29th International Conference on
Lightning Protection
23rd – 26th June 2008 – Uppsala, Sweden

IMPROVEMENTS OF THE FACILITIES FOR LIGHTNING RESEARCH AT MORRO DO CACHIMBO STATION

Guilherme M. Corrêa[1], André M. N. Teixeira[1], Larisse C. Pereira[1], Claudia R. Mesquita[1]
Silvério Visacro[1], Henrique R. L. Almeida[1], Alisson L. Senna[1]
Lothar Ruhnke[2], Vlad Mazur[2]
1. Lightning Research Center – UFMG, Brazil
2. National Severe Storms Laboratory, Oklahoma, U.S.A.
gmurici@cpdee.ufmg.br lruhnke@aol.com vlad.mazur@noaa.gov
LRC - Lightning Research Center UFMG - Federal University of Minas Gerais
Av. Antonio Carlos 6.627 Pampulha CEP 31270.901 - Belo Horizonte – MG - Brazil
Phone: +55.31.34994872 Fax: +55.31.34995455

Abstract - Improvements carried out recently in the lightning measuring system of Morro do Cachimbo Station are commented. They comprise new facilities for digital measurement of currents, electric fields, video recordings and induced voltages. Such improvements allowed the evolution of the station's research potential that was originally dedicated to characterizing parameters of the impulsive component of lightning currents to a new scientific perspective focused on the investigation of lightning formation processes.

1 INTRODUCTION

Located 15 km to the south of Belo Horizonte city (43°58´W, 20°00´S), Morro do Cachimbo Station (MCS) is a lightning research laboratory which is equipped to acquire data of direct lightning strikes to its 60 meter high mast. Built on a prominent hill, 1430 meters above the sea level, the station mast is stricken from 6 to 8 times every year. Figs. 1 and 2 depicts the station place and a detail showing the mast and the shielded shelter where the measuring devices are installed.

Since 1985 MCS is being used to investigate the lightning parameters in the region of Minas Gerais state such as the current peak, waveform, rise time and other quantities, whose knowledge is required for providing efficient lightning protection to lines and structures. The station also provides images of the events recorded from two remote camera stations located about half a kilometer from the main station facilities.

During the last years, the measuring capability of the station has been evolving as a consequence of the installation of new sensors and data acquisition systems that came to add to the original ones or to substitute them. These modifications have allowed enhancing the quality of information acquired in each event. The description of the improvements in the facilities of MCS and comments about the new research possibilities provided are the topics addressed in this article. Finally, some illustrative results recently obtained are presented.

Fig. 1 – View of MCS from the camera station.

Fig. 2 – Detail of the mast and main station.

2 THE MCS FACILITIES

The original configuration of the station measuring system was designed to allow registering the impulsive component of lightning currents in two oscilloscopes that used to operate in parallel. The system was able to register up to 15 strokes of a flash event, with a trigger level of 800 A and a time window of 400 µs for each stroke. It used to be activated by a field mill or a modified flash counter that were able to indicate lightning activity approaching the station.

Installed over high voltage insulators, the mast is supported by insulated guy wires and has a single conductor connecting its base to the grounding electrodes. Two Pearson coils with different sensitivities used to be installed along this conductor to provide current measurements in two scales, 20 kA and 200 kA. Also, a rough description of the electric field behavior used to be registered from a field mill during the time around events with lightning strikes.

Reference [1] presents a detailed description of the original station configuration and all the statistics corresponding to the database acquired during the period of that configuration. It comprises the lightning current parameters evaluated for 33 flashes confirmed by video observations of the 79 flash events recorded.

Fig. 3 illustrates the present station configuration, including the sensors, transducers and buildings.

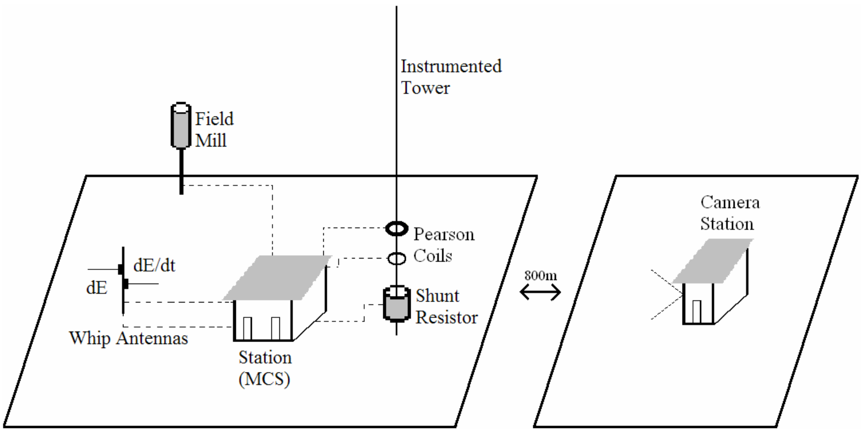

Fig. 3 – Representation of the sensors and transducers currently installed.

Basically, the most relevant improvements aimed to achieve some objectives: the digital storage of data; the recording of currents in a one-second window; the possibility of detection of currents as large as 200 kA and as small as the typical values for continuing current component; the recording of electric field in a compatible time scale to allow correlation with the measured currents; and the acquisition of images of stroke events using a fast camera. Each improvement is commented below.

3 IMPROVEMENTS OF THE CURRENTS MEASUREMENT AND ACQUISITION

The less sensitive Pearson coil (200 kA) was kept in operation while the more sensitive one (20 kA) was replaced by a new model. The latter allows acquiring signals of very low frequency (i.e. approx. 0.25 Hz) and also provides output for fast events such as the steps involved in the formation of the leaders. Additionaly, a special shunt resistor [2] designed by the LRC researchers was installed with the aim of recording both the impulsive and slow current phases of the return strokes. This set of sensors enables detecting high amplitude currents and also registering with good resolution low currents associated to both continuing current components and the charge displacements associated to upward leaders or to induced effects by nearby strokes.

A new data acquisition system was designed to improve the performance and realiability of the original systems. One computer was equipped with A/D converters and signal conditioning devices to substitute the previous data stations, being able to handle up to 60 million samples per second. One of the most important characteristics of this new system is the possibility of using software trigger together with a memory buffer. The new configuration setup enables the files recorded to have a determined number of pretrigger samples meaning that the initial steps involved in the formation of the discharge can also be recorded and analyzed.

The three transducers and the data acquisition system allows performing different and better kinds of physical analysis of the events recorded and studied. Fig 4. shows a diagram of the main station facilities and connections of sensors’ signals. The referred system and the electric field measurement acquisition system, described in topic 4, works with computers connected to GPSs. By doing so, events have their instant (Universal Time) recorded to allow correlating them to information of strokes supplied by the Brazilian Lightning Detection Network (LLS).

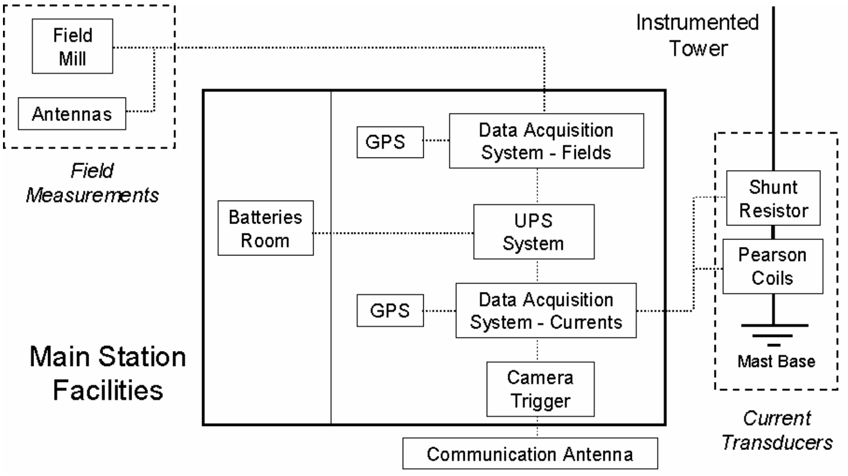

Fig. 4 – Diagram of the station facilities, sensors, signal connections and time reference devices.

Figures 5 and 6 depicts two interesting features ensured by the recent improvements: the time scale elongation and the increase in the sensitivity of measurements, resulting in a higher resolution of current registers. The presented record corresponds to a recent negative 152kA-stroke. Figure 5 shows a parcel of the event recorded during 1.2 ms before the moment that the current was clamped around 9 kA by the protective devices of the more sensitive Pearson Coil. In fact, the current pulses recorded begun 11.6 ms before the return stroke instant. A zoom of Figure 5 is presented in Figure 6, where currents a little larger than the noise level, around 25 A, are displayed, denoting the high resolution of the record.

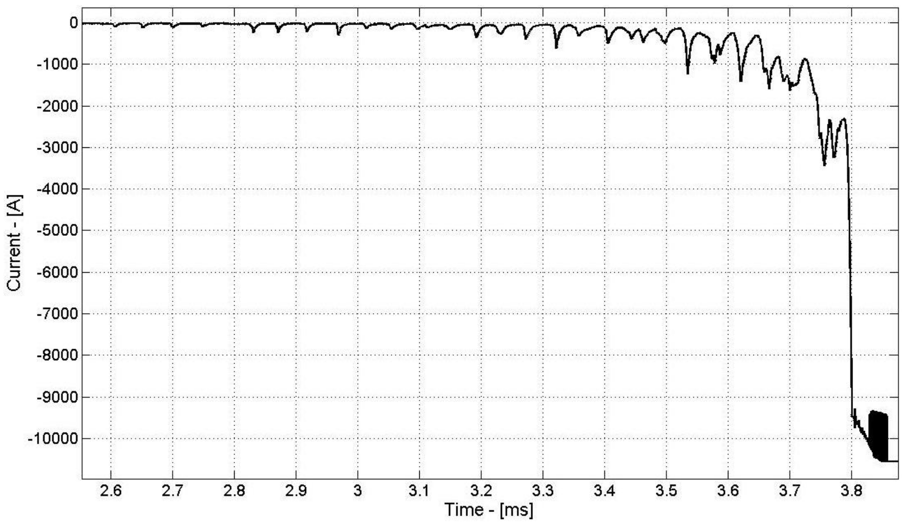

Fig. 5 – Full-scale record of 1.2 ms window before a negative 152 kA-peak return stroke.

4 ELECTRIC FIELD MEASUREMENTS

Since 2004, electric field data is being acquired in MCS in order to be correlated with recordings provided by the current sensors of the station and with the information supplied by the local Lightning Location Systems. This is part of a research project that is being carried out simultaneously in several sites in the United States together with the MCS named Upward Leader Initiation, a cooperation between the National Severe Storms Laboratory (USA) and the Lightning Research Center[3,4,5].

Two quantities of main interest in this investigation are the electric field changes due to the return strokes within a few kilometers away from the tower and the current waves induced along the tower. In order to measure both parameters, a measurement system using a data acquisition board (A/D converters) is connected to a PC together with a calibrated field mill and two whip antennas. The field mill provides the field reference while the whip antennas were adapted for measuring the electric field changes due to nearby lightning. The first one, (named as fast antenna) is used to acquire the dE/dt and the electric field changes with a time constant of 10 μs and the second one, (named as slow antenna) is used to measure electric field changes with a time constant of about 600 ms.

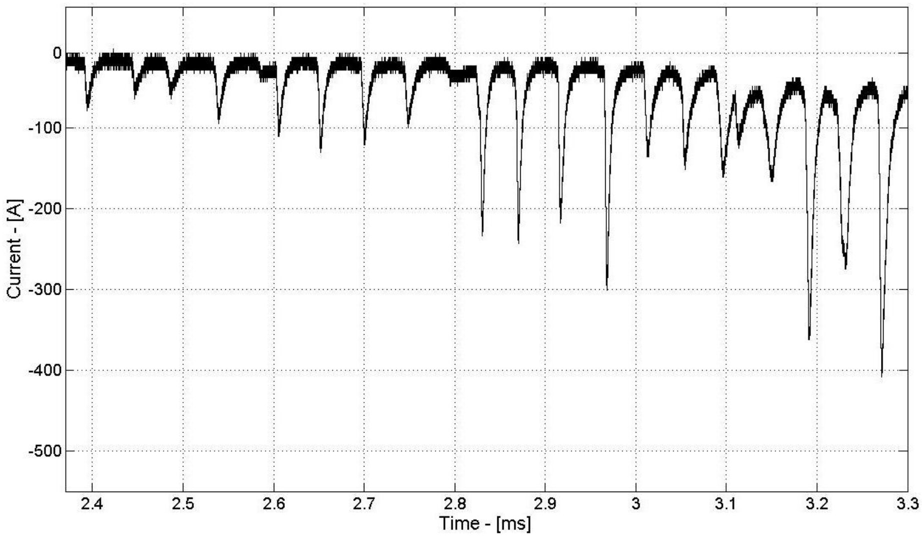

Fig. 6 – Detail of previous figure with 500A scale.

Fig. 7 illustrates an example of recorded electric field changes due to a flash that occurred on the 12th of November, 2007. According to the local Lightning Location Systems, the refered first strike occurred 830 meters away from the station tower. In this picture, it is possible to see the fine structure of the electric field with 10 return strokes recorded in this 500ms time window. One may notice that the first stroke occurs after the development of a stepped leader while the following strokes have dart leaders. Registers as good as this are being generated each time a thunderstorm approaches MCS.

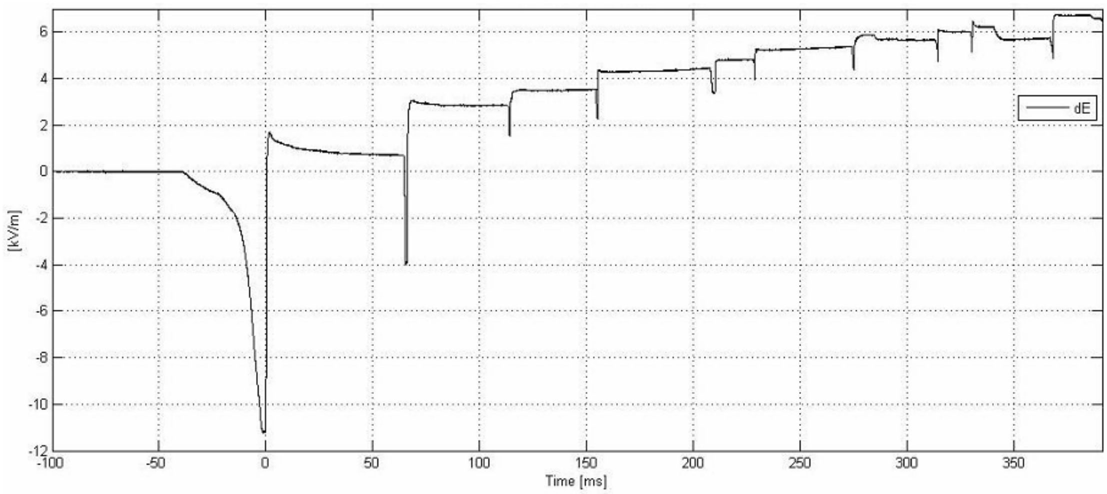

Fig. 7 – Record of electric field changes due to a 10-return stroke flash.

5 IMAGE ACQUISITION – FAST CAMERA

In a shelter built at the top of close hill, around 800 m away from the instrumented tower, (Fig. 3), a modern fast camera was installed to replace the old video camera and the photographic camera responsible for the still images of events used in the first years of the operation of MCS. This image laboratory consists basically of the fast digital camera (with a maximum rate of 16000 frames per second) and a computer which are fed by solar panels and batteries. A communication system was designed to receive the trigger information from the current sensors at the instrumented tower. Also, a magnetic loop and a electric field sensor were developed to provide the information about nearby atmosphere electricity activity, preparing the camera settings to a 'alert' mode when a storm approaches the station.

6 EXAMPLE OF CORRELATED CURRENT AND FIELD WAVEFORMS

In order to illustrate the potential of the new measuring facilities in MCS, figures 8 to 11 shows correlated registers of current and electric field, corresponding to the subsequent stroke of a multiple flash with two strokes. Fig. 9 depicts only a time scale detail of figure 8 in the.

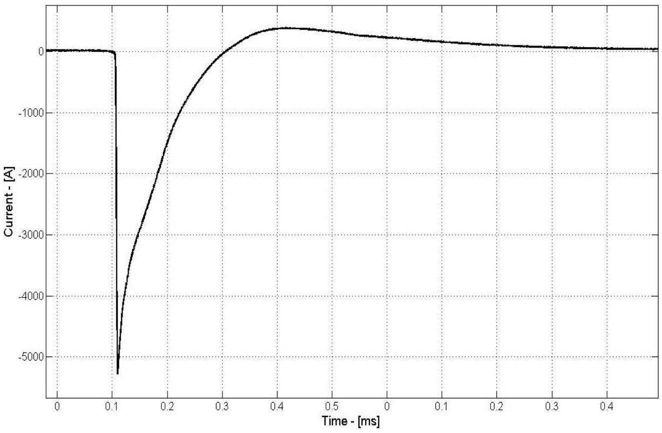

Fig. 8 – 5.2 kA subsequent return stroke current record.

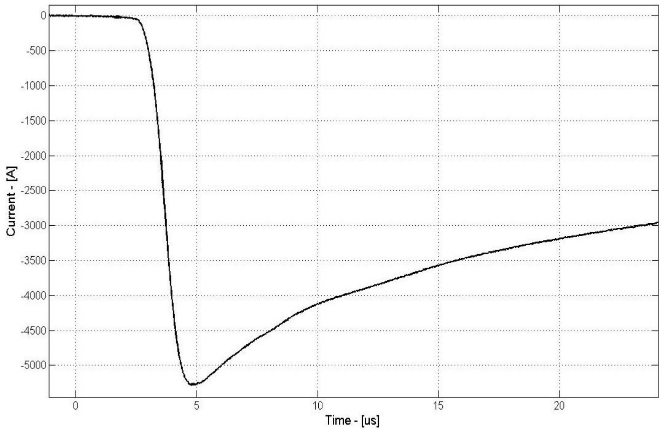

Fig. 9 – Detail of the impulsive part of the current shown in Fig.8

In this record, correpondig to a 5.2 kA-subsequent stroke, it is clear the difference in the current behavior during the period that preceeds the return stroke current in relation to the one shown in the register of Fig. 5. In that case, the pulses associated to the stepped leader reached values ranging from around 60 A to more than 1 kA, while in Fig. 9 it is seen a smooth curve associated to the dart leader.

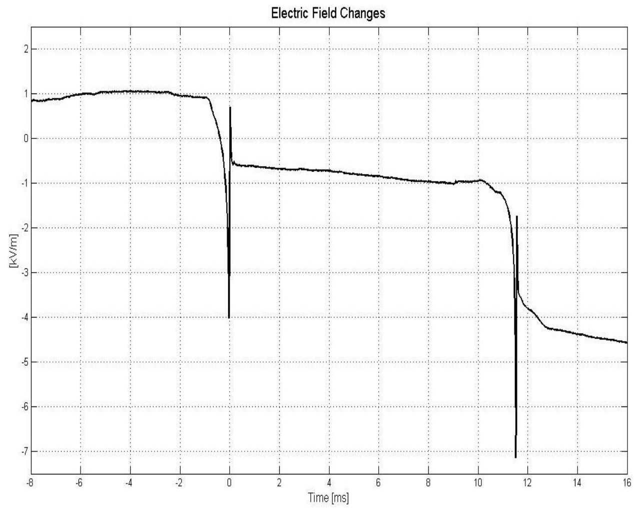

Fig. 10 – Electric field changes of the flash record.

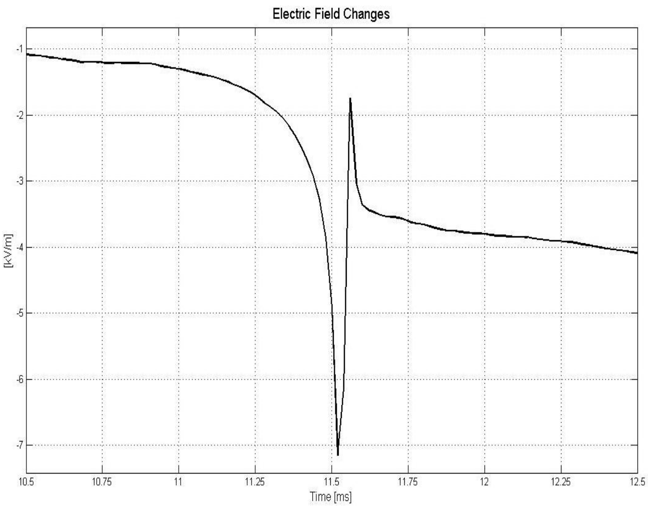

Fig. 11 – Detail of the electric field changes due to the return stroke current of Fig. 6

Fig. 10 and Fig. 11 displays the electric field changes due to the flow of the return stroke currents of both the first and the subsequent strokes. In Fig. 10, the electric field changes slowly in response to the electric activity on the clouds. Then, around −1 ms the breakdown condition is met and it is possible to see the stepped leader as it starts the development of the channel towards the ground. The first return stroke happens at 0 ms when a fast electric field change was recorded. After the flow of the first return current, the slow variations of the electric field are recorded for the a period of about 10 ms until the occurrence of the second return stroke around 11.53ms. This is the field record for the current waveform illustrated in Fig. 8. It is clear, in the second return stroke, a faster and smoother variation of the electric field, associated to the dart leader. A zoom in Fig. 10 in the period ranging from 10.5 to 12.5 ms is displayed in Fig. 11. This picture displays the typical features of electric field changes due to a nearby negative cloud-to-ground stroke. This kind of correlated data is very important for the investigation of the mechanisms and processes involved in the formation of lightning discharges.

7 CONCLUSIONS

This paper presents the main aspects in the evolution of the research facilities of Morro do Cachimbo Station. Originally, the station was designed and dedicated to characterize some specific lightning current parameters related to the impulsive current component.

A fisrt step to improve it concerned in the installation of facilities for evaluation of effects associated to lightning current strikes. Two experimental distribution lines were constructed besides the station and were supplied with resources for measurements of induced voltages to be correlated with currents records of strikes to the tower. Later, a two span experimental transmission line has begun to be constructed along a close hill for investigation of the direct strikes effects to transmission lines.

Recently, the most important improvements were implemented, allowing simultaneous measurement of electric fields at soil level and currents at the tower base. The facilities are still complemented by a new fast camera. All the records are acquired in a large time window including a pre-trigger period. Such improvements brought the station to a superior scientific level that allows investigating the mechanisms of formation of lightning discharges.

8 REFERENCES

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