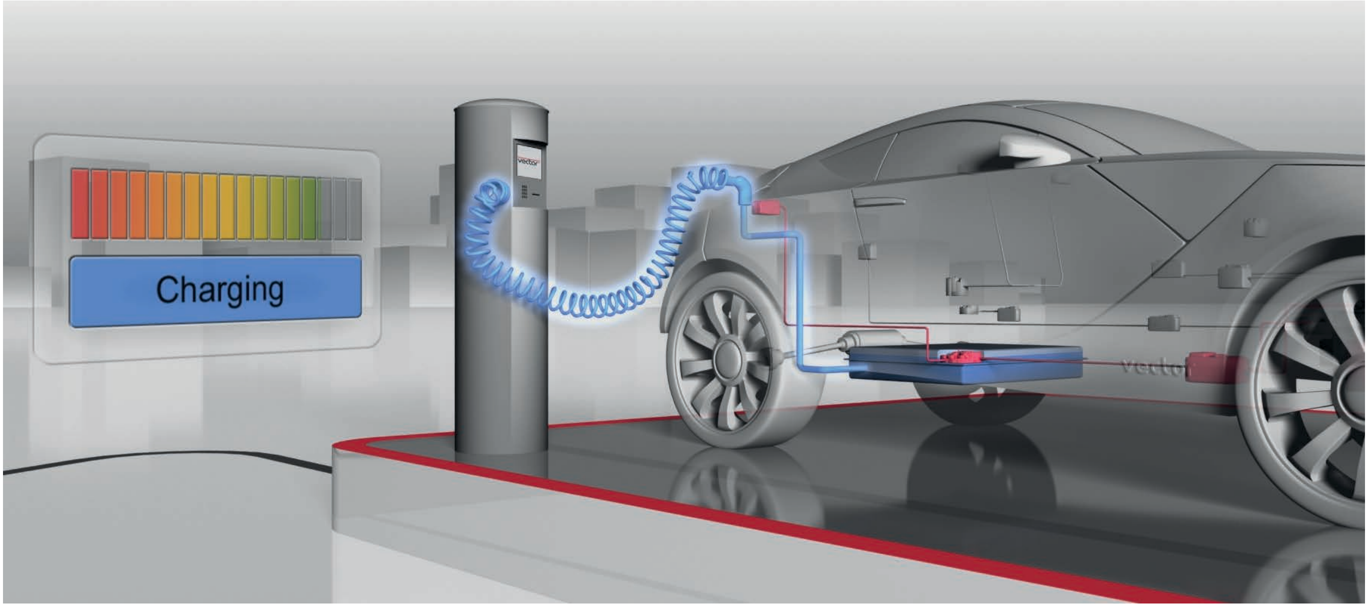
Smart Charging – A Key to Successful E-Mobility

Development and testing of charging electronics conforming to standards



Electric vehicle charging with AC current has been governed by the ISO/IEC 15118 international standard since it was fully adopted in spring 2014. For DC current charging, the industry has agreed on an applicable subset, which is described in DIN SPEC 70121 (Prestandard procedure). This article sheds light on some details of the two standards and points out ways that manufacturers of electric vehicles and charging stations can quickly develop and effectively test products conforming to the new standard.

Fueling a combustion engine vehicle is not very spectacular and is over within a few minutes. The corresponding operation for electric vehicles is quite another matter. Managing and optimizing the process of charging the battery is one of the primary tasks of vehicle and charging station manufacturers. In the context of the changeover to alternative energy sources and the future smart grid, the charging operation is much more complex than it might appear at first glance. It is necessary to consider not only basic information such as the power available at the charging station, the battery condition and the charging demand. However, more complex information, such as the energy resources available at the time of charging, must also be taken into account. Also important are aspects related to cost optimization, payment/billing modalities, and safety, as well as other questions, such as: How is the user authenticated? Does the vehicle need as much electrical energy as possible in a short amount of time or can the charging operation be extended over several hours until after work or the end of an extended shopping trip?

Smart charging according to ISO/IEC 15118 offers the opportunity to address these challenges in the best possible way in terms of vehicle owners, energy suppliers, charging station manufacturers, and last but not least, the environment. Uncontrolled charging processes in which users simply connect their vehicles to the available power supply system in order to charge them with maximum possible power will soon become a thing of the past or will be available only at a premium. Since electric vehicle charging re-quires relatively large amounts of power, locations such as parking garages that have a high demand factor can experience a significant power demand. Intelligent charging processes take this into consideration and grant the power supply company or smart grid the time needed to adjust to the changing load conditions. Blackouts during peak load times can be reliably prevented in this way.

HomePlug Green PHY: a single cable for energy and data

A basic prerequisite for smart charging is reliable information exchange between the vehicle and charging station. In this regard, ISO/IEC 15118 provides for HomePlug Green PHY as the physical layer. This is a PLC (Power Line Communication) method derived from HomePlug AV. The latter is widely used in homes for networking computers and audio/video components via a home's existing electrical wiring. Well-known Internet protocols from the IT world, such as TCP, UDP, IPv6, DNS, DHCP, are TLS, are all built on this. The initial establishment of a connection for the power line communication is described in more detail in the following.

SLAC ensures reliable establishment of a connection

Within the scope of high-level communication according to ISO/IEC 15118, the initial establishment of a connection between the vehicle and charging station is a critical event. As soon as a driver connects his/her vehicle to a charging station, the initial objective is to join a secured AV Logical Network (AVLN). Each AVLN is represented by a Network ID (NID). In addition, each node of an AVLN requires an NID-matching network membership key for encrypted communication.

At the beginning of communication establishment, the vehicle sends an Ethernet broadcast message to all possible network nodes. All charging stations that receive this signal respond with an Ethernet unicast confirmation. Since multiple charging stations can be supplied by one physical supply cable, the protocol is responsible for identifying the relevant charging station to which the vehicle is connected. Unfortunately, other charging stations not physically connected to the vehicle can also respond due to undesired coupled-in noise. The so-called SLAC mechanism (Signal Level Attenuation Characterization) of HomePlug Green PHY ensures a correct and reliable process for identifying the physically connected charging station. SLAC works according to the request/response method in which the request always comes from the electric vehicle. At the same time, the vehicle and charging station agree on a RunID – an unique identification feature that must be contained in all subsequent messages of the same SLAC session.

The establishment of a connection via SLAC runs sequentially through various phases such as the “Sounding Phase”, “Attenuation Characterization Phase”, “Validation Phase”, “Matching Phase” and “Amplitude Map Exchange Phase”. Based on signal attenuations of various degrees, the vehicle is able, with the help of the SLAC mechanism, to identify which charging station out of the many responding charging stations it is physically connected to. At the end of this process, an electric vehicle and charging station form a shared AVLN over which the higher protocol layers exchange encrypted information.

Embedded systems for ISO/IEC 15118 charging controllers

A major challenge for the automotive industry on the one hand and the manufacturers of the charging infrastructure on the other hand is the designing of products that conform to ISO/IEC 15118. The fastest way for automobile manufacturers to achieve functional results when developing the charging ECU is to use ready-made, field-tested embedded solutions such as MICROSAR V2G (Vehicle-to-Grid) of Vector. MICROSAR V2G **(Figure 1)** is a cluster of basic software modules and is part of an AUTOSAR-compatible product line, which allows users to assemble an ECU software package that is tailored to their exact requirements. MICROSAR V2G covers all technologies and protocols on the various ISO OSI layers that are needed for charging with AC and DC voltage current according to ISO/IEC 15118 and DIN 70121. This includes suitable hardware support for HomePlug Green PHY as well as implementation of a future-proof TCP/IP dual stack for IPv6 and IPv4. The smart charging communication counterpart for manufacturers of charging stations is called vEVSE. Based on Embedded Linux, it contains all ISO/IEC 15118 and DIN 70121-relevant components (SLAC, EXI, and message sequence).

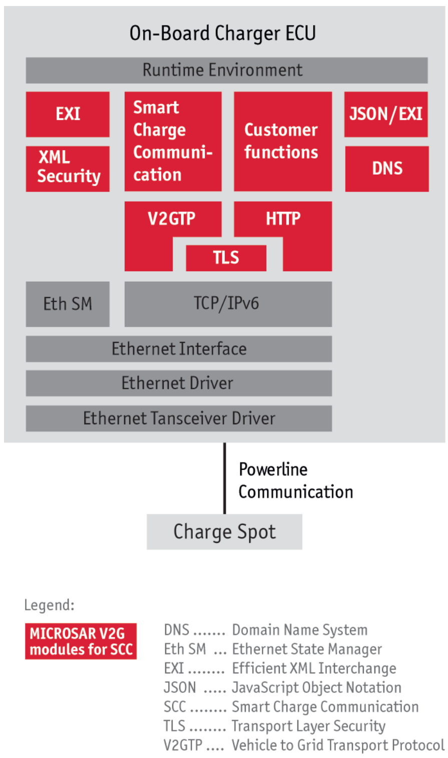


Figure 1:
MICROSAR V2G contains the software modules for Vehicle-to-Grid communication.

Special attention must be given to the testing of smart charging developments. A charging ECU that ist equivalent to ISO/IEC 15118 and DIN 70121 not only has to be integrated error-free in the vehicle's own electronics. Rather, it is virtually open to the outside where it will confront a varying charging infrastructure involving different power companies and manufacturers. “Impasse situations” at charging stations due to systems that are not fully compatible would be highly counterproductive and a serious setback for acceptance of electric mobility. In order to track down all conceivable errors and incompatibilities, a high level of test coverage and testing depth is needed. This can only be achieved by using systematic and automated test runs with powerful HIL (Hardware in the Loop) systems, for example.

Mastering new kinds of test requirements

Smart charging involves several new technologies that the test system must handle. It must provide hardware and software support for all methods used in ISO/IEC 15118 and cover all the test cases needed in this context. This extends across all ISO OSI layers from the physical layer of the PWM signal modulated for Power Line and HomePlug Green PHY and mechanisms such as SLAC to Internet and Ethernet technologies. A high-performance HIL system is able to completely and realistically simulate the environment for the system under test (SUT). In addition to the PLC and SCC (smart charging communication) methods, digital and analog values of sensors and actuators must be simulated so that the charging station side or vehicle side can be operated according to specification. A powerful remaining bus simulation additionally generates the events on vehicle buses, such as CAN, together with the underlying ECU logic.

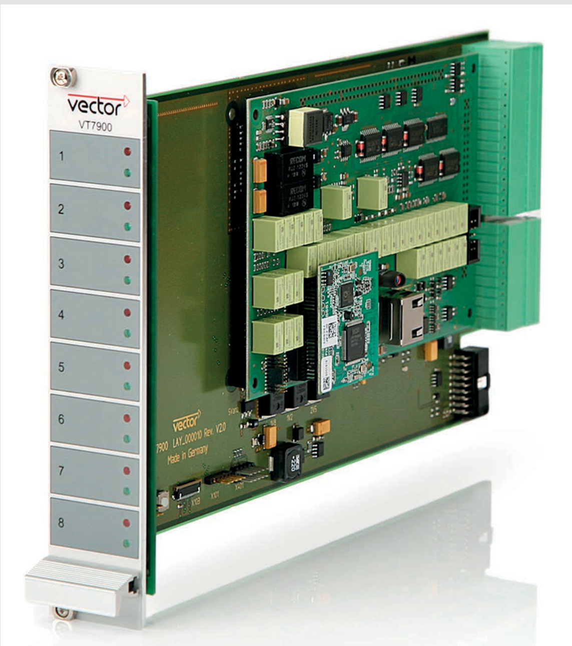


Figure 2:
VT7870 is the smart charging communication module for ISO/IEC 15118-compliant testing of charging communication

For testing of ISO/IEC 15118 and DIN 70121 developments, Vector offers a special plug-in SCC board for its VT System HIL tester. The VT7870 Board **(Figure 2)** provides two operating modes and is suitable for testing both electric vehicles and charging stations. When vehicles are tested, the HIL system simulates the charging station, and when charging stations are tested, it simulates the vehicle electronics. The board contains a Devolo dLAN Green PHY module with QCA7000 chip set that is used not only to receive the signal of the power line communication modulated for the control pilot but also to generate this signal **(Figure 2, text box below)**. The VT System has a modular design, can be flexibly scaled, and is capable of simulating error scenarios, wire breaks, and short circuits. For charging tests with real amperages and voltages, controllable power supplies and electronic loads can be connected. A PC with CANoe software, Ethernet, and the SCC add-on package is used for configuring test scripts and for test sequence control, report creation, and results analysis. If necessary, CANoe also performs the remaining bus simulation. The automated test cases can be defined with vTESTstudio – a powerful test design and authoring tool **(Figure 3)**.

Functions of the VT7870 hardware module:

- Simulation of charging station or vehicle
- PWM Control Pilot (CP) communication
- High level power line communication (PLC)
- Error simulation on Control Pilot
- Simulation of component tolerances
- Connection and measurement of the proximity contact

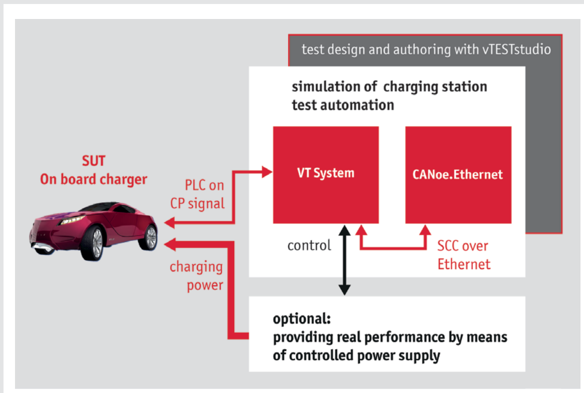


Figure 3:
Example of automated test setup for onboard charger ECUs with simulated charging station

Outlook

The expected growth in the numbers of both electric vehicles and charging station systems, which is accompanied by an increasing penetration rate for high-level communications, will lead to enormous increases in combinatorial complexity. This will create challenges in terms of interoperability of charging stations and vehicles and in terms of conformity to applicable standards. To successfully overcome these challenges, a reliable and well-developed product and testing strategy is needed, as are mutually coordinated components and tools. The presented line-up of products and services by Vector represents a universal approach that assures successful expansion of electric mobility.

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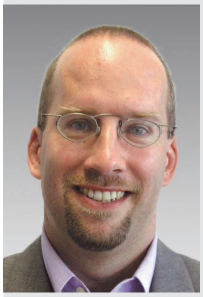
All figures:
Vector Informatik GmbH

Links:
More information about Vector´s solution for E-Mobility on:
www.vector.com/ev



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