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Lessons Learned from Interop Testing of the Combined Charging System & ISO 15118 via International CCS Testing Symposia

Jens Schmutzler, Sven Gröning, Christian Wietfeld

[1] *Dortmund University of Technology, Communication Networks Institute, Dortmund, Germany,*
Email: {jens.schmutzler, sven.groening, christian.wietfeld}@tu-dortmund.de

Abstract

This paper summarizes lessons learned from the Combined Charging System (CCS) and ISO/IEC 15118 Testing Symposia that were initiated as part of the eNterop project in 2014. In the meantime, it became a large international test event on EV charging alongside regular standardization meetings, where companies from all over the world come together for interoperability and conformance tests on CCS standards, like IEC 61851, DIN 70121 and ISO 15118. We will walk through the complete history of the event from its inauguration in 2014, until today. Furthermore, we address its relevance for the development and validation of conformance testing standards.

1 Introduction

The Combined Charging System (CCS) is a core enabling technology for fast charging EVs as well as for sustainable integration of EVs in future Smart Grids building upon renewables and highly decentralized grid assets. One focal part of CCS is the communication process between EVs and charging infrastructures, which is defined in ISO 15118, the Vehicle-to-Grid Communication Interface (V2GCI, charging control interface). Its interoperability is key for user acceptance and economies of scale of the of E-Mobility market. However, at the same time it is a major technical challenge due to the large amount of implementations from different vendors, individual use cases and application requirements on a diverse global market.

The ISO/IEC 15118 Testing Symposium embraces this challenge and brings together companies from the EV smart charging community and their technology experts to conduct conformance & interoperability tests for EVs and charging infrastructures. The event is also open to the testing of Electronic Control Units (ECUs) and respective Communication Controllers. Rather than talking about interoperability, this is a hands-on event, digging deep into the implementations by performing tests between independently developed prototypes and/or series production CCS equipment.

This paper introduces the complete history of the testing event, starting from its original inauguration in 2014 as part of the German research project eNterop until the latest event in June 2017. We will explain the testing process for CCS equipment and walk through some of the typical issues observed over time. The event also plays a fundamental role in validating the technical specification of CCS as well as corresponding conformance tests specifications and CCS test systems and apparatuses implementing these specifications.

2 eNterop – Driving Force behind ISO 15118 Conformance Testing

The original idea for the event came up as part of the German research project called “eNterop”. eNterop was a cooperation project conducted in the timeframe from mid-2012 until the end of 2014. The project was co-funded by the German Federal Ministry of Economic Affairs and Energy. The eNterop consortium members were BMW AG, Communication Networks Institute of TU Dortmund, Continental AG, Daimler AG, Fraunhofer IFF/IWES, RWE Effizienz GmbH (today part of Innogy SE), Siemens AG - Corporate Technology (project coordinator) and Volkswagen AG. The eNterop project had three fundamental technical goals:

- Development of an ISO 15118 reference implementation
- Definition of a common and systematic approach for automated test procedures of ISO 15118 along with a proof-of-concept implementation of the defined conformance testing methodology
- Formal description and specification of test cases for requirements defined in ISO 15118-2 and ISO 15118-3

The development of the ISO 15118 test system targeted to ease future testing processes between EVs and charging station communication controllers and prepare the technology for scalability. Due to the diversity of charging use cases, the underlying protocols defined in ISO 15118-2:2014, ISO 15118-3:2015 or DIN 70121:2014 carry a certain complexity that need to be covered in interoperability and conformance tests before a product enters the market. However, in a scalable industry such as E-Mobility, one-to-one component tests, as they were performed at that time, are not feasible due to the increasing number of implementations from different vendors available on the international market.

The eNterop project therefore started its work on conformance testing for ISO 15118-2 and -3 already in 2012 and had the following dissemination and exploitation goals:

- Contributions to standardization (ISO/IEC, DIN, DKE, NAAutomobil)
- Support of SMEs to reduce time-to-market for ISO 15118 based equipment
- Ensure open market approach and counteract market fragmentation

Figure 1 illustrates the transitioning process from the initial interop testing approach conducted by early adopters of the CCS technology towards a scalable conformance testing process that will ultimately lead towards a commonly accepted certification process. This comes along with a substantial improvement of scalability of testing that in turn translates to highly reduced costs for the development and testing of corresponding CCS-based equipment.

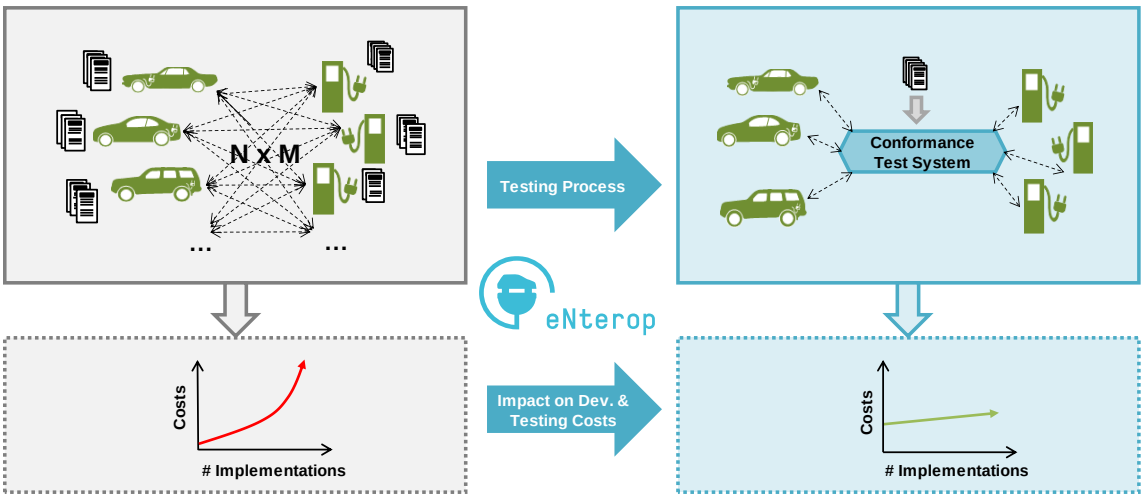

Figure 1 eNterop Project Motivation and Approach

The consortium members contributed their work to the ISO/IEC 15118 Joint Working Group. It soon became the core contribution and baseline for the early development of the ISO 15118-4 [1] and -5 [2] drafts dealing with conformance testing of the CCS control interface. At the end of 2013, we took over project lead and responsibility for the conformance test documents of ISO 15118.

3 First Public ISO 15118 Testival - Blueprinting an EV Plug-Testing Event

In order to validate the specification work on conformance testing as well as its implementation, the eNterop consortium organized a so-called “Testival” at the CNI of TU Dortmund and invited potential vendors of ISO 15118 implementations to test against the eNterop conformance test system. At that time (second half of 2014), only very few vendors were available and ready to test ISO 15118 prototype implementations. This was primarily because many vendors were fully concentrating on DIN 70121:2014 that first series production vehicles already used back then. DIN 70121 represents an early branch version of ISO 15118 with a substantially simplified technical scope and limited to DC charging only. Even though both standards are based upon the same principles, their implementations are not interoperable. Consequently, the testing methodology and underlying paradigms of the eNterop conformance test system are applicable to DIN 70121 but were not yet implemented in the initial version available at that time.

Figure 2 shows a few impressions from the very first public testing event on ISO 15118 implementations organized by the eNterop consortium held at the CNI of TU Dortmund.

Figure 2 Impressions from the initial ISO 15118 Testival at the CNI of TU Dortmund in 2014

For this event, scope of tests was limited to EV or EVSE ECU-testing against the eNterop conformance test system. Most participants focused on testing of link establishment via Powerline Communication (PLC) technology and its correlation with the PWM signal according to IEC 61851-1 Annex A. The take away from all participants of this initial test event was very good. Hence, the consortium decided to propose the organization of international “Testivals” alongside regular ISO/IEC 15118 Joint Working Group meetings. In these events, participating companies could test their EVs against EVSEs and vice versa or against dedicated test systems, like the one developed as part of eNterop. The community that is working on ISO 15118 and related standards granted the proposal, which marks the birth of what is known today as the *International CCS and ISO/IEC 15118 Testing Symposium*.

4 Evolution of the CCS & ISO/IEC 15118 Testing Symposium

Since the initial eNterop event, six *international* Testing Symposia were held. They took place in Chicago (USA), Tokyo (Japan), Dortmund (Germany), San Diego (USA), Jeju-Do (South Korea) and the latest in Versailles (France) in June 2017. CNI of TU Dortmund technically oversaw the test plans and schedules that follow a Round-Robin scheme and furthermore took over the responsibility to organize the Testing Symposia in very close collaboration with the respective hosts. Figure 2 provides an overview of all previous International CCS & ISO/IEC 15118 Testing Symposia.

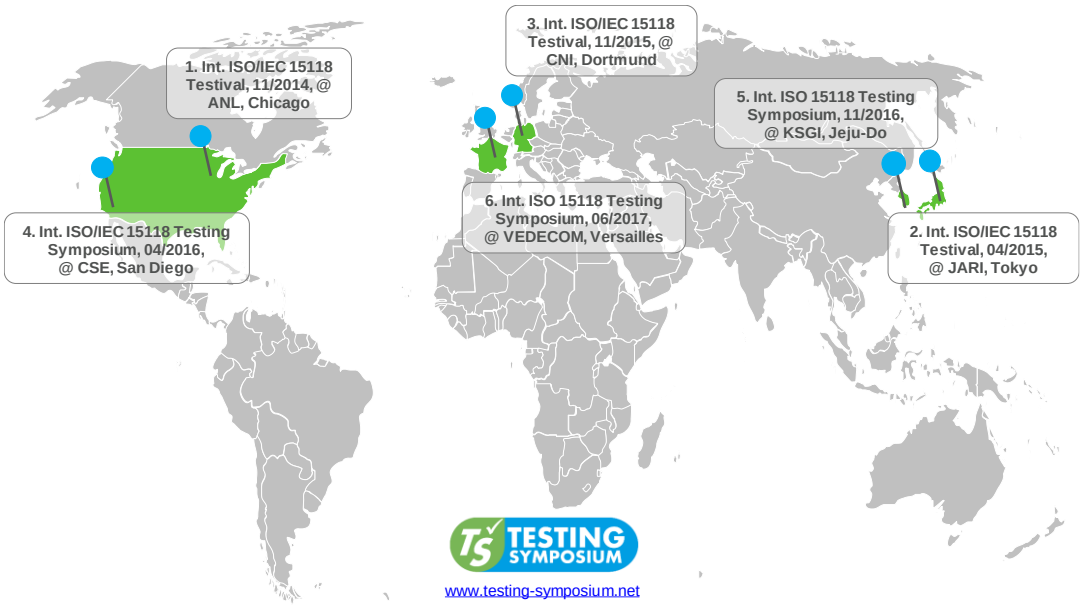

Figure 3 Overview of all previous International CCS & ISO/IEC 15118 Testing Symposia

The first International ISO/IEC 15118 Testival was held at the end of 2014 at the Argonne National Lab (ANL) in Chicago, IL, USA. The event featured testing for DC fast charging EVs and EVSEs according to DIN 70121 as well as ECU based tests for EV and EVSE controllers supporting DIN 70121 and ISO 15118. In general, we saw a major overweight of implementations supporting DC. Compared to the large amount of DC implementations, only very few companies participated with an AC implementation of ISO 15118. Another interesting finding was that even with series-equipment, there were quite a few issues that had to be resolved. Nevertheless quite a few implementations turned out to be interoperable, at least when running through plain and simple charging processes. However, in terms of compliance and robustness, nearly all implementations were quite far away from perfect. One major issue turned out to be crosstalk between all the independent test sessions conducted in very close vicinity. Compared to isolated lab test sessions previously conducted by most vendors, the PLC link layer association process was heavily disturbed because of cross-talk and so many concurrently running PLC association processes. More in-depth details and impressions are collected in [4].

The second International ISO/IEC 15118 Testival was held at the Japan Automobile Research Institute (JARI) in Tokyo, Japan in the beginning of 2015. Like the initial eNterop event, this event was limited to communication controller / ECU testing. Even though, nearly the same number of companies attended the event compared to the 1st international event in the US. Again, there was an overweight of DC equipment present. The technical issues observed were similar to the ones previously seen in the US.

At the end of 2015 the International ISO/IEC 15118 Testival came back to where it started a year before. The Communication Networks Institute (CNI) of TU Dortmund in Germany welcomed 45 companies participating with altogether over 100 persons to the third International ISO/IEC 15118 Testival. It was the first international testing event in Europe and immediately set a new record in terms of participating companies and test equipment with many prototype vehicles and charging stations participating. For the first time AC EV and EVSE test couples supporting ISO 15118 were present. In previous events, such tests were limited to very few ECU-only implementations. Another premiere was that a handful of equipment supported ISO 15118 with the Plug & Charge (PNC) authentication profile. Interestingly, this was limited to the AC participants. More details are available in [5] and [6] (both only available in German).

As part of the fourth iteration, the previously established title “Testival” was renamed to "International ISO/IEC 15118 Testing Symposium". It was held at the Center for Sustainable Energy (CSE) in San Diego, CA, USA in the beginning of 2016. Starting with this event a Test PKI was officially distributed to all PNC participants. Again, a solid number of DC EVs and EVSEs were participating in this first outdoor testing event of the series. Especially DIN 70121 implementations started to mature substantially among those who previously participated in the event. CSE published a press statement that is available in [7].

The fifth International CCS & ISO/IEC 15118 Testing Symposium was hosted at the Korea Smart Grid Institute (KSGI) on Jeju Island, South Korea in November of 2016. Due to the continuous broadening of scope of testing activities, CCS was included in the title of the event. At the same time the CharIN association, which was established about a year before, officially supported the event for the first time. This helped substantially in making the event more visible to the entire CCS & EV charging community. As part of this event the community asked for certification processes to be put in place that could coexist to pre-validation measures like the Testing Symposium. More details on the event were published by CharIN in [8] and CNI in [9].

The sixth International CCS & ISO/IEC 15118 Testing Symposium took place mid of 2017 and was hosted by the VEDECOM Institute in Versailles, France. After the 3rd International CCS & ISO/IEC 15118 Testival in Dortmund, this event set a new participation record. It was the second time the event was hosted in Europe and its record-breaking attendance with more than 80 companies from more than 15 countries and altogether more than 200 participants is a clear indication for major momentum in the CCS market development. For the first time, more than ten DC fast charging stations along with 6 DC EVs, a good handful of AC prototype and series production EVs and EVSEs as well as the first DC fast charging electric motorbike participated. The number of registered AC and DC equipment supporting PNC also increased substantially in this event. More details about the event are available in CharIN's press release in [10].

5 Impressions from CCS & ISO/IEC 15118 Testing Symposia

Figure 4 shows some impressions from the activities across all international Testing Symposia over the last three years. Representatives from all over the world with a wide range of background from the automotive, energy, infrastructure and communication technology industries participated throughout the events.

Figure 4 Impressions from CCS & ISO 15118 Testing Symposia

6 Lessons Learned from the CCS & ISO/IEC 15118 Testing Symposium

The nature of the Testing Symposium supports the community as a whole, in the process of identifying open issues within related CCS standards and specifications. It tries to provide a platform among experts in a non-competitive and non-binding environment. Next to the standardization process, this helps in the process to evaluate and find potential technical resolutions, ultimately improving underlying technical specifications and verification processes for compliance testing of CCS equipment based on e.g. ISO 15118, DIN 70121, IEC 61851 etc. Consequently, we have seen very good progress over the last few years in improved maturity of CCS implementations and corresponding testing equipment.

The conformance test standards - in particular ISO 15118-4 [1], ISO 15118-5 [2] and DIN 70122 [3] - continuously improved based on the steep learning curve that inevitably came along with hundreds of test sessions we conducted against different Systems under Test (SUTs). Among other measures, we are planning to continue maintaining them on this basis.

However, the Testing Symposium obviously cannot replace professional conformance testing services and certification procedures. It was never intended to do so. Instead, its overall goal and core motivation is to raise awareness about the underlying technological complexity of ensuring interoperability with a sharply increasing amount of independently developed EVs and EVSEs rushing into the market. It is crucial to understand and fully embrace that this process cannot be perfected in a locked-down environment. It requires an open community working closely together, even though members of the community are facing a highly competitive market environment.

Future Testing Symposia will continue to serve as validation platform for the ever-evolving technical specifications / standards, their implementations and test apparatuses. New use cases like Wireless Power Transfer (WPT), Bidirectional Power Transfer (BPT), Auto-Connect Charging Devices (ACD) etc. will sooner or later become part of its scope causing hundreds of engineers to jointly experiment with these new and challenging technologies.

In November 2017, the seventh Testing Symposium is planned and will take place at CSA Group in Mississauga (Canada). For any future updates on this or another follow-up event, you are invited to follow the Testing Symposium web site at www.testing-symposium.net [11].

Acknowledgments

Being part of the CCS & ISO/EC 15118 Testing Symposium from the very beginning, organizing it and even hosting it twice was – on many levels – an enlightening experience over the last few years. We would like to thank ALL previous participants and the entire community for their support and always-constructive advices continuously improving the CCS & ISO/IEC 15118 Testing Symposium format. With your participation, you actively contributed to the process of maturing CCS specifications and helped in the ongoing development of the Combined Charging System that is becoming more and more a key enabler for the E-Mobility market.

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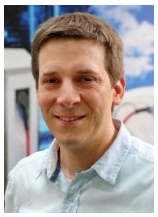
Authors



Jens Schmutzler is CEO and co-founder of verisco GmbH and senior researcher at the Communication Networks Institute (CNI) at TU Dortmund University (Germany). He is actively involved in the EV charging communication community since 2009 and coordinates the ICT for Energy Systems and E-Mobility research group at CNI. He is Project Team leader of the conformance testing work group within ISO/IEC 15118 JWG1 and responsible for the development of ISO 15118-4 and -5 (to be published in 2017). He also contributed to WG17 of TC57 in IEC 61850 targeting an object model for e-mobility for ICT integration of EVs into the Smart Grid. His research background is embedded Web Services and their impact on constrained communication networks. Jens Schmutzler is a Dipl.-Ing. of TU Dortmund and studied one year at the National University of Singapore (NUS).

Sven Groening is CTO and co-founder of verisco GmbH and senior researcher at the Communication Networks Institute (CNI) of TU Dortmund University (Germany). He is actively involved in national and international research projects on charging communication of EVs since 2011. He is an active member of DIN (German Standardization Body) and expert in the Joint Working Group for standardization of the Vehicle-to-Grid Communication Interface (ISO/IEC 15118). His research background is model based testing and its validation in against real-world applications like e.g. V2G Communication Interface. He graduated at TU Dortmund University in computer science.

Christian Wietfeld received his Dipl.-Ing. and Dr.-Ing. degrees from RWTH Aachen University. He is a full professor and head of the Communication Networks Institute (CNI) of TU Dortmund University, Germany. For 20 years, he has initiated and contributed to national and international research and development projects on wireless data communication systems in academia and industry. He published over 200 peer-reviewed publications and holds several patents. For his contributions to the standardization of next generation mobile network architectures, he received in 1999 an ITU-T outstanding contribution award. His current research interests include the system design, modeling and performance evaluation of communication networks in challenging environments. Christian Wietfeld is a Senior Member of IEEE and chairs the IEEE’s German sister organization VDE/ITG committee on ”Communication Networks and Systems”