International Lightning Protection Association Symposium
MARCH 13 – 14, 2014
CHAMONIX – FRANCE

Lightning measurements on radio-communication towers

Stéphane Pédeboy
Météorage
Pau, France
sp@meteorage.com

Sylvain Person
Orange
Lannion, France
sylvain.person@orange.fr

François Malaterre
Météorage
Pau, France
fma@meteorage.com

Ahmed Zeddam
Orange
Lannion, France
ahmed.zeddam@orange.fr

***Abstract*— Orange and Meteorage have unified their skills to set up an experiment related to the lightning storms. It consists in measuring the current values when direct strokes hit the air termination system on two radio telecommunication towers and in addition to check the way it is distributed within the structure. For Orange the results will be precious to contribute to the ITU-T Standardization in order to optimize the engineering rules for the radio communication towers electromagnetic protection. For Meteorage the interest is to strengthen and validate the algorithms of the stormy activity geo-localization, knowing that for a given lightning stroke Orange has this information. The two experimental sites are located in the Rhône-Durance (France) area. Each one is equipped with a field mill to register the electrostatic field in an area of 15km around the site, 24h a day, and with a digital oscilloscope to which are connected four current transformers dedicated to the direct lightning stroke current, to the current flowing through the surge arrestors, to the electric line and to the grounding system. The control of both instrumentations is performed through the 3G network. The paper focuses on the main objectives of this experiment, the difficulties encountered for the installation of the measuring equipment and the solution which have been implemented to fix them. Then the outcomes of the experiment will be discussed with regard to the ongoing work in standardization.**

Keywords—Lightning current; Lightning Locating System (LLS); Radio-telecommunication towers; standardization;

I. INTRODUCTION

Radio communication towers are generally highly exposed to lightning strikes causing damages and breakdowns in services. Such assets are preferably set on elevated ground and mountains top which exhibit a higher ground flash density compared to flat terrain. In addition, radio towers are elevated objects more likely to either attract or trigger lightning flashes. Then intense currents may flow in the metallic structure of the tower being possibly conducted to the electronic equipment installed inside the technical room. This results in failures producing a loss in service and generating repairs. It must be noted not only the direct strikes can cause damages but also nearby lightning strikes may induce currents or an earth potential rise strong enough to destroy sensitive equipment.

In order to better understand the pattern of the lightning current paths in the tower structure and define means to improve the lightning protection or prevention of the sensitive equipment, Orange and Météorage have unified their complementary skills in an original experiment. It consists of the instrumentation of two operational radio telecommunication towers located in the South-Est of France.

The interest in this study for Orange is to measure the effect of lightning currents on its radio telecommunication towers and improve the capability of the equipment to resist to current surges produced by lightning strikes. The opportunity for Météorage is to collect ground truth data from natural lightning in order to validate the detection efficiency and location accuracy of its lightning locating system (LLS). In addition, this experiment should help Météorage to check the parameters of peak current calibration model in use in the system.

This paper presents in details the experimentation and the measurement equipment that was deployed on June 2013. It gives a feedback of this first year of measurements that unfortunately produced no meaningful result. Nevertheless some future necessary improvements that should increase the measuring system reliability and efficiency were identified and are presented in this document.

II. THE MONITORING SYSTEM

The goal of the study is to measure in real time the lightning current distribution in a radio telecommunication tower. Several current sensors are installed in different part of the installation, including the top antenna and all the incoming cable paths in the technical building hosting the electronics.

Both sites are equipped with the same monitoring system which is made of two sub-systems: a remote controlled digital oscilloscope connected to current measurement coils and an electrostatic field mill. All measurements are accurately time stamped with a GPS synchronized clock in order all the data can be afterward time correlated. In addition to these direct measurement data, Météorage provides the lightning data that are collected in the vicinity of the experimental sites.

A. The lightning current measuring system

The scope is a LeCroy model 44XI with a bandwidth of 400 MHz and 4 different input channels operating at a maximum sample rate of 5 GS/s. The acquisition memory is settled in the sequence mode (10 blocks) in order to digitize all the subsequent strokes in flashes.

Channel 1 and 2 are connected to two Pearson-2093 current sensors which are installed at the top of the tower, at the base of the air-termination rod. Those coils are dedicated to the measurement of the lightning current in the antenna. Their characteristics are the following:

- Sensitivity 0.001 V/A +1/-0%
- Output resistance 1 Ohm
- Maximum peak current 500,000 A
- Maximum RMS current 2,500 A
- Droop rate 0.09 %/ms
- Usable rise time 2.0 µs
- Current time product 1,200 A-s
- Low frequency 3dB cut-off 0.15 Hz (approximate)
- High frequency 3dB cut-off 200 kHz (approximate).

The channels 1 and 2 use two different settings in order to insure the measurement of all the dynamics of lightning currents without saturation ranging from few kilo amperes up to 80 kA.

Channel 3 that is connected to one Pearson 110A current sensor type is dedicated to the measurement of surge currents flowing in the power supply surge arrestors. Finally, channel 4 connected to one Pearson 110A current sensor type is dedicated to the measurement of currents flowing in the power supply cable. The coils used in these measurements are similar with the following specifications:

- Sensitivity 0.1 V/A +1/-0%
- Output resistance 1MOhm
- Maximum peak current 10000 A
- Maximum RMS current 65 A
- Droop rate 0.8 %/ms
- Usable rise time 20 ns
- Max current time product 0.5 A-s
- Low frequency 3dB cut-off 1 Hz (approximate)
- High frequency 3dB cut-off 20 MHz (approximate)

It is interesting to note the coils used in the technical building measurements are more sensitive compared to those used to measure the root lightning current flowing in the antenna. This is because the expected range of currents entering the building is smaller as they are divided in several paths. Having a better sensitivity allows to make more accurate measurements.

B. *The electrostatic field mill*

As a complement to the lightning current measurements it is interesting to record the local electrostatic field generated by a nearby thundercloud. This is done with an electrostatic field mill from Duval Messien, the StormDetec^{TM}. The device monitors the local electrostatic field variations produced in the low atmosphere layer by the presence of a thunderstorm. Based on continuous and in real time measurements, the analysis of the symptomatic evolutions of the local electrostatic field determines the strong probability of an imminent thunderstorm and therefore the risk of lightning strikes. The dynamic of the electrostatic field measurement is very wide, about 650kV/m.

The operational management of the sensor is controlled by the oscilloscope computer. A daily file corresponding to a 24 h period of records is produced that can be downloaded afterwards for analysis.

The oscilloscope, the field mill monitoring unit and the 3G router are located inside the technical building in a faradized rack in order to get the best electromagnetic immunity to the equipment during the storms. The remote control of the instrumentation is possible from both Météorage and Orange laboratories through a 3G telecom link.

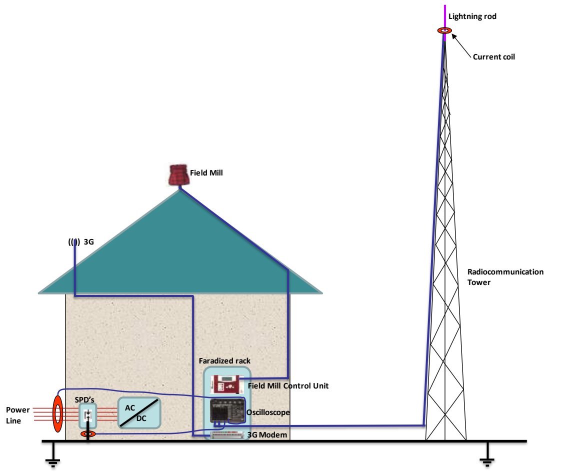


Fig. 1. Functionnal diagram of the experiment

Figure 1 presents the functional block diagram of the experimentation where we can see the current measurement sensors at the top of the antenna (up right), on the cables path entering the building and on the ground wire of the SPD (down left), the digitizer, the electrostatic field mill and the remote control box locations (down right). The electrostatic field mill and the GPS antennas are located on the roof.

C. *Météorage data*

Météorage is operating the French national LLS since 1986. It consists in a network of 19 Vaisala's LS7001 sensors covering all France. In addition, compatible foreign sensors are interconnected to this network leading to a better coverage at the borders, resulting in homogeneous performances on all the territory. The Météorage system locates in realtime the return strokes occurring in flashes. As a result it is possible to get data on flashes and strokes. Some recent studies showed the flash and stroke detection efficiencies are respectively 96% and 89% [1]. The relative location accuracy is estimated to be about a median value of 120 m [2]. This parameter determines the dispersion error or the measurement repeatability achieved by the LLS when it locates strokes using pre-existing channels. The absolute location accuracy traduces the error distance between computed and the real stroke locations. Some studies are currently held in France, including the present cooperation with Orange but no results have been published yet. However, according to results obtained on similar LLS in Europe and US one can consider the absolute location error committed by Météorage is less than 200m [3][4][5].

Météorage provides lightning data recorded on the vicinity of the two radio telecommunication towers. The time of every strokes located by the LLS is accurate down to the microsecond, making possible the time correlation with the other measurements data. The parameters available are the date, the location and stroke the waveform parameters including the stroke peak current and the polarity.

The first semester of 2013 was dedicated to the site selection, development of the measuring system, authorization process and finally the installation of the experimentation which was set fully operational on June 2013.

III. THE EXPERIMENTAL SITES DESCRIPTION

The instrumented sites were carefully chosen according to several important criteria. Obviously, the sites were selected in a region where the ground flash density is one of the highest in France in order to optimize the probability to get measurements. In addition, towers located on the top of mountains were preferred to other sites. Météorage lightning database was used to find such a highly exposed area based on historical analysis. As an example, figure 2 shows the ground flash density over the last 10 years period on the Rhône-Alpes region in the south of France. One can see a spot of high lightning activity (in red) that is caused by the Mont Ventoux which is an isolated mountain peak culminating at a height of more than 1900 m.

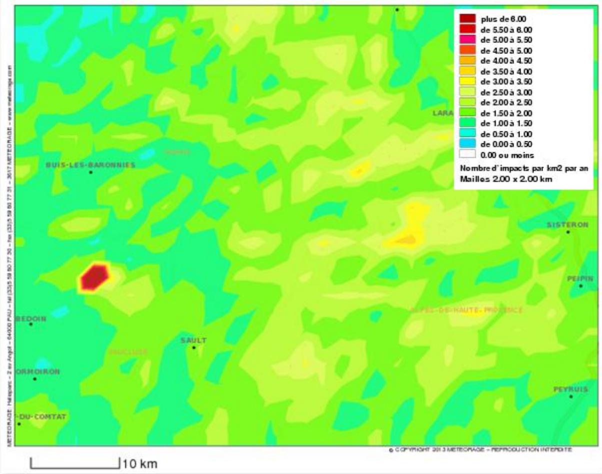


Fig. 2. Ground flash density in the experiment area

However, the lightning strike level is not the only important criterion, and the capability to easily maintain and service the equipment on the sites by local technical teams was taken into account too. Finally the sites had to get all the necessary authorizations to install and run the experiment during a period of several years without causing any break in operational telecommunication services.

A list of initial possible Orange's radio communication towers was made from which Météorage determined the two sites with the highest local ground flash density. This is not a surprise the two selected sites are located in Vaucluse and Drôme, two French departments exhibiting a mean ground flash density of about 1.8 flash/km²/year that is twice the national value. These areas are mountainous regions located in the South of France where temperatures are high during summer time favoring the convective storms production. In addition, during the autumn some local phenomenon known in France as "épisodes Cévennols" may produce. Such storms which are usually very strong and active occur because of the vicinity of the Mediterranean Sea that provides the necessary energy based on differences in temperatures between the water sea and the ground.

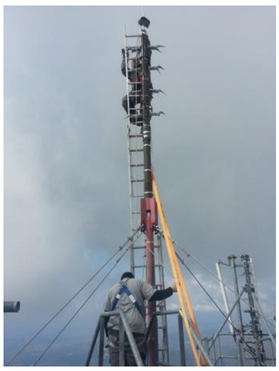
A. *The Mont Ventoux site*

The Mont Ventoux site is usually well known by any cycling passionate since it is a famous stage in the Tour de France because of its terrain roughness. The equipped tower is on the top of this mountain peak of 1912 m height (44.1745 deg. lat., 5.2789 deg. lon.). The antenna is mounted on a square tower made of concrete, and wood. At the top of the tower are many antennas, and the installation of the current coil has been possible by the use of a crane. It must be noted that Orange share this site with TDF (Télé-Diffusion de France) the latter operating a high telecommunication tower which is set at a distance of about 100 m from the instrumented tower. The TDF tower is much taller than the Orange one and should have ideally been a better site for this experiment. Unfortunately it was impossible to get an agreement to install the current measurement coils on the antenna. The possible drawback would be the TDF tower acts as a lightning rod protecting the Orange tower from most of the direct strikes.

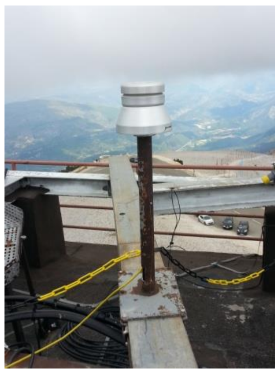
The statistics computed by Météorage on the Mont Ventoux region over the last 10 years shows a lightning density that reaches up to 6 flashes per km² per year. This high level of lightning strike is due to the very sharp shape of this mountain peak enhancing the collection of lightning flashes as it can be clearly see on the left part of figure 2.

A view of the tower

Coil installation



Air termination system



Electrostatic field mill

Fig. 3. Some photos from the Mont Ventoux site

B. *The Poêt Sigillat site (Drome)*

The radio-communication tower of this site is located on the top of a hill (1299 m) in the south of the Drôme department, at the 44.38 deg. of latitude and 5.33 deg. of longitude. It is made of a 40 m height metallic tower associated to a technical building, as shown on the picture below.

The mean ground flash density recorded over the last 10 years on this site is 3 flashes per km² per year which is half the value of the lightning density observed on Mont Ventoux.

A view of the site

The pearson coil

The Field mil

Faradized rack

Fig. 4. Some photos from the Poët Sigillat site

IV. RESULTS OF THIS FIRST YEAR OF EXPERIMENT

On 2013 the lightning activity in France was particularly high making this year one of the most active ever recorded over the 25 years of observation by Météorage. Unfortunately, the results obtain during this first semester of experiment are mitigated because no current or electrostatic field measurement data could be downloaded for analysis.

A. Results in Mont Ventoux

The 3G link on this site is actually poor and ineffective because of strong interferences with the local transmitters making impossible the download of the measurement data files. The access to the site is prohibited during winter time preventing any human intervention to get the data even manually. Today, the data is locally stored but one must wait springtime to schedule a maintenance trip on site. This telecom issue should be fixed by the use of an ADSL link for the coming lightning season.

Looking at Météorage data, from the 1^{st} of July to 31^{st} of December 2013, a total of 74 flashes were recorded within a 2 km radius around the tower in Mont Ventoux during 14 days from which 6 days in July. However, as expected most of the strikes were located on the TDF radio-communication tower and only a few of them actually struck the instrumented tower.

The analysis of the recorded data should help to validate this statement and nevertheless better understand the effect of nearby located lightning strikes.

B. Results in Poët Sigillat

The remote control of the instrumentation is functioning properly and both Orange and Météorage laboratories can access the equipment. Unfortunately, no data was recorded up to now on this site.

Looking at Météorage data, from the 1st of July to 31st of December 2013, a total of 23 flashes were recorded within a 2 km radius around the tower during 10 days among which 5 in July. As expected, the local conditions of this site make the lightning strike level less important than in Mont Ventoux.

However a detailed analysis of the Météorage's data shows flashes mostly struck apart the antenna with no direct strike on it which is consistent with the previous observation that no current measurements could be done.

V. CONCLUSION

Orange and Météorage started cooperation in a lightning measurements experiment using instrumented towers on two sites in the South-East of France. The experiment was set up on June 2013 and since that time collects data on lightning currents flowing in the cables path of the radio-communication facilities in Mont Ventoux and Poët Sigillat stations.

Despite 2013 exhibited a significant level of lightning activity in France the results of this first semester of experiment is mitigated because of several reasons. On Mont Ventoux strong local interferences making the instrument remote control communication link ineffective to download data files. In addition, the instrumented Orange tower might not be a perfect site because of a nearby elevated tower acting as a lightning rod. Nevertheless it may be interesting to analyze the induced effects of close lightning strikes on the Orange assets. On the opposite, the site in Poët Sigillat is fully operational but no lightning stuck the antenna this year and therefore no measurements could be done.

ACKNOWLEDGMENT

A special thanks to the Orange's engineers and technicians without whom the installation of this experiment could not have been done.

REFERENCES

[1] Pédeboy S., W. Schulz, "Validation of a ground strike point identification algorithm based on ground truth data ", ILDC 2014 Tucson.

[2] Pédeboy S., "Identification of the multiple ground contacts flashes with lightning location systems", ILDC 2012 Boulder.

[3] Schulz W., D. Poelman, S. Pédeboy, C. Vergeiner, H. Pichler, G. Diendorfer, S. Pack, 2014: Performance validation of the European Lightning Location System EUCLID, International Colloquium on Lightning and Power Systems, CIGRE Lyon 2014.

[4] Cummins K. L., M. J. Murphy, J. A. Cramer, W. Scheftic, N. Demitriades, A. Nag, 2010: Location accuracy improvements using propagation corrections: A case study of the US NLDN, 21st ILDC.

[5] Nag A., M.J. Murphy, K.L. Cummins, A.E. Pifer, J.A. Cramer, "Performances characteristics improvements of the US National Lioghtning Detection Network", Asia-Pacific International Conference on Lightning, Seoul 2013.