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LIGHTNING RISK ASSESSMENT FOR EXPLOSIVES SITES TAKING INTO ACCOUNT ZONES 0, 1 AND 2 AND ENVIRONMENTAL RISK

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Abstract - The newest draft version of IEC/EN 62305-2 standard dealing with risk management includes the environmental risk in a much better way than before. It takes also into account all the explosives zones when only zones 0 and 20 where addressed before. Purpose of this paper is to show how these changes will modify the level of risk obtained with previous version of standard. The environmental risk is clearly more tailored to what is needed with version 2 of the standard even if it may lead to increased risk compared to before when insufficient data exist. When taking into account the explosives zones 1, 2, 21 and 22, the risk may increase even if the new method tends to reduce the risk globally. An example of use of storm detectors to reduce the risk is also given.

1 - INTRODUCTION

The newest draft version of IEC/EN 62305-2 [1] standard dealing with risk management includes the environmental risk in a much better way than before. Initially the risk to environment was addressed as multiplying factor 20 to 50 on the human risk inside the structure. This mean that a structure with no human presence was having a risk virtually nil and multiplying this by 50 would still lead to a risk nil outside the structure fences even if the product stored inside the building are creating very dangerous smoke when burning. On the reverse, a structure with a high human risk inside the structure (for example, high fire load, 24 hours a day of presence...) will lead to high environmental risk outside the structure, by simply multiplying a high value of risk by 20 or 50. New standard proposal is making a sum for the risk inside structure and outside structure and thus allowing a better appraisal of the real risk and contribution of each of its components.
For explosive structure, present published standard only deals with zone 0 and 20 so almost permanent duration for explosive areas. Idea behind this, was that probability of having at the same time a lightning event and an explosive zone was only meaningful for almost permanent explosive areas so zone Z0 and Z20. But in fact, zone 1 or 21 could have a duration up to 1 000 hours so the probability to have at the same time lightning and explosive area is not so small. It has then been decided to include zones Z1 and zone Z21 into the new draft for the standard. Furthermore, even zone 2 and 22 that have short yearly duration are included. Of course a derating factor has been introduced to make zones 1 and 21 less important than zones 0 and 20 and same for zone 2 and 22 compared to zone 1 and 21.
This paper shows an example on a typical chemical site of the effect of taking into account these new explosive zones. As can be assumed the risk increases a lot as there are more zones 1 and 2 than zones 0. Influence of a storm detector compliant with the new European standard (final draft) will be also shown.
As far as environmental risk is concern, the detail of calculation is limited in the new draft and we will concentrate on showing by examples, how this new risk component can be used.

2 – RISK CALCULATED WITH ZONES 1, 2, 21 AND 22

2.1 – Definition of explosives zones

We need first to define what zones 0, 1, 2, 20, 21 and 22.

Gaseous zones :

Zone 0 : location where an explosive atmosphere made of a mix between air and flammable gas, vapor or fog, is existing permanently, for long periods or very frequently

Zone 1 : location where an explosive atmosphere made of a mix between air and flammable gas, vapor or fog, can exist temporarily in normal operation (less than 1000 hours / year)

Zone 2 : location where an explosive atmosphere made of a mix between air and flammable gas, vapor or fog, is not supposed to exist in normal operation or for only short period of time (less than 10 hours / year)

Dust zones :

Zone 20 : location where an explosive atmosphere made of a flammable dust cloud, is existing permanently, for long periods or very frequently

Zone 21 : location where an explosive atmosphere made of a flammable dust cloud can exist temporarily in normal operation (less than 1000 hours / year)

Zone 22 : location where an explosive atmosphere made of a flammable dust cloud, is not supposed to exist in normal operation or for only short period of time (less than 10 hours / year).

2.2 – Studied site

The site considered is a petro-chemical unit in a place where the flash ground density is 1.9 strike/year/km².
The building is made of a metal structure with dimensions 30 x 60 m with an average height of 12 m and a highest point (chimney) located at 50 m. The metal mesh is 5 x 5 m.

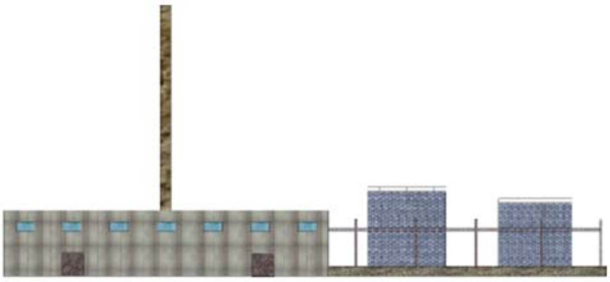

Figure 1 – Studied site

Connected lines are shielded and circulating on a metallic rack protecting them from direct lightning impact except the one located at the very top.
Presence of workers and maintenance technicians exist in or around the structure for more than 2 000 hours a year. A storm detector exist on the site that may be used to reduce the time or presence in case of a storm approaching. In that case, the time of presence can be reduced down to a little more than 400 hours (taking into account the efficiency of the storm detector based on data obtained from the manufacturer plus a necessary margin to take care of the fact that the draft standard for storm detector is not really giving figures for this efficiency nor a direct way to obtain it).
Products used and produced in that unit are dangerous for health and thus the risk for environment is considered in the calculation.
There is no explosive zone 0 or 20, but the fire risk is high due to the characteristics of the product and their quantity. There are numerous zones 1 and 2.

2.3 – Results obtained without explosives zones and without storm detector

We used Jupiter version 1.3.0 to make the calculations of the risk value with present version of the 62305-2 standard [2].

The result of the calculation is shown below :

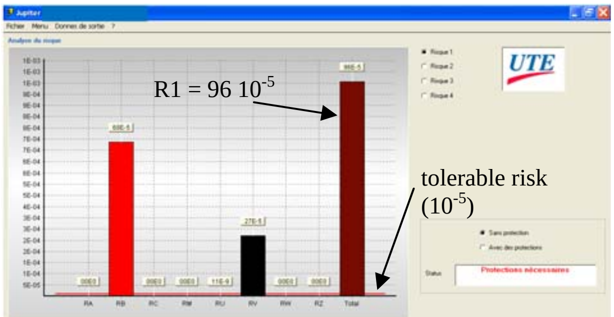

Figure 2 – Initial calculation of the risk (without protection)

The risk is higher than the tolerable risk as can be seen on figure 2. The tolerable risk (10^{-5}) is shown on the figure by the red line almost superposed with the horizontal axis. Component Rb (direct lightning strike on the structure, left in red) and Rv (direct lightning strike on the line, middle in black) exceed the tolerable risk as well as the total risk (right in brown). It is then needed to install a lightning protection system on the structure with a level higher than 1 due to high component Rb. A Pb equal to 0.01 is needed (we will call it level 1+ in that document). This Pb value means that natural components of the structure need to be used as downconductors. This requirement is easily achieved by the metal frame of the structure , This will mean that SPDs Type 1 will be needed at the entrance of the lines and this will also cover risk Rv (direct impact on line will be considered only for the risk of sparkover between the rack and the line circulating on it).
With these protection measures the calculated risk pass below the tolerable risk as can be seen in Figure 3.

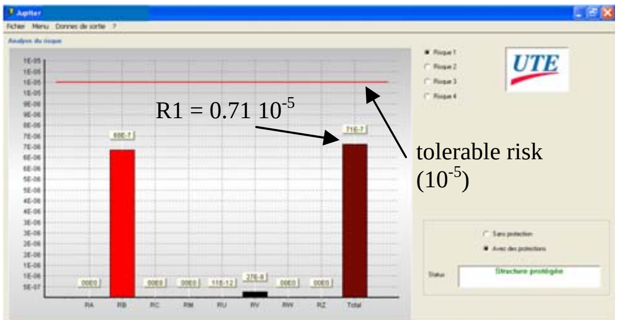

Figure 3 – risk calculated with level of protection 1+

Risk has been reduced from 96 10^{-5} to 0.71 10^{-5}.

2.4 – Results obtained without explosives zones but with storm detector

It is possible to reduce the risk and thus the needed level of protection by using a storm detector.
The following method has been proposed to be able to use storm detectors in risk calculation and is under discussions.
The reduction of the time of presence (tp) may be reduced by the mean of a storm detector provided that a procedure is defined and applied to reduce the time of presence based on information given by the storm detector. The storm detector should be according to the new CENELEC standard 50536 [3] or any equivalent national standard until an IEC standard is developed for such a device. The storm detector and the related procedure become then part of the protection plan and should be included in the data file for the project/site including the maintenance program.
The relevant parameter to reduce the time (tp) is named in the standard Failure to Warn Ratio (FTWR) and is defined as the ratio of failure to warn with respect to the total number of situations with lightning related events in target. As a matter of fact, if there is no indication the risk remains and cannot be reduced.
In the calculations the time tp can be reduced to obtain a time t'p by using the following formula :

$$t'p = tp * FTWR.$$

During the time of presence tp a certain number n of lightning events can occur. Amongst these n events, n1 will be detected and n2 = n - n1 will not be detected.

We have [4] [5] :

$$FTWR = n2 / n$$

$$\text{so} \quad n2 = n * FTWR.$$

Assuming, that the distribution of lightning events over the time of presence tp is constant (this is the basis for the risk calculation); we have n events during the time tp. The time tp can be divided into two periods of time :

- tp1 where people were evacuated from the dangerous area or the danger stopped (for example stopping a dangerous or explosive process by using storm detector indication)

- tp2 where people should have been evacuated but due to failure to warn, they have not been evacuated or the process stopped

We have:

$$tp = tp1 + tp2$$

$$\text{and} \quad tp/n = tp1/n1 = tp2/n2$$

The reduced time of presence t'z is equal to

$$tp2 = n2\ tp /n = n * FTWR * tp /n$$

$$\text{so} \ : t'p = FTWR * tp$$

In risk equations tp can then be replaced by t'z should a storm detector complying with the above requirements is used.
Based on such a method the risk can be reduced in combination with lightning protection measures at level 2 only instead of more than 1.

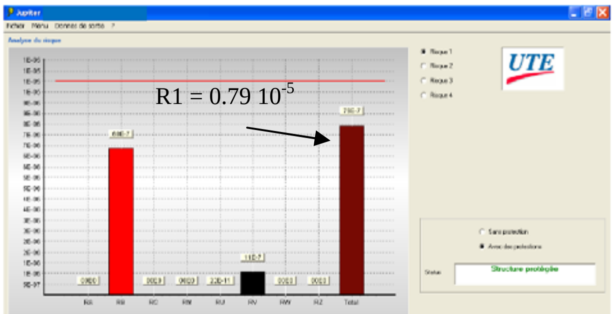

Figure 4 – risk calculated with storm detector and level of protection 2

Risk has been reduced to 0.79 10^{-5}.

2.5 – Results obtained with explosives zones 1 and 2

The chemical plants include numerous zones 1 and 2. The calculations includes a explosive risk (Rf = 1).
The initial risk is much higher than before and especially as many risk parameters are now calculated when they were not in absence of explosive zones.

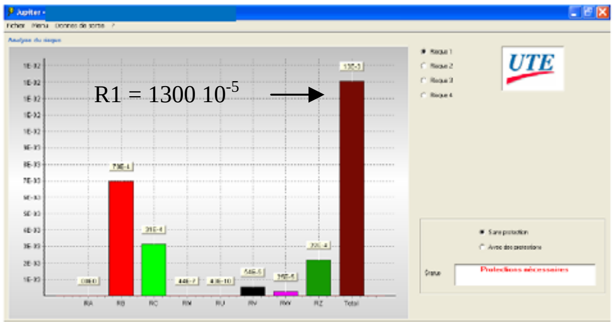

Figure 5 – Initial calculation of the risk taking into account zones explosives 1 and 2 (without protection)

However, the risk is now so high that even in using the highest possible protection means (Pb = 0.001, named level 1++ in our document) it is impossible to have the risk reduced below the tolerable risk.

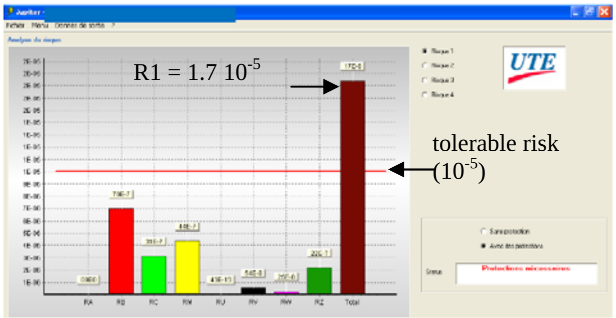

Figure 6 – calculation of the risk taking into account zones explosives 1 and 2 and maximum available level of protection

Risk has been reduced to 1.7 10^{-5} but remains well above the tolerable risk of 1 10^{-5}.

The easiest way to reduce the risk is then to use a storm detector in conjunction with a lightning protection system at level 1++. It need to be noticed than in chemical plant, mainly made of metal structure, level of protection 1++ is easily obtained with natural component. In addition, use of storm detection is often already used in this industry in order to avoid filling tank with dangerous or flammable products in lightning periods. The use of such storm detectors is then not quantified but procedures already exist. To introduce the local storm detectors in risk calculation doesn't create additional burden for the industry.

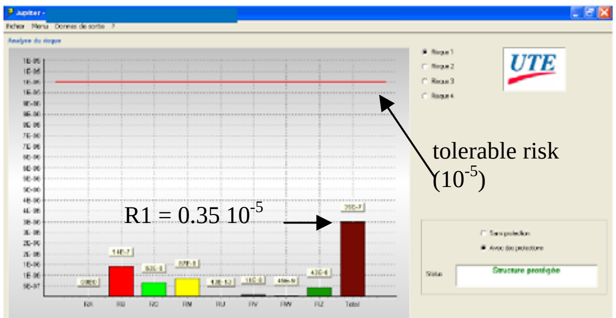

Figure 7 – calculation of the risk taking into account zones explosives 1 and 2, storm detection and maximum available level of protection

Risk is then very low at 0.35 10^{-5}.

2.6 – Conclusions on the effect of explosives zone 1, 2, 21 and 22

The needed level of protection without considering zones 1, 2, 21 and 22 is more than 1 (1+). This can be reduced down to a LPL 2.
By considering zones 1, 2, 21 and 22, the risk cannot be reduced below tolerable risk but conjunction of a LPL 1++ and a storm detector succeed in reducing the risk.

Based on this example we can derive more or less general rules : The risk increases a lot by taking into account zones 1, 2, 21 and 22 and especially zones 2 and 22 that are the most numerous as well as the one with significant volume outside of structure (vents ...). In some cases the zone 2 is having a radius of a few tens of meters around the structure and this is of course difficult to manage in the risk reduction process.

However, the main cause of the risk being so high is primarily due to the environmental risk considered in that study. As noticed previously this is badly addressed in today's version of the standard and it is expected that the new standard will lead to more realistic results

This being said, the explosives risks need to be addressed with care especially when they are spreading outside of the structure (fuel tanks for example) and a mix between deterministic and statistical approach will be probably needed to address in a realistic way the explosive risk. Zoning will also be the key issue to find appropriate lightning protection solutions. This is of course already done today in our studies but the big quantity of zones 2 inside structures and also the big quantity of structures with zones 2 within a chemical plant will mean that an extra care will be needed for the risk assessment studies.

3 – ENVIRONEMENTAL RISK

As explained previously the environmental risk will be better addressed by the new version of the standard. In addition, new calculations methods, especially for losses have been introduced and need to be considered for comparison sake.

3.1 – Studied site

To show the impact of the new standard, we have selected another example shown in the picture below.

The production facility is making dangerous chemical products and the danger study showed that environmental risk related to lightning should be considered. Due to mixing of structure and lines we will consider a single structure with different zones.

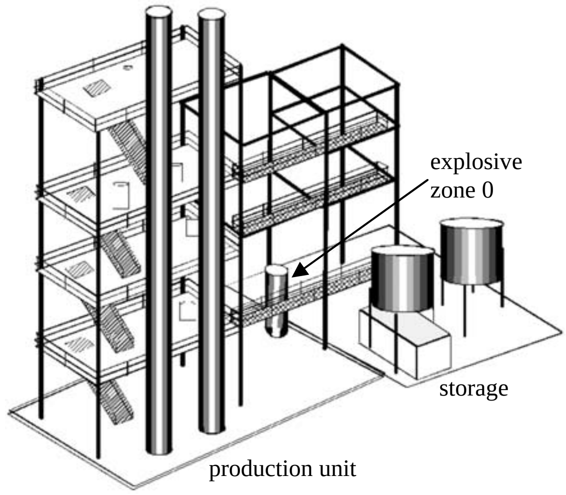

Figure 8 – typical structure for considering environmental risk

The structure contains in addition of the production unit two 50 m metallic chimneys and two metallic storage tanks. The collection area is mainly due to the chimneys.

Dimensions of the structure (not considering the chimneys) are: 20 x 50 m with an average height of 40 m
The production unit is made of a metallic mesh 5x5 m. It is connected to a remote control building by 40 m lines (both power and signal) running in a metallic tray at 6 m above ground level.

The structure includes an explosive zone 0, localized in a metallic tank. There is a fire detection and a local fire brigade is existing in the site.

Time of presence is different in the storage tanks area and in the production unit and this will lead to 3 zones inside the structure : storage, main part of production unit (including chimneys) and explosive zone 0.

3.2 – Risk result when comparing draft version of standard and present version of standard

The risk value calculated with present version of the 62305-2 standard is 4.5 10^{-3} when the risk obtained with the new draft of the same standard is 5.2 10^{-4}, that is almost 9 times lower.

The new draft doesn't increase the risk, rather the reverse. This is due to the fact that the loss factor is better defined in the draft and is related to the number of people in each zone when previously it was related to the number of victims that was generally difficult to assess [6] and then was either maximized to get a safety margin or using default values.

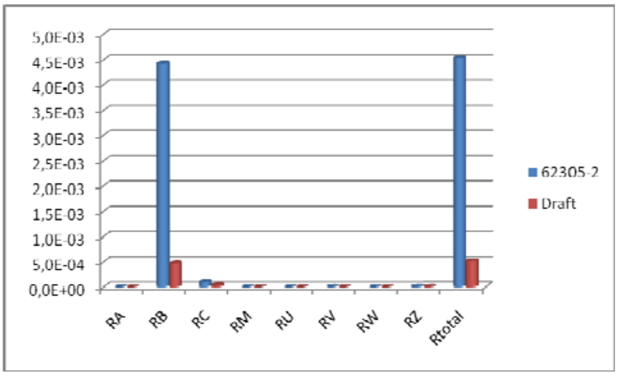

Figure 9 – risk comparison between draft and present standard

3.3 – Risk comparison with a single zone and environmental risk

To study the influence of the environmental risk proposed in the draft; we consider the same structure but as a single zone.

The risk calculated with the present version of standard is then 9.6 10^{-4}.

The new standard defines a human risk R1 evaluated to be equal to 2.3 10^{-4}, an environmental risk Re equal to 9.6 10^{-3} and then a total risk R1t equal to 9.8 10^{-3}.

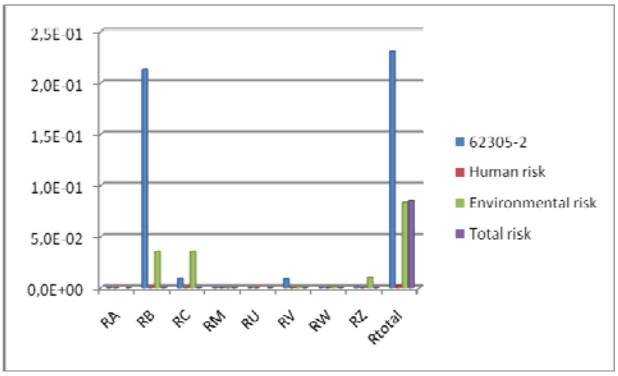

Figure 10 – risk comparison between draft and present standard regarding environmental risk

3.4 – Conclusions on the draft standard and environmental risk

Once again, the risk calculated with the new method is lower than with present standard (ratio greater than 100). Of course, the risk calculated with a single zone is greater than when a better description of the risk is done (3 zones) but this is much more significant with present standard than with draft standard.

The method seems to be better tailored for plants and in general allow more flexibility in calculation.

4 - CONCLUSIONS

The integration of explosives zones 1, 2, 21 and 22 in calculation lead to an increase of the risk with the present version of the 62305-2 standard. A way to reduce the risk is then to use a storm detector in conjunction with a lightning protection system. The new risk method will still lead to lower risk results as the benefit of using new method is much bigger than the drawbacks. This is especially true when environmental risk need to be considered.

The new draft standard for 62305-2 seems to be better tailored for chemical and petroleum plants and in general allow more flexibility in calculation and also more realistic results.

5 - REFERENCES

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[2] “Protection against lightning Part 2 Risk management”, IEC/EN 62305-2, 2006

[3] “Protection against lightning Thunderstorm detection devices”, pr EN standard 50536, 2009

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[5] Alain Rousseau, Wang Jian Chu, Wang Qiang, Ming Tao, “Testing facility and methodology for local detectors” ICLP 2008, paper IX-6

[6] Alain Rousseau, Pierre Gruet “Application of IEC 62305-2 in France on various plants - Proposals for improvements” ICLP 2006, paper VIII-9

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