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TESTING FACILITY AND METHODOLOGY FOR LOCAL LIGHTNING DETECTORS BASIS FOR SCIENTIFIC AND STANDARDISATION DISCUSSIONS

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Abstract - Lightning prevention techniques becomes very popular. The risk evaluation standard IEC 62305-2 published late 2006 will probably push forward that use. As a matter of fact, this risk evaluation technique means that you should provide protection measures until you decrease the calculated risk below a certain tolerable level. But in some cases, the risk is too high and standard lightning protection techniques cannot reduce it enough. This is particularly the case for large buildings with high risks, building with explosive atmosphere or place in the world where keraunic level is very high as for example Asia. What to do in such case? Basically, one of the only remaining option is to reduce the risk duration. This means to implement lightning prevention measures such as lightning detection. If the lightning detector is providing a signal early, it is possible to evacuate people from a dangerous zone, to stop a dangerous process or even to disconnect from the network and operate on independent power generators. This is nice in principle but this has a drawback. You can find any type of device on the market. You can find also various technologies such as for example magnetic field sensors or electrical file mills to speak only about local lightning detectors. But how to be sure that a) the device will warn you enough in advance b) that the warning is reliable c) that the warning will occur at all? Purpose of this paper is to debate about possible ways for testing these devices and to seek for advice from the lightning and standardization community.

1 INTRODUCTION

Lightning prevention techniques becomes very popular worldwide. The international risk assessment standard IEC 62305-2 published late 2006 will probably push forward that use. As a matter of fact, this risk evaluation technique means that you should provide protection measures until you decrease the calculated risk below a certain tolerable level which is basically the same around the word. But in some cases, the risk is too high and usual lightning protection techniques fail to reduce it enough. This is particularly the case for large buildings with high risks, building with explosive atmosphere or place in the world where keraunic level is very high as for example Asia. What to do in such case? Basically, one of the only remaining options is to reduce the risk duration. This means in practice to implement lightning prevention measures such as lightning detection. If the lightning detector is providing a signal early, it is possible to evacuate people from a dangerous zone, to stop a dangerous process or even to disconnect from the network and operate on independent power generators.

This is nice in principle but this has a drawback. You can find any type of device on the market at any price. Some are based on sound techniques and some have been developed on new concepts but are not really validated by the scientific community. You can find also various technologies such as for example magnetic field sensors or electrical file mills to speak only about local lightning detectors (lightning detector networks are outside the scope of that paper). How to be sure in such conditions :

- that the device will warn you enough in advance to allow you to implement the safety measures ?
- that the warning is reliable ?
- and that the warning will occur at all ?

This is linked to three main characteristics that such a device should have:

- to be reliable : if you give a false warning too often the user will stop believing in the device and can even in worse case disconnect the alarm

- to inform in advance : depending on the process you intend to stop or the time you need to react, it is justified to request a certain time before warning and possible first strike on the site. A typical timing which is wanted is 30 minutes.
- to not miss any dangerous event : this is particularly important for dangerous and expensive processes.

As we are living in the real world and that perfect devices do not exist, the characteristics of the device should be defined by a few parameters allowing comparing a product with the other:

- p1 : minimum time between alarm and event
- p2 : number of false alarms per period of time (1 year for example)
- and p3 : percentage of dangerous event which haven't been detected.

At the end of the process this may be defined as classes of detection in the same way that lightning protection measures lead to lightning protection levels 1 to 4. Based on these classes, specific parameters should be included in the risk assessment method. Basically, parameters p1 and p2 are related to user choice depending on his own local situation when parameter p3 has a direct influence on risk calculation.

What is needed is exactly the same that what is done for other devices: a standard to be able to characterize and compare performance of existing devices. A study group inside SEE (French electrical engineers association) has established the basis for the classification of such devices in early 2000. Based on this classification, a standard group started to make a technical guide on the subject in France in late 2003 and due to the fact that another group has been established to make a standard on such devices at the end of 2004 at the Cenelec level, the French group has been disbanded lately in order to join our forces with the European team. It appears, at least at the French level, that the possible testing means are very simple and probably not representative of field conditions and of long term testing needed to evaluate some characteristics in real environment.

Based on that approach and on long term cooperation between China and France regarding lightning studies, an idea raised in late 2005: use the existing laboratory facilities to create a field testing for such devices. In China, this is the Meteorologists who are also studying the lightning protection equipment. The Shanghai Lightning Protection Centre originally created to test SPD was then the appropriate place for creating this facility. It is also a severe area for lightning occurrence.

2 PRESENTATION OF THE SHANGHAI LIGHTNING PROTECTION CENTER

The SHanghai Lightning Protection Center (SHLPC) has been created in 2004 in Shanghai. Shanghai is located on the verge of the East Sea. Shanghai places at north latitude 31°14′22″, east longitude 121°29′. Its width from east to west is 100 kilometers and its length from south to north is about 120 kilometers. The earth area of whole city is about 6340.5 square kilometers. The climate of Shanghai belongs to the north semitropical climate. The yearly average number of lightning days is fifty. Shanghai lightning Protection Center is a direct subordinate enterprise to Shanghai meteorological bureau with a business range of lightning protection technological service, application and research. In 2004, with the support of China meteorological administration and Shanghai municipal government, Shanghai lightning protection product-testing center had been founded in Shanghai songjiang high scientific technology garden. The level of the equipments of Shanghai lightning protection product-testing center (mainly SPDs) meets the request of the IEC61643, UL1449 and China national standard GB18802. The center has imported the most advanced low-voltage SPD impulse-experiment instruments in the world and became a top-ranking testing institution in China and even all over the world as can be seen on Figure 1.

Fig. 1 – Example of testing means for SPDs in SHLPC
(from left to right 200-180 impulse current generator, PSURGE 30.2 and PSURGE 6.1 Surge Generators)

3 PRESENTATION OF THE STORM DETECTION TESTING PLATFORM

A Vaisala SAFIR system was already used in the Shanghai area and the data coming from that system are collected at SHLPC to study lightning activity in Shanghai area. As we needed a proved system to be used as a reference to compare the other local lightning detectors, we decided to use the well proven SAFIR system as a reference. This system has three branches which are set in three corners of Shanghai. The following figure 2 shows the three stations. The SAFIR system is able at least to locate 95% of all lightning strikes including the intra-cloud strikes. Detection accuracy for strike to ground is much greater. Ability to locate cloud to ground strikes and intra-cloud strikes will allow the system to determine the early warning capacity of tested local storm detectors as well as the failure rate. The location accuracy is at least 500 m. There is even a project to install a fourth sensor in order to be sure that at any time three sensors will be working to offer a 100% operational reference system.

Fig. 2 – From left to right : Nanhui, Haiyan and Chongming stations

The distance between the three branches and the distance between every branches and SHLPC ranges between 60 km to 150 km. The systems parameters are as follows:

- Average time of sampling: 100 µs
- Average time of sampling interval: 333 times per second
- Distance range of testing: about 200 kilometers

This system can also inspect the lightning density in the given area or in the given time. For example, it can inspect the lighting density in about 10 square kilometers or inspect the lightning density in a twenty minutes period. Using analyzing tools, it is possible to forecast the moving directions of thunder clouds with high level of confidence.

Information from SAFIR system and from the local detectors under test are transmitted to SHLPC control center, as can be seen on Figure 3 and Figure 4.

Fig. 3 – SHLPC control room where all data are collated and studied

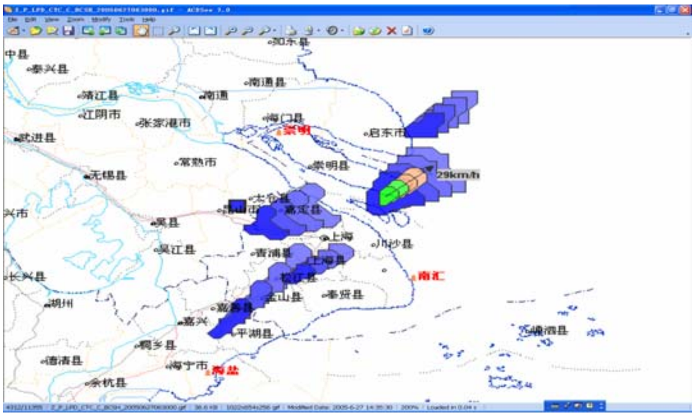

Fig. 4 – information transmitted by the system SAFIR to SHLPC control room

The facility is now operational and two field mill local lightning detectors are under test in this open air laboratory. One of them can be seen on Figure 5.

Fig. 5 – one of the local storm detectors in test in the open air laboratory

4 GENERAL DISCUSSION ON ELECTRICAL FIELD MILLS

There are a lot of influencing factors on the electric field and distinctive differences of monitoring data between different electric field mills do exit. So false warnings and missing warnings will occur. In order to solve this problem, a new method should be implemented to judge the occurrence of thunderstorm.

A. Influencing factors for the electric field

Because of numerous influencing factors on the electric field, there are obvious limitations to give thunderstorm warning based on a threshold level. When electric field is influenced by other factors than real thunderstorm, the electrical field can reach threshold level and thunderstorm warning will be issued by warning system, but actually there is no thunderstorm occurring at that time.

For example, Figure 6 shows the variation curve of electric field measured by electric field mill in Jiuting Town during two periods. The thresholds of different warning levels are set as follows: 3kV/m, 5kV/m and 8kV/m. Figure 1A shows that the value reached 10kV/m at 17:14, which exceeded the threshold of 8kV/m. Thunderstorm warning should be issued at that time but actually there was no thunderstorm observed. Figure 1B shows that electric field also reached the threshold of 8kV/m and there were electric field pulses in the curve. The warning system issued thunderstorm warning. Data from lightning positioning system and radar echo map showed that there was in that case thunderstorm really occurring over Jiuting Town.

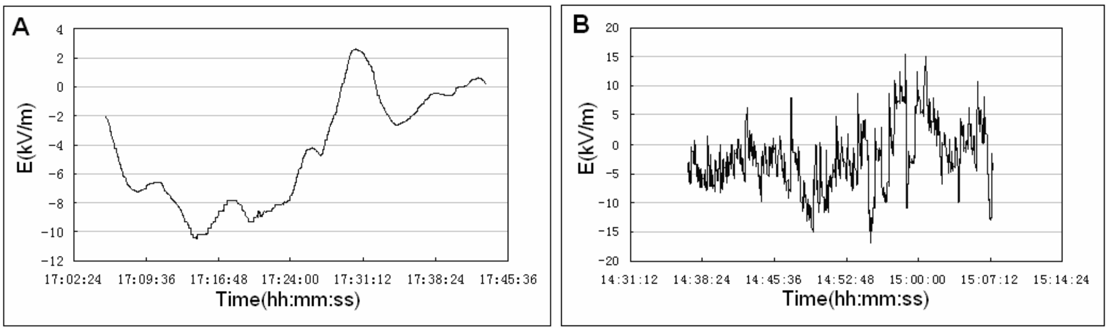

Fig. 6 – Variation curve of electric field observed in Jiuting Town during two different periods

B. Analysis of difference of measured electrical field on different weather conditions

Shanghai Lightning Protection Center is equipped presently with two field mills. With data obtained and numerous thunderstorms monitored during two years, several cases on different weather are selected to analyze temporal difference of electrical field. We can first note that even in clear weather, the field recorded are not always exactly the same. In case of thunderstorm the difference becomes larger. For example, during one event on July 21, 2007, there were obvious distinctions between data from the two device under test. The maximum and the minimum of electric field observed by one of them were 2.5kV/m and -12.7kV/m respectively when for the other they were ranging between 11.1kV/m and -11.75kV/m respectively as can be seen in Figure 6. Figure 7, shows the intra cloud and the cloud to ground recorded by the SAFIR system during the same event.

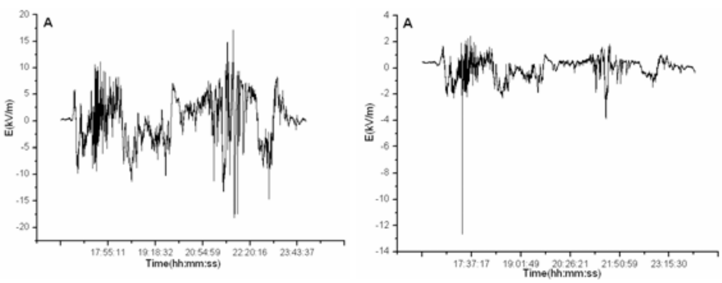

Fig. 6 – Difference of measured electrical field during one thunderstorm on July 21, 2007

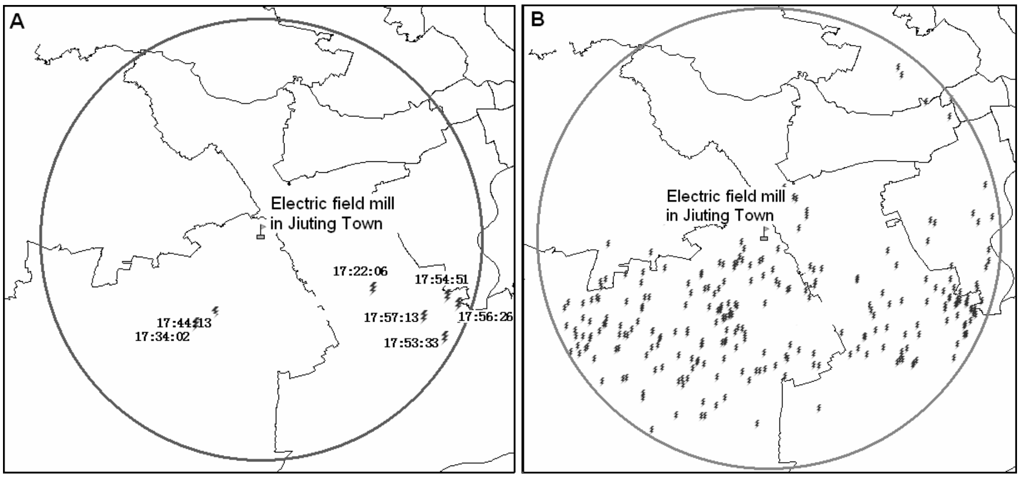

Fig. 7 – Location map for cloud to ground flashes on the left (A) and intra-clouds flashes on the right (B) on July 21, 2007

In future studies, the SAFIR system will be used to determine if the event recorded by the electrical field variation as shown on Figure 6 are consistent with the events recorded by the reference system.

5 OPEN DEBATE ON IN-SITU TESTING FOR STANDARD PURPOSE

Basically, the generic idea about standards is to perform tests in laboratories. The main reason about this is to allow tests to be performed in repetitive ways in various places in the world. There is a little number, to our knowledge, of tests performed on site included in a published standard. The field interest is of course not denied as many tests are running in the field but the purpose is mainly to support new laboratory tests to be included in future standards. In the field of lightning studies, rocket triggered lightning testing sites, such as Camp Blanding in USA, allow testing of equipment in real conditions. For example, this test site has tested equipment in a dummy house and data regarding earthing and real lightning current have been recorded and shared with the IEC SPD community. It remains that, there is little evidence in standards of open field tests. Purpose of that paper is to start a discussion at ICLP level in order to discuss the validity of in-situ testing laboratory to test local storm detectors. Depending of the outcome of the discussions at ICLP, the purpose would be to propose such a testing methodology to standard organizations. It should be noted that even if at the present time, only field mills are under test in the testing station, the test method can be used for any type of local warning systems including the ones based on magnetic field.

Purpose of this paper is to seek advice from the lightning and standardization community. Authors are looking, for example, for guidance regarding following topics:

- reference system. Today we use the SAFIR system. Should we use one or more ?, which types ? which requirements for such a reference system
- which parameters to be used to evaluate and compare the devices under test ? For the time being we are measuring : the failure rate (not detected events), the time being warning and event (in minutes), the number of warnings which occurred without any event.
- needed duration for the field tests (one year, more, less) ?

Of course, tests in laboratory for EMC, pollution, corrosion and environmental withstand will be needed. For field mills, electrical field can be generated in high voltage labs and difference between applied field and measured field can be determined in lab with accuracy. For magnetic field sensor, long impulse discharge can be also generated in air and detected by the device under test. But these are basic tests only. It is not possible, according to us, to determine the real efficiency of the device in field by such laboratory tests. Especially, the failure rate cannot be determined when this is so critical to include the storm detector in the risk assessment process adequately. Warning time advance as well as false detection will also be difficult to determine in laboratories. Performance of many tests in lab, even if this has a statistical meaning, will not include all the parameters needed for such an evaluation, as our preliminary evaluation has shown.

We do believe that to develop such an in-situ testing platform is the sole practical and reliable solution to assess performance of such products. Would such a testing mean be a good and acceptable solution for standard organizations?

6 CONCLUSIONS

In this paper, we have presented the state of the art of an in-situ testing station for storm detector. The station is already operational and tests such devices since a few years. The preliminary results obtained are showing that data collected are different from one device to another, mainly due to the software used internally to get the electrical field and take decisions in terms of alarms. From the user perspective, he needs to have a reliable device as the storm detector is a safety device. In addition, to include such a device in the risk assessment process it is necessary to determine the efficiency of the system in real use. Attempts to develop laboratory tests in standards for such products exist. Such standards are necessary and need to be developed. But our preliminary results are showing that, due to many parameters occurring in real conditions, only in-situ testing is able to validate the efficiency of the device and as such, should be included in the standards under development. Of course, include such open air – long term tests in a standard is not an easy task and validation of the proposal, both by the scientific and standardization community is really needed to go further. Purpose of that paper is to seek advice from both of them. Nowadays, LF detection networks such as Vaisala's LS series are able to provide the necessary information for such validation tests and most of these networks have been subject to many studies and scientific publications confirming that the location accuracy and the detection efficiency are perfectly in accordance with the validation purpose of this paper. There is an ongoing program with them to establish what should be the reference characteristics. This will be presented in a future conference.

7 ACKNOWLEDMENTS

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