Use of storm detector in risk analysis according to IEC 62305-2

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***Abstract*— Lightning detection techniques becomes very popular. The risk evaluation standard IEC 62305-2 Edition 2 published in 2010 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. What to do in such case? Basically, one of the only remaining options is to reduce the risk duration. This means to implement lightning detection measures such as local storm detector. If the storm 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. Purpose of this paper is to present how these devices may be used in the risk assessment procedure.**

I. Introduction

The storm detectors have now an European standard [1]. This preliminary standard is mainly describing the parameters that characterize a storm detector. How standards are foreseen in order to guide the user and also in order to test such devices. As a matter of fact for the time being, any device can exist on the market and there is no official mean to compare such devices and to check their announced efficiency, especially on the long term. To cover this many authors have shown that measurement of electrical field needs to be done in a careful way to be effective [2], [3], [4], [5], [6] and others proposed open field tests as a preliminary step to establish a product standard [7].

II. Parameters to characterize the storm detectors

As a matter of fact, false warning may occur. Also, even if the basic measuring device (field mill) seem the same for some storm detectors, the electronic treatment and numerical treatment may differ from one to another leading to different conclusions and thus to different level of reliability.

Parameters measured at the open air testing platform are [7] :

a) time between warning and event in minutes
b) number of warnings which occurred without any event in % of total number of alarms. It must be noted that the area around the site, used to determine if an event occurred or not should be fixed.
c) failure rate (not detected events, in spite of event being registered by SAFIR system) in %, used later on in the lightning risk assessment process)

Basically, parameters a) and b) are important for operation. Parameter a) characterize the time the storm detector will offer to the industrial to stop his dangerous process or evacuate people from a dangerous zone. Depending, on the type of process or site parameters (high tower for example) a 10 minute warning or a much longer warning (30 minutes) will be needed.

III. Application of the parameters obtained during tests in risk assessment

b) is a parameter which will make the user more confident in the system. However, this parameter cannot be included in the risk calculation for the human loss R1 as per IEC 62305-2 [9]. As a matter of fact, unnecessary alarms will not modify the risk value because there is no real event. This could be used for the economical loss risk calculation (not discussed in that paper, still under discussion at IEC level), because too numerous false alarms may lead to a lack of productivity of the plant due to the fact that some process have to be stopped or secured. b) is then an unwanted parameter.

a) is a wanted parameter, as you need to be informed in advance and this is a characteristic of the real efficiency of the device. But one more time this is a deterministic approach: either the time offered is sufficient for you to do something for safety sake (risk prevention measures that you may implement in that delay) or it is not. So it is an important parameter but not for the statistical calculation of the risk.

In the same way that efficiency of the lightning protection system is characterized by a probability that you will not catch lightning, storm detector can be characterized by a failure rate (named FTWR in the standard): there is a probability that the event is not detected in the necessary timing.

It should be noted that a storm detector who will allow the plant owner to evacuate a dangerous zone or to avoid the occurrence of a dangerous event will reduce the duration of presence of people in a dangerous zone in the same way. That the danger doesn't exist anymore or that it stills exist and has no impact on people because they are in a safe shelter has exactly the same influence on the risk assessment for the people.

Let's assume that the storm detectors are classified in the future by 4 categories (there are 4 levels of protection for lightning protection systems) as shown in Table 1. Category one is the most efficient as it is for lightning protection systems with an efficiency of detection of events fixed at 93% and the category 4 has an efficiency fixed at 50% only.

Category	a) (in minutes)	b)	c)
1	30	0,10	0,07
2	20	0,20	0,15
3	15	0,30	0,3
4	10	0,50	0,5

Table 1 – proposed categories for storm detectors

We do believe that it is of the interest of the user to have all parameters characterized by a single category. Of course a device being very efficient (low value for c) could offer a time between detection and event (a) large or small and can have a percentage of fake alarms large or not. If parameters are completely independent in the classification the fear is that a detector with small a) or high b) will be very considered as very efficient. As a matter of fact if you wait until the last moment to signal an alarm or if you signal an alarm any now and then, the probability that you don't miss any event becomes de facto quite large ! But the device is not really practical. Globally, a device having a low c) and large a) and a low b) would be the perfect one.

Values in Table 1 are hypothesis from our side just to show how this could work. It is also the purpose of the running test to allow fixing these parameters. Discussion on these parameters and how to use them in risk management is hopefully already existing [10] and will lead in future in a more scientific approach for these storm detectors. However, it is needed to use them now and the paper will show below what is possible in a near future.

IV. USE OF STORM DETECTORS FOR RISK CALCULATION BASED ON FTWR

Risk R1 (human and environmental risk) can be reduced by the use of a storm detector. This means either stops a process or transfer people in a safe shelter or avoid dangerous activity. It is also possible to disconnect from external services and use only local generators for example.
Risk R2 (services) could be reduced by use of a storm detector if the production of the service to the public can be still offered while a specific procedure is followed. But, by nature, all the external services need to be operational for providing the service. As such power, telecom and gas services cannot use storm detectors to reduce the risk. Only services where services are provided at distance (for example TV and radio) can have their risk reduced by storm detectors. In such a case, the storm detector can be used to move from external power supply to power generator inside the structure. But all other lines cannot be disconnected generally. As the storm detector as a Failure To Warn Ratio (FTWR), the lines need to be considered but risk link to some of them (mainly power lines) can be reduced This is quite complex to explain and the benefit appears to be low. It is then suggested in this preliminary stage to not use storm detectors for R2 especially because the way it is done in new version of the standard is only related to number of user per zone compared to number of user for structure and this is not related to use of storm detector.
Risk R3 (national herirage), cannot be reduced as well as storm detector cannot avoid lightning to strike an historical or national heritage building
Risk R4 (économic) can of course take benefit of using a storm detector but this is not so easy to introduce this effect is the losses calculation. It is suggested to do it on introducing a derating factor on Ng. Ng is based on a yearly distribution of lightning (the risk is calculated on an annual basis). If for a certain duration you avoid lightning ingress on lines by disconnecting them (mainly from the mains but we can imagine that other services are disconnected if not essential) you reduce the risk. In such a case, the "apparent" flash ground density for this line becomes Ng * (FTWR * 8760) / 8760 = FTWR * Ng. So this means that collection area for this line should be multiplied by FTWR. For simplicity sake it is suggested to apply this derating factor on Lc instead on collection areas to avoid misuse of this reduction factor. Of course this has also an impact on the protection measures cost.

A. Application to R1

The reduction of the time of presence tz may be reduced by the mean of a storm detector provided that a procedure is defined and applied to reduce the time of presence based on information given by the storm detector. The storm detector should be according to the standard [1] or any equivalent national standard until an IEC standard is developed for such a device. The storm detector and the related procedure become then part of the protection plan and should be included in the data file for the project/site including the maintenance program.
The relevant parameter to reduce the time tz is named Failure to Warn Ratio (FTWR) and is defined as the ratio of failure to warn with respect to the total number of situations with lightning related events in target. As a matter of fact, if there is no indication the risk remains and cannot be reduced.
In the calculations the time tz can be reduced to obtained a time t'z by using the following formula : t'z = tz * FTWR.
During the time of presence tz a certain number n of lightning events can occur. Amongst these n events n1 will be detected and n2 = n - n1 will not be detected. We

have FTWR = n2 / n so n2 = n * FTWR. Assuming, that the distribution of lightning events over the time of presence tz is constant (this is the basis for the risk calculation), we have n events during the time tz. The time tz can be divided into two periods of time :
- t1 where people were evacuated from the dangerous area or the danger stopped (for example stopping a dangerous or explosive process by using storm detector indication)
- t2 where people should have been evacuated but due to failure to warn, they have not been evacuated or the process stopped
We have tz = tz1 + tz2 and tz/n = tz1/n1 = tz2/n2
The reduced time of presence t'z is equal to tz2 = n2 tz /n = n * FTWR * tz /n = FTWR * tz
In risk equations tz can be then be replaced by t'z should a storm detector complying with the above requirements is used.

B. *Application to R4*

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 outside source and internal circuit cannot occur (enough distance or insulation is then necessary), Lc' could be used instead of Lc for these lines, with Lc' = FTWR * Lc
Lc for some lines may be reduced to Lc' by the mean of a storm detector provided that a procedure is defined and applied to disconnect theses lines in a safe way based on information given by the storm detector. The storm detector should be according to the standard [1] or any equivalent national standard until an IEC standard is developed for such a device. The storm detector and the related procedure become then part of the protection plan and should be included in the data file for the project/site including the maintenance program.

V. Application : risk calculation R1 with storm detector

Example N°1 : A fireworks production plant
The unit manufacturing fireworks has the following characteristics :
Dimensions : 10 x 5 m (height : 4 m), buried power line (150 m)
Flash ground density : 3,4
Explosion risk with people present for a total duration of 3000 h per year.

Application of risk calculation R1 according to IEC 62305-2 gives values as listed in table 1.
In this example, it is assumed that the factory under study doesn't meet the characteristics that will allow to use probabilities Pb smaller than 0,02.

In this first example, a Lightning Protection System alone cannot reduce the risk below the tolerable risk value fixed by standard at 10^{-5}. A storm detector category 1 (efficiency 93%) is then needed in addition to the LPS. The main reason is that presence in dangerous areas is quite large (3000 hours per year) in this plant until an appropriate storm detector is used to remove people from dangerous zones in case of a storm approaching.

Figure 1 shows in blue the parameters of risk without protection, in orange risk reduction obtained by the LPS (level 1: Pb = 0,02) and in green risk reduction with storm detector (category 1) in addition to LPS level1.

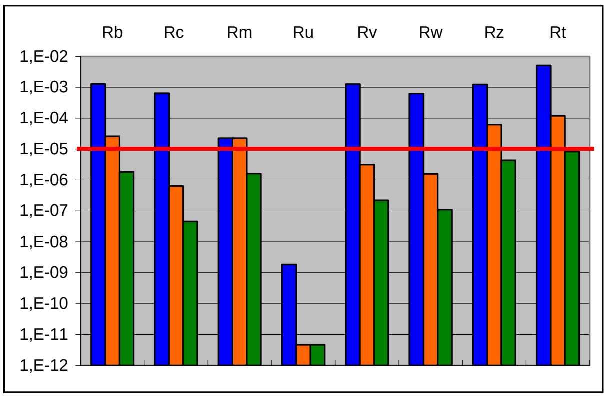

Figure 1 – Influence of LPS and storm detector on risk parameters in example N°1

<u>Example N°2 : A flammable product loading unit</u>

This unit has the following characteristics :
- Dimensions : 20 x 10 m (height : 7 m), buried power line (60 m)
- Flash ground density : 3,4
- Explosion risk with flammables vapours with people present for a total duration of 60 h per year.

Application of risk calculation R1 according to IEC 62305-2 gives values as listed in table 3. In this second example, it is also assumed that the factory under study doesn't meet the characteristics that will allow to use probabilities Pb smaller than 0,02.

In this case also, a Lightning Protection System alone cannot reduce the risk below the tolerable risk value fixed by standard at 10^{-5}. Two solutions are investigated :
- A storm detector category 2 (efficiency 85%) is then needed in addition to the LPS level of protection 1.
- A storm detector category 1 (efficiency 93%) is then needed in addition to the LPS level of protection 4.

It is interesting to note that an efficient storm detector can, in that case, be used in conjunction with a LPS to reduce the needed protective level of the LPS and still allow the risk to be below the tolerable risk.

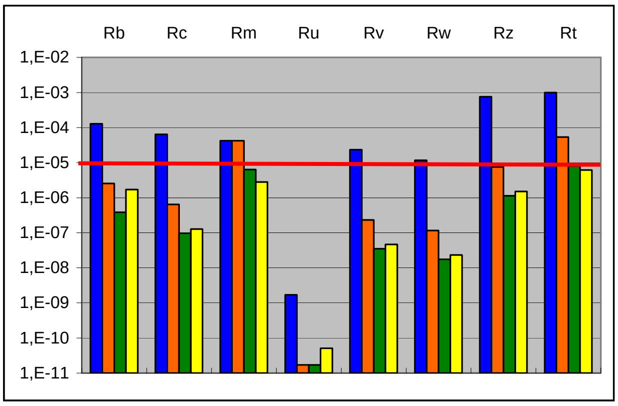

Figure 2 - Influence of LPS and storm detector on risk parameters in example N°2

Figure 2 shows in blue the parameters of risk without protection, in orange risk reduction obtained by the LPS (level 1) and in green risk reduction with storm detector (category 2) in addition to LPS level 1. In yellow is an other possibility to reduce the risk with a LPS (level 4 : Pb = 0,2) in addition to a storm detector (category 1).

Even if the distribution of risk components is different between case represented in green and case represented in yellow, it appears that the total risk is almost the same in both cases. So this means that the two solutions (LPS level 1 + storm detector category 2 and LPS level 4 + storm detector category 1) are almost equivalent from the user risk point of view and the main difference will be in the cost.

Structure protection level	Pb (as per IEC 62305-2)	Storm detector category	c)	Time of presence in the dangerous area in hours per year	Total risk R (as per IEC 62305-2)
none	1	none	1	3 000	510 10^{-5}
1	0,02	none	1	3 000	12 10^{-5}
1	0,02	4	0,5	1 500	5,8 10^{-5}
1	0,02	3	0,3	900	3,5 10^{-5}
1	0,02	2	0,15	450	1,7 10^{-5}
1	**0,02**	**1**	**0,07**	**210 h**	**0,8 10^{-5}**
2	0,05	1	0,07	210	1,1 10^{-5}

Table 1 – risk calculation for a fireworks manufacturing plant

Structure protection level	Pb (as per IEC 62305-2)	Storm detector category	c)	Time of presence in the dangerous area In hours per year	Total risk R (as per IEC 62305-2)
None	1	none	1	60	100 10^{-5}
1	0,02	none	1	60	5,3 10^{-5}
1	0,02	4	0,5	30	2,7 10^{-5}
1	0,02	3	0,3	18	1,6 10^{-5}
1	**0,02**	**2**	**0,15**	**9**	**0,8 10^{-5}**
1	0,02	1	0,07	4	0,4 10^{-5}
4	**0,2**	**1**	**0,07**	**4**	**0,6 10^{-5}**

Table 2 – risk calculation for a flammable loading unit

VI. CONCLUSIONS

From the user perspective, he needs to have a reliable device because 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 preliminary field 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. The paper is showing how the data obtained from the testing may be used for calculation of lightning risk evaluation for human losses, R1 (human and environment risk) according to IEC 62350-2 standard or R4 (economic risk). The parameters needed for characterizing the devices are discussed and their influence shown in some examples. It appears that three parameters are most needed, one of them being critical for risk evaluation (named FTWR in the storm European storm detector standard). There is a proposal to link these three main parameters in categories in order to facilitate the user choice.

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