

A Development of Mirroring for PLC Communication Data Verification

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Summary

EV(Electric Vehicle) has been developed has been developed in the form of a next generation power control(Smart Grid) through V2G(Vehicle to Grid) communication as a green vehicle using electrical energy. Charging control between the EV and EVSE(Electric Vehicle Supply Equipment) is using a PLC-based V2G communication protocol.

This paper proposes an evaluation method for real-time root cause analysis is possible, and verification of data reliability in the application layer from the physical layer to the problems that occur during the charging control using PLC communication between the EV and EVSE.

Keywords: Power Line Communication, Mirroring, Ethernet Packet Monitoring

1 Introduction

The automotive market is proceeding research for electric vehicle (EV) and a hybrid electric vehicle (HEV) cars for reduce the use of fossil fuels due to concerns about environmental pollution caused by steadily increasing gasoline prices and using fossil fuel.

Eco-friendly car that using electric energy an EV has been advancing in a way connected with a next generation power control(Smart Grid) through Vehicle to Grid (V2G) communication.

Charging control between the EV and Electric Vehicle Supply Equipment (EVSE) is using protocol of V2G communication based on a Power-line communication (PLC).

PLC is a communication protocol that uses electrical wiring to simultaneously carry both data, and Alternating Current (AC) electric power transmission or electric power distribution. This technique is capable of data communication via the existing power line installed in a home network-based digital communication technologies. Also a home network (Home Network) construction and industrial applications (car etc.) can be utilized even. Moreover, it is possible to transfer data, such as billing settlement and information about billing when charging the electric car.

EV is operated supplied the electric energy from EVSE through the charging cable by using the electric energy stored in the battery. In addition, it is the charge control and the PLC communication via the communication interface based V2G. However, it is difficult according to charging various environments and increasing time spent on analysis of cause-related problems due to limitations and needs assessment raw data obtained from monitoring chargers each manufacturer.

. In this study, we developed this evaluation efficiently as possible in the vehicle cause analysis steps for problems that occur during charging control using PLC communication between EV and EVSE. Through the above method it was analyzed and improve the problems that occur when a car test.

2 Main subject

2.1 Configuration of charging system

Today, charging mode of electric vehicle is fast charging mode of CCS type. The purpose of PLC communication dedicated gateway is data transfer about PLC communication information of charging system and in-vehicle high speed CAN communication information during fast charging of electric vehicles. Figure 1. shows charging layout of DC Combo (CCS) type between the electric vehicle and charger.

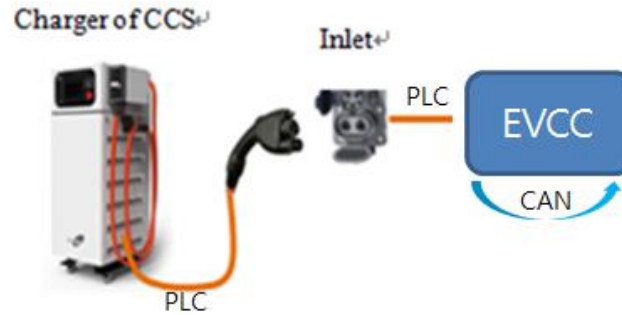


Figure 1: Layout of DC Combo(CCS) charging type

Key data between the vehicle and the charger using the PLC communication is as Table.1.

Table1: Items of the main transit data

Classification	Items of transmit data
Car/Charger	Charger/information of Car condition (Emergency Stop, Fail-Safe ...)
Additional Service	Certification : Driver, Car, Charger
Relation with charging	Possibility of charging, Current/Voltage, Remaining time

PLC-based charging communication sequence is as Table.2.

Table2: Charging sequence based PLC communication

Classification	Contents
Connection of Charging cable	User : Connection between the Car and the Charger by cable.
SLAC	Attenuation level measured for determining the charger
Set up of Logical Network	Setup of Logical Network (Car ↔ Charger)
IP Address assignment	IP Address assignment of the EV communication Controller
SDP	Get port number and IP address of SECC
TCP connection	Connection between EVCC and SECC
Session V2G	V2G communication step in the form of XML (using the EXI)
Finish of TCP Session	Finish of TCP Session
Remove cable	Removing cable of charging.

2.2 PLC (Power Line Communication) communication

The main purpose of implementing the PLC communication is based on XML-EXI received from the PLC node (charger internal communications controller, SECC) of the PLC node (electric communication controller, EVCC) charger (EVSE) using a PLC network in the electric vehicle (EV) those of the data through the vehicle network to transfer to a specific ECU (such as BMS) is intended to reconstruct the data transmitted through the network from a certain vehicle ECU back to the XML-based data transmission of the EXI through the PLC network. Send and receive data via this process is used for the control between the charging charger for supplying a particular ECU to the actual power of the vehicle interior.)

2.2.1 PLC (Power Line Communication) communication layer

OSI (Open System Interconnection) model is a model developed by the International Organization for Standardization (ISO), it is described by dividing the communications and computer network protocol design as a layer. Each layer provides a function to the upper layer by using only the function of the lower layer. The physical layer supports HPGP, and the data link supports the IEEE 802.3 Ethernet, PLC MAC Layer. The network layer protocol support IPv6, TCP, UDP, compatibility with IPv4, the presentation layer support charging protocol using XML and EXI. The application layer supports the message type defined in the ISO / IEC 15118-2. Layer used for PLC communication is defined as Table.3.

Table2: Contents of Layer – OSI 7 Layer

Classification	Contents
Physical Layer	Transmission and reception of raw bit streams over a physical medium
Data link Layer	Reliable transmission of data frames between two nodes connected by a physical layer
Network Layer	Structuring and managing a multi-node network, including addressing, routing and traffic control
Transport Layer	Reliable transmission of data segments between points on a network, including segmentation, acknowledgement and multiplexing
Session Layer	Managing communication sessions, i.e. continuous exchange of information in the form of multiple back-and-forth transmissions between two nodes
Presentation Layer	Translation of data between a networking service and an application; including character encoding, data compression and encryption/decryption
Application Layer	High-level APIs, including resource sharing, remote file access, directory services and virtual terminals

As it is shown in Table.3 and standardize the requirements for the network and application protocols. A flow of the charge control applied to PLC communication can be represented as Figure.2. Information on the PLC communication protocol stack in Figure.2 can be expressed in the OSI 7-layer model.

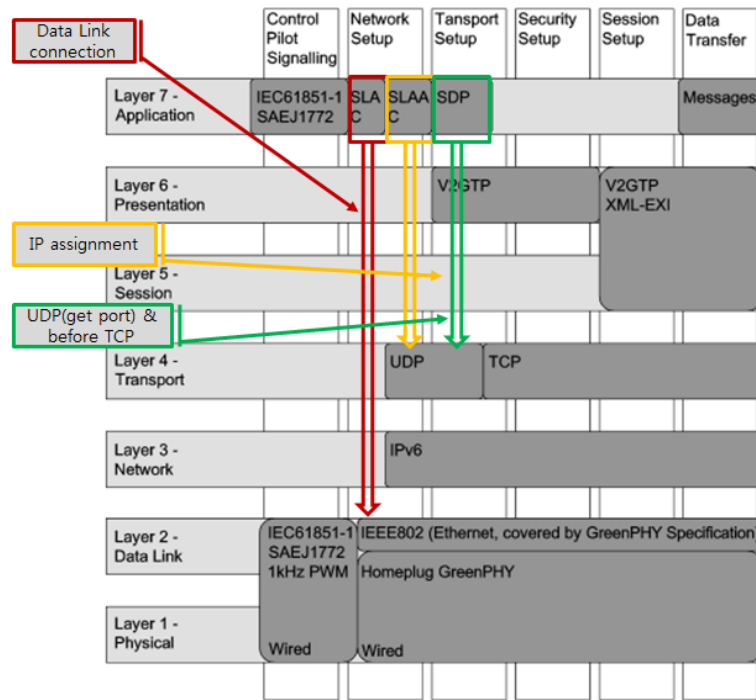


Figure 2: Stack of PLC protocol (based OSI model)

2.2.2 V2G(Vehicle To Grid) Messages

The V2G message uses the XML-EXI based model of the application layer. Communication of application layer between the communication controller of EV and the communication controller of the electric charger is based on a client / server architecture.

Chargers communication controller in the charging process will always act as a server, and electric communication controller is always the client.

Therefore, electric communication controller starts the communication by sending a request message to the communication controller charger.

V2G communication is composed of two different sets of messages. V2G message structure is shown in Figure 3.

- Handshake message of V2G Application Protocol (supportedAppProtocol)
- Message of V2G Application Layer (SessionSetup ...other messages)

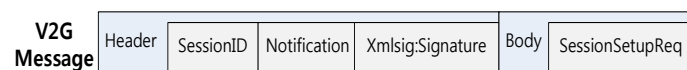


Figure 3: Structure of V2G Message

2.3 Developed contents for test of the real car

We analyze data through the ethernet module in the CCM controller of the vehicle.

It verifies the integrity for the messages (SLAC and V2G) which are sent and received by the controller CCM. Test structure is shown in Figure 3.

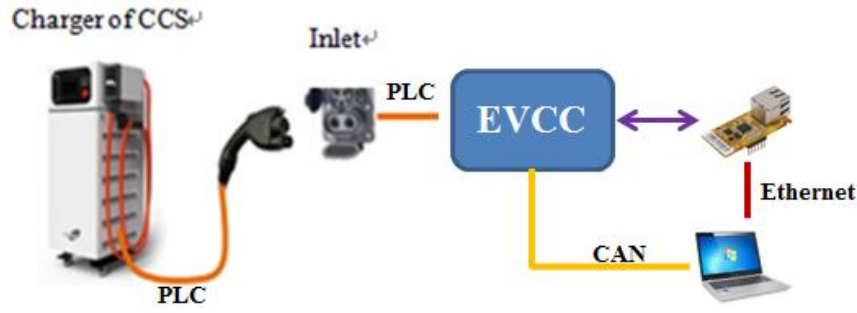


Figure 4: Toolkit composition for Data monitoring

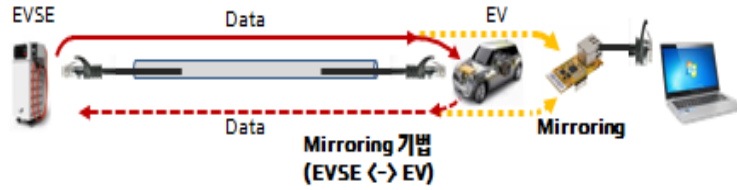


Figure 5: Mirroring organization

Vehicle Assessment screen, applying the techniques of the above test tool is as Figure 6.

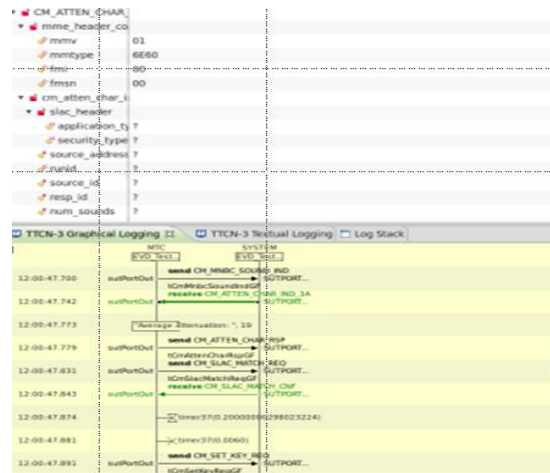


Figure 6: Data analysis methods applied to mirroring

2.3.1 Test items and Methods

We defined test items and methods targeting real AE EV vehicle using the above Mirroring evaluation technique, and verify the results.

- 1) Lay-out and wiring inspection: We checked interference with other unit, durability, application of the measures against noise, application of waterproof connector, possibility of erroneous connection with reference drawing.
- 2) PLC communication message integrity: We checked connection of the charger and charging sequence-specific message integrity in charged state.
 - ① SLAC integrity: We checked the signal attenuation level between chargers and number of transmissions.

1) SLAC Integrity

Part	Message	Description	Standard(DIN/ISO)	Result
SLAC	Common	Packet Length	Min, 60Bytes	PASS
	CM_MNBC_SOUND.IND	Sounding Count	10	PASS
	CM_START_ATTEN_CHAR.IN	Send Count	3	PASS
	CM_ATT_N_CHAR.IND	Attenuation Level	-	-

Figure 7: Results of the message integrity (SLAC part)

- ② IPv6 address assignment (SLACC): We checked the message transmission / reception procedure of the electric vehicle communication controller (EVCC) and IP assignment as the following sequence.
- ③ SDP integrity: We checked transmission messages of EVCC, IP address of SECC and port number response messages.

2) SECC Discovery(UDP) Integrity

Sequence (UDP)	Message	Type	Byte No.	Standard(DIN/ISO)	Result	Etc.
SECC Discovery Request	Header	Protocol Version	1	0x01	OK	V2G TP version 1
		Inverse Protocol Version	2	0xFE	OK	V2G TP version 1 (Inverse Protocol)
		Payload Type	3,4	0x9000	OK	SDP Request
		Payload Length	5,6,7,8	0x0000 0002	OK	-
	Payload	Security	9	0x10	OK	TLS -> Not used
		Transport protocol	10	0x00	OK	TCP
		IP (Source)	-	FE80 ~	OK	-
	IP/Port	IP (Destination)	-	FF02::1	OK	Multicast
		Port (Source)	-	49152 ~ 65535 (=C000 ~ FFFF)	OK	Dynamic Range
		Port (Destination)	-	15118 (=0x3B0E)	OK	-
SECC Discovery Response	Header	Protocol Version	1	0x01	OK	V2G TP version 1
		Inverse Protocol Version	2	0xFE	OK	V2G TP version 1 (Inverse Protocol)
		Payload Type	3,4	0x9001	OK	SDP Response
		Payload Length	5,6,7,8	0x0000 0014	OK	-
	Payload	IP (Source)	9 ~ 24	FE80 ~	OK	-
		Port (Source)	25, 26	49152 ~ 65535 (=C000 ~ FFFF)	OK	Static
		Security	27	0x10	OK	TLS -> Not used
		Transport protocol	28	0x00	OK	TCP

Figure 8: Results of the message integrity (SDP part)

- ④ V2G message integrity: We set up V2G communication session and checked V2G message request/response steps between EVCC and SECC in a predetermined sequence.

3. V2G Integrity

Sequence (V2G)	Message	Type	Byte No.	Standard(DIN/ISO)	Result_String	Result
Charge Parameter Discovery REQ	Payload	EV Ready	-	EV Ready = "False"	EV Ready = "False"	OK
		EVError_Code	-	EVError_Code = "NO_ERROR"	EVError_Code = "NO_ERROR"	OK
Charge Parameter Discovery RES		EVSEProcessing	-	EVSEProcessing = "Finished"	EVSEProcessing = "Finished"	OK
		EVSE Status Code	-	EVSE Status Code = "EVSE NotReady"	EVSE Status Code = "EVSE NotReady"	OK
Cable Check REQ	Payload	EV Ready	-	EV Ready = "True"	EV Ready = "True"	OK
Cable Check RES		EVSE Status Code	-	EVSE Status Code = "EVSE Ready"	EVSE Status Code = "EVSE Ready"	OK
		EVSEProcessing	-	EVSEProcessing = "Ongoing" EVSEProcessing = "Finished"	EVSEProcessing = "Ongoing" EVSEProcessing = "Finished"	OK
Precharge REQ	Payload	EV Ready	-	EV Ready = "True"	EV Ready = "True"	OK
Precharge RES		EVSE Status Code	-	EVSE Status Code = "EVSE Ready"	EVSE Status Code = "EVSE Ready"	OK

Figure 9: Results of the message integrity (V2G part)

3) PLC communication timing integrity (SLAC, V2G):

Check for timing of PLC communication messages each charging sequence in connection of the charger and status of charging in the real car. Measurement method is the same as integrity technique of the PLC communication message.

- ① Check the timing and other details of the figure transmit / receive messages for the sequence to proceed the SLAC.

1) Sequence 8|| Timing

Sequence	Message	Recv,Message	Standard(DIN/ISO)	Result	Etc,
SLAC	CM_SLAC_PARM,REQ	-	400 ms	OK	① TT_match_response
	-	CM_SLAC_PARM,CNF			
	CM_START_ATTEN_CHAR,IND	-	100 ms	OK	② TP_match_sequence
	CM_START_ATTEN_CHAR,IND	-	50 ms	OK	④ TP_EV_batch_msg_interval
	CM_START_ATTEN_CHAR,IND	-	50 ms	OK	
	CM_MNBC_SOUND,IND	-	50 ms	OK	⑤ TP_EV_batch_msg_interval
	CM_MNBC_SOUND,IND	-	50 ms	OK	⑥ TP_EV_batch_msg_interval
	CM_MNBC_SOUND,IND	-	50 ms	OK	⑦ TP_EV_batch_msg_interval
	CM_MNBC_SOUND,IND	-	50 ms	OK	⑧ TP_EV_batch_msg_interval
	CM_MNBC_SOUND,IND	-	50 ms	OK	⑨ TP_EV_batch_msg_interval
	CM_MNBC_SOUND,IND	-	50 ms	OK	⑩ TP_EV_batch_msg_interval
	CM_MNBC_SOUND,IND	-	50 ms	OK	⑪ TP_EV_batch_msg_interval
	CM_MNBC_SOUND,IND	-	50 ms	OK	⑫ TP_EV_batch_msg_interval
	CM_MNBC_SOUND,IND	-	50 ms	OK	⑬ TP_EV_batch_msg_interval
	CM_MNBC_SOUND,IND	-	50 ms	OK	⑭ TP_EV_batch_msg_interval
	CM_MNBC_SOUND,IND	-	50 ms	OK	⑮ TP_EV_batch_msg_interval
	-	CM_ATTEN_CHAR,IND	1200 ms	OK	⑯ TT_EV_atten_results
	CM_ATTEN_CHAR,RSP	-	100 ms	OK	⑰ TP_match_sequence
	CM_SLAC_MATCH,REQ	-	500 ms	OK	⑱ TP_EV_match_session
	-	CM_SLAC_MATCH,CNF	400 ms	OK	⑲ TT_match_response

Figure 10: Timing integrity results of charging sequence (SLAC part)

- ② Check send/receive timing of the V2G message the between the EV and communication controller of charger.

2) Sequence 8|| Message Timing (V2G_EVCC_MSG_Time)

Sequence	Send Message	Recv, Message	Standard (DIN/ISO)	Result
TCP	Supported App Protocol REQ	-	4 (2)	OK
	-	Supported App Protocol RES		
	Session Setup REQ	-	4 (2)	OK
	-	Session Setup RES		
	Service Discovery REQ	-	4 (2)	OK
	-	Service Discovery RES		
	Service & Payment REQ	-	4 (2)	OK
	-	Service & Payment RES		
	Contract Autentication REQ	-	4 (2)	OK
	-	Contract Autentication RES		
	Charge Parameter Discovery REQ	-	4 (2)	OK
	-	Charge Parameter Discovery RES		
	CP State = 'C' (6V)		-	-
	Cable Check REQ	-	4 (2)	OK
	-	Cable Check RES		
	Precharge REQ	-	4 (2)	OK
	-	Precharge RES		
	Power Delivery REQ	-	10 (2)	OK
	-	Power Delivery RES		
	Current Demand REQ	-	0,5 (0,25)	OK
	-	Current Demand RES		
	CP State = 'B' (9V)		-	-
	Welding Detection REQ	-	4 (2)	OK
	-	Welding Detection RES		
	Session Stop REQ	-	4 (2)	OK
	-	Session Stop RES		

Figure 11: Timing integrity results of charging sequence (V2G part)

- 4) Cooperative control communication consistency of the charging sequence: Check about each cooperative control and consistency of high-speed CAN communications whether is made in controller PLC, BMS, OBC. It does do monitoring about synchronization of high speed CAN data and PLC communication in the car through method of data mirroring.

- ① Check the PWM duty ratio of the PLC communicate data corresponding to the charging sequence and the CP line.
- ② Check that the PLC controller sends a message corresponding to the sequence and is the appropriate high-speed CAN data conversion well.
- ③ Check whether is made in collaboration between the PLC and BMS, OBC.
- ④ After charging is complete, check the trouble code stored in the PLC controller.

3 Conclusions

In this study, we made the following effects and conclusions it is reducing the time required for problem analysis because of the limited monitoring of the network connection step, when tests with the charger of abroad for analysis of problem efficiently by Ethernet raw data.

1) PLC communication Mirroring techniques is ensure the reliability of data in a vehicle equipped with a controller of the PLC-based communication and reducing the data analysis time and for improving the early problems ensuring the quality.

2) It is possible to find an error in accordance with a variety of test environment and method in advance through the Raw data obtained between the charger and the vehicle of each manufacturer.

3) It can be performed suitability test tasks to set up systematically how to check whether suitability in the real car only in vehicle electrical performance of PLC communication gateway.

4) It is possible to share with overseas companies improved information of the problems if it set up the evaluation method.

5) We can obtain the evaluation expertise and ability through the Ethernet analysis Raw data of PLC communication controller.

6) It is possible to analyzing data of error through data integrity verification of the charge sequence.

7) It is possible to reduce prepare time of evaluation by set up of this study.

8) It can be compared with competitors through a common data analysis and the results of the evaluation of the company.

9) Mirroring PLC communication technique has a great advantage significantly reducing the trial and error, can confirm the reliability of data, is possible to shorten the preparation time of evaluation, and obtained the error data.

References

- [1] "Road vehicles – Vehicle to grid communication interface – Part 1: General information and use-case definition", ISO/IEC TC22 SC03 JWG1, 2013.
- [2] "Road vehicles – Vehicle to grid communication interface – Part 2: Network and application protocol requirements", ISO/IEC TC22 SC03 JWG1, 2014.
- [3] *HomePlug Green PHY Specification, Release Version 1.1, 04 September 2012.*
- [4] Interference Analyses of Electric Vehicle Charging Using PLC on the Control Pilot, Christian Lewandowski, Sven Gröning, Jens Schmutzler, Christian Wietfeld, ISPCA2012, June 2012.
- [5] DIN SPEC 70121 Release, December 2014.
- [6] SAE J2931/4, October 2014.

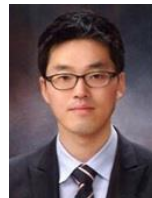
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