Direct Lightning Flash Protection of Satellite Antenna

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Abstract. It will cause some problems like improper way of lightning protection and improper height of lightning rod in the design for direct lightning flash protection of satellite antenna, which may increase the probability of lightning strike, due to the lack of express provisions in relevant standards about satellite antenna lightning protection level and direct lightning flash protection ways. A way was presented for the determination of lightning protection level based on probability and risk assessment of lighting through a specific instance, by comparing the probability of lightning, costs and difficulties for construction between two different types of lightning protection ways under the same conditions for indirect lightning protection, an appropriate way was proposed for direct lightning flash protection by using lightning rod installed on the satellite antenna.

1. Introductions
Lightning will generate lightning electromagnetic impulse, which can damage the insulation of electronic equipments and interrupt power supply, even lead to fire or electrical accidents. The satellite antenna installed exterior are more vulnerable to be attacked by lightning, and it will cause lightning over-voltage on signal lines and power lines which can damage the insulation of electronic equipments and result in serious consequences.

According to the express provisions in relevant standards, indirect lightning of satellite stations can be protected by adapting measures like distributary of lightning current, common earthing, equipotential bonding and electromagnetic shielding[1]. Due to the lack of express provisions in relevant standards, designers will often be puzzled by the choices of satellite antenna lightning protection level and direct lightning flash protection ways, and it will cause some problems like improper way of lightning protection and improper height of lightning rod in the design of satellite antenna lightning protection, which may ultimately results in lightning accidents.

2. Direct Lightning Flash Protection of Satellite Antenna
The lightning protection level of constructions has been classified into three levels according to the importance of construction and possibility of being struck by lightning, based on the code for design protection of structures against lightning. AS the constructions of satellite communication earth station and satellite antenna were classified as special constructions, the lightning protection level should be confirmed according to the importance of constructions, probability of lightning and risk assessment of lighting.

There are two ways for direct lightning flash protection of satellite antenna. One of the most simple, effective and economical way for that is to install lightning rods on the top of skeleton and vice-reflector of satellite antenna, another way is to install separate lightning rods on the ground which is more complicated and more expensive when compared with the first way. It was analysed in detail through a specific instance about the ways for direct lightning flash protection in design as follows.
2.1. Determination of lightning protection level

**Instance.** The diameter and rotational amplitude of satellite antenna were 9 meters and 14 meters respectively, the height of satellite antenna is 13 meters including the height of construction which the height is about 6 meters, the major structure of the construction was reinforced concrete, the thunderstorm day was 26.9d/a.

**Estimate the lightning frequency per year.** The lightning frequency of satellite antenna per year can be calculated by formula (1)[2].

\[ N = K \times N_g \times A_e = K \times 0.1T_d \times A_e \]  

(1)

\( N \) is the estimated frequency of lightning, \( K \) is the correction coefficient which is valued at 1 based on instance. \( N_g \) is the average density of lightning strikes on the ground. \( T_d \) is the average thunderstorm day. \( A_e \) is the equivalent area of construction when intercept the same number of lightning which can be calculated by formula (2)[2], as the height of satellite antenna is below 100 meters.

\[ A_e = [L \times W + 2(L + W) \times \sqrt{H \times (200 - H) + \pi \times H (200 - H)}] \times 10^{-6} \]  

(2)

\( L, W \) and \( H \) were the length, width and height of construction respectively. The value of \( N \) was about 0.03 times per year by calculating based on instance.

**Risk assessment of lighting.** Satellite communication earth station was classified as information system, the lightning protection level of satellite antenna should be determined according to the acceptable maximum lightning frequency per year and risk assessment of lighting, which can be calculated by formula (3)-(5) [3].

\[ N_c = 5.8 \times 10^{-15} / C \]  

(3)

\[ C = C_1 + C_2 + C_3 + C_4 + C_5 + C_6 \]  

(4)

\[ E = 1 - N_c / N \]  

(5)

\( N_c \) is the acceptable maximum lightning frequency per year. \( C \) is the all kinds of factors. \( C_1 \) is the materials structure factor of construction for information system. \( C_2 \) is the importance factor of information system. \( C_3 \) is the impact resistance type and impact resistance overvoltage capacity factor of information system and equipments. \( C_4 \) is the factor of lightning protection zone. \( C_5 \) is the consequence factor of information system when there was a lightning accidents. \( C_6 \) is the factor of thunderstorms level. \( E \) is the interception efficiency for lightning.

The value of \( C, N_c \) and \( E \) were 9, 0.02 times per year and 0.33 respectively by calculating based on instance.

**lightning protection level.** According to the results of calculation and code for design protection of structures against lightning, 0.01<N<0.05, E<0.08, the lightning protection level of satellite antenna can be classified as third-class. While consider the special function of satellite communication earth station, the lightning protection level of satellite antenna should be classified as secondary-class.

2.2. Schemes Comparison of Direct Lightning Flash Protection for Satellite Antenna

**Rolling sphere method.** The height of lightning rod can be calculated by formula (6) according to the rolling sphere method[4], the schematic as shown in Fig.1.

\[ r_c = \sqrt{h(2h_r - h)} - \sqrt{h_c(2h_r - h_c)} \]  

(6)

\( h \) is the height of lightning rod. \( r_c \) is the protection radius of lightning rod on \( h_r \) height. \( h_c \) is the rolling sphere radius. \( h_c \) is the height of protected objects.

**Scheme one.** By installing lightning rods on the top of skeleton and vice-reflector of satellite antenna, the satellite antenna can be protected from direct lightning flash. The schematic as shown in Fig.2.
As the lightning protection level of satellite antenna was considered as secondary-class, according to the rolling sphere method, the height of lightning rod was about 6 meters as the satellite antenna and construction were all protected from lightning, and it was about 3 meters when only considering the lightning protection of satellite antenna. In the actual projects, designers tend to pay more attention to the difficulties for installing higher lightning rods on satellite antennas.

**Scheme two.** By installing separate lightning rods on the ground, the satellite antenna and construction can be protected from direct lightning flash. The installation position of lightning rod should be beyond the rotational radius of satellite antenna. According to the rolling sphere method, the height of lightning rod was about 35 meters as the satellite antenna and construction were all protected from lightning, and it was about 25 meters when only considering the lightning protection of satellite antenna. According to the practical experiences, there are several problems with this scheme as follows. Firstly, it will block the signals of satellite antenna because of the unreasonable installation position of lightning rod. Secondly, it will increase the difficulties of installation and construction. Thirdly, it will increase the probability of lightning. Fourthly, it will increase the investments when compared with scheme one.

**Probability of lightning.** The probability of lightning is proportional to the height square of lightning rod according to formula (7)[5].

\[
N_d = N_g \times A_d \times C_d = N_g \times 9\pi h^2 \times C_d
\]  

(7)

\(N_d\) is the probability of lightning. \(N_g\) is the average density of lightning strikes on the ground. \(A_d\) is the equivalent area of construction when intercept the same number of lightning. \(C_d\) is the environmental factor which was valued as 1 when the lightning rod installed on the plains, and valued as 2 when the lightning rod installed on the mountain or hillside.

The value of \(C_d\) was 1 depend on instance. If considers the height of lightning rod as 25 meters, the probability of lightning was about 0.05 times per year. If considers the height of lightning rod as 35 meters, the probability of lightning was about 0.09 times per year. Obviously, the probability of lightning depend on scheme two were much higher than scheme one.

**Consequence.** According to the specifications of engineering design for the domestic satellite communication earth station. It was explicitly stipulated by article 8.5.6 that on the interface of satellite antenna should install lightning rod, and the lightning rod must leads directly to the earth
electrode beside the antenna foundation. It was explicitly stipulated by article 8.5.9 that specific measures for lightning protection should be taken when satellite communication earth station was located at region where is vulnerable to be stroked by lightning[6]. As the average thunderstorm day is only 26.9 days per year in the instance, by comparing scheme one with scheme two in terms of probability of lightning, costs and the difficulties for construction, the scheme one is more practical under the same conditions for indirect lightning protection.

3. Conclusions
Lightning protection of satellite communication earth station is a complicated and systemic work, it’s need to synthetically consider the nature of earth station, probability of lightning, direct and indirect lightning protection and other factors. As it can be seen from the analysis of specific instance, installing separate lightning rods will increase the probability of lightning. Therefore, installing lightning rods on the top of skeleton and vice-reflector of satellite antenna is the simpler and relatively efficient way for direct lightning flash protection when satellite communication earth station was located at region where is less vulnerable to be stroked by lightning.

4. References
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