Determination of Air Terminal for a Structure by using Rolling Sphere Method

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Abstract—**Lightning is a one of the natural events, that cannot be predicted when it occur. The effect of lightning strikes to structure can cause miscellaneous damage. In order to protect structure against lightning strikes, properly designed of type and location for lightning protection system (LPS) should be carefully considered. The MS_IEC_62305_2007 standard provides advanced information for the design of Lightning Protection System (LPS) with suggestion methods. This paper present a graphical method performed by rolling sphere with specific radius. This is an imaginary sphere which is rolled over structure. As a result, the structure are located in the radius of this method are protected from lightning strike.**

Keywords-component; Air termination design, lightning protection system (LPS), protect structure against lightning strike, rolling sphere method.

INTRODUCTION

What are causes of lightning? The issue that scientist were looking and trying to figure out a long times ago. Development in technology over a few 100 years ago, enable scientists learn and doing research to solve the issue. When the separation charges within the thundercloud occur it will create the lightning strike [1]. On the other hand lightning is discharge of atmospheric static electricity within cloud to cloud, from downward flashes initiated by a downward leader from cloud to ground, upward flashes initiated by an upward leader from ground to cloud [3].

A lightning strike has a temperature of about 54,000 degrees Fahrenheit which can generate heat. It also can produce high voltage and current which is in average 100 million Volts of electricity and current is up to 100,000 Amperes [2].

Lightning can strike everywhere and can caused severe damage to life and property in short period either directly or indirectly. Fire or explosion to the structure or service will happen when it was struck by lightning due to overvoltage and lightning current. Another effect that can be determined is failure of internal system such as malfunction of the electric equipment. Lightning strike also can affect to human life either injury or kill people or animals [4].

Based on the effect that can be determined, it shows that lightning strike is very hazardous and it must be prevented. At the same time most house, hospital and industry now a day are having more sensitive and expensive electronic equipment. In order to control and prevent damage due to lightning strike, a properly design of lightning protection system (LPS) are need to consider. Thus, it can say that lightning protection becomes important [6].

Because of that, this project presents the determination of air-terminal for a structure by using rolling sphere method based on MS_IEC_62305 (2007) standard. It is only focused for the external structure and its surrounding. There are a few steps need to be followed for design of lightning protection system (LPS) for a structure and it cannot just a simply install. The risk assessments need to estimate first, in order to determine whether a structure need or not the lightning protection system (LPS). According to MS_IEC_62305_1 (2007), the risk (R) can be predicted and when it is higher than the tolerable level (R_T) the lightning protection was required [2][4].

I. THEORITICAL BACKGROUND

A. Prospected Performance of the lightning protection system (LPS)

Lightning protection system (LPS) is able to separate into two types which are internal lightning protection system (LPS) and external lightning protection system (LPS) [5]. Since this project only focused for external structure and it's surrounding, so future information and discussion is about the external lightning protection system (LPS).

An external lightning protection system (LPS) is designed for protection of structures opposite to the direct lightning strike. It consists of three types of component. There are air termination system that located above the upper-most parts of the structure, down-conductors and earth-termination system [5].

First of all to select the suitable types of the component, the level of lightning protection system (LPS) need to be selected. Four classes or level of lightning protection are introduced. In MS_IEC_62305_1 (2007) lightning protection levels (LPL)

was identify based on it specification, and it used for decide the level of lightning protection system (LPS). One of the techniques to determine the characteristic of lightning protection system (LPS) is require knowing the characteristics of the structure to be protected [5].

B. Air Termination System.

While design the lightning protection system (LPS) for external structure, the first important thing require to consider is air-termination system because the main function is to prevent direct lightning strike from damaging the structure that need protection. And the location of air-termination system is at the top of the structure. So, it is the first items in lightning protection system (LPS) that will hit by lightning strike.

Thus, more attention should be considered while deciding the positioning of air-termination system on the structure. By attending a proper design of an air-termination system, the probability of structure hit by lightning strike causes damage will decrease. The air-termination system can be divide into three elements which is rods (including free-standing masts), catenary wires and meshed conductors. It can be combined together to use for protection. In standard which is MS_IEC_63205_3 (2007), there is no any rules or criteria must followed when make choice of the air-termination elements that will be use for protect structure [5][7].

Mostly the lightning will strike at the exposed points, corner and edges of structure. Hence, most importantly the position of air-termination components or elements that will be installed on a structure shall be located at the part that mentioned before. In determine the position and arrangement of the air-termination system at structure, three methods can be used. The three methods are rolling sphere method, mesh method and protective angle method. Be in mind, to choose the types of method that will be used for determination for positioning of air-termination system there are specifications that need to follow and fulfill [5].

Based on the specifications, the rolling sphere method will be used to determination of air-terminal system for a case study. Further explanation will be discussed in topic result and discussion. Another consideration need to taken into account is the construction of air-termination system which is for isolated and not isolated from structure.

C. Number of Down Conductors and Separation Distance

After complete the determination for positioning and arrangement of air-termination system, it will continue with down-conductor system. The installation of down-conductor system at the structure is connected with the air-termination system. It will act as component of external lightning protection system (LPS) that transmit lightning current from the air-termination system direct to the earth-termination system [5].

In order to design a great down-conductor system, proper arrangements from the air-termination system to earth-termination system need to take into account. One of the important things is the length of the down-conductor keep as minimum as possible. It is to conducting lightning current in a short period direct to earth or grounded. Thus, it can avoid melting of conductor that can cause failure to the electrical equipment and damage to the structure [5].

TABLE I. TYPICAL VALUE OF THE DISTANCE BETWEEN DOWN-CONDUCTORS AND BETWEEN RING CONDUCTORS ACCORDING TO THE CLASS OF LPS

Class of LPS	Typical distances (m)
I	10
II	10
III	15
IV	20

Installing the down-conductor in straight and vertical way is a good applying in order to reduce the probability damage and reduce cost of installation. Important and be in mind that the down-conductor system cannot be installed in gutters or down-spout. It is because to avoid producing the corrosion of the down-conductor [5].

Since this project focused on external protection, so the construction of down-conductor system same as air-termination conductor and also need to be considering while design. The positioning of down-conductor system is located around the perimeter of structure. The detailed about typical values of the distances between each down-conductors that installed at structure are given in Table 1, take out from Table 4 of the MS_IEC_62305_3 (2007) [5].

D. Earth-termination system

Last parts of designing the external lightning protection system (LPS) are earth-termination system. This part is important because it use to conduct and disperse lightning current with high frequency that flowing through down-conductor system into earth. Because of that, the shape and dimensions of the earth-termination system need to pay more attention [5].

Based on the MS_IEC_62305_3 (2007), it is recommended that the typical value of earthing resistance is lower than 10 ohms. The best and excellent value of earthing resistance is equal to 1 ohm during measuring at low frequency. It is because the characteristic of earthing will change if having other construction near to the earth-termination system and cause of the natural phenomena that occur [5].

Earth electrode arrangements are divide into two types which is Type A and Type B. The chosen of the type arrangement of earth electrode depend on the characteristic of the structure that needs to be protected [5].

II. LIGHTNING PROTECTION METHOD

A. Rolling Sphere Method

Rolling sphere method is one of the often used methods for lightning protection. This method is suitable in all cases of structure either for simple or complex structure [5]. It is the basic planning procedure for air terminations for universal or simple structures. The application of rolling sphere method is

about the imagination of a ball with sphere of specific radius *r*, over the air-termination network at structure that need protection.

The ball rolling on the ground, around and on top of the structure in all possible direction until it meets the ground plane or any permanent structure or object make contact with the ground plane. Hence, the sphere of imaginary ball should touch only the ground and or the air-termination system [5].

A piece of equipment or structure is protected from a direct lightning strike if it remains below a curves surface of the ball. The rolling sphere method is a way to detect the lightning strike. The lightning strike can be determined when sphere of the imaginary ball touch the structure or the existing of air-termination system.

In order to determine the radius *r*, of the rolling sphere, the classification of the level of lightning protection system (LPS) need to be choose first. It is because; the radius of the sphere depends on the class of lightning protection system (LPS) [5].

A 2-D graphical analysis Fig. 1 and Fig. 2 shows the structure need protection by using rolling sphere method with a radius related to the proper or mutual protection level. The difference between Fig. 1 and Fig. 2 is determination of the location for air-termination system for difference height of structure [6].

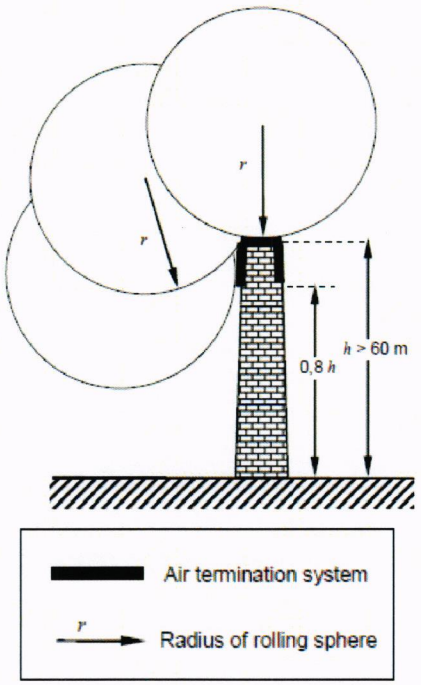

Figure 1. A 2-D simulation for a building with the surrounding structures by using rolling sphere method for height more than 60m

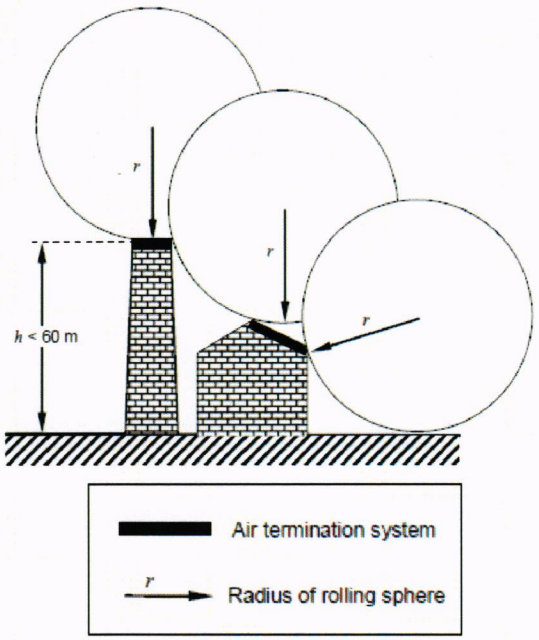

Figure 2. A 2-D simulation for a building with the surrounding structures by using rolling sphere method for height less than 60m.

III. CASE STUDY FOR A STRUCTURE

A case study that was being selected to protection the structure against lightning strike is police station complex located at Sri Hartamas, Mukim Kuala Lumpur. A police station complex that located in close areas where strategic services is generally arranged needs to be protected from the lightning.

The complex consists of an administration building, residence building, a mosque and a guard house. The height for administration building is 23.50m that measuring from the top to the ground consist of 2 storeys. While for the mosque and guard house the height for each of the building is 4.46m and 4.00m. For the residence building it consists of 13 storeys. Height for each of the storey is 3.20m and for the ground floor is 4.00m.

Based on the specification of building, the height for police station complex is less than 60m. It means that the position of an air-termination system located at the top of building as in Fig.2. The overview layout of the police station complex is shown in Fig. 3. The level of protection system applied is Class III since the structure is not very sensitive to the effects of lightning [5]. It means that the structure that being selected not have a chemical liquid or electronic equipment that will make explosion when only small changing in environment.

The police station complex has various types of building and structures. Most of the structures are constructed by using metal deck insulated sound proof panels and steel reinforced-concrete. The structures are made up of reinforced cement concrete. The air termination system was positioning by using rolling sphere method in Fig. 4. The radius for a sphere is 45m based on MS_IEC_62305_3 (2007) [5].

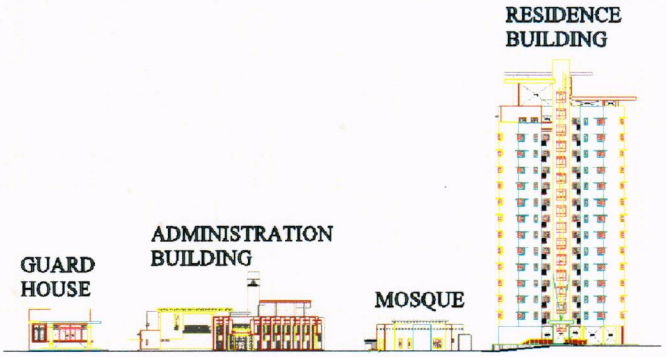

Figure 3. An overview layout of police station complex.

IV. RESULT AND DISCUSSION

A. Rolling Sphere Method

There are several reasons of choosing this method to determine of air-termination system for a building. Firstly is because, this method is suitable use in all cases. So according to the case study, the characteristic of the building not suitable for protective angle method because protective angle method cannot to be implement when the height is greater than the radius of sphere. Thus, based on the building in case study it height is 53m greater than radius of sphere that selected which is 45m.

While the mesh method not is used in these cases study because the mesh method is suitable for a flat roof of structure. By referring Fig. 3 it already determines that mesh method not very suitable to use.

B. Air Termination System

According to Fig. 4 when the rolling sphere method was applied and roll over to the building it shows that the residence building and administration building needed to install air-termination system. When 1m air-termination rod system was installed to the residence building first and the rolling sphere method will roll again to that building to get another situation. The result show that others building lower than residence building are already protected. It will be proven in Fig. 5.

The amount of air-termination rods that was installed on the roof of the building is four. Two of the air-termination rods were installed at the top of the building, which is at the in front and behind of building. Another two of an air-termination rod were installed on the roof at the right side and at the left side. For the administration building the horizontal air-termination conductor were installed on it. Fig. 6 shows the position of horizontal air-termination conductor.

The positioning of air-termination rods for residence building is to protect that building from lightning strike. The location of installing the air-termination system is based on the possibility of that place will hit from lightning protection system. Because of the highest position from other, it becomes one of the reasons why air-termination was installed. Moreover that part of building is a place for lift and at behind place for lift motor room.

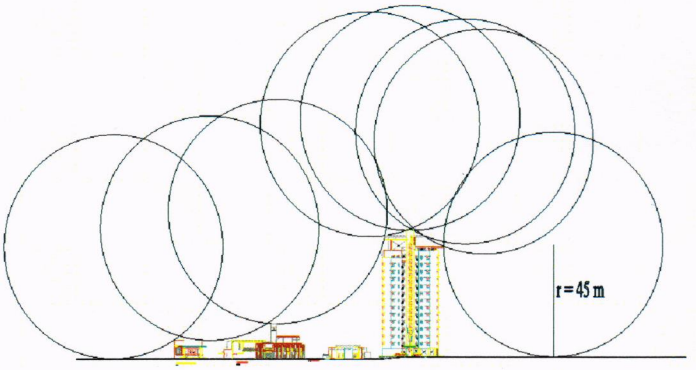

Figure 4. A 2-D plane for a building with the surrounding structures by using rolling sphere method.

For the other air-terminations rod, the reason it was installed at the part of the building because it is an edges side and also it near to the cage ladders. The horizontal air-termination conductor also was installed around the roof of building. For the administration building the air-termination was installed on the roof because when applied rolling sphere over the complex building the administration building was touched by the sphere. But the characteristic of that building is not very attractive by lightning strike so, the air-termination rod was not installed at there but it was replace by horizontal are termination conductor.

The air-termination system for these concrete roof buildings includes it other elements such as bare copper tape need to lie on parapet wall and air-terminal rods which are interconnected at their base.

These concrete buildings are having cable ladders, scupper drain, trays and ventilating ducts installed at roof level. In order to protect these metallic installations at roof level, 1m high air-terminals rods installed at the exposed corner of the roof. The position of these air-terminal rods are decided as per rolling sphere method with 45m radius.

The cage ladders used are at level above the parapet wall of roof, it may be subjected to direct lightning strikes: hence dedicated air-termination rods are provided near the cage ladders for protection against lightning strikes.

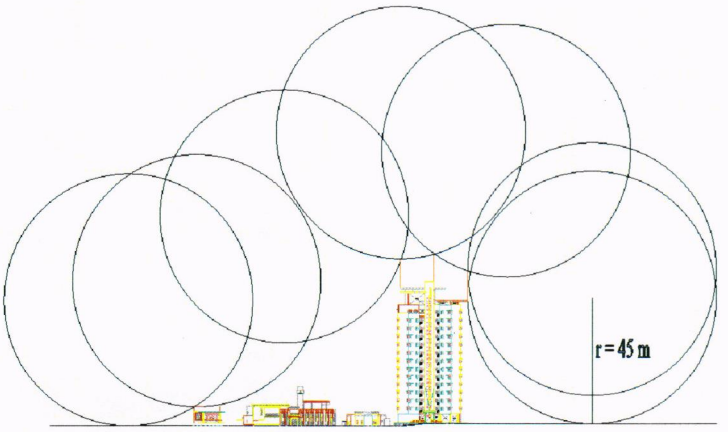

Figure 5. A 2-D plane for a building with the surrounding structures by using rolling sphere method. The radius for sphere is 45m.

C. *Number of Down Conductors and Separation Distance*

For the metal deck roof structures, the metal covering itself is used as natural down-conductor components. The steel inside the metal structures are used as natural down-conductors and electrical connection from metal roof to the vertical steel column is made with $50mm^2$ PVC insulated stranded cooper conductor [5].

For steel reinforced concrete building, the down-conductors are $50mm^2$ PVC insulated stranded cooper conductor installed at an interval of 15m around the edge, from roof level up to ground level [5].

D. *Earth Termination System*

For earth termination system Type-B was used to install since the building consider a complex building. Other elements for earth-termination system are earth mesh conductors around the building edge, concrete reinforcing steel bars and earth rods. The earth grid is buried at a sentence depth below ground level.

For steel reinforced concrete building, each down-conductor is terminated at the earth grid through disconnecting link installed above finished ground level. For load there are 4 earthing terminals available at bottom level. These earthing terminals are connected to the existing earth grid using $50mm^2$ PVC insulated flexible cooper conductors.

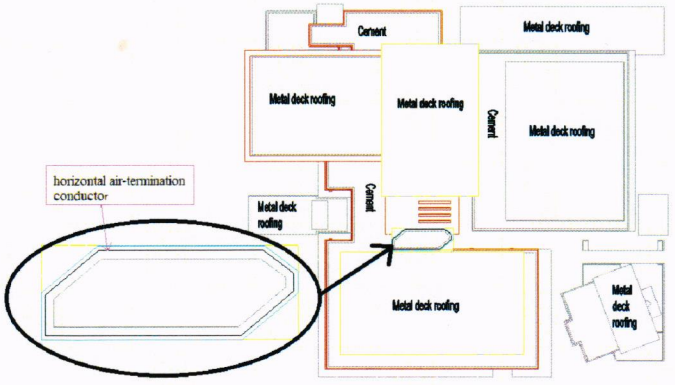

Figure 6. A top view of roof for administration building with the horizontal air-termination conductor

V. CONCLUSION

The lightning strike can cause verity types of damage and loss. To reduce the damage and loss, the proper design of lightning protection system (LPS) and the advance information was given in the standards MS_IEC_62350 (2007).

For the case study, the rolling sphere method was being selected based on the characteristics of the building. It has been shown that the rolling sphere method can be applied more effectively by a method which involves placing certain shapes over objects that form the lightning protection system (LPS) air-termination system. By applying this method it is possible to define the location on air-termination system, the surface area for that building that will protect and also a number of lightning rods or other protective devices.

The position of an air-termination system for the police station complex was identified. The residence for police station and the administration building was distinguished as place for air-termination system. The building was protected against direct lightning strikes, by providing Class III for lightning protection system as guide in MS_IEC_63205_3 (2007) by using rolling sphere method.

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