Communication Protocols for Electric Vehicle Charging – Meet ISO 15118-20

Newcastle University Webinar | Nov. 26, 2019
**E-Mobility Communication Stack**

- **ISO 15118**
  - Standard for digital communication between EV and charging station

- **IEC 61851**
  - Safety-related analog PWM-signalling

- **IEC 63110 (kickoff in early 2017)**
  - “Protocol for management of electric vehicles charging and discharging infrastructure”

- **IEC 63119 (kickoff in early 2017)**
  - “Information exchange for electric vehicle charging roaming service”

- **OICP (Hubject) / OCHP (e-clearing.net) / ...**
  - Roaming protocols between CPOs and EMSPs

- **Open Charge Point Protocol (OCPP)**
  - De facto standard for communication between CPO and charging station
ISO 15118 Use Cases
One Communication Solution for All Charging Needs

Automated authentication & authorization
- Two authentication & authorization mechanisms:
  External Identification Means (EIM) and more user-friendly and secure Plug & Charge (PnC)
- Plug & Charge enables security mechanism on transport layer (TLS) and application layer (digital XML-based signatures and digital certificates)

Automated billing
- Plug & Charge enables secure and automated billing via e-mobility contract

Optimized load management for AC (and DC) charging
- Cost-, renewable-, and battery-optimized charging with support for load levelling
- Fleet-charging management and grid services (e.g. provisioniong of balancing power) possible
- (Re-)Negotiation of charging schedules to quickly react upon unforeseen changes in grid situation
ISO 15118 Use Cases
One Communication Solution for All Charging Needs

Additional value-added services (VAS)
- Access to Internet-based services via separate HTTP(S) and FTP communication channels (vendor-specific VAS are possible)

Wireless power transfer (WPT)
- WPT and Plug & Charge in combination guarantee most convenient customer experience
- One wireless communication channel for fine-positioning, pairing, and charge control

Bidirectional power transfer (BPT) for real smart grid support

Automated connection device (ACD)
- Support for high power DC charging of electric busses for public transport
- Control of pantograph for connection / disconnection
## Charging Standards Compared

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ISO 15118 serves all use cases to enable seamless market introduction of Evs (cars, bikes, trucks, buses, ships, airplanes)

¹: Bandwidth limited due to CAN-based communication. HomePlug Green PHY (used in DIN SPEC 70212 and ISO 15118) allows for bandwidth of 10 Mbps and data security due to TCP/IP-based communication.
The ISO 15118 Document Family
### ISO 15118 Parts and OSI Layers

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*Note: IEC 61851 also applies.*

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## ISO 15118 Parts and OSI Layers

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**ISO 15118-2**
- Application layer messages (V2G Message), SDP (SECC Discovery Protocol)
- EXI (Efficient XML Interchange)
- V2GTP (Vehicle-to-Grid Transfer Protocol)
- UDP (User Datagram Protocol), TCP (Transmission Control Protocol), TLS (Transport Layer Security), IP (Internet Protocol), SLAAC, DHCP

**ISO 15118-20**
- 2nd generation network and application protocol requirements
- Enables V2G (bidirectional power transfer)

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Grid Codes – Safeguarding V2G
Vehicle-to-Grid – Let’s Talk About Grid Codes

Grid codes

Technical regulations that any generating device connected to the grid needs to comply with in order to guarantee a stable operation of the electrical grid.

Includes
- voltage regulation
- power factor limits (usually 0.9 – 0.95)
- reactive power supply
- response to short-circuits / frequency changes on the grid

Power Factor = \[ \frac{\text{Active power (Wirkleistung, kW)}}{\text{Apparent power (Scheinleistung, kVA)}} \]

Active Power (kW)

Reactive Power (kVAR)

Apparent Power (kVA)

„Wasted“ electricity

„Usable“ electricity

Power Factor = \[ \frac{\text{Active power (Wirkleistung, kW)}}{\text{Apparent power (Scheinleistung, kVA)}} \]
Handling Grid Codes In AC and DC Charging

Source: Phoenix Contact
DC Charging Simplifies Grid Code Handling

DC charging

Power converter is located “off-board” in the charging station. **Location-dependent grid codes** can be **programmed into the controller of the charging station** which manages power flow to and from the grid.

No additional grid-related information needs to be exchanged between EV and charging station.
AC Charging Requires Additional Communication

AC charging

**Power converter** that manages power flow is located „on-board“ *(inside EV).* Technical requirements needed to **clearly specify which information needs to be exchanged** between EV and charging station.

Source: Phoenix Contact
AC Charging Message Sequence
ISO 15118 – A Client-Server Protocol

- Electric Vehicle Communication Controller (EVCC) acts as client
- Supply Equipment Communication Controller (SECC) acts a server

- SECC can trigger certain request messages by setting a flag in response message (e.g. for renegotiation of charging schedule)

Server

Responds within 2 sec to 5 sec to incoming request (depending on message)

Client

Sends request every 60 sec at the latest
AC Message Sequence

States

Hardware and analog signal handling

Communication controllers

Request-response message pairs

Source: ISO 15118 Manual
Four Steps to Enable Vehicle-to-Grid Support

1. Check for Available Charging Services

- **EV Controller including IEC 61851-1 handling**
- **EVCC**
- **SECC**
- **EVSE Controller including IEC 61851-1 handling**

**State A**
Plug present, transition to state B

**State B**

**Establishment of IP-based connection via PLC**

- supportedAppProtocolReq/-Res
- SessionSetupReq/-Res

**Optional: Value-added services**

- ServiceDiscoveryReq/-Res
- ServiceDetailReq/-Res
- ServiceSelectionReq/-Res

**Optional: If contract certificate is not installed**
- CertificateInstallationReq/-Res

EV asks which **power transfer** and value-added services as well as **identification** services (EIM, Plug & Charge) the charging station offers.

Charging services include one of:
- **AC Charging**
- **DC Charging**
- **Support Bidirectional Power Transfer (BPT)**
- **WPT (Wireless Power Transfer)**
- **ACD (Automatic Connection Device)**

Source: ISO 15118 Manual
Four Steps to Enable Vehicle-to-Grid Support

1. Check for Available Charging Services

Assume:

EV chooses AC charging with **Bidirectional** Power Transfer

EV tells charging station which identification service (EIM or Plug & Charge), power transfer service, and value-added services it will select

Source: ISO 15118 Manual
Four Steps to Enable Vehicle-to-Grid Support

2. Mutually Exchange Charging Limits

- EVTargetEnergyRequest
- EVMAXimumEnergyRequest
- EVMinimumEnergyRequest
- EVMAXimumChargePower
- EVMAXimumChargeCurrent
- EVMinimumChargeCurrent
- EVMAXimumVoltage
- EVMAXimumDischargePower
- EVMAXimumDischargeCurrent
- EVMinimumDischargeCurrent

Source: ISO 15118 Manual
Four Steps to Enable Vehicle-to-Grid Support

2. Mutually Exchange Charging Limits

- EVSE Maximum Charge Current
- EVSE Nominal Voltage
- EVSE Nominal Frequency
- EVSE Maximum Discharge Current

Source: ISO 15118 Manual
Four Steps to Enable Vehicle-to-Grid Support

3. Calculate and Send Power Profile to Charging Station

Source: ISO 15118 Manual

EV calculates its charging schedule based on provided information. Charging can start now.
Four Steps to Enable Vehicle-to-Grid Support

4. Control the Charging Process in the Charging Loop

- **EVTargetEnergyRequest**
- **EVMaximumEnergyRequest**
- **EVMinimumEnergyRequest**
- **EVMaximumChargePower**
- **EVMaximumChargeCurrent**
- **EVMinimumChargeCurrent**
- **EVMaximumDischargePower**
- **EVMaximumDischargeCurrent**
- **EVMinimumDischargeCurrent**
- **EVPresentActivePower**
- **EVPresentReactivePower**

Control messages during charging loop. Renegotiation of charging schedule possible.

Source: ISO 15118 Manual
Four Steps to Enable Vehicle-to-Grid Support

4. Control the Charging Process in the Charging Loop

- EVSETargetFrequency
- EVSETargetActivePower
- EVSETargetReactivePower

Source: ISO 15118 Manual

Control messages during charging loop. Renegotiation of charging schedule possible.
When to Expect ISO 15118 EVs

- **BEVs with ISO 15118-2 with Plug & Charge**

- **Daimler already sells smart electric drive** with ISO 15118 support for AC charging with Plug & Charge
  - See also press release „Convenient charging of electric vehicles without the need for a card or app“
  - Hubject provides PKI ecosystem based on VDE application guide VDE-AR-E 2802-100-1

- **Innogy SE** is pioneer on charging infrastructure side, but more an more EV charging solution providers (e.g. Ebee/Bender) gain momentum
  (see **Market Overview on ISO 15118-Compliant Products** => V2G Clarity Newsletter)

  - 13th Testing Symposium, **May 14 & 15, 2020 in Stuttgart (Germany)**, hosted by Vector Informatik
  - 2nd CharIn Testival, **April 28 & 29, 2020, Newark (California, U.S.)** hosted by Lucid Motors
Cyber Security Features
Pillars of IT Security
The CIA Triad

**CONFIDENTIALITY**
The content of a message (plain text) shall only be readable by the intended recipient(s), but not by any unauthorized third parties.

- Secure exchange of information to calculate symmetric key achieved through ECDH
- Symmetric encryption through AES-128-CBC cipher

**INTEGRITY**
An unauthorized modification of the sent message shall be avoided or at least be detected.

- Asymmetric cryptosystem (public-key cryptography) and secure hashes needed (for creation and verification of digital signatures)

**AUTHENTICITY**
Assert that the communicating parties are really the persons or entities which they claim to be.

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Hybrid Cryptosystems

**ECDH**
Elliptic Curve Diffie-Hellman

- **Symmetric key (128 bit)**
  - Used with symmetric block cipher AES-128-CBC

- **ISO 15118 messages during TLS session**
  - Encrypt / decrypt messages between EVCC and SECC using TLS

- **Private key for contract certificate**
  - MO encrypts private key for EV, EV decrypts and stores priv. key

**ECDSA**
Elliptic Curve Digital Signature Algorithm

- **Create digital signatures**
- **Verify digital signatures**

**Asymmetric ciphers**
- Requires long key lengths compared to symmetric ciphers (computationally quite expensive), which is why **symmetric ciphers** are used for encrypting the communication.
ISO 15118 Public-Key Infrastructure

One PKI for each Plug & Charge market role

**Charge Point Operator (CPO)**
Operates and maintains the charging stations via its backend IT system

**Certificate Provisioning Service (CPS)**
Facilitates the installation of a new contract certificate for the EV through a digital signature

**Mobility Operator (MO)**
Provides a legal e-mobility contract and issues contract certificates associated with that legal contract

**Car manufacturer (OEM)**
Issues the unique OEM provisioning certificate needed to install a new contract certificate for Plug & Charge
Figure E.1 provides a visual overview of the resulting certificate structure and relevant validity periods. As one can see, the OEM Provisioning Certificates are independent from the PKI of the secondary actors below the (global) root certificates. The root certificate of an OEM Provisioning Certificate is created by the OEM itself. Therefore, there is no need to have a (longer) certificate chain. (For an explanation of the usage of the OEM Root Certificate and the OEM Provisioning Certificate refer to Annex 0. It is, however, allowed to reuse a V2G Root as a Mobility Operator Root Certificate or an OEM Root Certificate (suggested with dotted lines). All certificate chains have a maximum length of 3; i.e. including the root certificate 4 certificates are involved. The certificate chain of an SECC is transmitted to the EVCC to enable an authenticity check of the SECC before a TLS connection is established (cf. above: in order to avoid man-in-the-middle attacks). The certificate chain of a Contract Certificate is transmitted into the EVCC without a Root CA. This limits the transmission to 3 certificates, but this also means, that the vehicle cannot verify its own Contract Certificate. E.2 provides an example of simplified certificate management in private environments.

Hierarchical levels in each PKI

Root Certificate Authorities (CAs)
The top-level trust anchors that everyone must trust in. Issue self-signed certificates for themselves and certificates for sub-CAs

Subordinate CAs (Sub-CAs)
Issue certificates for either another sub-CA (sub-CA 1 issues for sub-CA 2) or for a leaf certificate. Min. one sub-CA is required, optionally two sub-CAs

Leaf certificates
The actual certificates used for authentication. For example: SECC leaf certificate, contract certificate, OEM prov. certificate
Available Resources to Get Started with ISO 15118
Market Overview on ISO 15118-Compliant Products

- Register your ISO 15118-compliant product at [https://v2gclarity.typeform.com/to/gylK5Z](https://v2gclarity.typeform.com/to/gylK5Z)
- Will be available to all subscribers of the V2G Clarity Newsletter (>> 1,600 subscribers)

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RISE V2G – ISO 15118 Open Source

github.com/V2GClarity/RISE-V2G

- Reference implementation of ISO 15118-2 that covers all features
  - AC and DC charging
  - EIM and Plug & Charge
  - TLS and certificate handling
  - For both EV and charging stations
  - Uses Exificient and OpenEXI

- Licensed under MIT
  → Can be used for commercial products

- Has been tested at all testing symposia so far; evolved as a highly appreciated solution by companies and research institutions worldwide

RISE V2G 2.0 will come with ISO 15118-20 – and stay open source
Knowledge Base Articles
v2g-clarity.com/knowledgebase

What Is ISO 15118?
Get to know one of the world’s leading international electric vehicle standards
Read more

The Basics of Plug & Charge
ISO 15118’s feature for a more user-convenient and secure way of charging electric vehicles
Read more

Secure and User-Convenient Charging with ISO 15118
A free, one-hour video introduction to the industry-approved EV charging standard.
View video

Vehicle-to-Grid Services
How electric vehicles help stabilize the electric grid by providing vehicle-to-grid (V2G) services
Read more
Reduce Complexity With the ISO 15118 Manual
v2g-clarity.com/iso15118-manual

Save time and money and avoid common mistakes with the easy-to-understand path to ISO 15118

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Online Courses to Deepen Your ISO 15118 Expertise

- [https://github.com/V2GClarity/RISE-V2G](https://github.com/V2GClarity/RISE-V2G)

- Online courses for in-depth guide through RISE V2G and ISO 15118

  **Revolutionize Electric Vehicle Charging**  
  (RISE V2G Basics):  
  [https://courses.v2g-clarity.com/p/riserv2g-basics/](https://courses.v2g-clarity.com/p/riserv2g-basics/)

  **Master the Communication for Charging Electric Vehicles**  
  (RISE V2G Advanced)  
  [https://courses.v2g-clarity.com/p/riserv2g-advanced1/](https://courses.v2g-clarity.com/p/riserv2g-advanced1/)

- Online course focusing on security-related topics, i.e. cryptographic foundations of Plug & Charge, TLS handshake, public key cryptography, etc.

  **Data Security and Plug & Charge With ISO 15118**  
Let’s Stay In Touch

Dr. Marc Mültin

Phone +49 (170) 8668645
Email marc.mueltin@v2g-clarity.com
Web www.v2g-clarity.com
LinkedIn www.linkedin.com/in/V2GClarity