Research on Early Warning Model of Electric Vehicle Charging Safety

Linru Jiang¹*, Yuanxing Zhang¹, Taoyong Li¹, Xiaohong Diao¹, Jing Zhang¹

¹Beijing Electric Vehicle Battery Charging and Replacement Engineering Research Center, China Electric Power Research Institute, 100192 Beijing, China

*Corresponding author: jianglinru@epri.sgcc.com

Abstract: At present, an effective evaluation system of the charging safety of electric vehicles has not been formed and lacks the corresponding safety early warning and protection control measures. It is of great significance to ensure the charging safety of electric vehicles and promote the rapid development of electric vehicles. Through the analysis of the establishment of the electric vehicle charging safety evaluation index system, the establishment method of the index system is studied. Finally, the demand analysis of the electric vehicle charging safety early warning and protection system is carried out. The function of establishing safety evaluation model in the system is clarified. For the comprehensive demonstration operation of electric vehicle, it is verified that the electric vehicle charging safety warning and protection system has real-time warning and protection function for battery, charging equipment and distribution network, which embodies the practical engineering value of the system.

1. Introduction

Electric Vehicle (EV), electric vehicles provide power by "charging" instead of "fuel ", which has the advantages of less emission pollution, low noise and high energy efficiency than traditional fuel vehicles, developing electric vehicles is an effective way to alleviate the pressure of environmental pollution and energy consumption. It is also an important measure to promote the sustainable development of automobile industry. It is also the strategic demand for China's automobile industry to transform and upgrade, cultivate new economic growth points, realize new leapfrog development and enhance international competitiveness [1-5].

In view of the problems existing in the development of electric vehicles at the present stage, the national key research and development plan “new energy vehicles” key special "electric vehicle infrastructure operation safety and interconnection technology" is born [6-8]. In view of our country has not carried on the research in the battery, the charging equipment safety aspect and the power supply level integration safety aspect, which has not formed the effective integration safety early warning appraisal index system [9]. Through the research of electric vehicle charging safety warning and protection in this paper, the integrated charging safety warning of vehicle pile network is formed, which can improve the evaluation effect of charging safety system and ensure the charging safety of electric vehicle. Promoting the development of electric vehicles has an important supporting role.

2. Safety Analysis of Electric Vehicle Charging

2.1. Structure and Working Principle of Charging Equipment

At present, the main charging equipment types of electric vehicles in China are mainly divided into two types: AC and DC. Although wireless charging equipment is also a trend, wireless charging is
temporarily in the research and demonstration stage due to high manufacturing cost and low charging efficiency.

AC charging equipment generally has human-computer interaction function, metering function, external communication function and software upgrade function. The man-machine interface provides the function of man-machine interaction, including display input, display equipment related information in various states, and provide manual setting parameters and so on. The metering module provides the metering of the output electricity, the charging equipment control unit has the interface with the external communication, and has the function of system upgrading. Among them, the common AC charging equipment electrical system schematic diagram as shown in Figure 1.

![Figure 1. Electrical schematic diagram of AC charging equipment](image)

In the electrical system of AC charging equipment, the general input protection circuit breaker, AC control contactor, AC intelligent meter and charging interface connector form the main electrical circuit. The input protection circuit breaker of the main circuit has the functions of short circuit, overload and leakage protection; the AC control contactor can control the power supply on and off; the AC intelligent meter is mainly used to measure the charging amount; the charging interface connector provides the charging interface between the equipment and the electric vehicle, and has the functions of locking device and anti-misoperation. The controller relay, the running state indicator lamp, the stop button, the intelligent controller of charging equipment and the human-computer interaction module constitute the electrical secondary circuit.

Common DC charging equipment system structure is mainly composed of charging equipment controller, man-machine interface, IC card reader, power conversion module, intelligent management module, metering and billing.

After rectifying and filtering, the three-phase AC of the electric system of the charging station becomes a high-frequency DC/DC power converter controlled by the DC input voltage supply drive circuit, then electrically isolated by the high-frequency transformer in the power converter, and then the DC output is obtained by filtering again.

2.2 Analysis of Security Characteristics of Distribution Network Charging

A large number of electric vehicles connected to the distribution network will have many effects on them. On the contrary, the operation safety of the distribution network is also related to the normal energy supply of electric vehicles. Therefore, electric vehicle and power grid are in a balanced state. In order to protect the charging safety of electric vehicle, the influence of electric vehicle on distribution network is analyzed.

(1) Impact on load characteristics

The charging load of electric vehicle has great randomness. If the electric vehicle charging is not guided in an orderly manner, the power load may be increased during the peak period of power
consumption, which will lead to the overload of the station to affect the safety of the power grid. Therefore, it is necessary to communicate with the power grid in real time to realize the orderly use of electric vehicle charging load, to realize the optimal distribution of power grid load to realize peak cutting and valley filling, so as to optimize the operation of power grid.

(2) Impact on electrical equipment

A large number of electric vehicle access will affect the node voltage of the line, especially the end node, which will seriously decrease the voltage, affect the charging safety of electric vehicles and the normal use of electricity by other users. Especially for the more sophisticated electronic equipment in the line caused serious impact, may bring huge economic losses.

Through the analysis of the charging safety of electric vehicles, the influence of charging safety of electric vehicles is analyzed, the structure and working principle of charging equipment are introduced, and the influence of existing charging safety is analyzed. The charging safety of charging equipment is summarized. Finally, the safety characteristics of distribution network charging are analyzed, which is of great significance to the charging safety of electric vehicles in the future.

3. Establishment of safety index system for electric vehicle charging

3.1. Principles for the establishment of an indicator system
The selection of evaluation indicators is directly related to the accuracy of evaluation results. When the number of selected indicators is too large, the indicators may be duplicated or intersected with each other, which improves the complexity of the evaluation index system. Reduce the accuracy of evaluation results. Therefore, in the process of evaluation, we should first establish the primary collection of evaluation indicators by corresponding methods, and then select those with high sensitivity and convenient quantification by effective methods. And rich connotation of the dominant indicators as the final evaluation standard.

3.2. Method for establishing an indicator system
The establishment of index system needs to go through a logical thinking process of "concrete, abstract and concrete ", and the evaluator’s understanding of the essential characteristics of the evaluation object should be refined, deepened, perfected and systematized step by step.

![Figure 2. Flowchart of Index System Construction](image-url)
At present, the comprehensive evaluation index system of electric vehicle safety is lacking, and the method of constructing the evaluation index system of electric vehicle charging safety can be constructed with reference to the analysis method, cross hair, comprehensive method and so on.

4. Charging Warning

Electric vehicle charging safety warning and protection system needs the information of electric vehicle, charging equipment, distribution network and so on. At the same time, it also needs the information provided by various collection and detection terminals and system servers. This paper will further study the effect of early warning load on the charge and discharge process of electric vehicle and its daily charging cost, and establish an optimization model. Considering that the purpose of EV users' participation in the V2G system is to promote the undetermined power system, consumers should not incur any additional costs due to battery deterioration or charging during peak periods. The optimization model consists of formulas (1)–(5), and the objective function is to minimize the total cost of each charge and discharge of an electric vehicle.

$$F = \sum_{t=1}^{t_{f}} \Delta t [P_{t}^{ch} (\alpha_{t} + \eta_{ch}^{ch} C_{DP}) - P_{t}^{dch} (\beta_{t} - \frac{C_{DP}}{\eta_{dch}})]$$

In the formula: $F$ is the total cost of charge and discharge per electric vehicle; $t_{s}$ is the beginning of time; $t_{e}$ is the moment of termination; $\Delta t$ is a time interval; $P_{t}^{ch}$ is the charge power; $\alpha_{t}$ is the discharge price; $\eta_{ch}$ is the discharge efficiency; $P_{t}^{dch}$ is the discharge power; $\beta_{t}$ is the discharge price; $\eta_{dch}$ is the discharge efficiency.

Electric vehicle charging power constraint:

$$0 \leq P_{t}^{ch} \leq P_{max}^{ch}$$

The formula is the maximum charging power of electric vehicle.

Electric vehicle discharge power constraint:

$$0 \leq P_{t}^{dch} \leq P_{max}^{dch}$$

In the formula, $P_{max}^{dch}$ is the maximum discharge power of electric vehicle.

Constraints that electric vehicles can not charge and discharge simultaneously:

$$P_{t}^{ch} - P_{max}^{ch} = 0$$

$$S_{t+1} = S_{t} + (P_{t}^{ch} \eta_{ch}^{ch} - P_{t}^{dch} \eta_{dch}^{dch}) \Delta t$$

In the formula, the $S_{t}$ is the battery storage state at the time.

As the daily discharge EV2G of electric vehicles increases, the cost of battery users is reduced. In Table 1, the user payment cost means that the consumer obtains the benefit from the charge and discharge process, and the positive payment cost means that the consumer pays the charge and discharge process.

| Scene | Time of early warning load | Discharge capacity EV2G | User pay |
|-------|----------------------------|-------------------------|----------|
| 1     | 16:30;20:30                | 7.21                    | -1.94    |
| 2     | 16:30;20:30                | 6.73                    | -1.65    |
| 3     | 16:30;20:30                | 6.21                    | -1.40    |

Figure 3. Electric vehicle SOC curve for early warning load

As you can see from the diagram, the different time of early warning load will have a great influence on the charge and discharge process of electric vehicle. Two warning loads appear at the beginning of the EV insertion period (at 16:00 and 20:00), Electric vehicle discharges equal to 7.2 kW/h. As can be seen from Figure 3, Compared with other cases, scene 2 user payment cost lowest. On the contrary, At scene 1, the user pays highest cost, This is because two pre-warning loads occur at the last time of the final charging process (04:00 and 05:00), Electric vehicle relatively few discharge3.11 KW/h.

5. Conclusion

This paper analyzes the safety factors of electric vehicles from the point of view of charging equipment and distribution network. According to the principle of establishing index system, the method of establishing index system is analyzed. Starting from the goal of evaluating the safety of electric vehicle, taking the charging equipment, distribution network and other aspects as the criterion, the evaluation index system of charging safety of electric vehicle is the analysis, and the evaluation index system of charging safety of electric vehicles is finally established. Based on the known early warning load, charge and discharge optimization can improve the participation of electric vehicle user V2G, effectively reduce the user cost, and alleviate the power grid pressure when the early warning load occurs.

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