2019 International Symposium on Lightning Protection (XV SIPDA), São Paulo, Brazil, 30th September – 4th October 2019.

Evian Project

An open air lightning laboratory

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***Abstract*—Most of what is known about the electric current of downward flashes and striking distance of lightning protection systems come from information gathered on tall towers. There are only a few observational data of lightning attachment to common structures or buildings (under 60 m) that are present in almost every city. In order to study lightning strikes to common buildings, several instruments will be soon installed in and around Evian building located in São José dos Campos city, Brazil. This paper describes the setup of electric field sensors, current transformers, X-ray sensors, high-speed video and standard video cameras. Some of the data we expect to obtain is also shown.**

***Keywords*- Upward connecting leader, cloud-to-ground flash, lightning rod, lightning protection systems, X-rays.**

I. Introduction

If a grounded structure height exceeds 100 meters the initiation of an ascending leader from its tip may lead to formation of an upward lightning flash. Most data available of lightning current and x-rays measurements were obtained from upward lightning initiating in instrumented towers or from triggered lightning flashes. A cloud-to-ground natural lightning leader will most probably connect a grounded structure if it is not higher than 100 meters. However the probability of a lightning strike to an instrumented building is very low. In order to observe the behavior of a lightning rod in response to a downward leader in common buildings (less than 60m tall) a continuous and long-term observation is required. Some measurements have been done in the city of S. Paulo and are described by Saba et al. [1]. An extension of this pioneering work will be described in the present work.

This work describes the setup of the instrumentation that will be installed before the summer of 2019 in the city of S. Jose dos Campos, state of S. Paulo, Brazil. The instrumentation will be composed of high-speed and standard video cameras, still photographic cameras, x-rays, electric field and current sensors. These observations can provide some parameters that are useful for the study of lightning attachment to grounded structures, which is crucial for the improvement of lightning protection standards.

II. The Building

The present study presents the plan of an open air lightning laboratory. The main object of study is a common 14-story apartment building (Evian, shown in Figure 1) in São José dos Campos city (southeastern Brazil) that has been instrumented to measure current, electric-field, and x-rays (23.206461° S; 45.953010°W). The tip of its lightning rod is at a height of 48 meters. Its steel reinforced concrete structure is used as natural lightning protection system (LPS). The flash density Ng for the region is about 11 flashes/km².year [2].

Figure 2 shows the location of the Evian building and cameras, it also shows the topography of the terrain along 2 km around the building. It can be seen that the building is located on a small hill. The high speed cameras are located inside other buildings around the instrumented one (Evian).

Fig. 1. Evian building and lightning rod to be instrumented.

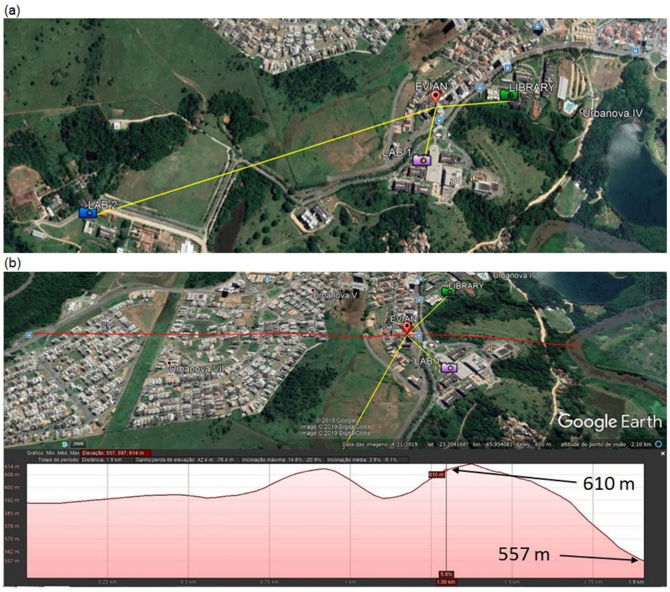

Fig. 2. (a) Location of the Evian building and cameras; (b) approximate elevations (meters) of the terrain taken from Google Earth.

III. Instrumentation

The equipment that will be used to monitor different process of lightning strikes at the building and around it is described in Table 1.

TABLE I. INSTRUMENTATION

Sensor	Instrument	Limits
A. Camera	Still Cameras (Nikon D200, D300, D800)	Exposure time of 20 s
	High Speed Cameras (Phantom V9.1, Phantom V711)	Up to 100 kfps
	Standard cameras	Up to 100 fps
B. Current	Shunt 1	Up to 10A
	Shunt 2 (LEMSYS ISM500)	Up to 100 kA
	TC (Pearson 301X)	Up to 50 kA
C. Electric field	Slow E-field	100 kS/s
	Fast E-field	5 MS/s - 60 MS/s
	Field Mill	50 S/s
D. X-rays	NaI (Tl) crystal + PMT	5 MS/s
E. Datalogger	PXI National Inst.	60 MS/s
	PCI National Inst.	5 MS/s

A. Video Cameras

In preparation for a study of lightning attachment, several cameras were placed in 3 different locations around the Evian building. Images from different angles will help to estimate the distances of different lightning processes to the lightning rods. A high-speed digital video camera (Vision Research Phantom v711) with time-resolution and exposure times of 12.5 and 100 microseconds (80,000 and 10,000 images per second) will use to record the images of the lightning attachments (Figure 3). For more details about the measuring systems and about the use of high-speed camera for lightning observations, see the works by Saba et al. [1].

Fig. 3. High-speed vídeo câmera and an image of a downward leader, with the response of the lightning rods.

The top of the building will be instrumented as represented in Figure 4.

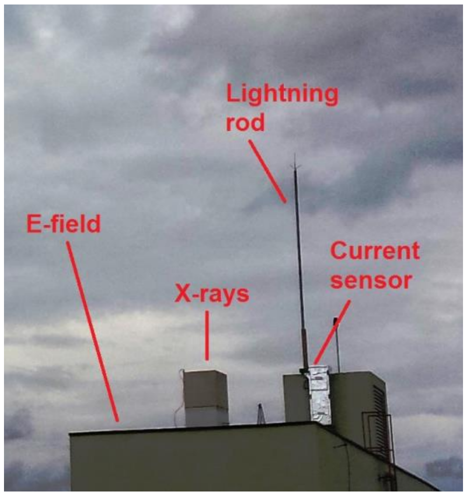

Fig. 4. X-ray sensor and other sensors as will be placed on the top of the building.

B. Current Sensors

One current transformer sensor (Pearson model 310X; see Figure 5a) will be installed on the lightning rod of the building. This current sensor is capable of recording current up to 50,000 A with an useable rise time of 200 nanoseconds, a low frequency 3dB cut-off of 5 Hz (approximate) and a high frequency 3dB cut-off of 2 MHz (approximate). A current-viewing-resistors (ISM 500; Figure 5b) will allow precise measurement of the peak value, the waveform of fast rise return strokes and also low current, long duration continuing currents. The output of the sensor is split in two channels (20 dB and 50 dB attenuation over 50Ω), and sent to a data acquisition system through a pair of fiber optic links. Before installation, these sensors were tested and calibrated.

To measure low-level currents, a tailor-made, passive 5 ohm shunt sensor has been designed and tested (Figure 5c) to be used in series with the lightning rods of the building. In this design, the shunt resistor is bypassed by a cascaded combination of surge arresters (metal oxide varistors MOVs, gas discharge tubes GDTs and diodes) conducting the high currents during a lightning strike. For this, several GDTs (each rated up to 100 kA) are arranged into a redundant and coordinated surge protection system, together with several MOVs rated up to 50 kA. The shunt sensor is designed to measure accurately low-currents in up to 4 lightning flashes of 100 kA (or more) or 20 flashes of 50 kA before damaged surge arresters need to be replaced. During a measurement season, the state of the sensor should however be followed by comparison of its output voltage and the signal from the high-current probes in the overlapping range between 8 and 10 A. This sensor allows to measure lightning currents between ±10 A with a resolution of about 10 mA and for frequencies from DC to about 10 MHz. The usable risetime for the measured currents is 500 ns. The usable voltage output of the shunt is ±10 V and it is limited up to ±15 V under a current of 50 kA.

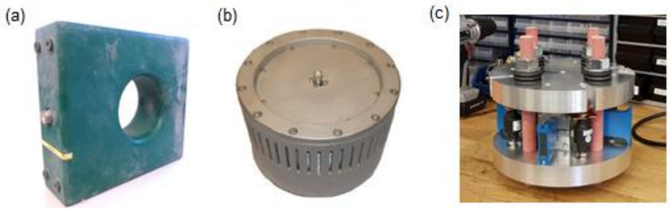

Fig. 5. Types of current sensors that will be use on the building: (a) TC Pearson Coil; (b) high current shunt and (c) low current shunt.

The current waveform of one return stroke and an M-component, that struck the lightning rod of a monitored building, is show in the Figure 6. This sample was obtained through the 310X Pearson, described in a previous work by Saba et al. [3].

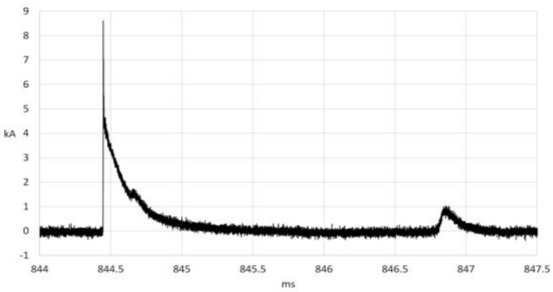

Fig. 6. Current waveform of the second return stroke, followed by an M-component. The flash discharge that strucked a lightning rod of an instrumented building on January 27, 2016.

C. Electric Field Sensors

1) Fast Electric Field

The measuring system for the fast electric field sensor consists of a flat plate antenna with an integrator and amplifier. Fiber-optic links will be used to transmit the signal from the integrator/amplifier to the digitizer. The lower frequency and the upper frequency limits of the electric field measuring system is 306 Hz and 1.5 MHz, respectively. The sensor will be placed on top of building Evian. Figure 7a shows the setup of the sensor.

2) Slow Electric Field

An electric field sensor was developed to measure the continuing current duration and amplitude (Figure 7b). The sensor is capable of measuring the field change produced by CC in nearby lightning flashes. The decay time constant of the sensor was measured and used to reconstruct what would be the real electric field changes if the decay time constant were infinite. Figure 7c shows a four-stroke flash measured by the fast and slow electric field antennas.

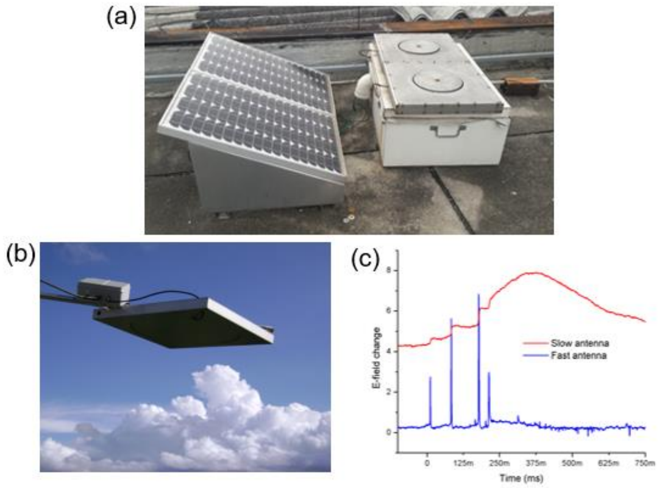

Fig. 7. Installed sensors (a) fast electric field; (b) slow electric field; (c) measurements obtained by the two sensors.

3) Electric Field mill (EFM)

EFMs (Figure 8a) detect the electrostatic field and relatively slow changes in that field. They detect the presence of charge separation and net charge directly above and in the immediate surroundings of the sensor. Depending on where the charge is located, the effective detection range of an EFM varies from a few kilometers to perhaps as much as 20 km [4]. An example of the measurement by the EFM is showing in Figure 8b.

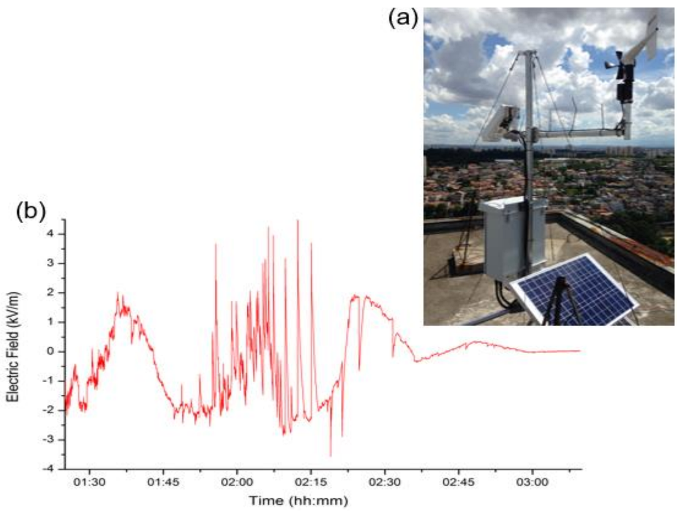

Fig. 8. (a) EFM; (b) measurements obteined by the sensor.

D. X-Ray

A crystal of NaI (Tl) coupled to a photomultiplier and a pre-amplifier are used as X-ray detector. They are enclosed in a heavy aluminum box with an optical fiber transmitter, both powered by batteries. This system is similar to the one used in several other works [5-8]. The X-ray detector will be located on top of the building (3 meters away from the lightning rod) in order to measure X-rays associated with the lightning discharge (Figure 9).

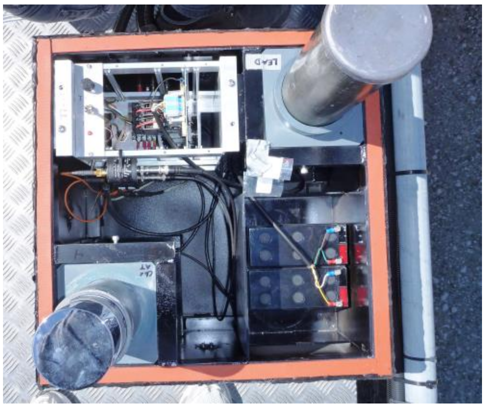

Fig. 9. X-ray sensors.

IV. USING THE TEMPLATE

This work describes the building, its surroundings and the instrumentation that will be used in the Evian project. The proximity of the sensors, especially of the high-speed camera and the high frame rate will allow us to see some interesting details that may improve the understanding of the lightning discharge, the attachment process and, consequently, the lightning protection studies. Thanks to the use of several cameras at different angles, it will be also possible reconstruct the 3D trajectory of the leaders. This will help to improve the understanding of the characteristics of the upward connecting leaders that may result or not in a connection to the structures below.

Hopefully, enough data will be soon gathered to study topics like:

Leader characteristics:	speed of the downward leader the length and speed of the UCL electric field changes due to leader propagation
Attachment process:	striking distance final jump
Return stroke:	peak current intensity di/dt charge transfer
Continuing current and	amplitude duration
M-components:	charge transfer
X-rays:	processes that produce them intensity

Contrary to past observational studies performed on tall structures (towers, wind turbines, skyscrapers, power lines, etc.) the information to be obtained from this facility will shed light on how lightning interacts with a type of building that is extremely common in cities. Note that laboratory long sparks, rocket triggered lightning and lightning initiated on very tall structures have different characteristics than the typical lightning that hits most structures worldwide.

ACKNOWLEDGMENT

The authors would like to thank Rajeev Thottappillil for providing the current sensors, and Amanda Romão, Diogo Custodio, Henrique Halada, Paulo Pino, Breno Pires and Gerhard Diendorfer for all support. The authors would also like to thank Paulo Sérgio Vilela and Luiz Paulo de Souza for all the information regarding the Evian building, and to the dwellers as well, for giving permission for this research to take place in their building.

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