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Review

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A comprehensive review on electric vehicles: charging and control techniques, electric vehicle-grid integration

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Abstract: Energy consumption in the field of transportation comes next to industrial consumption worldwide. If transportation is completely powered by renewable energy, the utilization of fossil fuels can be drastically reduced, which will result in a lesser amount of greenhouse gas emissions. Electric vehicles (EVs) can act as an alternative to make transportation pollution-free. Large-scale usage of EVs causes high electricity demand on the supply system. This problem can be overcome by utilizing renewable energy sources (RESs) for Electric Vehicle charging. Due to the unpredictability of RESs, coordinating EV charging with other loads and renewable generation is problematic. By using EVs as energy units, power fluctuations in the electric grid can be compensated. This paper presents a summary of recent research in the domain of integration of electric vehicles (EVs) to the smart grid. Electric vehicles-smart grid integrated systems face several issues related to communication, grid infrastructure and control in the future power system. Smart grid technologies are summarized in Section 2. The existing research articles in this area are classified into two based on the purpose: EVs integration into the electric grid and Vehicle to grid services. Finally, the research gaps and future scope of incorporating electric vehicles with renewable energy sources and the Smart grid are highlighted.

Keywords: charging techniques; control techniques; electric vehicles; EV-grid integration.

Introduction

Growing concern of carbon dioxide emissions, greenhouse effects and rapid depletion of fossil fuels raise the necessity to produce and adopt new eco-friendly sustainable alternatives to the internal combustion engine (ICE) driven vehicles. In order to assure a sustainable environment, dwindling fossil fuel reserves, global warming, and greenhouse gas (GHG) emissions must all be addressed. Transportation electrification is considered as a viable solution because the transportation industry is the second largest contributor to harmful emissions. EV technology has been around for about a century, with a commercial peak around the year 1900.

The progress of electric vehicles is depicted in Figure 1. Transportation electrification lowered reliance on petroleum imports, thereby improving energy security. Due to issues like high initial investment, battery deterioration, limited charging facilities, range anxiety, and so on, the adoption rate of electric vehicles is still slow (Asaad et al. 2018). Governments throughout the world have launched a number of plans and incentives to stimulate the use of electric vehicles and accomplish a complete transition to electric transportation. According to the publication "Global EV Outlook" by the International Energy Agency, the electric vehicles may count upto 130 million by the end of 2030 (Bunsen et al. 2018).

Electric Vehicles are moving single-phase loads. As a result, they can be connected to distribution networks at any of the three phases. As a result, one phase's electrical components, such as a transformer, overhead line, or power supply cable, may be overloaded when compared to the remaining two phases, which are unloaded (Mohammad, Zamora, and Lie 2020). Because EVs are unpredictable in terms of timing, handling them as new loads while maintaining grid reliability and security is a challenge. EV home charging and residential load peaks occur at the same time, producing extra system peaks. EVs consume comparatively high power from the grid during charging. Therefore, uncoordinated charging of a large

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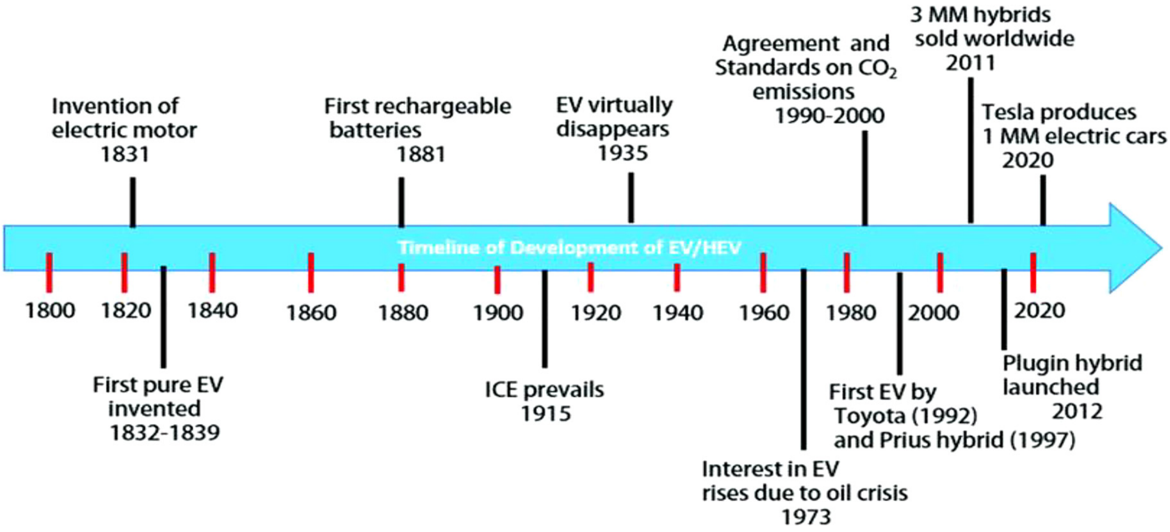

Figure 1: Development of electric vehicles (EVs).

number of EVs can have an adverse impact on the grid operation (power outages, unacceptable voltage fluctuations). To handle the peak demand of EVs, one possible solution can be to ramp up the power generation; however, this will lead to significant infrastructure cost. As an alternative cost-effective solution, smart grid allows EVs to coordinate their charging operations, which can improve frequency regulation (Mohammad, Zamora, and Lie 2020), smooth out intermittent power generation from RESs, and make the electric power usage efficient.

The conventional power industry based on fossil fuels is another significant source of harmful pollutants. Renewable sources (RES) like solar and wind are widely employed to reduce emissions in the power industry. Renewable energy's uncertainty, which is influenced by location, time, weather and other factors, causes voltage instability and grid reliability issues, necessitating the utilization of an energy storage system (ESS) (Jordehi 2019). Furthermore, the benefits of reduced emissions caused by electric transportation cannot be evaluated if non-renewable sources are used for EV charging. EVs have been shown to produce more emissions in regions where fossil fuels are the primary source of energy (Woo, Choi, and Ahn 2017). Using RES to charge electric vehicles reduces GHG emissions (Saber and Venayagamoorthy 2010). Several publications in the literature have looked at the connection between the EV–PV system and the distribution network. Fachrizal et al. (2020) examines charging electric vehicles with solar power, with an emphasis on control systems and algorithms, as well as the economic background. Yong et al. (2015) discusses the influence of EV charging circuits on power quality and the grid. Ahmadian, Mohammadi-Ivatloo, and Elkamel (2020) provides an overview of EV modelling strategies, with a focus on EV load and charging station modelling.

The following is about the organization of the paper: Section 2 gives a description of different charging techniques used in electric vehicles. Section 3 explains control techniques used for driving electric vehicles. The incorporation of EVs into the electric grid is explained in Section 4. Section 5 explains open issues and research directions.

Charging techniques

Electric vehicle batteries can be charged through conductive or inductive methods. Inductive charger are wireless charging systems (WCS). WCS can be stationary, which means that they can only be utilized when the car is parked or in stationary modes, such as in car parks, garages, or at traffic signals, or they can be dynamic. This latter method allows battery charging while the vehicle is in motion. In general, WCS can bring some advantages in the form of aesthetic quality, reliability, durability and user friendliness. Anyway, due to some challenges such as electromagnetic compatibility (EMC) issues, limited power transfer, bulky and expensive structures, shorter range, and lower efficiency, inductive chargers are not largely commercialized and employed as the conductive ones. Battery chargers can be implemented inside (on-board) or outside (of-board) the vehicle (Morris et al. 2020). Figure 2 shows the typical architecture of an electric vehicle charging system.

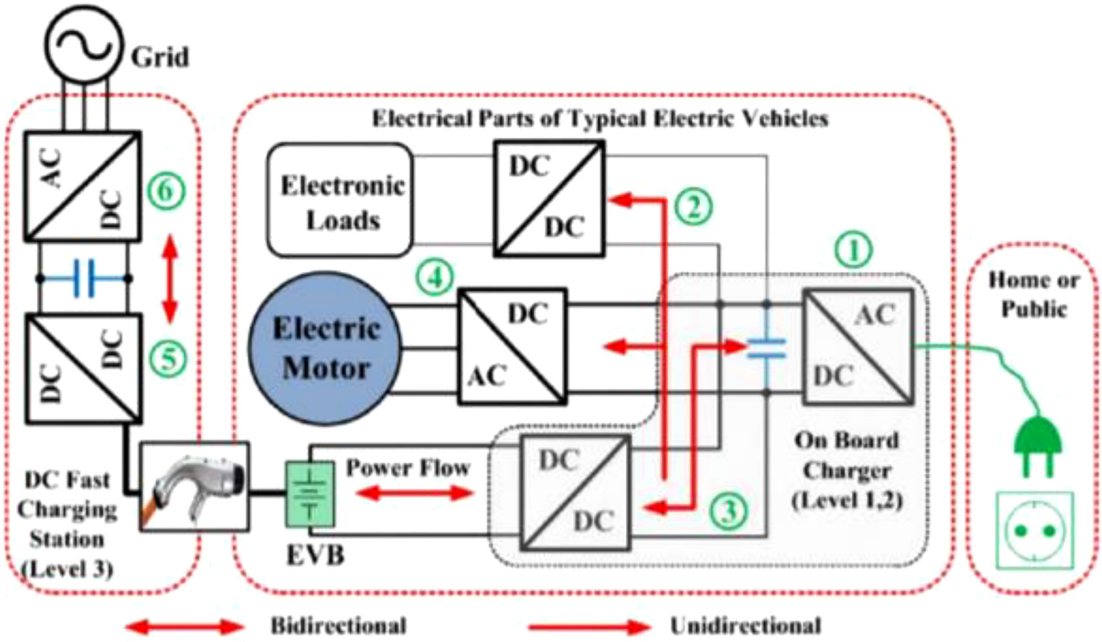

Figure 2: Charging system configuration for electric vehicle.

Onboard charger

Onboard battery chargers (OBC) are limited by size, weight and volume, for this reason they are usually compatible with level 1 and level 2 chargers. They usually have unidirectional power transfer capability; nevertheless, in some cases, a bidirectional power transfer can be achieved. Onboard chargers are typically composed of two stages: a front-end AC–DC stage and a back-end DC–DC stage. Different topologies are proposed in literature for both the converters. The front-end rectifier usually contains a boost power factor correction (PFC) converter to achieve high power factor and low harmonic distortion. The rectifier stage can be performed by a half-bridge, full-bridge or multilevel diode bridge. A full-bridge rectifier with interleaved PFC boost converter is shown in Figure 3.

If the ac–dc rectifier is combined with the dc-dc converter, a single stage battery charger is obtained. This topology of battery charger is used if lower cost and size are required, in fact single stage battery charger allows the elimination of some bulky and expensive components such as inductors and dc-link capacitors which instead are required in two-stage charger. However, the drawback is that single stage battery chargers with non-isolated converter suffer from a limited conversion ratio, which limits their application for the wide range of output voltage.

To maximize the reduction of components number and hence to further reduce the size, weight and cost of the battery charger several integrated topologies have been proposed and studied. The concept of integration consists of reusing some of the drivetrain components (inverter and motor windings) to implement the onboard charging system. However, some problems may be derived from this combination: like, access required to inaccessible points of the motor windings, and rearrangement of the motor windings required during the transition between different operation modes.

The last type of proposed OBC is the so called multi-functional OBCs. In this type of battery charger some components are shared to accomplish different aims. In this way higher fuel efficiency can be reached by smaller and lighter design. The multifunctional battery charger can charge the auxiliary battery via the propulsion battery when the vehicle is in a driving state, acting in this way as an OBC and as low-voltage dc-to-dc converter (LDC) jointly.

Off-board charger

The off-board charging system is most commonly composed of two stages: a grid-facing AC/DC converter followed by a DC/DC converter providing an interface to

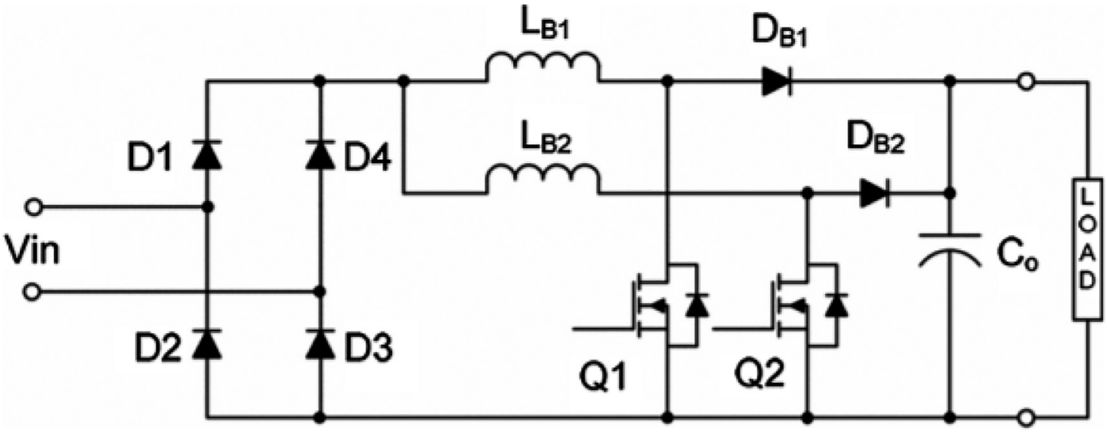

Figure 3: Full-bridge rectifier with interleaved PFC boost converter.

EV battery. Based on the converter topology, both these stages can allow unidirectional or bidirectional power flow. One of the most widely used bidirectional AC/DC converter is the three-phase LCL active rectifier. The advantages of this type of converter are low harmonic input currents, bidirectional power fow and power factor (PF) regulation. The frontend ac–dc conversion is performed by a neutral-point-clamped (NPC) three-phase three level converter. This converter has been used to increase the power density and to achieve low current harmonics distortion. Another advantage is that it allows the creation of a bipolar dc bus which can be used for the implementation of partial-power converters.

The most common unidirectional AC/DC converter used in off-board charging system is the Vienna rectifier. It has advantages such as low voltage stress on each switch and high efficiency. However, the main limitations are the restricted reactive power control and the need of a dc-link capacitor voltage balancing.

The main isolated DC/DC converter used in case of bidirectional power flow is the dual active bridge (DAB) shown in Figure 4, and its variants. In particular, this topology is gaining interest due to the capabilities of the new wide-bandgap semiconductor (Gan/SiC) devices which enabled the converter efficiency and power density improvements.

Control techniques

The electric vehicle controller is the electronics package that operates between the batteries and the motor to control the electric vehicle's speed and acceleration much like a carburettor does in a gasoline-powered vehicle. The controller transforms the battery's direct current into alternating current (for AC motors only) and regulates the energy flow from the battery. Unlike the carburettor, the controller will also reverse the motor rotation (so the vehicle can go in reverse), and convert the motor to a generator (so that the kinetic energy of motion can be used to recharge the battery when the brake is applied) (Haddoun et al. 2007).

In the early electric vehicles with DC motors, a simple variable-resistor-type controller controlled the acceleration and speed of the vehicle. With this type of controller, full current and power was drawn from the battery all of the

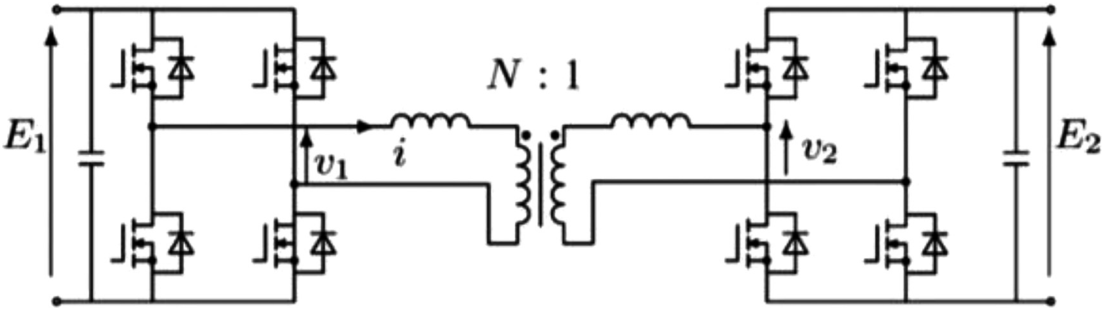

Figure 4: Dual active bridge converter.

time. At slow speeds, when full power was not needed, a high resistance was used to reduce the current to the motor. With this type of system, a large percentage of the energy from the battery was wasted as an energy loss in the resistor. The only time that all of the available power was used was at high speeds.

Modern controllers adjust speed and acceleration by an electronic process called pulse width modulation. Switching devices such as silicon-controlled rectifiers rapidly interrupt the electricity flow to the motor. High power (high speed and/or acceleration) is achieved when the turn off intervals are short. Low power (low speed and/or acceleration) occurs when the turn off intervals are longer. The controllers on most vehicles also have a system for regenerative braking. Regenerative braking is a process by which the motor is used as a generator to recharge the batteries when the vehicle is slowing down. During regenerative braking, some of the kinetic energy normally absorbed by the brakes and turned into heat is converted to electricity by the motor/controller and is used to re-charge the batteries. Regenerative braking not only increases the range of an electric vehicle by 5–10%, it also decreases brake wear and reduces maintenance cost. Figure 5 shows a universal framework for electric vehicle controller.

Integration of electric vehicle with grid

Incorporating a large number of electric vehicles into the power grid is a massive problem that will require comprehensive investigation and monitoring in view of economic effects, control, and operation benefits under ideal circumstances. Many studies have examined the effect of electric vehicles on the power system (Green, Wang, and Alam 2011), while others have examined specialized applications. Figure 6 displays a grid-connected electric vehicle (EV). V2G is a technique that permits bidirectional energy flow between the grid and electric vehicles. A transition from unidirectional to bidirectional mode was seen in the modelling of EV connection with the distribution network.

The concomitant technical issues of EV penetration, such as greater system cost, system imbalance, poor stability, as well as power quality, are becoming increasingly visible as a result of rising energy and demand. The G2V mode (unidirectional approach) has been investigated in the literature in terms of smart charging (Su, Lie, and Zamora 2019), safety (Chung et al. 2013), and control

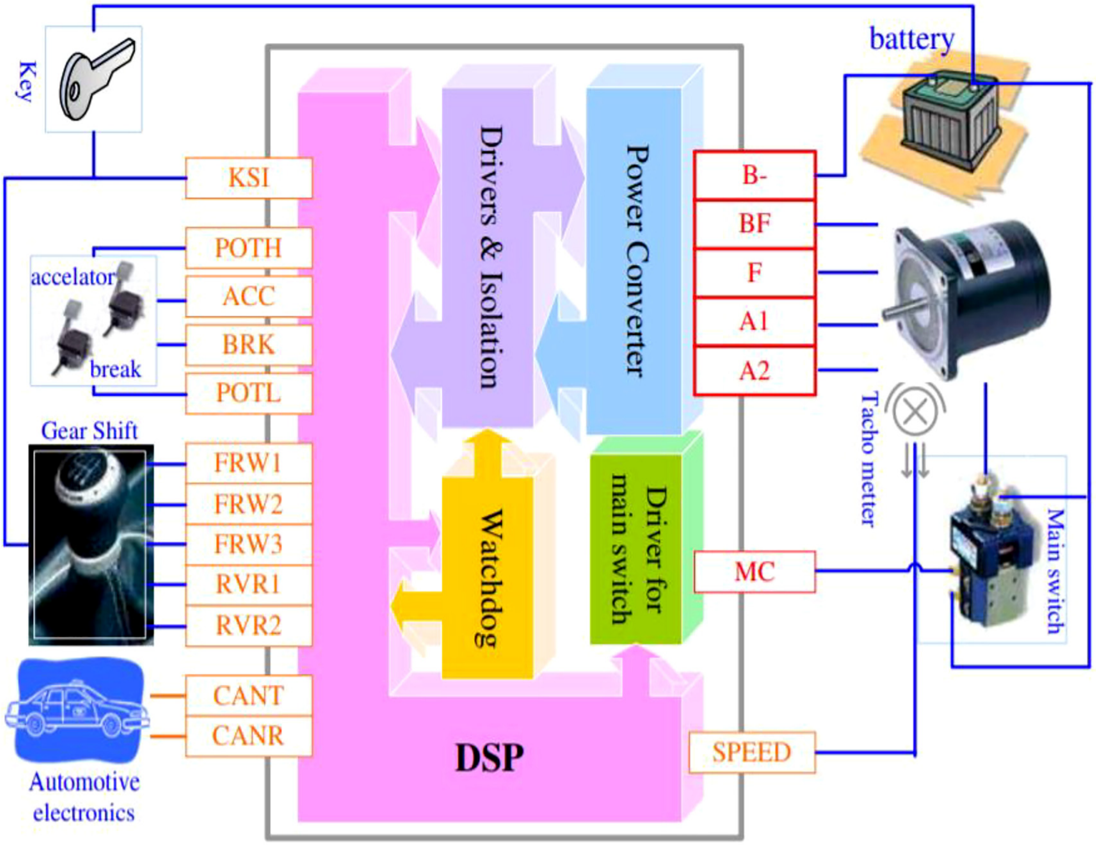

Figure 5: Model of electric vehicle controller.

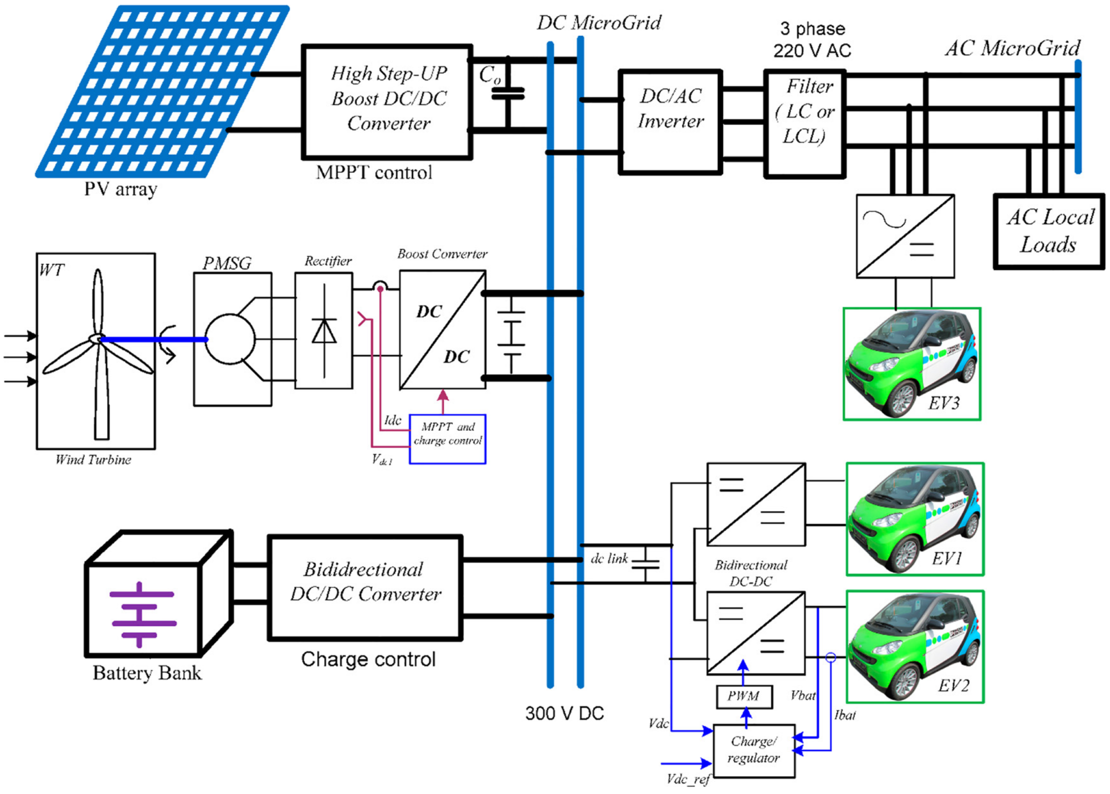

Figure 6: EV integration with the electric grid.

features (Zheng et al. 2019). These studies aim to lower charging costs (He, Venkatesh, and Guan 2012) or the effect on the distribution system (Hu et al. 2013).

In reversible mode, electric vehicles serve as a grid load as well as a distributed generating and storage system. Peak load shaving, or storing energy in electric vehicle batteries and sending it back to the utility at peak periods, is a concept that has been around for a while. Because each electric vehicle has a small battery, coordinating the charging and discharging procedures is a major challenge in making them act as a storage system.

Previously, V2G simply entailed energy transmission from electric vehicles to the distribution infrastructure. V2H and V2V, on the other hand, are two novel energy transfer modes that have emerged as a result of technological advancements.

As a result, the transfer of energy from an EV can now be divided into three categories:

A. Vehicle-to-grid (V2G): Transfer of energy from EV to the power grid.
B. Vehicle-to-home/building (V2H/V2B): Transfer of energy from EV to home/building.
C. Vehicle-to-vehicle (V2V): Transfer of energy from one EV to another EV.

Comparison of V2G, V2H and V2V schemes based on their features and functions is given in Table 1.

Charging of EVs using renewable energy sources and grid

The benefits of Electric Vehicle charging systems using photovoltaic panels have been examined in several research. Denholm, Kuss, and Margolis (2013) states the benefits of charging electric vehicles using solar energy, demonstrating that it allows for greater PV and EV penetration. Excess PV generation can also be mitigated by electric vehicles (Kempton and Tomić 2005). According to Tulpule et al. (2013), charging electric vehicles using solar panels is more cost-effective and emits a lesser amount of CO_2 than grid charging. In Kempton and Tomić (2005), the utilization of solar energy and the deployment of electric vehicles as energy storage units to reduce grid peak loads is considered. These studies show why Electric Vehicle charging using solar energy is preferable to grid-based EV charging (Nunes, Farias, and Brito 2015). All of the research in the field of smart charging concentrates on particular aspects of Electric Vehicle grid integration, such as slow/fast charging, market involvement, and auxiliary services.

Table 1: Comparison of V2G, V2H and V2V.

	V2G	V2H	V2V
Features	Large no. of EVs	A single EV to a single home	Multiple EVs
	Offering power services through the power grid	Most simple, least flexible	Power exchange within the local grid
	Least simple, most flexible	Simple infrastructure requirements and negligible transmission losses	Less simple, Less Flexible
	Complex control	Easy instalment	Uncomplicated infrastructure requirements and small transmission losses
	High infrastructure complexity and significant transmission losses	Operation in Home grid	Operation in community grid
	Operation in large scale		
Functions	Act as energy sources to provide grid ancillary services	Act as a home backup generator and a controllable load	Act as energy sources to other local EVs
	Act as controllable loads	Cooperate with domestic electrical devices for load shift	Reduce tariff by trading power within the local grid
	Release excess energy back to the grid at high priced peak time	Sell excess energy back to the grid at high priced peak time	Increase the charging and discharging efficiency of EVs
	Act as distributed storages	Charge energy at less expensive off-peak time	Establish an isolated V2V system
	Provide power for the premise	Contribute to home grid or a microgrid	Coordinate control of EVs
	Coordinate with renewable energies		Reactive power support
	Reactive power support		
	Stabilize the grid for short periods		

Moghaddam et al. (2018) and Mouli et al. (2017) are earlier studies on systems that combine a variety of topics that are often studied separately.

Smart charging, in combination with V2G technology, boosts PV self-consumption while lowering peak demand (Van Der Kam and Van Sark 2015). Unpredictability can be avoided by using sequential charging, which involves dynamically varying the number of Electric Vehicles undergoing constant power charging such that the PV generation is followed by net charging power (Kadar and Varga 2013). In Brenna et al. (2014), numerous examples are investigated to prove that sequential charging outperforms concurrent charging in terms of solar power usage under stochastic conditions.

Integration of renewable energy sources with electric vehicles

The introduction of renewable energy sources (RES) into the power system on a big scale is exciting. These sources, particularly PV solar energy and wind, provide an irregular and uncertain supply of electricity to the existing power infrastructure (International Electrotechnical Commission 2012). The majority of research found that the implementation of wind energy conversion systems (WECS) and photovoltaic solar systems into the power grid is quite realistic (Dallinger, Gerda, and Wietschel 2013). However, deploying stationary energy storage systems (ESS) or regulated dispatch loads (Battke et al. 2013) is a viable method for balancing the RES based power generation on the grid. When the power generation is excess, stationary energy storage devices absorb the electricity and supply it when the power generation is low (Mwasilu et al. 2014). EVs can consume excess energy produced by RES through various charging systems, or they can contribute energy to the grid during times of low energy production, thereby levelling grid operations (Richardson 2013). According to Saber and Venayagamoorthy (2011), a feasible solution for maintaining energy security can be obtained by adding Renewable Energy Sources and adopting EVs that can supply V2G services. The integration of PV sources and wind into the electricity system with EVs is depicted in Figure 7. In the V2G mode, the electric vehicles are assembled at a charging station and used to decrease power variations from these RES.

Feasibility of solar photovoltaic energy integration with EVs

With the growing popularity of electric vehicles, solar PV power is expected to be used for grid support and EV

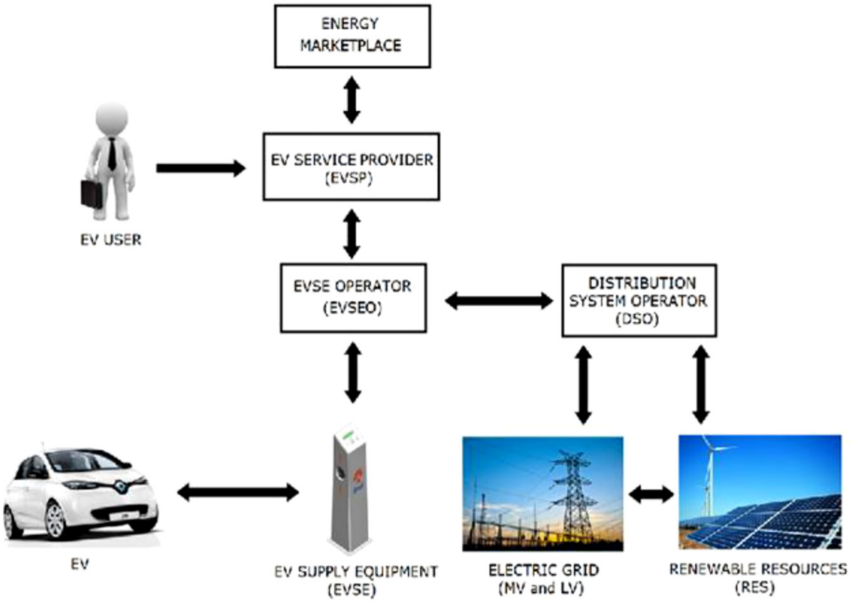

Figure 7: Integration of electric vehicles with renewable energy sources and grid.

charging. The deployment of solar panels on the roofs of parking areas for charging electric vehicles has been demonstrated to be quite exciting in numerous studies (Tulpule et al. 2013). A solar car park charging station with a bidirectional DC to AC power converter linked to the electric grid is shown in Figure 8. The diagram indicates how many charging points can be linked to the power system. Electric vehicles with a bidirectional DC charger, on the other hand, may absorb surplus power and are linked directly to the PV controller. According to Birnnie (2009), the DC electric grid is deemed to be a feasible and appealing solution in the power system architecture in future. It can also return stored power in batteries during peak load periods when solar power availability is low. Traube, Lu, and Maksimovic (2012) describes the research on the widespread use of PV panels on the rooftop and electric vehicles. Through V2G services, EVs can minimise the strain on the power distribution system. Derakhshandeh et al. (2013) provides a study of using solar panels on automobile parking areas in the Swiss city of Frauenfeld. According to the findings, PV installations on parking areas can meet 15–40% of EV energy requirements in the future (Justo et al. 2013).

Feasibility of wind energy integration with EVs

Wind farm-based energy conversion systems (WECSs) are an established and viable option for generating electricity. Various studies have explored the synergy between WECSs and EVs in various circumstances to determine their influence and viability on the electric grid (Lopes, Almeida, and Soares 2009). Lopes, Almeida, and Soares (2009) investigates the use of electric vehicles in the US energy market to provide subsidiary services and voltage management with WECSs. Borba, Szklo, and Schaeffer (2012) did an interesting analysis on extensive inclusion of renewable energy sources (particularly wind) into the North-eastern Brazil power system utilizing plug-in hybrid electric vehicles between the years 2015 and 2030. Wu et al. (2013) analyzed the massive incorporation of wind energy conversion systems into the microgrid (MG) using PHEVs. Liu et al. (2012) employed a two-stage stochastic unit commitment model that takes into consideration interconnections between thermal power plants, plug-in hybrid electric vehicles, and large-scale wind farms.

Vehicle-to-grid (V2G) services

Electric vehicles' batteries are primarily used for converting electrical energy into mechanical energy for propulsion. Feeding of energy back to the grid to increase grid reliability and stability is an additional feature of V2G (Su et al. 2012). According to Cazzola et al. (2016), by 2030, around 56 million electric vehicles will be actively used on the road, with battery capacity averaging 120 kWh. Since vehicles spend most of their time in parking areas, the SG may make effective use of them when they are parked (Letendre, Denholm, and Lilienthal 2006). The function of V2G in the electrical market, as well as its management concerns, are investigated in order to better understand V2G's prospective applications in the SG (Rajashekara 2013).

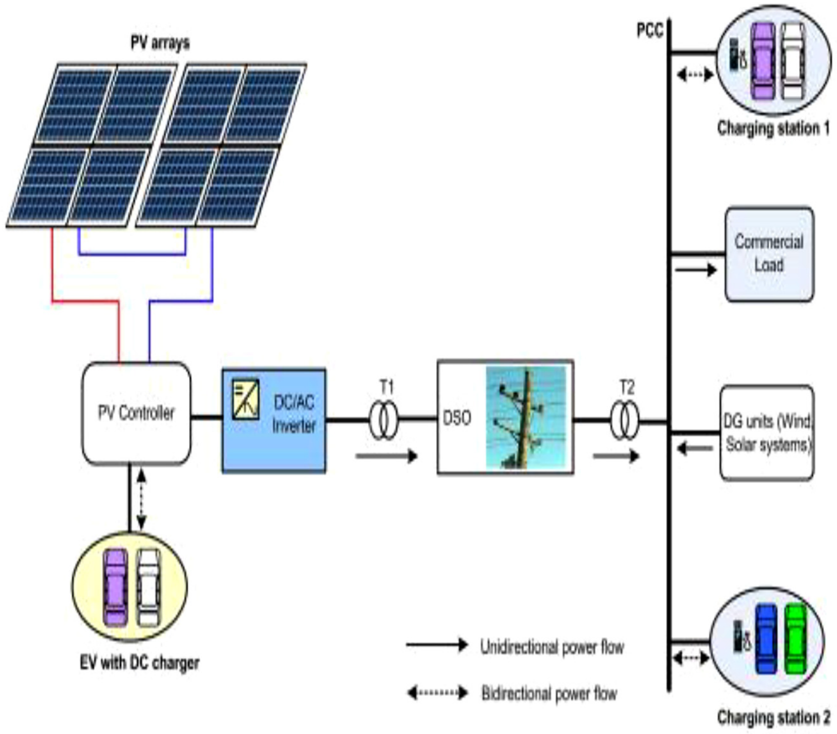

Figure 8: EV charging station with solar-powered grid-connected parking lot.

V2G services – roles and challenges in the electricity market

In terms of control mechanisms, the electrical market is divided into four submarkets: base, spinning reserve, peak power, and regulation markets. However, EVs' movability and range anxiety difficulties may block a seamless role transition from loads to energy prosumers (Chen et al. 2020). When it comes to administering V2G services, the following considerations should be made:

(1) The mobility of EVs adds to the V2G service's unpredictability and potential delay. While the damage can be mitigated in some circumstances through online generations.
(2) For optimal V2G scheduling, electric vehicle depth-of-discharge (DoD) conditions and travel demands should be taken into account.
(3) It's difficult to design data/command communication between the mobile EVs, SG, and AGs, because V2G services have a wide range of energy demands and reaction requirements (Chen et al. 2019a).

Energy management for V2G services

Based on the scheduling purpose, three different models of V2G operation exist. When house appliances are fed from EVs utilising renewable energy sources, vehicle-to-home (V2H) mode is engaged. Vehicle-to-building (V2B) discharging is possible when electric vehicles (EVs) are parked at offices or recreation centres and are getting charged in the parking area. It is obvious that V2G offers a wide variety of services, ranging from a single residential home to a large-scale microgrid.

Demand side management (DSM)

While electric vehicles discharge through aggregators, EV energy can be used to supply variable loads during peak hours, flattening the load profile. In DSM mode, the grid operator typically supervises the EV scheduling from a central location. As a result, V2G scheduling can be regarded as an optimization problem for lowering the scheduling cost.

(1) Load flattening

Load flattening is one of the primary V2G services in DSM. It is done by supplying excess demand with EV energy. Most of the electric vehicles will be in need of this service due to the long duration of peak load. However, the SoC state at the time of each EV's arrival and necessary departure SoC differ, necessitating adjustable scheduling and incentives to encourage them to discharge (Coelho et al. 2016). As a result, the cost of battery utilization is taken into account when determining the scheduling goal (Chen et al. 2019b).

(2) Outage management

When the local grid is under maintenance, electric vehicles can act as energy suppliers. When there is a power outage at home, the primary goal of V2G scheduling is to maintain the continuity of service (Alahyari, Fotuhi-Firuzabad, and Rastegar 2015; Maigha and Crow 2018; Xu and Chung 2016). The use of electric vehicles in outage management is required. The energy requirement can be fulfilled by using a large number of parked EVs (Farzin and Moeini-Aghtaie 2017; Unda et al. 2014) or large-capacity EVs like electric buses (Gao et al. 2017). Electric vehicle involvement has been discovered to reduce power interruption, ensure the regular functioning of an islanded microgrid, and decrease line loss.

RES integration

A high number of RES-DGs can be included in the SG as a green energy supplement to mitigate the effects of increased greenhouse gas emissions. The output variability caused by environment-dependent power generation could jeopardize the system's reliability (Farzin and Moeini-Aghtaie 2017). When connected to the SG and RES, EVs can store excess energy and fill up the energy gap when needed, acting as prospective energy storages that alleviate RES variability. In any residential building, renewable energy sources can be added into the smart grid as a second option, providing end-users with two benefits (Kavousi-Fard, Niknam, and Fotuhi-Firuzabad 2015; Liu et al. 2015a; Shafiq and Al-Awami 2015; Wang et al. 2018). Firstly, employing renewable energy during peak hours minimizes the need for retail electricity, lowering overall electricity costs (Wu et al. 2018). Second, RES assists in the provision of home appliances in the event of a power loss. Retarded demand response could result in wastage of energy for RES placed as a high-power rating farm. EVs can transport renewable energy to the energy required area in such instances (Yi et al. 2014).

Voltage and frequency regulation services

Regulation services are concerned with automated generation control that adjusts the voltage and frequency of the system by balancing demand and supply. The regulation's stochastic nature and time sensitivity make it an ideal market for EVs (Escudero-Garzás, García-Armada, and Seco-Granados 2012). The capacity of V2G to compensate for reactive power was investigated in Buja, Bertoluzzo, and Fontana (2017), with a focus on voltage regulation. Contracts with the SG are frequently required by AGs in order to settle down their service capacity and supply frequency regulation service (Lam, Leung, and Li 2016). Service capacity estimation is a new area of research due to restricted service capacity and EV mobility. Every quarter-hour, an AG model-based estimating approach is employed in Zhang et al. (2017) to keep track of EV frequency control capacity and forecast it. The major goal of a centrally managed scheduling is to maximise EV income (Escudero-Garzás, García-Armada, and Seco-Granados 2012), as the Regulation Up can generate concerns about battery depletion and range anxiety (Janfeshan and Masoum 2017; Karfopoulos, Panourgias, and Hatziargyriou 2016; Madawala and Thrimawithana 2011; Tan and Wang 2017; Wang et al. 2013; Yilmaz and Krein 2012).

Open issues and research directions

Three key open concerns shared by various aspects of interaction of electric vehicles with renewable energy sources are addressed in this segment.

Large scale RESs integration into the grid

There is a substantial distinction between RES-producing facilities and traditional power plants (Liu et al. 2015b). When it comes to integrating RESs into the electricity grid, the differences between them and traditional generators provide significant challenges. Harmonic distortion, fault current, flicker, and voltage control are all issues that affect the local power system. Large-scale penetration of renewable energy sources into conventional power systems may necessitate a gradual overhaul of the power system and its operation methods.

EVs battery utilization for RESs interaction

If there is a surplus of electricity from RESs, it can be stored in an EV battery. The battery of an electric car can be discharged to provide electricity at the time of a power outage. The battery's charging-discharging cycle will be lengthened as a result of this. Almost every electric vehicle on the market today uses lithium-ion batteries. As the number of charging-discharging cycles rises, Li-ion batteries' power and capacity will decline dramatically. The battery's usable life will be shortened as a result.

Feasibility of V2G supporting RESs interaction

V2G technology is not supported by the majority of EVs currently on the market. The fundamental goal of EV adoption in the transportation industry is to phase out internal combustion engines. Some issues must be addressed in detail in order for V2G to be viable. To begin, EVs must have bidirectional power converters and modern communications devices to be able to use the V2G feature. Second, the charging station must include smart charging terminals which can connect with the electric vehicle's control unit. Finally, as the number of electric vehicles (EVs) grows, grid operators' control strategies will get more complex. In V2G, electric vehicles are primarily employed as a source of energy or as a form of energy storage. The distribution of EVs can't be predicted precisely because they're moving. This could cause issues with the power distribution network's ability to schedule energy between EVs, RES, and charging stations.

Conclusion and future work

This paper elaborated different charging techniques and control techniques used in electric vehicles. This research also provided a thorough examination of how electric vehicles interact with smart grid infrastructure. The deployment of electric vehicles for the adoption of renewable sources to the smart grid has also been elaborated. Electric vehicles have been reported to supply subsidiary grid services such as frequency and voltage management, as well as reactive power support, in order to improve operational efficiency, lower power system running costs, and secure the electric grid. With sophisticated communication, control, and metering technologies, the study found that connecting EVs to the smart grid system would be conceivable. More studies are required, however, to support the V2G framework's acceptance over other energy storage methods. The final portion addresses open concerns and future research directions. This review is intended to help academicians and engineers gain a better knowledge of the field's current state and contribute more to it.

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