



# Lightning Protection of Electric Vehicle Charging Infrastructure

Jing Zhao, Hongwen Zhang, Qiang Lu, Changquan Xu, Guohua Yang  
Sichuan Zhongguang Lightning Protection Technologies Co. Ltd  
Chengdu, China  
Zhaojing@zhongguang.com

**Abstract**— The paper introduces lightning protection for electric vehicle charging infrastructure. It analyzes causes of lightning damage and introduces overall protection solution for electric vehicle charging infrastructure, including protection against direct lightning, earthing system, equipotential bonding, shielding, routing and installation of SPDs.

**Keywords**- electric vehicle charging station; lightning protection

## I. INTRODUCTION

With continuous improvement of China's economic and social development level, car ownership continues to rise. Increasing environment and energy pressure is forcing introduction of alternative fuel. Electric vehicle, which can speed up the use of alternative fuel and reduce vehicle emissions, has important significance for energy security, emission reduction, and atmospheric pollution control. By the end of 2014, 780 electric vehicle charging stations and 31 thousand AC and DC charging piles have been built up in the country, providing charging services for more than 120 thousand electric vehicles.

Like regular power substation, charging station can be affected by lightning. Most charging stations or charging piles are provided with sensitive components such as microprocessor and high precision integrated circuit, and are installed outdoor, thus more susceptible to lightning. The risk of lightning damage to charging station or pile is significantly high. In the summer of 2015, the electric vehicle charging station in Longquan, Chengdu city China was struck by lightning, which led the lightning strike counter installed in the high voltage cabinet operate, and two switches in rectifier cabinets were damaged. Thus, lightning protection of electric vehicle charging infrastructure is essential to reduce lightning damage and enhance reliability of charging infrastructure.

Lightning protection of electric vehicle charging infrastructure should take characteristics of charging infrastructure into consideration. Overall protection should be applied to provide a complete lightning protection system for electric vehicle charging infrastructure, including direct lightning protection, equipotential bonding, earthing, shielding, proper routing, and installation of surge protective devices. Protective measures against direct lightning and LEMP must be integrated to provide better protection results.

## II. DAMAGE ANALYSIS

Lightning damage to the charging infrastructure could mainly result from the following three sources (Figure 1):

- Overhead transmission lines are subject to direct lightning, lightning surge can invade auxiliary power supply system through auxiliary transformers. Lightning surge from power lines may reach magnitude of tens kA, resulting in very high overvoltage and damaging equipments.
- During direct lightning attachment to air-termination systems in electric vehicle charging station, lightning current flows through down conductors and is diverted into ground through earthing system, potential rise of earthing system may lead to back flashover to charging systems.
- Direct lightning attachment to air-termination systems in electric vehicle charging station or nearby ground can induce high lightning surge in metal lines without proper protections, such as power lines, signal lines, etc.

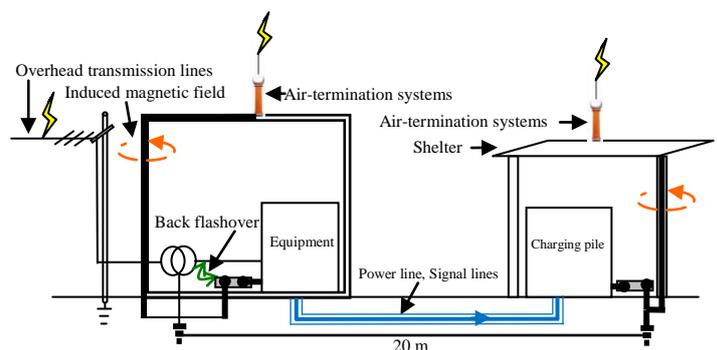


Figure 1. Sources of Lightning damage to the charging infrastructure

### III. PROTECTION DESIGN

#### A. Classification of charging infrastructure

The charging infrastructure may roughly be classified as centralized charging stations and distributed charging piles.

Centralized charging station consists of three or more charging equipments (at least one DC fast charger), and ancillary equipments, such as related power supply equipments, and monitoring equipments, etc. Centralized charging stations are generally equipped with both DC fast chargers and AC charging piles, which can provide charging service for several electric vehicles at the same time.

Distributed charging pile refers to the charging piles installed in the parking lots in such places as public institutions, business enterprises, office buildings, commercial buildings, transportation hub, large recreational and sports facilities, and roadside parking space, etc. The distributed charging piles usually either provide only AC charging outlet, or integrate AC supply and DC charger together in the pile and provide DC charging outlet.

Therefore, lightning protection for the two types of applications are considered respectively.

#### B. Lightning protection of centralized charging station

1) *Protection against direct lightning:* Building (structure) in charging station should be provided with direct lightning protection device. Air-termination rods, conductors, mesh or their combination may be adopted to build up a air-termination system. Metal plate roof of not less than 0.5mm thickness can be used as air-termination system, as long as the bonding length of metal plates is not less than 100mm and there isn't any flammable item below the metal plates.

Charging equipments installed in the outdoor should be provided with shelter with roof. When the roof is non-metallic or covered with thick insulating layer, it should be provided with air-termination rods or conductors, or their combination, the scope of protection is calculated by 60m radius of rolling sphere. Metal-props or steel bars in concrete column can be used as down-conductor system, which should be electrically continuous, otherwise dedicated down conductor should be adopted. Down conductor systems should be reliably electrically connected with air-termination system and earth-termination system (Figure 2).

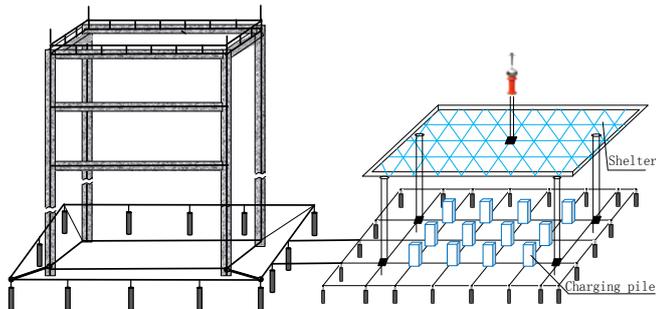


Figure 2. Lightning protection of charging station

2) *Equipotential bonding and earthing system:* Rectifier cabinet and distribution box should be provided with equipotential earthing terminal board. The copper bar with the cross-sectional area of not less than 50mm<sup>2</sup> can be used as equipotential earthing terminal board. PE wire, SPD grounding wire, metal enclosure of the rectifier cabinet and the distribution box should be reliably connected to equipotential earthing terminal board. Charging pile should be provided with equipotential earthing bolt. PE wire, SPD grounding wire, metal enclosure of the charging pile should be reliably connected to equipotential earthing bolt. Insulated copper wire with the cross-sectional area of not less than 16mm<sup>2</sup> should be used to connect equipotential earthing terminal board and bolt with earth-termination system.

Considering that substation, low voltage power distribution, rectifier or DC charger, and charging piles of the charging station are all located nearby, it is better practice to use a common earth-termination system. Lightning protection grounding, anti-static grounding, working grounding of electrical equipment, protective earthing and grounding of information system share the same earth-termination system, and grounding resistance should not be greater than 4Ω.

Natural earthing electrodes of building (structure), such as building foundation should be properly used as earth-termination system. When the grounding resistance of the natural earthing electrodes can't meet the requirement, the artificial earthing electrodes should be added. The steel bars in the foundation of the building should be connected with earth-termination system at different place. The reinforced concrete foundation of the shelter should be used as earth-termination system, and artificial grounding electrodes are preferably added to improve earthing performance. The artificial grounding electrodes are laid around the building or charging piles to form a ring earth electrode. Because the distance between the earth mesh of the shelter and the earth mesh of the substation/distribution/monitoring building is usually less than 20 meters, in order to form a common earth-termination system, at least two flat steels with the cross-sectional area of not less than 4mm×40mm should be used to connect them (Figure 2).

3) *Shielding and Routing:* Shielding shall first make use of spatial shielding provided by building structures and equipment enclosures. Steel reinforcement in building for charging sytem constitutes a large primary shield as long as its metal components are electrically continuous, which can effectively attenuate magnetic field. Since lightning current might be diverted to earth through steel reinforcement bars in peripheral columns, the further off the columns, the weaker the magnetic field, it is advisable that equipments be located in central area of the building to get better shielding effects. Optical-fiber cables are advisable for outdoor communication lines, outdoor cables with metal core shall be laid in steel conduits. Safety distances should be kept from possible lightning passages such as down conductors. Wherever safety distance cannot be assured, additional shielding should be provided. Cable routing shall avoid large loop to reduce effect of LEMP. All

metal pipes and lines into the building of charging station, including power supply lines and communication lines, preferably enter at the same location and are securely connected with nearby bonding terminal board.

4) *Installation of SPDs:* TN-S system is preferred for low voltage earthing system of charging station in accordance with Chinese national standard GB50343[1]. SPDs should be provided for power and signal lines in charging station to protect equipment ports from lightning surge. Design of SPDs should take into consideration characteristics, location, and installation methods of equipments to be protected. SPDs should be installed in such a way that they are close to equipments to be protected, their connecting conductors as short as possible, and effective protection level is lower than rated impulse withstand voltage of equipment to ensure satisfied protection results.

Multi-stage SPDs are recommended for surge protection of power supply for charging station. Number of stages depends on distance between SPD and equipment being protected, the length of connecting conductors, and rated impulse withstand voltage of equipments being protected, etc (Figure 3).

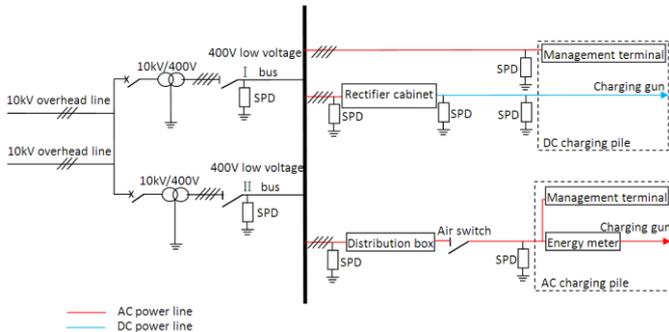


Figure 3. Installation of power supply SPDs in charging station

In general, three stages may be considered. The first stage is installed at the low voltage side of the transformer with impulse current of 12.5kA or above or nominal discharge current of 50kA or above.

The charging station is equipped with rectifier as well as DC and AC charging pile, installation of secondary stage and third stage SPDs are recommended as follows:

- For DC charging system, the secondary stage is installed at input port of rectifier cabinet with nominal discharge current of 20kA or above. The third stage is installed at input port of management terminal, output port of rectifier cabinet and DC input port of DC charging pile with nominal discharge current of 20kA or above.
- For AC charger, the secondary stage is installed at input port of distribution box with nominal discharge current of 20kA or above. The third stage is installed at input port of AC charging pile with nominal discharge current of 20kA or above.

Selection of signal SPDs in charging station shall be based on the parameters of signal lines such as working frequency, transmission rate, operating voltage, interface type, characteristic impedance, etc. The selected SPDs should have low insertion loss so as not to affect normal operation of equipments (Figure 4).

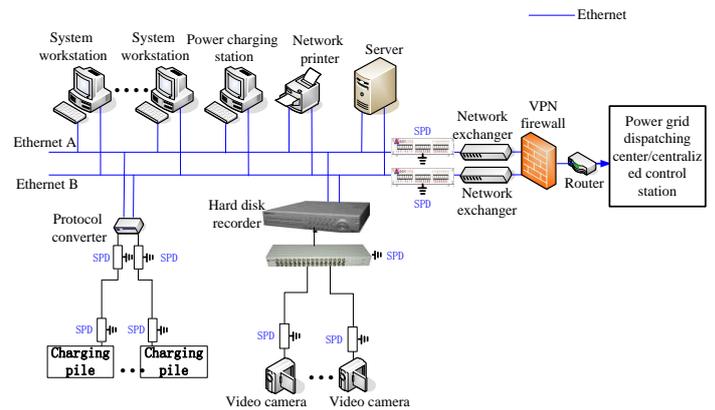


Figure 4. Installation of SPDs for monitoring system in charging station

Main protections for signal lines include:

- SPD of nominal discharge current of 1kA or above shall be provided at input port (RJ45 port) of network exchanger.
- SPD of nominal discharge current of 1kA or above shall be provided at video access terminal (RJ45 port) of hard disk recorder, and nominal discharge current of 5kA or above at BNC port.
- SPD of nominal discharge current of 1kA or above shall be provided at input port (RJ45 port) of protocol converter and signal output port of charging pile, and nominal discharge current of 5kA or above at CAN or RS485 port.

SPD of nominal discharge current of 10kA or above shall be provided at visual signal ports and control ports of outdoor video camera.

### C. Lightning protection of distributed charging piles

Air-termination system of nearby building (structure) should be used for protection against direct lightning of distributed charging piles, which should be installed in LPZ0<sub>B</sub>. The artificial grounding electrodes are preferably added for distributed charging piles, and are laid around charging piles as a ring earthing electrode. In order to form a common earthing-termination, at least two flat steels with the cross-sectional area of not less than 4mm×40mm should be used to connect the earth mesh of distributed charging piles to the earth mesh of nearby building/structure (Figure 5).

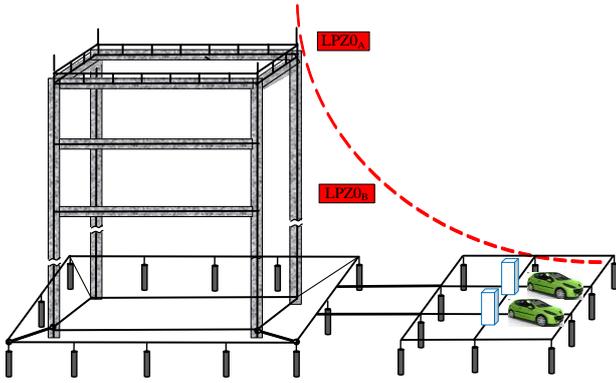


Figure 5. Lightning protection of distributed charging piles

The distributed charging pile comprises integrated DC charger and AC charging pile. When distributed charging piles are installed at locations with high risk of lightning strike, such as the open area, the roof of high building, etc, the following SPDs should be installed; when distributed charging piles are installed at locations with low risk of lightning strike, SPD with lower current capacity may be installed (Figure 6):

- SPD of nominal discharge current of 20kA or above shall be provided at three phase power input port of integrated DC charger.
- SPD of nominal discharge current of 20kA or above shall be provided at single phase power input port of AC charging pile.

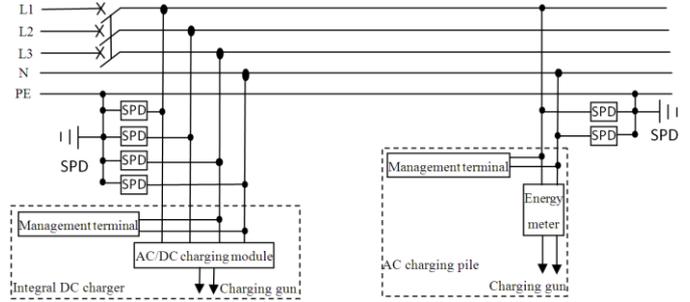


Figure 6. Installation of power supply SPDs for distributed charging piles

#### IV. CONCLUSION

Electric vehicle charging stations consist of power supply equipment, rectifier, charging pile, monitoring and communication equipments susceptible to lightning effects. Lightning protection should take characteristics of electric vehicle charging systems into consideration. Overall protection against direct lightning and LEMP should be applied to provide a complete lightning protection system to achieve better protection results. The application of the design concept can significantly improve safety and reliability of electric vehicle charging stations.

#### REFERENCES

- [1] Technical code for protection of building electronic information system against lightning, GB 50343-2012.