2022 IEEE North Karnataka Subsection Flagship International Conference (NKCon)

Development of Communication Simulator for Electric Vehicle Charging following ISO 15118

Madhusudhanan S
Department of Electrical and Electronics Engineering
Amrita School of Engineering
Amrita Vishwa Vidyapeetham
Coimbatore, India
madhusudhanan0407@gmail.com

Sivraj P.
Department of Electrical and Electronics Engineering
Amrita School of Engineering
Amrita Vishwa Vidyapeetham
Coimbatore, India
p_sivraj@cb.amrita.edu

***Abstract*— Electric Vehicles (EV) are set to become the mainstream automotive option, as they minimize the dependence on conventional fuels and decrease carbon footprint. Well-defined communication process among EV, Electric Vehicle Supply Equipment (EVSE) and Central Management System (CMS) is important for smooth, effective and reliable charging of an EV. This paper presents the development of a software-based simulator for EV–EVSE–CMS communication. Message exchange between EV and EVSE is implemented following ISO 15118 over Power-Line Communication (PLC). The EVSE-CMS communication is implemented over Ethernet following Open Charge Point Protocol (OCPP). Both these implementations are done using functionalities of various toolboxes and systems in MATLAB and Simulink. An interactive simulator is created by developing a Graphical User Interface (GUI) which mimics EV, EVSE and CMS in MATLAB. In addition to understanding the message sequence during EV charging, the simulator can also be used as a teaching tool for ISO 15118 and OCPP. The simulator can be further enhanced by implementing message exchange using other charging protocols such as CHAdeMO, GB/T, Open Charge Point Interface (OCPI), Open Automated Demand Response (OpenADR), etc. using various wireless and wired communication technologies.**

Keywords— EV, EVSE, CMS, ISO 15118, OCPP

I. INTRODUCTION

Automotive industry is gradually moving towards adoption of Electric Vehicle (EV) as mainstream automotive option over conventional fuel powered vehicles. This shift has become need of the hour, in order to combat global warming and environmental degradation [1]. Various countries have taken numerous initiatives to accelerate the usage of EVs. Indian government has introduced Faster Adoption and Manufacturing of Electric Vehicles (FAME) scheme through which incentives would be given on purchase of new electric vehicles. It is projected that 30% of vehicles in India would be electrical by 2030 [2].

Widespread use of EVs could not be seen in last decade, even though EVs have significant advantage over conventional fuel powered vehicles. Major factors that slow down the proliferation of electric vehicle include inadequate electric vehicle charging infrastructure, less driving range and larger charging time [3]. Number of charging stations are gradually being increased to facilitate the charging of EV, globally. DC fast charging technology has reduced the charging time drastically [4].

Charging infrastructure involves communication between EV, Electric Vehicle Supply Equipment (EVSE) and Central Management System (CMS) for effective operation and maintenance [5]. CHAdeMO, GB/T and Combined Charging System (CCS) are the three widely accepted standards for communication between EV and EVSE [5]. CHAdeMO is a fast charging standard that is widely adopted by Japanese automobile manufacturers. GB/T is Chinese national standard, defining communication between EV and EVSE [6]. CCS has adopted ISO 15118 standard for supporting high level communication between EV and EVSE. It has been widely adopted by European automobile manufacturers [7]. Open Charge Point Protocol (OCPP) is an open communication standard that enables communication between EVSE and CMS from different vendors, resulting in interoperability [8] [9].

This paper presents development and implementation of a software-based simulator for EV-EVSE-CMS communication. The work includes implementation of ISO 15118 message exchange between EV and EVSE over PLC and OCPP message exchange between EVSE and CMS over Ethernet in MATLAB and Simulink. EVSE-CMS communication is implemented using Transmission Control/ Internet Protocol (TCP/IP) over Ethernet. User can simulate the message sequence in the setup as in true scenario for various operational conditions of a vehicle charging process.

In this article, section two discusses related work. Third section deals with the system considered for simulator. Fourth and fifth section explains the implementation of EV-EVSE and EVSE-CMS communication, respectively. Section six deals with GUI developed as part of the simulator. Section seven concludes the work.

II. LITERATURE SURVEY

International communication standards enable safe, reliable and structured EV-EVSE communication. CHAdeMO, GB/T and ISO 15118 are compared based on various parameters such as compliance to CAN, connector cost, supported charging modes, additional controller cost, etc. and GB/T scored more than the other two protocols [10]. An

978-1-6654-9790-9/22/$31.00 ©2022 IEEE

2022 IEEE North Karnataka Subsection Flagship International Conference (NKCon) | 978-1-6654-5342-4/22/$31.00 ©2022 IEEE | DOI: 10.1109/NKCON56289.2022.10126833

existing EV can be enabled to feed electrical energy back into the grid using Vehicle CHAdeMO interface (VCI) [11]. Dynamic charging of EV was implemented using solar powered bidirectional EV charger, compatible with CCS and CHAdeMO protocol [12].

A complete overview of features and functionalities provided by ISO 15118 is explained in detail [13] [14]. A test system for communication between EV and charging station has been developed based on ISO 15118 [15]. ISO 15118 also facilitates reverse power transfer and wireless communication [16]. A prototype for wireless V2G communication for conductive charging was implemented based on ISO 15118 [17]. Security assessment of EV smart charging system reveals several vulnerabilities present in this system [18]. Use cases, messages and security issues, found in ISO 15118 standard were analyzed and counter measures for security vulnerabilities were proposed [19].

A smart management system has been implemented using OCPP in a smart city named as Secure Electric Vehicle Charging Ecosystem in Smart Grid (SecCharge). This system reduces charging time and manages power fluctuations in smart grid [20]. OCPP is enhanced through addition of reservation phase which enables user to reserve a charging station and negotiate various parameters of a charging session such as duration, price, power required, etc. [21].

A hardware-based communication test-bed for EV charging infrastructure based on GB/T has been developed [22]. Communication test-bed consisting of software and hardware modules was developed and implemented based on CHAdeMO protocol [23]. Software-based simulator for EV-EVSE-CMS communication has been developed and implemented, involving EV-EVSE communication based on GB/T and EVSE-CMS communication based on OCPP [24].

It is evident from the literature survey that the deployment and operation of charging infrastructure involves EV-EVSE-CMS communication. Research work on development of simulators for communication standards have been limited. Most of the available simulators are hardware-based and their work on EV-EVSE-CMS communication is also limited. Software simulators provides more flexibility for addition of newer functionalities and enables smooth integration of different technologies. A software-based simulator with features, necessary to perform both EV-EVSE and EVSE-CMS operations would be more helpful in understanding these communications.

III. PROPOSED METHOD

The charging system under consideration consists of modules that mimic the communication capabilities of EV, EVSE and CMS. EV module communicates with EVSE over PLC following ISO 15118. Also, the EVSE module communicates with CMS module over Ethernet following OCPP, as shown in figure 1. Both these communications are implemented in MATLAB/Simulink.

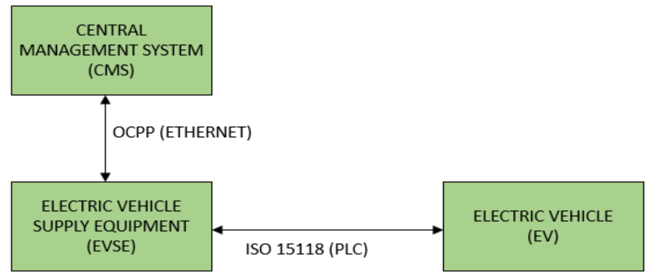

Fig. 1. Block Diagram of EV Charging Simulator

A. *EV-EVSE Communication*

ISO 15118 has adopted PLC for communication between EV and EVSE. PLC involves transmission of data on a conductor that is also used concurrently for transmission of electric power. PLC model in MATLAB/Simulink [25] has been modified through removal of bit rate checking module and noise generator module. This PLC is capable of 8-bit data transmission and reception The PLC Simulink block contains three components as shown in figure 2 [25]. It includes data generation, data transmission and data collection. In data generation block, a binary sequence is given as input. It is then modulated using Frequency-Shift Keying (FSK) modulation scheme. The modulated signal is combined with power line signal in data transmission block. The transmitted signal is filtered through the combination of high pass filter and low pass filter, in order to remove noise and harmonics. This signal is demodulated using FSK demodulation and the output signal is obtained in data collection block.

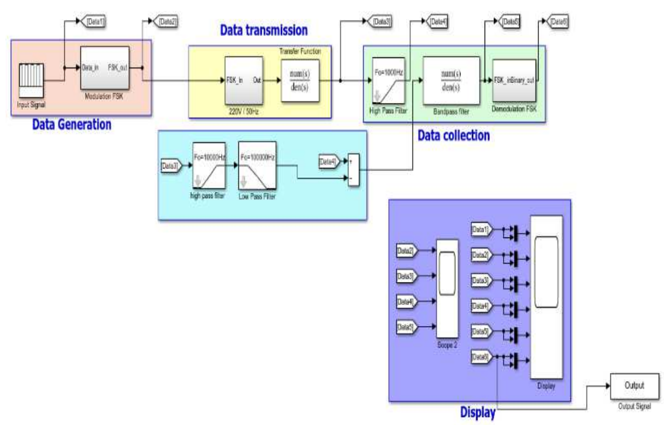

Fig. 2. Simulink Block of PLC in MATLAB

B. *EVSE-CMS Communication*

EVSE communicates with CMS over Ethernet following OCPP. The most recent release is OCPP 2.0.1. It defines various messages exchanged among EVSE and CMS, which are grouped under numerous functional blocks. The list of functional blocks and their operations, that have been implemented as part of this work has been shown in Table I.

TABLE I. OCPP FUNCTIONAL BLOCKS

Functional Block	**Operations**
Reservation	Reserve a Connector
Transactions	Start, Update and Stop Transactions
Authorization	Authorization using contract certificates
Smart Charging	Notify EV Charging Needs, Notify Central Charging Needs

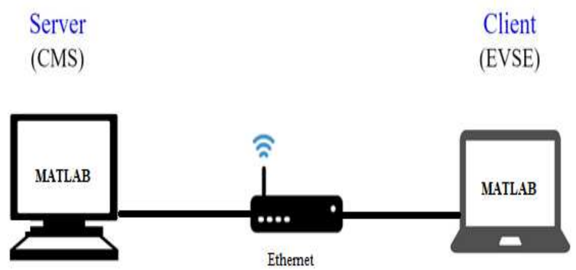

Fig. 3. Ethernet connection between Client and Server in MATLAB

EVSE-CMS message-exchange is executed as client-server model. MATLAB supports socket programming which can be implemented using '*tcp/ip'* function present in instrument control toolbox. The desktop computer has been configured as server and laptop as client as shown in figure 3.

C. *EV-EVSE-CMS Communication*

ISO 15118 adheres to request-response message sequence for message-exchange between EV and EVSE. EV always sends request message and EVSE replies with response message. Message sequence for an Alternate Current (AC) charging session has been implemented as part of this work.

The message sequence for ISO 15118 has been broadly divided into five stages such as communication setup, identification & authorization, target setting, charging loop and end of charging. Communication setup stage involves checking of compatibility of ISO 15118 versions present in EV and EVSE and assigning unique session ID for the session. In identification and authorization stage, EV receives information on the services offered by EVSE, selection of mode of payment and authorization of EV. ISO 15118 provides two mode of payment. They are External Identification Means (EIM) and Plug and Charge (PnC). In EIM, the EV user is required to do additional steps such as Quick Response (QR) code scanning, Radio-Frequency identification (RFID), etc. for authentication. PnC has been implemented as part of this work since it enables automatic authentication of EV through digital contract certificates installed in EV. Digital certificates ensure integrity of data through digital signatures. The energy requirement of incoming EV is exchanged with EVSE and charging process is started during target setting stage. The energy exchanged between EV and EVSE is monitored in charging loop and the communication session is terminated in end of charging stage.

Similarly, OCPP also involves request-response message pair. It consists of both EVSE initiated operations and CMS initiated operations. Here, based on the requirement, either EVSE or CMS would send request message and the other would provide response message. The message sequence for EV-EVSE-CMS communication starts with reservation of a connector at charging station, accompanied by charging process and updating CMS about different transactions, as shown in figure 4.

IV. IMPLEMENTATION OF EV-EVSE-CMS COMMUNICATION SIMULATOR

An 8-bit binary data level encoding has been adopted for transmission of messages between EV and EVSE over PLC. Each V2G message consists of a header and body. The header consists of session ID and the body contains actual message content. Similarly, each message of EVSE-CMS communication consists of different fields which are filled with their respective values following the format as specified in the OCPP.

A Graphical User Interface (GUI) has been developed in MATLAB to make the simulator more interactive. 'Activate' button establishes TCP/IP connection between EVSE (laptop) and CMS (desktop computer) over Ethernet. The desktop computer acts as server and waits for connection from client. The laptop acts as client, creates a client interface and connects with server (desktop computer). This enables data exchange between server and client. The messages are exchanged between EVSE and CMS based on OCPP. The functional block to which each message-pair belongs and details about each message are displayed in dashboard.

Then 'START' button click in GUI resembles plugging of cable into EV. This initiates communication between EV and EVSE based on ISO 15118 over PLC as in real time. Normal workflow continues if no error occurs during charging process. User can select any error from dashboard to observe message exchange during error scenarios.

V. RESULTS AND DISCUSSION

The simulator is analysed during normal workflow of both ISO 15118 and OCPP message sequence and error scenarios of ISO 15118. The error conditions include sequence error, unknown session error, invalid service selection error and no-charge service error. The messages exchanged among EV-EVSE-CMS, total battery capacity of EV, requested energy by EV, status of contactor and the different stages of each message exchange are displayed on the dashboard. Figure 5 shows complete operation of simulator during normal workflow of EV-EVSE-CMS communication.

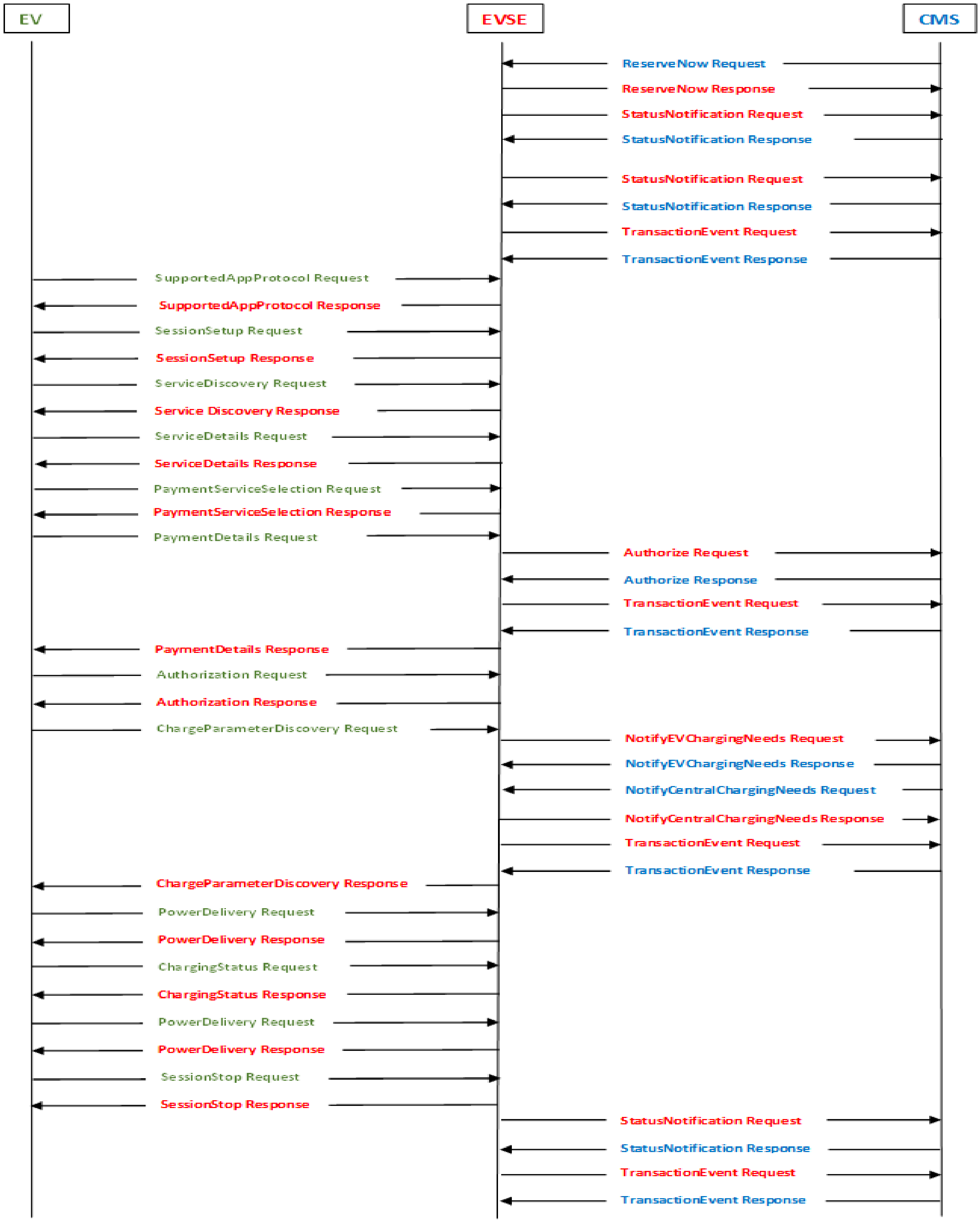

Fig. 4. Message Exchange during EV-EVSE-CMS Communication

Fig. 5. EV-EVSE-CMS Communication Simulator

```
supportedAppProtocol Request

    ProtocolNamespace : iso:15118:2:2013
    VersionNumberMajor : 2
    VersionNumberMinor:  0
    Schemaid : 20
    Priority : 1
--------------------------------------------

supportedAppProtocol Response
    ResponseCode : OK_SuccessfulNegotiation
    Schemaid : 20

--------------------------------------------
```

Fig. 6. EV-EVSE Message Exchange

The implementation of supportedAppProtocol request message and supporedAppProtocol response message, when an EV approaches EVSE for a new charging session is shown in figure 6. The request and response message-pair of TransactionEvent message, exchanged between EVSE and CMS following OCPP is shown in figure 7 and figure 8. Error sequences can be observed by clicking on corresponding radio button under error panel. Sequence error is shown in figure 9.

```
Functional Block: Transactions
Transaction Event Request

Function: Update Transaction
Transaction Event: Started
Date and time: 25-Jun-2022 11:22:22
Reason for Trigger: Cable Plugged-In
Sequence Number: 1
Transaction ID: 15

Transaction Event Request Completed
Waiting for response from Central Management System ......
```

Fig. 7. TransactionEventRequest Message

```
Functional Block: Transactions

Function: Start Transaction

Start Transaction Event Response
The Transaction has been started

Central Management System is Successfully informed

Start Transaction Event Response Completed
```

Fig. 8. TransactionEventResponse Message

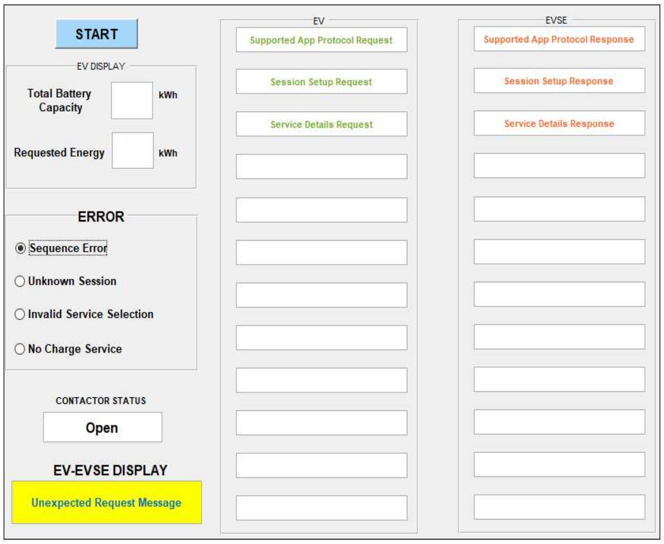

Fig. 9. Sequence Error in GUI

VI. CONCLUSION AND FUTURE SCOPE

An EV-EVSE-CMS communication is cornerstone of charging infrastructure. The paper presents a software-based simulator developed for EV-EVSE-CMS communication in MATLAB. Communication between EV and EVSE follows ISO 15118 standard implemented over PLC and communication between EVSE and CMS follows OCPP over Ethernet. This simulator can aid in academic and industrial training and facilitate the in-depth understanding of the message exchanges in these protocols.

This simulator can be enhanced through addition of wireless communication available in ISO 15118. Furthermore, this work can be extended through implementation of other protocols such as CHAdeMO, GB/T, Open Charge Point Interface (OCPI), Open Automated Demand Response (OpenADR), etc.

REFERENCES

[1] S. Chalia, A. K. Seth and M. Singh, "Electric Vehicle Charging Standards in India and Safety Consideration," 2021 IEEE 8th Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON), 2021, pp. 1-6.

[2] K. Sreeram, P. K. Preetha and P. Poornachandran, "Electric Vehicle Scenario in India: Roadmap,Challenges and Opportunities," 2019 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT), Coimbatore, India, 2019, pp. 1-7.

[3] Govindarasu and A. S. Venkatesh, "Electric Vehicle Vision 2030 Challenges and Solutions," 2019 IEEE Transportation Electrification Conference (ITEC-India), Bengaluru, India, 2019, pp. 1-3

[4] C. Suarez and W. Martinez, "Fast and Ultra-Fast Charging for Battery Electric Vehicles – A Review," 2019 IEEE Energy Conversion Congress and Exposition (ECCE), Baltimore, MD, USA, 2019, pp. 569-575.

[5] M.Parchomiuk, A.Moradewicz and H.Gawinski, " An Overview of Electric Vehicle Fast Charging Infrastructure", 2019 Progress in Applied Electrical Engineering (PAEE),pp. 1-6, 2019.

[6] M.Multin, "ISO 15118 as the Enabler of Vehicle-to-Grid Applications," 2018 International Conference of Electrical and Electronic Technologies for Automotive, 2018, pp. 1-6.

[7] "Open Charge Point Protocol 2.0.1", OCPP 2.0.1, March 2020.

[8] V. S. Gowri and P. Sivraj, " A Centralized Management System Software Framework to aid in EV Charging," 2019 4th International Conference on Recent Trends on Electronics, Information, Communication & Technology (RTEICT), Bangalore, India, 2019, pp. 500-504.

[9] A. Dhianeshwar, P. Kaur and S. Nagarajan, "EV: Communication Infrastructure Management System", First International Conference on Sustainable Green Buildings and Communities (SGBC), pp. 1-6, 2016.

[10] S. Rumale, H. A. Ashkar, T. Kerner, F. Koya and M. Eitzenberger, "Design and Implementation of an On-Board Vehicle CHAdeMO Interface for Vehicle-to-Grid Applications", 2020 IEEE International Conference on Power Electronics, Smart Grid and Renewable Energy (PESGRE2020), pp. 1-6, Jan. 2020

[11] G. R. C. Mouli, J. Schijffelen, M. V. D. Heuvel, M. Kardolus, and P. Bauer, "A 10 kW Solar-Powered Bidirectional EV Charger Compatible With Chademo and COMBO," IEEE Transactions on Power Electronics, vol. 34, no. 2, pp. 1082–1098, 2019.

[12] ISO 15118 – 2 Road Vehicles- Vehicle to Grid Communication Interface – Part 2: Network and application protocol requirements.

[13] A. Berrada, F. Annen, M. Gurcke and J. Haubrock, "Integrating electric vehicle communication in smart grids," 2021 IEEE Madrid PowerTech, 2021, pp. 1-5.

[14] M. A. Kippke, P. Arboleya and I. El Sayed, "Communication Infrastructure for E-Mobility Charging Stations V2G Applications," 2020 8th International Conference on Power Electronics Systems and Applications (PESA), 2020, pp. 1-3.

[15] N. -O. Song and B. -J. Kwak, "International Standard Trend of Vehicle to Grid (V2G) Communication Interface for Wireless Communication and RPT," 2019 IEEE Transportation Electrification Conference and Expo, Asia-Pacific (ITEC Asia-Pacific), 2019, pp. 1-5.

[16] N. E. Sayed, "A Prototypical Implementation of an ISO-15118-Based Wireless Vehicle to Grid Communication for Authentication over Decoupled Technologies," 2019 AEIT International Conference of Electrical and Electronic Technologies for Automotive (AEIT AUTOMOTIVE), 2019, pp. 1-6.

[17] J. Antoun, M. E. Kabir, B. Moussa, R. Atallah and C. Assi, "A Detailed Security Assessment of the EV Charging Ecosystem," in IEEE Network, vol. 34, no. 3, pp. 200-207, May/June 2020.

[18] S. Lee, Y. Park, H. Lim and T. Shon, "Study on Analysis of Security Vulnerabilities and Countermeasures in ISO/IEC 15118 Based Electric Vehicle Charging Technology," 2014 International Conference on IT Convergence and Security (ICITCS), 2014, pp. 1-4.

[19] B. Vaidya and H. T. Mouftah, "Deployment of Secure EV Charging System Using Open Charge Point Protocol," 2018 14th International Wireless Communications & Mobile Computing Conference (IWCMC), Limassol, 2018, pp. 922-927.

[20] S. Orcioni, L. Buccolini, A. Ricci and M. Conti, "Electric Vehicles Charging Reservation Based on OCPP," 2018 IEEE International Conference on Environment and Electrical Engineering and 2018 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe), Palermo, 2018, pp. 1-6.

[21] Lathika and S.Nithin, "Development of a Communication Test Bed for Electric Vehicle Charging", 2020 International Conference on Electronics and Sustainable Communication Systems (ICESC), pp. 1127–1130, 2020.

[22] L. M. Menon and S. Nithin, "Development of a communication simulator for Electric Vehicle charging based on GB/T," 2021 6th International Conference on Communication and Electronics Systems (ICCES), 2021, pp. 177-183.

[23] D. Anil and P. Sivraj, "Electric Vehicle Charging Communication Test-bed following CHAdeMO", 2020 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT), pp. 1-7, 2020.

[24] Tran Nguyen, "Power line communication", Available:https://in.mathworks.com/matlabcentral/fileexchange/30047-power-line-communication/. [Accessed 10 December 2021].