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How to deal with environmental risk in IEC 62305-2

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***Abstract* - The 2nd edition of the lightning risk management standard (IEC 62305-2) considers structures, which may endanger environment. In these cases, the loss is not limited to the structure itself, which is valid for usual structures. In the past (Edition 1) this danger was simply taken into account by a special hazard factor, multiplying the existing risk for the structure with a number. Now, in the edition 2, we add to the risk for the structure itself a "second risk" due to the losses outside the structure. The losses outside can be treated independently from what occurs inside. This is a major advantage to analyze the risk for sensitive structures, like chemical plants, nuclear plants, or structures containing explosives, etc. In this paper, the existing procedure given by the European version EN 62305-2 Ed.2 is further developed and applied to a few structures.**

Keywords-lightning, risk, overvoltage, envrionment, chemical, explosion, nuclear

I. INTRODUCTION

Risk management for lightning and overvoltage protection is an essential tool, to estimate the vulnerability of a structure and the people and content inside against lightning and overvoltage threat and to ensure, that the necessary and most effective protection measures are selected in the required quality.

Since the 1st edition of the lightning protection standard series IEC 62305 and with that EN 62305 (and the related European national standards) in 2006 risk management investigations according to the part 2 of the standard series were performed for a great number of structures. The experiences with the investigations lead to some improvement. In 2010 the 2nd edition of the international standard IEC 62305-2 [1] was published. In Europe some further modifications, essentially belonging to the use of thunderstorm warning systems and to the calculation procedure for economic losses, were implemented, so that the EN 62305-2 Ed.2 [2] was finally released in May 2012.

This 2nd edition of the lightning risk management standard also allows a more detailed view to structures, which may endanger their surroundings due to explosion or contaminations. In these cases, the loss is not limited to the structure itself, which is valid for usual structures. In the past (Edition 1) this danger was simply taken into account by a so-called special hazard factor, multiplying the existing risk for the structure with a rough and integer number. Now, in the edition 2, we add to the risk for the structure itself a "second risk" due to the losses outside the structure. With that, the losses outside can be treated independently from what occurs inside. This is a major advantage to analyze the lightning and overvoltage risk for sensitive structures, like chemical plants, nuclear plants, military structures containing explosives, etc.

In this paper, the existing procedure given by the European standard EN 62305-2 Ed.2 is further developed and applied to a variety of structures. Common for all these structures is that they may represent a further risk to their surroundings when they are exposed to a lightning event.

II. GENERAL

The risk due to lightning (including overvoltages) is the sum of different risk components, differing in their source of damage (S1, S2, S3, S4) and their type of damage (D1, D2, D3). We distinguish between:

- 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.

In total, with that we get the eight risk components R_A, R_B, R_C, R_M, R_U, R_V, R_W and R_Z. Each of this risk component is 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 (see also Annex A of [2]);

P_X is the probability of damage to a structure (see also Annex B of [2]);

L_X is the consequent loss (see also Annex C of [2]).

The number N_X of dangerous events is affected by the lightning ground flash density (N_G) and 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 affected by the characteristics of the structure to be protected, the connected lines and the protection measures provided.

The consequent loss L_X is affected by the use to which the structure is assigned, the attendance of persons, the type of service provided to public, the value of goods affected by the damage and the measures provided to limit the amount of loss. If the damage to a structure due to lightning also involves surrounding structures or the environment (e.g. chemical or radioactive emissions), a more detailed evaluation of L_X that takes into account this additional loss should be performed.

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.

III. LOSS FACTOR FOR THE STRUCTURE

The values of amount of loss L_X should be evaluated and fixed by the lightning protection designer or the owner of the structure. Typical mean values of loss L_X in a structure given in [1, 2] are merely values proposed by the IEC. Different values may be assigned by each national committee or after detailed investigation.

For the cases to be investigated, structures being dangerous also for their surroundings, the two following types of losses are of interest:

- L1: loss of human life
- L4: economic loss

All other types of losses can be excluded here.

In addition to that, only the types of damage D2 and D3 are investigated. D1 as the injury to living beings due to electric shock is a consequence of step and touch voltages. With that, it is only relevant in the structure to be protected, not in the surroundings. Consequently, the risk components R_A and R_U can be neglected.

A. *Loss of human life (L1)*

The loss value L_X for each zone can be determined according to (2) and (3), considering that:

- the loss of human life is affected by the characteristics of the zone. These are taken into account by increasing (h_z) and decreasing (r_t, r_p, r_f) factors;
- the maximum value of loss in the zone must be reduced by the ratio between the number of persons in the zone (n_z) versus the total number of persons (n_t) in the whole structure;
- the time in hours per year for which the persons are present in the zone (t_z), if it is lower than the total 8760 h of a year, also will reduce the loss.

$$L_B = L_V = r_p \cdot r_f \cdot h_z \cdot L_F \cdot n_z/n_t \cdot t_z/8760 \qquad (2)$$

$$L_C = L_M = L_W = L_Z = L_O \cdot n_z/n_t \cdot t_z/8760 \qquad (3)$$

where:

L_F is the typical percentage of persons injured by physical damage (D2) due to one dangerous event (see Table I);

L_O is the typical percentage of persons injured by failure of internal systems (D3) due to one dangerous event (see Table I);

r_p is a factor reducing the loss due to physical damage depending on the provisions taken to reduce the consequences of fire (see Table II);

r_f is a factor reducing the loss due to physical damage depending on the risk of fire or on the risk of explosion of the structure (see Table III);

h_z is a factor increasing the loss due to physical damage when a special hazard is present (see Table IV);

n_z is the number of persons in the zone;

n_t is the total number of persons in the structure;

t_z is the time in hours per year for which the persons are present in the zone.

When a structure is treated as a single zone the ratio n_z/n_t should equate to a value of 1. Where the value of t_z is not known, the ratio t_z /8760 should equate to a value of 1.

Both types of damage D2 and D3 are relevant for this type of structure. An overvoltage and consequently the loss of a control system can result in a danger for human beings inside (and later also outside) the structure.

TABLE I. TYPE OF LOSS L1: TYPICAL MEAN VALUES OF L_F AND L_O

Type of damage	**Typical loss value**		**Type of structure**
D2 physical damage	L_F	10^{-1}	Risk of explosion
		10^{-1}	Hospital, hotel, school, civic building
		$5 \cdot 10^{-2}$	Public entertainment, church, museum
		$2 \cdot 10^{-2}$	Industrial, commercial
		10^{-2}	Others
D3 failure of internal systems	L_O	10^{-1}	Risk of explosion
		10^{-2}	Intensive care unit and operation block of hospital
		10^{-3}	Other parts of hospital

These values of Table I (Table C.2 in [1, 2]) refer to a continuous attendance of people in the structure. In case of a structure with risk of explosion, the values for L_F and L_O may need a more detailed evaluation, considering the type of structure, the risk explosion, the zone concept of hazardous areas and the measures to meet the risk.

TABLE II. REDUCTION FACTOR r_p AS A FUNCTION OF PROVISIONS TAKENTO REDUCE THE CONSEQUENCES OF FIRE (TABLE C.4 IN [1, 2])

Provisions	r_p
No provisions or structures with a risk of explosion	1
One of the following provisions: extinguishers; fixed manually operated extinguishing installations; manual alarm installations; hydrants; fire compartments; escape routes	0.5
One of the following provisions: fixed automatically operated extinguishing installations; automatic alarm installations [a]	0.2
[a] only if protected against overvoltages and other damages and if firemen can arrive in less than 10 min.	

If more than one provision has been taken, the value of r_p should be taken as the lowest of the relevant values.

TABLE III. REDUCTION FACTOR r_f AS A FUNCTION OF RISK OF FIREOR EXPLOSION OF STRUCTURE (TABLE C.5 IN [1, 2])

Risk	**Amount of risk**	r_f
Explosion	Zones 0, 20 and solid explosive	1
	Zones 1, 21	10^{-1}
	Zones 2, 22	10^{-3}
Fire	High	10^{-1}
	Ordinary	10^{-2}
	Low	10^{-3}
Explosion or fire	None	0

Notes for Table III:

In case of a structure with risk of explosion, the value for r_f may need a more detailed evaluation.

Structures with a high risk of fire may be assumed to be structures made of combustible materials or structures with roofs made of combustible materials or structures with a specific fire load larger than 800 MJ/m^2.

Structures with an ordinary risk of fire may be assumed to be structures with a specific fire load between 800 MJ/m^{2}and 400 MJ/m^2.

Structures with a low risk of fire may be assumed to be structures with a specific fire load less than 400 MJ/m^2, or structures containing only a small amount of combustible material.

Specific fire load is the ratio of the energy of the total amount of the combustible material in a structure and the overall surface of the structure.

For the purposes of this part of IEC/EN 62305, structures containing hazardous zones or containing solid explosive materials should not be assumed to be structures with a risk of explosion if any one of the following conditions is fulfilled:

a) the time of presence of explosive substances is lower than 0,1 h/year;

b) the volume of explosive atmosphere is negligible according to IEC 60079-10-1 [3] and IEC 60079-10-2 [4];

c) the zone cannot be hit directly by a flash and dangerous sparking in the zone is avoided.

For hazardous zones enclosed within metallic shelters, condition c) is fulfilled when the shelter, as a natural air-termination system, acts safely without puncture or hot-spot problems, and internal systems inside the shelter, if any, are protected against overvoltages to avoid dangerous sparking.

The values given in Table III for a risk of explosion consider in a simplified manner the existence of an explosive atmosphere, i.e. the time per year, where explosion really can occur. For an explosion, two events have to occur simultaneously: the lightning strike <u>and</u> the existence of an explosive atmosphere. With that, and if more detailed information is available, the parameter r_f can also be evaluated as:

$$r_f = t_{ex}/8760 \tag{4}$$

where:

t_{ex} time in hours per year, for which explosive atmosphere is present in the relevant structure or zone.

TABLE IV. FACTOR h_z INCREASING THE RELATIVE AMOUNT OF LOSS IN PRESENCE OF A SPECIAL HAZARD (TABLE C.6 IN [1, 2])

Kind of special hazard	h_z
No special hazard	1
Low level of panic (e.g. a structure limited to two floors and the number of persons not greater than 100)	2
Average level of panic (e.g. structures designed for cultural or sport events with a number of participants between 100 and 1 000 persons)	5
Difficulty of evacuation (e.g. structures with immobile persons, hospitals)	5
High level of panic (e.g. structures designed for cultural or sport events with a number of participants – greater than 1 000 persons)	10

B. Economic loss (L4)

The loss value L_X for each zone can be determined according to (5) and (6), considering that:

- the loss of economic values is affected by the characteristics of the zone. These are taken into account by decreasing (r_t, r_p, r_f) factors;
- the maximum value of loss due to the damage of the zone must be reduced by the ratio between the relevant value in the zone versus the total value (c_t) of the whole structure (animals, building, content and internal systems including their activities). The relevant value of the zone depends on the type of damage:

  D2 (physical damage): $c_a + c_b + c_c + c_s$ (value of all goods)

  D3 (failures of internal systems): c_s
  (value of internal systems and their activities only)

$$L_B = L_V = r_p \cdot r_f \cdot L_F \cdot (\mathrm{c}_a + \mathrm{c_b} + \mathrm{c_c} + \mathrm{c_s}) /\mathrm{c}_t \quad (5)$$

$$L_C = L_M = L_W = L_Z = L_O \cdot \mathrm{c_s} /\mathrm{c_t} \quad (6)$$

where:

L_F is the typical percentage of economic value of all goods (animals, building, content, internal systems) damaged by physical damage (D2) due to one dangerous event (see Table V);

L_O is the typical percentage of economic value of all goods (internal systems) damaged by failure of internal systems (D3) due to one dangerous event (see Table V);

r_p is a factor reducing the loss due to physical damage depending on the provisions taken to reduce the consequences of fire (see Table II, in structures with a risk of explosion, $r_p = 1$ for all cases);

r_f is a factor reducing the loss due to physical damage depending on the risk of fire or on the risk of explosion of the structure (see Table III and (4));

c_a is the value of animals in the zone;

c_b is the value of building relevant to the zone;

c_c is the value of content in the zone;

c_s is the value of internal systems including their activities in the zone;

c_t is the total value of the structure (sum over all zones for animals, building, content and internal systems including their activities).

TABLE V. TYPE OF LOSS L4: TYPICAL MEAN VALUES OF L_F AND L_O

Type of damage	Typical loss value		Type of structure
D2 physical damage	L_F	1	Risk of explosion
		0.5	Hospital, industrial, museum, agricultural
		0.2	Hotel, school, office, church, public entertainment, commercial
		10^{-1}	Others
D3 failure of internal systems	L_O	10^{-1}	Risk of explosion
		10^{-2}	Hospital, industrial, office, hotel, commercial
		10^{-3}	Museum, agricultural, school, church, public entertainment
		10^{-4}	Others

Again, in structures where there is a risk of explosion, the values for L_F and L_O may need more detailed evaluation, in which considerations of the type of structure, the risk explosion, the zone concept of hazardous areas and the measures to meet the risk, are addressed.

Furthermore, also for the type of loss L4 the values given in Table III for the parameter r_f can be evaluated as described by (4), if a more detailed approach is possible and necessary.

IV. LOSS FACTOR FOR THE ENVIRONMENT

In this context, the international standard [1] differs in some points from the European one [2]. However, both standards define a concept for the inclusion of effects to the surroundings, which cannot be accepted for all structures:

- in the European standard the provisions taken to reduce the consequences of fire (r_p) are not adequately taken into account for the evaluation of the loss factors for the surroundings;
- in the European standard the reduction factor r_f describing the risk of fire or explosion of a given structure is not adequately taken into account for the evaluation of the loss factors for the surroundings;
- in the international standard the zoning of the structure as well as the increasing factor h_z for the situation inside the structure influences misleadingly also the losses for the surroundings;
- in both standards the overvoltage related risk components due to the type of damage D3 have no direct influence on losses for the surroundings. In cases with process control applications, for example, where the loss of such equipment or internal systems may create a situation where there is a release of a chemical harmful to the environment, the consideration of these risk components is necessary.

Therefore, it seems useful, to investigate in detail the influence of different characteristics and conditions of the structure and its surroundings to the additional losses at these surroundings due to a lightning event to the structure.

A. Loss of human life (L1)

When the damage to a structure due to lightning involves surrounding structures or the environment (e.g. chemical or radioactive emissions), additional losses ($\mathrm{L_{XE}}$) should be taken into account to evaluate the total loss ($\mathrm{L_{XT}}$):

$$\mathrm{L_{XT}} = \mathrm{L_X} + \mathrm{L_{XE}} \quad (7)$$

where:

L_X is the loss factor for the losses of human beings inside the structure as given in (2) and (3);

$$L_{BE} = L_{VE} = r_p \cdot r_f \cdot L_{FE} \cdot t_e/8760 \quad (8)$$

$$L_{CE} = L_{ME} = L_{WE} = L_{ZE} = r_p \cdot r_f \cdot L_{OE} \cdot t_e/8760 \quad (9)$$

where:

L_{FE} is the typical mean percentage of persons outside the structure injured by physical damage (D2) due to one dangerous event (see Table VII);

L_{OE} is the typical mean percentage of persons outside the structure injured by failure of internal systems (D3) due to one dangerous event (see Table VII);

r_p is the factor reducing the loss due to physical damage depending on the provisions taken to reduce the consequences of fire (see Table II, in structures with a risk of explosion, $r_p = 1$ for all cases);

r_f is the factor reducing the loss due to physical damage depending on the risk of fire or on the risk of explosion of the structure (see Table III and (4));

t_e being the time of presence of persons in the potentially dangerous place outside the structure.

If values of t_e are unknown, $t_e/8760 = 1$ should be assumed. In the surroundings of the structure usual residential areas may exist with a permanent attendance of people.

Otherwise the values proposed in Table VI can be used. These values are based on a French official document [5] giving the basic rules for counting the number of people around an industrial site and with that the potential number of victims in case of an event inside the site having an effect outside of the site.

TABLE VI. TYPE OF LOSS L1: PROPOSED TYPICAL VALUES FOR THE RELATED TIME OF PRESENCE FOR PEOPLE $t_e/8760$ IN DIFFERENT ENVIRONMENT AS LIMITED BY TABLE VII

Type of surrounding	**$t_e/8760^{(1)}$**
Working people inside the fence	0.25
Necessity of controlled area inside the fence Operation of plant with more than one shift	1.0
Establishments Receiving of Public (ERP)	0.5
Zones of activities (industries and other activities not receiving usually from public)	0.75
Residences	1
Automobile lanes :	1
Railway ways	0.25
Inland waterways	0.1
Ways and ways pedestrians	0.75
Non made-up grounds and very little attended (fields, meadows, forests, waste lands, marsh…)	0.25
Usable airfields but little attended (horticultural gardens and zones, vines, fishing zones, marshalling yards …)	0.25
Usable airfields and potentially attended or very attended (carparks, parks and parks, zones of supervised bathes, sports grounds	0.5
Special cases (extremely temporary occupations)	0.1

1 : In case of "mixed" environments with different values, the highest value should be used.

For L_{FE} and L_{OE} the values given in Table VII are a proposal. More detailed calculations may be performed. Otherwise these values could be evaluated or based on authorities having jurisdiction documents. Of course, when there is no risk for the surroundings, $L_{FE} = L_{OE} = 0$ should be assumed.

Table VII (as well as the later Table VIII) is based on experience of a working team built in France to analyze the environmental effect when using IEC/EN62305-2. It has neither be published nor approved by the said team. It has been developed and refined by the authors to be able to make calculation on some examples. It is a proposal that needs to be thoroughly fully discussed. However the typology of cases introduced in these tables seems adequate to reflect the possible impact of a lightning event to the surrounding and to the environment.

TABLE VII. TYPE OF LOSS L1: TYPICAL MEAN VALUES OF L_{FE} AND L_{OE} OUTSIDE THE STRUCTURE

Values of L_{FE} and L_{OE} Scenario	**Environmental risk – remaining inside the site fence**		**Environmental risk – spreading outside of the site fence**	
	$L_{FE}^{(7)}$	**$L_{OE}^{(7)}$**	**L_{FE}**	**L_{OE}**
Explosion and overpressure $^{(1)}$	0.25	0.025	0.5	0.05
Thermal flux $^{(2)}$	0.05	0.005	0.1	0.01
Toxic fumes $^{(3)}$	0.1	0.01	1.0	0.1
Soil pollution $^{(3)}$	0.1	0.01	0.5	0.05
Water pollution $^{(3)}$	0.25(4)	0.025	2.5	0.25
Radioactive material $^{(3), (5), (6)}$	0.5	0.05	5	

1 : The overpressure exceeds a value of 50 hPa

2 : The thermal power per area exceeds a value of 3 kW/m^2

3 : These maximum values could be reduced based on quantity of pollutant, danger of the pollutant and sensitivity of the environment

4 : only if pollution can reach the water bed or fresh water or sea/oceans

5 : this may not be applicable when a specific study including all scenario have been developed

6 : this is not applicable to sealed sources for example used in measuring devices or medical equipment

7 : In case of a TWS the values for LFE and LOE inside the site fence are multiplied by (1 – PTWS).

Note: damage to windows (explosion with limited effect) are excluded from this investigation and should be dealt with, if any, by specific protection measures.

B. *Economic loss (L4)*

When the damage to a structure due to lightning involves surrounding structures or the environment (e.g. chemical or radioactive emissions), additional losses (L_{XE}) should be taken into account to evaluate the total loss (L_{XT}):

$$L_{XT} = L_X + L_{XE} \tag{10}$$

where:

L_X is the loss factor for the economic losses inside the structure as given in (5) and (6);

$$L_{BE} = L_{VE} = r_p \cdot r_f \cdot L_{FE} \cdot c_e/c_t \tag{11}$$

$$L_{CE} = L_{ME} = L_{WE} = L_{ZE} = r_p \cdot r_f \cdot L_{OE} \cdot c_e/c_t \tag{12}$$

where:

L_{FE} is the typical mean percentage of economic value of all goods outside the structure damaged by physical damage (D2) due to one dangerous event (see Table VIII);

L_{OE} is the typical mean percentage of economic value of all goods outside the structure damaged by failure of internal systems (D3) due to one dangerous event (see Table VIII);

r_p is a factor reducing the loss due to physical damage depending on the provisions taken to reduce the consequences of fire (see Table II, in structures with a risk of explosion, $r_p = 1$ for all cases);

r_f is a factor reducing the loss due to physical damage depending on the risk of fire or on the risk of explosion of the structure (see Table III and (4));

c_e is the total value of goods in potentially dangerous place outside the structure.

c_t is the total value of the structure (sum over all zones for animals, building, content and internal systems including their activities).

If values of c_e are unknown, $c_e/c_t = 100$ should be assumed.

For L_{FE} and L_{OE} the values given in Table VIII are a proposal. More detailed calculations may be performed. Otherwise these values could be evaluated or based on authorities having jurisdiction documents. Of course, when there is no risk for the surroundings, $L_{FE} = L_{OE} = 0$ should be assumed.

TABLE VIII. TYPE OF LOSS L4: TYPICAL MEAN VALUES OF L_{FE} AND L_{OE} OUTSIDE THE STRUCTURE

Values of L_{FE} and L_{OE} Scenario	**Environmental risk – remaining outside the site fence**		**Typical economic relation**
	L_{FE}	**L_{OE}**	**c_e/c_t**
Explosion and overpressure (1)	0.5	0.05	1
Thermal flux (2)	0.1	0.01	1
Toxic fumes (3)	0.5	0.05	5
Soil pollution (3)	0.2	0.02	10
Water pollution (3)	0.5(4)	0.05	50
Radioactive material (3), (5), (6)	1	0.1	100

1 : The overpressure exceeds a value of 140 hPa

2 : The thermal power per area exceeds a value of 8 kW/m2

3 : These maximum values could be reduced based on quantity of pollutant, danger of the pollutant and sensitivity of the environment

4 : only if pollution can reach the water bed or fresh water or sea/oceans

5 : this may not be applicable when a specific study including all scenarii have been developed

6 : this is not applicable to sealed sources for example used in measuring devices or medical equipments

Note: damage to windows (explosion with limited effect) are excluded from this investigation and should be dealt with, if any, by specific protection measures.

V. APPLICATION TO A FEW STRUCTURES

In this clause, applications of the values given in Table VII and VIII are made to illustrate the proposal. The two cases are focused on physical damage (D2) only.

A. *Case 1 - Industrial structure with danger for the environment*

This is a hypothetical structure. The structure 50 m x 30 m x 12 m is surrounded by smaller structures. The ground flash density N_G = 2 strike/year/km². A single LV line is connected and the building is considered as a single zone. There are fire provisions: automatic extinguishers, and the risk of fire has been evaluated as being ordinary. In case of fire the structure can release toxic fumes but they will remain inside the site fence due to wind direction and amount of such fumes. To evaluate the risk we have compared results obtained if using Ed.1 of EN 62305-2 [6] and the proposed methodology derived from Ed.2 of EN 62305-2 [2]. L_B, L_{BE}, L_V, and L_{VE} as proposed above have been calculated leading to the following results (see Table IX).

TABLE IX. PARAMETERS CALCULATED FOR CASE 1

Values for various parameters	**Risk evaluated with Ed.2 of EN62305-2 modified**	**Risk evaluated with Ed.1 of EN62305-2**
L_B	$6.39 \cdot 10^{-5}$	$1.28 \cdot 10^{-2}$
L_{BE}	$5.00 \cdot 10^{-5}$	/
L_B total	$1.14 \cdot 10^{-4}$	/
L_V	$6.39 \cdot 10^{-5}$	$1.28 \cdot 10^{-2}$
L_{VE}	$5.00 \cdot 10^{-5}$	/
L_V total	$1.14 \cdot 10^{-4}$	/
R_B	$1.29 \cdot 10^{-6}$	$1.45 \cdot 10^{-4}$
R_V	$2.68 \cdot 10^{-7}$	$3.01 \cdot 10^{-5}$
R_1	$1.56 \cdot 10^{-6}$	$1.75 \cdot 10^{-4}$
Level of protection for LPS and SPDs	Self-protected	II
R_1 reduced thanks to LPS	$1.56 \cdot 10^{-6}$	$7.85 \cdot 10^{-6}$

In such a case, the risk evaluated with Ed.1 gives a higher risk (coefficient 20 multiplying the risk of loss of people inside the structure due to danger for environment) than if we use Ed.2, modified by the proposed methodology (risk being a sum of risk of loss of people and risk directly related to the environment).

However, it must be noted that if we use the Ed.2 of EN 62305-2 without the suggested modifications (introduction of r_p and r_f in the calculation of L_{BE}), the risk evaluated is higher than for Ed.1 (level of protection I necessary instead of II). One of the main reasons to revise the environment risk was because this risk was very often overestimated by using a multiplying factor related to the risk inside the structure to describe what happens outside of the structure. To achieve this goal of risk reduction, it is necessary to help the users of EN 62305-2 Ed.2 estimating the environmental risk described therein. This is the main purpose of this contribution.

B. *Case 2 - Laboratory with possible release of radioactive elements dangerous for the environment*

This case is based on a real structure for which the risk was evaluated according to EN 62305-2 Ed.1 [6] and for which a danger study has been elaborated to evaluate the impact of the structure to the environment. The structure has an equivalent capture area of 8 100 m² and is surrounded by smaller structures. The flash ground density N_G = 2 strike/year/km². There are 6 lines (LV, data …) connected to 5 different adjacent buildings and a power substation. The building is considered as a single zone. There are fire provisions: automatic extinguishers, and the risk of fire has been evaluated as being ordinary. The yearly time of presence inside the structure is 2 800 hours. One of the scenarios leads to a possible release of radioactive elements but quantity and severity of this release is such that no danger is considered outside the fence of the site. To evaluate the risk we have compared, as for case 1, results obtained if using Ed.1 of EN 62305-2 [6] and the proposed methodology derived from Ed.2 of EN 62305-2 [2]. L_B, L_{BE}, L_V and L_{VE} as proposed above have been calculated leading to the following results (see Table X).

TABLE X. PARAMETERS CALCULATED FOR CASE 2

Values for various parameters	Risk evaluated with Ed.2 of EN62305-2 modified	Risk evaluated with Ed.1 of EN62305-2
L_B	$4.11\cdot10^{-5}$	$8.22\cdot10^{-3}$
L_{BE}	$2.50\cdot10^{-4}$	/
L_B total	$2.91\cdot10^{-4}$	/
L_V	$4.11\cdot10^{-5}$	$8.22\cdot10^{-3}$
L_{VE}	$2.50\cdot10^{-4}$	/
L_V total	$2.91\cdot10^{-4}$	/
R_B	$2.37\cdot10^{-6}$	$6.69\cdot10^{-5}$
R_V	$1.21\cdot10^{-5}$	$3.41\cdot10^{-4}$
R_1	$1.45\cdot10^{-5}$	$4.08\cdot10^{-4}$
Level of protection for LPS and SPDs	III	III with SPD having a level of protection > 1 (P_{SPD} = 0.005)
R_1 reduced thanks to LPS	$5.26\cdot10^{-7}$	$8.40\cdot10^{-6}$

As above (case 1), the risk evaluated with Ed.1 gives a higher risk than if we use Ed.2, modified by the proposed methodology.

However, it must be also noted that if we use Ed.2 of EN 62305-2 without the suggested modifications, the risk evaluated is much higher than for Ed.1 (level of protection better than I necessary corresponding to a probability P_B and P_{EB} of 0.001 instead of level III for LPS and P_{SPD} = 0.005 for SPDs).

For this case, the danger study provided by the site manager clearly indicates that the risk evaluated by Ed.1 needed to be reduced to reflect the real potential of risk. Without appropriate changes to the method and easy evaluation of key parameters (mainly introduction of r_p and r_f in calculation of L_{BE} and L_{VE}, and proposed evaluation of parameters t_e and L_{FE}), the risk cannot satisfactorily reflect the risk evaluated by other means (danger study).

VI. CONCLUSIONS

As a conclusions of these two cases (and other cases not documented in the paper) it appears clearly that the calculation of L_{BE} and L_{VE} (and consequently also of the overvoltage related loss factors L_{CE}, L_{ME}, L_{WE}, and L_{BE}) needs to be amended to better reflect the reality and not to overestimate the risk outside the structure, i.e. for the environment. In addition, to make the calculation easier and to cover cases where these parameters are hardly known, it is necessary to give typical values for L_{FE} and t_e.

Proposals being made in the present contribution will need to be further discussed and evaluated. The case of structure with risk of explosion will need to be further analyzed. Previous calculations on the base of EN 62305-2 Ed.1 [6] and on the base of the unmodified EN 62305-2 Ed.2 [2] have shown that an explosive scenario leading to an “effect area” outside the site fence cannot be satisfactorily reduced with usual protection measures of usual quality. Only if the modifications to the calculation described in Chapter IV are considered (see (8), (9), (11), (12)) and the values proposed in Tables VI – VIII are used, the protection measures seem to be realistic and comprehensible.

VII. ACKNOWLEDGEMENT

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[3] IEC 60079-10-1: Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres.

[4] IEC 60079-10-2: : Explosive atmospheres – Part 10-2: Classification of areas – Combustible dust atmospheres.

[5] Circulaire DPPR/SEI2/CB-06-0388 du 28/12/06 relative à la mise à disposition du guide d’élaboration et de lecture des études de dangers pour les établissements soumis à autorisation avec servitudes et des fiches d’application des textes réglementaires récents.

[6] EN 62305-2:2006-02: Protection against lightning – Part 2: Risk management.