

# Electric Vehicle Charging Interoperability Test & Evaluation

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**Abstract**—This paper studies key technologies of charging interoperability test and evaluation for electric vehicles, analyses the standard system and test methods of charging system for electric vehicles in China. Aiming at the charging interoperability problem since the release of the new national standard for charging, a large number of charging interoperability test and evaluation of electric vehicles are carried out by using AC/DC charging test system. Five main problems in charging interoperability are summarized for enterprise products development, provided charging interoperability technical support.

**Keywords**—EV; EVSE; charging interoperability; test and evaluation

## I. INTRODUCTION

In recent years, China's electric vehicle (EV) industry has developed rapidly. By the end of 2018, the number of electric vehicles has reached nearly 3 million and the number of EV supply equipments (EVSE) has reached over 800 thousand[1], more and more charging problems of electric vehicles have been exposed, among which charging interoperability has become a key issue restricting the further development of electric vehicles. One of the questions [2].

Charging interoperability is the ability of charging interconnection between the same or different models and versions of power supply equipment and electric vehicles through information exchange and process control. Because the charging system of EV consists of three parts: EV, charging facilities and connecting devices, it needs a good cooperation of the three parts to solve the charging interoperability problem.

Firstly, a relatively perfect standard system has been established for charging electric vehicles in China. As shown in Table 1, the technical requirements from charging system to vehicles, power supply equipment to high-voltage accessories are included.

Among them, the 15 editions of the new national standards GB/T 18487.1-2015, GB/T 27930-2015, GB/T 20234.1/2/3-2015, issued in 2015, are collectively referred to as the five charging standards in the industry, which stipulate the technical indicators of the charging system of electric vehicles. On this basis, two testing standards were issued in 2017: GB/T 34657-2017 electric vehicles conductive charging interoperability test. The test specification and the conformity test of communication protocol between non-vehicle conductive

charger and battery management system of electric vehicle GB/T 34658-2017 achieve the unification of technical standards and test standards, thus forming a complete conductive charging standard system of electric vehicle [5].

TABLE I. ELECTRIC VEHICLE CHARGING STANDARD SYSTEM

NO.	Standard contents	Standard number
1	Charging system	GB/T 18487.1
2		NB/T 33001
3		NB/T 33002
4	EVSE	NB/T 33008.1/2
5		NB/T 42077
6		GB/T 34657.1
7	Communication and Connection	GB/T 20234.1\2\3
8		GB/T 27930
9		GB/T 34658
10	EV	GB/T 34657.2
11		QC/T 895
12		GB/T 24347

Secondly, the industry has also issued relevant policies to promote charging interconnection, in order to solve the problem of charging interoperability.

Although a relatively perfect standard system has been formulated, charging interoperability still occurs frequently. Therefore, this paper focuses on the charging interoperability of electric vehicles under the current standard system.



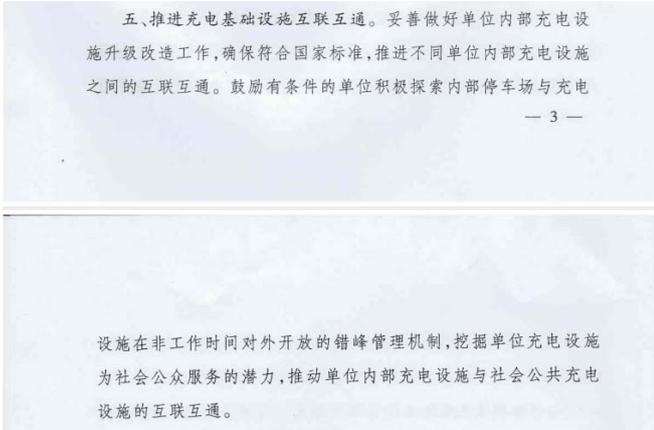


FIGURE I. GOVERNMENT DOCUMENT

II. CHARGING INTEROPERABILITY TEST METHOD

The test method of vehicle charging interoperability is mainly in accordance with GB/T 34657.2-2017. The test items are shown in Table 2. The test system simulates charging piles to test whether the electric vehicle can meet the requirements of charging interoperability. The test items include charging interface interoperability, DC charging interoperability and AC charging interoperability [6].

Spatial dimension inspection of sockets mainly tests the spatial dimension of vehicle sockets. When testing, vehicle plugs satisfying the maximum external expansion size of GB/T 20234.2/3 are used to test, so as to ensure that the vehicle plugs can be inserted normally without interference [7].

The charging interoperability test of EV is shown in Figure 1. The charging interoperability of EV is tested by simulating charging facilities in the test system. The DC charging interoperability test items are divided into four parts as shown in Table 2, which respectively specify the DC charging control and guidance function of electric vehicles, charging sequence of each charging stage, safety protection function in case of abnormal situation, safety protection function in case of abnormal situation and parameters of control and guidance circuit within the limit value. Test rules, test conditions, test items, test methods and qualification evaluation of charging ability.

AC charging interoperability test is divided into four parts: charging control process test, charging control timing test, charging abnormal state test, charging control guide circuit test. Compared with DC charging interoperability project, charging control output test is added to test the different output capacity of electric vehicle in AC charging facilities. Response and performance [8].

TABLE II. ELECTRIC VEHICLE CONDUCTION CHARGING INTEROPERABILITY VEHICLE SIDE TEST PROJECT [6]

NO.	Test Object	Test Item
1	EV	Inspection of charging coupler space size
2		Vehicle Charging and Driving Interlock Test
3		Connection Confirmation Test
4	Charging Control Process Test	Self-test phase test
5		Charging Readiness Test
6		Charging Phase Test
7		Normal Charging End Test
8	EV(AC Charging)	Charging Connection Control Sequence Test
9		Insulation Fault Testing
10		PE Broken Test
11		Communication interrupt test
12		Other Charging Fault Testing
13		Control Guidance Voltage Boundary Value Test
14	Control pilot voltage boundary value test	Boundary Voltage Measurement of Auxiliary Power Supply
15		Vehicle Charging and Driving Interlock Test
16		Connection Confirmation Test
17	Charging Control Process Test	Charging Readiness Test
18		Start-up and Charging Phase Test
19		Normal Charging End Test
20		Normal Charging End Test
21	EV(DC Charging)	Charging Abnormal State Test
22		Switch S3 Disconnection Test
23		CC circuit breaking test
24		CP circuit breaking test
25		PWM duty cycle change test
26	Charge Control Output Test	PWM duty cycle overrun test
27		PWM Frequency Boundary Value Test
28	Control Loop Test	Boundary Voltage Measurement of CP Loop
		Measurement of CC Circuit Boundary Resistance



FIGURE II. CHARGING INTEROPERABILITY TEST OF ELECTRIC VEHICLE

III. TEST VERIFICATION

Since the release of the five national standards for charging, the laboratory has tested with the CHROMA 8000 test system. As shown in Figure 3, the left picture is the DC charging test bench, and the right picture is the AC charging test bench. The test system mainly includes power supply, signal generator, oscilloscope, industrial computer and integrated control system. Over 500 charging interoperability tests have been carried out using the test system. The test vehicles cover different types of pure electric and hybrid vehicles, different battery capacities,

different BMS systems and so on. More than 300 problems have been encountered, including five aspects: interface connection and installation, charging timing, communication protocol, charging performance and design. Functional issues, the following mainly from these five aspects for a simple analysis.



FIGURE III. TEST PHOTOS

A. Charging coupler problems

Because of the size error of charging coupler or the insufficient consideration of operating space in the design of vehicle socket, it is easy to cause the problem of interface connection and installation in practical use. As shown in Figure 4, there are some problems in the experiment that the charging plug can not be fully inserted or the plug-in gun interferes, leading to the failure of charging or poor contact of charging interface. Another case is shown in Figure 5. Although there is no interference in the normal plugging of the charging plug, there will be interference when the operator operates, which will affect the user's experience.

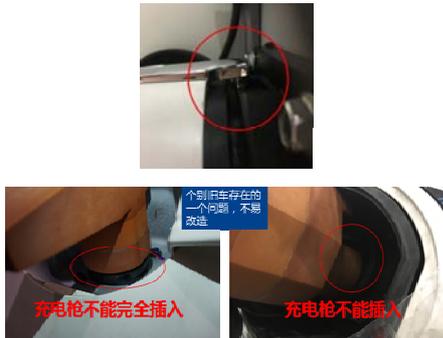


FIGURE IV. INTERFACE INTEROPERABILITY ISSUES



FIGURE V. INTERVENTION OF PLUG-IN OPERATION

B. Timing violations

The timing violations mainly includes two aspects: one is that the control timing does not meet the standard GB/T 18487.1-2015 requirements; the other is that the charging communication message timing does not meet the standard GB/T 27930-2015 requirements which mainly appears in DC charging.

Case analysis: In the waveform of Fig. 6, the vehicle can not stop charging within 3 seconds after the EVSE stops outputting PWM, the EVSE is cut off without detecting the S2 disconnection, the vehicle is not cut off in time, the charging pile actively cuts off the power supply circuit, and cuts off the relay live, which is easy to cause arc drawing or adhesion of the relay, and there are some hidden safety hazards. According to the requirements of GB/T 18487.1 and GB/T 34657.2, electric vehicles need to stop charging within 3 seconds after the AC charging equipment stops outputting PWM signals. [9]

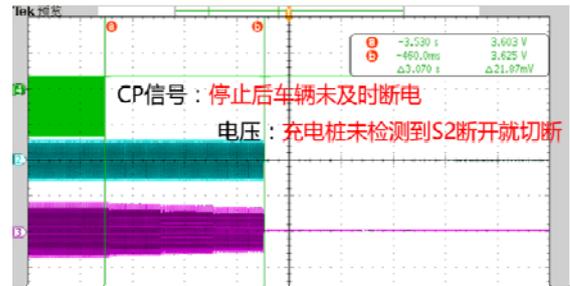


FIGURE VI. TIMING VIOLATIONS

C. Communication Protocol Problems

The charging communication protocol problems of electric vehicles include irregular message sending, period, byte length, byte filling and so on, which will not meet the requirements of GB/T 27930-2015. The main problems arise in the following aspects:

1) *Message cycle does not meet the standard requirements:* Periodic fluctuations are caused by hardware failures, and may be caused by the zero-out of the neglected time in the initial transmission. Such problems occur less frequently and involve a smaller scope.

2) *Message length does not meet standard requirements:* In the 7.10 of GB/T 27930-2015, it is clearly stipulated that "the length of message, the type content and format of necessary items should be sent in accordance with the provisions of Chapter 10 of GB/T 27930-2015". Therefore, it is easy to appear that the length of test message section does not meet the requirements of the standard. This problem usually occurs by filling each byte into eight full bytes. In addition to this representation, there is also a more frequent case of BRM byte length errors. GB/T 27930-2015 stipulates that the byte length of BRM is 41. This is a printing error. The standard corrections have corrected this error. The byte length of BRM is 49 bytes.

3) *The byte content does not meet the standard:* Generally, the message in this case is the bit not specified in the standard or reserved bit. In the testing process, some models have strict requirements for charging piles. They will verify the byte content of each bit. Once they find that there is something that does not meet the standard, they will terminate the charging process and affect the charging compatibility.

Case study: As shown in Figure 6, there are non-standard messages in EV.

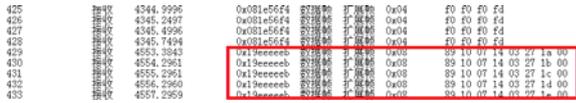


FIGURE VII. COMMUNICATION PROTOCOL PROBLEM

D. Charging with Boundary Parameters.

As shown in Figure 8, there are two problems: one is that the vehicle can not charge at the PWM frequency boundary value, which will cause charging compatibility problems. This problem is mainly caused by the difference in the understanding of standards among automobile enterprises, which is easy to occur in the boundary value. Therefore, enterprises should strengthen the understanding of standards when designing products, or even participate more in the process of standard formulation. The second problem is that when the duty cycle of PWM exceeds the limit, the electric vehicle can still charge normally. It belongs to charging when it should not be charged, which has potential safety hazards.



FIGURE VIII. CHARGING WITH BOUNDARY PARAMETERS

E. Design Function Problems

According to GB/T 18487.1, the DC auxiliary power supply is + 12V power supply. In the test, it is found that some vehicles need + 24V auxiliary power to wake up when DC charging, which may cause a lot of charging compatibility problems. There are also some non-vehicle charger auxiliary power supply using the + 12V/+24V switchable mode, once the user forgot to switch, may lead to the wrong voltage burning electric vehicle control circuit. Therefore, when designing products, enterprises should not only focus on the

announcement items of communication protocol and charging interface, but also consider the provisions of the whole standard system.

IV. CONCLUSION

Charging system is a key system of EV for ordinary users directly. Its interoperability and safety problems will lead to poor user experience, affect the safety of EV and will directly affect the development of the industry [10]. This paper studies the evaluation technology of charging interoperability of electric vehicles, and focuses on the introduction of standards and regulations, test methods and test verification. Based on the test method of GB/T 34657.2-2017, the charging interoperability test of mainstream electric vehicles is carried out. Five main problems are analyzed and listed, which provide technical support for improving charging safety and compatibility and developing enterprise products, and provide data support for the further revision of the next "Five New National Standards for EV Charging".

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REFERENCES

- [1] "Research Report on Energy Planning of the State Energy Administration in 2019," 2019-017
- [2] LI Liang, GUO Yi. Outstanding obstacles and policies expected in electric charging facilities construction for newenergy vehicles in China[J].Energy of China, 2016, 38(1):37-39, 36.
- [3] XU Chenxi. The new national standard electric vehicle charging equipment interconnection to cure ills [J]. China Strategic Emerging Industry, 2016(3):46-48.
- [4] HE Chun, CHEN Zhuo, FENG Jintao, et al. Analysis and solution on the safety of electric vehicle charging[J]. Distribution & Utilization, 2017, 34(1):12-18, 50.
- [5] GB/T 34657.1-2017 Interoperability test of electric vehicle conductive charging-Part1: Supply Equipment.
- [6] GB/T 34657.2-2017 Interoperability test of electric vehicle conductive charging-Part2: Vehicle.
- [7] GB/T 18487.1-2015 Electric vehicle conductive charging system-Part2: General requirements.