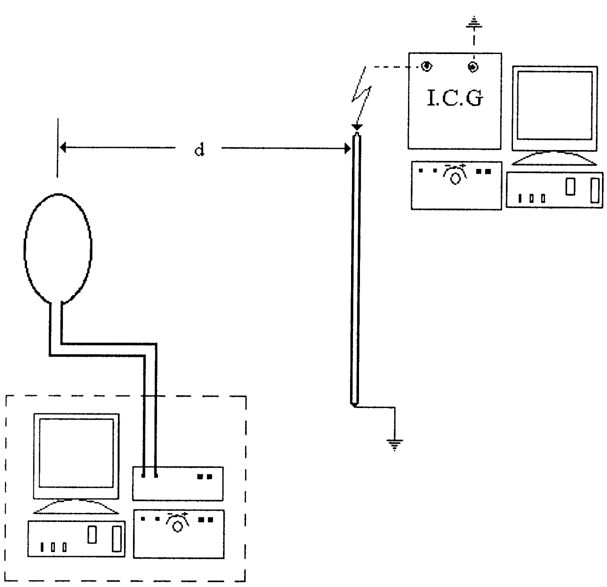

Fig. 3: Experimental layout.

4. MEASUREMENTS

It must be mentioned that all the measurements were performed in the High Voltage Laboratory of the National Technical University of Athens [9].

A copper electrode of 2 m height and 2 cm diameter had been placed in a small distance from the generator, which had created a short circuit in the outputs of it. A particular emphasis had been given in the correct alignment of the impulse current generator with this electrode, which was placed in a special wooden base.

The loop-antenna had been placed in a distance d from the electrode. Both the electronic integrator and the arrangement for collecting and analysing of received signals were placed in a chamber Faraday (Fig.3).

The distance d, the angle φ that was formed from the vertical to the loop-antenna vector and the straight line (which was connected the loop-antenna with the electrode) and the maximum current which was produced from the generator were changed during the experiments. Several measurements were performed and the electronic circuit's output signal was recorded for each one of the above cases. These recorded output signals were quite accurate and as they expected to be.

The measured output signal of the electronic circuit that was produced by the discharging of the impulse current generator is shown in Fig. 4.

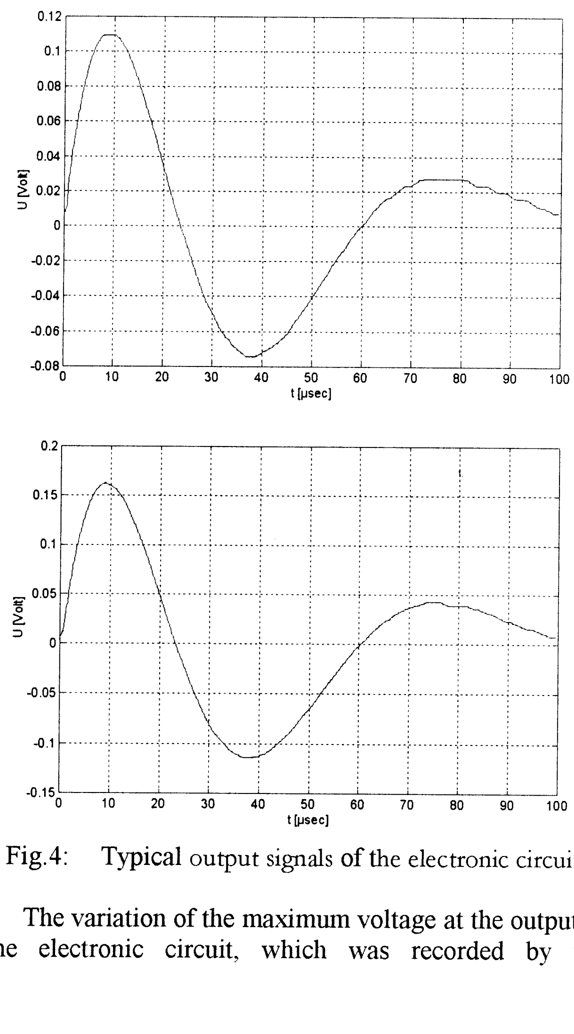

Fig.4: Typical output signals of the electronic circuit.

The variation of the maximum voltage at the output of the electronic circuit, which was recorded by the developed system, versus the charging voltage of the impulse current generator is shown in Fig. 5. The variation of the minimum voltage at the output of the electronic circuit, which was recorded versus the charging voltage of the impulse current generator, is shown in Fig. 6.

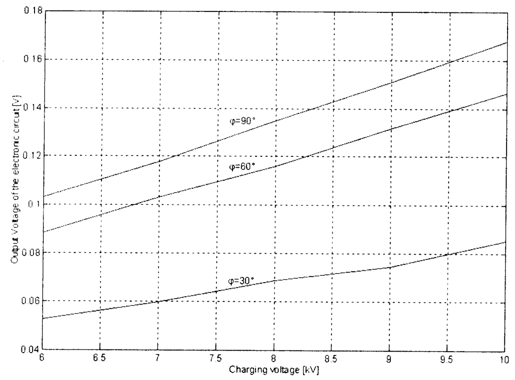

Fig.5: Variation of maximum voltage at the output of the electronic circuit, versus charging voltage of the impulse current generator.

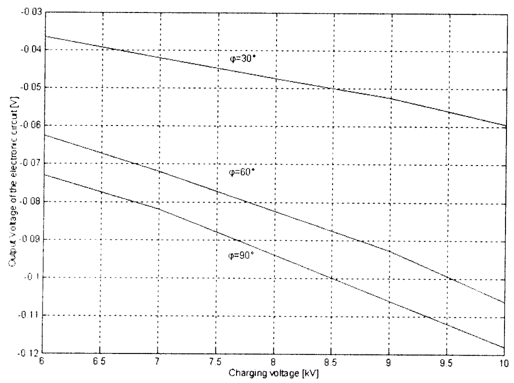

Fig.6: Variation of minimum voltage at the output of the electronic circuit, versus charging voltage of the impulse current generator.

5. CONCLUSIONS

The developed system was tested experimentally by recording impulse lightning currents applied on a vertical rod by impulse current generators. The system gave very reliable results during its experimental application. It is believed that the low cost of the system and its simplicity will greatly facilitate scientific projects and applications in the area of the research of the effects of lightning strokes. Furthermore, the test of this system for a longer period of time and for several positions will give better conclusions about its reliability.

REFERENCES

[1] Gonos I.F., Stathopulos I.A., Topalis F.V.: "Development of Lightning Recording and Location System", Proceedings of the 11th International Symposium on High-Voltage Engineering (ISH 99), London, UK, 23-27 August 1999, Vol.2, pp.196-199.

[2] Uman, M.A.: "The lightning discharge", International Geophysics Series, Vol 39, USA, 1987

[3] Sorensen, T.: "Lightning registration systems analysis, optimisation and utilisation", Ph. D. Thesis, Technical University of Denmark, 1995

[4] Kalaidopoulos, A., Varnas, V., Mitsiadis, D.: "An electronic apparatus for the recording of lightning strokes", National Technical University of Athens, Greece, 1992.

[5] Krider, E.P., Noggle, R.C. and Uman, M.A.: "A gated, wideband magnetic direction finder for lightning return strokes", *Journal of Applied Meteorology*, 1976, **15** pp. 301-305

[6] Krider, E.P. and Noggle, R.C.: "Broadband antenna systems for lightning magnetic fields", *Journal of Applied Meteorology*, 1975, **14** pp. 252-256

[7] INTERNATIONAL ELECTROTECHNICAL COMMISSION: "High-Voltage test techniques. Part 1: General definitions and test requirements", IEC 60060-1, 1989-11, Switzerland, 1989

[8] Gonos, I.F.: "Development of a software package for measurement, recording and analysis of lightning strokes", National Technical University of Athens, Greece, 1993.

[9] Zervas V. and Kranidiotis K.: "Measurement and testing of an experimental apparatus for the recording of impulse currents", National Technical University of Athens, Greece, 2000.

Address of Authors
National Technical University of Athens
Dept. of Electrical and Computer Engineering
High Voltage Laboratory
9, Iroon Politechniou Str., GR-15780
Zografou,Athens, Greece
Tel.: +30-1- 7723582, 7723627
Fax : +30-1- 7723504, 7723628
e-mail : igonos@softlab.ece.ntua.gr
ekonomou@power.ece.ntua.gr
topalis@softlab.ece.ntua.gr
stathop@power.ece.ntua.gr