Research on Fault Diagnosis and Safety Early Warning Strategy of Electric Vehicle Charge and Discharge Based on Artificial Intelligence

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Abstract. With the large-scale development of electric vehicles, in order to reduce the potential safety hazards in the charging process of electric vehicles, in this paper, through analyzing the characteristics of the faults in the charging process of electric vehicles and the charging and discharging fault location of electric vehicles based on artificial intelligence, a fault location method based on theoretical information fusion is proposed. The fault location method mainly includes three key modules which is fault data acquisition, address label analysis and information reverse traceability. Through the analysis of the hidden dangers of the electric vehicle charging process, the corresponding early warning process is analyzed by the established integrated safety protection model for electric vehicle charging. In this way, the structured design of the early warning system and the construction of the integrated charging and discharging safety early warning process for electric vehicles can effectively improve the charging safety of electric vehicles and promote the healthy development of electric vehicles.

1. Introduction
Since the reform and opening up in 1978, China's economy has made great progress. With the rapid development of China's economy, the demand of automobile transportation from all walks of life expands, and the people's strong pursuit of automobile travel modes which are the fundamental driving force for the rapid development of China's automobile industry in the past two decades.

Some researches have been carried out on fault diagnosis and safety early warning of electric vehicle charging process at home and abroad [1-3]. In recent years, charging safety accidents still occur from time to time. How to improve the safety of charging equipment is still the focus of research and attention in various countries around the world. For vehicle power batteries, foreign scholars have carried out many studies. The research results of a German research center on the safety of lithium batteries under extreme conditions show that lithium dendrites are the main cause of battery charging heat out of control [4]. A national laboratory in the United States has established a three-dimensional battery electric heating model to study the thermal safety of lithium batteries under abuse conditions [5]. A Japanese company has improved the thermal stability of large-capacity lithium batteries by adding flame retardants to ensure the safe use of batteries, which used in 36kW·h lithium battery system [6]. Domestically, with the support of the national key research and development plan New Energy Vehicles, the special Electric Vehicle Infrastructure Operation Safety and Interconnection Technology project, the State Grid NARI Technology Co., Ltd. project research team established the interactive response mechanism between electric vehicles, charging infrastructure, and an integrated monitoring platform,
and proposed a multi-time-scale power battery safety risk assessment and warning method, which effectively improves the safety and reliability of the power battery [7-12]. Various methods of mechanical fault diagnosis and safety early warning are emerging at home and abroad. But there are few studies on fault diagnosis and safety early warning problems encountered in the charging process of electric vehicles, and there is no more suitable fault diagnosis and early warning method for electric vehicle charging evaluation.

This paper analyses the characteristics of faults in the charging process of electric vehicles, and locates charging and discharging fault of electric vehicles based on artificial intelligence, and proposes a fault location method based on theoretical information fusion. By analysing the hidden dangers of the electric vehicle charging process, and based on the established electric vehicle charging integrated safety protection model, the corresponding early warning process is analysed. The structured design of the early warning system is carried out and the electric vehicle charging and discharging integrated safety early warning process is constructed, in order to effectively improve the charging safety of electric vehicles.

2. Fault location during electric vehicle charging

In traditional equipment management software, for the same failure of the same equipment, multiple periodic alarm event information will be generated due to different channels. In the past, when dealing with alarm events, it was single that data items without correlation analysis between events and events result in a massive warning. Users confuse primary and secondary, and cannot proceed.

Normally, many alarms are actually caused by a root-cause fault. The fault traceability technology compresses events through repeated alarms to filter out occasional events and reduce the rate of false alarms. Based on software and hardware relationships and data quality analysis analyzes the correlation of events, finds out the root fault events behind the events, and divides the alarms into levels. So that users can focus on the optimized alarms and deal with them in time, which reduces the workload of event processing and improves the efficiency of fault handling.

Accurate positioning of electric vehicle charging and discharging faults based on artificial intelligence mainly includes three key modules: fault data acquisition, address label analysis, and information reverse traceability.

2.1. Technology for obtaining fault information during charging and discharging of electric vehicles

During the charging process of electric vehicles, data such as batteries, charging equipment, and distribution networks are transmitted through communication channels, which mainly include vehicle terminals, wireless network, power network, 3G/4G/APN mobile Internet, optical fiber and others.

For fault location, the definition of information acquisition can be summarized as: multiple sensors are used to detect multiple physical quantities of the system from multiple aspects, and multi-source information and data are classified and processed to determine the state of the system accurately and timely. It proposes the correct judgment of system failure and fault mode, and analyzes the relationship between status (fault), phenomenon (symptom) and cause. The diagnosis method based on information acquisition can eliminate the limitations of a single or a small number of sensors and improve the effectiveness, accuracy and reliability of the equipment fault location system.

The actual needs of system fault location and the uniqueness of information fusion technology make it possible to apply information fusion to fault location to solve uncertain problems. At present, the information fusion methods of fault location are mainly divided into the following types according to their different fusion algorithms: information fusion fault location method based on Bayes's theorem; fuzzy information fusion fault location method; evidence theory information fusion fault location method, etc. This paper mainly adopts the evidence theory information fusion fault location method.

As an effective means of uncertainty reasoning, evidence theory has been fully applied in information fusion. Evidence theory refers to the complete trust in the proposition as the trust function, and the maximum trust in the proposition as the likelihood function. The trust function and the likelihood
function form the uncertainty interval. By applying Dempster synthesis rule, evidence from multiple evidence sources can be combined to obtain more accurate fault location information.

In fault location, the application of evidence theory for fault location of information fusion generally adopts the following steps:

1) According to the level of data that needs to be fused, based on in-depth analysis of data and sensor types and measurement ranges, construct a fault location identification framework;
2) According to the collected data of each evidence body, combined with the characteristics of each subset in the identification framework, determine the basic trust distribution function of it;
3) Determine the confidence interval of each subset under a single evidence body as needed;
4) Apply D-S synthesis rules to synthesize, and obtain the total trust distribution function of multiple evidences;
5) Calculate the confidence interval under the combined effect of the evidence body;
6) Construct the fusion result of the corresponding data layer, feature layer and decision layer according to the specific diagnosis problem.

According to the evidence theory information fusion fault location method, the information fusion of the faults in the power battery, charging facilities, distribution network and other objects during the charging process of the electric vehicle is carried out, as shown in Figure 1.

![Figure 1. Fault location method based on theoretical information fusion fault information fusion.](image)

2.2. Reverse source tracing of fault information in electric vehicle charging process

Through extensive research on data traceability literature at home and abroad, it is found that the research on data traceability model is still at the conceptual level. Therefore, it is necessary to study the overall framework of data traceability from a systematic perspective. The hierarchical data traceability security model in this paper combines different research perspectives. Based on the research of data traceability by domestic and foreign scholars, the semantic level, logical level, and security level are connected to form a whole, and it is a simple summary of the data records involved at each level provides a basis for in-depth research in the field of data traceability.

In the hierarchical data traceability security model, the three levels are progressive. The security layer is the outermost layer, the logical layer is the middle layer, and the semantic layer is the innermost layer. The overall model is shown in Figure 2.

![Figure 2. Hierarchical data traceability security model.](image)
At the logic level, the basic information of the data object and the traceability information of the data object are independent and dependent on each other. When accessing the data traceability information of a certain data object, first find the corresponding data object, and the data object corresponds to the corresponding processing process, that is, the traceability process of the data object and the transition process between the states of the data object. The data traceability information, that is, the information about the state transition process of the data object, corresponds to the traceability record at the semantic level. Based on this, the semantic level and the logical level are connected.

The security level is mainly used to prevent external intrusions and prevent internal personnel from improper operation. The access control model consists of a set of states and the set of primitive operations imposed on these states. Each state includes a subject set S, an object set O, and an access control matrix A. A[S, O] is a set of access rights. The row in matrix A represents the subject S, and the column represents the object O. In this way, Aij represents that the subject Si has access authority to the object Oj. This access authority can restrict unauthorized persons from entering the system to maliciously tamper with the data object information.

3. Safety early warning for electric vehicle charging process

The battery safety warning of electric vehicles includes short-term warning and long-term warning. Short-term early warning is divided into the current BMS alarm collected through on-board settings and the early warning dynamically calculated by the system based on real-time battery data and short-term early warning models. Long-term early warning, based on the Hadoop big data platform and the long-term data analysis of the battery to obtain the battery health status, combined with the battery health status to update the battery safety characterization parameter threshold and level, thereby improving the early warning rate of battery safety hazards.

3.1. Analysis of hidden dangers of electric vehicle charging safety

At present, common faults of electric vehicles include overvoltage, undervoltage, overcurrent, overtemperature, SOC jump, excessive pressure difference, excessive temperature difference, total pressure too high, total pressure too low, overdischarge, overcharge and other faults. The occurrence of any of the above faults will reduce the effective life of the battery, and the accumulation of frequent short-term faults over time will eventually lead to long-term safety hazards of the battery and affect the performance of the entire vehicle. The occurrence of these faults played a role in protecting the battery, and it also explained the fault of the corresponding functions of the battery system.

1) At the time of data reporting, GPS data is reported normally. If there is no battery data or battery data is incomplete, a reminder is required. Data integrity is the basis for subsequent warning.

2) SOC jump fault is one of the main reasons that cause the vehicle to break down. The main problem that causes the SOC jump is that the BMS has a large deviation in the estimation of the SOC. The accuracy of the SOC directly or indirectly affects the accuracy of other functions such as the power prediction module. Since the accuracy of the SOC algorithm of different BMS providers is different, obtaining a safe and controllable SOC accuracy cannot rely on BMS estimation alone. Therefore, SOC correction is carried out through platform monitoring data during charging.

3) The main cause about the overvoltage of the battery cell is that the charging current or the recharging current of the battery exceeds the actual charging or recharging capacity of the battery. When the power prediction function of the BMS is working normally, the BMS can provide accurate battery recharging current limit to the vehicle controller or charging limit to the charger to ensure that overvoltage does not occur. The individual overvoltage fault is the result of the fault of the BMS power prediction module. Normally, SOC will be used as an input of the power prediction module. The fault of the power prediction module may be a problem of SOC estimation or a power prediction algorithm. Power prediction based on charging detection data can better ensure the safety of the vehicle. Undervoltage and overvoltage are the same analysis ideas. The problem of undervoltage is usually that the discharge current predicted by the power is greater than the actual discharge capacity of the cell. A single undervoltage fault reflects the fault of the power prediction module.
4) Excessive pressure difference is usually a direct manifestation of the deterioration of battery consistency. The reasons are reflected in two main aspects. One is the cell process, such as the fast capacity decay of individual cells, the fast internal resistance increases or the abnormal self-discharge. Second, the battery balancing function fails, and the SOC difference between the cells caused by the normal self-discharge difference cannot be eliminated.

5) Battery overtemperature is usually a consequence of the fault of the thermal management function of the battery system or the increase of the internal resistance of the battery aging. The main reason is the abnormal increase of the internal resistance of some batteries, which is generally accompanied by the phenomenon that the voltage difference is too large.

6) When the total voltage of the battery system is too high or too low and the single cell is not over-voltage or under-voltage alarm, the main reason is that the connection resistance of the system is abnormal. At this time, poor contact may easily lead to local overheating.

7) Before the battery is overcharged or overdischarged, there will usually be an overvoltage or undervoltage alarm. When there is a problem with voltage sampling, it is easy to cause the battery to be overcharged or overdischarged without reporting overvoltage and undervoltage.

3.2. Early warning process analysis
According to the established electric vehicle charging integrated safety protection model, it is necessary to analyze the corresponding early warning process to carry out the structural design of the early warning system. The process of electric vehicle charging and discharging safety early warning is shown in Figure 3. It is necessary to obtain the data information of the relevant safety indicators through the interconnected data platform, and then use the expert database to score the indicator weights based on the improved gray correlation method, and then compare the standard thresholds of the indicator data, and determine the membership through the trapezoidal linear distribution degree matrix, and obtain the safety score through the fuzzy comprehensive safety evaluation model, and give the corresponding safety level. If it is safe, output the corresponding safety level and do not deal with it. If it is dangerous, you need to give the corresponding treatment measures. Early warning protects the safety of electric vehicle charging and discharging.

Figure 3. Flow chart of electric vehicle charging and discharging safety early warning.

3.3. Short-term and long-term safety warning strategy
The process of the short-term safety early warning program is shown in Figure 4. The charging and discharging current, cell voltage, total voltage of the battery pack, and ambient temperature of the lithium battery are detected in real time. According to these data, the possible faults of lithium battery
are judged, and corresponding treatment measures are given to avoid serious faults and accidents of lithium battery. The data are uploaded to the cloud server for processing, and used for medium and long-term safety warning.

4. Conclusion
By analyzing the fault characteristics of EV charging process, this paper proposes a fault location method based on artificial intelligence for electric vehicle charging and discharging, including three key modules: fault data acquisition, address label analysis, and reverse information traceability. This paper also proposes a fault location method based on theoretical information fusion. By analyzing the hidden dangers of the electric vehicle charging process, and based on the established electric vehicle charging integrated safety protection model, the corresponding early warning process is analyzed, so as to carry out the structured design of the early warning system and construct the electric vehicle charging and discharging integrated safety early warning process. The research results of this paper can effectively improve the charging safety of electric vehicles and promote the healthy development of electric vehicles.

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