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APPLICATION OF RISK ANALYSIS METHOD FOR TEMPORARY EVENTS

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ABSTRACT

This paper intends to show how to apply lightning risk analysis methods for temporary events or activities and also how to use the monthly flash ground density

1 INTRODUCTION

The risk assessment method developed in IEC/EN 62305-2 is based on assumption that the industrial activity is on a yearly basis and that the lightning activity is spread at random over this yearly period.

However, this is not always the case. Often dangerous activities in an industrial plant are of limited duration within the year. This is why, for example, the published standard (not exactly identical to the current draft of the revisions sent recently for enquiry at IEC level) deals only with explosive zone 0 or 20. Such zones have a an exposure greater than 1,000 hours per year. Therefore probably of occurrence of lightning and explosive zone at the same time must be considered. Other explosive zones such as 1 or 10 (less than 1,000 hours per year) and 2 or 20 (less than 10 hours a year) are neglected.

The lightning activity per year is not spread at random. There are many months with significant lightning activity while others have limited number of lightning strikes. Current lightning risk methodology only consider results over a full year. Given current methodology, if a dangerous industrial activity occurs during a period of heavy lightning activity the risk is greater than calculated. When the dangerous activity/zone occurs only when lightning activity is lower than the risk calculated.

In order to conduct an accurate lightning risk assessment when a dangerous activity occurs for less than a full year, a new methodology is required. For example, people working in mountains during the summer time have a higher exposure to lightning activity.. A supervisor of a mountain refuge is exposed to a higher risk than this yearly the method could predict. Conversely, the same man in charge of the refuge during winter seasons experiences a lower risk.

It appears that with new techniques and meteorology networks it is now possible to get the lightning probability distribution over the year. Typically it is possible to get the flash ground density (Ng) data at monthly intervals..

In this paper the authors are proposing a new lightning risk methodologies for temporary events. The paper will show how the proposed lightning risk analysis methods can be used for activities spanning less than a year using monthly flash ground density distribution. This paper will also show that using monthly average lightning data compared to using actual monthly flash ground density distribution can lead to risk calculations that are either lower or higher than the actual expected risk.

2 LIGHTNING RISK ASSESSMENT PRINCIPLES

Risk is generally defined as the product of the probability of an event occurring and the consequences of the event. However, for some risks there is not always a consistent consequence to the occurrence of a given event. This is true for lightning risk assessments as there is a wide variety of probability in the severity of any one event. In the case of lightning risk assessments, this general risk formula is often expressed as:

$$R = (N)\ (P)\ (L)$$

where:

risk (R) is the product of the number of dangerous events (N) times the probability of damage per event (P) times the expected yearly loss resulting from the event (L). In most detailed risk assessments, the overall risk due to lightning is broken down into specific risk categories which can be computed independently using specific risk components based on location of strike, source of damage, type of damage and type of loss. For simplicity, this paper will concentrate on the number of dangerous events, and not focus on the probability of damage per event and expected losses..

The number of lightning flashes influencing a structure and its services depends on the following :

- dimensions and the characteristics of the structure and of the services,
- environmental characteristics of the structure, and
- lightning ground flash density in the region where the structure and the services are located.

For lightning protection assessments, the number of dangerous events are primarily the product of the ground flash density (Ng) and the equivalent collection area characteristic of the structure (Ad), while taking into consideration correction factors based on the relative location of the structure. This makes the ground flash density a very important parameter in the risk assessment because of its prominence in the determination of the number of dangerous events.

Lightning protection risk assessment methodologies such as those included in IEC/EN 62305-2 and proposed for inclusion in NFPA 780-2011, are based on a yearly average of lightning activity for a given location. However, in very few locations is the probability of lightning activity consistent over all 12 months of any given year. Generally in the northern hemisphere, there are more days with lightning activity in the spring, summer and early fall than in the winter.

The probability of lightning damage per event is generally related to the physical characteristics of a structure or operation and to the susceptibility of the contents. Examples of physical characteristics of a structure or facility that influence the probability of damage per event are:

- construction techniques and materials
- the number and location of incoming services, and
- shielding provided for protection against lightning electromagnetic pulse (LEMP).

These characteristics are typically not time-variant. While it is possible for the susceptibility of the contents to change with time, this is generally true only in cases where the contents of a structure change.

The expected loss resulting from a lightning event is generally related to:

- value of the structure and its contents,
- protection measures provided, and
- exposure of personnel to the threat.

The expected loss resulting from a lightning event is not necessarily constant over the year where the probability of damage usually is. The most relevant example of a time-variant factor associated with the expected loss is the exposure of personnel. The number of personnel exposed to a potentially hazardous event will depend upon the status of the operation being performed (i.e. explosives operations, maintenance, security, etc.).

The accuracy of any lightning risk assessment is maximized with a consistent exposure to the lightning threat and consistent probability of the type and amount of loss experienced during the period of the assessment. If one were to attempt to perform a lightning risk assessment for a specific location over a specific time period, the accuracy of the assessment would be highly dependent on the accuracy of the data available for the number of expected events and the expected probability of the loss of failure per event. Where the expected loss and probability of such loss is very high, the accuracy of the number of strikes per square kilometer used in the assessment is critical.

3 PROPOSED METHODOLOGY

3.1 General

In order to assess the lightning risk for an operation that would involve a temporary lightning exposure (less than one year continuous), it will be necessary to address how to determine the proper ground flash density (Ng)used in the assessment. Section 3.2 provides recommendations on how to address Ng.

While the relationship between the is fairly duration of the operation and the ground flash density, its effect may not be obvious for the calculation of the expected losses. The basic formula for the calculation of various types of loss (L) is k * Lf where Lf is the product of the ratio of endangered persons to total persons exposed (np/nt) and the ratio of total number of hours persons are exposed to the total hours in a year (t/8760) and k is a parameter describing the structure content and hazards. For many explosives operations, one may assume that all personnel in the structure are likely to be at the same level of risk. The primary variation in the loss will be in the ratio of the total exposure in hours (t) to the total number of hours in the period of interest (T).

In section 3.3, a theoretical example that shows the impact of a smaller time of observation than a complete year is demonstrated.

3.2 Considerations on how to Pro-Rate the Ground Flash Density (Ng)

Since the ground flash density is prominent factor in a lightning risk assessment, it is important to keep in mind that the accuracy of the value used is highly dependent on the data source and sample size. The two most common methods to determine ground flash density in use today are ;

- archived data from lightning detection networks and
- calculations of ground flash density from thunderstorm days taken from isokeraunic maps.

There are several formulas available to calculate the ground flash density from the number of thunderstorm days. The simplest formula and the one used in most risk assessments assumes the ground flash density (strikes per square kilometer) is one tenth of the number of thunderstorm days [4]. Since the determination of thunderstorm days per year is not the most accurate technique the use of this simple formula is justifiable.. This value is based on the observation and recording of thunder being heard at a number of recording locations (which are likely some distance from the structure under consideration). In the case of ground flash density taken directly from lightning detection networks, there is also an inherent inaccuracy depending on the following:

- number of sensors used in the network,
- accuracy of the error correcting software, and,
- most importantly, the number of years of data available.

It is obvious that using the yearly average strike density and divide by the total number of months to arrive at an average strike per month per square kilometer will result in lower or higher prediction when compared to archival monthly data. For those cases where the operations in a structure are not consistent or where the operation may be at a temporary location, some types of loss will be overestimated during some periods and underestimated during other periods if a yearly average technique is used. The amount this will (or should) effect the calculated risk will depend upon whether the month or months the operation is being conducted is coincident with the period that the ground flash density is above average.

All current lightning risk assessments [4][5] are based on yearly averages of ground strike density, probability of failure, and expected losses (including the exposure of personnel to dangerous conditions. It is recommended that the minimum number of days that should be considered for the lightning risk assessment of a temporary event be one month. Local lightning detection networks that provide the required ground strike data by months are sometimes available . However, in very few cases is this data available down to the specific day of the month. Even if this data were available, the variability in the probability of lightning activity on any given day based on previous history of lightning on that day is random. For example, Table 1 provides a breakdown of 20 years of data from a localized lightning detection network. The top row is a breakdown of total number of strikes per square kilometer recorded for the local area over a 20 year period. The middle row is an indication of the number of days by month over this 20 year period there was lightning recorded in the area. The table shows that there was no month in which the average number of days with lightning activity exceeded one per month. Thus, it would be unrealistic to attempt predicting the likely hood of an event on a specific day. Taking the example of the probability of lightning occurring during the period 13-17 September, there was lightning activity recorded two days during the month of September for the 20 year period. This results in a probability of approximately 1 in 60 of lightning occurring some time during the 5 day period. A more accurate result could be provided by local weather forecasts.

3.3 Proposed Methodology

To illustrate the relationship of number of flashes to ground (Ng) and the duration of exposure of the event (T) on the calculated risk, it is best to work some theoretical examples. The values of probability, loss and collection area will be set to a typical condition simplifying so the math be allowing the user to focus only on the method. In addition, these examples will show how the tolerable risk (R_T) needs to be prorated.

These theoretical examples we will focus on a large production or manufacturing operation. For simplicity, this example does not consider all of the risk components that may be applicable but will instead consider only the risk of physical damage due to a direct strike to the structure (R_B). The structure is in a remote area without other structures in the vicinity. The equivalent collection area of the structure is 0,01 km² (107,636 ft²) and the ground flash density (Ng) is six flashes per square kilometer per year. it is assumed that all personnel working in the building could be endangered as a result of physical damage due to a direct strike. In this structure the operation is limited to a six month .IEC 62305-2 identifies that the risk of physical damage due to a direct strike (R_B) is the product of the number of dangerous events (N_D) times the probability of physical damage to the structure due to the strike (P_B) times the loss to the structure related to physical damage due to a strike to the structure (L_B).

To compute the risk of damage due to a direct strike, the number of dangerous events from a direct strike (N_D) must first be calculated. The number of dangerous events is the product of the ground flash density and collection area. In this case, the size of the structure was selected to simply the math, so N_D = 0,06 strikes per km² per year to the structure. The probability of loss due to a strike to a structure is a function of the protection level provided and the characteristics of the structure. Since this factor will essentially be constant in this example and the purpose of the example is to show the relationship between risk and exposure to the lightning environment, it is assumed that there is no protection provided and each event is likely to result in physical damage (P_B = 1). The loss considered in this case (L_B) is primarily related to the ratio of the number of endangered persons to the total number of persons in the structure and to the time in hours per year for which the persons are present. Considering the case where the operation is conducted only one-half year, the loss factor will be 0.5 and the risk of physical damage due to a direct strike would be 0.03 losses per year. This assumes that the average number of flashes per square kilometers per year will all occur only in the period in which the operation is planned.

Using the same example, but consider only the six month period that the operation is conducted, it is assumed that all of the 6 strikes to ground per year will occur in the six month period spanning April through September. To show the extremes, consider the case where the operations are conducted during the period October through March as opposed the case where the operations are conducted April through September. For the period October through March, the number of dangerous events is zero (Ng=0); therefore the resulting risk of physical damage is zero. For the period April through September the number of events during the period will be 6 (N_D = 6), there is no LPS provided for the operation (P_B = 1), all personnel in the structure will be subjected to the danger (np/nt = 1), and the operation will be conducted during the entire 6 month period (t/T = 4380/4380 = 1). The resulting risk (R_B) = 0,06x1x1x1 = 0,06. This is twice the value of the calculation taken from the standard when the assessment is considered over a one year period. The real risk is higher than that indicated by the average calculation.

Furthermore, due to a need to modify the tolerable risk, the real risk is actually higher. Table 2 below shows the influence of the time of observation on the tolerable risk (RT) we have establish..

The example changes to an R&D facility with the same collection area that is manned by a total of six people for a total of 12 hours per day. Three people at the site are not directly involved in explosives operations and are located in a safe area on the other side of a substantial dividing wall, so they are not considered to be in danger should an explosion happen (np/nt = 0,5). The building does not have a lightning protection system installed (P_B=1). The construction of the structure and the low explosives yield involved in the operation will ensure there is no risk to either the environment or surroundings. L_B = k (Lf) and based on hypothesis above k = 2 according to IEC 62305-2.

Table 2 considers the following scenarios:

Case 1 – provides the basic calculation for the structure and operation based on the operation being performed year round. This calculation will be the baseline for comparison to the other methods of calculating the risk.

Case 2 – considers an analysis of the same site, operation, and time of operation but it considers that the probability of lightning activity is consistent over the period of the year (6/12 = 0.5/month). It then considers the risk if the operation is conducted only during a single random month. Case 1 is then 12 times case 2

Case 3 – considers the same situation but assumes that the operation will be conducted during one of the 6 months that experience 1 flash per square kilometer.

Case 4 – considers the case for the other 6 months that has no lightning activity.

Case 5 – represents the example combining 3 months of Case 3 with 3 months of Case 4.

Case 6 – considers the case where the entire 6 months that contains the lightning activity is considered in one case. Thus this case is 6 times Case 3.

Case 7 – addresses the remaining 6 month period where there is no lightning activity. Thus this case is 6 times Case 4.

Case 8 – represents the combination of 6 month periods when compared with the yearly average. Thus this case is combination of Case 6 plus Case 7 and is the same than case 1.

An important observation Table 2 is that the ratio of calculated risk to tolerable risk can be maintained as long as the level of tolerable risk is reduced by the same percentage as the amount of time the operation is performed. As a matter of fact, the ratio R/R_T is related to the level of protection needed for the installation. For case 2, R_T if is not prorate it can be concluded that level of protection needed for case 1 is much larger than that needed for case 2. But in fact, case 2 is exactly the same risk as case 1. It is only the period of observation that is changing. R_T needs then to be prorated to avoid misinterpretation of the result of a risk study performed per month.

Table 2 confirms the suggestion that the risk of physical damage can be calculated for periods of less than a year if the number of strikes per square kilometer (Ng), the total number of hours in the period under consideration (T), and the tolerable risk (R_T) are all pro-rated.

4 CONCLUSIONS

In summary, there exists a need for a method to conduct a lightning risk assessment for various scenarios that are one-time events or events that do not occur over a period of a year or more. The risk assessment methods currently available are based on the number of dangerous events and losses averaged over a one year period. The tolerable level of risk is also expressed in terms of probable average annual loss.

Considering the assessment of a risk of an operation lasting less than one year, using the yearly assessment procedure would underestimate the actual risk for operations conducted during a period of the year when lightning activity is greater than average. Conversely, it would over overestimate the risk when the ground flash rate is less than average. This paper demonstrated that an accurate assessment of risk is made where the evaluation period is less than a year if the level of tolerable risk is reduced by the same percentage as the time the operation. In conclusion, the risk of physical damage can be calculated for periods of less than a year if the number of strikes per square kilometer (Ng), the total number of hours in the period under consideration (T), and the tolerable risk (R_T) are all pro-rated.

5 REFERENCES

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[3] Guthrie, Mitchell and Alain Rousseau, "Lightning Protection for Critical Explosives Operations", Minutes of 33rd DoD Explosives Safety Seminar, August 2008.

[4] IEC 62305-2, "Protection against lightning – Part 2: Risk management," First Edition, International Electrotechnical Commission, Geneva, January 2006.

[5] NFPA 780, "Standard for the Installation of Lightning Protection Systems," 2011 Edition, Annex L, National Fire Protection Association, Quincy, MA, October 2011

Table 1: Example of Breakdown of Lightning Flash Density by Month (20 year sample)

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Total strikes/km²	0	0	0	21	10	45	30	30	5	7	0	1	149
Total number of days with lightning activity	0	0	0	2	5	9	11	14	2	6	0	1	50
Average strikes/km²/yr	0	0	0	1.05	0.5	2.25	1.5	1.5	0.25	0.3 5	0	0.05	7.45

Table 2: Relationship between consideration of Ng and calculated risk (R) as well as tolerable risk RT

Case	Prorated Ng	n_p/n_t	t	T_{total}	N_D	P_B	L	R	non prorated R_T	R/non prorated R_T	Prorated R_T	R/Prorated R_T
1	6	0,5	4320	8640	6,00E-02	1	0,5	3,00E-02	1,00E-05	3 000	1,00E-05	3 000
2	0,5	0,5	360	720	5,00E-03	1	0,5	2,50E-03	1,00E-05	250	8,33E-07	3 000
3	1	0,5	360	720	1,00E-02	1	0,5	5,00E-03	1,00E-05	500	8,33E-07	6 000
4	0	0,5	360	720	0,00E+00	1	0,5	0,00E+00	1,00E-05	-	8,33E-07	-
5	3	0,5	2160	4320	3,00E-02	1	0,5	1,50E-02	1,00E-05	1 500	5,00E-06	3 000
6	6	0,5	2160	4320	6,00E-02	1	0,5	3,00E-02	1,00E-05	3 000	5,00E-06	6 000
7	0	0,5	2160	4320	0,00E+00	1	0,5	0,00E+00	1,00E-05	-	5,00E-06	-
8	6	0,5	4320	8640	6,00E-02	1	0,5	3,00E-02	1,00E-05	3 000	1,00E-05	3 000