Unsustainable trends in lightning protection industry.

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Every single second, 50 to 100 lightning strike the Earth's surface. This natural phenomenon has always caused fascination, not only because of its beauty but also because of its destructive power. Statistics of damage caused by lightning are rather impressive: around 2 000 people are killed each year, thousands more survive with sequels, and material damages are estimated in the order of $4-$5 billion in the US only. The widely extended belief that lightning strike is completely random is actually untrue: shape of the structures and objects and its conducting properties largely condition strike probability (for instance, the Empire State building is stroke between 20 and 25 times each year).

Protection against lightning is widely justified by these facts, and is nowadays systematically applied to populated areas and industrial sites. Several standards and technical whitepapers regulate and even impose the installation of lightning protection systems in all these sensible areas. As a consequence the industry developed around lightning protection deals with an increasing business: it is estimated that this market will amount up to $695.5 million in 2011[1].

Without any doubt, the main milestone in lightning protection is the use of a single rod as a lightning receptor, by Benjamin Franklin (around 1750). Ever since, the image of a single lightning rod topping tall buildings has remained in popular culture as *the* protection system. However, other system proposed by Maxwell (in 1876), the so-called Faraday cage or mesh cage, is also widely applied nowadays. The working principles of those systems (Single rod and Faraday cage) are almost antagonists.

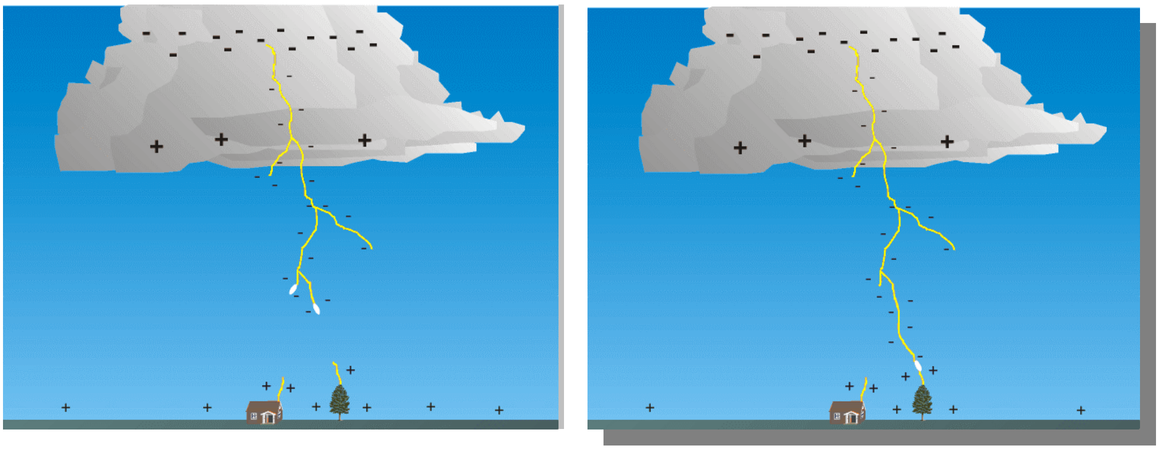

Figure 1: The Lightning mechanism. In charged clouds, certain not well known physical processes lead to a descending plasma (electrically charged) channel. As it approaches the ground, it causes electric field at the earth's surface to rise dramatically, causing ionisation of air. This effect is more pronounced in sharp edges, and takes place in many different points and objects (picture on the left). Free ions follow electrical field and therefore progress towards the descending plasma channel, forming ascending channels. When one of these channels contacts the descending one, a strong electrical discharge takes place (picture on the right). All other ascending channels are dissipated.

[1] See « World Lightning Protection Technologies (LPT) Markets, by Frost & Sullivan, June 28, 2005.

The Single rod takes advantage of the mechanism of lightning itself. Although very fast for the human timescale, lightning is indeed a complex process (see Figure 1), in which a plasma channel descending from the cloud towards the ground causes the apparition of other plasma channels ascending from the ground[2]. When one of these ascending channels (whose creation is favoured by sharp edges) enters in contact with the descending one, a strong electrical current is established, giving place to the characteristic light flash and shock wave (thunder) that we all identify as the lightning strike. Single rods are placed in high spots, seeking to ensure that the ascending plasma channel originated at the rod is the one that will establish contact with the descending one in first place. The electrical discharge is then guided to the ground through a metallic guide.

Mesh cages do not take account of the nature of lighting, but only of the simple fact that electromagnetic fields do not propagate inside cages formed by electrical conductors. A protection system based on this principle does not aim to attract lightning towards a specific point, but rather expects it to hit anywhere along a grid of metallic conductor, which will then guide the discharge towards the ground. Obviously, for this type of system to be effective, the grid of conducting wire must be dense enough to avoid lightning striking in unprotected areas between wires.

There is a remarkable unbalance between the amounts of attention that the research community has devoted to each of the types of lightning protection systems. Single rods have been subject of intense research during the last half century. Part of this activity has focused on the (still ongoing) assessment of the performance of evolved forms of the single rods, namely the ESE devices. Another significant part of this activity has been devoted to develop the so-called electro-geometrical model and its derived engineering methodology (the most relevant one being the "Rolling Sphere" method), which allows designing consistent protection structures. This contrasts with the background behind Faraday cages, whose installation still relies in the meshwork method, largely based on accumulated experience, rather than theoretical deduction[3].

At present, both types of protection systems coexist and are employed massively. So far there is no scientific evidence that one of these types of protection will be better than the other, although it is commonly agreed that poor installation design dramatically decreases the efficiency of the protection system[4]. Nevertheless, there is no discussion around the fact that scientific research is the only way that will allow developing more efficient lightning protection systems through a better understanding of the amazingly complex subject of physics of lightning.

The importance of the scientific debate has overshadowed some other issues which have nevertheless become crucial in the dawn of the 21st century. Last decade has seen the economical rise of countries like China or India, which enormous populations concentrating into large cities and developing large industrial sites. The acceleration of consumption has made obvious that it is impossible to conceive a highly developed society at a global scale without focussing into industrial production schemes that are sustainable. However, this is not the case of some of the models proposed by the lightning protection industry.

Both types of protection systems, single rods and Faraday cages, are mainly composed of metal, particularly copper, in the form of large section wire. Although copper has been known and used since at least 10 000 years, 95% of the overall amount has been mined in the 20th century. Price of copper has multiplied by 5 in the period 1999- 2006 only.

In the case of single rods, two wires are used to guide the discharge from the rod itself towards the ground, so the amount of wire used is roughly equivalent to twice the height at which the rod is

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[2] In purity, this is only one possible mechanism (the most commonly found in nature). The other situation, with first plasma channel moving from the ground towards the cloud, can also be observed.

[3] *See « A Discussion of 'Faraday cage' lightning protection and application to real building structures »* by M. Szczerbinski; J. Electrostatics, **48**, 145-154 (2000).

[4] For an updated study, see *« New guidelines regarding the positioning of prospective air terminations on structures using e-field modelling techniques ».* F. D'Alessandro, J. Electrostatics, **67**, 501-506 (2009).

placed. In the case of Faraday cages, a much larger amount of copper wire is needed in order to build the grid which wraps around the whole structure to be protected. Figure 2 shows a comparison of the amount of copper needed to protect a medium-size basement following current standards. This example illustrates how a protection based in a Faraday cage type of system does not fall at all into a sustainable logic.

It may be argued that such type of systems is only to be used in high risk sites, and not as a general use protection system. However, as it has been already discussed, there is no proof that the Faraday cages will perform better than a consistently constructed single rods structure, which will be much less consuming of natural resources.

All the facts listed concern a situation which is amazingly complex, and precisely because of this very vulnerable to abuse. The search for protection against a powerful and destructive natural phenomenon is legitimate. The fear against lightning is as old as humanity itself and therefore plenty of prejudices and myths, some of them senseless. Care should be taken that the irrational part of this fear does not interfere both with the scientific debate and the common sense of good resource management. The need of protection has allowed the development of some industry which cannot face the current needs of sustainability and management of natural resources. This situation strikingly contrasts with the general political and social trend, which is forcing industry and consumers to adopt responsible aptitudes through regulation and policy making (a recent example of this could be the interdiction of manufacturing and sales of incandescent bulbs for lighting in the EU, in 2009). As it is yet to be proved that these resource consuming systems offer better protection than other existing technologies, it is time to take these important socio-economical factors into account and proceed accordingly.

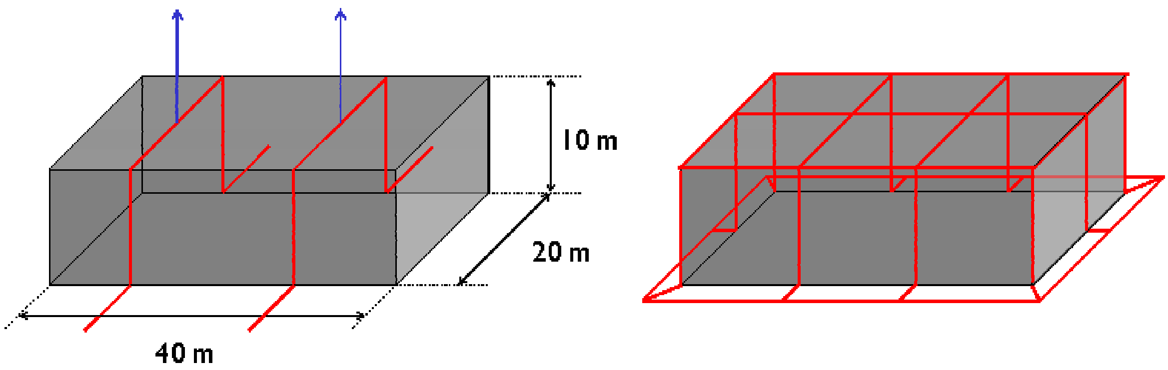

Figure 2 - The schematic representations above correspond to lightning protection systems of single rod type (left side) and mesh cage type (right side), designed to protect a basement measuring 40 meters long, 20 meters wide and 10 meters high. It is assumed that the building has a poor conducting structure, as wood. The systems have been designed following the specifications of standard 62 305-3, to achieve protection of level II. The red lines represent the copper wiring with section of 50 mm^2. Taking into account the lengths of wire and the density of copper (8920 kg/m^3) we can estimate the amount of copper used in the installations, which is approximately **22 kg in the Single rod type, and 217 kg in the Faraday cage.**

The impracticality of the Faraday approach becomes evident as soon as calculation is applied to a group of basements, like those which could be found in almost any neighbourhood or industrial area. The red region shown in the left picture contains a group of 52 buildings, each one with dimensions similar to the example calculated above. Protection against lightning of the basements will require 11.3 tons of copper, using mesh cage systems. The large green field appearing the top right of the picture cannot be protected. In contrast, the whole area could be protected using two single rod system, which will need of 1,1 kilos of copper. Single rod type allows improving protection over wide open spaces such as the green field of the picture. The region protected is still a minuscule fraction of a populated area, in this case Metropolitan London (pictured on the right).