Thunderstorm Warning Systems: IEC 62793 standard

Stéphane Schmitt
METEORAGE
Pau, France,
stephane.schmitt@meteorage.com

Alain Rousseau
SEFTIM
Vincennes, France
alain.rousseau@seftim.fr

Abstract— **Draft standard IEC 62793 deals with Thunderstorm Warning Systems (TWS). This standard introduces many definitions and deals with many technologies. The study concentrates on Lightning Location Systems (LLS) and local field mill detectors. Regarding LLS, the European lightning detection network is used as an example for determining its efficiency with respect to warnings of cloud-to-ground lightning in Western Europe using the definitions given by the standard. In terms of field experience, LLS have maintenance rules that are under responsibility of the LLS operator. But in case of local sensors such as field mill detectors it is crucial that maintenance is made by the user or a specialized company. Field experience in harsh environment shows that local sensor of the field mill type may give false warnings or at the opposite no warning if not properly maintained. The new draft standard IEC 62793 Ed. 1 addresses specifically tests on local sensors introduced to increase their withstanding against environment.**

Keywords- thunderstorm warning systems; lightning location systems, field mills, risk assessment, standard, field experience

I. INTRODUCTION

There are basically two types of Thunderstorm Warning Systems (TWS): Lightning Location Systems (LLS) and local detectors mainly of the field mill (FM) type. New draft standard IEC 62793 Ed. 1: Protection against lightning - Thunderstorm warning systems [1], covers both. At the same time, efficiency of TWS is included in draft standard IEC 62305-2 for risk assessment. It is then necessary to take care of field experience to be sure that IEC 62793 standard will cover the need of the users. Basically a user needs an early and reliable warning. The failure to warn ratio is then an important parameter especially for risk management. A failure to warn may mean a big loss or even a personal injury. This paper will first concentrate on the performance analysis of the European lightning detection network with respect to warnings of cloud-to-ground lightning in Western Europe. In the second part of the paper we will discuss field experience, maintenance and the tests included in the draft standard for local sensors.

II. METHODOLOGY USED TO ASSESS THE PERFROMANCE OF THE EUROPEAN LIGHTNING DETECTION NETWORK

A. Lightning warnings provided by a lightning detection network : basic principles

By creating a virtual monitoring area (MA) surrounding a site to be protected, the alarm is triggered as soon as a lightning intra-cloud (IC) or cloud to ground (CG) occurs within this area.

In a second step, the alarm will lapse after a time interval, named dwell time (DT), with no more lightning flash inside the area.

For the current study we have considered a 20 km radius area circle MA and a DT of 60 minutes, with a triggering at first IC within the MA, which are very common parameters.
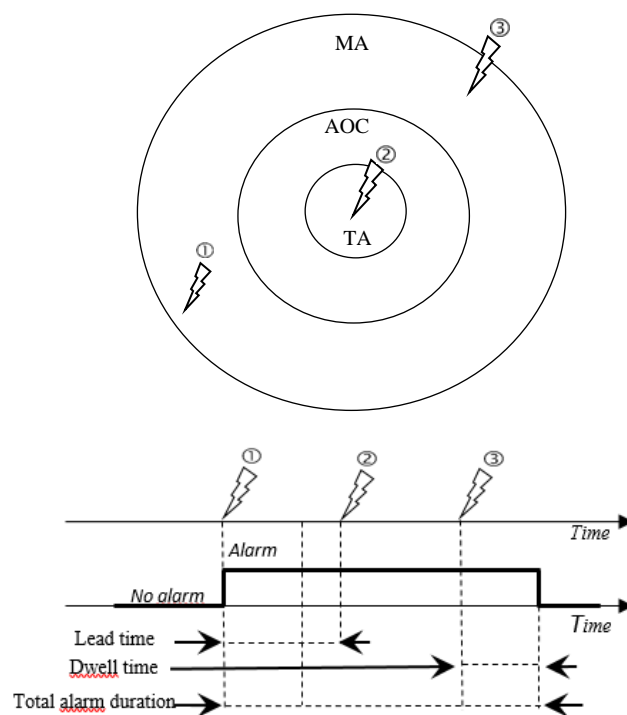

Figure 1. Principles

B. Evaluation methodology

We have randomly selected 105 specific locations all over Western Europe as seen in Figure 2.

For each location, we have defined:

- A target area (TA), characterized by a 2 km radius circle centered on the site

- An area of concern (AOC), characterized by a 5 km (AOC5) or a 10 km (AOC10) radius circle centered on the site.

- A monitoring area (MA), used to trigger an alarm, characterized by a 20 km radius circle centered on the site.

Figure 2. Maps of random locations used for the study

All the lightning related events (LRE) detected on a 5 years' period (2010-2015) were analyzed for each site.

Therefore, it was possible to determine whether a LRE into the TA was preceded by a LRE into the MA, and to calculate the time interval between these 2 occurrences, that being a lead time (LT).

The following parameters were also determined :

- The probability of detection (POD) of a thunderstorm, that being the ratio of successful warnings to the total number of episodes with a CG into the TA, and its associated value named the failure to warn ratio (FTWR), which is 1-POD.

- The respect of a lead time, with is the time between the start of the alarm and the occurrence of an episode with a CG in the target area. For the current study we have considered a 20 minutes' period (POD20').

- The number of false alarms, that being the triggering of an alarm not followed by an episode with a CG into an AOC, and its ratio named false alarm ratio (FAR).

The main statistical metrics are resumed below :

$$POD = \frac{EA}{EA+FTW} \quad (1)$$

$$POD20' = \frac{EA20'}{EA20'+EA+FTW} \quad (2)$$

$$FAR = \frac{FA}{EA+FA} \quad (3)$$

A. *POD*

If we consider the system's ability to warn before the occurrence of a CG in the target area, the system would have sent 1845 effective alarms (EA) for 72 failures to warn, that being more than 96% of successful warnings.

We also have calculated this metric for both areas of concern (see Table 1), essentially to point out the fact that in more of 80% of the cases, a LRE within a 10 km area was preceded by an effective alarm.

TABLE I. EFFICIENCY IN TERMS OF POD

	TA (2 km)	AOC5	AOC10
CG	4412	27930	111601
EA	1845	5032	8718
FTW	72	476	1947
POD	96,2%	91,34%	81,7%

For 3 of the TA, there were no CG detected during the study period. Thus the POD TA was calculated for 102 sites instead of 105.

54 locations have reached a POD TA of 100%, and 88 sites (86% of the population) obtained a result higher than 90%.

In order to avoid some weak statistical results due to a lack of data (e.g location 12 in UK obtained a 50% POD but only with 2 CG), a second study was done after removing sites with less than 10 CG. This study shows no result under 80% (see fig.3)
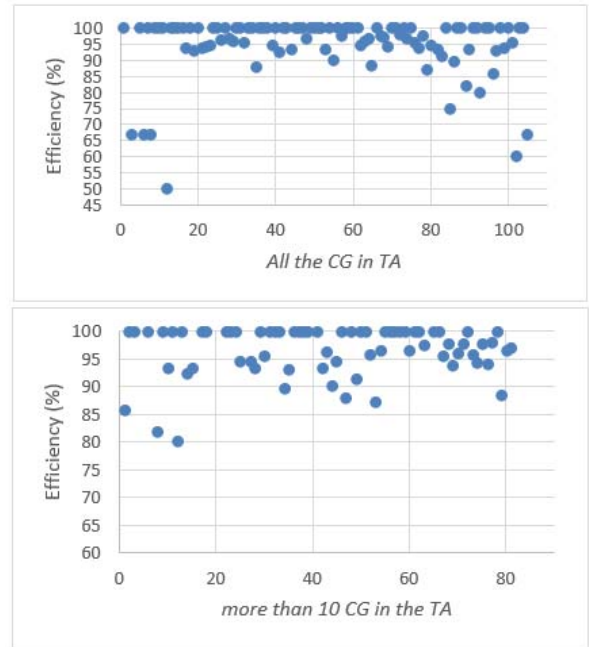

Figure 3. Efficiency in terms of POD (target area)

B. POD20'

Based on our operational users' feedback, we have considered a 20 minutes lead time, assuming it was sufficient for the user to apply its safety procedures in case of thunderstorm. The POD20' was calculated for each LRE on the TA and we obtained values above 81%.

Despite some variation, the POD20' is better than 80% for 57 locations out of 102, and if we remove the locations with less than 10 CG to avoid some potentially unrepresentative statistics, the POD20' is always higher than 60% (see fig.4).
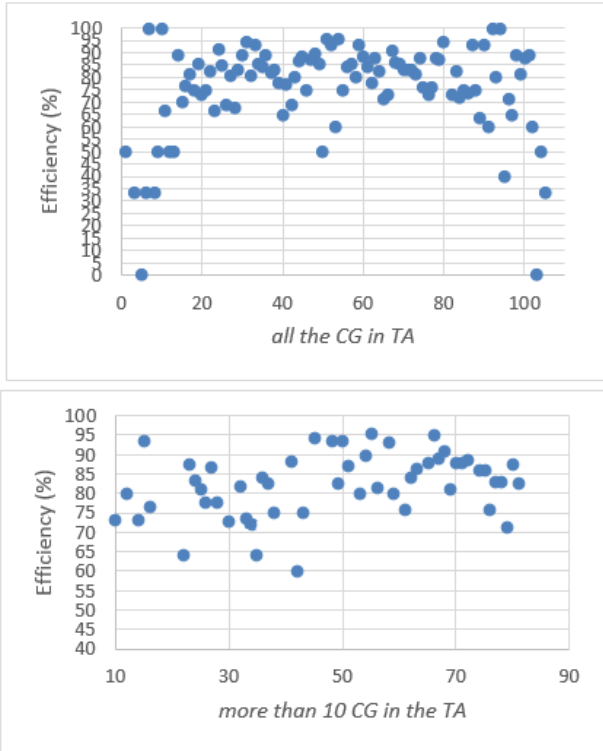

Figure 5. Efficiency in terms of POD20'

C. FAR

The third metric to consider is the false alarm measuring the alarms never followed by a CG in the TA or an AOC.

The false alarm (FA) concept should probably be clarified, in particular because of the various caused of false alarms.

Some systems deduce the existence of a thunderstorm by analyzing the electric field, they can induce some alarms generated by some external events such as dust storms, blowing sand and snow as mentioned for example in Murphy et al., [2008] [3].

The consequence of such a false alarm will certainly be different than an alarm not followed by a CG in the TA, in particular because the user will not be able to consider this second case as a false alarm before a retrospective analysis of the event.

These precisions on the false alarm concept should not disguise the consideration that if the number of alarms is too high, even in case of a real lightning activity, it will probably hinder the vigilance of the user.

Nevertheless, with an average of 46 warnings per site and per year, we consider these figures as acceptable in an operational configuration.

As shown in figure 6, only 5 sites have obtained an average number of alarms per year greater than 100, but they are located in very active thunderstorm areas (e.g with location 71 in Italy where the average number of CG per year in the TA is 35).
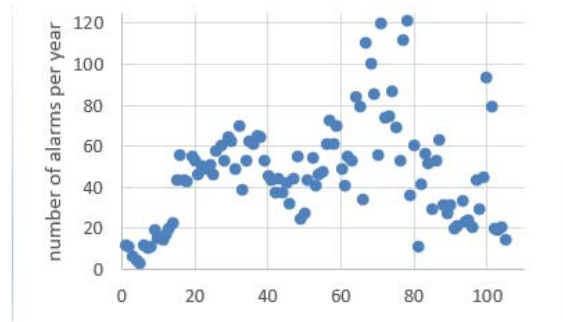

Figure 6. Number of alarm per year

As LLS systematically deliver a warning in presence of a thunderstorm because the alarm is triggered when a CG occurs, we could almost consider a 0% FAR although we should take into account the LLS detection efficiency.

In an another way, we could also consider that, if there were no CG in the target area, the event could also be qualified as a false alarm. In this case, we must admit that, for the current study, the FAR would reach 92,5%.

The FAR was then calculated on various areas in order to put these results into perspective, and show as an average value, that less than 1 thunderstorm out of 10 will lead to a CG in the target area, 1 out of 5 in the AOC5, and approximatively 1 out of 3 in the AOC10.

TABLE II. FALSE ALARM RATE IN FUNCTION OF THE AOC SIZE

AOC	FAR
2 km	92,5%
5 km	79,6%
10 km	64,6%
20 km	0%

D. Results per country

Except Portugal and Ireland where a lack of data seems to be responsible of the lower result, 9 countries of western Europe have an average value higher than 90% in terms of POD, and 5 countries have reached a POD20' higher than 80%.

We assume those results as representative for a large part of western Europe although some specific studies could be made in a future work to determine if these results could be reached for Portugal and Ireland.

Country	EA	EA20'	FTW	POD	POD20'
France	525	449	16	97%	83%
Italy	484	420	16	97%	84%
Spain	301	259	18	94%	81%
Germany	285	233	9	97%	79%
Austria	68	62	3	96%	87%
Switzerland	57	47	1	98%	81%
NL	42	33	1	98%	77%
Belgium	39	28	1	98%	70%
UK	30	21	3	91%	64%
Portugal	10	6	3	77%	46%
Ireland	4	2	1	80%	40%

E. Conclusions of the study on European Lightning Detection Network

The purpose of this present study was the LLS efficiency in terms of warnings.

The convincing results confirm that LLS provide a reliable system, with an average POD higher than 96% in western Europe, allowing to reach a 20 minutes LT in more than 81% of the cases for a very common configuration which could be improved (e.g variation of DT, MA, triggering threshold,…)

These results are also in accordance with some previous studies where LLS had obtained some good results in terms of warnings. For example, Holle et al. [2014] had used some similar parameters than the present study excepting for dwell time and obtained a 95% POD and a 86% FAR [5].

Some results certainly deserve to be put into perspective for some countries (Portugal, Ireland, and to a lesser extend Belgium and the Netherlands) where a lack of events does not allow to calculate some truly representative metrics.

However, these results seem valid for a large part of Europe, where the POD's analysis matches the situation where thunderstorms evolve in large fronts gradually moving from MA to the TA, as, for more than 80% of the events, lightning discharge firstly occurred between 10 and 20 kilometers, then between 5 and 10.

This is symptomatic for location 51 in France for example, where only 2,4% of the CG had appeared within a 10 km area without any previous alarm.

Finally, the system performances are already high but will probably be enhanced by some future works based on a cell identification method, especially to reduce the number of false alarms but also to characterize the thunderstorm severity.

IV. FIELD EXPERIENCE FOR LOCAL DETECTORS AND TESTS PROPOSED BY THE STANDARD

Local TWS, mainly of the field mill type, are used throughout the world. They may be used in place where no other lightning protection solution exist, such as golf course, football fields, outdoor activities and so on. They are also used by the industry. In this case this allows to delay some actions or to reduce the protection level of the Lightning Protection System needed for some structures.

Experience on these local detector in harsh environment is by now becoming long enough to draw preliminary conclusions. When the environment is fair it is easy to maintain the local sensor but in places where salt fog sprays exist such as marine environment, or in case of industrial pollution or dust or even in case of tropical climate, experience shows that it is difficult to maintain the sensor and keep it in working order. This maintenance is either the duty of the user or of a specialized company and should include the sensor itself, the cabling, the terminal and its software as well as the energy supply and possible remote system (telecom line, visual or sound signal …). When maintenance is poor the result is an increase of false warning and in some cases no warning in spite of thunderstorm activity. Both are causing problems as most users in case on too many false warning are disconnecting the sensor and it is then not able to provide its function. In many case, the use of the TWS was made mandatory by the Lightning Risk Assessment according IEC 62305-2. To cover this concern, the draft standard IEC 62793 Ed.1 has introduced many tests.

A specific annex of this standard, informative at this stage, applies to outdoor thunderstorm detectors. It does not cover software and indoor hardware. It does not apply either to LLS where maintenance is the duty of the TWS operator. As a matter of fact for a LLS in case one sensor is no more working, others are still operational. But when a single local sensor is used, such as a field mill, it is vital for safety that such a sensor be always operational.

These tests include:

- Resistance to UV radiation tests

- Resistance tests to corrosion

- Mechanical and marking tests

- Index of protection confirmation

- Electric tests (tests under DC electric field, tests with high current impulse)

- Electromagnetic compatibility test (both immunity and emission).

In addition, optional tests in an open air platform under natural lightning conditions are proposed to take care of real lightning conditions. In this case parameters measured at the open air testing platform include Lead Time, PODx (percentage of alarms delivered with a lead time of more than x minutes), False Alarm Ratio and Failure To Warn Ratio.

It is too early to draw some conclusions on the efficiency of these tests as the standard is not published yes and is still at its draft stage. A previous version of the standard is existing at the European level but didn't include any tests. IEC 62793 has then introduced many tests to take care of field experience that is showing that some sensors may behave badly in harsh environment. Performing tests on local detectors will not be replace the maintenance need may are targeted to increase their susceptibility to the environment (salt, industrial pollution, electromagnetic disturbances and so on) and can then reduce the maintenance need. For LLS maintenance is the duty of the operator and the number of sensors doesn't make this maintenance as crucial as it is for single local detectors.

REFERENCES

[1] IEC 62793 Ed. 1 draft 2016-02: Protection against lightning - Thunderstorm warning systems.

[2] IEC 62305-2 Ed.2:2010-12: Protection against lightning – Part 2: Risk management

[3] Murphy, M.J, et al. (2008), cloud to ground lightning warnings using electric field mill and lightning observation, paper presented at International Lightning Detection Confererence, Tucson, USA.

[4] Holle, R.L, et al. (2014), Lightning warnings with NLDN cloud and cloud-to-ground lightning data, paper presented at International Lightning Detection Confererence, Tucson, USA.

[5] Schulz et al. (2015), The European lightning location system Euclid – Part 1. Performance validation, journal of the European Geosciences Union, NHESS.