Storm detectors. Tests and application

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Storm Detectors - Tests and Application

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Abstract—**The storm detector standard is now published at European level [1] and is also introduced in the IEC program of work. However, this standard is only a first document that even if very important will not be enough to apply safely the storm detectors in field. First regarding application, it is assumed in the standard that a setting process will be possible for any device installed but in practice, for many industrial applications, this procedure will be very weak and the device should be able to meet the industry requirements in a very short time to be efficient and thus settings procedure should be very straight forward. Second regarding long term withstand, it is very important that the device be reliable and thus tested.**

This paper will investigate both sides:

- application from need definition to how to use the storm detectors. This will be illustrated by real case applications.

- tests : laboratory tests as well as open air tests will be introduced

Keywords-storm detector; tests, application; risk

I. INTRODUCTION

Lightning prevention techniques becomes very popular. The risk evaluation standard IEC 62305-2 will in a near future introduce such measures in its risk calculation. 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 especially in high keraunic areas 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 sole remaining options is to reduce the risk duration. This means to implement lightning prevention measures such as storm detectors. If the storm detector is providing an early warning, 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 field mills to speak only about local storm detectors as networks exist in many countries. 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 [2], [3], [4].

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. This is also the case is the storm detector is too often faulty or even damaged by pollution.
- 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 between warning and possible first strike on the site. A typical timing which is wanted by users is 30 minutes but this is the limit for many systems.
- to not miss any dangerous event : this is particularly important for dangerous and expensive processes.

The storm detector European standard (future IEC 62793) has defined many parameters that are useful for the user as well as a procedure to define these parameters as well as the covered area precisely.

But this is not enough; it is also needed to have tests in the same way than what is done for other devices: a standard to be able to characterize and compare performance of existing devices. Basic tests are needed such as pollution tests or EMC tests but this not enough as the testing means in laboratory are limited and probably not representative of complete field conditions and especially not of long term testing needed to evaluate some characteristics in real environment.

II. APPLICATIONS

The European standard has defined many parameters to allow the use and setting of storm detectors as well as to characterize the various technologies. These parameters are reviewed in the paper by splitting them in 3 categories [5]:

- parameters to define the appropriate technology for a specific site and use
- parameters to allow the setting of the device to meet its goals

parameters to be used in risk assessment procedure.

A. Parameters used to define the appropriate technology

There will be mainly a comparison of available product for industrial users i.e. magnetic sensors, field mills and networks of sensors.

The standard defines 4 classes of devices:
– class I: they detect a thunderstorm over its entire lifecycle (from initial phase to dissipation phase);
– class II: they detect intra-cloud and cloud to ground flashes (from growth phases to dissipation phase);
– class III: they detect cloud to ground flashes only (from mature phase to dissipation phase);
– class IV: they detect cloud to ground flashes (mature phase only) and other electromagnetic sources with very limited efficiency.

As a matter of fact device that measure only electromagnetic radiation at low frequency have little interest for users, due to the fact that they are not able to provide enough lead time or to provide it with enough reliability. Due to their limited price, such sensors are highly used by the industry but they have limitations. One example will show this; such a storm detector was used on a building located on a top of a hill. This building was dedicated to seismic activity and as such was supposed to work under any meteorological conditions. To achieve this, such a magnetic detector was used in order to switch the power to a power generator and get decoupling from the network and its overvoltages. One day, the first flash occurred right on the top of the hill on the main building and there were of course no warning at all. Since then, they move to another technology: static field sensor.

Network of sensors is an interesting technology because most of the parameters needed for application on site (lead time, Failure To Warn Ratio) have been validated by the provider of this system on a large scale. However, drawbacks can appear if the number of sensors is too small or if the studied site is in a location were accuracy of detection is not so good for any reason. In addition, these networks are generally able to detect the evolution of stormy cloud over a large area such as a country, mainly by detecting the cloud to ground flashes. So this means that, as above, when the first flash appears on the studied site it is too late to give any warning.

Parameters defined in EN 50536 standards and especially FTWR should be published by the provider for its network. It is wise to ask to the network provider an evaluation of all these parameters for the exact location of the studied site as these parameters can take various values over the network covered area.

Such networks don't exist in all countries and in some places, the parameters given by the network may not be enough for the desired application (too small lead time for example or bad FTWR). In these cases, a local static field sensor is the good option.

B. Parameters used used in risk assessment

setup of an alarm given in the standard includes three steps:
– areas definitions;
– alarm triggering criteria;
– alarm information delivery

The standard recommends that any new installation need a prior adjustment period before it is considered to be working at its optimum level. This adjustment shall be made by a technician specifically authorized by this manufacturer. It is possible to optimize the warning system parameters and then improve the quality and the reliability. The alarm can thus be better adapted to the end user applications. It is recommended to establish an evaluation procedure. In this procedure the user should provide information about previous experiences (e.g. number of alarms, failure to warn, false alarms, damages, etc.).

In practice this is a quite difficult process for most of the industrial users. If it is clear that the device will be set-up by the manufacturer itself, the adjustment of parameters will be done at installation stage so generally under fair weather conditions. The second step, regarding adjustment of parameters during stormy conditions, will generally be done by the user itself if any. The only existing possibility to adjust the parameters for stormy conditions will be to send a data log to the manufacturer for him to analyze results and propose adjustments. More likely this will be done when the maintenance is made, this means one year after set-up. During one year the user will live with parameters adjusted at installation stage, whatever is the quality of this initial setting. Comparison of data recorded by local detector and lightning location data available from many sources (lightning detection networks, satellite observations, etc) is quite an extensive task especially is performed only after one year. In practice, this procedure is not performed and the setting of parameters is only based on experience of the technician from the manufacturer.

Furthermore, another problem may occur. The user is generally allowed to modify the settings of the device to meet his goal. Even if this procedure is protected by password allowing only one or two people in the site to make the changes, they may not have the background to make this adjustment. Risk is that a user, disturbed by too many false alarms decides to increase warning levels until it becomes not efficient at all.

To illustrate this difficulty in fixing parameters, we will show two examples using static field sensors (field mills).

The first one is a very polluted site in a coastal area. For that site the storm detector is used for people safety. Workers may be present on a 140 m tower and they need around 15 minutes to go down by stairs and ladders. There are many places including the top of tower that are dangerous for them in case of storms and reliable information should be provided to allow them to go down safely. Due to the fact that the site is near the sea and in a very specific topography, many lightning are occurring and most of them without any prior signs and some time without any dangerous clouds in vicinity. To provide this reliable warning a field mill has been installed on shore at the main building. People working on the tower should keep a phone with them to receive warning when storms are approaching. The system has been adjusted over a one year period. Parameters received by the system were transferred to the manufacturer and fine tuning of parameters possible. This worked fine for one year. After a few more years, the user started to complain. In presence of clear storm conditions, the user got no indications from the sensor. on the reverse, in clear conditions, there were many false alarms.

The user lost confidence in the device and disconnected it a few months after. It has been shown that the reason was corrosion due to salt fog within less than one year. This is why the proposed tests (see part 3 below) includes corrosion test. A new technology appeared recently: there are no more rotating parts and corrosion effect is then better mastered.

The second case is an industrial site in rural area. Due to the high risk generated by this site and a quite extended site to be covered, the user decided to install 2 field mills at two opposed locations on his site. The two devices are communicating together and decision to warn the user is based on data coming from the two sensors. This has proved to be a good way to reduce the risk in a safe way (even if one device fails the second one can still provide enough detection capability.

Figure 1. Corrosion marks of the rotating part as well as fix part. Note that blades are damaged.

This was very important due to the dangerous industrial process and the will of the user to protect safely workers and environment) and also to better adjust the settings of the device by comparing recorded data from two sensors. This is based on a PLC box located in a building where of the sensor is installed. This box allows controlling the total warning system. The alarm is given by dry contacts with positive safety able to pilot more than on signalization equipment. In addition, a PC is used to monitor events. The sensors are communicating by an ethernet link.

C. Parameters used to allow setting of the device

The EN 50536 standard has introduced an application guide where 3 steps are defined to establish if a storm detector is needed or not.

- hazardous situations identification;
- type of loss determination;
- risk control: options to reduce the risk (selection, implementation and follow-up of the proper measures for the control and reduction of risk)

Let's take the example given in the standard for a wind turbine farm. Based on the parameters taken for this example, the conclusions is that implementation of adequate thunderstorm warning system is very highly recommended. A wind turbine is a basic service whose continuity, quality or fast recovery shall be guaranteed but also is a workplace with risk in case of a thunderstorm and both situations have to be analysed. The risk to human life can be reduced by avoiding having workers on the wind turbine during thunderstorms. The risk of damages and service losses due to a direct strike cannot be completely eliminated but it is possible to take preventive actions (disconnection of sensitive equipment, park wind turbine in a safe mode, etc.).

A wind turbine has also been studied according to IEC 62305-2 Ed. 1. This is based on a real case wind turbine farm. The wind turbine is having following characteristics :

- blades : 33 m long
- rotor + blade : total length 70 m
- height of rotor : 70 m
- 1500 kW

Site has a Ng = 2. The design has defined three zones:

- Z1 outside
- Z2 tower
- Z3 nacelle

and three lines:

- L1 power line connected to the power shelter
- L2 data line coming from the meteo sensor on the top of the wind mill
- L3 power line from rotor to the electrical cabinet in the nacelle.

The result is as follows:

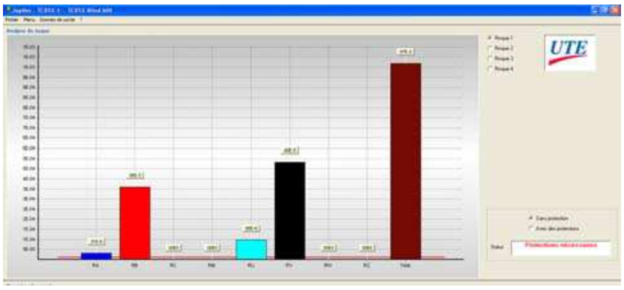

Figure 2. Risk assessment before implementation of protection and prevention measured.

The red line of the figure above is the tolerable risk RT that should not be exceeded and the various color columns correspond to risk components. The right brown column is the total risk (some of all components).

The risk component exceeding RT are :

RA (dark blue): safety risk for people near the tower base

RB (red): direct strike on the wind mill

RU (light blue): risk for people inside the nacelle

RV (black): risk for equipments inside the wind mill

By implementing lighting protection level 1 we get the following figure:

It can be observed that to decrease risk RA for people in vicinity of the wind mill is not possible even by using the highest protection level of the standard.

In addition, when analyzing risk per zone it appears that the risk in nacelle cannot be reduced as well.

So risk can be reduced neither for people around the wind mill nor for the nacelle zone.

This means that a limiting warning system needs to be implemented as well.

As a conclusion, there is no need for structures to apply the 3 step procedure defined for risk control in EN 50536 as the existing risk method defined in IEC standard 62305-2 is fully applicable. On the opposite, for open areas 62305-2 is not relevant and the three step procedure will show its benefit.

To cover fully the need, IEC 62305-2 will soon introduce a way to incorporate the storm detection in its method. This will be based on FTWR and will apply mainly on the losses by reducing time of presence in dangerous areas.

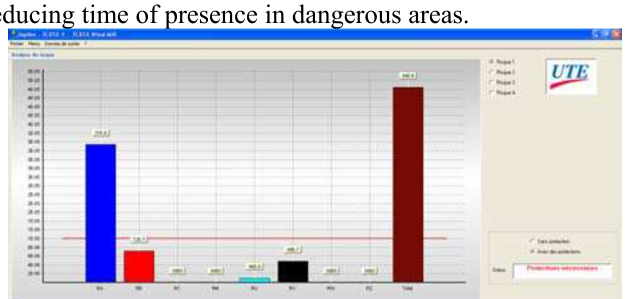

Figure 3. Risk assessment after implementation of protection at level 1 (highest level).

When a storm detector is used to disconnect a line from an external source and provided that this disconnection is made in such a way that flashover from an outside source to an internal circuit cannot occur (enough distance or insulation is then necessary), collection areas for these lines can be reduced by applying the FTWR.

D. Applications

Some applications are reviewed below to show what is needed by industrial users and what are the possible problems encountered in field:

- application to a site under construction in Brazil [6]
- application to a petroleum company in a tropical climate
- application to an ammunition storage

methodology used to validate a magnetic sensor installed in a explosive manufacturing company

1) Applications

In Brazil [6] has shown that storm detection combined with protective measures as well as risk assessment can be applied to a petrochemical site under construction to define places were workers should stand during stormy period. This original approach could be applied in future to many sites where construction stage can be long and lightning risk high (tall towers, extended sites, scaffolding higher than roof level, tent structure above building to protect people against climatic conditions …). This applies also to renovation of building where very often lightning protection systems have be partly dismantle for a quiet long duration.

A petroleum company in tropical climate needs lightning protection due to risk (explosive areas, highly flammable materials etc.) and large flash ground density. However, this is not enough, as it is necessary to avoid presence of people on tank roofs, near explosive areas or even on metallic structures. Storm detection is then needed and a static field sensor has been implemented locally (there is no lightning location network in this area). However, due to salt fog and industrial corrosion problems as well as humid conditions and small animal possible ingress, it has been decided to use a technology without rotating parts. This has been selected based on previous good experience in coastal areas.

Ammunition storage is generally well protected by lightning protection based mainly on natural component (for example concrete structure will well protect these explosives areas). However, the ammunition should one day or another move from these safe shelters and to avoid that this is done under stormy conditions, this is generally monitored by a storm detector. Maintenance is an important issue and is made on a yearly basis as suggested by the manufacturer but experience has shown that many problems may still occur in the one year period: connection between sensor and based damaged by people working on roof, degradation of internal batteries, damage to electrical circuit due to poor power regulation. To covers this it is important that maintenance be done by a qualified personal and be extensive enough and that communication between users and specialist is good. Also preventive actions are needed to avoid operation disruption including battery change at an early stage. An UPS may then be a good option especially when power regulation is poor.

2) Tests to validate magnetic sensors on site

An explosive manufacturing company was using a storm detector made of a magnetic sensor installed on top of the main administrative building to stop work in case of stormy conditions. At this time there was no standard for such devices and it has been necessary to check its efficiency.

In order to control the detection efficiency of such a device on site without waiting for real lightning conditions, it is necessary to generate an electromagnetic field for which the level at the detector sensor is equivalent to the one generated by a real lightning in the monitoring area.

To achieve this and in order to use testing means with limited dimensions, it is necessary to generate a high impulse current near the sensor. We used an impulse current as we had not information regarding how the sensor and device was designed.

We calculated the field generated at some distance by a lightning current, and we compared it to what the French draft standard proposed for magnetic storm detectors as a minimum level to detect: 0,06 A/m. This shows that a magnetic sensor needs to have detection efficiency sufficient to detect lightning current as a distance of a few kilometers.

To maximize the field level generated by the test means, we decided to use a loop. It was then necessary to evaluate the field generated by this loop at some distance of the testing means. In addition, the generator impedance as well as the loop impedance were considered for determining the generator current to be used. This led to a 35 cm loop and a distance between sensor and testing means of 10 m as well as 4 kA testing current. The generator is a combination wave generator connected to the loop by a coupling circuit. This circuit was necessary to maximize the radiation at frequency proposed by the French draft standard: 220kHz.

TABLE I. FIELD AS A FUNCTION OF DISTANCE AND CURRENT.

	Distance between flash and sensor		
Lightning current	***2km***	***5km***	***10km***
5kA	0.14 A/m	0.03 A/m	0.01 A/m
10kA	0.28 A/m	0.06 A/m	0.02 A/m
50kA	1.41 A/m	0.30 A/m	0.08 A/m

Figure 4. On site testing for a magnetic field sensor

Tests have shown that the device was not linear and that sensitivity of the sensor was different under various axes. This was certainly due to the antenna technology. Globally anyway, these tests have shown that the storm detector was working relatively well and was corresponding to principles defined in the French draft standard : its indicator changed from green to orange for a field a little below the level defined in the document.

However, the risk assessment method used on that site has shown that the user needed a longer lead time and a better Failure To Warn Ratio. Thus he moved to a static field sensor a few months after the study has been made.

III. TESTS

This will described minimum tests that seem to be needed to demonstrate long term reliability and efficiency of local sensors.

A. EMC tests

EMC tests as per IEC 61000-4-6 are needed as the storm detectors are used in harsh electromagnetic environment and need to send reliable warning.

B. Pollution tests

Tests described in EN 50164-1 need also to be applied to storm detectors sensors. The specimen shall be subjected to corrosion tests consisting of a salt mist treatment in accordance with IEC 60068-2-52 followed by a humid sulphurous atmosphere treatment ISO 6988. It is also important to test the resistance to UV radiation tests (exposure to Xenon arc lamp for a duration of 1 000 hours or alternatively to Carbon arc lamp or to Fluorescent lamp) for non-metallic sensor housings.

C. Electrostatic tests

The sensor is mounted below a testing plate with dimensions so that the electrical field in the area centred below it is homogeneous (variation around the linear electrical field by less than 2%). The sensor should be mounted as in normal use and should be located so that its highest point is at 1 m above the ground plate located below the testing plate.

The testing plate should be at 2 m (so 1 m above the highest point of the sensor) at ± 1 cm. The voltage applied on the plate should be a DC high voltage (negative polarity) to obtain an electrical field at sensor head varying from 1 kV/m to 10 kV/m. The voltage is increased to obtain at the sensor head 10 values equally distributed between 1 kV/m and 10 kV/m.

D. *Electromagnetic tests*

The sensor is mounted as in normal use and located at least 5 m from a discharge path created between two electrodes with a distance of at least 1 m between them and with a Marx generator, organized in such a way that the impulse current meets the criteria of a 8/20 wave. The generator should be at adjusted to obtain a current à < 1 kA and ≥ 3 kA 8/20.

E. *IP and mechanical tests*

These tests with IEC 60529 are also needed on the sensors.

The sensor should also be subjected to mechanical test by applying mechanical impacts. The impacts are carried out on the accessible parts of the sensor which may be mechanically stressed accidentally.

F. *Open air tests*

Based on long term cooperation between China and France regarding lightning studies, an idea raised in late 2005: use existing field facilities to create a field testing for such devices. 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 [7].

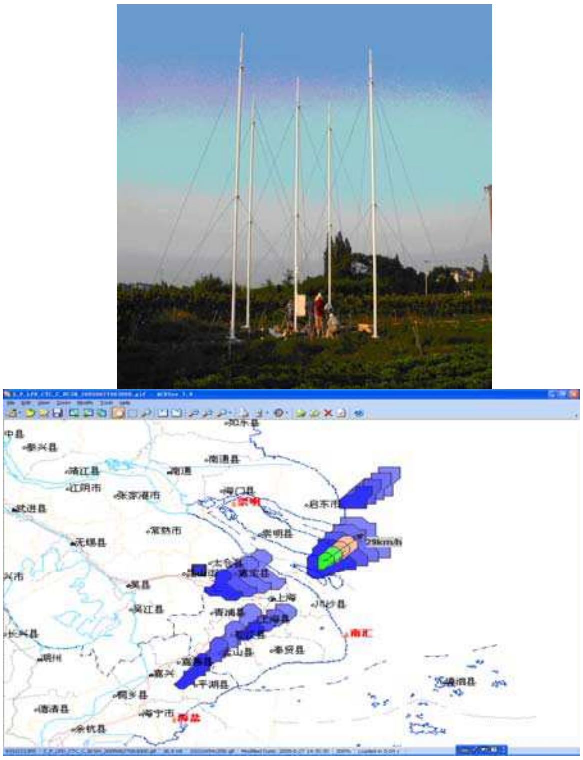

Figure 5. Nanhui station and information transmitted by the system

A Vaisala SAFIR system was already used at the place to study lightning activity in Shanghai area. As we needed a proved system to be used as a reference to compare the other local storm 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.

This system can not only inspect the lightning between clouds but also the lightning between clouds to earth, even the lightning temporal density. It also can 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 the given twenty minutes.

The facility is now operational and field mill local storm detectors have been tested and have proved the efficiency of such a testing platform.

Figure below shows the variation curve of electric field measured by two different sensors (A and B) during the same lightning event.

We can first note that even in fair weather, the fields recorded are not always exactly the same. In the case of thunderstorms the difference becomes larger. The software and techniques used by the sensors is proprietary but the warning provided to the user should be similar or at least consistent with what is declared in the sensor data sheet.

For example, during the above event, there were obvious distinctions between data from the two devices under test. The maximum and the minimum of the electric field observed by one of them were 2.5 kV/m and -12.7 kV/m respectively when for the other they were ranging between 17 kV/m and -17 kV/m respectively during the same event.

This figure shows the benefit of an open air testing station. Testing duration is usually between 6 months to one year. Parameters measured at the open air testing platform are :

- time between warning and event in minutes,
- number of warnings which occurred without any event (as shown by the reference system) in % of the total number of alarms,

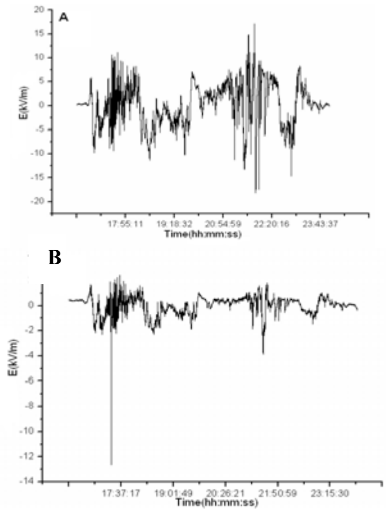

Figure 6. Difference of measured electrical field during one thunderstorm event

- FTWR (events not detected, in spite of the events being registered by the reference system), in %.

IV. CONCLUSIONS

Tests to prove long term efficiency of storm detectors are proposed and this could be a basis for a future addition to the storm detector standard.

Application of storm detectors is also presented with regard to risk assessment as well as need to simplify the selection for industrial users.

REFERENCES

[1] EN standard 50536 Protection against lightning - thunderstorm warning, May 2011

[2] Qiang Wang, Jianchu Wang, Xiaodong Xv, Jia Jia, Yudan Gu, “Validity Analysis of Electric Field Temporal Difference in Thunderstorm Warning”, Internal Publication, 2008.

[3] Qing Meng, “Application of Detection Data from Electric Field Meter on Ground to Lightning Warning Technique”, Meteorological Monthly, 31(9), 2005 : 30-33.

[4] Yao Chen, “Lightning monitoring and warning system”, Thesis of master degree, Graduate University of Chinese Academy of Sciences, 2006.

[5] Attila Gulyas, Balint Nemeth, Istvan Kiss, Istvan Berta, “ Theoretical framework of prevention lightning protection”, ICLP 2008, paper 08-07

[6] Hélio Eiji Sueta, Miltom Shigihara, José Aquiles Baesso Grimoni, Geraldo Francisco Burani, Wallace José Damasceno Nascimento, "risk analysis associated to lightning refinery construction sites", ICLP 2012, paper 09-1323

[7] Alain Rousseau, Wang Jian Chu, Wang Qiang, Ming Tao, Testing facility and methodology for local detectors – basis for scientific and standardization discussions, ICLP 2008, paper 10-06