SENSITIVITY ANALYSIS FOR CONDOMINIUM LIGHTNING PROTECTION RISK ANALYSIS

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ABSTRACT

Today we live in an accelerated world. In our environment there are more facilities to serve our needs than ever before, and today's devices have multiple functions, and probably they will gain new functions as well. They are called smart devices. Smartphones, tablets, smart TV-s and potential smart vehicles will create a new environment. As a result of the continuous development of human living communities (villages, towns and settlements), the dominant usage of smart tools and technologies already represents a new quality level (Smart City). These new devices require a new level of lightning protection. Natural forces endanger buildings as well as human lives. The protection of artificially created objects and of the built environment has always played a prominent role, and nowadays, one of its main areas is the lightning protection of structures. The calculation of the lightning protection is based on the MSZ EN 62305 [1] standard. In the past, several changes were made in the standards and decrees [2], and now the current standard is the MSZ EN 62305. It contains the exact mathematical methods of risk assessment using the parameters of buildings and their installations (e.g. lightning protection installations, cables, flooring etc.). The present research aims to identify the relationships between output parameters determined by the input parameters based on the current standards, and the identification of risks by their analysis in different types of buildings.

KEY WORDS
structure safety, lightning protection, risk analysis, safety instructions, sensitive check

CLASSIFICATION
ACM: 10002978.10003029

JEL: D81, C61

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INTRODUCTION

Natural forces endanger buildings and human lives. The protection of artificially created objects has played a prominent role, and nowadays one of its main areas is the lightning protection of structures. When Benjamin Franklin invented the first lightning rods [3], people started to protect their structures against lightning strikes. Nowadays, based on the observation of natural phenomena, it can be concluded that due to the global warming caused by infrastructural activities, the number of lightning strikes has increased. As much as 1 % of temperature rise will increase the number of lightning strikes by 6 % per annum [4]. Lately, new standards have been issued with the collection of rules on designing lightning protection for buildings. The lightning protection systems of buildings are designed and implemented for the protection of human lives and property. The scope of the present research is to prioritize input parameters for the lightning protection risk management of buildings for different common structures (e.g. condominiums, hospitals, schools, etc.). It is based on the risk computing IT program the author has written. This program calculates the lightning protection risk components using the current standard's calculation method and then aggregates them.

Today many people believe that it is enough to protect against lightning with a lightning rod. Indeed, 50-100 years ago this was enough. The reason is that at that time electrical equipment was quite simplistic compared to the present, and it needed special protection on a very basic technical level. However, today the lightning rod alone is not enough. During that time, lightning protection was enough against fire protection, but as mentioned above, now there are new (sensitive) electrical devices which need a "new" type of protection. This protection is against the secondary effect of lightning strikes [5]. So, this external protection against fire is not enough anymore because of the need for the individual protection of electrical devices and equipment inside the building [6]. While in the past our environment consisted of relatively few components (e.g.: building, heating system, energy supply), by now our artificial environment has become much more complex, thus making lightning protection risks more complex. The earlier standard, with its simpler calculation methods, kept pace with the state-of-the-art and technological development for some time, but after a while it was no longer suitable for this purpose, so MSZ EN 62305 came into force.

INTRODUCTION OF THE SCIENTIFIC PROBLEM

There are 58 parameters for calculating risk. When the building is complex, a large number of parameters has to be taken into account. In addition, the development of lightning protection is becoming more complex. The high number of parameters can also make the design and construction of the lightning protection system of the building considerably more difficult, therefore, knowing the priority order of the existing unique parameters specific to the given building can reduce its complexity.

During the process of risk assessment and the development of lightning protection, it was doubted whether all parameters have the same effect on the result. The present research has a practical benefit. When the building is in the design phase and its lightning protection is being designed, the use of visible solutions for lightning protection, which are almost irreplaceable afterwards, can be avoided.

This research on the lightning protection risk analysis of buildings wishes to identify general and specific parameters and their changes.

During the calculation of risk assessment, the following topics were set up to do this research:

- Grouping of input parameters into strong[1] and not strong groups.
- Identification of extremely strong[2] parameters in strong group.

Due to some co-areas, some other questions arose. This research can be completed with the following topics:

- Lightning protection for non-metallic body vehicles.
- Detection of possible shortcomings in the future draft standards.

The present research aims to achieve the first objectives. Details and other topics will be presented in the final dissertation.

QUESTIONS ABOUT THE RESEARCH

Research questions were set up during the risk assessment of different buildings. The questions and ideas were raised during the calculation and some practical development processes.

RQ_1: Not all input parameters can affect output equally (so can they be grouped into strong and not strong categories?).

RQ_2: If RQ_1 is answere positively, can some parameters be identified as priority within a strong group?

RQ_3: Do the parameters categorized as strong and not strong in the current standard match the strong and not strong grouping of future parameters in the standard?

RISK CALCULATION METHOD

The present research will be based on the calculation of the standard. The lightning protection requirements and the calculation for buildings are contained in the standard MSZ EN 62305 [1], which currently consists of four parts (Figure 1). The specific risk calculation method is described in document 62305-2.

GENERAL PRINCIPLES (MSZ EN 62305-1)

RISK MANAGEMENT (MSZ EN 62305-2)

PHYSICAL DAMAGE TO STRUCTURES AND LIFE HAZARD (MSZ EN 62305-3)

ELECTRICAL AND ELECTRONIC SYSTEMS WITHIN STRUCTURES (MSZ EN 62305-4)

Figure 1. MSZ EN 62305 Standard family [1].

The standard defines four possible risks for lightning strikes:

Table 1. Types of risks [1].

Risk symbol	Risk description
R_1	Risk of loss of human life (including permanent injury)
R_2	Risk of loss of service to the public
R_3	Risk of loss of cultural heritage
R_4	Risk of loss of economic value

The present research will focus on the risk of the loss of human life (R_1).

The standard defines four possible points for the location of a lightning strike (Table 2 and Figure 2) [1]:

Table 2. Types of sources [1].

Source symbol	Source description
S1	Flashes to a structure
S2	Flashes near a structure
S3	Flashes to a line
S4	Flashes near a line
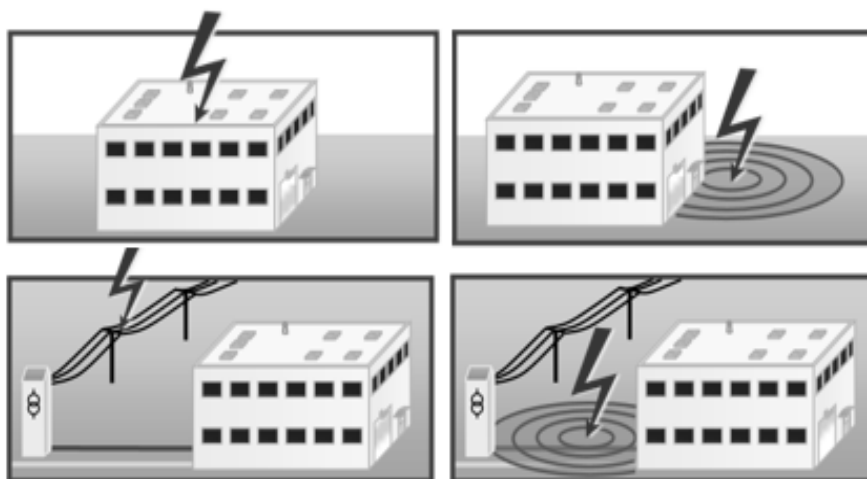
Figure 2. Possible sources of lightning [7].

The calculation of risk is specifically included in the standard. The standard defines a building as legally protected if the calculated risk (R_1, R_2, R_3, R_4) is less than the officially stated value (R_T) in the standard. An exception is the risk of public service disruption (R_2), where the National Fire Protection Code (OTSZ[3]) [8] required a stricter reference value than R_T, but it returned to the standard value from 2020 January. In technical terms, there is always a residual risk. The risk calculation takes into account the parameters of the building and its installations (e.g. the lightning protection of structures, cables, floors, etc.). The result of the risk calculation (R_1) gives a value whether the tested building is protected against lightning or not. This parameter R_1 is the sum of the partial results R_A, R_B, R_C, R_M, R_U, R_V, R_W and R_Z. If the value is less than or equal to $R_T = 10^{-5}$ ($R_1 = < R_T$), then the building can be considered lightning protected. If it is greater than 10^{-5}, lightning protection measures are required. The result of the risk calculation shows whether the building is legally protected from lightning protection or not. If the result shows that it is not, further lightning protection measures must be taken and the calculation must be performed again. If the result is repeatedly "unprotected" then the lightning protection measures must be improved until the result is "protected". In many cases, for the sake of transparency, the result obtained is compared to $R_T = 10^{-5} = 100$ %, so the percentage of the result obtained.

The risk of losing human life (R_1) consists of 8 parts. The risk of losing R_1 human life can be calculated by adding up these partial calculations:

$$R_1 = R_A + R_B + R_C + R_M + R_U + R_V + R_W + R_Z. \tag{1}$$

The partial calculations of the standard use the multiplication method of

$$R_X = N_X \times P_X \times L_X,$$

where N_X is number of dangerous events per annum, P_X – probability of damage to a structure and L_X – consequent loss.

Defined as components of R_1: x ϵ {A, B, C, M, U, V, W, Z}

This short example shows some main parameters of a building, and the R_1 result:

Dimensions of building: L,W,H = 30 m ; 20 m ; 20 m
Lightning strike number per annum: $N_G = 2$
Structure location factor: $C_D = 1$
LPS[4] level: LPS = II
Length of power line: $L_L = 200$ m
Type of power line: Buried $\rightarrow C_I = 0,5$
Length of telecommunication cable: $L_L = 100$ m
Type of telecommunication cable: Buried $\rightarrow C_I = 0,5$
Material of floor   Wooden $\rightarrow r_{ta} = 10^{-5}$
Material of ground around building   Grass $\rightarrow r_{tu} = 10^{-2}$
Factor reducing loss depending on risk of fire $r_f = 0,1$
Factor reducing the loss due to provisions against fire $r_p = 0,5$
Number of people in zone $n_{z1} = 100$ persons
Number of people in front of building $n_{z2} = 15$ persons
Total number of people $n_t = 15 + 100 = 115$ persons

$R_1 = 0,8524 \times 10^{-5}$
Because $R_T \geq R_1 \rightarrow$ building protected

The Sensitivity test targets to analyse the effect of single unit changes in the input parameters being examined on the output. There are two types of input parameters (independent variables). One has fixed values defined in the standard, and the others have variable values. These are parameters about lengths. During the test, a change in the value of an input parameter at a time is used to determine the output change, examined separately for each input parameter. At the end of the test, it can be seen whether there is a parameter (strong parameter) which, with a small change in its value, will have a decisive influence on the value of the output (R_1) lightning protection risk. The present research was performed with the program written by the author.

RESULT OF THE TEST

After finishing the sensitivity check, it can be expected that the input parameters can be grouped into strong and not strong parameters, respectively. Strong parameters should be able to identify an extremely important factor that has a decisive influence on the output. If the strong parameters and the 'weak points' of the building are known, the lightning protection engineer can make suggestions to the architect to change or install parts or components, which will no longer be possible once the construction has begun. There are several options to consider before the construction begins. One option is the use of a grounding net, which must be installed in the ground. It is also economically useful to know the parameters beforehand. Another example is the type of the roofing material. Lightning protection is decisively influenced by the type of the roofing material, so it is possible to decide before the construction that the roof will not be made of a combustible material (e.g. sandwich panel) but rather of a more expensive but non-combustible rock wool.

After finishing the sensitivity test, it has been found that unit changes for the input parameters do not affect the output R_1 (lightning protection risk) in the same way. A group of the so-called weak parameters has a minimal effect or nothing on the R_1 output, which stays below the tolerated value $R_T = 1 \cdot 10^{-5}$. On the other hand, five parameters have been identified, whose unit changes have a decisive influence on the R_1 output. These are the following:

r_p – fire protection measures,
r_f – fire risk,
LPS – lightning protection level,

h_Z – type of special hazard,
L_0 – Internal System Failure (only hospital and explosion dangerous building in case of).

There are two parameters which raise the value of R_1 immediately above $1 \cdot 10^{-5}$, removing the lightning protection of the building. They are r_f and L_0. The other three parameters (r_p, h_Z and LPS) either raise R_1 immediately above $1 \cdot 10^{-5}$ or already touch the 25 % ($0{,}750 - 1{,}000 \cdot 10^{-5}$) security range. It is the task of the lightning protection designer to determine the amount of lightning protection that he/she is considering for certain buildings. Experience has shown that this ranges from 20 % to 25 %.

If the strong parameters are known, it can be a help the architect and the lightning protection designer. The design can be cheaper, simpler or faster. There is also an advantage of knowing the weak parts of the building: the "invisible" natural lightning rods of the building can be used during the design, in order to avoid any non-aesthetic elements on the building.

The sensitivity test results on several building types with 270 different attributes will be presented in the author's dissertation.

CONCLUSION

The calculations of the present study show that the examined 58 input parameters do not affect the output in the same way, so the new theses are the following:

- parameters can be grouped into strong and not strong parameters,
- in the strong parameters group, some parameters were identified as extremely strong (priority).

Based on the above, hypotheses 1 and 2 have been proved. The draft version of the standard has been rejected, and its content will be revised, so hypotheses 3 must also be rejected.

It must be emphasized that among these five parameters, two of them can be considered as extremely strong. It means that they always increased the risk value of the tested building by changing one unit immediately above the allowed R_T limit. These are the fire protection measures (r_f) and the failure of the building's internal systems (L_0)

In conclusion, the above calculations can help the architect and the lightning protection designer during the design period of the building. Knowing these parameters – weak points – of the buildings, the lightning protection design can be simpler, faster and in some cases, it can create a better-looking image. For example, it will allow the use of the natural elements of the building to avoid non-aesthetic lightning protection solutions which do not fit in their environment, and, as a result, the architect can keep the visual image of the building an that is important to maintain our cultural heritage for future.

REMARKS

[1]Strong parameter: parameters whose unit changes have a decisive influence on output.
[2]Extremely strong parameter: whose unit changes raises the output immediately above R_T allowed limit.
[3]OTSZ stands for Országos Tűzvédelmi Szabályzat, i.e. National Fire Protection Code.
[4]LPS stands for Lightning Protection Level.

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