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An Overview on the Protection Measures for Air-Port Protection in High Density Lightning Regions

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[1]***Abstract*—Air-ports belong to structures, which – due to their location and spatial configuration are especially exposed to the lightning flashes. Moreover theirs dynamic character due to stocked air-crafts, variable in time, has an impact on the lightning attachment issues. This aspect is particularly important taking into account low values of lightning current. In the present paper, rolling sphere method on lightning protection is presented and adequate conclusions are formulated.**

***Index Terms*—Lightning, protection measures, rolling spheres, airport.**

I. Introduction

Lightning is known as a discharge of atmospheric electricity. Lightning discharges belong to natural weather phenomena, which cannot be prevented, because no effective devices or methods for it exist. Therefore adequate protection measures against effects of lightning operation had to be developed [1].There are some such countries in the world and they have a high cloud to ground lightning activity in different regions, finding ground flash density higher than 40 flashes/km^2 [2]. That is why it is important to study thunderstorm behavior in order to have methodologies for accurate forecasting of lightning concurrency. The climatology map between the years of 1998–2007 regarding to lightning imaging sensor is given in Fig.1.

The up-to-date values of lightning current and adequate statistic for practical applications are given in [3]. The identification of thunderstorm cells is very important for understanding atmospherically phenomenon and for the development of forecasting and nowcasting systems [2], [4], [5].

In a work a methodology for tracking thunderstorms in order to obtain statistical data of the movement, speed, duration, thunderstorm starting and ending regions, to be used as input in lightning warning methodologies have been examined [2]. In a paper, a group of scientists have determined criterions for reducing physical damages due to direct flashes [6]. Eriksson [7] addressed the lightning attractive radius concepts for estimating lightning flashes to power lines.

In the present paper; it has been dealt with rolling sphere method’s protections to airports in high density lightning regions. Some suggestions related with RSM protection such as lightning and air termination rods have been given.

II. Air–Port from Lightning Hazard Point of View

Generally a civil air-port consists of landside and airside areas. Landside areas include parking lots, public transportation train stations and access roads. Airside areas include all areas accessible to aircraft, including runways, taxiways and ramps. The waiting areas which provide passengers accessing to aircraft are typically called concourses, although this term is often used interchangeably with terminal. The area where aircraft park next to a terminal to load passengers and baggage is known as a ramp. Airports can be towered or non-towered, depending on air traffic density and available funds.

Current of a lightning striking an airport can give damages to the structure and to its occupants, contents, including failure of equipment. The damages and failures may also extend to the surroundings of the structure and may even involve the local environment. The effects of this expansion depend on the buildings and lightning flashes

III. Protection Measures

Lightning flashes to a structure of air-port or in the worst case to an air-craft stocked may influence internal power and communication systems wholly or partially lightning current flowing to earthing layout.

Possible protection measures are given in IEC 62305 standards series and can be summarized as following:

–Protection measures for reducing physical damage are achieved by the lightning protection system which includes air termination, down-conductor, earth termination systems, lightning equipotential bonding, and electrical insulation against the o lightning protection system;

–Protection measures such as earthing and bonding measures, magnetic shielding, line routing, isolation interface are coordinated by surge protective device system.

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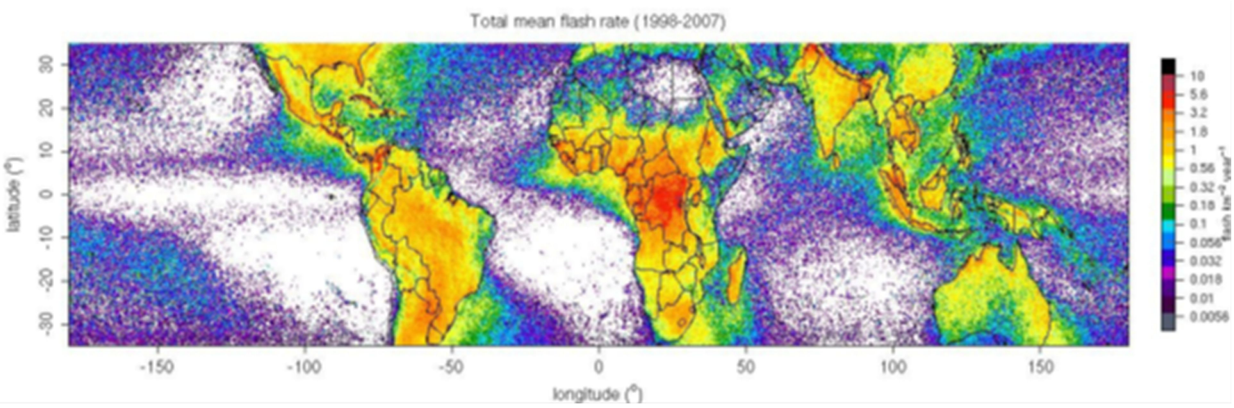


Fig. 1. Distribution of total lightning activity from 1998 to 2007 [9].

For lightning flashes to earth, a downward leader grows step-by-step in a series of jerks from the cloud towards the earth. When the leader of lightning approaches to the earth approximately ten meters, the electrical insulating strength of the air which is near the ground is exceeded. An additional leader similar to the downward one begins to grow towards the head of the downward leader. The upward leader defines the point of lightning strike. The starting point of the upward leader and hence the subsequent point of strike is determined mainly by the head of the downward leader. The head of the downward leader can only approach to the earth within a certain striking distance. A figure with an air-craft near a gate is presented in Fig. 2 [8]. On Fig. 3, two rolling spheres radius and arrangements for lightning attachment by air termination on roof are presented. The protective guard wires and pylons are used as the basis for electro–geometric model.


Fig. 2. An air-craft near a gate: On the figure, one rolling spheres radius is being seen on the top of tower.

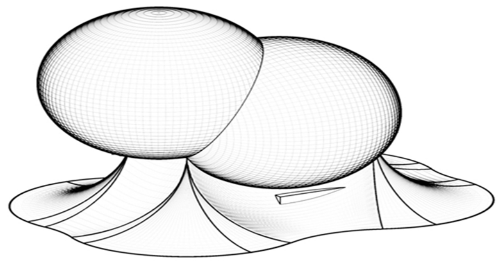
Air-termination components can be installed on a structure shall be placed on the upper level of any facades, in accordance with rolling sphere method. In order to assure an effective lightning attachment by air terminations (rods), the followings should be obeyed:

– To avoid application of single air terminations;

– To quit from the utilization of external spaces of rods and to utilize only the internal space between two or more rods;

– To limit the application of air termination rods to local protection (to protect individual devices on the roof).

The air termination rods create internal protected spaces in satisfactory agreement with spaces created by the written down sphere with radius $r = 20$ m. External protection angles have not been taken in account because they are extremely small and don’t cover the structure edges, which should be equipped with additional air terminations, according to the rolling sphere method limiting the protected space.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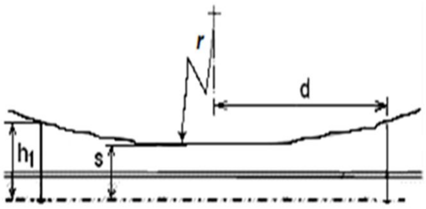


(b)

Fig. 3. Views of rolling spheres and distances created by air termination: (a) perspective view of two rolling spheres radius; (b) Arrangements for lightning attachment by air termination on roof.

The dimensions of internal spaces determined by protection angle and by rolling sphere methods, confirm that the great angle values connected with short rods are quite correct provided that they are properly applied. On the base of this figure it may be clearly stated that the greater angles are attributed to smaller rods. The positioning of an air-termination system is adequate if no point of the structure to be protected comes into contact with a sphere rolling around top of the structure. In this way, the sphere only touches the air-termination system. The aim is to demonstrate the requirements on the air–termination systems as the radius of the rolling sphere decreases which areas have additionally risks by lightning strikes. In case of this circumstance, it is recommended that designers must abide to LPS II class [10].

Considering the local protection of roof devices by vertical and horizontal rods, some additional features should be recognized and solved involving the RSM. Radius of the rolling sphere is given in (1) [10]. A distance between this surface and bottom point of sphere should be assured, described as given in (2):

$$r = 10 \cdot 10^{0.65}, \quad (1)$$

$$s \geq h_1 - r - (r_2 - d_2)^{0.5}, \quad (2)$$

where r is meter, I in kA, s is distance between roof surface and bottom point of sphere (m), and h_1 is air termination rod height (m).

From (2) the distance d (horizontal distance from sphere bottom to rod) should always be less than air termination rod height, when it is written as given in (3)

$$d < h_1. \quad (3)$$

Particular caution should be paid to the protection of a roof which contains some metal elements. If the direct lightning strike to the sheet of the roof has to be excluded, an additional air termination system must be installed. In order to assure proper attachment selectivity the separation distance s should be assured according to condition [11]. It should be noted that in this case the spark gap coefficient should be taken in account, what means that the distance between leader tip and the conductive sheet of the roof should be greater than the distance to the rod. Moreover the conductivity of insulating sheets due to pollution should be taken in account.

The distance may be replaced by air termination rod or may be eliminated by application of horizontal air termination conductor on the roof surface below the sphere bottom point. As a principle the rolling sphere should touch only the ground surface and air terminations positioned on the structure surfaces but never should it touch these surfaces.

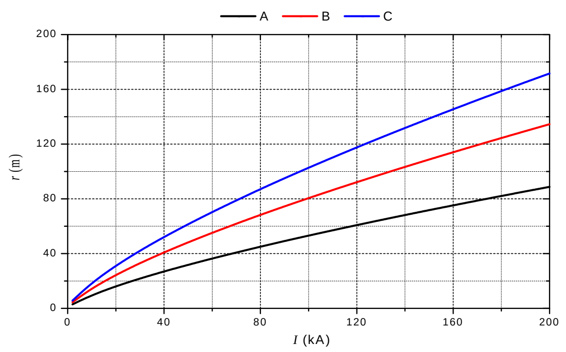
IV. RESULTS AND DISCUSSIONS

The penetration of lightning current can be estimated by electro-geometrical model. These elements consist of a severe case in terms of lightning protection by means of lightning attachment. Attraction radius of lightning currents for three different heights of pole has been obtained in the study. The graphics $r(m)$ versus $I(kA)$ are given in Fig. 4.

Coefficient m for lightning protection levels are defined by IEC standards. According to this standard, 4 lightning protection levels are determined [12]. For all, maximum and minimum lightning current parameters are fixed. Each protection classes (I–IV) is associated a set of minimum and maximum values of the parameters bound to imposed lightning currents. The minimum lightning current for the different LPL are used to derive the rolling sphere radius in order to define the lightning protection zone which cannot be reached by direct strikes. They are used for the positioning of air terminations in the external protection and to determine the lightning protection zone.

From Fig. 4, it is seen that the radius of single conductor line is obtained from 5 m to 200 m, and similarly the radius of pole is obtained from 5 m to 240 m for heights of 5 m–15 m. The more radius it reaches the higher pole it supplies.

Air–termination rods are frequently used to protect the surface of a roof, against a direct lightning strike. The arrangement of the air–termination rods means that the sphere sits deeper, thus this increases the penetration depth of the sphere.



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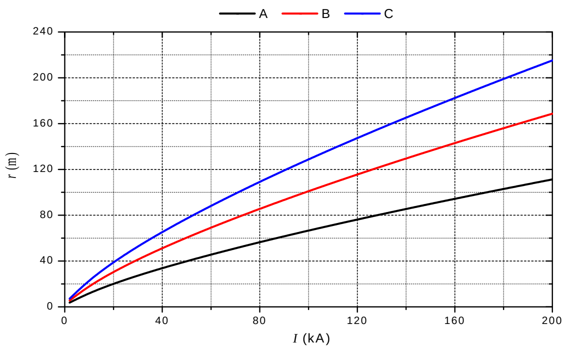


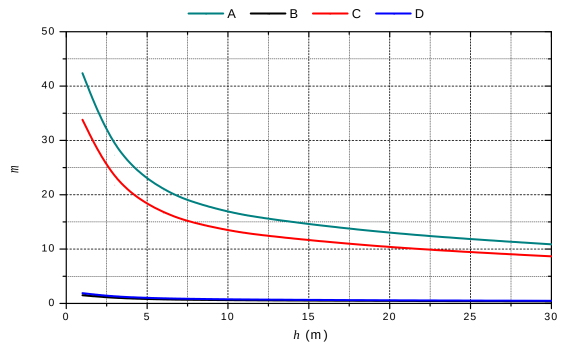
(b)

Fig. 4. Graphics for three different heights of pole (A–5 m, B–10 m, C–15 m): (a) attraction radius of single conductor line as a function of lightning current; (b) attraction radius of pole as a function of lightning currents.

In Fig. 5(a)–Fig. 5(d), coefficients m for LPL I–IV as a function of heights for pole and line have been shown as graphics (where A–$I_{p\,max}$, B–$I_{l\,min}$, C–$I_{l\,max}$, D–$I_{p\,min}$).

From Fig. 5(a)–Fig. 5(d), it should be noted that the penetration of lightning current can be determined approximately by rolling spheres. The heights of poles and lines would be maximum while the I_p was maximum. From the figures above, it is understood that the best protection level for airports would be provided at level IV. The more heights it reaches, the greatest lightning protection level is obtained.

The penetration depth of the rolling sphere is governed by the largest distance of the air–termination rods from each other. The air–termination rods are dimensioned according to the height of the structures mounted on the roof and the penetration depth.



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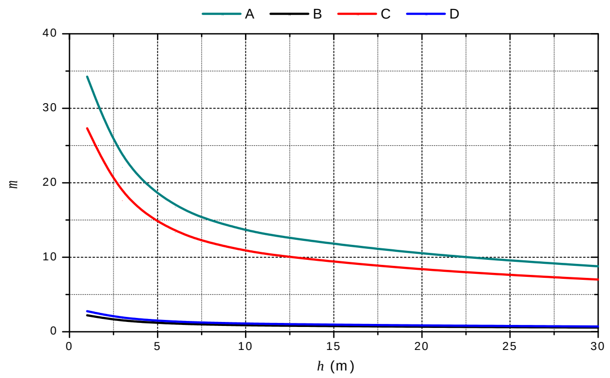

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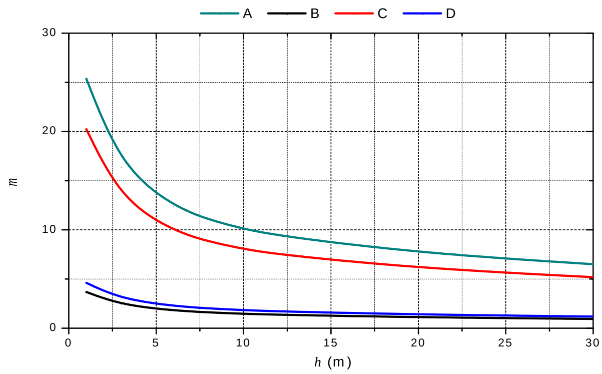

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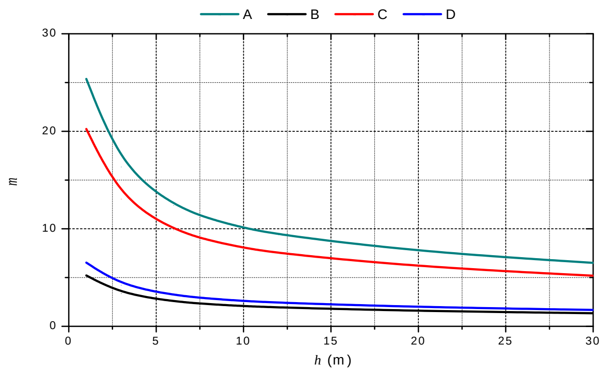

(d)

Fig. 5. Function of heights: *m* versus *h* (*m*) for LPL I–IV for pole and line: (a) coefficient m for LPL I; (b) coefficient m for LPL II; (c) coefficient *m* for LPL III; (d) coefficient m for LPL IV.

V. CONCLUSIONS

An air-port generally has a complex dynamic structure. Air-crafts which are stocked up in an airport can be directly endangered due to low values of lightning current. In this study, it has been tried to show the selected aspects of lightning attachment. In terms of RSM protection, the conclusions below have been inferred:

– Selection of lightning rods must be based on the RSM; moreover protection angle method ought to be limited to special cases and to internal spaces between two or more air terminations;

– Small vertical air termination rods which have great values of their protection angles must be suggested for local protection of appliances protruding above the roof surface provided that they are involved into integrated air termination system of the structure;

– Local rods on the roof must be well coordinated with its entire air termination system;

– Upper part of the space protected by a single vertical rod is over estimated and the efficiency of protection in this part is particularly reduced.

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