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Lightning risk: how to improve the calculation?

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SUMMARY

IEC 62305-2 is the reference standard for lightning risk calculation. Its formulas are used by many other standards including electrical installation, photovoltaic systems and wind turbines. First standard has been published in 2006 but is based on IEC report dated 1995. In spite of this long experience there are still fields of improvements. The edition 2 of this standard appears as too complex for simple cases and too simple for complex cases. The complexity can be addressed by software also the paper concentrates on improvements for the most complex cases.

High rise structures or structures located on a top of a hill/mountain are presently covered by an environment factor Cd defined in IEC 62305-2. The maximum value 2 for this factor Cd seems to be too low. The new draft for wind turbine lightning protection standard is proposing other concept and values for this factor Cd. Recent experience has also shown that the risk for regular structures using this factor Cd may be underestimated and the shape of the terrain should be better described.

For Lightning Location Systems that don't provide directly the lightning ground strike-point density Nsg, a safety margin should be applied to the flash ground density Ng even if the ratio between the two are not constant in places and in time.

Temporary activities with a duration of less than a year should be covered by the standards. There is a benefit to address the lightning density per month, but it is not suggested to use a shorter time window.

Nsg is a mean value based on 10 years' observation. It is suggested for more sensitive or riskier activities to consider the highest value for Nsg during these 10 years and not the mean value.

Soil resistivity is a key parameter for underground services. However, soil resistivity is very difficult to obtain on a large scale when a service can extend up to 1 km away from the structure.

Probabilities related to the use of Surge Protective Devices are currently confusing as it is only based on SPD withstand when an SPD can withstand and not protect equipment. What is important to protect are equipment and not SPDs. Pspd should include both the SPD withstand and the protection efficiency near sensitive equipment.

Losses is also another confusing parameter because it is mainly based on fire risk when the damages caused by lightning may not involve a fire. The concept of losses should be replaced by the frequency of damage that would allow to define the protection based on what is really needed associating damage scenarios to the frequency of damages.

KEYWORDS

Lightning; risk; standard; LLS; Ng; Nsg, Pspd, SPD

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INTRODUCTION

The lightning risk is well defined in IEC 62305-2 [1] since 2006 and before a Technical Report IEC TR 61662 [2] was also existing since 1995. Use of this method is then quite long and experience gained by users has helped to improve the method and refine calculations. A few other standards are based on this general method such as IEC 60364 part 443 [3] for electrical installation of buildings, IEC 60364 Part 7-712 [4] for photovoltaic (PV) systems or IEC 61400-24 [5] for wind turbines. However, general consideration based on field experience tends to show that for a few cases the risk has been underestimated when for a few others, the calculated risk seems to be too high [6]. It is important that the risk is well estimated because it results in a level of protection and thus an economic pressure for the user. Then there is a clear need to refine a few formulas and this often means more complexity. However, such an improvement in the calculation makes only sense for the most sophisticated sites (such as data centres) or for the most dangerous sites (oil & gas, nuclear, chemistry …) when for a more general use such as offices buildings or commercial centres the calculation should be kept easy.

Even if well accepted and also well understood, this method still presents possibilities to improve that are commented below after a quick summary of the method.

IEC 62305-2 RISK METHOD

The risk due to lightning is the sum of different risk components, differing in their source of damage (S1, S2, S3, S4) and type of damage (D1, D2, D3) defined as follows

- S1: flashes to the structure;
- S2: flashes near the structure;
- S3: flashes to the lines connected to the structure;
- S4: flashes near the lines connected to the structure.

and:

- D1: injury to living beings by electric shock;
- D2: physical damage (fire, explosion, mechanical destruction, chemical release) due to lightning current effects, including sparking;
- D3: failure of internal systems due to LEMP.

From this, the user can calculate up to eight risk components R_A, R_B, R_C, R_M, R_U, R_V, R_W and R_Z. Each of the risk components being expressed by the following general equation:

$$R_X = N_X \cdot P_X \cdot L_X \qquad (1)$$

where:

N_X is the number of dangerous events per annum;

P_X is the probability of damage to a structure;

L_X is the consequent loss

The number N_X of dangerous events is influenced by the lightning ground flash density (N_g), by the physical characteristics of the structure to be protected, its surroundings, the connected lines, and adjacent and connected buildings.

The probability of damage P_X is influenced by the characteristics of the structure to be protected, the connected lines and the protection measures provided.

The consequent loss L_X is influenced by the use to which the structure is assigned, the attendance of persons, the type of service provided to public, the value of goods involved in the damage and the measures provided to limit the amount of loss.

If the structure is partitioned in individual zones, each risk component shall be evaluated for each zone. The total risk R of the structure is the sum of all risks components over all the zones which constitute the structure.

The values of the acceptable amount of loss L_X should be evaluated and fixed by the lightning protection designer or the owner of the structure, unless otherwise fixed by the authority having jurisdiction. Typical mean values of loss L_X in a structure given in [1] are values proposed by the IEC. Different values of acceptable loss may be assigned by each National Committee (or other authority having jurisdiction) or after a detailed investigation.

Each of the part of the risk equations, namely the number of dangerous events per annum N, the probability of damage to a structure P and the consequent loss L, will be addressed successively.

GROUND FLASH DENSITY AND COLLECTION AREA

The ground flash density is the value that is used in present edition of the standard 62305-2. However, it has been shown [7], [8], [9] that a better way to assess the severity of an area is the lightning ground strike-point density that takes into account that a single flash may have more than one striking point to the ground. Both ground flash density and lightning ground strike-point density are mean values over a defined area. The size of this area may be sometimes quite large if the lightning activity is too low, in order to meet the LLS standard requirements [10] that impose a sufficient number of events for determining the density. In addition, the profile of the terrain may have also some influence depending on the slope: if most of the strikes occur to a prominent point, the consideration of the surrounding surface will tend to dilute the density. This may not cover adequately a few high-rise structures or structures located on a high point such as a hill or a mountain.

To cover the influence of such high-rise structures or structures located on a high point, the risk calculation integrates a factor Cd but this may not to cover all the cases adequately. This is a problem, because these high-rise structures are generally sensitive ones and more at risk due to their geographic exposure. In addition, it must be considered that these high-rise structures initiate upward flashes. Predicting the number of upward flashes initiated by a tall structure is complex [11], [12], [13].

Figure 1 below shows for example, the influence of the Eiffel Tower on the surroundings, with a map using a 1 km x 1 km mesh. The local density on Eiffel Tower is more than 5 times bigger than the lowest value obtained in the surroundings and 3,1 times bigger than the mean value (over an 8x6 km surface). That would lead to a Cd value of 3,1 instead of the maximum 2 considered by the standard. Compared to neighbouring places the local density on Eiffel Tower could be up to 6,5 times bigger.

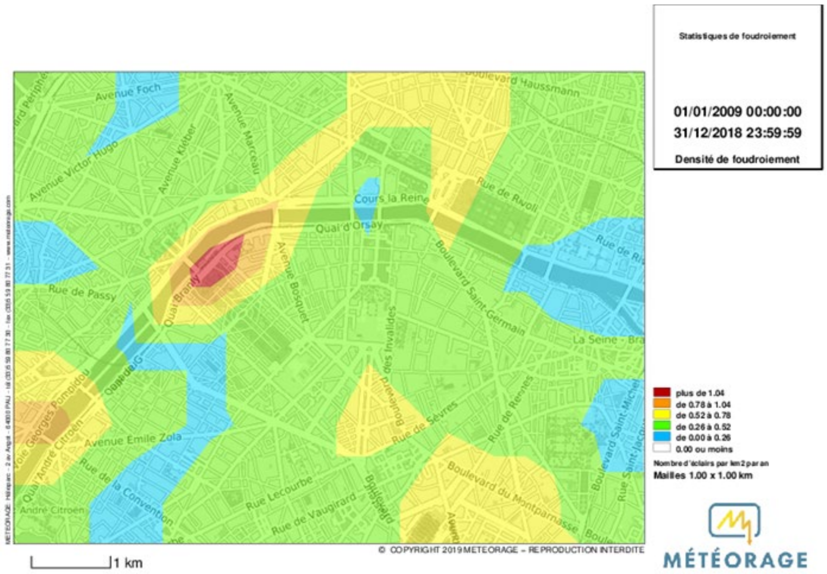

Fig. 1. Influence of Eiffel Tower on the surroundings

IEC has periodically considered to revise the formula but it appears that the formula, is well adapted for structure higher than 45 m and a little under estimated for structures below 45 m. The formula has then not been changed.

Recently a structure located on a plateau on the top of a mountain (1 100 m high) has experienced 3 strikes in a 5 months period. The structure is not particularly high (much less than 60 m considered in the standard as the limit above which lateral strikes have to be considered and even less than the 45 m introduced above). Calculation based on IEC 62305-2 formulas would lead for that particular structure to a number of years between 2 strikes ranging from 12,5 to 50 years by using the present IEC 62305-2 formula and ranging from 8 to 16 years with a better formula for structure less than 45 m considered

(but not published) by IEC 62305-2. This is not compatible with the recent experience on that site. Even the consideration of the concept of effective height introduced by Eriksson based on observation of increased lightning activity to towers of moderate height (less than 100 m) on high mountains, would only lead to a strike to the structure every 25 years.
This may be considered has a unique event but the new draft standard for wind turbines has introduced different values (higher) for the factor Cd with a slightly different concept [5]. The particularities of wind turbines are related to the fact that winter lightnings are specifically addressed as well as the height above sea level and the terrain shape. But even in that case, at best this structure should experience a strike every 6 years.

It is the likely that the formula given in IEC 62305-2 for direct strikes to the structure, even if this formula could be improved taking care of parameters proposed for wind turbine for example, will not cover satisfactorily the event described above. The shape of the terrain should be better considered either in the requirements for Nsg (allowing a smaller surface for calculating Nsg) or with a better coefficient Cd or both. It is then at least suggested for structures located on a hill or on a mountain to correct the formula of the collection area by a bigger factor Cd taking care of the shape of the terrain and especially the slope.

LIGHTNING GROUND STRIKE-POINT DENSITY

When the lightning ground strike-point density is not directly accessible by the Lightning Location System, a safety margin is proposed for the risk calculation: a few documents introduced a factor 2 between Nsg and Ng (1,5 to 1,7 coming from literature rounded to 2 with an additional 30% safety margin) but more recent data tend to retain 1,5 instead of 1,7 and the good performances of modern LLS may not justify a safety margin at all. To use such a fixed factor to estimate the lighting risk is not fully satisfactory (either 1,5 - 1,7 or even 2) because experience shows that depending on location this coefficient differs. For example, in Pau (France) the Ng value on the period 2009-2018 is 1,03 when Nsg on the same period is 1,24. The ratio is then 1,2 very far from values suggested by literature. This factor will also depend in France of the seasons (winter: 1,2 to 1,3 and summer: 1,4 to 1,5) and of the location (south-east: 1,7 to 1,8 and north-west/Brittany: 1,1 to 1,2). It should then be recommended for LLS to access to Nsg directly and when this is not possible, the risk evaluation should take into account a safety margin, perhaps higher than the 30% mentioned above, to estimate Nsg from Ng (when you don’t know the key parameters precisely, you should take a safety margin. This Nsg value is only used for risk evaluation and risk should never be under-estimated). For that reason, the factor 2, even if technically incorrect for most of the locations, is probably the best we can choose when Nsg is not obtained directly from the LLS.

For countries without LLS, it is possible to use the data provided by NASA (Nt = total - Cloud to Ground and Intra Clouds - density of optical flashes per km^2 per year) and to divide this value by 4 to obtain Ng. This factor 4 is based on hypothesis that satellites can detect 100% of flashes that is doubtful. It seems, based on recent observations, that satellites mainly detect the upper intra-clouds that are detected, and this is not directly related to the ground flashes. Two examples can illustrate the level of approximation given by the satellite map: in Kourou (French Guyana) Nt is 4 (so Ng should be 1) when based on local records (network of sensors located in the area mainly for the space centre needs), it is recommended to use Ng =4. In Botswana, Nt is 15 (so Ng should be 3,6) when a local study gives Ng =4,6 (it should be noted that the local study was only over 5 years instead of the 10 years recommended usually). This is clearly better than nothing but not accurate and not recommended when other data exist. What should then be the coefficient to apply to obtain Nsg in such a case? One more time, it is likely that the accuracy is low and thus a minimum safety margin of 2 should be used. However, risk methods should clearly ban the use of rough data such as Nt for risk evaluation when LLS exist in the country and especially when Nsg can be obtained directly from the LLS.

In the text below, when the discussion applies both to Ng and Nsg the term “lightning density” will be used to make the discussion as general as possible.

TEMPORARY ACTIVITIES

The risk calculation according to IEC 62305-2 is made on a yearly basis: the ground flash density and lightning ground strike-point density are defined per year and the activity inside the structure is also supposed to be equal all over the year. For activities that are not permanent or for events having a duration lower than one year (for example temporary events or storage), the risk should be calculated on a shorter duration than a year and the method should be detailed in the standard to avoid risk underestimation or at the reverse overestimation. There are a few attempts to address this issue especially for explosive or ammunitions storage [14].

The table I below shows the monthly distribution of ground flash density over a 10 years period and a 20 years period in two different places in France. The red values in Table I are when the mean value (given in the bottom of Table I, that is in fact the Ng value you get from the LLS) is exceeded and the green values are when the mean value is higher than experienced. The Ng value given by LLS can be exceeded in both cases for the more severe month by a ratio 3,5. For a few months, the risk is in fact underestimated when for a few others the risk is overestimated.

TABLE I
Distribution of flash density over a 10 years period and over a 20 years period in France.

Month	Ground flash density per month (2009-2018) in South East of France	Ground flash density per month (over 20 years) in North of France
January	0	0
February	0	0
March	0,16	0
April	0,48	1,05
May	1,53	0,5
June	2,33	2,25
July	3,64	1,5
August	1,91	1,5
September	2,14	0,25
October	0,16	0,35
November	0,03	0
December	0	0,05
Mean value (Ng)	**1,03**	**0,62**
Max value	3,64	2,25

By using a yearly average (usual Ng value), it may then overestimate or underestimate the risk depending upon period of consideration, as indicated in Table I. It is suggested, to evaluate the risk for such activities, to obtain from the LLS provider the monthly distribution of lightning density. The monthly average for the considered months, should then be used instead of the yearly average. When shorter durations than one year are considered, the tolerable risk must be of course prorated by the time of exposure considered. It is indeed not suggested to consider a time of exposure shorter than one month in the risk evaluation because the lightning activity may be too erratic on a shorter time period and the risk calculated may have no meaning. For example, for the site in the North of France addressed in Table I, when there is a lighting activity it may be for 1 day or for a few months for up to 14 days. Considering a few days period for the risk calculation may be tricky for the months where there is only a single day of lightning activity.

When the activity is covering a full year, the ground flash density and lightning ground strike-point density provided by LLS are mean values over 10 years considered on a yearly basis. This means that for a few months of the year the density is higher than the mean value and for a few other months of the year, the density is lower. This is fine for activities that are always the same all year long, but for a few activities, there is also a variability over the year. For example, if the month of August is used for maintenance because most of the work force is on holidays and if August is also the most severe month of the year for lightning activity, the calculated risk using the mean value is probably too high. A monthly analysis, even in the case could be beneficial.

PERIOD OF OBSERVATION

The ground flash density or lightning ground strike-point density are mean values over at least a 10-year duration. In practice, the lightning activity is not the same every year and this means that for a few years the risk will be lower than calculated and for a few other years the risk will be higher. If this is acceptable for most of the application, a few more sensitive or riskier activities may need to consider the worst case, when risk is evaluated. This is especially the case when human risk is considered as for example for leisure parks or activities involving a large number of people.
Table II below presents the spread over a 10 years period for the lightning ground strike-point density in a city located in South West of France. In the same way than for Table I, the red values in Table II are when the mean value (that is in fact the Nsg you can get from the LLS) is exceeded and the green values are when the mean value is higher than experienced. The mean value can be exceeded by a ratio almost equal to 2 (1,8 in fact).

TABLE II
Distribution of lightning ground strike-point density over a 10 years period in France.

Year	Lightning ground strike-point density per year
2009	0,89
2010	0,86
2011	2,2
2012	0,64
2013	1,05
2014	1,69
2015	1,08
2016	1,15
2017	1,56
2018	1,24
Mean value (Nsg)	**1,24**
Max value	2,2

This means that when you protect a structure located in that city by an LPS with a level of protection obtained from the risk calculation based on Nsg you may underestimate the risk by a factor 2 if the lightning event occurs in 2011 and on the reverse for 60% of the years you have overestimated the risk. In 2011, the risk was greater than expected and thus a better lightning protection would have been needed. For 60% of the years between 2009-2018 the level of protection was probably too high compared to the risk but as risk evaluation means by definition a safety margin, so it is not a big deal. Considering the present change in climate and possible increase of lightning activities or at least a bigger uncertainty in lightning activity, it may be wise for more sensitive or riskier activities to consider the highest value for Nsg and not the mean value.

SOIL RESISTIVTY

A few other parameters need to be better addressed when calculating N, as for example the soil resistivity. This parameter is important for underground services, but it is difficult to obtain this value because the lines are running over a large area (for example power lines) and the soil resistivity is generally not known except at best in the close vicinity of the studied structure. This means that the default values (400 ohm.m is the basis for values given in the standard) are used almost all the time even if the standard clearly indicates that the ground resistivity affects the collection area of buried services. In general, the larger the ground resistivity, the larger the collection area (proportional to $\sqrt{\rho}$). A resistivity of 1000 ohm.m would increase the collection area of buried lines by a factor 1,6 and thus the risk.

PROBABILITIES

Most of the probabilities described in IEC 62305-2 are easy to evaluate. However, the probabilities related to the use of Surge Protective Devices is incomplete in its present description. It is in fact related to two probabilities one named Peb (reducing the probability of injury to living beings by electric shock and probability of physical damage to a structure related to flashes to a connected line, depending on line characteristics) and the other Pspd (reducing the probability of failure of internal systems related to flashes to a structure, the probability of failure of internal systems related to flashes near a structure, the probability of failure of internal systems related to flashes to connected line and the probability of failure of internal systems related to flashes near a connected line, when a coordinated SPD system is installed).
The probability Peb is related to the SPDs located at line entrance (equipotential bonding) when the probability Pspd is related to a coordinated set of SPDs (SPDs coordinated and installed to form a system intended to reduce failures of electrical and electronic systems).
Peb is related to the surge withstand of the SPD located at the entrance of electrical installation (generally Type 1 SPD) that is itself depending on the level of protection of the Lightning Protection System. The probability Peb is then mainly depending on the current Iimp that the SPD can withstand.
It is indicated in the standard that the probability Peb can be reduced for SPDs having better protection characteristics (higher nominal current In, lower voltage protective level Up, etc.) compared with the requirements defined for lightning protection level I at the relevant installation locations. But unfortunately, no formula is proposed to determine these lower probabilities. In addition, the key parameter for a better protection is only related to the voltage protective level Up. To use an SPD with a higher nominal current In will not necessarily result in a better voltage protection level.
Pspd is defined exactly with the same table and with the same indication related to the possibilities to reduce the probabilities below the value defined for lightning protection I, but it is related to a coordinated set of SPDs. Standards [15] defined originally a coordinated set of SPDs as a system of SPDs that work together on a power line in such a way the lightning energy injected in the system is shared between all the SPDs in order that none of the SPD's energy withstand is exceeded. It is concentrating on SPD survival not on equipment protection. However, an SPD may not fail but may not be able to protect if the current flowing through is between its nominal discharge current In that defines Up for most Type 2 SPDs and its maximum discharge current (usually named Imax).
Presently, a better definition for coordination exists that relates to the SPD voltage protection level. The voltage at the terminals of each SPD of the coordinated system should remain below its voltage protective level. It is much more stringent because the current should then remain below the nominal discharge current In when for energy coordination the current in each SPD should only remain below the maximum discharge current.
Because table giving probabilities for probabilities related to SPD are the same, in the text below we will use exclusively the term Pspd. Present description of Pspd is then insufficient as it relates only to energy sharing. It mentions the possibility to reduce Pspd for SPD providing a better protection level but only for a few cases (the SPD should first have the surge withstand defined by level of protection I) and fails to provide a formula to calculate this lower probability.
The problem is coming from the definition of Up, the voltage protective level of the SPD. This value Up is based on the measurement of two parameters (when applicable): the residual voltage and the sparkover voltage. For example, for a spark gap, the appropriate parameter is the sparkover voltage when for a MOV the appropriate parameter is the residual voltage.
If the entrance SPD is for example of the MOV type, the protective level is only defined by the residual voltage Ures at its nominal discharge current In.
However, the curve U.vs.I of a varistor is non-linear. For a typical varistor the residual voltage at In (5 kA) is 1,5 kV when the residual voltage at a higher current (for example 12,5 kA) is 2 kV.
For example, an LPS having a lightning protection level III (i.e. max current of 100 kA) is protecting a building where an equipment having a surge withstand of 1,5 kV is protected by such a MOV type SPD with 4 internal varistors connected to active conductor to earth (3 phases plus neutral, TT system).

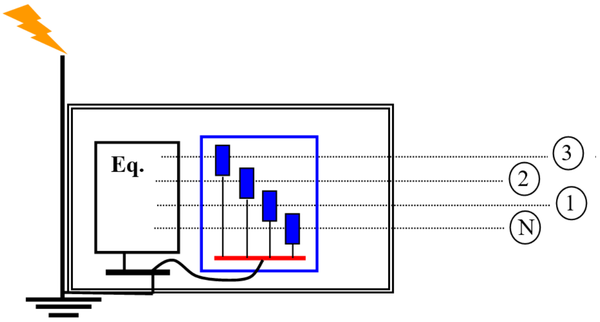

Fig. 2. SPD Type 1 varistor based 3 phases and neutral protecting an equipment (Eq.)

In that case, everything is correct but in case the maximum lightning current occurs (100 kA), the current inside the power system will be 50 kA, which means 12,5 kA in each varistor and so a voltage at SPD terminals of 2 kV, which is higher than the withstand of the equipment. In that case, the equipment will fail. In that case, the probability Pspd is not 0,05 as given in 62305-2 standard but much higher because it is not important the SPD survives if the equipment fails. It is needed that the current inside each varistor remains below or equal to 5 kA for being sure to provide adequate equipment protection.

This means a total current inside the SPD of 4 x 5 = 20 kA and a current inside the LPS of 2 x 20 = 40kA (assuming 50% of current inside the earthing system). Any time the lightning current striking the LPS exceeds 40 kA, there is a failure of the equipment.

According to 62305-1, the probability for having a positive lightning current (related to Class 1 test – i.e. 10/350) of 40 kA is 45%. As there are 10% of positive flashes, we got a probability of 4,5%, rounded to 5%. If we consider any lightning current (positive and negative), the probability would be much higher 39%. In fact, any current that exceeds 5 kA may lead to an equipment failure because for electronic components the surge voltage applied is as important as the surge duration. For simplicity sake, we consider below that equipment to be protected will fail due to insulation breakdown and for that reason we consider only long duration surges (10/350) but it must be considered that the failure rate of equipment may be much higher than evaluated.

The probability Pspd should be the combination of 2 events:

- Either SPD fails (it is the probability Pspd existing so far, i.e. in our case 5%)
- Or the SPD does not fail but does not protect the equipment either (that probability is also 5%, see above)

The probability Pspd depends on:

- the probability P1 that the value of the expected current, associated with the current flowing through the SPD at its point of installation, exceeds the current tolerated by the SPD;
- the probability P2 that the value of residual voltage at SPD terminals exceeds the required protection level Up

Then the probability Pspd is given by:

$$\mathrm{Pspd} = 1 - (1 - \mathrm{P1})(1 - \mathrm{P2}) \qquad (1)$$

Pspd should then be 10% instead of the 5% used so far.

Of course, this is an extreme case based on a single SPD providing at the same time equipotential bonding function and protection function. In most of the cases, the presence of many cascaded SPDs will help reducing that problem.

However, the tables proposed so far in IEC 62305-2 are incomplete by providing no formula for calculating the probability Pspd and confusing by restricting the use of a better probability only if the current withstand is greater than the one defined for level I. Furthermore, having two tables one for Peb and for Pspd can create more confusion trying to separate the two phenomena (equipotential bonding and system protection). It also gives the feeling that only 2 SPDs that are energy coordinated will solve the problem when in general there are many SPDs on a single line (for example one SPD at installation entrance – main panel board, one SPD in one or more subsidiary panels and finally SPD in front of equipment or in front of UPS). All these SPDs should be coordinated and in such a way the current injected in the last SPD in front of sensitive equipment will be very reduced providing a better voltage

protection than Up written on the nameplate. At the moment there is no way in the IEC 62305-2 standard to take benefit of such a frequent installation.
The draft edition 3 of 62305-2, has recently proposed to correct these drawbacks but unfortunately failed the vote.

LOSSES AND FREQUENCY OF DAMAGE

The risk calculated today is defined by formula R = N x P x L where N and P are well defined, even if improvements are possible or needed, but L is mostly coming from the sky. For example, the fire means are considered as a reduction factor of the losses when the physical damage considered in the standard IEC 62305-2 covers not only fire but also mechanical damage. If a lightning strike punctures a metal roof or if a wall corner falls down in the street, is the firefighting means of any help? Another factor that is questionable is the factor increasing the relative amount of loss in presence of a special hazard. This factor is associated to a level of panic but in many places (nuclear plant, oil & gas, hospitals …) people are trained to not panic. Is that mean that, in such places, the risk is lower than in the same place when people are not trained? The values of parameters involved in the loss calculation are all, to some extent, rather artificial and it is probably one of the reasons why the risk is overestimated for a few structures compared to the experience.
The draft edition 3 of 62305-2, has recently introduced the concept of frequency of damage F = N*P that is a better appraisal of the need for lightning protection. It defines how many times par year a damage related to a lightning event will occur. The user or the designer performing the risk calculation can then assess, without introducing any artificial parameter, this frequency of damage. The amount of damages due to a lightning strike can then be evaluated by a deterministic approach including various scenarios.
For example, without any lightning protection system, a lightning strike can occur on the structure with current up to 200 kA or even higher. Improved lightning protection models [16] can assess what is the level of current that can strike the structure: it may be lower than 200 kA thanks to neighbouring structures. Based on the possible impact location determined by the model, possible magnitude of the lightning current and structure natural resilience, it is possible to determine the amount of damage associated to such a high lightning current. Based on the rolling sphere model it is also possible to know what is the lowest lightning current that can strike the structure. Such a low lightning current is supposed to create a small damage to the structure but it may impact a safety device (for example an aircraft warning light) or allow a disturbing current to enter to the internal services following a strike to a roof or façade equipment. This type of damage may be more important for a few applications than the structural damages. If the amount of damage associated to the highest possible lightning current or if the disturbances created by the lowest possible lightning current, and the frequency of damage, are not acceptable for this structure or for the user, a Lightning Protection system or Surge Protective Devices on a particular circuit may be installed to reduce the frequency of damage and the amount of damages.
At the present time, it is assumed in IEC 62305-2 that any lightning strike in absence of LPS or SPDs will create a damage on the structure or on the services. But the amount of damage is never addressed or to be more precise, it is addressed by the concept of losses in such a way that it is often unrealistic. In addition, the protection means proposed by this standard approach are associated to a complete structure when only a part of the structure may be involved and deserve a protection.
The difficulty of the frequency of damage is that the calculation is only one step and a significant part of the study remains to be done (scenario approach, amount of damage, location of damages …) when the calculation is done. A tolerable frequency of damage concept has been proposed by the draft edition 3 of IEC 62305-2 but this tolerable value is removing a big part of the interest of calculating the frequency of damage: what is tolerable is not only very depending on the type of application and user’s feeling but, in addition, it removes the analysis of the amount of damages. Today’s method of calculating the risk is providing a straight through result explaining why it is familiar and largely used: calculated risk is greater than the tolerable risk and lightning protection is needed or is lower than the tolerable risk and lightning protection is not mandatory. It is very simple even if it is based on a few shortcuts and it leads often to greater protection levels than needed. However, there is probably no need to improve the definition and calculation of other parameters, as detailed above, if such an important parameter like the losses L is addressed in a very rough way.

CONCLUSIONS

History on application of lightning risk method is by now quite long (more than 20 years if we consider the first published technical report at IEC level). It is also used as a basis for many other standards. It should then be mature but in fact it appears that the use of the standard can be summarized by the following sentence: it is too complex for simple cases and too simple for complex cases. The development of many software helps the user to apply the standard easily for simple cases and this covers the first part of the sentence. But for complex cases, or only to take care of field experience, it is necessary to improve the standard.

Field of improvements described in the paper are:

- Addressing high rise structures or structures located on a top of a hill/mountain in a better way: the shape of the terrain should be better described than only by the environment factor Cd defined in IEC 62305-2. The maximum value 2 for this factor Cd seems to be too low.
- Use of the lightning ground strike-point density: this parameter is important as it multiplies all the risk components but in places where the LLS doesn't provide directly Nsg a safety margin should be used to obtain Nsg from Ng (accessible from LLS) to cover the worst case. The use of the data provided by NASA are too broad to be used when a local LLS exists.
- Temporary activities: these activities with a duration of less than a year should be covered by the standards. Even for activities spreading all other the year but not the same all the year, for example with maintenance activities in summer, there is a benefit to address the strike density per month. It is not suggested to analyse the LLS data with a time window shorter than a month.
- Period of observation: Nsg (or Ng) are based on 10 years' experience and are mean values over these 10 years. It is suggested for more sensitive or riskier activities to consider the highest value for Nsg during these 10 years and not the mean value.
- Soil resistivity: this is a key parameter for underground services. However, this is very difficult to obtain, especially when a service could be considered up to 1 km away from the structure. Means to obtain the soil resistivity on a large surface for services should be described in the standard based on geological data or other means.
- Probability Pspd: the probability in the standard is today totally confusing as it is only based on SPD withstand when an SPD can withstand and not protect equipment. What is important to protect are equipment and not SPDs that are weak point be definition. Pspd should include both the SPD withstand and the protection efficiency near sensitive equipment.
- Losses: this is also another confusing parameter because it is mainly based on fire risk when the damages caused by lightning may not involve a fire. The risk of panic is also involved in the present calculation of the losses when this concept is understood differently by different people. Are people working in nuclear activities supposed to panic? They are trained for not. Is that mean that there is no lightning risk for nuclear activities or that risk is lower than in a commercial centre? The concept of losses should be replaced by the frequency of damage that can be calculated without any shortcut. In addition, this concept would allow to define the protection based on what is really needed, associating damage scenarios to the frequency of damages.

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