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Reduction and mastering of electromagnetic field due to lightning in a structure

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***Abstract*—This paper proposes a new method to reduce and control the electromagnetic field due to a lightning current flowing down the down-conductors around a structure. The influence of the number of down-conductors and the earthing resistance value on the radiated field is studied thanks to a parametric study.**

Keywords-lightning, radiated fields, down-conductors, earthing systems

I. INTRODUCTION

With the development and the progress in electronics, more and more sensitive equipment are installed in the structures. Thus, the electromagnetic field created by the lightning current can perturb or destroy the equipment.

Many papers [1] can be found in the literature in this aera, but we propose in this study a solution to improve the protection and its implementation.

Moreover, dangerous sparkling can appears between a down-conductor and a metallic element in the proximity. As a consequence, in order to protect person and equipment, we develop a statistical and parametrical method to reduce and mastering the electromagnetic field by optimizing the earth resistance, the number of down conductors and the equalization of potential.

II. STRUCTURE TO BE PROTECTED

First, we model a simple structure and we calculate the field radiated in respect with the earth resistance and the number of down conductors.

The calculations are realized with the OPEN TEMSI-FD software, based on the Finite Difference Time Domain method (FDTD) developed by C. Guiffaut [3] in the XLIM laboratory.

A. FDTD method

The FDTD method permits to solve the Maxwell's equations in the time domain inside a Cartesian grid. Thanks to Fourier's transformations, FDTD solutions can cover a wide frequency range with a single simulation run, and treat nonlinear properties in a natural way.

The FDTD method seems to be well adapted to our problematic, i.e. to show the variation of the lightning impulse around the structure.

The FDTD method enables to implement Perfect Matched Layer (PML) at all the boundaries of the calculated volume.

The PML [4] is an absorbing boundary condition permitting to consider models in free space, avoiding reflections at the boundaries of the calculation volume.

B. Parametrical analysis on a simple structure in various cases of LPS

The structure is a cube of 10m.edge size. In order to reduce the calculation time, the mesh has been chosen of 1x1x1m in the three directions.

The volume contains 100x100x100 cubic cells.

Various cases are studied in order to show the importance of the earth resistance value and of the number of down conductors to minimize the electromagnetic fields (E and H).

In order to compare all cases, it has been decided to choose constant dielectric properties for the walls and the ground.

The walls of the structure are defined as concrete (σ=0.002 $S.m^{-1}$; ε=4.5) and the soil (σ=0.01 $S.m^{-1}$; ε=3) is defined with quite good electrical properties.

For each case, the lightning impulse is simulated with a perfect conductive linear channel (wire) ran down by a perfect current source with a bi-exponential waveform (8/20 µs) at the impact point.

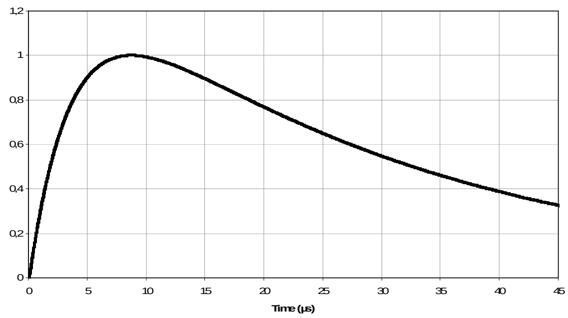


Figure 1. Normalized 8/20µs bi-exponetial waveform.

The peak value of the current applied is 200kA.

The figure 1 gives the normalized impulse current waveform.

We have chosen 3 observation points (blue points in figure 2) for the electromagnetic (E and H) fields:

- Inside the structure (50;50;25)
- Outside the structure (50;30;25)
- In the soil (50;30;10)

Moreover, we have observed the current flowing in the earthing system for the study to validate our method.

1) Studied cases: Influence of the earthing system and of the number of down-conductor

Firstly, the air-terminal presents only one down conductor. This down-conductor is directly linked to an earthing system with a resistance equal to 9.1 Ω (case 1) and 40 Ω. (Case 2)

The figure 2 gives the considered volume and structure for the first case.

We can naturally see in figure 3 that the current is more important in the earth with the lower resistance. Moreover, the radiated electromagnetic field is greater for the 40Ω resistance.

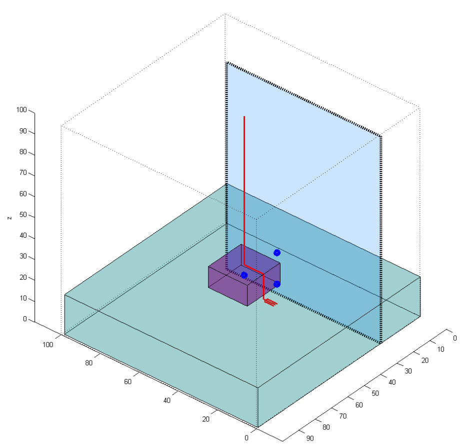


Figure 2. One down conductor with R=9Ω.

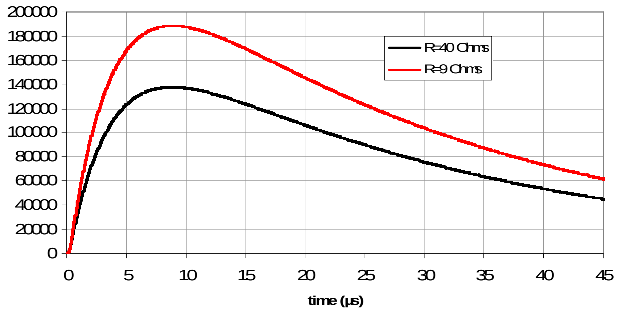


Figure 3. Lightning current in the earthing system for on down conductor cases (N°1 and N°2).

Regarding the H field, we can note that the level is very close for the two cases.

- Solid line is for inside
- Small dashed lined for outisde
- Large dashed line for the soil

The electric radiated field E is lower for the case 1. Indeed, more current is conducted to earth, implicating that less E field can penetrate inside the structure.

So it is important to have a good earthing system to reduce the electromagnetic field

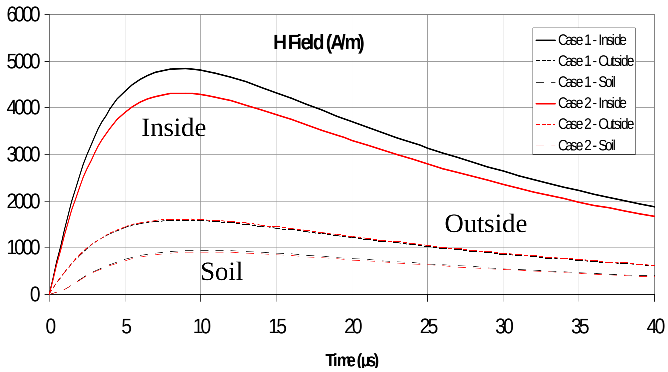


Figure 4. H field for Case 1 and Case 2.

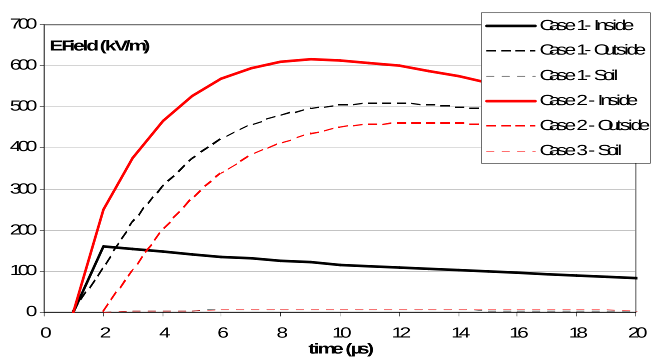
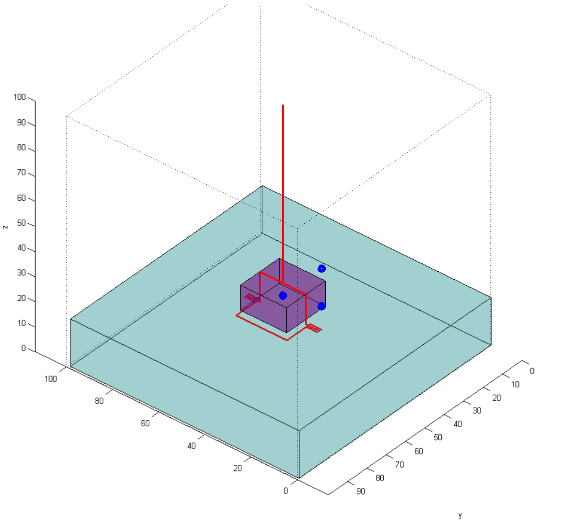


Figure 4. E field for Case 1 and Case 2.

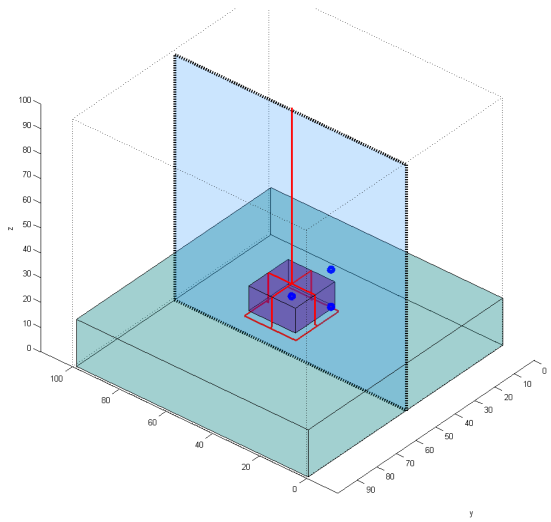


According to standards [5], the air-terminal has to be linked to ground by at least two down conductors.

Then, the air-terminal can be connected to two, three or more down conductors.

This separation of the current permits to reduce the electromagnetic field around the structure.

Each down-conductor is connected to an earthing system (9 or 40 Ω taken separately). The different earthing systems are inter-connected in the soil.



a) b)

Figure 5. Two down-conductors system (Case 5 - a) and 4 down-conductors with a ring earthing (Case 7 - b).

A low earthing resistance value implicates a high level of current drained in the earth.

2) Cross-table of the results

All the studied cases and the results are given in the Table II below.

TABLE I. CONDUCTED CURRENT (IN THE EARTHNIG SYSTEM)

Cases	**% I**
N°1 (R=9.1Ω & n=1)	94
N°2 (R=40Ω & n=1)	69
N°3 (R_{eq}=9.1Ω & n=2)	94
N°4 (R_{eq}=6.3Ω & n=2)	96
N°5 (R_{eq}=3Ω & n=2)	98
N°5bis (R_{eq}=1.7Ω & n=2) + Earth ring	99
N°6 (R_{eq}=4.6Ω & n=3)	96
N°7 (R_{eq}=3Ω & n=4) + Earth ring	98

Each case presents a specific earthing resistance and a specific number of down-conductors.

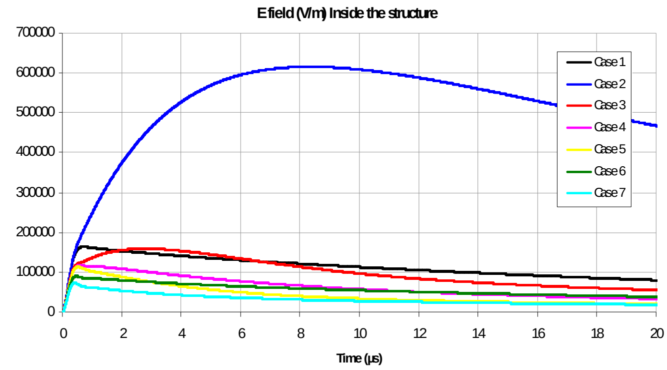
The Table I gives the percentage of current drained by the earthing system.

Morever the Table II presents the peak value of the electromagnetic fields E and H for the three points of observation (inside and outside the structure, and in the soil).

We decide to compare two cases particularly : the case 5, and case 7.

TABLE II. RADIATED FIELDS

Cases	**E (kV/m)**			**H (kA/m)**		
	In	**Out**	**Soil**	**In**	**Out**	**Soil**
N°1 (R=9.1Ω & n=1)	164	508	5	4.84	1.58	0.95
N°2 (R=40Ω & n=1)	615	461	6	4.32	1.61	0.91
N°3 (R_{eq}=9.1Ω & n=2)	158	509	5	4.82	1.45	0.89
N°4 (R_{eq}=6.3Ω & n=2)	117	512	5	2.05	1.46	0.90
N°5 (R_{eq}=3Ω & n=2)	113	515	5	0.43	1.46	0.88
N°5bis (R_{eq}=1.7Ω & n=2) + Earth ring	113	516	5	0.17	1.44	0.86
N°6 (R_{eq}=4.6Ω & n=3)	90	512	4	1.85	1.45	0.90
N°7 (R_{eq}=3Ω & n=4) + Earth ring	73	517	7	0.12	1.81	0.84



. Figure 6. Hz field at t=10µs for Case 7.

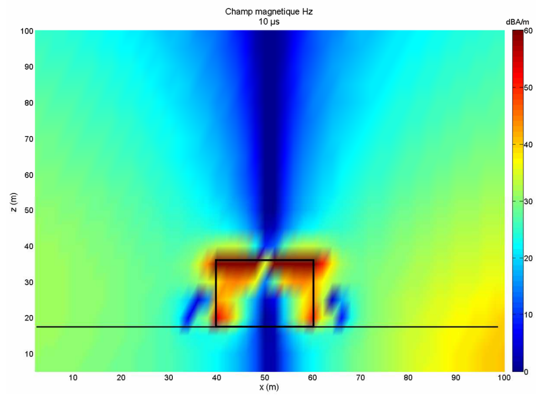
All the peak values (3 observation points) are very closed excepted the inside E field but with a relatively negligible difference.

This means that the two configurations present identical properties and the same efficiency in reducing the radiated field.

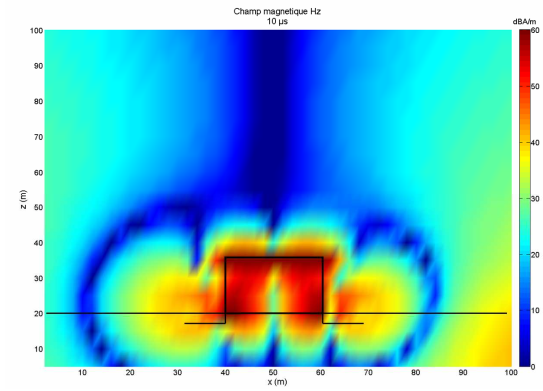
III. H FIELD IN THE LIGHTNING PLANE

The figures below give the Hz magnetic field in the space 10 µs after the beginning of the impulse

We can see that the radiated H field is a little bit more important inside the structure in the Case 5 than in the case 7



(a)



(b)

Figure 7. Hz field at t=10µs for Case 5 (b) and 7 (a).

It is known that the best way for the equalization of potentials consists in a toric shape earthing system [6], like the case 7.

But, the table II and the figure 6 show that add electrodes with resistance lower than 5Ω to the ring minimize the E and H fields.

For real and more complex structures, the studies and analyzes of radiated fields E and H have been done.

For lightning technical studies, this method permits us to suitably define the number and the location of down conductors in order to reduce and master the E and H fields.

IV. CONCLUSION

To conclude, the results confirm that the earthing value needs to be lower than 10 Ohms in order to limit the electromagnetic field

Moreover, the parametrical analysis highlights the importance of having a very good earthing system combined to an accurate number of down-conductors. In order to reduce the electromagnetic fields around the structure, it could be better to request the 10Ω value or a lower one such as 5Ω for example.

REFERENCES

[1] TX Song, YH Liu, JM Xiong, "Computations of electromagnetic fields radiated from complex lightning channels" PIER 73, pp93-105, 2007

[2] Heidler F., Cveticand JM, stanic BV, Calculation of lighning current parameter. IEEE Transaction On Power Delivery .1999 April, 14(2) 399-597

[3] C. Guiffaut, "Guide de l'utilisateur TEMSI", 2007.

[4] J. Berenger (1994). "A perfectly matched layer for the absorption of electromagnetic waves". *Journal of Computational Physics* **114** (2): 185–200. Bibcode 1994JCoPh.114..185B

[5] IEC 62305 standards " Lightning protection" 2010, NFC 17-102 Edition 2011

[6] .Golde, "Lightning Academic Press", NY Vol2 Chapter 19, 1977.