Research on charging safety and early warning of intelligent networked electric vehicles

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Abstract. With the continuous reduction of renewable resources and the increasing awareness of environmental protection, the phenomenon of replacing oil with electricity has become more and more common. Electric vehicles are an obvious example. In the past few years, electric vehicles have developed rapidly and become more and more popular in people's lives. However, imperfect technology has caused frequent safety accidents. The main reason for this is the charging safety risk. In this paper, there are many complex factors affecting the charging safety of electric vehicles in terms of the safety of electric vehicle charging and the energy and data exchange direction between charging piles and electric vehicles. Based on the analysis of the factors that affect the charging safety of electric vehicles, this paper combines big data technology to study the charging safety of electric vehicles.

1 Introduction

Environmental pollution is becoming more and more serious. In order to reduce carbon dioxide emissions and adhere to sustainable development, vigorously developing electric vehicles is an effective way. According to data from the China Charging Alliance: as of the end of 2019, China's electric vehicle ownership reached 3.368 million. It accounts for 1.46% of the total number of vehicles, and the supporting charging facilities reach 1.291 million vehicles per year, a year-on-year increase of 50.8%. With the increasing number of electric vehicles, there are more and more safety accidents, and the causes of accidents are also diverse. For example, if the battery management system (BMS) main board fails and the charger knows the battery cell voltage and total voltage protection limit, but the actual value exceeds the limit and no measures are taken, overcharging will occur. Failure to cut off the power in time during charging affects the service life of the battery. The charging equipment and battery of electric vehicles are the two main aspects that cause frequent safety accidents. However, there is still no effective method to evaluate its safety level. For this reason, the reference [1] puts forward the "safety protection qualification rate of electric vehicle charging equipment". The evaluation index is applied to the comprehensive evaluation system of electric vehicles to improve the safety protection capabilities of electric vehicles. Reference [2, 3] proposed a comprehensive evaluation method that considers both the safety of electric vehicles and charging stations. On this basis, Fabio Freschi et al [4] further discussed the safety of electric vehicle charging, and proposed to equip electric vehicle charging equipment with an insulating transformer to isolate the current from the grid for monitoring the safety of the electric vehicle charging process sex. In the reference [5], Claus-Christian Carbon et al improve the safety of charging infrastructure by providing data and materials within a safe range, thereby ensuring the safety of electric vehicle charging. Reference [6] pointed out the importance of battery safety for electric vehicle charging safety, and proposed a high-dimensional data flow outlier detection algorithm (DSOD) based on angular distribution for the safety assessment of battery systems. With the rapid development of big data technology, its simple and fast features have also been applied in the field of electric vehicle safety. In [7], Tomasz Wierzbicki proposed a data-driven security envelope algorithm to ensure its safety in order to solve the problem of easy damage to electric vehicle battery packs. Domestic research on charging safety is still in its infancy. It mainly studies charging equipment and environmental factors based on charging safety. Qian Lijun et al [8] analysed the influence factors of electric vehicle charging safety and used genetic wavelet neural network training principles and with the characteristics of multi-scale and multi-resolution, a charging safety warning model is designed to improve the safety warning capability of the charging system. Reference [9] summarizes the safety factors in the charging process of electric vehicles from four links, including equipment, technology, monitoring, and management. And a dynamic early warning method of battery short or micro short circuit based on monitoring data is proposed to control and eliminate potential faults. Reference [10] defines the safety level of charging facilities, and combined with the 5 new national standards released in 2016, analyses the factors affecting the charging safety of electric vehicles, and gives a solution to the charging safety. Generally speaking, most foreign studies focus on the evaluation

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methods of electric vehicle charging safety, while domestic research mainly focuses on factors such as the charging process of electric vehicles, charging equipment and batteries.

2 Functional requirements, logical architecture, communication architecture

Based on the ubiquitous Internet of Things, the functional requirements of electric vehicles and charging facilities networks should meet the five major characteristics of the ubiquitous power Internet of Things: terminal ubiquitous access, platform open sharing, computing cloud and fog collaboration, data-driven business, application free need to be customized. The logical architecture should follow the four-layer architecture of the power Internet of Things. Its architecture follows the three-layer architecture of the Internet of Things perception extension layer, network transmission layer, and platform application layer, adding an edge computing layer. The communication architecture should consider the network communication layer composed of two parts: the local communication network and the remote communication network.

3 Electric vehicle charging safety classification

According to the charging process of electric vehicles, charging safety can be divided into grid side safety, charging equipment side safety, vehicle side safety and monitoring system safety (Figure 1).

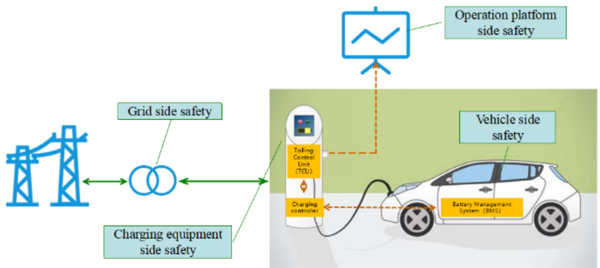

Fig1. Electric vehicle charging safety classification

3.1 Charging safety accidents

The main problem of charging safety on the grid side lies in the adverse effects of the charging behaviour of electric vehicles on the stable operation of the grid. Including: iolation of load limit, power quality limit, resonance risk, relay protection action and lack of anti-islanding protection function.

The charging safety issues on the charging equipment side are mainly the adverse effects of electric vehicle charging behaviour on personnel, electric vehicles, and charging facilities. Including: equipment leakage, charging equipment failure, charging incompatibility, charging start failure, abnormal protection measures are not in place.

The charging safety problem on the charging vehicle side is mainly the defective battery or battery management system. Including: excessive impurities in the electrolyte, unqualified process, defects of the diaphragm itself, and unreasonable structural design, the safety protection measures of the BMS management system are not in place.

The charging security problem of the platform monitoring system is mainly due to the lack of completeness of the system itself, which mainly includes the risk of electricity theft. Among them, time-sharing rental cars have the largest proportion of electricity theft in the early industry, abnormal charging transactions, too much or too little billing, and the charging equipment is offline without local charging countermeasures, lack of experience, hacker attacks on the operating platform, and the risk of service network paralysis.

3.2 Safety measures

Safety measures on the grid side. Promote coordinated charging technology in stations. Take the station area as the unit, hierarchically partition the charging load management, collect the charging load information and the electric load situation of the station area through the coordinated charging controller (energy controller, energy router, etc.), and according to the user charging and car time demand, arrange the charging plan to meet the cluster charging demand in the case of the distribution transformer of the station area without expansion, and achieve peak shaving and valley filling. (Figure 2)

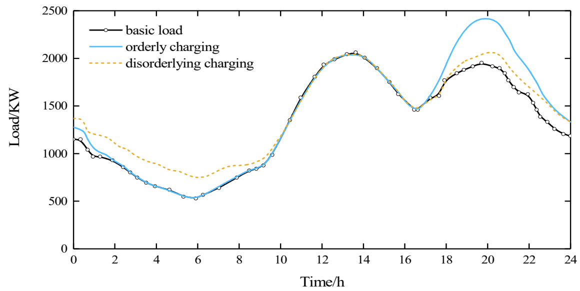

Fig2. Coordinated charging measures on the grid side

Safety measures for charging equipment. Before charging, recheck the size of interface, size and tolerance of mechanical locking mechanism. During charging, check the locking time and state of electronic lock (check whether the charging plug is pulled out by pressing the mechanical lock button) to avoid potential safety hazards. In the charging process, the content, format, cycle and time sequence of communication messages will be judged in real time. If there are abnormal messages or logical errors, the charging will be stopped or the power will be reduced according to the specific situation; in addition, the abnormal communication and error messages will be processed in real time, fault messages or charging suspension messages will be sent, and charging will be stopped directly if necessary. Research the classification of charging faults, fault characteristic values, safety thresholds, collection and judgment methods, quickly analyses the specific causes and handling methods of faults, improve the accuracy of charging fault location, and provide convenient charging fault solutions for operation and maintenance personnel.

Safety measures on the platform side. Add inter-regional access control, improve network boundary protection measures, improve system security configuration, and strengthen information security monitoring mechanisms.

Safety measures on the vehicle side. Battery status detection: it can effectively measure the cell voltage, total voltage, current, temperature, insulation resistance and other parameters of the battery system. The measurement accuracy and frequency should meet the requirements of national standards under normal working conditions and severe extreme working conditions.

4 Build database

Collect electric vehicle charging safety cases, collect daily driving rules, charging times, charging duration, and alarm operation information in a certain area through sampling, and combine specific cases and expert analysis to establish a characteristic database of electric vehicle charging safety accidents. From the perspective of charging safety, establish a network database of regional charging business information and equipment safety information; propose a quality evaluation method for the full life cycle of charging facilities; establish a database of regional charging service capability information and equipment operation safety information. However, with the rapid development of the ubiquitous Internet, if all the data generated by the Internet is transmitted to the cloud computing center, this will greatly increase the network load, cause information congestion, and thus lead to delayed information transmission and difficult to ensure the safety of charging. Edge computing can effectively solve this problem. Edge computing can meet the computing capabilities of edge devices by deploying small devices with computing, storage and network access capabilities at the edge of the network, and being closely connected with smart sensors, wired meters and users. Expanding demand can effectively reduce network load and data delay.

5 Security detection and early warning technology based on charging real-time data stream

Insulation resistance test: before the insulation resistance test, the external power supply connection of the charging equipment should be disconnected, and the input and output circuit switches should be closed. Between the independent live circuits of the electrical connection of the charging equipment, and between the independent live circuits and the protective grounding conductor (metal shell) Apply 500V direct current (DC) voltage, and check that the insulation resistance of the charging equipment is not less than 10MΩ.

Input overvoltage protection test: connect the charging equipment to the analog load, set the analog load at the rated power value, load and run and reach a stable state, adjust the output voltage value of the charging equipment power supply to be higher than 115% of the rated voltage value, and check whether the charging equipment starts input The overvoltage protection function cuts off the output and issues a fault alarm.

Input under voltage protection test: connect the charging equipment to the load, set the rated power to load and run and reach a stable state, adjust the output voltage of the power supply of the charging equipment to be lower than 85% of the rated voltage, and check whether the charging equipment has activated the input under voltage protection function and whether it has issued a fault alarm.

Output short circuit protection test: short-circuit the output of the charging equipment, load and start, check that the charging equipment should not allow output charging, and issue an alarm. Short-circuit test during operation: the charging equipment is connected to the load, the load is running and reaches a stable state, the output short-circuit failure of the charging equipment is simulated, and the charging equipment should be checked immediately to limit the current output or cut off the output, and issue an alarm.

Power cut off and restart test: connect the charging device to the load, set the rated power to load and run and reach a stable state, disconnect the alternate current (AC) side power supply, and check the output of the charging device. Keep the charging connection device fully connected, reconnect the AC side power supply, check that the charging device should not be able to continue to output charging, it needs to be manually replugged, and the connection is established before the next charging is allowed.

Output adhesion test: simulate the contact adhesion of the contactor, check that the charging equipment should not allow charging and issue an alarm.

Emergency stop test: connect the charging equipment to the load, load and run and reach a stable state, press the emergency stop button, and check that the charging equipment should be able to immediately cut off the output.

Connection and disconnection contact sequence test: in the process of checking the charging connection and disconnection, the ground terminal and contact of the charging connection device should be connected first and disconnected last.

Abnormal charging connection test: when an abnormal control pilot signal occurs during the charging process (such as signal short circuit, signal open circuit, signal grounding, etc.), the charging equipment should be able to disconnect the power supply circuit within 100ms.

6 Principles of information monitoring and safety alarms during charging

The electric vehicle charging process includes 6 stages: physical connection completion, low-voltage auxiliary power-on, charging handshake stage, charging parameter configuration stage, charging stage, and charging configuration stage. No matter in which phase the charger and BMS do not receive the other party's message or the correct message within the specified time, it will be judged as timeout and enter the error processing state. Using this principle, we can use efficient judgment software and calculation software to analyse the charging process. The CAN communication message between the charging equipment and the battery management system can realize the information monitoring and safety alarm of the charging process. Build a system local area network between on-site charging safety detection terminals, charging station monitoring systems, and fire safety early warning systems. The on-site charging safety detection terminal uses edge computing to quickly collect and analyse the life cycle operating information and fault information of the charging pile, and transmit the collected data and analysis results to the local area network in real time. The charging station monitoring system and the fire safety early warning system can obtain effective charging process information and accident early warning information in the local area network, and realize information sharing.

7 Conclusion

Electric vehicle charging safety involves four levels of electrical, communication, physical, and information safety factors such as vehicles, piles, networks, and operating platforms. Therefore, it is a system engineering. The design of protection functions, product design and material selection in accordance with standard requirements, passing safety test verification, regular maintenance and other factors will affect the safety of the charging system. Electric vehicles should be charged less quickly, and overcharged, and charging equipment should be output according to demand to improve the security risk resistance of all links. With the development of 5G technology, information transmission is more accurate and timely, and there are fewer and fewer factors restricting the development of electric vehicles. The research in this paper can effectively realize the charging safety control and eliminate potential dangers of electric vehicles, and is beneficial to the evaluation of electric vehicle charging safety indicators and fault location, and provide theoretical guidance for establishing a complete charging safety standard system.

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