Research on Safety Evaluation Method of Integrated Optical Storage and Charging Station

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Abstract. This paper studies the correlation between charging process performance indicators and charging safety of Solar-Energy storage-Charge station, analyses the influence of environmental factors, technical factors, design factors, management factors and user factors on charging process safety of energy stations. The projection pursuit algorithm is used to evaluate the influence degree of each parameter on the safety of charging process; through the establishment of charging safety evaluation system, the safety risks of battery damage and even fire caused by excessive charging current and high battery temperature are identified. The monitoring parameters corresponding to the charging safety state are determined. According to the different battery types adopted by different vehicle models, the corresponding charging mode is determined. According to the monitoring results of key data of the core equipment in the charging process, such as charging current, charging voltage, battery temperature, etc., the charging strategies of different vehicle models and different battery types are analysed, which provides reference for the safe operation of charging process.

1 Introduction

In the aspect of charging safety protection, the main body of the research focuses on the charging equipment itself and the power battery. Safety accidents such as spontaneous combustion and explosion of power battery caused by battery failure; safety accidents caused by battery overcharge caused by communication fault between battery management system and charger; safety accidents caused by abnormal conditions such as over-current, short circuit and leakage of charger or failure to effectively deal with these conditions. In order to improve the electrical safety of charging equipment and the protection ability of charging battery, it is necessary to put forward a quantitative safety evaluation method of charging process, which aims to contribute to the electrical safety of electric vehicle charging equipment and guarantee the charging effect [1-3].

Recently, some scholars study and select the rating index system according to different types of charging infrastructure. Firstly, analytic hierarchy process (AHP) [4-5] is used to determine the comprehensive weight of each index, and then fuzzy comprehensive evaluation is applied to score the performance of charging infrastructure, and the evaluation value of charging infrastructure health status is obtained. [6] Different from the above, in this paper, the projection pursuit method [7-8] is applied to establish the relationship between the operating parameters of the main equipment in the Solar-

Energy storage-Charge station [9-10] (referred to as the “energy station” in the following) and the charging safety, and a projection pursuit classification model based on real coded accelerating genetic algorithm is established to evaluate and classify the charging process safety.

2 System architecture

Before studying the charging safety evaluation method, it is necessary to clarify which factors will lead to safety problems in the charging process. In this paper, such problems are divided into five categories: environmental factors, technical factors, design factors, management factors and user factors, which are shown in Figure 1.

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Fig1. Influencing factors of energy station operation safety

This paper introduces a new type of intelligent charging station, which can realize the optimal configuration of energy, classify and identify the charging vehicles. The station can realize the optimal configuration of energy, equipped with a variety of intelligent charging strategies for different batteries, and can achieve efficient utilization of energy. Firstly, the structure of the intelligent energy station is introduced, as shown in Figure 2.

Fig2. Structure diagram of intelligent charging station

As is shown in Figure 2, the safety monitoring center is the core part of the whole power station. The center is responsible for monitoring the key operation data of a variety of core equipment and early warning of possible safety accidents. According to Figure 1, the battery overcharge accident caused by the communication failure between the battery management system and the charger can be classified as technical factors; the abnormal conditions such as over-current, short circuit and leakage of the charger itself can be classified as technical factors; the decline of charging capacity caused by insufficient

load capacity of the charger can be attributed to design factors; the fault of battery itself can be classified into user factors, etc.

Due to the existence of the above security risks, the energy station needs to monitor the charging safety during the charging process. The specific safety monitoring system framework is shown in Figure 3.

Fig3. Safety monitoring of charging process in energy station

As can be seen from Figure 3, the system will carry out safety monitoring on the whole process of charging vehicles from entering to leaving the station. Such as identifying battery types, detecting battery life, to charging strategy selection, charging voltage monitoring, current monitoring, overcharge protection, et al. Meanwhile, a large number of key data of core equipment will be obtained. Especially important, these key data will be used in the research of safety evaluation methods.

3 Algorithm selection

As mentioned in the previous article, there are many factors that affect the charging safety. However, which factors are the main ones and whether these factors can be evaluated by a mathematical model, so as to identify the potential charging safety hazards as soon as possible is a crucial issue. The appropriate algorithm selection can simplify the problem and find the core parameter anomalies quickly and effectively. In this paper, the projection pursuit algorithm is used to evaluate the influence degree of each parameter on the safety of charging process.

Project pursuit is an exploratory data analysis method directly driven by sample data. In this method, the high-dimensional data is projected into the low-dimensional subspace through some combination. For the projected configuration, the projection index function is used to describe the possibility of the projection exposing some sort structure of the original system, and the projection value that makes the projection index function reach the optimal (that is, to reflect the high-dimensional data structure or characteristics as accurately as possible) Then, according to the projection value to analyse the classification structure characteristics of high-dimensional data (such as projection pursuit clustering evaluation model), or according to the scatter diagram between the projection value and the actual output value of the research system, an appropriate mathematical model is constructed to simulate the output of the system (such as projection pursuit grade evaluation model). The projection pursuit grade evaluation model will be applied in this paper.

The application process of project pursuit method is shown in the Figure 4.

Fig4. Algorithm flow chart

4 Mathematical model

Before establishing the mathematical model, in order to find the relationship between the key parameters and charging safety, Firstly, the parameters should be normalized to integrate the data into (0, 1) through a large number of basic data:

$$a_i = \frac{a_t}{\sum a_{ti}} \quad (1)$$

Where the a_t represents monitoring data, a_{0i} represents optimal data, for example, a_i represents actual charging current, a_{0i} represents theoretical safe charging current. Similarly, the monitoring information such as charging voltage and battery temperature can also be processed according to this method. According to this, every car which is charged in this station will have a vector:

$$\vec{A}_i = \{a_{i,1}, a_{i,2}, \dots, a_{i,j}\} \quad (2)$$

Where A_i represents all the charging monitoring data of the i th vehicle.

Aiming at the charging safety detection problem of this project, various detection parameters such as battery temperature, charging voltage, charging current, battery life and other parameters can be constructed into multi-dimensional space. Different variable parameter values constitute different high-dimensional vectors. If these high-dimensional vectors are projected into low-dimensional space, different projection rules will get

different low-dimensional point sets. Through optimization algorithm, the shadow index function is maximized to obtain the projection direction which can reflect the high-dimensional set. The process of finding the maximum projection function is the process of global optimization. After finding the best projection value by using genetic algorithm. The specific solution flow is shown in the Figure 5.

Fig5. Solution flow of genetic algorithm

As mentioned above, the contribution rate of the above parameters to the optimal projection can be calculated, which can be written as follows:

$$\eta_{s(m),i} = \frac{a_i}{\sum_{i=1}^n a_i} \quad (3)$$

Where, $s(m)$ represents the best projection value and represents each parameter. It can be found:

$$\sum_{i=1}^n a_i = s(m) \quad (4)$$

Through formula (3), the contribution rate of each parameter in the optimal projection can be obtained, that is, the weight vector of each parameter in the evaluation of charging safety can be obtained, which can be written as formula (5):

$$\{\eta_{s(m)}\} = \{\eta_1, \eta_2, \dots, \eta_n\} \quad (5)$$

When the best projection value is obtained under various working conditions, the scatter point set of charging state will be obtained, At the same time, we can get the safety evaluation grade according to the value of the best projection direction, and the best fitting function of scatter point can be found to establish the evaluation model of charging safety state.

$$D = k(a_1, a_2, \dots, a_n) \quad (6)$$

Where " $a_1, a_2, \dots, a_n$ " represents the key parameters, such as battery temperature, charging voltage, charging current, etc., which parameters should be determined according to the data provided by the safety monitoring center. The charging process can be evaluated by publicity

(6), and finally the evaluation matrix can be obtained as follow:

$$D = \begin{bmatrix} k(a_{11}, a_{12}, \dots, a_{1n}) \\ k(a_{21}, a_{22}, \dots, a_{2n}) \\ \vdots \\ k(a_{i1}, a_{i2}, \dots, a_{in}) \end{bmatrix} = \begin{bmatrix} D_1 \\ D_2 \\ \vdots \\ D_i \end{bmatrix} \quad (7)$$

After comparing the data in the matrix with the best projection value, the safety evaluation grade can be obtained. For example, we can define three levels of safety, insecurity and danger according to the deviation between each data and the best projection value. Which is shown in Table 1.

Table1. Setting Word's margins.

Sample	Data range		
value	0-0.6	0.6-0.8	0.8-1
Security status	danger	insecurity	safety

When the dangerous state is found, the specific analysis is caused by the abnormal parameter, so as to identify all kinds of safety hazards early.

When the score is within the insecurity range, the system will find the abnormal parameters according to the fitting function. If it belongs to the category of charging station (such as charging current and charging voltage), the controller will inform the technician to adjust. If it belongs to user factors (such as battery failure), the controller will also inform the user. And when the charging process is in a dangerous state, the charging process will stop immediately and give an alarm. According to the fitting function, the abnormal parameters will be quickly located and the maintenance will be prompted. The safety hazard identification and implementation work-flow of safety assessment system is shown in Figure 6.

Fig6. Safety hazard identification and implementation flow chart

Randomly select 7 charging stations in a province, and obtain the corresponding projection values according to the above method. As shown in Figure 7. Corresponding

to Table 1, it can be seen that charging station 2 is safe, charging stations 3 and 5 are unsafe, and the remaining charging stations are dangerous.

Fig7. Safety projection value of each charging station

Fig8. Projected component of charging station

The projection component values of charging station 1 and 2 are shown in Fig. 8. The abscissa is the factors that affect the safe operation of charging station in Figure 1. The value of each component represents the degree of influence on safe operation. Through comparison, we can see that the safety evaluation model established in this paper is effective. After comparison, it can be seen that the effectiveness of the safety evaluation model established in this paper is.

5 Conclusion

In this paper, in order to study the correlation between charging process performance index and charging safety of energy station, environmental factors, technical factors, design factors, management factors and user factors are set as the factors that may affect the charging process safety of energy stations. At the same time, the security monitoring system framework of charging station is introduced, and the important monitoring parameters of each core equipment are used to establish the mathematical model of charging process safety. Through the establishment of charging safety evaluation system, the safety risks of battery damage and even fire caused by excessive charging current and high battery temperature are identified. It provides a reference for safe operation of charging process.

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