Industry Standards

1 Outline of ISO/IEC 15118 Vehicle-to-Grid Communication Interface (V2G CI) International Standardization Activities

In 2009, ISO/IEC 15118 V2G CI was approved as a new work item proposal (NWIP), initiating the formulation of communication protocol standards for the charging control of electric vehicles (EVs). The standardization activities were actively undertaken by the joint working group (JWG) of ISO TC 22/SC 3 (vehicle electrical and electronic equipment) and IEC TC 69/WG 4 (electric vehicle power supplies and chargers). In April 2014, both 15118-1 (general information and use case definition) and 15118-2 (network and application protocol requirements) had already been issued as international standards (IS). In addition to the proposals for the first two items listed above, the scope of the work and the content to be handled was expanded by the following additional proposals: the physical layer of the wires, conformance testing, and wireless communication. Table 1 shows the list of international standards that are currently being created in the series of 15118.

By the first half of 2014, the international standards that dealt with wired charging communication (15118-1, 15118-2, and 15118-3: physical layer and data link layer requirements), had all become settled as IS or reached the final draft of international standard (FDIS) stage. This article provides further explanations of the communication technologies that were prescribed in the international standards mentioned above. Other topics that are related to these communication technologies will also be touched on briefly as necessary.

2 Architecture of ISO/IEC 15118 V2G CI

2. 1. Actors

Defining the prerequisite communications system is necessary in order to prescribe the communication protocol. First, the actors (what is working within the charging scenario) that define the communication-related functions in 15118 are introduced below.

The actors are divided into two types: the primary actors that are directly involved in the charging scenario and the secondary actors that are indirectly involved. The primary actors are composed of the EV and the electric vehicle supply equipment (EVSE). The central primary actors are the communication controllers, i.e., the electric vehicle communication controller (EVCC) and the supply equipment communication controller (SECC). Figure 1 shows examples of the main actors.

ISO/IEC 15118 prescribes the communication protocol between the EVCC and SECC shown in the figure. A request message is sent indirectly to the secondary actors via the SECC as necessary and then, after the necessary processing, it is sent back to the EVCC.

2. 2. Architecture of communications system

The actors include items that process communication messages (EVCC, SECC, and secondary actors) and items that define the hardware functions (charger and contac-

Table 1 List of ISO/IEC 15118 international standards.

Standard No.	Content	Year proposed	Status
15118-1	General information and use case definition for charging scenario	2009	Already issued as IS (2013)
15118-2	Network and application protocol requirements	2009	Already issued as IS (2014)
15118-3	Physical layer and data link layer requirements	2011	FDIS balloting underway (2014)
15118-4	Network and application protocol conformance test	2012	CD
15118-5	Physical and data link layer conformance tests	2012	CD
15118-6	General information and use case definition for wireless communication	2013	CD
15118-7	Network and application protocol requirements for wireless communication	2013	WD
15118-8	Physical layer and data link layer requirements for wireless communication	2013	WD

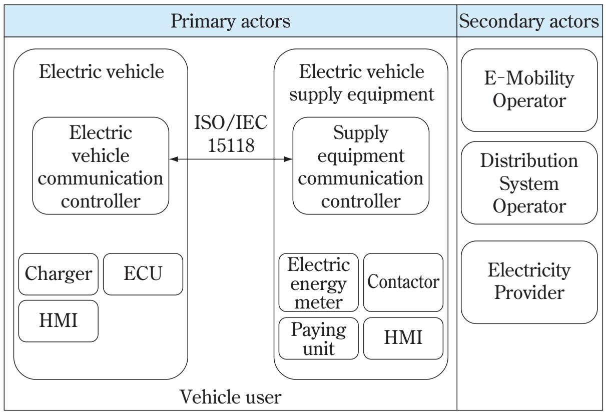

Fig. 1 Examples of actors participating in charging scenario.

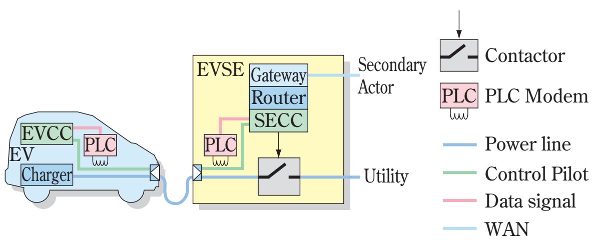

Fig. 2 Example of EV and EVSE basic architecture.

tor). In contrast, the architecture expresses the physical layout of these items, and is important information that helps to define the charging scenario. Figures 2 and 3 show examples of the main EV and EVSE architectures.

Figure 2 shows the most basic example, in which the EV and EVSE are connected one-to-one. In addition to the actors described previously, other actors, such as a contactor, which is the on-off switch for the power supply line, and the control pilot, which is established in parallel with the charging cable and provides control via pulse width modulation (PWM), have also been added. These other actors are defined in another standard that covers charging equipment for EVs (IEC 61851-1), which is separate from 15118. The communication requirements defined in ISO/IEC 15118 comply with the requirements defined in IEC 61851-1.

The arrangement of the power line communication (PLC) signal is of particular importance. It is superimposed on the control pilot line rather than the power supply line. This signal system is called in-band communication and is chosen to minimize the impact on the surrounding environment by the PLC signal.

Figure 3 shows an example where multiple EVSEs are established in parallel, with a shared SECC outside the EVSEs. An arrangement such as this, where multiple

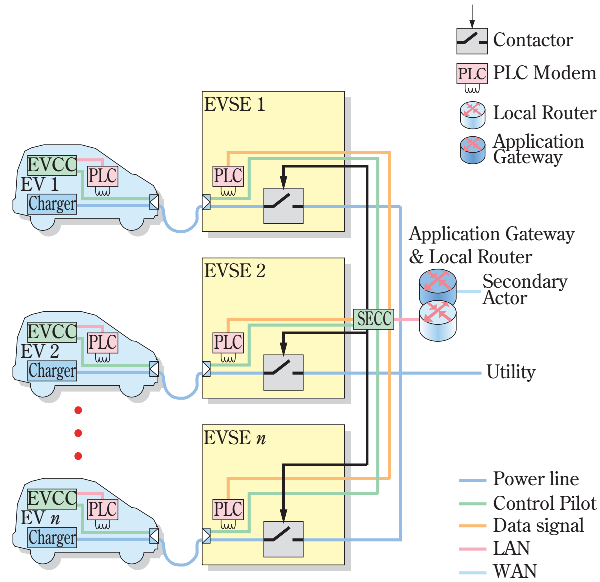

Fig. 3 Example of EV and EVSE expanded architecture.

Table 2 List of vehicle states.

Vehicle state	Voltage	Status	Charging possibility
A	12 V	Vehicle is not connected	Not possible
B	9 V	Vehicle is connected	Not possible
C	6 V	Charging is possible, ventilation unnecessary	Possible
D	3 V	Charging is possible, ventilation necessary	Possible
E	0 V	Charging not possible due to supply-side situation	Not possible
F	− 12 V	Charging not possible due to charger situation	Not possible

EVSEs and vehicles are established in parallel, is also referred to as a fleet. This arrangement has been examined mainly in Europe, especially as part of the demonstration program in Germany called e-Mobility.

2. 3. Vehicle state

The control pilot is specified in Annex A of IEC 61851-1. This performs the charging control while confirming the mutual states of the EV and EVSE via the voltage and oscillation. The signal voltage is resistance-divided and grounded by the opening and closing of each switch, and the state on the EV side is then converted to voltage and transmitted to the EVSE. The function that displays these states is called the vehicle state. Table 2 shows a list of vehicle states.

2. 4. Smart charge

Basic EV charging can be performed safely due to the control pilot. In ISO/IEC 15118, further communication is added, and the charging load smoothing and charging fee optimization functions are realized via confirmation of the electric power contract, integration into the household electric power bill, and adjustment of the system load. The two types of in-bound communications that occur in conjunction with the control pilot are called basic signaling and high level communication respectively. The charging that is performed by combining both of these types of communication, while also realizing the various added functions described above, is referred to as a smart charge.

3 Charging Scenario of ISO/IEC 15118 V2G CI

3. 1. Use case elements

When the charging scenario is defined, it is possible to define the detailed charging control states. These are referred to as use case elements and a bundle of these elements is called a charging scenario. Different charging scenarios can be created depending on how the use case elements are selected. Table 3 shows a list of the function groups of the use case elements.

Each individual use case element is defined with the state prior to processing implementation, the processing implementation content, and the state after processing implementation. This allows a detailed description of the control state to be made.

3. 2. Start of charging and establishing communication

Charging begins when the charging cable is plugged in and connected. Charging control begins when the vehicle state shifts from A to B. Subsequently, if the preparations on the EVSE side are complete, then the control pilot is oscillated and charging permission is transmitted to the EV. When the permission for charging is given, the EV and EVSE begin to establish communication.

Once communication has been established, the EVCC and SECC respectively obtain independent internet protocol (IP) addresses. In addition, the SECC will answer a request from the EVCC to obtain each other's IP address so that communication can begin.

3. 3. Approval of certificate and charging permission

The service provision contract is confirmed by having the EVCC and SECC approve each other's certificates and then the charging service can be provided. Once the contract is confirmed, permission is given to create the charging plan and then carry out the charging process.

There are two ways to carry out the approval process: one in which approval is given via the charging communication, which is called plug and charge (PnC), and another in which the approval is given by some other means established within the EVSE, which is called the external identification means (EIM).

Table 3 List of function groups for use case elements.

Group	Details
A	Start of charging process
B	Establishment of communication
C	Update and introduction of certificate
D	Approval and authentication processing
E	Creation of charging plan
F	Charging control
G	Additional services
H	Finishing process

3. 4. Creation of charging plan

A list of the services that can be used is obtained when the charging permission is given and then the charging plan is created at that point. In the charging plan, the time is listed along the horizontal axis and the charging power is entered at each of the time marks. This plan is created so that the required electric power can be provided up until the charging is completed. The plan is also created to smooth the system load and to minimize the charging power fees. The plan is based on information such as the electric power rate schedules for each time zone obtained from power distribution companies, the upper limit of rechargeable power for each time zone, the power transmission upper limit table from the power transmission company, and the maximum charging power of the EVSE.

3. 5. Charging control and signature on the electric power receipt

The actual charging control begins when the charging start time is reached in accordance with the created charging plan. The EV sends a message requesting that electric power be provided, and closes a switch on the EV side. This shifts the vehicle state from B to C or D, and the vehicle enters the charging status. When the EVSE receives the request message and confirms the vehicle state, the contactor of an internal switch is closed, the power supply line is connected, and the electric power is supplied. Once the charging control starts, the charging will continue until the target electric power is achieved, while the charging power is changed based on the charging plan.

Under charging control, a charging power receipt is sent regularly from the EVSE to the EV. The EV confirms the electric power that was received, places its signature on the receipt, and then sends it back to the EVSE. This process is repeated and finally the receipt with the accumulated amount of charging power is signed.

3. 6. Value-added services

There are cases in which a service that provides additional information, such as described above, is ancillary to the charging control. One example of this is when the charging plan, the charging progress status, and vehicle status information are all provided to the EV user. These kinds of incidental one-way or two-way information providing services are called value-added services (VAS).

4 Communication Protocols of ISO/IEC 15118 V2G CI

4. 1. Functions of each communication layer

In general, communication protocols are defined by an open systems interconnection (OSI) reference model that has been divided into a hierarchical structure. Table 4 shows the composition of 15118 protocol and the scope of responsibilities for each standard.

Table 4 OSI reference model of ISO/IEC 15118 V2G CI.

OSI layer	Item	Details	Responsible standard
1st layer	Physical layer	In-band communication	15118-3
2nd layer	Data link layer	Apply PLC signal specifications	15118-3
3rd layer	Network layer	IP, ICMP, SLAAC	15118-2
4th layer	Transport layer	TCP, UDP, TLS	15118-2
5th layer	Session layer	V2GTP	15118-2
6th layer	Presentation layer	EXI	15118-2
7th layer	Application layer	V2G message	15118-2

The 15118-2 standard prescribes the transmission control protocol (TCP)/IP communication protocol for the network layer and above, while the 15118-3 standard prescribes the protocol for the physical and data link layers. This section describes an outline of each layer.

4. 2. Physical layer

The physical layer is the first layer of the OSI reference model and it defines the medium of the physical signal and the signal strength. In 15118, standardization work started with HPGP, which is a high-speed PLC, and G3-PLC, which is a low-speed PLC, as the candidates. After this, an in-band communication system that superimposes the PLC on the control pilot line rather than the power supply line was proposed. Then it became a choice between a total of four systems composed of two types of PLC signals and two types of media. The state of development in each country and the legal and regulatory systems in each market were then taken into consideration when performing the evaluation testing and examinations. As a result of those examinations, the HPGP in-band communication system was selected as the first candidate because it has a wide bandwidth, high-speed communication is possible, and the impact on the environment is small. If HPGP cannot be used, then it is also possible to select the G3-PLC in-band communication system.

4. 3. Data link layer

In the data link layer, the PLC signal specifications are basically used unchanged, but with two special features. One feature is the I/O-control service access point (SAP) that incorporates the state of the control pilot into the data link layer. The other is the signal level attenuation characterization (SLAC) that measures the signal strength and then makes a judgment about whether there is an actual connection.

The SAP is used to deliver signals between each layer of the OSI layer. Conventionally, the vehicle state, which is expressed via the control pilot rather than the PLC signal, is not inputted. However, in 15118, the reading of the vehicle state, which is sent in conjunction with the request to begin charging from the EV, is necessary. Therefore, the I/O-control SAP, which makes it possible for the state of the control pilot to be sent and inputted into the data link layer, was added, making it possible to send information to the upper layers. Thanks to this function, the control pilot can be treated as a communication protocol without any need for additional software processing.

The second special feature of the data link layer is the SLAC. The SLAC measures the signal strength between the EVCC and the SECC. The SLAC is able to determine whether that signal was received via a pilot line that was actually connected by measuring this signal strength. If that is not the case, the signal that was received may have been propagated from an adjacent or shared power supply line, which is referred to as cross talk or shared media. This function allows the EVCC to find the directly-connected SECC properly.

4. 4. Network layer/transport layer

In the network layer, an IP address is obtained to carry out TCP/IP communication. There are two types of IP address: the widely used IPv4 and the newer IPv6, which expands the address space. In 2009, when the standardization work began, there were already concerns that the IPv4 address space was close to being exhausted, so IPv6 was made mandatory and IPv4 made optional.

In the transport layer, communication is generally performed using the TCP and the user datagram protocol (UDP). In the case of TCP, the address of the destination must be specified, while in the case of UDP, a message can be broadcast without the need to specify the destination. In both cases a transport security layer (TLS) is generally used to encrypt the communication.

4. 5. Session layer/presentation layer

In the 5th layer, which is called the session layer, the vehicle-to-grid transfer protocol (V2GTP) is used to specify the communication data structure, header structure, and port address as the message format in the 6th layer, which is called the presentation layer. In 15118, each message is defined with extensive mark-up language (XML) because this is widely used for internet-based communication. However, efficient XML interchange (EXI) is used for the actual sending and receiving of messages to reduce the communication load.

4. 6. Application layer

In the 7th layer, which is called the application layer, the message set used by the EVCC and SECC for communication is defined in accordance with the charging scenario described in section 3 above. The communication between the EVCC and SECC is of the server-to-client type and the messages are sent from the EVCC. Messages sent from the EVCC are defined as "requests" and replies sent from the SECC are defined as "responses." Table 5 shows a list of the messages that are used in 15118.

Each message is composed of a request-response pair. In the case of "SECC Discovery," the EVCC will send a "SECC Discovery Request" and the SECC will send back a "SECC Discovery Response." The circles in the "AC" and "DC" columns on the right side of Table 5 indicate whether or not each message set is included in the AC or DC charging scenarios.

Table 5 List of request-response messages for ISO/IEC 15118 V2G CI.

Name of message set	Details	AC	DC
SECC Discovery	Obtain SECC address	○	○
Session Setup	Establish communication	○	○
Service Discovery	Obtain list of services	○	○
Service Detail	Obtain service details	○	○
Service & Payment Selection	Select service and payment	○	○
Payment Details	Obtain payment details	○	○
Charge Authorization	Create and approve charging plan	○	○
Charge Parameter Discovery	Obtain charging parameters	○	○
Power Delivery	Supply electric power	○	○
Charging Status	Charging status	○	○
Metering Receipt	Confirm total electric power	○	○
Certificate Update	Update certificate	○	○
Certificate Installation	Obtain certificate	○	○
Cable Check	Confirm cable connection	—	○
Pre Charging	Conduct pre-charging	—	○
Current Demand	Request DC charging	—	○
Welding Detection	Confirm welding	—	○
Session Stop	End communication	○	○

5 Main Discussions in International Standardization Activities

Standardization activities for 15118 have been actively undertaken since the proposal was approved in 2009. There have been many discussions over the past five years during these international standardization activities.

5. 1. Main discussions of 15118-1 (general information and use case definition)

The main discussions in Part 1 concerned the architecture and charging scenario. The connections between the EV and EVSE are common around the world, but the discussions concerning the arrangement of single and multiple EVSE, the arrangement of the EVCC and SECC, and the network configuration came to strongly reflect the circumstances in each individual nation. There were many discussions with huge differences between the sides until the visualization and sharing of the architecture, which is the basis of these discussions, could finally be settled upon.

In the case of the charging scenario, in the e-Mobility demonstration program in Germany, the EV obtains the fee table from the electric power company and then creates the charging plan. This is different from Japan, where it is common for the charging plan to be created on the server side. In Europe, since the electric power companies are different in each region and country it was decided to implement a common charging plan that would be handled on the EV side. In Japan, it is more common for the charging plan to be created on the server side, so this proposal from Japan was also added to the charging scenario.

5. 2. Main discussions of 15118-2 (network and application protocol requirements)

The discussions that emerged from Part 2 of this standard were more technical and detailed and a larger number of such discussions were necessary. Since Germany possesses many development assets, it insisted that it should still be possible to select IPv4 IP addresses despite the imminent exhaustion of these addresses and the fact that IPv6 was an essential item of the standard.

The German and French arguments concerning the order to start supplying electric power were in direct opposition to each other. Germany argued the importance of reducing cost by having all such orders carried out via communication, while the French wanted to reduce cost through the conventional method of adding a communication device to the charger. The German proposal was to allow the vehicle state to shift from B to C via communication. The French proposal was that the vehicle state should only ever be shifted via the control pilot and that communication should be added only as an auxiliary function.

There was no sign of this discussions when the committee draft (CD) was formulated, but it finally emerged later when French development had made progress. A long time was required until an agreement could finally be settled upon.

5. 3. Main discussions of 15118-3 (physical layer and data link layer requirements)

The greatest discussions in this part of the standard was in regard to the selection of the PLC technology and the communication medium. Once again Germany and France stood in heated opposition to each other from the beginning as Germany proposed using the high-speed PLC, HPGP, and France proposed using the slower speed PLC, G3-PLC. First, the communication medium and not the PLC technology was selected, and it was decided to select the option of superimposing the PLC on the control pilot line rather than the power supply line. This decision succeeded in separating the debate from the background situation in each nation. The request for real time information to be provided, which is required for DC charging control, then made it possible to select HPGP in-band communication as the first candidate. In the end, the G3 in-band communication was also allowed to be selected as an option.

In addition, South Korea argued strongly that these selections would cause interference with the PLC technology already being used in Korea: HS-PLC or High Speed PLC (ISO/IEC 12139). As a result of a great deal more discussions, the relevant descriptions and information were added to the standard.

6 Conclusions

In April of this year an international conference was due to be held in Berlin, Germany by the German Association of the Automotive Industry (VDA). Various opinion exchanges and discussions were to be held at this conference in regard to topics such as the method of entering the information about the South Korean PLC into 15118-3 FDIS (physical layer and data link layer requirements, final draft), and how to best proceed with requests concerning wireless communication in parts 6, 7, and 8 of 15118.

The standardization work for 15118 began back in 2009, but 15118-1 and 15118-2 have already been issued as international standards, and 15118-3 is expected to be issued during the first quarter of 2015. The international standardization work concerning wired charging communication has now been settled and, from this point forward, conformance testing and wireless communication will become the focus of the activities.

Given the opportunity presented at this time, this article has tried to take a look back at the past five years of international standardization work. This article has been written for the purpose of providing those who are unfamiliar with this topic a general overview of the relevant information, but due to the constraints of available space and the skills of the author, it has barely brushed the surface. Therefore, it is strongly recommended that interested parties should actually read the details of standard 15118.

The international standardization of charging communication for EVs involves a complex entanglement of factors, such as the EV side, the EVSE side, and the existing infrastructures in each nation. The work progressed slowly while individual points of agreement were selected. It is hoped that the reader will be able to imagine the many circumstances swirling in the background of this standardization work while reading through the descriptions in this article.