Analysis of Lightning Protection and Grounding Effect of Shared Iron Tower

Mao Xiaopo, Zhang Yaodong, Zhou Xueming, Feng Zhiqiang, Huang Zeqi, Ren Xiang, Shi Tianru, Fu Jianjin, Huang Junjie

Electric Power Research Institute, State Grid Hubei Electric Power Corporation, Wuhan, Hubei, 430077, China

Abstract. By analyzing the lightning protection and grounding requirements of the respective systems of the communication base station and the power tower, the impact of the towers on their respective systems is analyzed. By establishing a simulation calculation model of the shared tower’s grounding grid, a mature algorithm is used to analyze the current distribution of the typical shared tower. And ground potential distribution, so as to obtain the degree of influence of the equipment when the respective system is struck by lightning. According to the impact, the lightning protection grounding technical requirements and common scheme of the shared iron tower are proposed.

1. Overview
For a long time, the power system has had a great influence on the information and communication system. When a short-circuit occurs in the high-voltage transmission system, the fault current can reach several tens of thousands of amperes, and the increase in ground potential will cause damage to the communication system. From the 1960s to the present, there have been no breakthroughs and engineering solutions at home and abroad in the theory and protective technology of the dangerous impact of high-voltage transmission systems on information and communication systems. The main technical measures adopted in the past are that the two are far away from each other [1-3].

The communication base station usually includes an equipment room (cabinet), base station main equipment, antenna feeder system, and power supply system. The base station ground network consists of the machine room (cabinet) ground network, machine room ground network, tower ground network, and transformer ground network. The lightning protection and grounding of the mobile communication base station are based on the overall concept, integrating several isolated subsystem equipment of the base station into a whole communication system, and comprehensively measuring the lightning protection and grounding problems of the base station [4-5].

The main ways for the base station to be subjected to lightning strikes include lightning strikes invading power lines, lightning strikes in signal lines, lightning strikes in antenna feeder lines, and ground network intrusions (ground potential counterattack).

Thunderbolt can affect the normal operation of the mobile communication base station from four ports of mobile communication base station equipment: power port (power port of various devices connected to the power supply, AC and DC remote ports), signal/control port (various devices transmit signals Port, monitoring signal port, control signal port, etc.), antenna feeder and antenna feeder port (all kinds of antenna feeder signal interfaces, such as antenna, GPS, etc.), ground port (ground port of equipment).
2. Technical requirements for lightning protection and grounding

Base station lightning protection grounding and ground network requirements: According to the requirements of GB 50689-2011 "Communication Bureau (Station) Lightning Protection and Grounding Engineering Design Code" and YD/T 5230-2016 "Mobile Communication Base Station Engineering Technical Specifications". Line pole tower Lightning protection and grounding requirements: According to GB/T 50545-2010 "110kV ~ 750kV overhead transmission line design specifications", GB/T 50061-2010 "66kV and below overhead power line design specifications" and GB/T 50065-2011 "AC electrical installations" "Grounding Design Code" requirements.

By analyzing the lightning protection and grounding requirements of the respective systems of the communication base station and the power tower, analyzing the impact of the towers on their respective systems, by establishing a simulation calculation model of the shared tower’s grounding grid, and using mature algorithms to analyze the current distribution and ground of a typical shared tower Potential distribution, so as to obtain the degree of impact of the equipment when the respective system is struck by lightning. According to the impact, the lightning protection grounding technical requirements and common scheme of the shared iron tower are proposed.

Comprehensive base station lightning protection requirements and line pole tower lightning protection requirements, as well as the height of the base station antenna on the line pole tower, the communication antenna will not affect the line pole tower lightning protection, and the line pole tower lightning protection can basically meet The lightning protection requirements of the relevant specifications of the communications industry. If it is not within the protection scope of the lightning protection line, the lightning protection down line of the antenna equipment lightning protection device should be specially set up. If the electrical connection of the metal components of the tower is confirmed to be reliable, no special down line can be provided. In areas with high thunderstorms, in order to prevent the large electromagnetic pulses generated by lightning strikes from damaging the base station and antenna equipment, various types of surge protectors (also known as SPDs) are installed at the base station electrical equipment ports and other places to avoid the surge damages the equipment in the circuit.

3. Calculation of the ground network scheme for the communication antenna mounted on the tower

Select 220kV transmission pole tower, calculate the ground potential rise, lightning current distribution, power line shield current, and core skin potential difference under different connection methods when the soil resistivity is 600Ω.m. The CDEGS lightning protection grounding calculation module is used for calculation. When the communication device is installed on the tower body, Table 1 shows the calculation indicators of the 220kV pole tower. The part of the simulation results are shown in Figure 1-6.

| Number | Connection method     | Grounding situation                     | Ground potential rise (kV) | Power line shield current (kA) | Core potential difference (kV) |
|--------|-----------------------|-----------------------------------------|----------------------------|-------------------------------|-------------------------------|
| S1     | Single point connection | Not sharing the ground network           | 280                        | 23.04                         | 11.21                         |
| S2     | Single point connection | Single point connection between the two places | 280                        | 13.77                         | 6.70                          |
| S3     | Single point connection | Three-point connection between two networks | 275                        | 8.53                          | 4.15                          |
| S4     | Pole tower net only   |                                         | 424                        | 9.02                          | 4.39                          |

Table 1. Calculated indicators under different conditions
|   | Description                                                                 | Value | Value | Value |
|---|------------------------------------------------------------------------------|-------|-------|-------|
| S5| Not sharing the ground network                                              | 280   | 23.05 | 11.21 |
| S6| Single point connection between the two places                              | 280   | 13.77 | 6.70  |
| S7| Three-point connection between two networks                                 | 275   | 8.53  | 4.15  |
| S8| Pole tower net only                                                         | 424   | 8.63  | 4.21  |

Figure 1. S1 communication grounding network ground potential rise and lightning current distribution

Figure 2. S1 cable shield current and cable core skin potential difference

Figure 3. S2 communication grounding network ground potential rise and lightning current distribution

Figure 4. S2 cable shield current and cable core skin potential difference
Figure 5. S3 communication grounding network ground potential rise and lightning current distribution

Figure 6. S3 cable shield current and cable core skin potential difference

After calculation, it is concluded that the number of connections between the power line of the antenna device and the tower hardly affects the calculation results; the common grounding grid can ensure the equipotential between the tower ground and the base station ground, and the power line shield current and core potential difference are small; In the case of non-shared ground network, multi-point connection can effectively reduce the power shield current and core skin potential difference, but there is a potential difference between the ground network: the above indicators are more serious when the soil resistivity is large.

For comprehensive consideration, the common ground network should be preferred. If it is not easy to realize, consider the multipoint connection form of the ground network.

4. Scheme comparison

According to the analysis of the grounding requirements of the base station and the grounding requirements of the line tower, the grounding schemes are mainly divided into two types:

Option 1: The grounding of the base station and the grounding distribution of the line tower are arranged to meet the requirements and standards of the grounding arrangement of the respective industry, and form their own independent grounding network, which meets the requirements of their respective grounding resistance values. Affected, the signal line and power line connected to the antenna equipment are all insulated from the iron tower, and no ground point is set. Through calculation and analysis, there are certain problems in this scheme. Due to the constraints of the location of the power tower and the communication room, it is generally difficult to meet the need to re-lay a complete telecommunications base station ground network. Even if they can be laid separately, the distance between the two ground networks is also It is not easy to meet the needs of forming mutually independent systems. When a lightning strike occurs, the potentials of the grounding points of the two systems may be very different, there is a high potential difference between the grounding grids, and the probability of lightning damage to the antenna equipment and equipment in the equipment room (cabinet) is high.

Option 2: The newly-built communication room base network of the communication base station and the original grounding network of the line pole tower are connected to a unified grounding grid by welding to form an equal ground potential. The line pole tower and the communication base station share the grounding grid. The signal line and power line connected to the antenna equipment are grounded at the connection point of the iron tower and the place close to the tower, respectively. Although the minimum grounding resistance value of the communication base station is different from the minimum grounding resistance value of the power tower, according to the characteristics of the
grounding resistance, the area of the grounding network is inversely proportional to the grounding resistance. By connecting into a unified grounding grid, the area of the grounding grid expands and the grounding resistance decreases. Moreover, the communication industry has not set a specific resistance value for the grounding resistance of the communication base station after the soil resistivity is greater than 1000Ω, but there is a clear numerical requirement for the grounding resistance value in the power industry, so the communication base station and the power tower share a grounding grid solution, which can The grounding resistance value of the base station and the iron tower is effectively reduced, and the grounding protection effect of the communication base station with a grounding resistance greater than 1000Ω is effectively improved, and the realization of equipotential connection is conducive to lightning protection. But the original power tower grounding grid needs to be transformed.

5. Conclusion
The newly built computer room ground network of the communication base station and the original grounding network of the line tower are welded to form a unified grounding network to form an equal ground potential. The line tower and the communication base station share the grounding network. The common grounding scheme of the communication base station and the power tower can effectively reduce the grounding resistance value of the base station and the tower, and effectively improve the grounding protection effect of the communication base station with a grounding resistance greater than 1000Ω. At the same time, it can realize the equipotential connection is beneficial to lightning protection.

References
[1] L. Dellera, E. Garbagnati. Lightning Stroke Simulation by Means of the Leader Progression Model Part I: Description of the Model and Evaluation of Exposure of Free-standing Structures[J]. IEEE Trans. on Power Delivery, 2015, 12(4): 2009-2012.
[2] T.Yamada, A. Moehizuki. ExPerimental evaluation of a UHV tower model for Lightning surge analysis[J]. IEEE Transactionson Power Delivery, 2015, 10(3): 393-402.
[3] Steiner A, Shamai S. On queueing and multilayer coding [J]. IEEE Transactions on Information Theory, 2010, 56(5): 2392-2415.
[4] Almirall,E, Wareham,J, Ratti,C, Conesa P, Bria F, Gaviria A, and Edmondson A. Smart Cities at the Crossroads: New Tensions in City Transformation[J]. California Management Review, 2016, 59, (1): 141-152.
[5] Greenwood, B N, and Wattal S. Show Me the Way to Go Home: An Empirical Investigation of Ride-sharing and Alcohol Related Motor Vehicle Fatal [J]. MIS Quarterly, 2017, 41, (1): 163-187.