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Research paper

Communication Interoperability between EV Charging Infrastructure and Grid

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Abstract

Background/Objectives: Although ISO/IEC 15118 deals with data communication between an electric vehicle and a charging station, communication with the extern is essential for establishing a system for V2G service.
Methods/Statistical analysis: Data mapping table is created by comparing and analyzing the data model of electric car charging infrastructure and the data model of grid network communication.
To integrate into IEC 61850 communications, the electric vehicle data model is expressed as SCL.
The gateway links data between the electric car and the power network.
Communication interoperability is an important issue to share the syntax of data.
Findings: This research selects messages that communicate with the power grid among the use cases of the EV charging infrastructure. It is important to maintain the syntax for communication interoperability between two domains. The gateway we built ensures interoperability between the charging infrastructure of the EV and the grid. We verify the information of EV charging infrastructure in power grid through communication link between ISO/IEC 15118 electric vehicle model and IEC 61850 standard MMS protocol.
Improvements/Applications: This is demonstrated so that the communication data is linked with the micro-grid system. This could be used as an element technology in other distributed power in the future.

Keywords: *Electric Vehicle, Communication Integration, EV Charging Infrastructure, SmartGrid, Interoperability*

1. Introduction

A recent issue of EV (Electric Vehicle) is the implementation of V2G (Vehicle-to-Grid) by transmitting power back through OBC (On-Board Charger) application. The introduction of this concept can mitigate the power load at the peak of power and create a new revenue model [1]. For this purpose, the management system must be able to manage the charging status of the car, energy reserve, charge schedule, etc. through communication and build a bi-directional charging system [2]. ISO/IEC 15118 [3], which is the standard for electric vehicle charging infrastructure, can only provide communication services between electric vehicles and electric vehicle chargers. In Section 2 of this study, we examine the characteristics of each of these through the ISO/IEC 15118 standard for electric vehicle charging infrastructure and the IEC 61850 communication protocol for electric power networks. In Section 3,we explain how to associate messages for it. In conclusion, we have designed and demonstrated a communication gateway to verify the information of electric vehicle charging infrastructure in electric power system through communication link between ISO/IEC 15118 electric vehicle model and IEC 61850 MMS protocol.

2. Related standards

ISO/IEC 15118 specifies the communication between an electric vehicle and an electric vehicle charger [4]. It deals with the message (V2G Message) between the electric vehicle and the electric vehicle charger and the use case.IEC 61850 is a standard for communication networks and systems for power utility automation. It defines an architecture that focuses on the application, including the content of the communication protocol.

In this study, IEC 61850 based model of electric vehicle data model of ISO/IEC 15118 is modeled and IEC 61850 based data model [5-6] of electric vehicle charging infrastructure by mapping the communication message of the charging infrastructure of ISO/IEC 15118 and the electric vehicle data model to which the communication environment can be established.

2.1. ISO/IEC 15118 of Electric Vehicle Charging Infrastructure

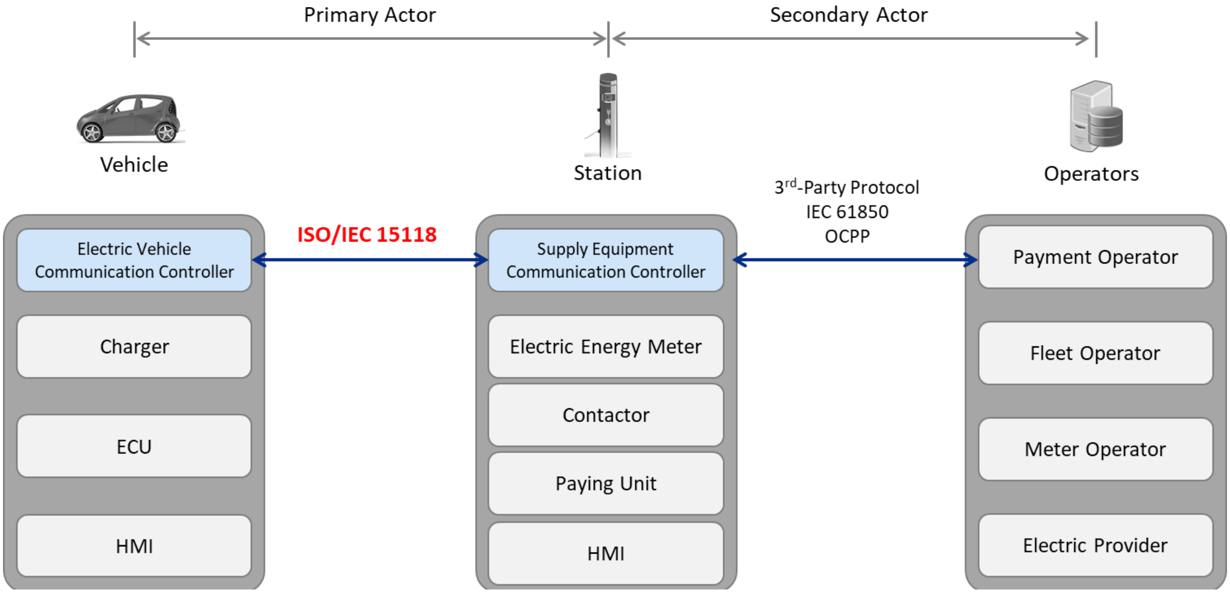


Figure 1: Scope of ISO / IEC 15118 Electric Vehicle Infrastructure Standard

As shown in <Figure 1>, ISO/IEC 15118 is a communication protocol for exchanging data between the EV and the EV charger, and it is an international standard developed to provide efficiency, safety, and compatibility [3].

In the past, the EV environment only enabled low-level communications to transmit basic information including the maximum available current information for minimum safety. However, high-level communication is required to include a large amount of data as the demand for more various charging functions and additional services increases. To support this requirement, ISO/IEC 15118 supports high-level digital communication to support charging start and end, payment of fees, authentication and security, charge control, scheduling and additional services [7-8]. ISO/IEC 15118 defines general information about electric vehicle charging infrastructure and use cases for electric vehicle charging process.

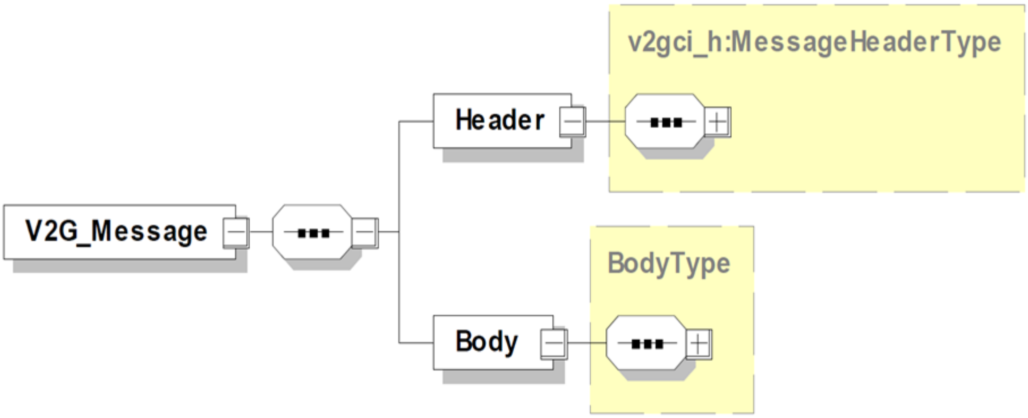


Figure 2: V2G Message scheme of ISO / IEC 15118

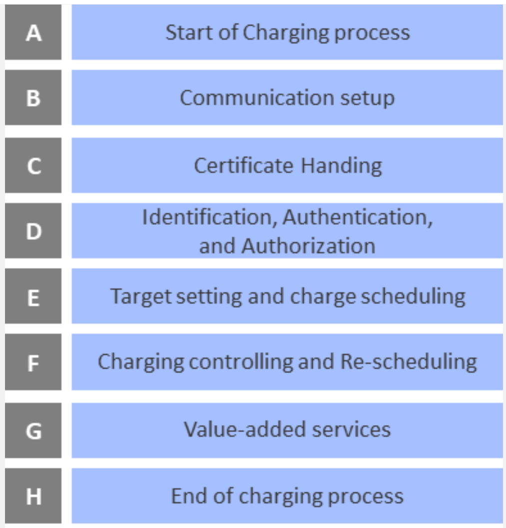
ISO/IEC 15118 has use cases that require two-way communication. Typical examples are use cases that start the charging process by changing the state of the charger, authentication systems for authenticating the train, and charging schedules by checking the charging status. Messages for this use case are those of the electric vehicle, ISO/IEC 15118 In addition to the electric vehicle charger, it should also be able to communicate with the management system.

Implementing ISO/IEC 15118 use cases as messages is a V2G Message. This V2G message has the structure as shown in <Figure 2> and is described in EXI format, and consists of a message header and a body.

The message header includes information about the communication object such as the Session ID, and the body includes the type and value of the SECC Discover Protocol (SDP) message for charging the electric vehicle.

The types of V2G messages exchanged between the electric vehicle and the charging device are mapped to the use cases as shown in Table 1, and each message includes a request message that the electric vehicle transmits to the charging device, they form a pair with a response message

Table 1: Use-case Group of electric vehicle charging and V2G messages



Use Cases	Types of V2G Messages	
A	Session Setup	
B	Service Discovery	Service Detail
B	Service and Payment Selection	
C	Certificate update	Certificate Installation
D	Charge Authorization	
E	Payment Details	
E	Charge Parameter Discovery	
E	Power Delivery	
F	Charging Status	
F	Metering Receipt	
F	Cable Check	Welding Detection
F	Pre Charging	
F	Current Demand	
H	Session Stop	

2.2. IEC 61850 for Power Grid Communication

IEC 61850 is an international standard for automation across power utilities and provides data models and communication protocols for the exchange of information among power-grid-connected intelligent electronic devices (IEDs). IEC 61850 not only provides interoperability between power equipment, but also enables real-time fault detection and diagnostics to predict premature failure. By separating the application model from the communication model, it is possible to define all the functions required for power system automation and flexibly cope with new communication technologies.

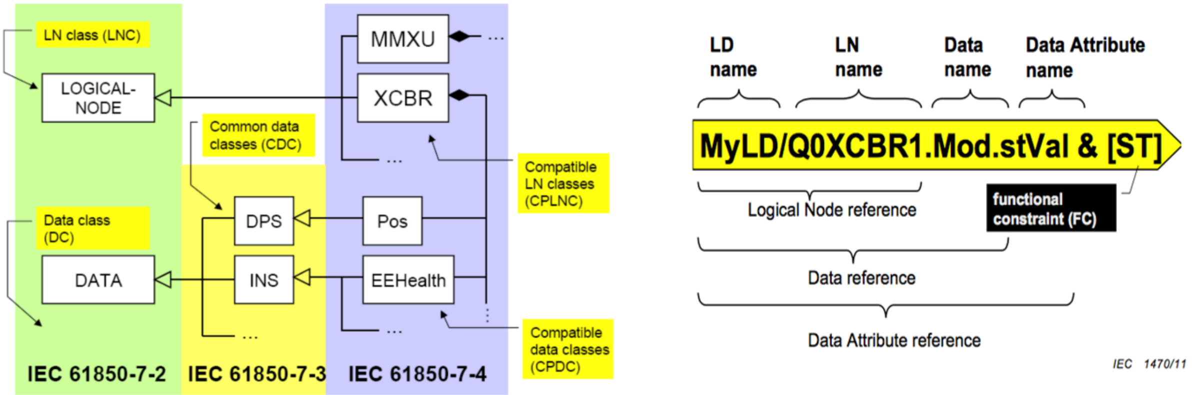


Figure 3: Data stack and Data representation method of IEC 61850

Thus, IEC 61850 is a standard for communications networks and systems for power utility automation. Defines an architecture that focuses on the application, including content about the communication protocol. IEC 61850 data stack is composed as shown in <Figure 3>. Device Logical Device (LD) is divided into Logical Nodes (LN) which are functional units. This LN is composed of Common Data Class (CDC) and Datatype hierarchy. This model is modeled based on XML [9] to embody a power network communication model [5].

IEC 61850 models such data structures as XML-based to embody the grid communication model. Because it is a data stack with a hierarchical structure, IEC 61850 represents data as shown in <Figure 3>.

IEC 61850 was limited to communications networks and systems in substations prior to 2007, but since then the scope has extended to telecommunications networks and systems for power utility automation.

IEC 61850 consists of 10 core parts and their sub-parts. Among them, IEC 61850-7-x and IEC 61850-90-8 are representative parts necessary for linking with electric vehicle charging infrastructure. IEC 61850-7-x defines the information model, data class, and services to meet the requirements of power utilities. IEC 61850-7-420 describes an information model for organically connecting a variety of Distributed Energy Resources (DERs), including electric cells, photovoltaics, and cogeneration facilities, to the grid.

IEC 61850-90-8 (IEC 61850 Object Models for Electrical Mobility) is a standard for linking electric vehicles to IEC 61850 communication protocols used in power systems.

In this study, IEC 61850 communication model of the electric vehicle data model of ISO/IEC 15118 was studied to have communication interoperability [10] with the existing system.

3. Communication interoperability

The power grid must be capable of two-way communication with the EV charging infrastructure for V2G power flexibility as shown in figure 4. To this end, IEC 61850-based communication will be possible through the interoperability model of the message of the ISO/IEC 15118 standard in the electric vehicle charging infrastructure.

Figure 4: Design of Improved Decision tree algorithm for Educational Data mining

The Interoperability Model, which acts as a gateway for interoperability, is divided into three modules:

- ISO/IEC 15118 Message Receiver

- EV Message to Grid DataModel Mapping Module

- Grid Message Generator

It receives the message of the electric vehicle charging infrastructure and maps it to the data model of the power network. And it should be able to create and transmit communication messages of the power grid. By assigning these roles to the Interoperability Model, we can improve the interoperability of data, semantic interoperability, data interchangeability, communication interoperability, and ensure interoperability.

As shown in Table 2, there are three main parts to be examined in order to determine whether the IEC/ISO 15118 and IEC 61850 communication links of the electric vehicle charging infrastructure are established.

Table 2: Communication Interoperability Verification Methods and Items

Group	Details
DocumentConfiguration	DUT (Device Under Test)
	Test Simulation (Software)
	Test Analyzers (Software)
	Configuration Files (ICD, SCD)
DataModel	Header (Identifies the config files)
	Communications (Address, Subnet)
	IED (Device function and setting)
	DataType Templates (Object oriented)
ACSI ModelService	Application Association
	Report/Log Control Model
	Time Synchronization Model
	Control Model
	Server, LogicalDevice, LogicalNode
	DataSet, Data Attribute Model

First, make sure that there are all the components necessary for communication linkage. The DUT and the experimental scenarios, the indicators for analyzing the communication results, and the structure data file of the communication object are required.

After that, the data model is confirmed by using the structure data file. Check the data model header and data communication information, and verify that the IED is logically defined based on the Data Type Template. When the object is checked, the messages presented in ISO/IEC 15118 and the ACSI model are confirmed. Communication interoperability can be confirmed through experiments on communication connection and report control in Fig. 5, experiment on time synchronization and data control, and standard conformance test of data path through each data inquiry.

In this study, IEC 61850 communication environment is established by using data model of electric vehicle charging infrastructure IEC / ISO 15118, and communication interoperability is confirmed through the following process.

- Data model connection using IEC 61850-90-8

: Receives data of an electric vehicle outside the charging infrastructure of an electric vehicle

- Linking ISO/IEC 15118 messages with IEC 61850 messages

: Semantic understanding of electric vehicle message outside electric vehicle charging infrastructure

: Linking the meaning of the message to the message of the power grid

3.1. ISO/IEC 15118 of Electric Vehicle Charging Infrastructure

IEC 61850-90-8 describes an information model for information exchange between electric vehicles and the power grid.

The charging device and the power network use IEC 61850 communication protocol to exchange information. <Figure 5> shows representative IEC 61850 information models needed to build an electric vehicle charging system that supports IEC 61850 communications. Most of the information models are defined in IEC 61850-7-420 and include DESE, DEEV, and DEOL Logical Nodes (LNs) newly added in IEC 61850-90-8 to transmit information collected from electric vehicles to the power grid.

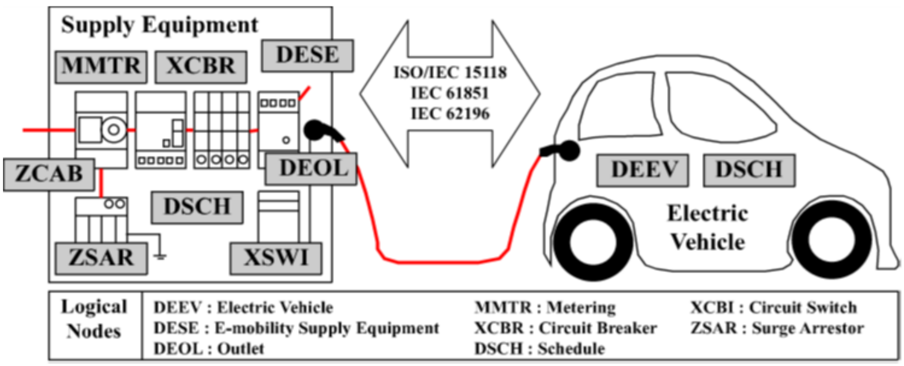


Figure 5: Linkage model of electric vehicle data in IEC 61850-90-8

DEEV (E-mobility Electric Vehicle) logical node. This data can be classified into descriptive information, status information, setting information, and measurement information.

Name information, such as a name, manufacturer, and product number, is included in the descriptive information. The status information includes connection type information is stored. The setting information includes the charging end time, the charging demand amount, the maximum voltage for use in an electric vehicle, the current and the minimum current information designated by the electric vehicle, and the layer information includes the current energy holding amount of the electric vehicle.

Table 3: Example of IEC 61850-90-8 Electric Vehicle Model (DEEV Logical Node)

DEEV Class (IEC 61850-90-8 Data Model)			
Type	**Data Name**	**Syntax**	**Description**
Description	EVNam	EV Nameplate	EV manufacturing information
Status Information	ConnTypSel	Connection Type	Connection type with EVSE 1: DC 2: Single-phase 3: Two-phase 4: Three-phase
Status Settings	DptTm	Departure Time	Charging end time specified by electric car
	EnAmnt	Amount of Energy	Charged amount requested by electric car
	VMax	Maximum Voltage	Maximum allowable voltage of EV per phase
	AMax	Maximum Current	Maximum acceptable current of EV per phase
	AMin	Minimum Current	Minimum acceptable current of EV per phase
Measured and Metered Values	Soc	State of charge	Current energy amount

As shown in table 3, the IEC 61850 standard requires a gateway model to link the IEC 15118 data model and communication messages of the electric vehicle with IEC 61850 because the expansion of the electric vehicle charging infrastructure has been extended to use it as a distributed power source.These data items are used to exchange messages according to the use case of ISO/IEC 15118 and are provided to the grid using the ASCI service specified in IEC 61850-7-2.

To define the data model, an abstract model can be designed to represent the constituent devices of an electric vehicle. A logical node (LN) of an electric vehicle should be able to represent all attributes and data, and exchange information using this logical node.

The data model of the electric vehicle IEC 61850-90-8 uses the System Configuration Description Language (SCL).

SCL is based on XML and is defined in substation standard IEC 61850. The SCL configuration provides communication synchronization between the systems of the EV charging infrastructure by defining the functions and data of IED (Intelligent Electronic Device), electric vehicle and charger, and configuring various parameters necessary for communication.

[Table 4] is examples in which the data model of electric vehicle charger and electric vehicle is composed of SCL, and the detail object of each logical node is declared as DEEV_TYPE. This DEEV_TYPE declares the detailed data attributes of the LN in the *DataTemplate* of the SCL, and the Common Data Class (CDC) and Data Types of these Data Attributes are defined in IEC 61850 hierarchy. In the above table, only the LN is represented, but the *DataTemplate* is defined in the same hierarchical manner.

In this way, each LN_Type is declared, data of each LN is defined, and the data type is declared again, so that an electric vehicle charging infrastructure model can be created and used for communication with an XML-based configuration file.

Using the SCL representing the electric vehicle model, the EV charger can construct a data model for transferring data to an IEC 61850-based management system such as SCADA. IEC 61850 communication stack can be used to create an electric vehicle and charging station object made of SCL and to transmit data.

In the data transmission part of the EV charging infrastructure, the IEC 61850 message is transmitted using the SCL in which the data of the charging infrastructure of the EV is defined in order to link the data with the power network. Since the data receiving part of the power network sends data to the electric vehicle charging infrastructure through the IEC 61850 protocol, it can receive the data by parsing the message if it has only the data structure of electric vehicle charging infrastructure (SCL).

Table 4: Example of SCL setting for electric vehicle and charger data model

System Configuration Description Language (Station)		**System Configuration Description Language (Vehicle)**
<?xml version="1.0" encoding="utf-8"?> <IED name="EVSE_01"> <LDevicedesc="EVSE01" inst="LDEVSE01"> <LN lnClass="LPHD" inst="1" lnType="LPHD_TYPE_0" /> <LN lnClass="DESE" inst="1" lnType="DESE_TYPE" /> <LN lnClass="DEOL" inst="1" lnType="DEOL_TYPE" /> <LN lnClass="DSCH" inst="1" lnType="DSCH_TYPE" /> <LN lnClass="XCBR" inst="1" lnType="XCBR_TYPE" /> <LN lnClass="XSWI" inst="1" lnType="XSWI_TYPE" /> <LN lnClass="MMTR" inst="1" lnType="MMTR_TYPE" /> <LN lnClass="ZSAR" inst="1" lnType="ZSAR_TYPE" /> <LN lnClass="ZCAR" inst="1" lnType="ZCAR_TYPE" /> </LDevice> **</IED>**		<?xml version="1.0" encoding="utf-8"?> <IED name="EV_01"> <LDevicedesc="EV 01" inst="LDEV01"> <LN lnClass="LPHD" inst="1" lnType="LPHD_TYPE_0" /> <LN lnClass="DEEV" inst="1" lnType="DEEV_TYPE" /> <LN lnClass="DSCH" inst="1" lnType="DSCH_TYPE" /> </LDevice> **</IED>**

3.2. Linking the Message of Electric Vehicle Charging Infrastructure

IEC 61850 communication from the electric vehicle charging infrastructure to transmit the data of the electric vehicle charging infrastructure ISO/IEC 15118, and receive the message of the electric vehicle charging infrastructure in the electric power network and receive the data. We have built a communication data model between the electric vehicle charging infrastructure and the power grid, and now we have to map the data to convey the meaning of the data. Electric Vehicle Charging Infrastructure Data mapping is needed to use the transmitted messages in the power network service. It is necessary to convert the data transmitted through the ISO/IEC 15118 message to the information of IEC 61850 in order to transmit it to the power network using the IEC 61850-based information model. Table 1 in section 2.1 above summarizes the V2G messages of ISO/IEC 15118 exchanged between electric vehicles and chargers according to use cases. Most of the V2G messages are intended to exchange status and configuration information between an electric vehicle and a charging device for charging and discharging an electric vehicle, but also include information to be transmitted to the power network during the V2G messages of ISO/IEC 15118.Typically, charge details and payment information of the electric vehicle, and user authentication data [11] have such a characteristic.

Table 5: DEEV Logical Node and ISO / IEC 15118 Message Mapping in IEC 61980-90-8

ISO/IEC 15118		IEC 61850-90-8	
V2G Message	Element	Logical Node	Data Object
SessionSetup	EVCCID	DEEV	EVNam
ChargeParameterDiscoveryReq	RequestedEnergyTransferMode		ConnTypSEl
	DepartureTime		DptTm
	EAmount		EnAmnt
	EVMaxVoltage		VMax
	EVMaxCurrent		AMax
	EVMinCurrent		AMin
CurrentDemand	EVStatus->EVRESSSOC		Soc

In order to transfer the collected information from the electric vehicle to the power network via the charging device, the corresponding data is extracted from the ISO/IEC 15118 message and mapped to the IEC 61850 information model of the same meaning, and the mapped logical node data is IEC 61850-7-2 And is provided to the power grid using the ASCI service specified in FIG.

Table 5 maps the data of the DEEV logical node of IEC 61850-90-8 from the V2G message of ISO/IEC 15118. For example, in the mapping of the *CurrentDemand* message to the SoC data, the electric vehicle proceeds charging and transmits a *CurrentDemand* message to the electric vehicle charger while energy is supplied to periodically notify the current charging status (EVRESSSOC). Also, the charger can transmit the current charge amount (SoC) transmitted to the electric vehicle to the electric power system to analyze the current state and to estimate the charge.In this way, the data model of IEC 61850-90-8 and the message of ISO/IEC 15118 can be mapped.

4. Conclusion

ISO/IEC 15118 is a standard for communications and services for electric vehicle charging infrastructure. Although this standard deals only with data communication between an electric vehicle and an electric vehicle charger, communication with the outside is essential for establishing an authentication system for vehicle certification and V2G service for electric power transmission.It is designed to verify the information of electric vehicle charging infrastructure in electric power system through communication link of ISO/IEC 15118 electric vehicle model and IEC 61850 standard MMS protocol. This can be used not only in electric vehicles but also in other distributed power sources as element technology in the future.

In this study, the data model of the charging infrastructure of the electric vehicle was accepted. However, even if it is necessary to communicate with other distributed power facilities, it can be utilized as a method for collecting data of various environments using XML based data model and message linkage. In addition, IEC 61850 has been conducting a lot of studies in connection with various protocols of industry such as OPC UA.We can expect additional services using communication interoperability with other industries through connection with electric vehicle charging infrastructure and IEC 61850 communication protocol.

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