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The charging security study of electric vehicle charging spot based on automatic testing platform

Yulan Li[1*],Zhangli Yang[2] Bin Zhu[1] and Shengyi Ran[1]

[1]Chongqing College of Electronic Engineering, No. 76, University Town East Road, Shapingba District, Chongqing, China
[2]State Grid Chongqing Elect Power Co, Elect Power Res Inst, Chongqing, China

*Corresponding author: 153033107@qq.com

Abstract. With the increasing of charging spots, the testing of charging security and interoperability becomes more and more urgent and important. In this paper, an interface simulator for ac charging test is designed, the automatic testing platform for electric vehicle charging spots is set up and used to test and analyze the abnormal state during the charging process. On the platform, the charging security and interoperability of ac charging spots and IC-CPD can be checked efficiently, the test report can be generated automatically with No artificial reading error. From the test results, the main reason why the charging spot is not qualified is that the power supply cannot be cut off in the prescribed time when the charging anomaly occurs.

1. Introduction

According to the guidelines for the development of electric vehicle charging infrastructure (2015-2020 years) ([2015]1454), by 2020, the number of replacement power plants will reach 12 thousand, and charging spots will reach 4 million 500 thousand. Also in China, electric vehicles and their infrastructure showed explosive growth, the industry has entered the fast lane.

However, the interconnection and product security problems that have been plaguing the industry are becoming more and more prominent. It is necessary to carry out systematic test on charging security and interoperability of electric vehicle charging spots [1]. Before 2015, the detection of charging spots was generally adopted by industry standard NB/T 33008-2013 [2-3]. At the end of 2015, 5 national standards for electric vehicle charging interface and communication protocol was promulgated by AQSIQ and the National Standard Committee jointly [4-6], the compatibility provisions was further refined, the communication version control was added, the charging timing logic and time definition were defined and so on. The latest test specifications for conduction charging interoperability testing rules, condition, items and qualifying the judgment has been carried on [7].

At present, there are few studies on the testing of charging facilities, and there are few relevant research literatures. In literature [1], the necessity of conformance testing and interoperability testing of electric vehicle charging facilities is analyzed. The schematic diagram of the test structure and the application in the power industry, especially the smart grid are introduced. The paper introduces the research and design of a mobile testing platform for the electric vehicle charging facilities [8], carries out the demand analysis, the scheme design, draws the test diagram. In literature [9], the basic functions and working principle of the charging control circuit of electric vehicle are introduced. A method of matching resistance and voltage state test in different charging modes is designed. In a word, nowadays the charging facilities electrical performance and interoperability testing mainly rely on testing staff manual one by one to detect, manually read the instrument data, and then make a judgment [10]. Therefore, for detection efficiency on the electric vehicle charging facilities is low, heavy workload, prone to human error, testing personnel demanding high, the automatic detection platform of electric vehicle charging spots is designed and built, and the abnormal states that may occur during the charging process are tested and analyzed according to the new national standard and the latest interoperability test specification.

2. Hardware platform

The design schematic diagram of the automatic test platform for electrical car charging spots is shown in figure 1 below. On the platform, General electric characteristics and interoperability of ac charging spot can be tested automatically. The platform contains these following equipment, such as Programmable ac power supply, Programmable AC load, Ac charging test interface simulator, The oscilloscope, High precision power meter, High performance data acquisition card, Serial server, Signal selector, Industrial computer and so on. Automatic detection platform is shown in figure 2.

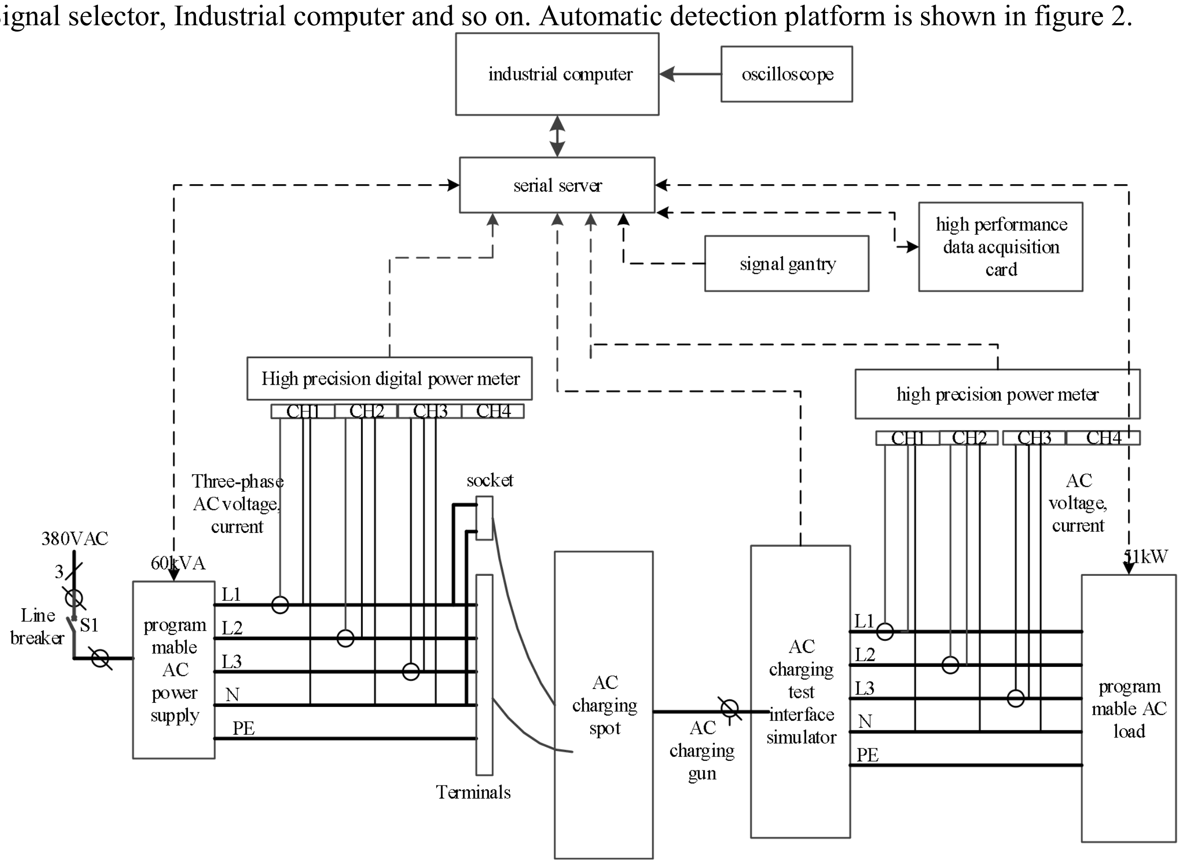

Figure 1. Test equipment schematic diagram of A.C. charging spot and in-cable control and protection device (IC-CPD).

Figure 2. Automatic detection platform.

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3. Ac charging test interface simulator

Schematic diagram of the ac charging test interface simulator is shown in figure 3.On the device, the changes in guidance resistor, the faults of signal grounded or broken and switch on-off logic can be simulated, Electrical characteristics and control guidance tests of AC piles can be finished under the coordination of power supply and load, even the compatibility and correct exit for protection action of the electric vehicle can be tested . The device is also provided with a dedicated socket and an interface of IC-CPD and the AC pile input power, so the simulation test of the IC-CPD and the AC pile can be finished.

Simulation methods for various situations and detailed implementation are as follows,

The insulated analog resistor and the analog switch are connected between the L1 and the PE, if the insulation resistance reduction occurs, the leakage protection action of the charging spot is caused, and the residual current function can be tested.

The ground resistance and the analog switch are connected between the CC and the PE to simulate CC grounding fault, if they are connected between the CP and the PE, CE grounding fault is simulated.

The R2 resistor analog circuit can simulate the 5 resistor positions of the R2 resistor, 909, 1261, 1300, 1339 and 1723 ohms respectively.

The R3 resistor analog circuit can simulate the 5 resistor positions of the R3 resistor, 1820, 2658, 2740, 2822 and 4610 ohms respectively, resistance accuracy 0.2%F.S., power >0.5W.

The vehicle control simulator is composed of DSP and peripheral circuits, DSP is the core component, and the peripheral circuits is composed by the IO input and output and analog acquisition. The vehicle control simulator can also communicate with secondary centralized control unit by 485 interface and Receive instructions and return the internal state. Each contact including L1, L2, L3, N, PE, CP and CC is equipped with analog switches, which can simulate the fault state.

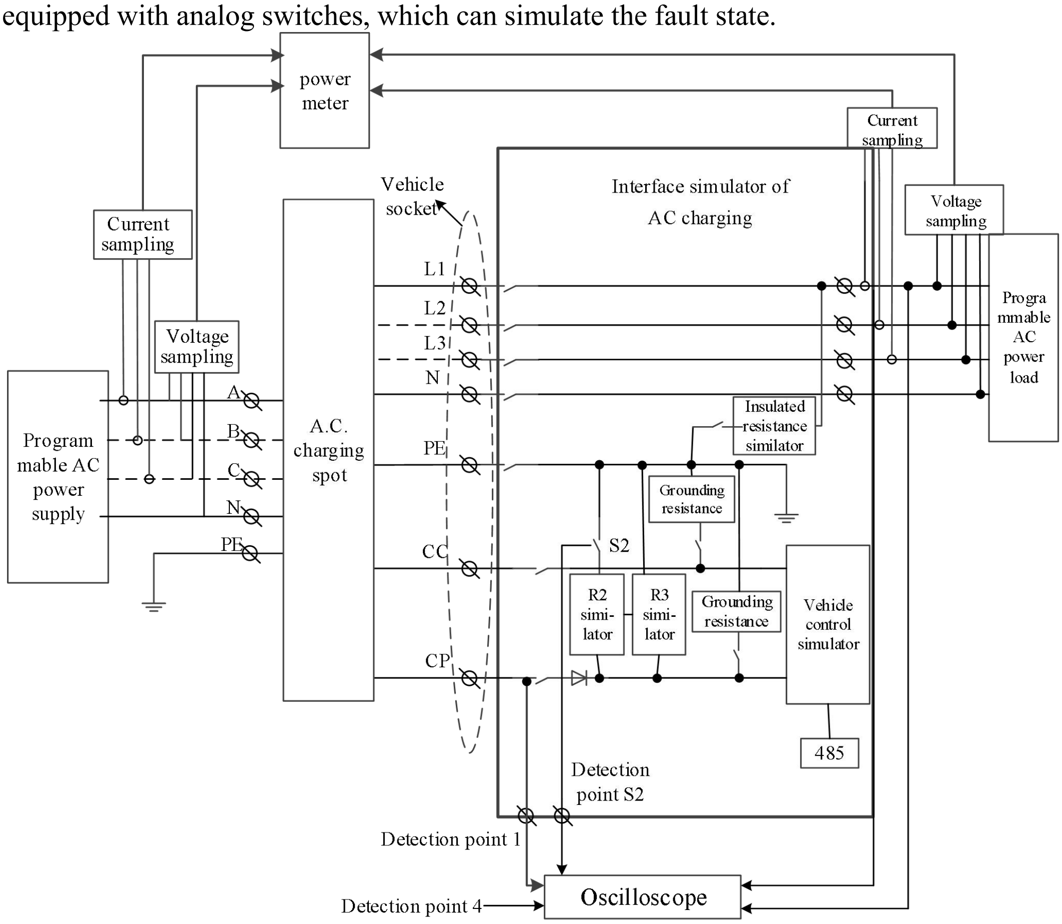

Figure 3. Test equipment schematic diagram of A.C. charging spot and in-cable control and protection device (IC-CPD).

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4. Test items and results

According to the test specification of electric vehicle conduction charging interoperability, part 1: power supply equipment (press release), The interoperability test items and IC-CPD for ac charging spots are shown in table 1. This paper tests the abnormal conditions during the charging process, and the test results are described below.

Table 1. Test items be carried out.

Number	Test items	remarks
A1.1001/I1.1001	Connection confirmation test	The test point 4 only for connection mode B
A1.3001/I1.3001	Charge preparation test	
A1.4001/I1.4001	Start-up and charging stage test	
A1.5001/I1.5001	Normal charging end test	
A1.6001/I1.6001	Charging connection control timing test	
A1.3501/I1.3501	CC disconnection test	only for connection modeA or B
A1.3502/I1.3502	CP disconnection test	
A1.4501/I1.4501	CP Grounding test	
A1.4502/I1.4502	Protective grounding conductor continuity loss test	
A1.4503/I1.4503	Output overcurrent test	
A1.6002/I1.6002	CP loop voltage limit test	

4.1. CP disconnection test

The item checks whether the charging pile can stop charging when the CP is disconnected, before charging and charging, respectively. According to the standard, if the CP disconnection occurs in charging, the power supply control device should disconnect ac power supply circuit within 100 ms, if the CP disconnection occurs before charging, The charging control switch S1 switch to +12V ,and does not close the power supply loop. The CP broken test results are shown in table 2.

Table 2. Test results of simulation CP disconnection.

	Test point 1			Stop charging time (S)
	High level (V)	Low level(V)	Frequency(Hz)	
Before charging	12.960	11.040	6779.700	-
charging	12.960	10.800	5970.100	0.069

4.2. CP grounding test

The item checks whether the charging pile can stop charging when the CP is grounded, before charging and charging, respectively. According to the standard, if the CP grounding occurs in charging, the power supply control device should disconnect ac power supply circuit within 100 ms. The results of simulation CP grounding are shown in table 3. it can be seen that the Stop charging time is out.

Table 3. Test results of simulation CP grounding.

Test point 1			Stop charging time (S)
High level (V)	Low level(V)	Frequency(Hz)	
2.400	0.720	2020.200	0.585

4.3. Protective grounding conductor continuity disconnection test

Whether the charging spot can stop charging can be checked in this item when the Protective grounding conductor continuity loss. Normally, Electric vehicle power supply equipment should disconnect power supply within 100 ms. The results are shown in table 4, and meet the standard requirements.

Table 4. Test results of protective grounding conductor continuity disconnection.

	Test point 1			Stop charging time (S)
	High level (V)	Low level(V)	Frequency(Hz)	
Before charging	12.960	11.040	1960.800	-
charging	12.960	10.800	1754.400	0.068

4.4. Output overcurrent test

Whether the charging spot can stop charging can be checked when output overcurrent occurs. When the PWM signal is generated from the charging spot, the corresponding maximum power supply current is less than 20A and the amplitude of simulated charging current is 2A more than the maximum power supply current of the charging spot and maintains 5s, or the corresponding maximum power supply current is more than 20A and the amplitude of simulated charging current is 1.1 times higher than the maximum power supply current of the charging spot and maintains 5s, the output supply power should be disconnected and the switch S1 should be switched to the +12V connection state .From table 5, The test sample is still charging when at 9.636S and does not meet the requirements.

Table 5. Test results of output overcurrent.

Test point 1			Output voltage (V)	Output current (A)	Stop charging time (S)
High level (V)	Low level(V)	Frequency(Hz)			
5.760	-12.240	1000.000	212.920	36.500	9.636

4.5. Switch disconnection state test

Whether the charging spot can stop charging can be checked when the switch s2 is switched off here. When the voltage amplitude of test point is 9V, S2 is switched off, the power supply control device should disconnect ac power supply circuit within 100ms according to the requirement and generate PWM output continuously. From table 6, the sample meets the requirements.

Table 6. Test results of disconnect switch S2.

Test point 1			Stop charging time (S)
High level (V)	Low level(V)	Frequency(Hz)	
8.880	-12.240	1000.000	0.055

4.6. Loop voltage limit test

The voltage value of the test point 1 is normal or not represents the charging spot is charging or not. If the positive voltage value at the detection point 1 is within the range of nominal value of the corresponding state, the charging spot should be allowed to charge or recharge normally, otherwise the charging spot should not be allowed to charge or recharge. From table 7, the sample meets the requirements.

Table 7. Test results of loop voltage limit.

	Test point 1			Output voltage (V)	Output current (A)	Stop charging time (S)	remarks
	High level (V)	Low level(V)	Frequency(Hz)				
Before charging	10.800	8.880	5263.200	-	-	-	Upper limit
charging	6.960	-12.240	999.938	220.360	0.000	0.544	
Before charging	8.640	6.960	651.466	-	-	-	Lower limit
charging	5.760	3.840	490.196	0.000	0.000	0.584	

5. Conclusion

Ac charging test interface simulator is designed and automatic test platform for charging spots of electric vehicle is set up in the paper. This platform is used to test and analyze the abnormal state which may occur during the charging process. On the platform, the charging security and interoperability of ac charging spots and IC-CPD can be checked efficiently, the test report can be generated automatically with No artificial reading error. From the test results， the main reason why the charging spot is not qualified is that the power supply cannot be cut off in the prescribed time when the charging anomaly occurs.

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