Chapter 10
Vehicle to Grid Technology

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1 Introduction

In the present world, the major requirements for higher productivity both in the area of industries and agriculture are needed for uninterrupted electricity. The electricity generally is generated by using fossil fuels and other alternatives are by solar, wind and nuclear energy. In India, the majority of electricity is produced by using hydropower, coal and nuclear power. There is a need for utilization of power as and when required. Whenever excessive power is generated, it is stored in the batteries but the biggest challenge is that it requires a huge number of batteries. To avoid this and to maintain the power supply whenever higher power demand is present, we can focus on vehicle to grid technology (V2G). The V2G technology utilises the energy stored in the battery which can be supplied to the grid and whenever required, it is possible to take the energy from the grid to charge the battery of the electric vehicle (EV). This concept will be realised by using plug-in electric vehicles. In the current scenario, every country's requirement is focused on reducing CO_2 emissions and the best alternative for reducing CO_2 emission is by promoting the usage of EV. Here, an attempt is made to highlight mainly on how effectively we can establish the V2G communication in EV. One of the major requirements for electrical engineering is the creation of grid technology which is smart. By creating an eco-friendly advanced grid technology, the economic growth of individuals and the nation as a whole can be enhanced. To make electrical energy mobility, we require a strong, safe, smart and intelligent communication between

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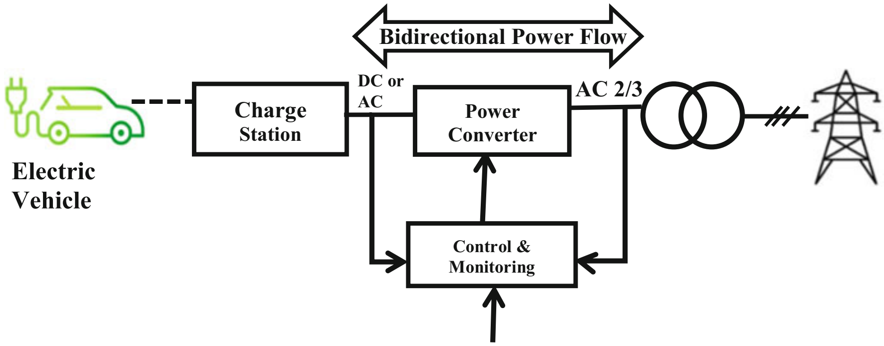

Fig. 10.1 Smart charging communication protocol

plug-in EV, charging station and the grid. It also needs a two-directional energy transfer between all of the three. All the stakeholders such as EV owners, EV manufacturers, power grid, charging stations, Government & private authorities, etc. should be defined with their roles to play with the understanding of the importance of communication and coordinated system operation. To realize all these and to have commonly accepted regulations, there is a need for standard communication models and protocols which will strengthen the application of V2G technology.

The manufacturers of the EV provide first information on availability of charging stations and charging process. But there is no communication available for the consumer and smart grid for charging in both directions. Presently, EV uses the smart connect technology which enables them to connect to charging stations and other utility services. There are no proper standards for V2G technology. Some of the standards are developed by automotive societies, manufacturers and service providers.

Fig. 10.1 outlines the general structure of V2G technology. The connection between charging stations, electric vehicles and grid is standardized by the International Electrotechnical Commission (IEC) 61851 and ISO 15118 [1].

The Society of Automobile Engineering (SAE), American National Standard Institute (ANSI), the International Electrotechnical Commission/International Standards Organization (IEC/ISO), National Institute of Standards and Technology (NIST) and several other industrial organizations are aiming towards the development of interoperability standards. On the basis of V2G communication interface standardization and study of the integration of the EV to grid, the V2G interface needs to be analysed. Along with all these, there is also a need for standardisation of the V2G interface and the structure of message patterns.

2 Vehicle to Grid Communication Flow Structure

V2G basically needs an effective two-way communication protocol, less time delay and higher reliability. The SAE J2931 under V2G facilitates the various stakeholders to communicate. The process is grouped into serially connected blocks as shown in the Fig. 10.2. The groups are Utility-Independent system operator (U-ISO) to Aggregator EV Service Provider (A-EVSP), A-EVSP to EV Supply Equipment (EVSE), EVSE to EV-Battery Management System (BMS).

SAE J2931 under V2G technology allows different stakeholders to operate in different modes. The software needs to support all the customers simultaneously without any confusion but with synchronisation. They are allowed to communicate with the next level in either receiving or sending message mode. This means that the stakeholder can receive or send a message to the next stakeholder as in Fig. 10.2. The example messages are also mentioned under the stakeholder in the Fig. 10.2. These modes are considered with respect to some factors such as the price of charging, availability of energy, availability of charging point, etc. This V2G technology allows the operator of the vehicle to program when to charge the battery, time of recharge and duration of the charge. They can also get information about the cost of energy, various tariffs, etc. It helps the utility also with various options such as price flexibility, user preferences and managing the bulk number of vehicles simultaneously.

In addition, it has to consider the stability of the grid and efficient use of available power in the grid and there should be provision for taking energy through renewable energy which is intermittent in nature. The users of energy for EV can have

	Utility-ISO	Aggregator-EVSP	EV Supply Equipment	EV-BMS
SEND messages	· Registration In/Out signals · Energy Price · Capacity parameter	· EVSE control parameters · Performance statistics · Participant parameter	· Change signal · verification & confirmation signal · Recorded data	·Battery Capacity ·Charge/ discharge rate ·Battery SOC
RECEIVE messages	· Verified Aggregator Control response · Power Grid balance signals	·ISO/ RTP signal · Valid EVSE control response · EV's energy need command · Market tariffs	· Aggregator control signal · EV requirement priority input	·EVSE battery charge controlling signal

Fig. 10.2 Representation of communication path under V2G technology

Table 10.1 SAE standards for communication between various stakeholders

SAE Protocol	Details about the communication
J2836 (Part 1 to 5)	Power transfer between PEV and the GRID & also reverse flow of power
J2847 (Part 1 to 5)	Apply of use cases as defined under J2836
J1850	Vehicle and EVSE network
J2293	V2G bidirectional power flow, updation of communication medium to PLCC or wireless
J2931	Communication needs for EVSE with home, EMS and GRID

information on when the grid is receiving energy from the renewable resources and they can select the charging time during such periods, thus reducing the emissions and pollution. With such communication, the renewable energy resources can be effectively utilised, which otherwise may be left wasted. With advancements of technology, it is possible to develop standards and protocols for effective utilisation of the system for all the stakeholders. The standards and the protocols that regulate the use of the V2G technology are also being formulated by SAE. Some of the SAE standards related to the communication are defined under the codes as given in the Table 10.1.

The standards provided in Table 10.1 facilitate standard requirements to ensure that the different manufacturers of EVSE develop products that are in agreement with the standards to their network interfaces (DOE, 2010). The NIST, National Institute of Standards and Technology standard and the IEEE 1547 standard give use cases for the communication, monitoring and management of distributed sources related to the power grid.

The standards and protocols developed are discussed in the preceding section.

3 Codes and Standards

Although a lot of technical research and policy debates have been conducted to verify the V2G concept, many practical standards for flat grids, vehicle-related standards and V2G equipment need to be revised or a practical framework to be created for the support of the V2G business model. On the contrary, they are specifically developed for the flow of power in one direction.

In the fields of equipment installation, communication, security, intercommunication, billing, approval, etc., also formulate standards of behaviour and practice. For many reasons, it is necessary to adopt a common set of norms and standards. Each participating public charging station requires an electronic identity certificate, so that the participating electric vehicle owners can establish a connection and participate in V2G operations that require electronic quotation and customer agreement to power contracts. For the purpose of billing, each vehicle needs an identifier which can report the global position of the EV, the meters implemented and the agreement between vehicle operator and the utility company. It is designed to enable vehicle and network operators to control the energy transmission rate and limit the energy that can be extracted from the vehicle. This enables network operators to do predictions and adjust traffic load while receiving data in the real time. Systems which are recording the information (such as customer requirements and cancellations) and support customer interactions with utilities require powerful and predictable management capabilities. To encourage the owners of EV who are participating in the energy exchange market, some standards should be established for prices that change over time. Network security standards should be established which are universally accepted, especially when protecting many charging stations located in public places such as malls and public parking places. Since many cars are connected to the network and left unattended, personal information needs to be protected from intruders. Cover the vehicle to maintain the ability to interrupt the charging process when the battery condition is unsafe, even if there is a charging command from the main power source. When the transition from internal combustion engine vehicles to automobiles begins, electrical, automotive, and utility companies need to work together to help provide compatible and safe systems for their mutual customers.

The codes, protocols and standards are usually related, although they have different meanings. The standard specifies that the necessities of all the stakeholders must be satisfied and supported by regulatory requirements and compliance. The competent authority is responsible for reviewing permits and other documents to ensure compliance and compliance with relevant regulations. Regulations usually aim to protect safety, health, collaborations and are approved by local governments or regulatory agencies. The prime goal of the standard development organizations is to have secure, robust, safe and common charging methods which can be integrated and can work in synchronization with the smart grid. The various standard developing organizations are IEEE, SAE, NEC, IEC, ISO and so on.

There should be interactive communication methods between the electric vehicle and smart grid for charging and to have collaborative operation. No interruption to be tolerated during communication. This has to be considered while designing the charging stations and network sharing. With an improved communication, this can be assured in V2G communication. Mismatched communication and miscommunication are to be avoided between different service-providing companies. For this to happen, there is a need for communication standards which are to be followed by all the vehicle manufacturers.

There are standards that are to be maintained and considered for effective communication which was developed by IEC (International Electrotechnical Commission). The parameters considered for the standardizations are plug, communication, vehicle couplers, vehicle inlet, communication network, switchgear, charging method, EV conductive charging system for both AC & DC, UPS, safety, etc. The standards for these under IEC are IEC 62196-1, IEC 62169-2, IEC 62196-3, IEC 61850-x, ISO/IEC 15118, IEC 61851-21, IEC 61851-22, IEC 61851-23, IEC 61851-24, IEC 61851-21, IEC 61140, IEC62040, IEC 60529, IEC 60364-7-722, ISO 6469-3 [1, 2]. These standards are described in Table 10.2.

Table 10.2 IEC/ ISO standards for the PEV charging components

IEC 62196-1	Charging of EV up to 250 A AC and 400 A AC with conductive charging, vehicle couplers, plugs, vehicle inlets and socket-outlets
IEC 62196-2	Socket-outlets, plugs, vehicle inlets and connectors, charging of EVs, compatibility with dimension, and exchangeable needs for contact tube and AC pin accessories
IEC 62196-3	With rated operating voltage 1000 V DC and current up to 400A with exclusive DC charging. vehicle couplers, socket-outlets and plugs Conductive charging of EV, compatibility with dimension exchangeable need for contact-tube coupler and pin.
IEC 61850-x	Systems and network communications in distribution substations.
ISO/IEC 15118	Communication interface for V2G.
IEC 61439-5	Control gear assemblies and low-voltage switchgear and assemblies for distribution of power in public networks
IEC 61851-1	General requirement for EV charging.
IEC 61851-21	AC/DC supply for EV requirements and conductive charging system for EV.
IEC 61851-22	Charging station for AC EV.
IEC 61851-23	Charging station for DC EV.
IEC 61851-24	Controlling communication protocol between EV and on board DC charger- EV conductive charging system.
IEC 61140	General aspect of protection from shock during installation of equipment.
IEC 62040	Uninterrupted power supply (UPS)
IEC 60529	Level of protection supported by the safety enclosures (IP code)
IEC 60364-7-722	Electrical installations of low voltage, need for special installations or locations for supply of EV
ISO 6469-3	Protection from electric shock for persons and EV related with V2G

The other important technology, policy and advocacy organizations which are contributing to the developments of the standards for V2G are National Resources Defence Council, Electric Power Research Institute, National Renewable Energy Laboratory, California Energy Commission, Edison Electric Institute, Electric Drive Transportation Association, U.S. Department of Energy, Pacific Northwest National Laboratory, California Public Utilities Commission, Idaho National Laboratory, Rocky Mountain Institute, National Association of Regulated Utility Commissions, Argonne National Laboratory, Oak Ridge National Laboratory.

The vehicles and electric vehicle supply equipment (EVSE) are going to be principally standardised through the IEEE, SAE and/or NIST proceedings which all the automotive makers should follow. As per the native jurisdiction, the car makers can follow any of the standards and rules that may drive V2G technological developments.

4 Protocols

The field of communication protocols for network operators to control electric vehicles is developing rapidly, and each protocol is becoming more and more extensive. The Information Technology Certified Associate (ITCA), a standard development organization, continues to formulate standards and certification procedures for protocol selection.

Although messaging protocols must technically support messages for specific use cases, this is not enough. First, the availability of the product IEEE 2030 can be used for disaster recovery, but requires a lot of industry investment to achieve a strong interoperable ecosystem, or use cases that are likely to be inconsistent (or interoperable) between utility and utility and between provider and provider such as authentication. The new DNP3 AN-2019 provides a technical specification for the inverter curve and AC Regulation 21 configuration required for transmission via IEEE 1815/DNP3. Manufacturers now support it in their DER, but there is currently no certification program to ensure interoperability. These systems can interact with each other without certification; however, certification alleviates interoperability issues caused by misunderstandings in standard terminology, which manifest as delays or change requests.

There are various protocols for V2G Technology framed by different standard development organizations. Some of them are as follows.

1. OCPP—Open Charge Point Protocol
2. OCPI—Open Charge Point Interface
3. OICP—Open Intelligent Charging Protocol
4. OSCP—Open Smart Charging Protocol
5. OCHP—Open Clearing House Protocol
6. Open Interchange Protocol—OICP
7. E-MIP—e-Mobility

4.1 OCPP—Open Charge Point Protocol

The OCPP is a communication application protocol, which is used for communication between central management systems and vehicle charging stations. It is developed internationally and is freely available. It is open source and seller-independent.

Open Charge Alliance has developed this protocol for the market of EV infrastructure. These protocols are the real application of standards for interoperability, infrastructure market for all the manufacturers of charging equipment. It is also taken as standard by charging network operators, software and system providers and research institutions. The protocol has proved that it minimises the cost and risk for the investment in the development of infrastructure and is easily accessible by EV owners.

The present version of OCPP is OCPP 2.0. It has more improved and newly added features for transaction handling, device management, display, security, smart charging functionalities, messaging and many additional developments as per the need of the EV charging community. Additionally, OCPP 2.0 provides the facility to plug-in and charges the EVs, thus supporting the ISO 15118 protocol.

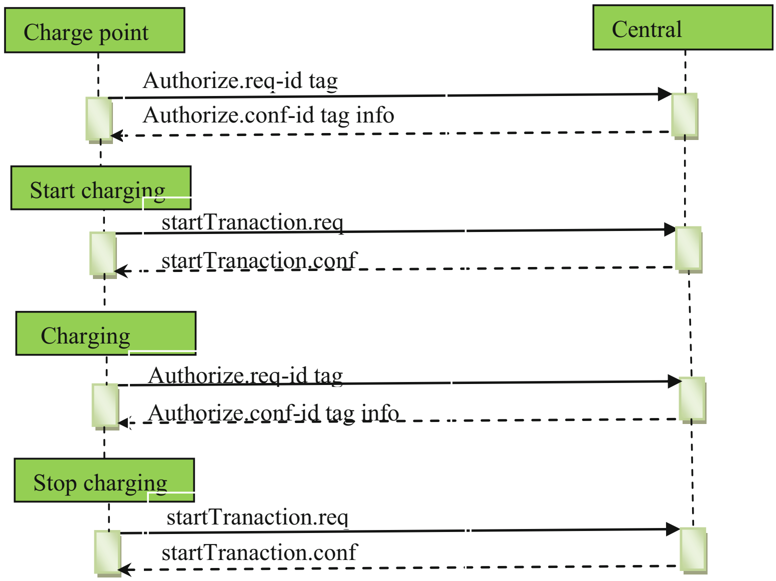

Fig. 10.3 Sequence diagram: Starting and stopping transaction example

This protocol supports communication between the charging point and the central system, when an agreement requires one or the other to take a specific action or response [3]. Figure 10.3 describes the general process between the charging point and the central system in two cases. One is the charge point requisition for card authentication and sending the charging status and the second one is the request by the central system for the charge points for updation of the firmware. It also indicates the sequence diagram showing the start and stop of a transaction. The sequence diagrams are the ones which are presented in the standard documents of IEC and ISO for various protocols. Here, one of them is presented to give an idea about the process flow due to any event.

When the charging station is ready to charge the EV, the user must be authenticated first and then the charging process can start. If the user is authorised, then after completion of charging the battery, it checks for the completion of task and checks whether the user belongs to the authorised group, then allows them for completion of battery charging. The central system is kept informed by the charging point that it has stopped charging the EV.

Figure 10.4 presents the sequence diagram for the updation of the firmware. When the charge point has to match with the updated new firmware, the central system sends the information to the terminal device about the update of the new firmware. During each step of updating the software, the charge point should send information to the central system, receive authentication and complete the installation process.

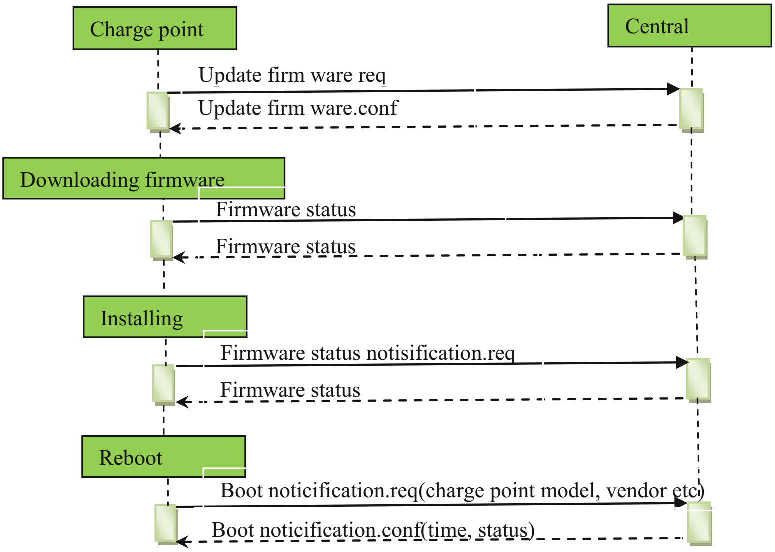

Fig. 10.4 Sequence diagram: a firmware update example

4.1.1 Local Authorisation and Offline Behaviour

If there is a communication problem or it may be a central system, when the charge point is autonomous. This situation means that the charge point is not connected. To improve user experience, the purpose of authorisation may be maintained with a local authorisation ID, an associated authorisation cache of the degree of victimisation, and/or a list of allowed areas.

This helps for two purposes. They are the authorisation of offline users and a quick authentication time when the link between the central unit and charge point is slow.

The configuration key *'LocalAuthorizeOffline'* determines the authorisation of the charge point even when offline. This can be done by use of local authorisation cache. Whether the charge point can use this option to initiate a new transaction without any delay can be controlled by the configuration key '*Local Preauthorize*'.

4.1.2 Authorisation Cache

The local authorisation list can be an identifiers' list to be checked with the central processing system. This list consists of an authorisation status and authorisation status/expiration date of all (or more) identifiers. Identifiers in the own authorisation list are considered valid, expired, (temporarily) blocked or blacklisted, similar to the Id Tag Info status value. These values usually also provide additional details. Users (such as viewing messages) are authorised locally. The authorisation list of this machine must be saved in nonvolatile memory for loading and must be maintained during restart and power failure.

4.1.3 Local authorisation list

This list has identified users who are all synchronised with the central processor. The list of users will have different tags based on whether they are valid, expired, blocked or unauthorised users. This process helps in authorising the charge point at the stage for confirmation of identity so that they receive permission for charging. The central system can take action based on the identity of the user being connected as indicated in the Fig. 10.5. Similarly, a detailed process, actions implemented and authorisation schemes are explained in detail in the standard document on OCPP. The relation between authorising agent and the local list, unknown offline cases are all dealt in detail. These sequence diagrams are from the standard document of OCPP. More detailed structures and sequence diagrams can be referred from the document mentioned in the references list [3].

The transaction in relation to energy transfer period, ID tokens, transaction-related messages, connector numbering, parent id tag, reservations, vendor-specific data transfer, smart charging, time zones all have rules and conditions to be followed under this protocol. The document on this protocol provides a detailed description of these cases with illustrative diagrams and examples.

The transaction for energy transfer period has protocols to be followed between the EV and EVSE during the charging period and the not connected mode.

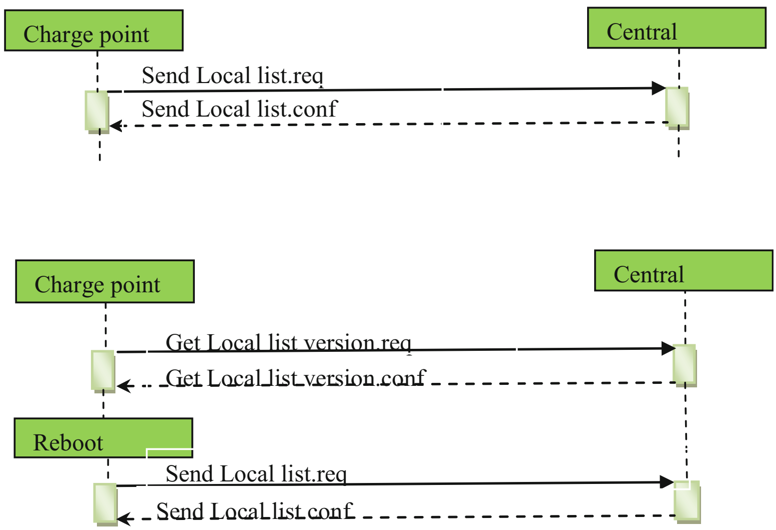

Fig. 10.5 Sequence diagram: a differential local authorization list update example

The transaction messages deal with giving and receiving messages between the charge point and the central unit. All types of messages had a tag which indicates the information. The messages are defined and also considered in some predefined order for every status that is to be considered during all the processes.

The error responses are also dealt with by certain defined rules and order. Upon identification of any failure in delivering messages, the stats should be handled with predefined preferences which are all defined in this protocol.

The numbering of the connectors is also considered to be one of the important considerations. The connectors should have identifiable numbering. A connector Id 0 has been reserved for the main controller of the charge point.

The ID tokens deal with the UID value of the physical card that the customer will have. An ID is assigned for every charge which is considered as the virtual transaction code. Also a central account code known as parent ID will be provided. The data type of the ID also has predefined constraints.

A parent ID tag refers to the ability of the central system to have token sets as a 'Group' to allow any one member in the group having that token to make communication for starting or stopping the transaction. This protocol helps in using the token ID by a family with multiple drivers using the same vehicle with a single contract number.

Reservations help in reserving the charge point up to the required but a valid time. This allows reserving a particular connector in the charging station.

The vendor-specific data transfer enables for the interchange of information which may not be defined under OCPP, thus enabling a possible implementation of additional functions if the central system accepts the function.

One of the important functionalities under this protocol is smart charging. The central system has capability for controlling the charging parameters like power and current to a particular EV. It can monitor the energy consumption by each EV, at each charging point, grid connectivity, energy available from the grid, the type of connector, specific limits, charging profiles, charging purposes, etc. Under this protocol, three types of smart charging options are facilitated. They are load balancing, smart central charging and smart local charging.

The above mentioned processes can be well understood with the sequence diagram for the process given in reference [3].

All the above mentioned categories have detailed processes and tagged transactions. All of these are having different tags for each of the processes which the charge points should follow and satisfy. The operations that can be started by the charge point are Authorize, Meter values, Boot notification, Firmware status notification, Data transfer, Heartbeat, Start transaction, Status notification, Diagnostics status notification, Stop transaction. Each of these operations is defined with the protocols that need to be followed. The charge points should follow the protocols as mentioned under each of these processes so as to have collaborative transactions. By doing this, a standardised messaging structure is assured.

Similarly, the operations that are supported by the central system are Cancel reservation, Change configuration, Change availability, Clear Cache, Clear charging profile, Data transfer, Get composite schedule, Get configuration, Get diagnostics, Get local list version, Remote stop transaction, Remote start transaction, Reserve now, Reset

Send local list, Set charging profile, Trigger message, Unlock connector, Update firmware. These steps involved with respect to the central systems enable for the monitored transactions under V2G technology.

4.2 OCPI—Open Charge Point Interface

The Open Charging Point Interface (OCPI) aims to exchange charging point information between charging point operators and electric vehicle service providers to realise the scalability and automatic roaming of electric vehicles. Specifically, they provide session information, duration including location information. It supports send commands remotely such as backup commands. Provide detailed billing records (CDR) for billing. Use token exchange to authorise charging sessions. E-mobility operators and service providers support authorisation, exchange of charging point information (including real-time status updates and transaction events), exchange of transaction details, billing records, remote charging point command, exchange of smart payment-related information between parties. An inter-network (international) roaming solution that avoids costs and frustrations through innovations related to modern handheld solutions or central roaming centres. In this way, it can help electric car drivers charge for rapid development in a fully informed market and help seafarers. Guide participants so that they can implement their business model in the best way.

Main features of the protocol:

- Real-time information on location, prices and availability
- Better roaming system (two-way use and/or via a hub)
- Unified data exchange (notification data collection and accounting data collection) after, during and before the transaction.
- No prior registration is required to access mobile remote support for each charging point.

OpenADR-an open and secure information interoperability exchange framework to promote automatic query operators (DSO), utilities energy management and control the system to balance the peak energy demand, which led to the development of OCPI in 2014, which has supported the OCPI international group of companies initiated by EV Box. There are several organisations and platforms such as The New Motion, GreenFlux, ElaadNL, Freshmile, BeCharged, Plugsurfing, and Last Mile Solutions, ihomer and Siemens who are involved in participation. The Dutch Freight Infrastructure Knowledge Platform (NKL) supports and coordinates the project to ensure progress and feasible results [4].

4.2.1 EV Charging Market Roles

In the EV charging infrastructure under V2G, various market roles are identified as mentioned below. The following Table 10.3 presents various roles taken up by the typical modules. The Table 10.4 shows the typical communication role such as sender, receiver and/or both.

4.3 OpenADR 2.0

The protocol OpenADR 2.0 provides standardisation of distributed energy communication (DER), demand response (DR) and automated DR/DER processes. It provides protocols to simplify the customer's energy management and removes unused assets.

Table 10.3 Market roles of service providers

Role	Description
Charging Point Operator (CPO)	Operates a network of charge points
E-mobility service provider (eMSP)	Provides EV drivers to access to the charging services
Hub	Multiple CPOs are linked to multiple eMSPs
National access point (NAP)	Provides a national-level database with all charging
Navigation service provider (NSP)	Provides EV drivers with location information of charge points
Smart charging service provider (SCSP)	Provides smart charging service to other stakeholders and can use a lot of different sources for energy to calculate smart charging profiles

Table 10.4 Typical communication role: Receiver, Sender or Both. S-Sender, R-Receiver, B-both

Modules	CPO	eMSP	Hub	NSP	NAP	SCSP
CDRs	S	R	B			
Charging profiles	R		B			S
Commands	R	S	B			
Credentials	B	B	B	B	B	B
Hub clients info	R	R	S	R	R	R
Locations	S	R	B	R	B	
Sessions	S	R	B			R
Tariffs	S	R	B	R	B	
Tokens	S	R	B			
Versions	B	B	B	B	B	B

OpenADR: A protocol that enables automatic demand response (ADR) procedures, along with the potential for collector intervention. It is an open protocol standard which is based on Energy Interoperation version 1.0 (EI) of Organisation for the Advancement of Structured Information Standards (OASIS). The OpenADR 2.0b [5] has some of the services mentioned in the EI. The prime features implemented by OpenADR 2.0 b are EiEvent, EiReport, EiRegisterParty and EiOpt. The services permit the stakeholders to register to an event, change resources, reports and options to participate in the events [6]. According to the document, the OpenADR protocol is mainly aimed at the electricity charging market (but it can also be used to exchange real power, reactive power, etc.). With this in mind, the OpenADR protocol attempts to implement EI. The focus of implementation is demand response (DR) management. There are several implemented interfaces that provide the functions provided by the OpenADR standard.

4.4 OSCP—Open Intelligent Charging Protocol

It is one of the important open protocols used for communication between the charging point control system and the site owner's power management system or DSO system. The real-time estimation of the grid energy capacity can be transmitted to the charging point operator through the agreement. OSCP provides capacity-based intelligent charging of electric vehicles.

4.5 OSCP—Open Smart Charging Protocol

This is an open communication protocol that can send a 24-h local available capacity forecast to charging point operators. Service providers will adjust the charging configuration of electric vehicles within the framework of available capacity. It is an agreement between the charging point management system and the power management system or DSO system of the site owner. So this applies to website owners and DSOs.

4.6 OCHP—Open Clearing House Protocol (e-clearing.net)

The OCHP is an open source protocol that allows for simple and consistent communication between freight management systems and information exchange systems. OCHP allows unlimited charging of electric vehicles through a network of charging stations (electronic roaming). With OCHP, electric vehicle service providers can connect with electric vehicle charging providers and operators to access their networks. The location of the electric vehicle clearing house, especially the

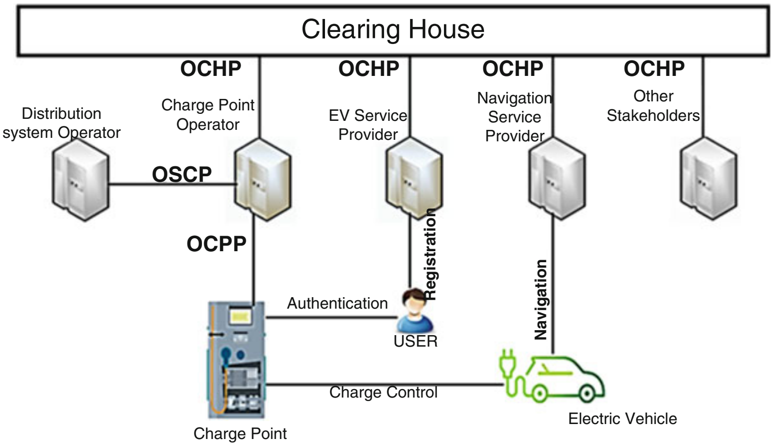

Fig. 10.6 Relationship between the clearing house and the electric vehicle service provider

location of the European electric vehicle clearing house, is shown in Fig. 10.6 and it shows three types of stakeholders, but these procedures can be conveniently extended to other cases of similar types.

The following listed stakeholders are directly related to clearing houses: Other (local) clearing houses, which are of two types: Clearing houses that do not conduct financial transactions, so related (secondary) parties must take over financial transactions. Currently, this type includes ECH, the clearing house that handles financial transactions, and acts as counterparty for transactions in its infrastructure without delay, such as Ladenez.de.

For an electric vehicle mobility service provider with multiple customers, the preliminary idea is that the clearing house provides 'roaming support' for every electric vehicle mobile service provider connected directly or through other clearinghouses. The ultimate goal of EV consumers is to be able to easily charge their EV at any charging station of any EV service provider. The clearing house provides the support of roaming and with this the complexity of the relationship can be reduced from the many-to-many two-way relationship with the electric vehicle service provider to the single-to-multiple relationship between the clearing house and the electric vehicle service provider.

4.7 OICP—Open Interchange Protocol

OICP was developed on a platform called Hubject and is a communication standard implemented between the systems of electric vehicle service providers (EMSP) and charging point operators (CPO) through this Hubject platform. The agreement is based on the contractual relationship between EMSP and Hubject's CPO to achieve

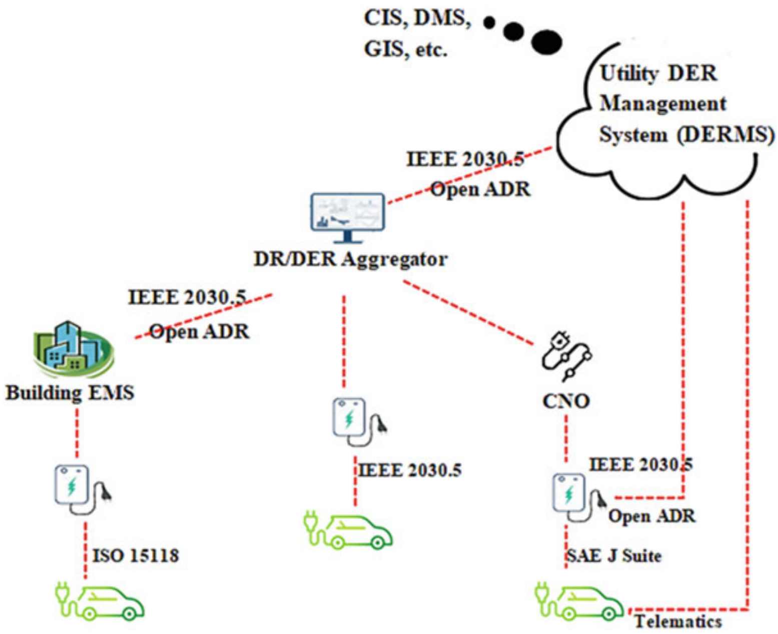

Fig. 10.7 Communication standard implemented between the systems of electric vehicle service providers (EMSP) and charging point operators (CPO)

information exchange, which enables them to provide reliable roaming services for EV drivers (Fig. 10.7).

Interoperability requires flexibility and collaboration between market participants. The open standard aims to open up the electric vehicle charging market. Two of them are initiatives of their own associations for the development of OCPI and OCH protocols. Also by using proprietary standards for PEV, it can be used by everyone at free of cost. Open standards for roaming electric vehicles are proprietary, but they can also be used publicly and free of charge. GIREVE and Hubject establish user friendly and new service network for charging. Hubject and GIREVE on-site facility providers, automobile manufacturers, power suppliers and authorities provide a wide range of cost-effective solutions and simplified communication advantages [7].

Hubject designed OICP in 2012 by an established German automobile professional. In addition to the roaming platform, Hubject gives roaming platform, technical facility and prescribed provisions for electronic roaming. The general construction of OICP is partitioned into two sections, in particular e-Mobility specialist co-ops and charging administrators; however, the item range is continually growing. Hubject said that OCIP is ‘the most generally utilized standard for communication among e-MSP and CPO frameworks in Europe’. The most recent adaptation 2.3 was delivered in October 2020. The most recent updated protocol addresses market issues: it enhances the nature of POIs in the extended market, which grows legally, compliance, data processing performance, and ensures greater transparency for different load applications. In addition, Hubject provides many useful CPO-related remote tests to fully explore various use cases. The agreement is free and open and does not require registration. As of May 2019, OICP is a free and open source agreement that is provided on the website of Hubject as open source supply systems. The main objective is to have more customers to involve in the development of communication systems. This protocol works in real time. It is a real-time protocol and also provides asynchronous operation. Also there is a backup database; Hubject does not support uploading to charging stations. The platform records data of transactions.

The established market role of documentation in OICP protocol as mentioned below.

Service provider e-Mobility needs to make charging points available to owners of electric vehicles. In most cases, using a valid agreement with e-MSP and transmits the information to the charging point operator through the platform. Hubject provides connectivity through the e-MSP aggregator to communicate with the platform. This means that multiple eMSPs can be integrated through one e-MSP aggregator, so that sub-partners do not have to work with Hubject.

- Charging point operators (CPO) manage charging points. Through the Hubject platform, the operator can sign a contract and exchange any information. Like e-MSP, multiple CPOs can be integrated through the CPO aggregator. Therefore, the sub-partner does not have to register with Hubject as the communication with Hubject is through the CPO aggregator.
- Hubject, which is a roaming centre, establishes connection between e-MSP and CPOs through the EV platform.

Functionalities Supported by OICP

- Roaming via hub—Using web-based service e-MSP and CPO are connected through the platform.
- Ad hoc payment—This allows vehicle owner to make contactless payment for changing battery.
- Authorization—Hubject binds e-MSP or CPO ID and SSL certificate information. Then each author is allowed to download the session. The Hubject database is used as a backup, but it does not allow downloading from its database to the charging site.
- Reservation—Owners of electric vehicles can reserve charging points through the e-MSP application. Hubject tests the compatibility of charging points with electric vehicles. If it matches, the CPO request is sent, and if the reservation is successful, the CPO request will respond. You can also withdraw your reservation.
- Billing—Total duration of charging has been recorded and stores in the system for the billing process
- Charge point information—The information stored in the database is downloaded and transferred between e-MSP and CPO which include all the data, like contact

point ID, name, location, time, availability, price, method of payment, performance and all the real-time status information.
- Real-time charge point information—This provides availability of charge, status and price information at present time.
- Session information—This will provide information on charging duration, ID-like session, service, start–stop authorisation, meter, used energy.
- Remote start/stop—Using this application, it is possible to control the complete process without human intervention, that is, without fully automatic.

4.8 e-MIP—e-Mobility Interoperation Protocol

The e-Mobility Interoperation Protocol has been developed by French start-up company French players in Electric mobility in 2013. The main objective of this protocol is to facilitate an 'open access protocol to vehicle charging stations'.

The e-Mobility interworking protocol facilitates you to move through clearing-house data. The protocol provides access to the database of the charging point and helps for smart charging functions.

In 2018, the GIREVE platform complies with the OCPI standard. The roaming platform is currently active in 28 countries/regions. The latest version of e-MIP 1.7 was released in late July 2019. GIREVE also provides certification services. Platform, e-MIP platform is not suitable for point-to-point connections in practice. To provide a latest quotation and high degree of architectural openness, GIREVE negotiated with stakeholders on possible future functions. GIREVE assumes full responsibility. In contrast to the above methods, the e-MIP protocol does not have a formal association of e-MIP members. E-MIP is based on Simple Object Access Protocol. Basically, the e-MIP is designed as a real-time protocol but it allows asynchronous operation. The characteristics of the e-MIP architecture make it highly adaptable and flexible: the definition table can be used to quickly add each new type of data message or identification method.

Market roles of e-Mobility include charging vehicles, vehicle sharing, charging infrastructure and data on the flat form.

The e-Mobility Inter-operational Protocol supports the following functionalities:

- Roaming through hub
- Authorisation
- Synchronous Authorisation
- Asynchronous Authorisation.
- Asynchronous Authentication Data Exchange and Synchronous Authorisation
- Reservation
- Billing
- Real-time charge point information
- Static charge point information
- Charge point search

- Session information
- Real-time session information
- Remote start/stop
- Platform monitoring

A single network will be effective because EV owners and service companies can improve their services, offering better services for customers. The company develops the protocol for electric vehicles that use their charge infrastructure with specific simple instructions. The cross-border networks are available, and the support of road experts and commercial leaders promises the unit and resilience of the network. Please note that both grids have developed their own custom protocols (OCP and EMIP), they also have contributed to the development of OCHP and OCPI.

5 Present V2G Communications and Protocols

EV charging using V2G technology is an important setup which helps to obtain a net zero case, but this technology is difficult to be utilised by EV owners before the end of this decade.

- According to the National Grid ESO's prediction on future scenarios on energy, up to 45% of the domestic consumers may actively participate in V2G services by 2050. This survey has been provided in July 2020.
- Many EVs are currently unable to participate in V2G technology due to the interfacing issues, as predicted by the experts.

The Figure 10.8 shows how the developments in the field of smart charging will lead to the increase of V2G utilization by 2050.

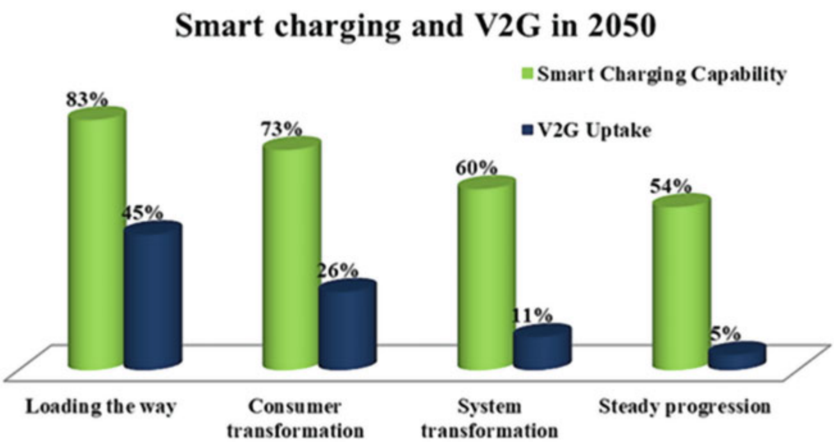

Fig. 10.8 Smart charging and V2G in 2050

When all electric vehicles are connected at the same time, such as during peak load at 5:00 pm, the rapid increase in the number of electric vehicles on our roads leads to higher demand on the local grid. 7:00 in the evening. Controlling the charging time of electric vehicles, as tested by Electric Nation's original project, helps avoid this.

However, V2G charging will be more efficient than smart charging because electric vehicles can be connected and a large amount of energy can be fed back to the grid during peak hours, just like in a huge decentralised power plant. In addition to reducing the demand on the power grid and providing cleaner and cheaper power to electric vehicle drivers, the power grid is also required to provide additional power that is usually produced by fossil fuels during peak hours.

As per the National Grid Electricity System Operator (ESO) future national grid scenario, as many as 45% of the companies will be actively involved in V2G communication services by 2050, and V2G services can provide 5.5 million vehicles with up to 38 GW of flexibility. However, the range of results is wide. For the V2G technology in the ESO national grid scenario, the lowest estimate of the number of households that will actively provide vehicle-to-grid services in 2050 is 4.6%. V2G is also considered to be slow to market, and there will be a 5- to 15-year delay between buying an electric car and participating in V2G.

The take-up ranges from 5% to 45% throughout the transition to V2G, with 45% being the 'Leading the Way' early delivery of Net Zero in 2050. The two other Net Zero compliant studies show 11% and 26% in 2050, exhibiting the uncertainty in the implementation of V2G technology.

5.1 Guidelines for Setting Up of Control Architecture for Messaging

The control architecture of the electric vehicle communication infrastructure describes the communication architecture used to receive messages from/to network operators and controlled terminal devices. For example: one model assumes that the actual endpoint is controlled by the building energy management system (EMS) that actually communicates with the Utility-DERMS. In this case, the operator will contact the EMS, which is responsible for addressing the terminal device [8]. A similar and supporting discussion on control architectures and quality logic has been done earlier by the authors of references [9, 10].

The Control architecture related to EV communication issues are:

- **Direct control**: The utility program sends configurations or requests directly to the EV or EVSE. This currently only applies to V1G use cases.
- **Pass-thru Aggregation**: The smart inverter settings and emergency call transmission commands are designated by the energy supply company for each inverter and 'passed' to the aggregator, CNO or other inverter gateways.

- **Smart DR/DER aggression:** (Demand Response and Distributed Energy Resources): This process is usually used by the utilities to manage DR and DER, in which smart gateways are implemented to convert the utility guidelines to check what settings or instructions are to be sent to the stakeholders receiving the energy. The communications information may be advisory types which are specific mandatory needs of DER or DR or for both.
- **Third-party charging network operator:** This is the setup made between the utility and the third party who implements the charging stations with some intelligent system for managing the EVSE, V1G and V2G vehicle charging setups. Here, only the EVs are managed and the utility grid is not controlled.
- **Vehicle measurements:** It is a substitute path for communication between the EVs and utility DERMS without the involvement of the EVSE. This network is implemented for managing EVs in either V1G or V2G technology.

From the point of view of the protocol, the architecture implemented decides the requirements of messaging, its functional features, and messaging protocols that are implemented in the architecture. It varies from architecture to architecture with varying protocols and facilities included.

5.2 Requirements of Communication for EV

The main intention of messaging requires that it gives the information about the type and the content of messages which are used to exchange information between the two parties for some application. These are obtained from the different cases. For example: in many control architectures, the EVSE and the EV will communicate among themselves to make an agreement about the charging session and other issues related to it.

The requirements for information exchange are ownership information, billing method, battery-related parameters, energy price, charging time and schedules, authentication-related certificates, agreements between the two parties, start and end of charging time, etc. After the required tasks are identified, which the architecture should satisfy, the various applicable protocols can be determined. Various types of messaging preferences, architectures and messaging protocols can be defined based on the various aspects of requirements. And there is no one single fixed technique or type for messaging requirements.

One of the examples of messaging types and groups could be as shown in Table 10.5. This example considers DER administration, grid requirements, prices, DER operations, groups, PEV messages, reporting and monitoring, various other transactions, etc.

Various technologies have different strengths and options for messaging and communication with the other stakeholders. The table gives summary of how the messaging is applied under different groups (also called as use cases) with respect to various factors as mentioned. Considering the cases as V1G-residential, V1G-workspace and V2G (AC or DC) as shown in the Table 10.6, it can be observed

Table 10.5 DER and DR message groups for V1G and V2G applications

DER Administration • Enrolment/registration • Asset owners/utility programs • Individual DER device knowledge	**Grid Requirements** • Volt/freq support • Emergency dispatch • Notifications/alarms • 61850-7-420	**Prices/Events** • Price signals: Time of use, CCP • RT pricing CPR • Events/schedules
DER operations (real-time operations) • DER settings/schedules for automatic responses • Emergency dispatch • Notifications/alarms • 61850-7-420 information mode	**Reporting/Monitoring** • DER information/status • Configuration • Metering/performance • Telemetry	**PEV-Specific Messages** • PEV SOC/status • Start/end times • Energy required • Ramping/charge rate • Restart
Targeting/Groupings • Group Assignments • Aggregators	**Built-in Cyber Security**	**Transactions** • Bids/negations • Forecasting • Settlements

that there are certain similarity and also some differences for the messaging requirements by these cases. We can observe that the V2G technology does not involve price signals but V1G has to utilize that with incentives upon participation.

There are some conceptual groups which can be used relating to prices and certain events under DER managements, but this selection depends on the rule under the selected model of DER management. In Table 10.5, the transaction group is included. This group is considered whenever pricing and related negotiations are involved between the EV owners and the grid.

5.3 Selection Guidelines for Messaging Protocol

The suitable protocol chosen for EV communications can be based on the capacities of the messaging protocols and other important factors and implications of a selected protocol. The existing ecosystem should be first understood with respect to the possibilities for improvement, initiatives that can be taken and the possible time for its implementation for usage.

5.4 Other Factors in Protocol Selection

Although messaging protocols must technically support messages for specific use cases, this is not enough. The availability of the product and the authentication should be checked [8].

Table 10.6 Messaging requirements for some use cases

Messaging types	V1G Residential	V1G workspace	V2G AC or DC
DER Administration	✓	✓	✓
DER operations	-	-	✓
Target groups	✓	✓	✓
Reporting & monitoring	✓	✓	✓
PEV specific messaging	✓	✓	✓
Prices	✓	✓	-
Transactions	✓	-	-
Cyber security	-	-	✓

The factors to be considered in protocol selection include:

1. **Maturity of protocol ecosystem:** Ecosystem is a collection of equipment, systems, procedures and stakeholders related to the agreement. This protocol may be very suitable for applications; however, mature ecosystems generally have lower costs and faster recovery than less mature ecosystems. Immature ecosystems can guarantee cost, time, and opportunity; however, they may not have been fully field tested.

   (a) **Product availability**: Implementing a protocol means the protocol must be supported by EVs, EVSEs, and associated management systems. If little to no technologies and vendors support the protocol (including devices or control systems), then additional R&D or costs may be required for products to be available in time for a utility program.

   (b) **Conformity assessment tools**: Even though protocols may be robust, there is always room for misinterpretation or vague language. Tools and processes to validate that EVs, EVSEs, and associated management systems can facilitate this.

   (c) **Industry experience**: The more stakeholders have experience with the protocol, the more likely interoperability will occur at interconnection. Maturity in this factor includes individuals with experience across utilities, aggregators, manufacturers, consultants, and other stakeholders.

   (d) **Use-cases understood**: The protocol requirements to implement a specific application (variants of V2G and V1G) vary. Application specific profiles narrow down the complexity of implementation by providing guidance on how to implement programs consistently so that products can be made to support them.

(e) **Certification program(s):** These are critical for ensuring that vendors implement the protocol consistently for the applications certified.

2. **Mandates/adoption**: Protocols are adopted based on natural industry adoption but outside motivators like mandates can nudge the industry in a specific direction.
3. **Cyber security**: Any time connectivity is added to a system or device, the security of the asset and associated data needs to be considered. Different protocols support different cyber-security capabilities. For instance, IEEE 2030.5 and OpenADR both include cyber security in the standard while IEC 61850 and DNP3 rely on separate cyber-security standards.
4. **Internal factors**: Adopting new protocols can be an expensive and time-consuming endeavour. It is natural that EV/EVSE manufacturers, utilities, and management system providers will gravitate to protocols they have the most experience in or already have on their roadmaps.
5. **Applications addressed**: While a protocol may be a good technical and business match for a specific use case application, consideration should be given to other DR/DER use cases that are likely to be implemented. The fewer protocols required addressing the anticipated DER use cases, the less time and expense will be involved in implementing them.

6 Summary

To make electric vehicles as a feasible solution for transportation, smart communication between electric vehicles, charging stations and infrastructure, as well as two-way energy transmission (V2G and Grid for Vehicle, G4V) and end-to-end communication are needed to eliminate the manual billing and make it more effective. Considering all these requirements, safety is of the utmost importance, especially during the charging process, which will go out of control over time. In the field of signalling and voice communication, knowledge, experience and standardisation are required to help in the development. Various concepts and technological understandings such as the electrical characteristics of the battery's state of charge, the expected charging time (idle time) of the battery, user authorisation and prevention of abuse, safe supply of charging stations by different operators in different countries, standardization of connections and interfaces and implementation of new value-added services are to be known.

Electric vehicles have the significant capability to reduce the consumption of imported oil and create many high-paying jobs by creating various businesses. To realize this potential and fully penetrate the consumer market, electric vehicles must undoubtedly be safer, cheaper, and meet the expectations and needs of users. This chapter focuses on light plug-in electric vehicles (PEV) that are charged via electrical connections and supports PEV charging, including battery all-electric vehicles (AEV) and sometimes vehicles (BEV) and hybrid electric vehicles (PHEV) are called battery electric vehicles. An electric vehicle (EREV) that works as an AEV also has the function of extending the vehicle's range beyond the battery (e.g. by using gasoline generators and other functions). A traditional hybrid electric vehicle (HEV) charged by an internal combustion engine is a different type of electric vehicle. Although it is not the subject of this roadmap, it will be highlighted when there are related safety issues and other considerations. In view of the current range limitations of plug-in electric vehicles that only use battery power, it is important to support the charging infrastructure so that the vehicles can be charged at office, at home and in public places. Regardless of the PEV or charging system used, the infrastructure must be reliable and largely compatible. It is also important to establish a strong and comprehensive support service department, including training for emergency personnel, technicians, electricians and inspectors, as well as training for competent authorities, owners and consumers. However, although the times seem particularly promising, electric vehicles face major challenges as they become mainstream. Electric vehicles are not as safe as traditional internal combustion engine vehicles and have unique safety challenges and risks, which need to be understood and considered as part of the vehicle life cycle. Widely and extensively penetrate into the consumer market. Safe charging anytime, anywhere will greatly improve the driver's flexibility and convenience and the function of technological development.

Impact on environment: The requirements from customers and manufacturers for environmentally friendly vehicles which have the highest efficiency and reduce the usage of fossil fuels. The PEV should meet standards, codes and regulations along with conformance and educational programs to take the advantages of PEV for development of home PEV and enterprise in infrastructure for a cleaner environment.

7 Future Challenges and Implementations

The protocols and the standards are framed so as to have a common platform for successful communication between the grid and the vehicle. Hence, its implementation for synchronised operation is very crucial. Constant innovations are being identified in this field and are successfully being standardised and implemented. It is important to identify the challenges in this regard so that future planning can be taken up by the researchers to propose innovative ideas in manufacturing of vehicles and also framing protocols to have reliable V2G technology and communication.

Technology challenges: The disadvantages of V2G communication are having major drawbacks such as technological problems related to communication and monitoring and also improper communication, reduced battery life [11].

The increases in the cost of V2G services of PEVs are due to a number of parameters such as power electronics converters, communication and control. And others pointed out that the commercialisation of V2G may depend on technological improvements in dispatching, modelling, and freight communications.

Many other engineering studies have confirmed that there are considerable technical obstacles due to design considerations and patents required for enhanced communication, control and coordination systems. Some of the research works at some Universities show that they can be solved.

The effect of PEV demands on the mid-voltage distribution network is not clear, and there are many bottlenecks and real risks of lowering charges, especially low-voltage transformers and line interruptions.

Adding to this, the spread of PHEV will have a 'strong impact' on many distribution networks. Second, the provision of V2G services will inevitably shorten battery life; the question is how much is the relationship between battery consumption when driving alone. The only quantitative answer published concluded that the provision of V2G will require continuous battery replacements throughout vehicle service.

Using accelerated aging tests to model 100 BEVs with two different configurations of lithium-ion batteries, it was found that the battery performance would change significantly due to battery chemistry, weather and weather conditions, temperature and processing methods. In some cases, it is expected to exceed. But they will not meet each other. Also larger the battery, smaller the marginal advantage of V2G vehicles. Diesel vehicles are more suitable for large vehicles such as vans (based on cost) evaluated based on types of PEV and ranges. There is a need for higher range and maximum battery power level.

As per the available data, the battery can be used upto 70% to 80% of the capacity after that it cannot be used in PEV and that leads to shorter life of the batteries which in turn increase the capital cost [11].

Finance: The first cost barrier: The financial outlook of the V2G system is not absolute, and is still limited by the first cost barrier: V2G-enabled PEV may be more expensive than traditional PEV, and traditional PEV is already more expensive than traditional alternatives.

Revenue/share: Compared with the predictions of the rational participant model, the savings in fuel or electricity costs are greatly underestimated. In fact, a survey found that no one estimated the current value of fuel economy when making a new car purchase decision. Another study of vehicle owners found that none of the respondents consistently analysed vehicle fuel costs. Few people track gasoline expenditures over time, and few see transportation fuel expenditures. . The International Energy Agency (IEA) found that consumers who are concerned about fuel economy when buying a vehicle expect to spend the first 3 years or less improving vehicle efficiency within a period of time. Consistent with consumers, they will consider only the present cost or investments on vehicle and fuel. Also revenue can be generated by establishing V2G infrastructure.

Social Ecology: Negative externalities is another category of issues belonging to the category of social environment, including negative externalities related to the V2G system, especially issues related to the wider use of PEV. For example, switching from internal combustion engines to electricity may increase power consumption, which may have a negative impact on water distribution, required for power generation using fossil fuels and nuclear power. Thermal power plants utilise huge amounts of water for producing steam and cooling purposes. This leads to more water storage which increases the complications in transportation of electricity.

Also increase in the BEV production and usage leads to problems of battery disposal as it may cause harm to the environment and disposal of other components of BEV.

Behaviour: Inconvenience, suspicion, confusion and worry about the ranks.

Important obstacles for establishing a V2G program include error in the program which leads to problems in connecting PEV at any point of time to estimate the range of PEV. That is, the V2G program that sells electricity and the effect on the charging process. The availability of power at the grid during an emergency will affect the consumer mind or lead to usage of ICE then electricity in PHEVs. Most consumers worry about the range of BEV that can travel per charge and high capital cost of batteries. Also there is a need for proper understanding between different service providers and vehicle owners. V2G communication programs should assure the customers about their secure customers' privacy data. Consumers think about immediate requirements of instant battery charging during long-distance travel and proper communication without any failure in the programme.

The fourth potential obstacle to the use of V2G is consumers' fear of battery degradation. Studies have shown that this problem currently only occurs in PEV, because customers have very minimal technical knowledge about the battery life.

8 Research Opportunities

The views and analyses on technical procedures in V2G will offer complete scope of its utilisation. Additionally, the research gaps should also be identified to enhance the features of the technology and improve upon its regular usage. There are four important fields of research with respect to V2G technology. These topics are discussed in the preceding section. The research opportunities are need for widening of the VGI cases, overcome failure of transformation, practical models of V2G and exploring interdisciplinary methods.

8.1 Need to Widen the VGI

Future research on V2G can be extended to a wider range of case studies, that is, the vehicle layout, users, and system functions that can be transferred to the vehicle to grid integration (VGI) system. As mentioned, the existing literature on V2G tends to focus on automobiles like BEVs but is not focusing on PHEVs, focus on V2G but not on V1G (V1G is energy transfer from grid to EV only). To study and model the various advantages and disadvantages of different vehicles, more extensive comparison work is needed. The type of vehicle (light/medium and/or heavy duty electric vehicles), types of owners (owners of light-duty vehicle and cargos), agreement of ownership (private and car sharing), type of technology (PHEV and BEV and degree of automation), degree of VGI (types of V1G and V2G), and method of V2G participation (time-sharing price, revenue sharing, controlled charging plan or voluntary participation.) Researchers, policy makers, and other stakeholders should prioritise V2G development work to seize opportunities that are more feasible and more likely to bring social or economic benefits in different time frames.

8.2 Overcoming Transformative Failures

The next scope of research is to understand how to accept the high level of transition towards V2G from the existing practices.

Further research can be explored based on the Weber and Roracher framework [12], which is composed of 12 kinds of errors that hinder change and categorized into three groups.

First, the market failures which consider knowledge diffusion, effects, and short-sighted investors should be considered which leads to misutilization of the various resources leading to wastage in the technology and innovations. In short, this leads to under investment in V2G innovation, which naturally takes a longer time to mature and generate revenue.

Second, the system has structural flaws, including the lack of infrastructure; hence, the companies, research institutions, and service providers need to support the large-scale transition to V2G. The innovative research may aim for improvising the existing systems, understand and evaluate the effectiveness of new methods to overcome the shortcomings. For example, a study has been conducted on the efforts of the California independent system operator in the interest of a wide range of public and private stakeholders to establish a V2G roadmap, including V2G case definitions. Elaborate case study can be done to understand the efforts in incorporating guidelines and codes into all institutions [13].

Third, the deficiencies of the transformation system due to the lack of a common vision among key stakeholders or ‘the focus is wrong’. Different stakeholders like utilities and vehicle manufacturers may have diversified views on VGI and different views on the possibility of V2G success in the future. For example: the different design standards of EVSE [charger] may result in restricted access to V2G services [13]. Such gaps in views and other obstacles are to be minimised by following a common policy, including Weber and Roracher’s concept of policy coordination [12].

To reduce greenhouse gas emissions, a high-carbon tax can stimulate the ethical transportation practices and also power sectors can be encouraged to innovate in a low-carbon direction, which may include the development of V2G. Studies suggest that carbon tax alone may not be enough but an encouragement can be made to incline towards the renewable resources of power. Although these measures can be complementary, they rarely target different sectors. Hence, a detailed analysis on implementation of V2G technology has to be studied which can be successfully implemented and operated. Many discussions are still in the documentation level. A thorough understanding is needed for its practical implementation. So there is an encouragement required to provide incentives to do innovations helping for easy and smooth transition from current practice to V2G technology.

User complexity: There is little research information on the consumer aspect of V2G Most V2G modelling studies generally assume the estimated number of PEVs participating in the V2G program, and PEV is calculated based on a hypothesis. The problem considers only one side constraint such as to optimise network operation or minimise the download cost of individual PEV owners. The study that has been conducted has made assumptions regarding the number of PEVs, charging time, grid conditions, etc. But considering the constraints from the point of view of consumers in the model is important. The consumer perceptions and participations are more critical and challenging to make the system more flexible and collaborative in nature.

Although there are many conceptual studies to learn from references [14, 15], some provide illustrative examples of the concepts of Axsen and Kurani, which were first developed to classify consumers' perceptions of PEV from two dimensions [16].

The first one is functional and symbolic. The PEV technology and V2G can provide both cost benefits and functional profits like cost savings and symbolic benefits, such as informing consumers that they are environmentally friendly or care for the environment. The second consideration is private participation and the societal dimension. We can realise that social benefits are used by the whole society, for example, by reducing greenhouse gas emissions and air pollution. Axsen and Kurani [16], in their work have distinguished two types of societal frames and have presented the functional and symbolic aspects for both. The functional frame gives the impact of the vehicle on the environment, resources usage pattern and energy-related aspects and the symbolic frame relates the ability of the vehicle to encourage others to participate in such activities to impact the society positively. The structure combines the capabilities of tools to incentivise other users, various stakeholders, companies, and governments to participate in activities, which in turn has an impact on society in a broader sense, and supports or amplifies existing negative impacts (such as low-carbon fuel) [5, 17].

Due to the complex dynamics, passenger cars can be seen as an integrated commodity with public and private dimensions, specifically secondary/alternative fuel vehicles and transportation modes where pollution causing impact to nature is usually the main driving factor for development [18]. This concept is a convenient method for collecting a wide range of consumer opinions on V2G, but this will not assume that all PEV owners optimise their behaviour based only on functional personal motivations (such as cost savings) [19].

8.3 Exploring Interdisciplinary Methods:

Cross-disciplinary modelling methods are to be implemented and a model to be developed considering technical, social, economic and financial dimensions. The final loophole and potential priority of future V2G research are to develop in the direction of interdisciplinary and multidisciplinary efforts. Technology, finance, social ecology and personal/behaviour related are the four important categories between which relations can be drawn. The widely considered connection is between technical- and finance-related aspects or between V2G technical and economic evaluations. Few studies include both complex behavioural models and technical, economic or ecological models. As mentioned above, V2G modelling research usually relies on some type of modelling and discipline and makes assumptions on consumers such as vehicle usage rates, participation pattern and PEV adoption rates of PEV owners. Often, there is little or no recorded evidence to validate the assumptions. In some cases, greater integration (and better understanding) can be achieved by using more than one method. For example, although optimization models dominate V2G modelling, energy economic 'simulation' models can be implemented to represent the task of stakeholders and the customers in a given political context, while taking into account their preferences and views [20]. One innovation is to directly combine the empirical results of surveys and interviews with the V2G participation model to model the technical, economic and ecological impact of these systems. The study depends on endogenous and consumer-informed views on PEV purchasing behaviour and V2G share and optimisation models representing the power grid. More comprehensive research study is needed that also adds an overall institutional component to describe the transformative system-level interruption that is an obstacle for the transition to V2G.

8.4 Conclusions

In short, moving to V2G can bring many benefits to the community. Convincingly transform the vehicle from the centre of the traffic problem to part of the solution. This transformation has enabled the EVs to increase the efficiency of grid along with increasing the profits to the power company. With PHEVs, there is a reduction in greenhouse gas emissions, adaptation to low emissions of CO_2 energy and it is cost-effective for owners, drivers and other users. However this transition is quite difficult as it must face many obstacles related to technical aspects such as vehicle subsystems, batteries, configurations, and communication systems, financial aspects such as purchase prices and the negative environmental impact of initial costs. Behavioural problems, including discomfort, self-confidence, confusion and fear of hierarchy. In addition, the net impact of a V2G system may depend on which goals are prioritised; for example, a V2G system that cannot guarantee minimisation of costs will reduce environmental impact, especially when politics has not yet considered negative external environmental impacts. Therefore, when we consider the future prospects of converting to V2G, we must not only consider vehicle structure/configuration, batteries, vehicles, and power plants but also the entire social technology system. We need to expand the research agenda of V2G to examine more cases, overcome transformative errors, understand user complexity and apply interdisciplinary and hybrid methods. If we accept the choice of cars for reasons other than 'rational' or 'technical', then the direction of transportation research and development aimed at promoting new modes of transportation must undergo tremendous changes. Although billions of dollars have been invested in R&D, procurement, tax relief, grants, regulations and grants, there are many obstacles and more sustainable modes of transportation. As long as the barriers are addressed in such a way that researchers, scientists and engineers overcome the challenges, the prospects for new transportation or energy systems like the extensive and socially beneficial V2G program will continue to exist. The stakeholders' involvements, their values, expectations and roles are all very essential parameters to obtain an improved technology for determining the V2G services.

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