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Solution for Power Distribution Design of Charging Piles in Underground Garages of Civil Buildings

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Abstract: With the continuous improvement of people's living standards, private cars have almost become a necessary means of transportation for every household, which has brought great pressure to the ecological environment. To improve this situation, the country has gradually attached importance to the development of new energy vehicles and achieved certain results. As a type of new energy vehicle, electric vehicles have already occupied a certain market share. However, the difficulty in charging and finding charging locations has hindered their popularization. In this regard, the construction of charging piles in underground garages of civil buildings to provide electricity for electric vehicles is of great significance to their popularization.

Keywords: Civil buildings; Underground garages; Charging pile power distribution design

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1. Introduction to charging piles in underground garages of civil buildings

1.1. Classification of charging piles

As an infrastructure for supplying electricity to electric vehicles, charging piles function similarly to fuel dispensers in gas stations. They can be fixed on the ground or walls and are widely used in public buildings, parking lots of residential communities, and professional charging stations. They can meet the charging needs of various electric vehicles according to different voltage levels.

In terms of classification, charging piles can be divided into floor-mounted charging piles and wall-mounted charging piles based on installation methods. The former is suitable for parking spaces far from walls, while the latter is more appropriate for locations close to walls[1]. From the perspective of installation sites, charging piles can be further divided into public charging piles and private charging piles. Public charging piles are set in public parking lots and provide services for social vehicles in combination with parking berths. Private charging piles mainly exist in the self-owned parking lots of units to serve internal staff, or in personal parking spaces to exclusively provide charging support for private users. According to the number of charging interfaces, charging piles can also be divided into two types: one pile with one charging interface and one pile with multiple charging interfaces. In addition, in terms of charging methods, charging piles include three forms: DC charging piles, AC charging piles, and AC-DC integrated charging piles. Finally, when classified by charging speed, charging piles are categorized into conventional charging (slow charging) and fast charging. This classification reflects the differences in time efficiency among different charging technologies. The above

various classification methods comprehensively demonstrate the diversified characteristics of charging piles in practical applications and their important role in promoting the popularization of electric vehicles.

1.2. Technical parameters of charging piles

The rapid development of electric vehicles has driven continuous progress in charging pile technology. Although the types of charging piles are increasingly abundant, from the perspective of technical parameters, they can be mainly divided into two categories: DC charging piles and AC charging piles. These two types of charging piles have significant differences in structure, function, and application scenarios.

DC charging piles consist of a DC charging device and a charger cabinet. They feature a wide range of voltage and current adjustment, and can directly deliver electrical energy to the lithium batteries of electric vehicles, thus achieving a relatively fast charging speed and meeting the needs of various vehicle models. However, this charging method causes certain damage to the battery, which may shorten the battery life. At the same time, due to the large size of the equipment, it occupies a relatively large area. Based on these characteristics, DC charging piles are mostly used in scenarios such as urban transportation parking lots and enterprise - dedicated parking lots, while their application in parking lots of civil buildings is relatively limited[2].

AC charging piles have the advantages of a simple system structure, small floor space, and convenient operation. But they have a long charging time and are usually suitable for scenarios such as underground garages in residential communities. This type of charging pile provides charging power for electric vehicles equipped with on-board chargers and can be divided into single-phase and three-phase forms according to the input method.

In terms of technical parameters, the DC charging device, commonly known as “fast charging”, is mainly used to provide efficient charging services for electric vehicles. Its input voltage adopts three-phase four-wire AC380V ± 15% with a frequency of 50Hz, and the output is adjustable DC power, which is directly connected to the power battery of the electric vehicle for charging. DC charging piles can provide large power, with a wide range of output voltage and current adjustment. They can complete full-load charging within 1 to 2 hours, meeting the needs of various vehicle models. However, this method causes great loss to the battery and the equipment occupies a large area. Therefore, the main application scenarios of DC charging piles include urban transportation parking lots, highway service area parking lots, and enterprise - dedicated parking lots. There are also a small number of them set up in large commercial office parking lots.

AC charging piles, commonly known as “slow charging”, provide charging power for electric vehicles with on-board chargers. They are characterized by not containing a rectifier and need to be connected to the on-board charger to realize the charging function for electric vehicles. The system design of AC charging piles is relatively simple, with small floor space and convenient installation, but the charging time is long, usually taking 5 to 8 hours to complete full-load charging. Therefore, this type of charging pile is mainly applicable to residential community parking lots, large commercial office areas, and public parking lots. Specifically, residential community parking lots usually mainly use AC charging piles, while the parking lots in commercial office areas are equipped with DC charging piles and AC charging piles in an appropriate proportion according to the different frequency of electric vehicle entry and exit to meet diverse needs. This reasonable layout not only improves charging efficiency but also takes into account the actual usage needs of different user groups.

2. Technical requirements for charging piles in underground garages of civil buildings

The technical requirements for charging piles in underground garages of civil buildings involve multiple aspects. As the main type, AC charging piles need to provide sufficient and safe power support for electric vehicles. During operation, they should be capable of displaying charging status, billing information, and other functions to ensure that users have a clear understanding of the charging process. Charging piles need to support on-off control at any time, and in case

of overload or high-voltage abnormalities, they can activate self-protection mechanisms and trigger alarm functions to ensure the safety of equipment and personnel. From the perspective of electrical design, the power cords of AC charging piles should be flame-retardant cables, used in conjunction with cable protection pipes to enhance safety. In addition, by installing air switches, rapid self-protection can be achieved in case of electric leakage. The protective grounding terminal of AC charging piles should be reasonably set according to local environmental requirements to ensure reliable grounding effect. In terms of low-voltage power distribution systems, the TNS system that meets the requirements of civil buildings should be adopted. This system has excellent grounding protection performance and can effectively meet the design specifications of electrical engineering in civil buildings. The implementation of these technical requirements is crucial for improving the safety and stability of charging piles, and also provides a solid guarantee for the popularization of electric vehicles in civil buildings.

3. Issues needing attention in the power distribution design of charging piles in underground garages of civil buildings

The power distribution design of charging piles in underground garages of civil buildings involves multiple technical points, and comprehensive consideration should be given to safety, practicality, and management convenience. As an important place in people's daily life, the underground garage in civil buildings is an ideal area for configuring electric vehicle charging facilities. The following is a detailed discussion from the aspects of circuit setting, installation method, distribution box arrangement, and charging pile location planning.

In terms of circuit setting, the power distribution system of charging piles in underground garages should adopt low-voltage circuit breakers with short-circuit protection and residual current protection functions to ensure electrical safety. This design can effectively ensure the stability of charging piles during operation and provide reliable protection for the personal and property safety of residents. A reasonable circuit configuration not only improves the reliability of the system but also meets the actual needs of electric vehicle charging.

Regarding the installation methods of charging piles, two forms are usually adopted in underground garages of civil buildings: floor-mounted and wall-mounted. Among them, floor-mounted installation is relatively simple, generally, the equipment can be deployed by placing it at the end of the parking space about 30 centimeters from the ground. Wall-mounted installation, on the other hand, requires fixing the charging pile on a column or wall, and its installation height is significantly higher than that of floor-mounted equipment. Each of the two methods has its advantages and disadvantages, and the choice should be based on actual site conditions and usage needs.

In the link of distribution box setup, to ensure the sufficiency of power supply and the convenience of management, a number of distribution boxes should be reasonably arranged near the charging piles and installed in the high-voltage electricity room. Construction personnel also need to set up an appropriate number of circuits at the low-voltage cabinet in the electrical room according to the parameters of the distribution box, so as to realize direct power supply to electric vehicles. In addition, to avoid potential safety hazards caused by short circuits or overloads, low-voltage circuit breakers can be introduced into the circuit design, and residual current protection can be implemented through the working mechanism of rated operating current. This measure helps to significantly reduce the risk of fire, thus ensuring the safety of charging piles during operation.

Regarding the location configuration of charging piles, multiple factors need to be comprehensively considered, including the type of electric vehicles, traffic flow distribution, underground garage layout, and power distribution system settings. When planning the number and location of charging piles, it is necessary to ensure their reasonable distribution and ease of use for users. For AC charging piles, it is recommended to arrange them as scattered as possible in different fire compartments to reduce the risk of fire spread; for DC charging piles, they can be preferentially placed in the fire compartments near the garage entrances and exits. If the number of charging piles is small, they can be centrally placed in the same fire compartment for unified management and maintenance. However, when there are sufficient

charging piles, they should be scattered in each fire compartment according to the characteristics of different charging equipment and their application needs. For example, DC fast charging piles are usually more suitable to be set in the garage entrance and exit areas to meet the demand for rapid energy replenishment; while AC slow charging piles can be widely distributed in each fire compartment to serve daily parking and charging scenarios.

In conclusion, the power distribution design of charging piles in underground garages of civil buildings needs to take into account both technical specifications and actual needs. Through scientific and reasonable planning and implementation, the safety, economy, and convenience of charging facilities can be ensured, so as to better serve the daily travel needs of residents. Relevant staff should fully consider various influencing factors in the design process and formulate optimized schemes in combination with the actual situation to achieve the best configuration effect of charging piles.

4. Power distribution design solutions for charging piles in underground garages of civil buildings

4.1. Pay attention to the setting of power distribution access points for charging piles

The setting of power distribution access points for charging piles in underground garages of civil buildings needs to focus on power supply load and system stability. Night is not only the main time period for electric vehicle charging but also the peak time for residential electricity consumption. If the charging piles are directly connected to the residential power supply network, it may increase the load of the residential power supply system, thereby adversely affecting the stability and reliability of power supply.

Take a large residential community as an example. The total construction area of the community is 300,000 square meters, and the number of designed parking spaces in the underground garage is 2,200. According to the requirements of relevant regulations, new civil residences need to be equipped with charging pile facilities according to 20% of the number of parking spaces. However, the popularity of new energy vehicles is currently limited, and the construction cycle of residential communities is short. Equipping charging piles according to this proportion may lead to the idleness of some facilities. Therefore, consideration can be given to directly connecting the power supply of the charging piles corresponding to the 20% proportion to the community's power distribution station, so as to avoid additional burden on the residential power supply network and effectively improve the capacity utilization rate of the power distribution station. In addition, it is of great significance to reserve an independent distribution room in the center of the residential community. This measure can provide a guarantee for the expansion needs of charging piles in the underground garage in the future. When it is necessary to add charging piles later, the independent distribution room can quickly respond and provide stable power support for the underground garage. It can be seen that in the scheme design stage, full consideration should be given to the power demand of charging piles, and the design and capacity calculation of the independent distribution room should be reasonably planned to reserve sufficient space for the future development of the community.

4.2. Setting up intelligent sensing programs

Generally, the service life of lithium batteries is 5-8 years, and the charge cycle life is 600-1000 times. To ensure the quality and service life of lithium batteries, it is necessary to charge them when the battery power drops to 20% to prevent over-charging and over-discharging. When the power is charged to 80%-90%, charging should be stopped [3]. Only in this way can the battery energy supplement and driving range be guaranteed, without affecting people's use of electric vehicles. In the operation of electric vehicles, the energy density and driving range of power batteries are two important parameters, which are directly related to the service life of the battery. However, usually, users pay little attention to the safety of battery life. When charging electric vehicles, most of them charge at night and turn off the charger the next morning, which brings negative impacts on the battery. In this regard, when configuring charging piles,

intelligent programs should be set up so that the charging piles can automatically sense the charging capacity of electric vehicles and stop supplying power immediately when it reaches about 80%-90%, so as to protect the service life of lithium batteries in electric vehicles and provide better services for users[4].

4.3. Scientifically setting the number of charging piles

In the early design stage of residential quarters, in accordance with relevant requirements, charging piles should be configured according to 20% of the total number of parking spaces, that is, about 400 charging piles. For the input capacity of a single charging pile, the overall capacity required to meet 20% of the number of parking spaces can be calculated. In this process, the staff also need to evaluate in combination with the actual operation of electric vehicles. According to research data, an electric vehicle can travel 150 to 250 kilometers after a full charge, while the average daily driving distance per person is about 20 kilometers. Based on this, in the early design, the probability that more than 400 charging piles are in the charging state at the same time is about a quarter, and this probability will not increase significantly in the later design. In addition, the construction personnel should conduct in-depth analysis on the capacity required for the power distribution of charging piles to clarify the working capacity of AC charging piles. In actual operation, the output power of the electric vehicle charger is usually lower than that of the AC charging pile, so the finally calculated input power is also smaller than the ideal value. This phenomenon requires the staff to fully consider the impact of the above factors in the analysis process to ensure the scientificity and rationality of the design scheme[5].

At present, the energy density of lithium batteries in electric vehicles has reached a new height, and their driving range can reach more than 300 kilometers, which can basically meet the commuting and short-distance travel needs of most users. With the increase of the driving range of electric vehicles, the shortening of charging time and the improvement of popularity, it is only necessary to reasonably set up charging piles in civil buildings to meet the basic needs of users. However, how to scientifically set up charging piles to meet the actual needs of residents while ensuring the minimum cost has become a key problem to be solved urgently. In the past, the driving range of electric vehicles was mostly about 150 kilometers, but with the progress of science and technology and the country's attention to the driving range of electric vehicles, this index has been significantly improved, thus better meeting customer needs and promoting the popularization of electric vehicles. Assuming that an electric vehicle travels an average of 24 kilometers per day, each electric vehicle needs to be charged about every five days, and the corresponding ratio of parking spaces to charging piles should be 5:1. With the continuous progress of electric vehicle technology, the setting scheme of charging piles in the future needs to be further optimized. For example, dynamically adjust the number of charging piles according to the actual use, or introduce an intelligent management system to improve resource utilization efficiency. At the same time, factors such as the carrying capacity of the power supply system and users' charging habits should be comprehensively considered to ensure that the design scheme meets both technical requirements and economic feasibility. In this way, the needs of residents can be met, and the coordinated development of electric vehicles and supporting facilities of civil buildings can be promoted.

4.4. Long-term parking space design for charging pile power distribution

At present, the development speed of electric vehicles in China has shown a curve upward trend, and the number of charging piles in the underground garages of civil buildings should be gradually increased to meet the needs of residents. When configuring electric vehicle charging piles in underground garages, it is sufficient to set up 20% of the number of parking spaces in the early stage. However, with the continuous popularization of new energy vehicles, the number of residents buying electric vehicles is increasing, and the number of charging piles will inevitably have insufficient power distribution, affecting residents' use. In this regard, in the power distribution design of charging piles, relevant personnel should observe the charger technology, battery technology, and safety detection technology of charging piles of electric vehicles, so as to lay a good foundation for the power distribution of 100% of the number of parking spaces for charging piles in the later stage.

5. Conclusion

To sum up, with the continuous promotion of energy conservation and emission reduction in China, electric vehicles, as a new technical means, will be more widely applied and developed, which also means that the construction of charging piles will be the focus of our attention in the future. The study found that there are still many problems in the current charging and power distribution design of underground garages in civil buildings. Therefore, in the power distribution design work, the staff should comprehensively analyze the technical requirements of charging piles, especially strengthen the analysis of power distribution design work, and put forward more reasonable problem responses and solutions in practical work. It is hoped that through the research of this paper, the staff can pay attention to this problem and actively explore in the power distribution design of charging piles in underground garages of civil buildings, so as to build a good foundation for the stable and long-term development of China's economy.

Disclosure statement

The author declares no conflict of interest.

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