Trends in the lightning risk assessment methods in France

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Abstract

IEC risk management standard has been transformed to a French document in order to get experience and facilitate his acceptance when time of voting at CENELEC level will come. Authors have extensively used this method on various cases. Based on their experience a few recommendations are made. Tools used to facilitate application of the method are also presented.

1. Introduction

IEC 62305-2 standard for risk assessment is about to be published. This is a part of the group of new standards that IEC TC81 (International Electrical Commission - technical committee N°81 in charge of lightning protection of structures) is about to deliver.
62305-1 deals with general matters
62305-2 deals with risk assessment : do I need protection and if yes which one ?)
62305-3 deals with lightning protection systems (LPS) : how to set-up such a system and select its components ?
62305-4 deals with lightning electromagnetic pulse (LEMP) : how to set-up and design shields and bonding as well as selection of SPDs (surge protective device) used for equipotentiality ?
and 62305-5 deals with telecom and power networks

France was using so far its own standards for risk (either risk against direct lightning NFC 17-100 or risk against induced surges C 15-443. From time to time we were also using IEC 61662 (ancestor of IEC 62305-2) for complex sites. Recognizing that method described in 62305-2 is more powerful than previous methods, French National Committee has decided to adopt the latest version of the CDV (document for voting just before it becomes a standard) version in a French document. Purpose of this was to get experience on this method and been able to make comments and propose improvements especially at CENELEC level. To achieve this, CDV version has been improved by some last minute modification brought by the IEC Working Group, it has then been adapted to the French need and also of course translated in French. Last modification has been to remove from the document the part dealing with services as it was thought by French National Committee that his part was not really relevant to our needs. This document has for the time being the status of a Guide and not a standard due to European rules which prevent development of a national standard when an IEC or CENELEC standard is under project.
Since publication of this document in early 2005 the method (called C 17-100-2 in France) has been extensively applied by the authors on many site including chemical sites, explosive sites as well as other industrial sites. Purpose of this paper is to present the tools developed to help applying the method both for getting data from the site as well as for making all calculations. We will also present the difficulties we met as well as some need of clarification in the standard.

2. Quick description of the French standards for risk assessment

There are mainly two standards which were used until now.

First one is 17-100 (national lightning protection standard) which includes an annex dealing with risk assessment. Basically this is using parameters describing the building dimensions and structure (roof, walls …) as well as its use and content including some environmental risks and the flash ground density.
These parameters are connected together with two formulas which are assessing the lightning occurrence from one side and the acceptable risk from the other side. Comparison of both gives the needed protected level for the LPS.

Advantages : simple method, easy to collect raw data, based on experience of the working group which made the proposal
Drawbacks : oversimplified method, lack of taking into account natural components, parameters are not based on scientific calculations

Second standard that we are considering is the NFC 15-100 (our national electrical code) including application guide C 15-443. In the same way a few parameters are used including flash ground density, length of LV overhead line, and cost of equipments, loss of use and consequence on human life. Parameters are grouped in two formulas one describing surge occurrence and the other one describing the consequences of surges.

Advantages : simple method, easy to collect raw data, based on experience of the working group which made the proposal
Drawbacks : oversimplified method, parameters are not based on scientific calculations

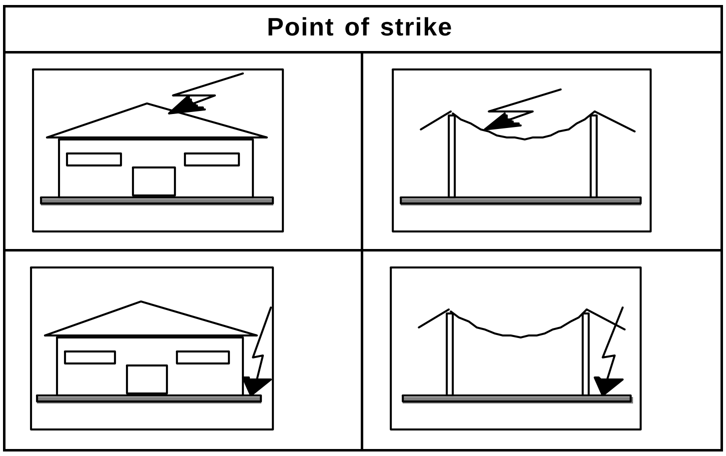
The main criticism we can make on both methods is that they are too specific and they didn't take into account the risk on a global way (lightning, surges …).

3. UTE C 17-100-2 method

As previously explained this method is based on previous IEC 61662 standard which has been published originally in 1995. Both authors have used such a method and it was already found very powerful. However, its complexity pushed it to be used only for complex sites.

The new method is not so different in essence from the original one but many parameters have been refined. Opposed to other French methods, this one is purely based on probabilistic calculations and the parameters are coming from international scientific studies which have been largely documented and published. This method based on an existing one (61662) with already ten years experience, with better definition of parameters and accepted with a quite large international consensus was a sound basis for developing the French document.

4 sources of damage are defined (see figure below) : flashes to a structure, flashes near a structure, flashes to a service and flashes near a service.



3 types of damages are defined : injuries to living beings; physical damage (damage to the structure i.e. destruction by direct hit, fire, explosion …) and failures of electrical equipments.

4 types of losses are defined : loss of human life, loss of service to the public, loss of cultural heritage and loss of economic value (structure and its content, service and loss of activity). For each of this loss a risk is defined.

This can be summarized on the following table, where risk associated with damages are defined by letters S standing for safety, F standing for fire and O for overvoltages :

Risk in a structure for each type of damage and of loss

Loss **Damage**	**L1** **Loss of human life**	**L2** **Loss of service the public**	**L3** **Loss of cultural heritage**	**L4** **Loss of economic value**
D1 Injuries to living beings	RS	–	–	RS(1)
D2 Physical damage	RF	RF	RF	RF
D3 Failure of electric equipments	RO(2)	RO	–	RO
1 – Only for properties where animals may be lost 2 – Only for structures with risk of explosion and for hospitals or other structures where failures of internal systems immediately endangers human life;				

The total risk is then calculated has a sum of risk components defined below:

Risk component for a structure due to flashes direct to the structure :

- RA: component related to injuries of living beings caused by touch and step voltages in the zones up to 3 m outside the structure.
- RB: component related to physical damage caused by dangerous sparking inside the structure triggering fire or explosion, which may also endanger the environment.
- RC: component related to failure of internal systems caused by LEMP.

Risk component for a structure due to flashes near the structure :

- RM: component related to failure of internal systems caused by LEMP.

Risk components for a structure due to flashes to a service connected to the structure :

- RU: component related to injuries of living beings caused by touch voltage inside the structure, due to lightning current injected in a line entering the structure.
- RV: component related to physical damage (fire or explosion triggered by dangerous sparking between external installation and metallic parts generally at the entrance point of the line into the structure) due to lightning current transmitted through or along incoming services.
- RW: component related to failure of internal systems caused by overvoltages induced on incoming lines and transmitted to the structure.

Risk component for a structure due to flashes near a service connected to the structure

- RZ: component related to failure of internal systems caused by overvoltages induced on incoming lines and transmitted to the structure.

For each of the risk associated to losses (called R1 to R4) and which need to be considered for the studied structure, the total risk will be calculated according to table below.

Risk components to be considered for each type of loss in a structure

Source of damage	**Flash to the structure**			**Flash near the structure**	**Flash to a line connected to the structure**			**Flash near a line connected to the structure**
Risk component Risk for each type of loss	RA	RB	RC	RM	RU	RV	RW	RZ
R1 Risk of loss of human life	**RA +**	**RB +**	**RC1) +**	**RM1) +**	**RU +**	**RV +**	**RW1) +**	**RZ1)**
R2 Risk of loss of service to the public		**RB +**	**RC +**	**RM +**		**RV +**	**RW +**	**RZ**
R3 Risk of loss of cultural heritage		**RB +**				**RV +**		
R4 Risk of loss of economic value	**RA2) +**	**RB +**	**RC +**	**RM +**	**RU2) +**	**RV +**	**RW +**	**RZ**

1) Only for structures with risk of explosion and for hospitals or other structures where failures of internal systems immediately endangers human life 2) Only for properties where animals may be lost

Let's imagine a telecom center (service to the public) which is located inside a building which is a national heritage. The owner of the building is willing to know if lightning protection will provide some savings to him. In addition, risk for loss of human life need to be considered as there are some people inside (workers and customers). In such case risk R1, R2, R3 and R4 will be calculated. For each of the risk the appropriate protection measures may differ. For the simplest case of a building where only protection of human being is considered then only R1 will be calculated.

Each of the risk components itself will be calculated by using the generic formula given below

$$RX = NX\ PX\ LX$$

NX is the number of dangerous events for that risk
PX is the probability of damage for that risk;
LX is the consequent loss for that risk
And X can take the values A, B, C, M, U, V, W or Z

The risk component is defined as the number of lightning strikes on the building multiplied by the probability that this strike lead to a damage (hopefully not all strikes will create a damage) and multiplied by a loss factor taking care of the amount of losses (how many people are possibly injured, what are the possible protection measures)

For risk R1 to R3 the total risk need to be lower than the acceptable risk given in the standard(see table below)

Typical values of tolerable risk RT

Types of loss	**RT** (year^{-1})
Loss of human life	10^{-5}
Loss of service to the public and Loss of cultural heritage	10^{-3}

For risk R4 there is no tolerable risk as the economic perception is different from a small company to a large group. Calculation is then made by comparing annual amount of losses without protection, annual amount of residual losses as soon as protection measures are implemented and annual cost of protection measures taking care of maintenance. The result is then an annual saving for the owner of the structure.

When risk cannot be sufficiently reduced, it is possible to defined specific zones inside the building to better protect the areas which are the more dangerous and avoid to over protect the complete building.

4. Tools developed to apply this method

As previously mentioned, this IEC standard became a French document in January this year. As such it is used and will be used more and more and will replace existing documents dealing with the same topic. To allow the use of this standard for most of the lightning professionals it has been decided to provide tools to the user in order to facilitate his job. These tools are described below

Forms

INERIS has developed in France a qualification for lightning protection professionals. This is called Qualifoudre. Under this qualification scheme, a professional can claim expertise for site survey, production of lightning protection equipment, set-up of protection measures and control of installations. His expertise in the selected field is attested by a letter which can be S for professional being able to work on simple structures (a house, small office) or C for complex structures (chemical plant for example) or even I for intermediate ones (not a simple nor a complex structure). For companies which are claiming study capability "C" the ability to use UTE C 17-100-2 risk method needs to be proved. Under the Qualifoudre scheme many tools are provided to qualified companies, one of them being a form to facilitate data collection.

Fac simile of first page of Qualifoudre data collection form (in French)

Modèle QF_ARF_R1
juin 2005

Fiche descriptive d'une structure à protéger contre la foudre

DESIGNATION DE LA STRUCTURE (N°, nom, fonction):

....

A. STRUCTURE

Dimensions (Longueur, largeur, hauteur maximale, hauteur de cheminée ou de la protubérance quand elle existe)	
Situation relative de la structure (déterminée à partir du plan de masse : éloignement de(s) la structure(s) la plus proche en m)	
Nombre de niveau	
Type de mur (béton, métallique, bois…)	
Type de couverture (béton, métallique, fibrociment, tuile…)	
Type de sol à l'intérieur (béton, linoléum, bois…) et à l'extérieur	
Distance entre les fermes de la charpente métallique	
Distance entre les pannes qui relient les fermes	
Résistivité du sol (ohm.m)	
Type de sol (argile, granite, silice, humus…)	
Y a t il une prise de terre en fond de fouille ?	
Les liaisons d'équipotentialité des masses sont elles réalisées ? Sont elles conformes aux exigences des normes « foudre » ?	
Les ferraillages du béton armés sont ils reliés entre eux et au fond de fouille ? (quelle est la dimension des mailles)	

B. INSTALLATIONS COMPLEMENTAIRES

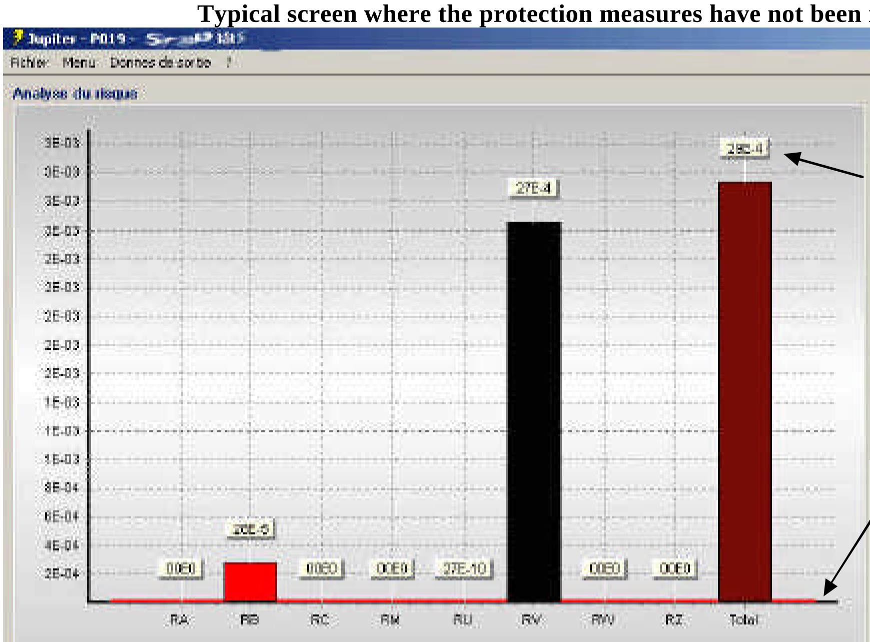
Mur coup feu séparant 2 zones (durée)	
Peut-on définir des zones dans le bâtiment ? (avec des caractéristiques physiques bien déterminées comme un blindage complémentaire ou un lieu de stockage dangereux fermé)	
Stockage extérieur à moins de 3 m du bâtiment (produit, quantité, contenant): ??? vient d'où ?	
Installation de paratonnerre sur le bâtiment (type, année, état)	
Nombre de conducteur de descente du paratonnerre	
Nombre de prise de terre pour la foudre	
Nombre de compteur de coup de foudre	

In addition, under the Qualifoudre banner, an internet forum offers possibility to users of the method to exchange on problems encountered or even to ask for some help.

Jupiter Software

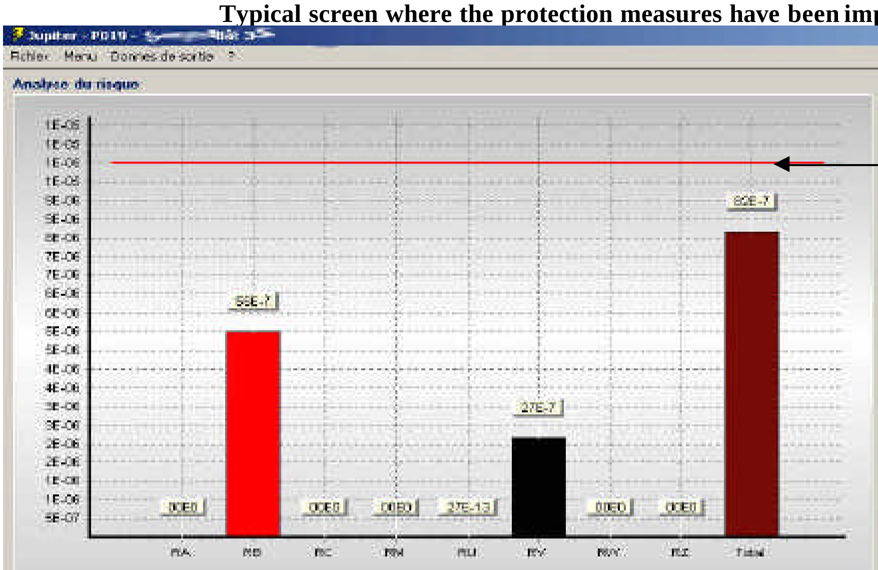
This has been developed by UTE. The software is taking into account all the parameters described in the standard and offer to the user practical facilities such as the possibility to test immediately various possible protection means effect and selection of the most convenient one.

Typical screen where the protection measures have not been implemented



The user of the software should the introduced some protection measures in order to have the total risk below the red line (tolerable risk)

Typical screen where the protection measures have been implemented



With the software you have also access to many features. One of them is the green/red color code. Every risk component which is red is greater than tolerable risk. It is green in the other case. It is then very easy to determine the part of structure which needs a special care.

5. Needs for clarification

No doubt UTE C 17-100-2 is a powerful tool. However, it is needed to clarify a few things to cover all the needs of the French lightning protection community (and perhaps of other countries too).

SPDs : there is no relationship between SPD characteristics and probability value that you can select in the standard. Of course, when you are an expert you know how to select the appropriate SPD and if one SPD is better than another. But who is really able to select the probability associated with an SPD which is behaving better than the requirements given by the calculation. An SPD protecting at1 kV offers a better protection than an SPD protecting at 1,5 kV. How can we quantify this ? If the need protection level is 1,5 kV and the needed lightning discharge capacity is 10 kA who could say which of the following SPDs is the best ? SPD1 has a current capability of 40 kA and protective level of 1,5 kV. SPD2 has a current capability of 15 kA and a protective level of 1 kV. It is already not easy to say what is the best choice but it is furthermore difficult to associate probabilities to both.

In addition, the concept of coordinated SPD is defined. You need to use SPDs in front of each sensitive equipment and SPDs should all be coordinated together. But if you use only entrance SPDs (SPDs for equipotentiality) and other SPDs in front of a particular zone (with a high fire risk for example) are you complying with criteria to consider you have a coordinated system ?

Shielding of cables : the key parameter is the shield resistance. How is able to give this value in practice ? Surely not the electrical responsible for the building. Should we make measurements ? Try to locate the manufacturer reference number and try to gte data from him ? If you have many days in front of view it is perhaps possible but for most of the cases a simplification is needed.

Number of people injured inside a building in case of a lightning strike : in some cases this data can be obtained from discussions between the structure owner or manager and the lightning expert but in a lot of other cases this is quite difficult to achieve. In addition, external zones are only considered for the risk of touch and step voltage but if you have an explosive area in the building or if you store dangerous products with possible impact on environment it is likely that people outside the building will be injured and not due to step and touch voltage. This needs to be considered. In addition, when a toxic cloud is released to the atmosphere in case of surges generated by a lightning strike, how should we consider the number of people potentially injured ? 1000, possibly more … All of that should be better defined in the standard.

6. Conclusion

French national committee has decided to implement the draft international standard IEC 62305-2 into a French document numbered UTE C 17-100-2. This is clearly supported by most of the actors and especially INERIS which has included this requirement in his qualification scheme named Qualifoudre. To support this development, tools have been developed and UTE, the French electrical standard body, has developed a powerful software. This will allow a greater number of people to use the method. At the same time, to allow this general use, a few parameters need to be clarified. They are accessible to the lightning expert, even if in some cases it may be quite difficult to get the data or relate these data to probability values. But for less skilled users, the task may be discouraging. The risk calculation being so powerful it should be a pity to not make the necessary simplifications and clarifications which will make this document the only reference in lightning risk management.