APPLICATION NOTE

Scienlab Charging Discovery System

Verification of Interoperability of all EV and EVSE Charging Interfaces

KEYSIGHT

Introduction

Although differences are found among countries and regions, global diffusion of electric vehicles (EVs) is still in its development process. While China and some European countries have established EV policies and the penetration rate of EVs is expected to rapidly increase, common requests for improvement in EVs necessary for the penetration include:

- Acceleration of charging speed.
- Extension of travel distance per charge.
- Increase in the number of charging stations.

EV charging systems standards are still in the development stage. For instance, in Japan, the CHAdeMO standard is advancing from the current mainstream Rev. 0.9 to 1.x and then to 2.0, responding to larger power that enables charging in a shorter time. Furthermore, the new CHAdeMO standard 3.0 has already been announced to be coming soon.

Charging Standards in the World

Unfortunately, the current charging standards are not globally standardized.

For DC fast charging, a standard called CCS Type 1 is used in the United States, CCS Type 2 is used in Europe, CHAdeMO is used in Japan, and GB/T is used in China.

Each of these standards use varying communication methods as well as have differences in physical shapes of components including the charging connectors.

While CCS standards in the US and Europe use powerline communication (PLC), CHAdeMO and GB/T use CAN as communication methods.

Currently, EVs use standards that are not shared globally, and the standards are rapidly changing.

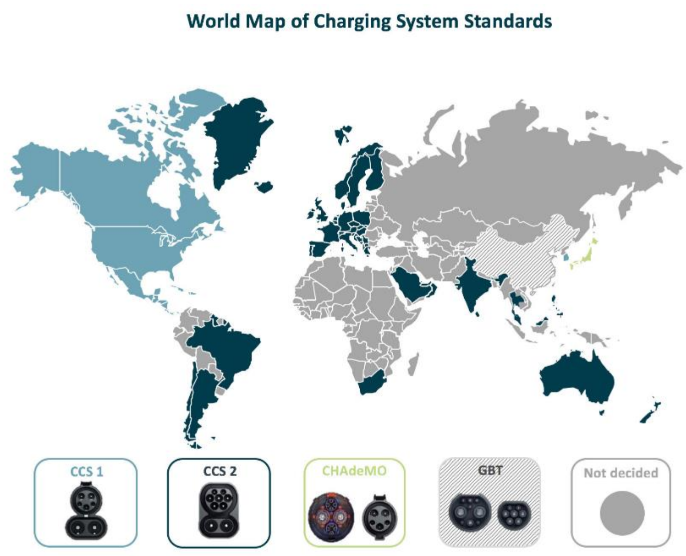

Figure 1. Courtesy of CharIN e. V. (https://www.charinev.org/)

Trend in Verification of Interoperability

While charging standards are rapidly changing, EV drivers still face problems with charging in many cases. One of the keys to facilitate EVs market penetration is to achieve interoperability, i.e. a state in which any EV can be charged at any charging station, and any EV can be charged using any manufacturer's charger. At present, the mainstream method of examining such interoperability is a field test conducted by pairing an actual EV and a charger. However, verification of true interoperability is difficult in the combination tests using actual EVs and chargers.

1. **Quantitative decision**

   Although the field test allows the decision of whether charging is successful, it does not allow quantitative evaluation of how far above the standard the combination passed the test. If it narrowly passed, there is a risk that charging will not be successful if the EV or charger is paired with other chargers or EVs.

2. **Ease of debugging**

   If charging was not successful in the field test, it is difficult to isolate and investigate in detail what symptoms appeared and where they appeared despite the error messages shown on the vehicle or charger.

3. **Testing threshold limits and creating error cases**

   It is difficult to create error cases in the field test and testing at threshold limits can be hazardous.

4. **The number of combinations**

   The number of combinations becomes too large to handle as types of EVs and chargers increase. In addition, conducting field tests of vehicles with overseas standards is difficult.

For these reasons, evaluation using a measuring instrument has been increasing in recent years. Using a charging analyzer as a reference measuring instrument…

- allows quantitative decisions of the charging status rather than limiting the selection to either passing or failing a test,
- makes it easier to determine symptoms and problems when an error occurs, allowing quick debugging and consequent reduction of development cycle time, and
- allows accurate reproduction of threshold limits, boundary values, and error cases establishing test cases to contribute to development of more reliable charging systems.

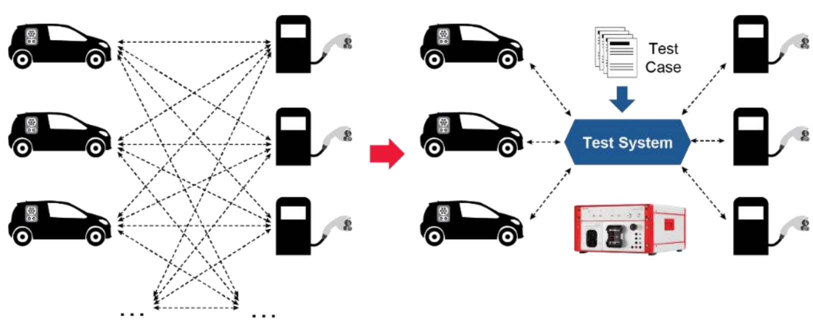

Figure 2. Scienlab Charging Discovery System as reference measuring instrument.

Key Functions of the Charging Discovery System

The Scienlab Charging Discovery System from Keysight functions as a standard for both EVs and chargers and performs emulation under various conditions; therefore, it is equipped with:

- Functions to perform accurate measurement of voltage, current, and decryption of protocols.
- Additional circuits to create conditions for standard tests and abuse testing.
- Charging adapters corresponding to various charging standards used in the world.

The Charging Discovery System also has specifications capable of handling voltage up to 1000 V and DC current up to 400 A in order to analyze the high-power, fast-charging systems that have been emerging in recent years.

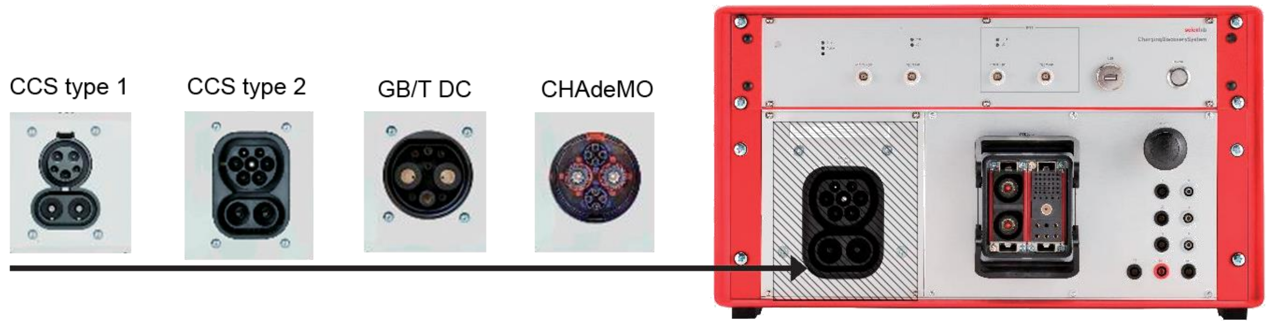

Figure 3. Scienlab Charging Discovery System – Portable Series with various charging standards.

Typical Use Cases of EV and EVSE Charging Tests

The Charging Discovery System can be used for interoperability testing which include three major types of use cases.

First is the man-in-the-middle test, which examines the conventional tests of actual EVs and chargers. Placing the Charging Discovery System between the actual charger and EV allows accurate observations of the state of charge, including the actual voltage, current, and decryption of protocols, rather than the conventional, simple assessment of whether charging was successful. This allows for quantitative verification of the amount of margin from the standard as well as examination of the data in the case of failure.

The second use case is an EV test that evaluates EVs by combining a power source and the Charging Discovery System to emulate a charging station. A high-precision power source and the Charging Discovery System play the role of a charger standard to observe the DUT behavior in detail. The Charging Discovery System is capable not only of simulating an ideal charger, but simulating breakdowns (error cases), reproducing rare cases, which is difficult when using actual EVs and chargers, and safely and accurately reproducing threshold limits and boundary values. It, therefore, increases the completeness of verification and contributes to the development of more reliable charging systems.

The last use case is a combination of the Charging Discovery System and an electronic load that emulates an automotive battery to emulate an EV. This is called an EVSE test. Like in EV tests, the completeness of verification can be increased by running test cases in EVSE tests.

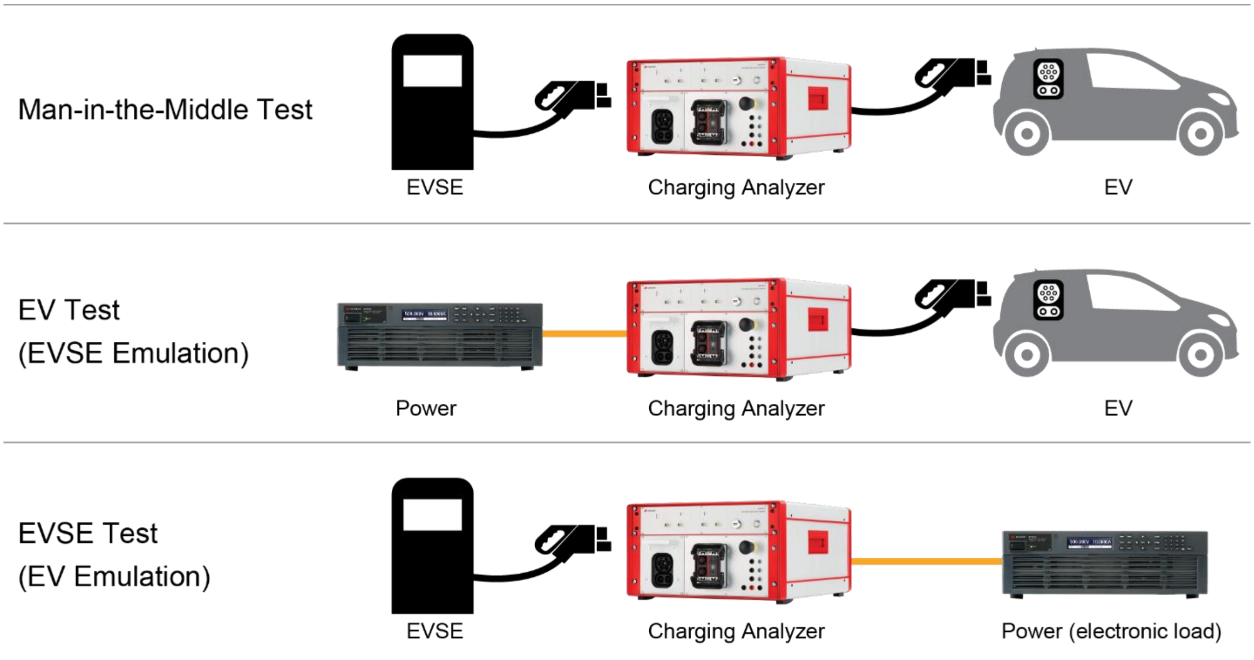

Figure 4. Use cases of EV and EVSE charging tests

Analysis Using the Charging Discovery System

With the Charging Discovery System, not only the charging voltage and current waveform but also the pilot line, CAN messages, and other information must be observed in a time series.

Voltage and current can be measured precisely using the measuring instrumentation in the Charging Discovery System.

Messages for a CHAdeMO-standard charger are transmitted between an EV and charger through the CAN, and messages for a CCS-standard charger are sent through pulse width modulation (PWM) on the pilot line. These cannot be read directly as signals; therefore, the Charging Discovery System must decode the signals upon receiving them and display them as messages. The Charging Discovery System's message view can display messages between an EV and EVSE and state transition in a time series.

Because these messages include information on the charging status, the analysis is made easier by displaying them not only as messages but also with the charging waveform on the trace window.

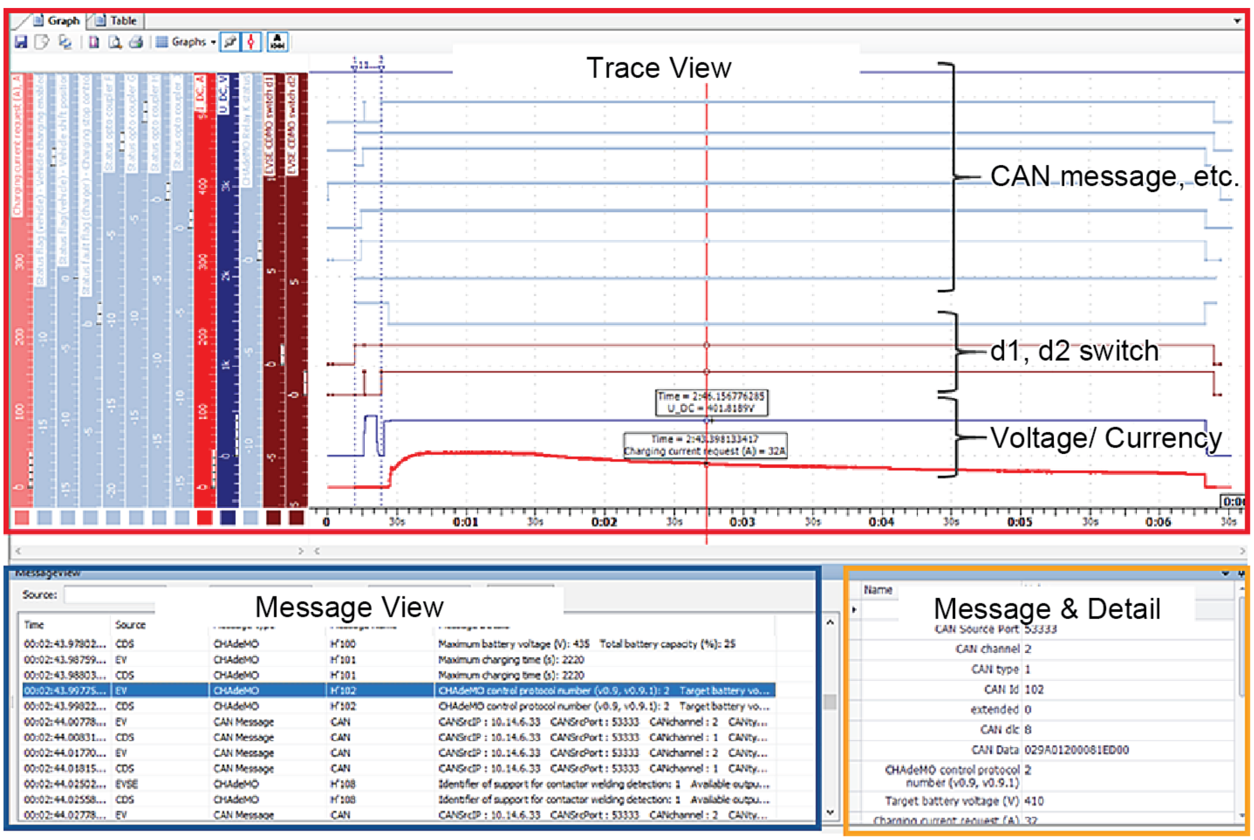

Figure 5. Analysis of Charging: Trace view, message view and details

SLAC Analysis of Powerline Communication

In a communication method that uses powerline communication (PLC) the charging station must first recognize the vehicle connected to the system.

The EV identifies the charging station to which it is physically connected based on the signal attenuation level using the method called Signal Level Attenuation Characterization (SLAC). For PLC that uses pulse width modulation (PWM) on a powerline, careful attention must be paid to noise on the powerline and signal attenuation level.

The PLC attenuation analysis using Charging Discovery System is able to evaluate the SLAC very clearly.

Figure 6. PLC attenuation analysis

Example of Failure Analysis Using the Charging Discovery System

The Charging Discovery System is effective to analyze why and when charging fails.

The example in the diagram below shows that the d2 switch[1] and optocoupler G[2], which should not have been turned on yet, moved while the insulation was being checked, this made the inhibition of charging permission invalid[3], the invalidation of the vehicle chargeable flag was sent from the vehicle to the charger through a CAN message (H'102.5)[4], and the charging ended with an error.

The d2 switch is repeatedly turned on and off immediately after forcing voltage for insulation checking[5], which suggests the possibility that noise made from the charger when forcing voltage is having a negative impact on the sequence circuit.

In the field test using the actual EV and charger, failure analysis must be performed based on error numbers and limited error information and often a large amount of time is required for determining the cause. By using the Charging Discovery software like in the example below, the problem can be clearly identified and the cause can be promptly determined.

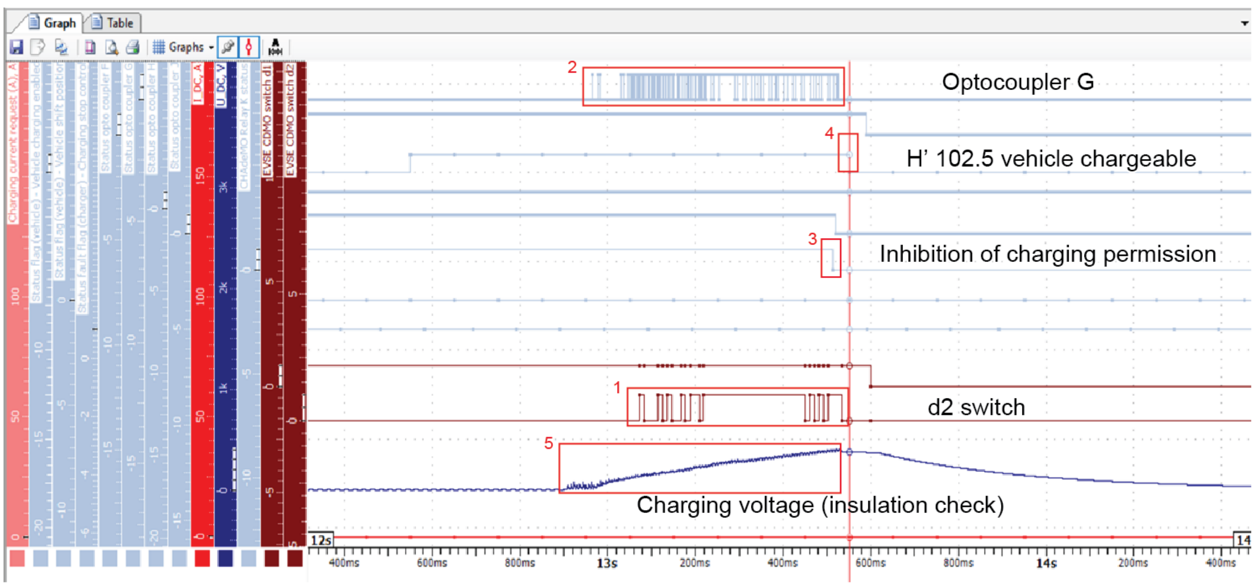

Figure 7. Failure analysis: Identify the problem easily with Charging Discovery software

Example of a Test Using Charging Discovery System

One of the benefits of using the Charging Discovery System, in addition to simulating an ideal charger and EV, is the ability to create its own error cases.

A load dump test to check the behavior when the power line is cut off during charging is one of the error cases commonly used. However, this scenario cannot be easily performed in the field test. To block the power line, safety devices such as an interlock must be disabled which may expose the test engineer to danger.

Such an error case can be easily and safely created by using the Charging Discovery System which is equipped with a power line break function. With the Charging Discover software, the Test System is also able to accurately reproduce rare cases, which are difficult to create using an actual EV and charger and perform threshold limit tests.

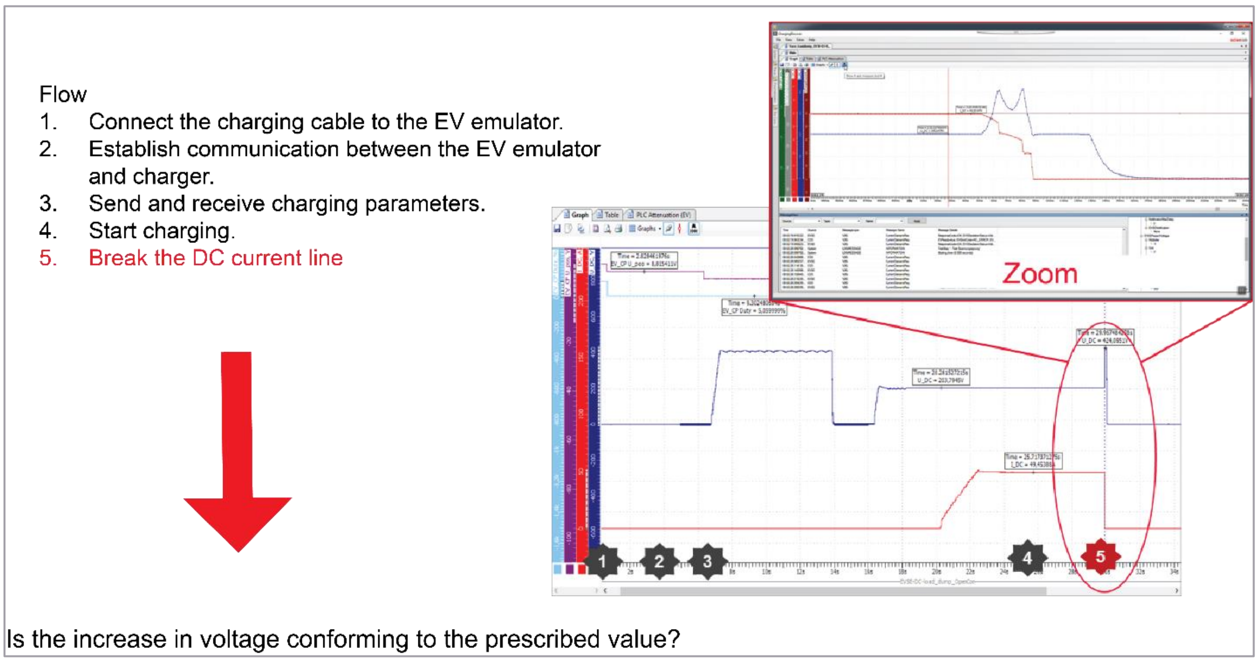

Figure 8. Load dump test: Simulation of power line break during charging

Conclusion

Improvement of charging systems is the key for EVs to be used more widely. To this end, charging standards are updated regularly and functions are being expanded. Currently, charging standards are not globally uniform, and different sets of standards are used in the United States, Europe, Japan, and China.

Given this situation, analysis and simulation using the Scienlab Charging Discovery System from Keysight, in addition to the conventional testing based on actual EVs and chargers, has become an effective tool in verifying interoperability.

Having this additional data allows quantitative decision of how far above the standard the EV was successfully charged, rather than the simple selection of either passing or failing the test. The Charging Discovery System also allows easier analysis and debugging of the cause when charging is not successful, contributing to the reduction of development cycle time. Moreover, the Charging Discovery System makes it easier and safer to accurately reproduce test cases, which is difficult when using actual EVs and chargers. Overall, the Charging Discovery System helps increase the comprehensiveness of testing and supports the development of reliable charging systems.

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