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Research on an On-site Detection System of Electric Vehicle Charging Facilities

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Abstract. With the continuous development and promotion of electric vehicles, the safety and reliability of electric vehicle charging facilities are paid more attention. In order to serve users better, this paper analyzes the existing charging facilities and clarifies the technical requirements for on-site detection, and an on-site detection system of electric vehicle charging facilities is proposed based on the analysis. The practical application proves that the system can detect the electrical performance, protection characteristics and restriction characteristics effectively, which could provide reference for the operation and maintenance of the charging facilities.

1. Introduction

In recent years, with the continuous and massive exploitation and consumption of petroleum energy, the energy crisis and environmental problems have intensified, which have brought tremendous pressure to the global transportation industry. As a new type of vehicle, electric vehicles have an irreplaceable advantage in energy saving and emission reduction [1, 2]. As the main energy provider of electric vehicles, the security of electric vehicle charging facilities is related to the reliable operation and practical application of electric vehicles directly.

With the construction and commissioning of a large number of electric vehicle charging stations, however, more and more problems have been exposed. For instance, the quality problems and service capabilities of charging facilities fail to meet the requirements. Problems such as incompatible of the charging facilities and all the models, interruption during charging, complicated charging process are common. Besides, safety risks exist in the use of electric vehicle charging facilities, resulting in frequent accidents and long-term social concern. Considering the above problems, it is necessary to perform a comprehensive and detailed detection of the charging device. At present, most of the existing well-functioning testing facilities are running in a laboratory environment, which cannot meet the rapidly growing demand for on-site operation.

In order to effectively cope with the problem of insufficient service capability of on-site detection, it is of great importance to study the on-site testing technology of electric vehicle charging facilities on the basis of analysing the charging process and on-site detection requirements. The overall on-site performance verification could provide guidance for the acceptance tests of electric vehicle charging facilities, which is greatly beneficial of simplifying the routine maintenance process of the charging facilities, ensuring that the electric vehicles can be charged in a safe environment [3, 4].



2. Test requirements analysis

With the development of testing standards for electric vehicle charging facilities and the improvement of testing technology, most of the indicators testing experiments including performance, protection, limitation, timing logic and interoperability could be carried out under laboratory conditions to make a comprehensive evaluation of the charging device to determine whether the charger can still be put into normal use. However, due to multiple factors such as the detection environment and the mobility of the detection device, on-site detection cannot provide testing environment consistent with the laboratory conditions. Based on the analysis of the on-site detection requirements, comprehensively considering factors such as the environmental conditions, detection efficiency, volume limit, weight limit and the feasibility of the detection scheme, the following detection indicators are clarified.

2.1. Performance indicators

The low output voltage of the charging facilities will cause the car battery to be unsaturated and the small output current will prolong the actual charging time. However, the car battery will be overcharged and damaged if the output voltage, output current, and output power are too large. Taking account into the above factors, several electrical performance indicators such as voltage regulation accuracy, current regulation accuracy, voltage ripple coefficient, current ripple coefficient, power factor and efficiency are selected to detect and evaluate the output voltage, output current and output power of the charging facilities.

2.2. Protection indicators

The voltage and current of the input and output terminals of the charger must always be limited within the rated range. The charger should turn on protection mode to limit or cut off the input or output when it exceeds the given value so as to avoid serious accidents such as explosion and fire. Protection indicators such as input overvoltage protection, input overcurrent protection, output overvoltage protection, and output overcurrent protection are the basic indicators for measuring the safety level of charging facilities. However, it is quite difficult to simulate the conditions of input overvoltage and input overcurrent at the test sites, only the protection indicators of the output are selected to evaluate the charger.

2.3. Restriction indicators

While working under constant current mode, the charger should automatically reduce the output current value to limit the increase of the output voltage after adjusting the load to increase the output voltage beyond the set value. Similarly, while working under constant voltage mode, the charger should automatically reduce the output voltage value to limit the increase of the output current after adjusting the load to increase the output current beyond the set value. Output overvoltage and overcurrent would appear if the charger does not execute corresponding adjustment behavior, which may bring safety problems. Therefore, restriction indicators such as output voltage limiting and output current limiting are an essential part of on-site detection.

3. Hardware platform

Based on the fundamental design principle of safety and controllability, hardware platform of the test system is built by comprehensively considering reducing the size and weight while satisfying the test requirements maximally. The test system could be loaded on a van, which guarantees its excellent maneuverability. The industrial computer is the control center of the platform, and the power analyzer, PLC, electric energy meter and electronic load are integrated in the periphery. The industrial computer establishes a communication connection with the power analyzer through the TCP/IP protocol, communicates with the charger through CAN-bus, and interacts with the energy meter and the electronic load through the RS232/RS485 port. The system composition is shown in Figure1.

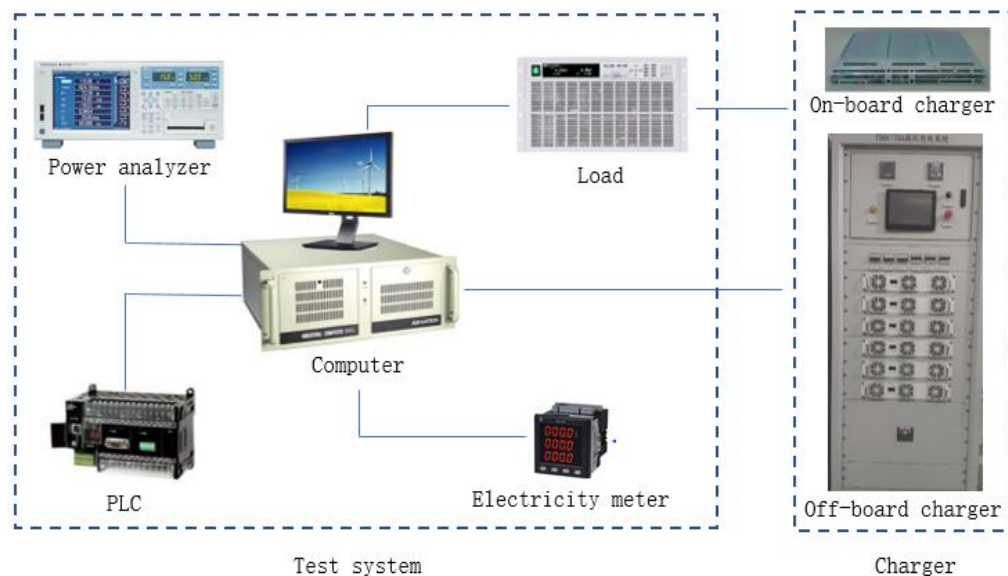


Figure 1. System composition.

The power analyzer and the electric energy meter in Figure 1 are measurement and display parts, which monitor the AC input and charging output of the charging facilities in real time. The high-precision current sensor of the power analyzer guarantees the measured data to be accurate. The programmable logic controller (PLC) is the protection part of the test system. Sensors on the DC bus could monitor the DC voltage and current and convert the analog information into digital information so that the PLC could recognize. The industrial computer gets the digital information through information interaction to determine the switch output of the PLC, and controls the switch state of the device to achieve the purpose of system protection. The system selects the electronic load as the test load. Compared with the traditional load, the electronic load is small in size and light in weight, which can work under constant current, constant voltage, constant resistance, constant power and other modes to meet the test requirements of the on-site detection. Due to power limitations, the electronic load in this system is mainly used for testing of on-board chargers. Literature [5] proposes a topology scheme of a lightweight controllable charging load using a vehicle-mounted power battery pack cascaded DC converter of a mobile detection vehicle, which can be used for tests of off-board charger.

4. Software design

Relying on the above hardware platform, a Winform application software is designed in the Visual Studio environment using C# language.

The system program can be roughly divided into: a display part, a record part, a hardware interaction part, and a data analysis part. On the one hand, the test software should display the user's operation and test data in real time friendly. Therefore, a large number of visual controls provided by Winform are used so that the test system could present good human-computer interaction. On the other hand, the test program need to record the test process edited by the user, and then form a complete process file. The part of the program responsible for interacting with the hardware could parse the corresponding process file, configure the hardware platform according to the test requirements, and store the test data in the database. The data analysis section can generate an intuitive test charts after extracting and analyzing the data in the database. The main interface of the test software is shown in Figure 2.

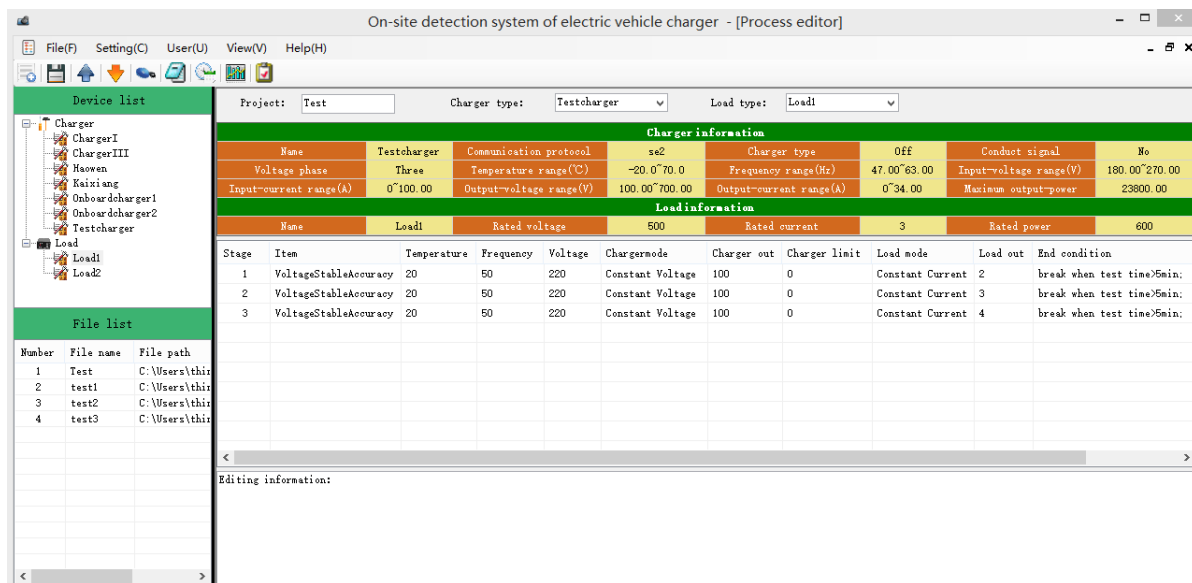


Figure 2. Main interface of the test software.

New device information can be created in the main interface, users can see the corresponding parameters after selecting the corresponding charger and load model while editing the test flow. In order to ensure the relative safety of the charging process, several electrical rules have also been considered to add to the design. For example, the system will give a warning message while the set current exceeds the limit value. The load can only select the constant current, constant power, and constant resistance working modes when the charger selects the constant voltage working mode.

5. Practical application

Taking an on-board charger module as an example, tests include the electrical performance, protection characteristics and restriction characteristics of the charging device are carried out. Due to space limitations, this paper only uses some of the test indicators as an example to illustrate the test results.

Figure3 and Figure4 are the test results of the voltage regulation accuracy and power factor of the charging facilities generated by the system when the output current is set between 2A-6A and the output voltage is set between 250V-495V.

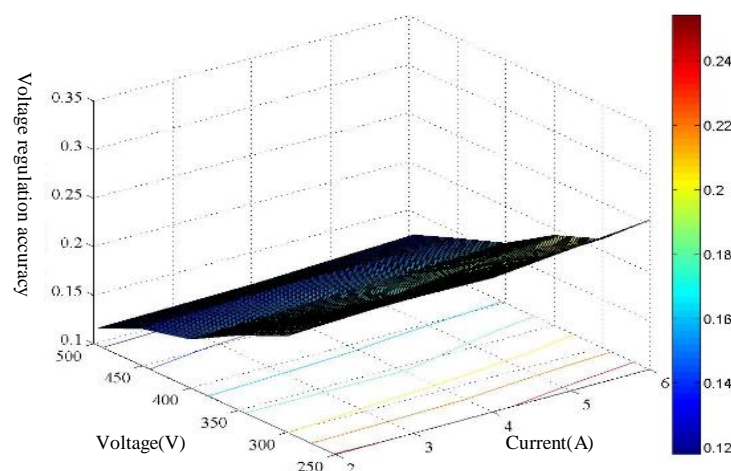


Figure 3. Test result of voltage regulation accuracy.

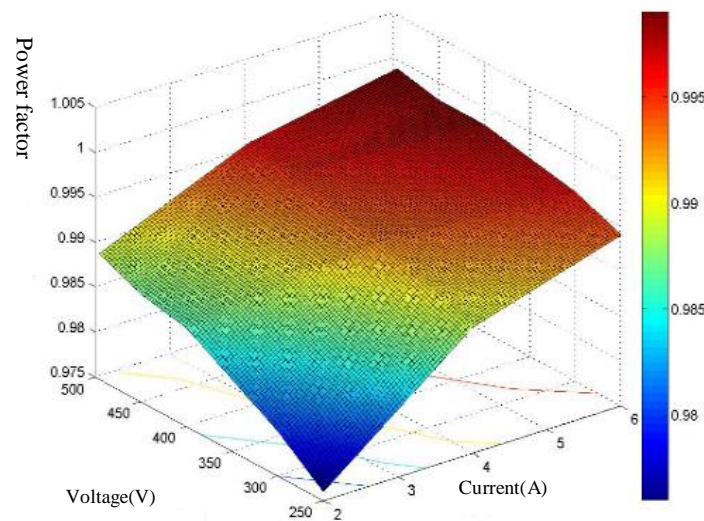


Figure 4. Test result of power factor.

Table1 and table2 are the corresponding tabular data. It can be viewed that the voltage regulation accuracy reaches a maximum value of 0.254% when the output voltage is 250V and the output current is 6A. The overall voltage regulation accuracy can meet the requirements of the accuracy lower than 0.5%, so the voltage regulation accuracy of the charger module is qualified. It can also be seen that the power factor has a minimum value of 0.976 when the output voltage is 250V and the output current is 2A, which can meet the test requirements of power factor more than 0.95 under load conditions between 50% and 100%. Therefore, the power factor indicator is qualified.

Table 1. Test data of voltage regulation accuracy.

Voltage(V) Current(A)	250	300	350	400	450	495
2	0.241%	0.199%	0.177%	0.15%	0.138%	0.118%
4	0.238%	0.206%	0.175%	0.156%	0.143%	0.12%
6	0.254%	0.211%	0.192%	0.161%	0.143%	0.126%

Table 2. Test data of power factor.

Voltage(V) Current(A)	250	300	350	400	450	495
2	0.976	0.98	0.983	0.986	0.987	0.989
4	0.989	0.991	0.993	0.994	0.995	0.996
6	0.994	0.996	0.997	0.998	0.998	0.999

Figure5 shows the test result while controlling the DC output current at 3A and selecting the DC output voltage point between 490V and 510V. As can be seen, when the test point is in the range of 490V-498V, the charger can output a corresponding voltage value. However, the actual output DC voltage of the charger is stable at around 498V when the test point is in the range of 498V-510V, which indicates that the charger has started overvoltage protection and enters the voltage restriction state.

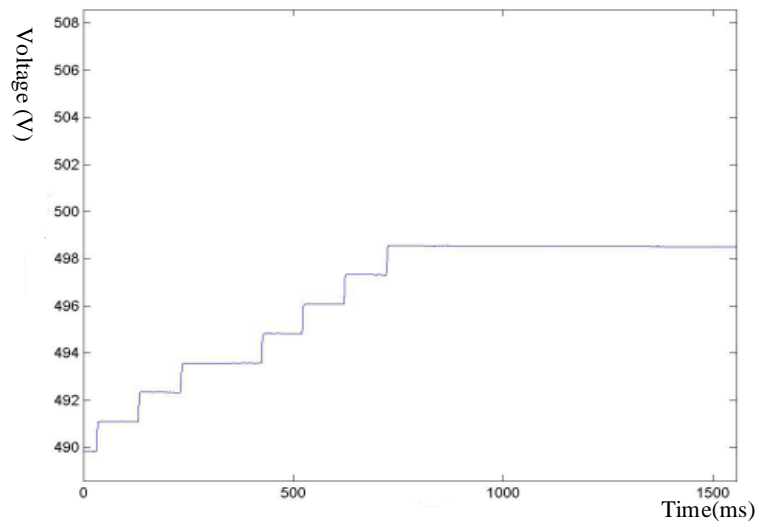


Figure 5. Test result of overvoltage protection.

Figure6 and Figure7 are the output voltage waveform diagram and the output current waveform diagram obtained by limiting the output voltage to 400V when the output current is constant at 4A. It can be viewed that the charger is in constant current charging state when the time is within 0-430ms, the output current is stable at about 3.9A, and the output voltage is gradually increased. When the output voltage reaches 400V, the output current begins to drop, which limits the output voltage to 400V, indicating that the charger has good voltage limiting characteristics.

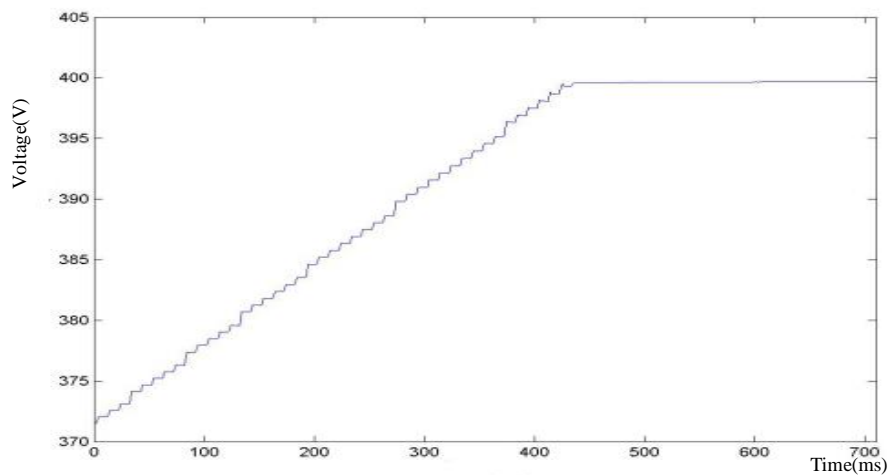


Figure 6. Waveform of output voltage.

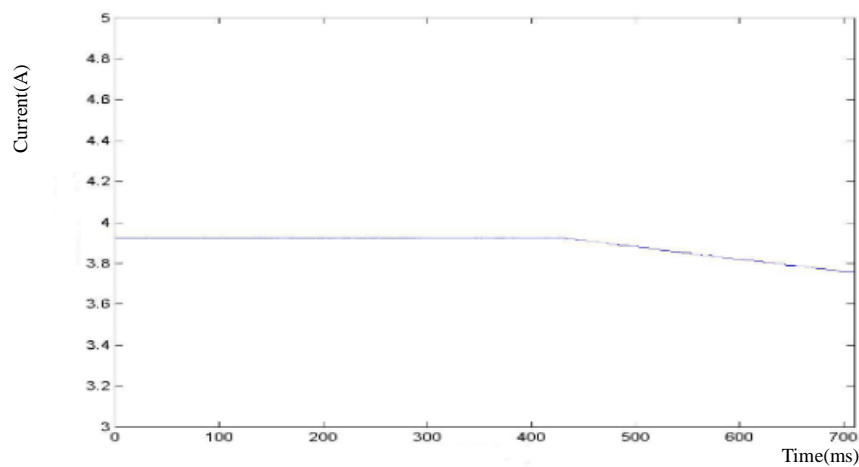


Figure 7. Waveform of output current.

6. Conclusion

Based on the analysis of the on-site detection requirements of charging facilities, a hardware platform and test software are built. Experimental tests show that the electrical performance, protection characteristics and restriction characteristics of charging facilities could be tested and intuitive test charts could be generated, which has certain application value.

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