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Review

Grid-Vehicle-Grid (G2V2G) Efficient Power Transmission: An Overview of Concept, Operations, Benefits, Concerns, and Future Challenges

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Abstract: Electric vehicles (EVs) are proportionally increasing day-by-day with the inclusion of upgraded technology toward considered zero carbon emission efforts. To mitigate greenhouse gas emissions from the transportation sector, grid-to-vehicle (G2V) and vehicle-to-grid (V2G) technologies are getting significant attention nowadays. EVs equipped with modern technology can help to stabilize the power grids through load-balancing topology during peak hours. The improvement in EVs can support the surroundings in numerous ways, such as power grid voltage and frequency regulations, harmonics distortions, accessible solar energy implemented to the grids, and peak load stabilizations. This literature review analyzes G2V and V2G impacts in more depth, namely opportunities, improvements in strategies, operation, control, issues, and new technology adoptions. This paper emphasizes the possibilities of bringing advancements in EV technology, smooth operations between grids and EVs, fast bidirectional charging and discharging scopes, control of grids and EVs structures, issues, benefits, pitfalls, challenges, and recommendations.

Keywords: electric vehicles (EV); vehicle-to-grid (V2G); grid-to-vehicle (G2V); power transmission; energy efficiency

1. Introduction

Power is delivered to the consumer or consumers at home by the power distribution system (PDS), which receives it from the transmission system. Primary and secondary distribution systems are the two main divisions of the PDS. Heavy loads and factories are directly connected to the primary supply grid's 11 kV and 33 kV medium-voltage stages. Secondary distribution systems are utilized in residential market agitation when the voltage is between 400 V and 230 V [1]. To facilitate the flow of electricity, a primary and secondary PDS network are connected and take the shape of a mesh network. A network comprises nodes representing the paths between nodes and aligned branches. Power generation, transmission, and distribution networks have developed. Consumers have been using power from transmission lines through a PDS. There are different voltage levels from generation to consumer points. The power distribution system has primary power distribution and secondary power distribution networks [1–3].

The primary distribution system has 7.2 kV, 11 kV, 33 kV, and 46 kV stages, supplying power directly to higher and industrial loads. Moreover, for household consumers, the secondary power distribution levels are 480 V and 230 V. Power distribution systems deliver electrical energy from the distribution substation to the service-entrance equipment at residential, commercial, and industrial consumer facilities. Most distribution systems in the United States operate at primary voltages between 12.5 and 24.9 kV. Some operate at 34.5 kV [4]. Distribution transformers convert the primary voltage to the secondary, consumer-required voltage level according to applications. The industry uses standard distribution system voltages between the secondary and 34.5 kV [4]. For instance, many power companies have standardized distribution at 12.5 kV to 25 kV. Additionally, some distribution companies use 13.2 kV, 13.8 kV, 14.4 kV, 20 kV, etc. [4]. There are several areas still using 4.16 kV systems. These lower-voltage distribution systems are quickly phased out due to their high losses and short distance capabilities. Table 1 shows the various voltage distribution systems commonly used in North America. This can vary with other companies according to their designation system voltage levels.

Table 1. Typical distribution voltage in North America from grid networks [4].

System Voltage	Voltage Class	Nominal Voltage (kV)	Voltage Category
Secondary	Under 600	0.120/0.240/0.208 0.277/0.480	Low Voltage (LV)
Distribution	601–7200	2.4–4.16	Medium Voltage (MV)
Distribution or Sub-transmission	13,800 15,000 25,000 34,500 46,000	-	High Voltage (HV)

A common grid connection, called an interconnected grid, is established for both primary and secondary consumers for smooth electricity flow. Due to these various voltage stages, many substations have been built for the required voltage levels. Power distribution networks and infrastructure have been proposed and implemented in this research. Specifically, plug-in electric vehicles (PEVs) and hybrid plug-in electric vehicles (HPEVs) have been developed and become omnipotent around the modern world due to the concern of fossil fuel, increasing energy prices, protection of energy resources, expanding business, and growing customer demand [5]. Therefore, the PEVs and PHEVs are not prevalent yet because of constraints and visible obstacles, such as lack of required vehicle parts, technological restraints, barriers from society, and higher expenses compared to traditional, recently developed internal combustion engine (ICE) vehicles [6]. Recently, hybrid electric vehicles (HEVs) and traditional internal combustion engine (ICEs) vehicles have been manufactured abundantly by the industry worldwide and have presented more advantages accordingly. In the recent research, the grid or power distribution networks showed that PEVs could behave as a vehicle-to-grid (V2G) technology during plug-in conditions [7,8]. Much more research has been conducted to develop the PEVs for higher efficiencies and integrate the grid into vehicles and vice versa into the current power distribution networks. A case study was run for the smart charging of electric vehicles with photovoltaic power and vehicle-to-grid technology in a microgrid (MG). A suggested method aims to improve the multi-MG system's survivability while maintaining MG functionality. The existing EVs in MGs can be used to boost the resilience of MGs, increasing profit for EV owners without adding new costs to MG operators [9,10]. Additionally, with no direct power connectivity between the MGs, the suggested algorithm may deliver electricity to islanded

MGs so that they can withstand critical loads. In recent work, [11] built and used various solar-spectrum-irradiance-modeling models and datasets to estimate PV power output. The power extracted from EVs can be similarly applied to grid power systems. A novel optimization approach and a bidirectional charging station were presented to charge PHEVs to address the electricity system's voltage and frequency control issue. They describe an accurate continuous charging control technique for PHEVs that considers the battery's state of charge (SoC), which simultaneously regulates the voltage and frequency. According to the described strategy, when various events occur throughout the day, it may concurrently control the battery charger connected to the grid and regulate the frequency and voltage of the power grid throughout the charging time. In that article, the simulation result proved that the control strategy could coordinate with plug-in hybrid vehicle integrations, reduce peak demand, and improve power quality. Numerous advancements in the development and integration of renewable energy sources (RESs) and battery energy storage systems (ESS) have been produced during the past 11 years, and this has encouraged a great deal of research and further breakthroughs [12]. Over the past few decades, substantial advancements in ESSs with electric power generation have influenced new approaches, investigations, and potential advancement for energy storage (ES) technologies. To create a hybrid power system, a statistical method of all expertise channels using statistical and mathematical methods of hydrogen ESS was shown in [13]. The evolution of earlier battery management systems (BMS) was also analyzed, along with a multidimensional architecture design for advanced BMS that comprises three progressive layers. The algorithm layer sought to give a thorough understanding of the power application server and maintained a safe and effective rechargeable battery by effective monitoring, and the fundamental level concentrated on the physical basis and theories of the system. An extensive review of each layer was provided from an engineering and academic perspective. A comprehensive review of different intelligent approaches and control schemes of the battery management system in electric vehicle applications was delivered in [14], which examined the accuracy, configuration, structure, features, benefits, and drawbacks of the intelligent battery state estimation algorithms. This study identified a few significant issues, difficulties with computing complexities and implementation constraints, and several internal and external aspects. In articles [15–17], EV charging and EV interconnection between grids were more challenging at the state of charge and discharge conditions. The stability of the power system was impacted significantly since the power quality, voltage distortions, frequency, and harmonics fluctuated during the incorporation of EVs with grids. In addition, battery life span and storage capacity could be reduced due to the frequent physical connection of V2G or G2V. Well-known wireless power transfer (WPT) methods include electromagnetic radiation and capacitive and inductive coupling [18]. The technology of WPT is both ancient and ground-breaking. Near-field WPT techniques are frequently used for charging mobile devices and body area networks. Besides that, WPT technology has considerable power losses despite some of the possibilities of EV charging technology.

According to recent literature reviews, EVs, HEVs, and PHEVs have certain benefits compared to conventional ICE types of vehicles because of the flexibility of the vehicles, energy savings, environmental friendliness, and ease of manufacture. EVs, HEVs, and PHEVs are growing abundantly in cities daily with the rising efficiencies of the current version of EVs and the influence of EV-maker industries [19]. Around the world, more specifically, developed countries have taken the initiative to cut traditional vehicles and introduce EVs to reduce greenhouse gas emissions, oil dependency, climate impacts, environmental hazards, and global warming. For instance, the government has aimed to lead the EVs market and desires to bring all lightweight vehicles to zero emissions by 2025 [20]. For example, the EV demand has been increasing in the United States because of the following factors: environmentally reduced emissions, demand-side subsidies, battery cost declines, charging infrastructure, product quality, and cultural acceptance from the community. The EVs' adoption was increasing worldwide; for example, the global stock of light-duty electric vehicles (LDEVs) exceeded 7.2 million in 2019 [21]. Regarding the rising number of EVs, China, the European Union, and the United States have taken significant steps toward the adaptation of EVs, and they are the most important contributors globally.

Consequently, China, the European Union, and the United States have introduced several jurisdictions and adopted action plans to expand the EV market. For example, China put in place financial subsidies for new EVs; the European Union has reformed new tax schemes; many regions in the United States and Canada have enacted incentives for zero-emission vehicle programs. By 2030, the EV stock is required to increase by 140 million, according to the International Energy Agency [20,22].

Therefore, to improve the quality of the environment, all of the implemented EVs can act as renewable energy resources when incorporated into the grids, which is now a prime desire for scientists and researchers. A grid-connected load-following hybrid PV and small-hydro microgrid with grid-isolated EV charging technology was presented in [23]. In this article [23], decentralized multi-agent smart voltage network reactive power compensation was dynamically regulated and the network limits were monitored based on the node's local measurements. A second-order generalized integrator (SOGI) filter-based synchronous reference frame PLL (SRF-PLL) was represented [24] to enhance steady-state stability in the presence of distorted and imbalanced grids. The natural frequency and damping coefficient, two PLL parameters, were created to lengthen the PLL's locking time to correct high-frequency fluctuations. Whenever load voltage is at its highest throughout the day, the solar system may be able to support hydropower. When irradiation reaches its lowest level, hydropower can be used to recharge the battery. Energy can be generated from the surplus balance output as load points for each EV's charging. Excitation control and maximum power point tracking (MPPT) have been integrated into the photovoltaic (PV) power EV to govern the grid networks [23].

An experimental control technique for EV charging technology has been proposed, consisting of a PV array, converters, a power grid emulator, and a programmable DC electronic load representing a Li-ion battery emulator. During grid interconnections' charging and discharging states, they can act as V2G, G2V, and vehicle-to-home (V2H) technologies. For wireless EV battery charging applications, a three-coil inductive power transfer system has been developed [25]. This research proposed a hybrid model predictive control and perturbation and observation (MPC-P&O)-based double-sided control technique to optimize the efficiency of a three-coil S-S-S compensated wireless battery charging system. The battery's constant-current and constant-voltage (CC-CV) charging algorithms were implemented using PI controllers on the secondary side. The MPC-P&O controller was presented for optimum system efficiency and better dynamic response under load variation and coil misalignment.

Currently, most people from all working classes know that EVs have many positive outcomes for our environment. They are significantly cost-effective compared to traditional existing internal combustion engine (ICE) vehicles and can efficiently work in balance with on-grid networks. During peak hours, grid network electricity consumption is higher; the V2G charging technology should be able to contribute to the grid system smoothly. In theory, the end consumers can stop building new power stations and substation capacity by exploitation of EVs for grid stability, and they can be used as a personal power storage system. The electric cars can participate when emergencies arise by any chance, such as the failure of any feeders, a phase-to-ground fault for any transmission lines, or any bus failures, sudden significant load shifts, tripping of generators, or distribution branches. The EVs can provide grid protection when necessary by minimizing voltage variations with considerable cleaning-time durations. EVs can store energy from the grid and renewable resources and release energy from storage to the grid when needed for the grids [2,26]. Therefore, EVs have become the most convincing technology and easier to utilize, decreasing the dependency on oil use. The EVs reduce the hazardous CO_2 emissions and impacts of global warming and assist us to have an eco-friendly environment. In recent years, we have seen that the V2G system is incredibly incorporated into the power system grid and is a reliable technology. In this developed technology, it is possible to transfer energy bi-directionally;

i.e., energy can be switched from Grids to EVs and vice versa very conveniently. These EVs will ensure more dependable grids for modern-tech society [6,26]. As a result, EVs such as electric battery vehicles (EBVs), PHEVs, and HEVS have numerous advantages over conventional ICE vehicles.

When any car runs simultaneously in two ways, namely in the case of ICEs and EBVs, it is called a hybrid vehicle. Motor vehicles are called PHEVs when they can recharge themselves from the power grid system and store energy in the cell systems. Hence, they can be recognized as PHEVs electrically; that is, called grid-enabled vehicles (GEVs). On the contrary, these vehicles can transfer energy to the grid networks, referred to as V2G operations [27,28]. To summarize, it can be said that PEVs can act as G2V and V2G technologies. Hence, a wide-ranging review of the influences of G2V and V2G technologies was conducted. Primarily, it focused on charging techniques, G2V and V2G operations, control strategies, and challenges. Thus, this review article emphasizes the operation and charging technology, issues, and challenges of G2V and V2G in real-field applications.

The review literature can be summarized below:

- This paper talks about and investigates the G2V and V2G opportunities, improvement strategies, issues, and challenges when they transmit energy bi-directionally at the state of connection of both sides.
- Future prospective turns, operations, applications, and issues of G2V and V2G process flow analyses are run in detail.
- PHEVs, HEVs, charging controllers, operations, control, significant features, upgraded pieces of details, positive and negative sides, and relevant technologies are reviewed.
- The future market for G2V and V2G is to increase adoption widely, and their performance improvements are forecasted based on the review.

2. Review Methodology

This rigorous study was conducted with content analysis. For this literature review, we selected use of the Google Scholar database, covering Research Gate, Scopus, Google Scholar, Web of Science citations, and some websites. The authors used keywords for search-related publications, i.e., G2V, V2G technologies, charging controller, grid systems, charging control systems, EVs, HEVs, PHEVs, bi-directional power flow or transfer, grid networks, smart grids, Power Distribution Networks, and EV Battery management. Initially, more than 460 papers were selected based on several keywords, and we chose the papers based on title, abstract, keyword, literature review, journal scope, and interest. Finally, the authors decided on 160 articles for analysis and identification from reputed journals, conferences, professional websites, and newspaper data.

The achievement of the review is summarized in five sections: first, the general ideas and concepts of electric vehicles (EVs) with hybrid technologies are summarized, containing various production companies, software, and hardware-based study; secondly, the charging control schemes for G2V and V2G technologies and related conditions; thirdly, EV-applicable battery storage performance when connected to the grid systems, i.e., on-grid and off-grid storage testing conditions; fourth, based on the analyzed review, issues and challenges summarized so that researchers can overcome the problems; and lastly, recommendations presented for future improvement, contributing to developing appropriate PHEVs for both G2V and V2G EVs.

3. Electric Vehicle (EVs) Trends with Hybrid Technologies

In the literature review, EV is the overview of all types of electric vehicles. They could be solely or partially powered by the battery. For example, some are combined with conventional ICEs, and some are fully electric with battery power. Therefore, EVs can be categorized in below-following ways:

1. Pure EVs: These EVs are fully powered battery sources and can run up to 200 miles on a single charge. Moreover, almost every car manufacturer offers pure electric vehicles.
2. PHEVs: These EVs have ICE and a battery range of over 10 miles. Typically, the battery range is around 20–30 miles, suitable for short urban journeys. When the battery range is utilized, the vehicle reverts to the full hybrid capability for a higher mileage range.
3. Extended-Range EV: These EVs have a similar configuration to Pure-EVs but with a lessened battery range of 50 miles. However, an ICE-driven generator can improve the mileage range and provides extra miles. Despite having an inbuilt ICE generator that can recharge the battery whenever the charge level dips below a particular threshold, Extended-Range EVs can normally drive up to 150 miles on a single charge.
4. Ultra-low emission vehicles (ULEVs) are any vehicles with low-carbon technologies emitting less than 75 g of CO_2/km from the exhaust. The ULEVs combine ranges from pure and fuel cell EVs (FCEV) to PHEVs and extended-range EVs [29]. The maximum ULEVs on the road use substitute fuels such as hydrogen and electricity to run an EV, where batteries are commonly used as an ESS. The above batteries are usually plugged into a designated charging location or the mains. In contrast, hydrogen vehicles can be refueled at specific refueling stations, similar to refueling a petrol or diesel vehicle.
5. Hydrogen and FCEV: To make a cleaner environment and better air quality for the surroundings, fuel cell electric vehicles are a promising technology that can help to decrease CO_2. FCEVs are relatively new to the UK's EV market; the first models didn't appear until mid-2014. The Automotive Council's Passenger Car Zero Emission Roadmap includes FCEVs as a core component, and its recently released Energy and Fuels Roadmap includes hydrogen as a transportation fuel. The UK H2 Mobility roadmap predicts annual UK FCEV sales of more than 300,000 by 2030, backed by 1150 hydrogen refueling stations (HRSs) offering complete national coverage. In the meantime, 1.6 million of these vehicles may be on the road.

The EV structure in Figure 1 and the development trends of different kinds of electric vehicles are shown in Table 2. It can be easier to control the running cars by adopting electric drive. They run quietly and smoothly and have good acceleration. Those EVs run solely on electricity and do not have a gearbox. Even though PHEVs have a gearbox and can be controlled manually, these vehicles are automatic. The primary goal of EVs is cutting CO_2 per kilometer, which is decreasing significantly with the development of EV technology.

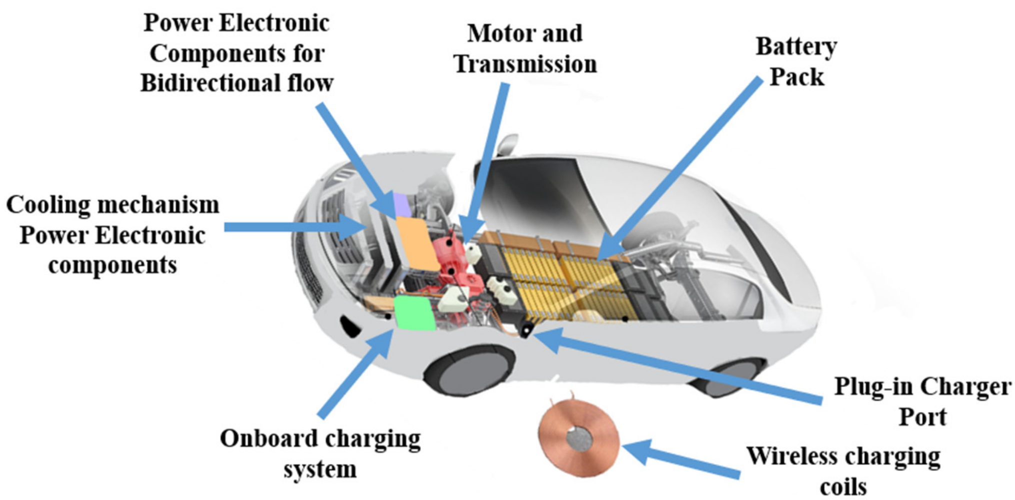

Figure 1. Conceptual EV structure and components.

Table 2. An overview of different vehicles from ICE to EV trends.

Vehicle Types	Specification	Feature	Drawback
Alternative Fuel Vehicle (AFV)	Any vehicle not entirely powered by traditional fuels (i.e., petrol or diesel) is considered an alternative fuel vehicle.	Low emissions, complex structure of drivetrains.	Complex structure of drivetrains, short driving range.
ICE vehicles	When vehicles are solely dependent on fuels such as oil or gas, they are called ICE vehicles.	Can drive on highways and city, reliable and flexible for maintenance.	High carbon emissions, oil-dependent, complex structure of drivetrains.
EV	When a vehicle uses, in part or in full, a battery that can be plugged into the mains for charging.	Zero carbon emission, high energy efficiency.	Battery capacity, driving range, charging facilities.
Pure-Electric vehicles (PEV)	A vehicle powered only by a battery charged from main electrical sources. Currently, typical pure electric cars have a range of about 100 miles.	Ultra-low carbon emission, high energy efficiency, maintains the speed at a different level.	Battery capacity, charging facilities.
PHEV	A vehicle with a plug-in battery and ICE. Typical PHEVs have a pure-electric range of 10–30 miles. After the pure-electric range is used up, the vehicle reverts to the benefits of full hybrid capability.	Medium emissions, good efficiency, can drive on highways and city, reliable.	Oil-dependent, complex structure of drivetrains.
Extended-Range EV	An extended-range EV has a battery and also has an ICE-powered generator inside. Extended-range EVs are similar to pure EVs but have a battery range of about 50 miles. An inbuilt generator increases the range and adds extra kilometers of mobility.	Zero carbon emission, reliable and flexible for maintenance.	Battery capacity, charging facilities.
HEV	A battery and an ICE power a hybrid vehicle.	Medium carbon emissions, can drive on highways and cities with good efficiency, reliability, and flexibility for maintenance.	Complex structure of drivetrains, oil-dependent.
Mild Hybrid	A mild HEV cannot run entirely on batteries or be plugged in. However, it does capture electricity in regenerative braking and utilizes this during acceleration.	Low emissions, can drive on highways and city, good efficiency, reliable and flexible for maintenance.	Complex structure of drivetrains, oil-dependent.
Micro Hybrid	A stop/start mechanism and regenerative braking are frequently used in micro hybrids to recharge the 12 V battery.	Drives in highway and city, good efficiency, reliable and flexible for maintenance.	High carbon emissions, complex structure of drivetrains, oil-dependent.
Stop/Start Hybrid	When the car is stopped, the engine is turned off via a stop/start mechanism. The excessive frequency of engine starts is supported by an improved starter motor.	Drives in highway and city, good efficiency, reliable and flexible for maintenance.	High carbon emissions, complex structure of drivetrains, oil-dependent.
Electric Quadricycle	Similar to how a motorbike or three-wheeled scooter is classified and tested, but this is a four-wheeled vehicle.	Low emissions, drives in highways and city, good efficiency, reliable and flexible for maintenance.	Battery capacity, driving range, charging facilities.

Thus, the current EVs not only reduce CO_2 but are also becoming efficient significantly. The EPA combined mileage has increased immensely with the advancement of the mechanism of current EV technology. The combined performed range seen in city and highway is up to 520 miles (837 km). However, the mileage range generally depends on battery size, conversion process steps, and the capabilities of battery materials.

Recent studies showed that the grid is profitable when PHEVs have established grid connections. The researchers in [30] extensively analyzed G2V and V2G for positive economic outcomes and found significant benefits in their studies. It is beneficial for both parties since the grid owner can take power from EVs during peak energy demand, and EVs can be charged themselves when the grid system is stable enough to release energy. As is depicted in Figure 2, they can successfully transfer energy bi-directionally, which is sensed by control and operation units. They have several energy transmission conversation stages to activate G2V and V2G successfully. They must install a fast bi-directional charging system on-broad or off-board.

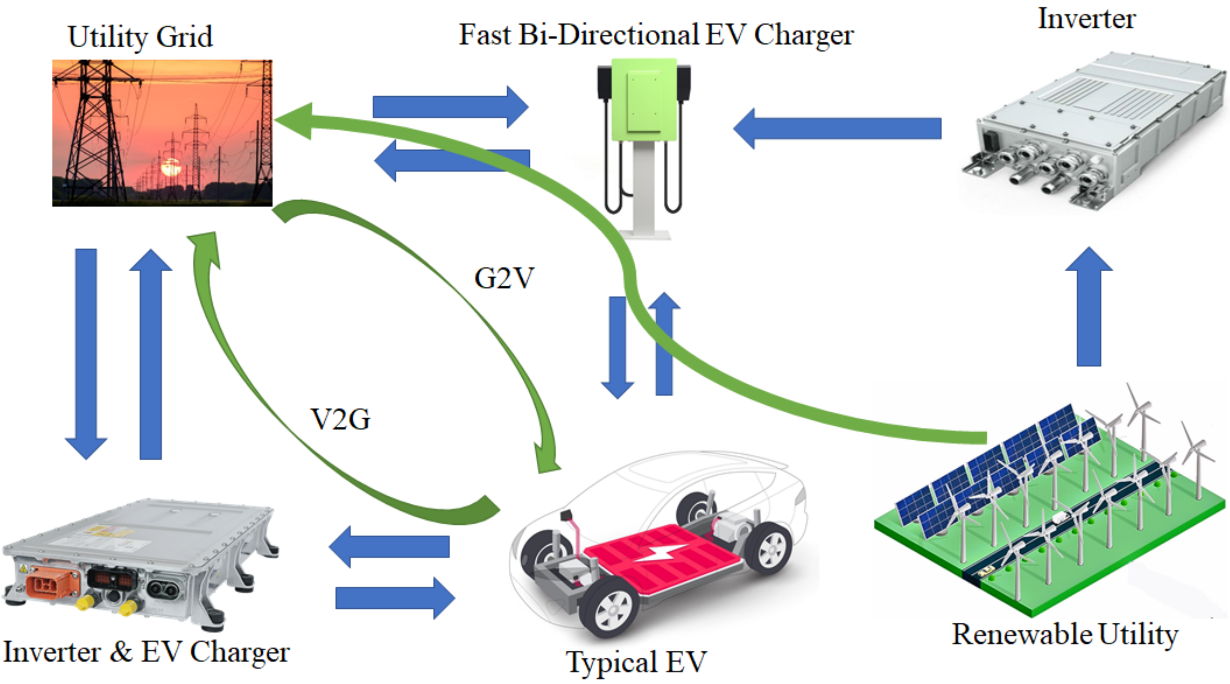

Figure 2. G2V and V2G power flows block diagram.

However, it has been noticed that there is significant power loss during conversation of energy from AC to DC or DC to AC, and it is about 12% to 36% as seen in [31]. As a result, it will be better if the conversation mechanism steps are kept minimal and straightforward. At this point, it is also crucial to implement an accurate, widely certified metering system on the EVs and the grid owners.

4. The Concept of G2V and V2G, System Requirements, and Wireless Energy Transfer

4.1. Bi-Directional Power Flow Concept Realizations

Power distribution outlets and arrangements can charge EVs. Moreover, the running cars themselves can charge the battery packs when desired to do so. The charging system has been improved and can be adopted in two ways: a wired method, such as plug-in, and without a wired connection, such as wirelessly.

The sitting EV battery pack can be charged by sensing the power grid conditions during lower power demands and stopping the charging during consumers' peak hours. PHEVs can run in either a conventional ICE or electric mode. Three significant components should be mandatory for EVs to keep running: (1) energy flow configurations, (2) a control system with communication networks that cooperate with grids, and (3) a digital onboard monitoring system that provides dynamic measurements. The connection between the grid and vehicles is shown schematically in Figure 3. The bi-directional power in Figure 3 can be realized as well. At this point, the question is: how will the signal be controlled between the grid operators and the vehicles? Communication is achieved via a broadcaster or wireless antennas, direct internet links, or power-grid-established network systems. In Figure 4, the communication is completed wirelessly, and a currently updated version of RF transcribing technology can be implemented in this scenario. Recent work in [32] showed that 3D-printed antennas can be mounted on a car's uneven surfaces, if required. Considering the cost and ease of manufacture [33], these RF antennas can be used for wireless communication with grid operators and transcribing of signals between physical charging stations. An idle or sitting car can establish a connection with grids whether it is at home or outside, wirelessly. The research article in [25] implemented a three-coil inductive power transfer system for wireless EV-charging systems. Figure 4 shows a successful interconnection grid diagrams with EVs achieved by plug-in and wirelessly. Therefore, currently developed inductive coil methods are being utilized and can be used for charging and discharging EV batteries, and, consequently, energy transmission can be completed in both directions effectively.

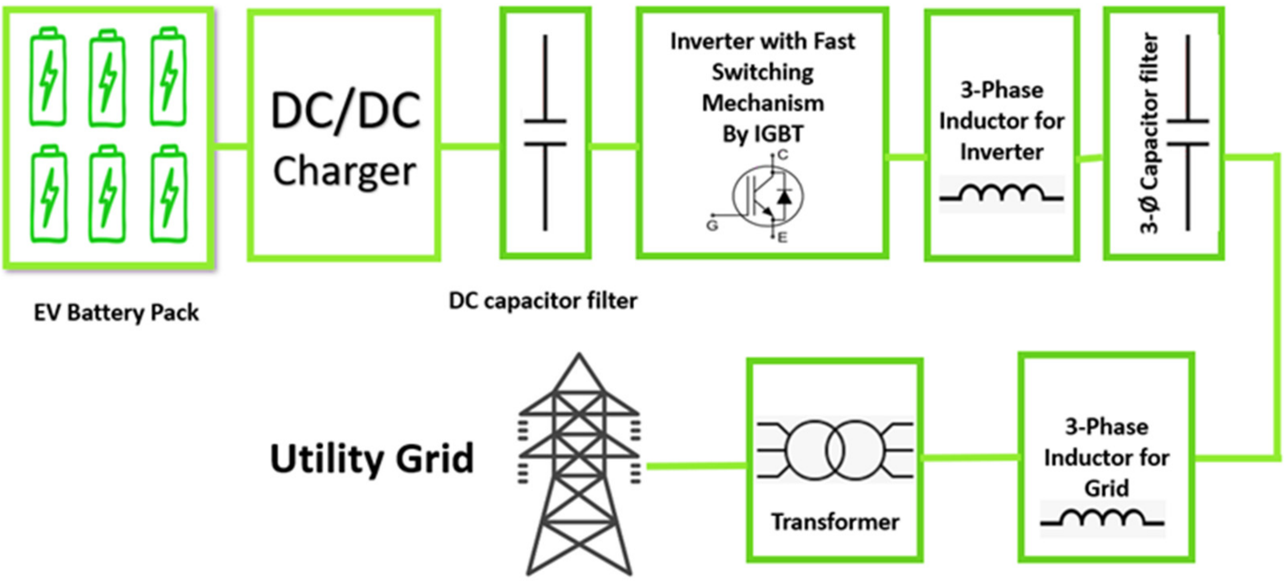

Figure 3. Fast bidirectional charger schematic for EV charging stations.

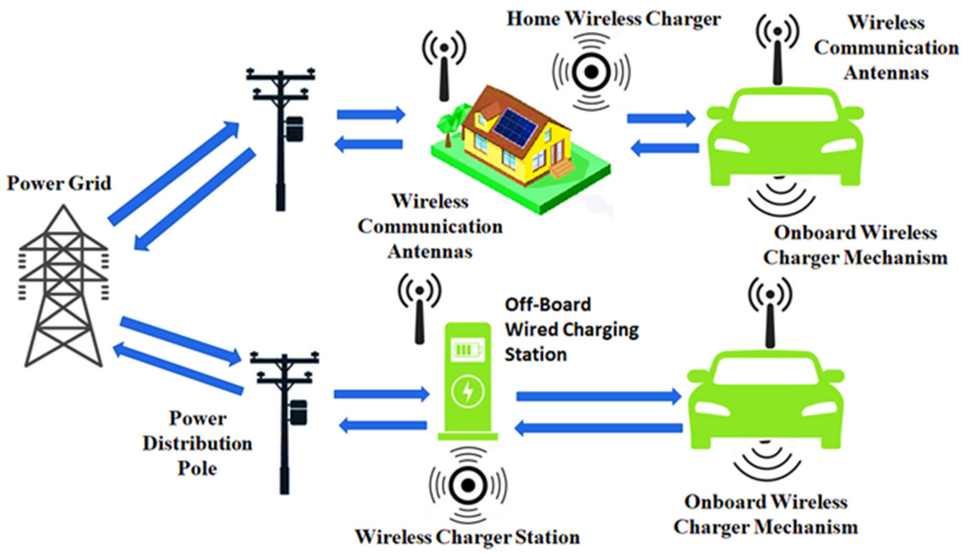

Figure 4. Power distribution line, plug-in, communication control links, and wireless charging technology with the grid.

4.2. Bidirectional Power Transmission Operation Topology

4.2.1. Bidirectional Power Transmission Concept

Bidirectional energy flow concepts are mainly accomplished in three steps. In the first phase, an active power factor adjustment mechanism is required to convert AC from power grids to DC. Secondly, the EVs need an effective bidirectional DC–DC control converter for the higher charging and discharging current transfer in both directions. Finally, during the inverting phase, it is also a prerequisite to provide pure sinusoidal voltage and recent waves for both receiving ends. More attention is required so that the transfer will be clean energy, harmonics-free, distortion-free, and voltage- and frequency-stable. For system upgradation and grid stability, a bidirectional electrolytic capacitor was proposed in [34,35] for PEVs for higher efficiency and grid stability. To enhance the overall system performance, the EVs and the power grids must keep in series to reduce the IGBTs switching losses. In energy storage degradation, battery life is lessened due to bidirectional charging and the discharging characteristics. Considering battery life degradation, a control solution for EVs battery's SOC, which simultaneously controls the frequency and voltage, was introduced in [36–38]. In addition to the above considerations, Bidirectional concepts have conversion losses and meter-setting complexities, and with whole-system adoptions it is challenging to accomplish higher efficiency with bidirectional EVs.

4.2.2. Bidirectional Hardware Strategy Adoption on EVs

Recent research in [39,40] developed a bidirectional battery charger for EVs with two power conversion modes: G2V, a full-bridge AC–DC converter, and V2G, a reversible DC–DC converter. If we look at the depth of the conversion operation, then, at the first mode, for the G2V step, the full-bridge (AC–DC) bidirectional converter acts as a rectifier and the reversible (DC–DC) converter acts as a buck converter. For the V2G step, the full-bridge (AC–DC) bidirectional converter acts as an inverter, and the reversible (DC–DC) converter acts as a boost converter. A bidirectional energy flow conversion schematic operation mode is depicted in Figure 3, where the operation shows that it can transmit power in two directions. Bidirectional power can flow from AC sources to DC sources and vice versa.

In the last few years, it has been seen that researchers develop conversion strategies for EVs that can transmit in two directions. Conversion of bidirectional energy flow for HEV applications was analyzed in [41], and good agreement was reached when transferring voltages from different DC voltage levels. The three-phase charging converter (AC–DC), DC–DC Bi-directional converter, and discharging technique were overviewed in [42] and presented convincing efficiency for PHEVs. Thus, it can be said that EVs can charge and discharge when they are in the parking lot and sitting in idle conditions. Figure 5 illustrates the uni-directional and bi-directional power flow operations for typical EVs, HEVs, and PHEVs. The schematic diagram portrays a detailed directional topology with clean and distortion-free energy conversion attained with filter inclusions.

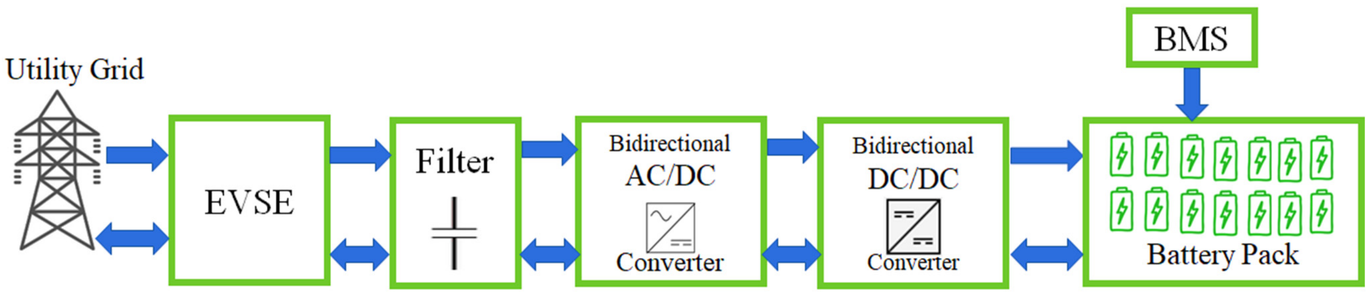

Figure 5. Uni-directional and bi-directional power flow for typical EVs.

In addition, the EVs and the grid's bi-directional power flows have seen numerous benefits and positive outcomes. An "intelligent charging scheduling algorithm (ICSA)" can be implemented in EVs with the adaption of Henry solubility optimization to minimize the average daily price proposed by grid operators [43]. In that article, the authors successfully incorporated the G2V and V2G technology strategy with minimal conversion-steps loss for scheduled charging and discharging EVs.

4.3. G2V and V2G with Wireless Charging Technologies

The fast bi-directional battery charger allows EVs to receive energy from power grids (G2V) and deliver EV energy in reverse to the power grids (V2G) from battery sources during instability in the power grid systems. By realizing the ideas of these bidirectional energy transmissions, EVs can benefit from personal and commercial perspectives, where the small community and national community can benefit from this EV development. This system can power home management, especially in sending priority energy during outages and other crises. From the perspective of power grid owners, EVs can offer positive outcomes to ancillary services and act as a compensator for renewable energy sources (RES) by providing backup, storage, and load shift [44,45]. Therefore, EVs need to be designed with fast bidirectional energy flow capabilities. EVSE must be updated to current technologies, such as EV power exchange equipment (EVPEE) [46]. This EVPEE exchange infrastructure can transmit power from EVs to anything. It is required to introduce fast bidirectional chargers for EVs, making this easy for EV technologies. This can be a fast wireless charger or a wired charger. Day-by-day, EV technology is being upgraded; therefore, it is the right time to adopt fast wireless chargers, including wired charging stations for EVs. The research article in [25] implemented a three-coil inductive power transfer system (IPTS) mechanism for charging EV batteries wirelessly. The grid operator owners and the EV owners can simultaneously or separately build wireless charging spots. Thus, the EV maker can adopt wireless charging options, including wired systems. The EV owner should make charging systems that can charge the EVs with wired plug-ins and wirelessly. On the other hand, grid operators should widely adopt the same charging structures technology so that individual EV owners can power their vehicles when required. A three-phase fast plug-in wired charger can charge EVs and reverse energy flow from EVs to grids.

4.4. Bidirectional Rapid-Charging Node Locations with a Metering System

A charging station can be onboard or off-board technology of EVs. The onboard charging technology is on the EVs, whereas the off-board charging station is on the site of the grid operators. As EVs have increased exponentially in the past few years, the charging stations or nodes multiply similarly. The optimum location for charging EVs was presented in [47], where a 24 h load demand was varied at junction nodes. The corresponding sensitivity indexes were determined throughout this timeframe. In that article, the Newton–Rapson power flow analysis aided in finding the appropriate location for EV charging. Today's EV smart meter is crucial to EVs' metering system. It is essential since it is necessary to calculate the energy flow in and out for EVs. EVs' bi-directional exchange energy transmission information can be measured by Ethernet and Zigbee networks [2]. The bidirectional charger can charge the electric vehicle's batteries and discharge the energy back to the grid networks, and EV owners can make money. A small control module vehicle sensor unit (VSN) [31] has been in research analysis to manage communication with the EVSE and the EV interface. It also helps to optimize the aggregator. These types of characteristics of EVs make them valuable for power grid systems and EV owners. From these practical works, VSL helps to determine the control rate of energy and the direction of energy flow in and out, which the EVs can forecast. In Figure 6, the power electronics unit (PEU) acts on converting the grid AC power to the DC battery voltage and DC storage to AC grid energy. The energy flow and conversion amount can be calculated by the AC and DC meters. Communication can be done with serial cable wired and wireless systems using RF antennas.

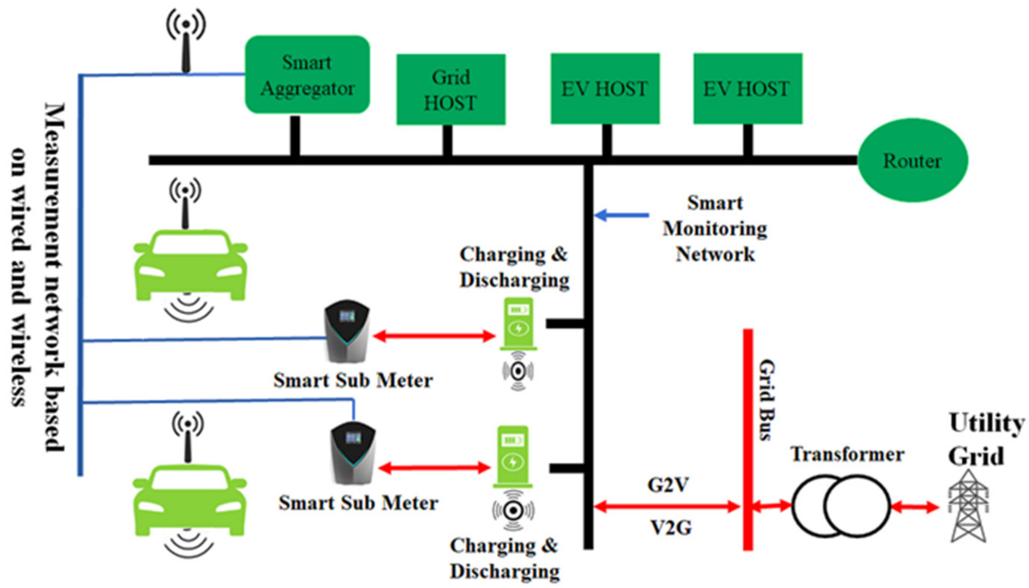

Figure 6. Smart meter architecture for bidirectional energy measurement on EV applications.

4.5. Charging and Discharging System Upgradation for Batteries and Grids System

For electric vehicles, charging and discharging are always burning issues when designing the mechanism for EVs. There is a vast amount of research and development work going on with EVs, and charging and discharging components for EVs are always a prime concern. There is a target for EV manufacturers to consider a fast, efficient, robust charger for the current plug-in and wireless EVs. In recent times, low charging times for EVs have been pushed to increased priority to make high-power charging (HPC). In the research of [48], the authors developed a comprehensive mathematical framework for modeling and quantifying GWP footprints for HPC. However, it has been tenacious work to develop fast bidirectional EV chargers until now, and researchers have a very promising charger for dual-mode bidirectional energy transmission.

On the other hand, it is necessary to build charging stations commercially and individually to tackle the increasing number of modern EVs. Guidelines for the optimal scheduling of large-scale EVs connected to the grid have been portrayed [49]. A research group investigated regulation, future-proof charging stations for a residential structure, and analyzing and minimizing the effects of nearly 100% e-mobility in personal vehicle transportation on the power grid [50]. The proposed dynamic charge management successfully changes the charging timings and reduces the power generation needed for BEV charging, avoiding grid peaks.

5. G2V and V2G Control Systems and Applications in Distribution Networks

5.1. Bidirectional Power Flow Control Systems

As the bidirectional charger works in two directions, it has two stages: one side is connected to the grids, and the other is connected to vehicles. The first phase is called the bidirectional ac–dc converter, and the other phase is called the dc–dc converter control to help charge the battery and discharge the EV battery. As a result, during the conversion stages, it is required to provide smooth dc to batteries and a pure sinusoidal pattern during the return of the power to grids. These steps must ensure conversion control techniques to accomplish the bi-directional power flow. In [51], an efficient and accurate bidirectional charging control strategy considers the battery's SoC, simultaneous frequency, and voltage regulation for the PHEV. A bi-directional fast DC charging station with novel control topology is proposed to solve the unitability and voltage drop on the grid. The authors presented a new constant current/reduced constant current approach that has controlled switching of power converter modules of the DC fast-charging station to fast charge the

EVs. Another research group presented, in [52], a multi-control V2G with bi-directional power capability. The proposed bidirectional charger can help stabilize the vehicle power grid, such as through grid voltage regulation, power factor correction, and reactive power compensation, along with providing both directions of power flows. Model predictive control (MPC)-based PHEV charging and a regulation algorithm was developed by [53] to control the scheduled charging and discharging.

5.2. Smart G2V and V2G Systems Implementation by the Automatic Detection Method, an MPC System with Sensors, Estimations, and Statistics

During EVs' charging and discharging, they can create unstable grids by destabilizing the voltage drop, frequency variation, voltage distortions, harmonics, etc. A significant grid voltage drop may violate the grid voltage limits while charging the EV at a unity power factor. According to the state of the power grid, researchers developed an autonomous multi-control selection algorithm to transition between the various charger controls dynamically [52]. Results indicated that, if the grid voltage exceeded the permitted voltage limits, the suggested algorithm effectively taught the charger to operate in efficient control modes. The charger automatically transferred to grid voltage control for power grid voltage regulation whenever the grid voltage exceeded the limits. Predictive control algorithms for four alternative charging strategy models can reduce electricity costs and peak power for a local electricity system [54]. To transmit power bi-directionally, the EV and grid owners must adopt an autonomous system that helps support the EVs and grids for long-run operation efficiently and smoothly; that could be a digital estimation method, using statistics and by implementing MPC with sensor technologies.

5.2.1. G2V and V2G Autonomously Distributed Control

Electricity distribution networks face new difficulties due to the shift to EVs, mainly because of the unplanned and haphazard charging operations that could strain the system. As a result, there will be more network overloads, significant voltage fluctuations, losses, cable aging, suboptimal generator dispatch, decreased system efficiency, increased transformers, and a higher likelihood of blackouts [55–58]. An optimization algorithm to coordinate the charging of EVs was developed and implemented using a Genetic Algorithm (GA), where the voltage limits, load on transformers, thermal line limits, and parking availability patterns were taken into account to establish an optimal load pattern for EV-charging-based reliability [59]. How to frame a hierarchical autonomous load management algorithm as an effective power tracking issue was demonstrated [60]. The distribution grid operator uses the demand flexibility for EVs to regulate a power signal sent to all EV controllers to fill the valleys in the non-EV load profile. Power flow directions and distribution requirements are calculated from both parties. It is mandatory to transmit clean, error-free energy during the power flow to the grid and when receiving power from grids. The grids are unstable and inefficient for EVs and themselves because of voltage, frequencies, and harmonics distortion. A second-order active disturbance rejection controller (ADRC) with an extended-state-observer was modeled as a secondary controller to reduce voltage and frequency deviations and steady-state error [61]. A series of ESS, namely battery, super/ultra-capacitor string voltage balancing circuits, based on a single LC energy converter, is presented in this paper [62]. The active balancing circuits shown can achieve maximum energy recovery, high efficiency, a quick balancing speed, small size, cheap cost, and cost-effectiveness. Near-zero current systems are used to operate all MOSFET switches, and synchronous trigger patterns are used to control complimentary-plus-wide-modulation signals. The article's author [63] presented the impact of fast-charging EVs on the distribution network. A bi-directional DC fast-charging station with novel control topology was proposed to solve the voltage drop problem due to EVs' fast charging. A comprehensive bidirectional power transmission is depicted in Figure 7. The component details and operation to realize the bidirectional energy flow between EVs and grids are overviewed in that figure.

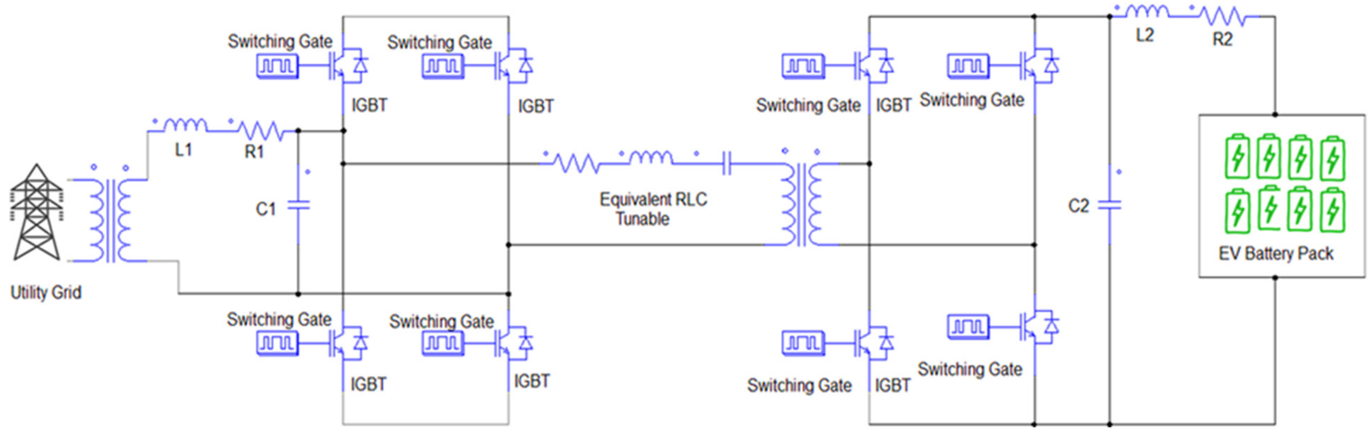

Figure 7. Bidirectional dual active full-bridge converter adoption.

For the inductive coil-based wireless power mechanism and control operations, the MPC and P&O controller on the primary side and CC/CV controller on the secondary are established and analyzed in Figure 8. In [64,65], a model is presented for MPC-based PHEV charging, and a regulation algorithm is anticipated to schedule the charging and regulation processes. The optimal charging and frequency regulation processes for every PHEV, the impact of the price prediction error on PHEV cost, and the effect of the penalty factor for plug-out SOC were all determined using numerical experiments. It was also shown that the PHEV owner can reduce his cost and depart with the desired SOC by taking the optimal control sequences [65].

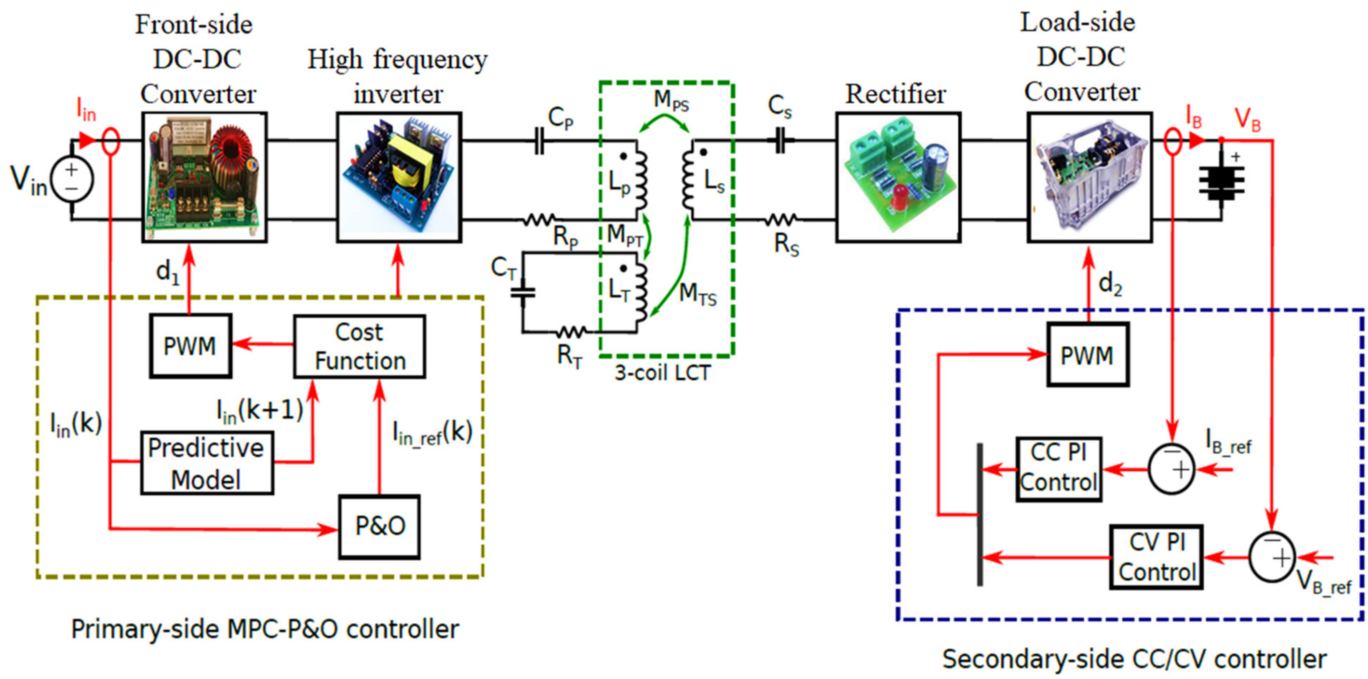

Figure 8. Control narrative in a wireless EV charger.

5.2.2. Bidirectional Wireless EV Charger Adoption

A flexible, programmed, reliable, and safe charging and discharging system for EVs and HEVs is vital in G2V and V2G operations. The bi-directional inductive WPTS is ideal in G2V and V2G operations. With authentic power-flow models for the analysis, researchers optimized bi-directional inductive WPTS and the EV and grid interaction performance [66–68]. The authors presented a harmonics-based theoretical power-flow model for bi-directional inductive WPTS charging and discharging of EVs in V2G applications. The proposed model accurately estimates the active and reactive power flow during V2G and G2V modes. There are three different grid integration technologies employed by BD-IPT systems [69]. They are conventional implementation, matrix-converter-based implementation, and active-filtering-based implementation.

6. Some Positive Outcomes on G2V and V2G Technologies

6.1. Benefits, Robustness, and Impacts of G2V and V2G Systems Operation

Grids and EV owners have realized robustness in energy transmission in both directions. Versatile, broad, positive, efficient bi-directional energy is seen between grids and EVs. The efficiency, reliability, and stability of power grid performance can be achieved from G2V and V2G concepts and by keeping the running operation of EVs. EVs with bidirectional capabilities can support the power grids in multiple ways, such as regulating the power, providing reacting power support, tracking renewable energy sources, balancing load, and filtering harmonics. EVs have a beneficial environmental impact, and ground EVs are one of the most environmentally friendly forms of transportation now accessible. Implementing and utilizing the EV makes it possible to stabilize the grids and achieve more significant economic perspectives [70,71]. In [72], a research group showed that electric vehicles may increase peak power systems demand by 36–51% in the grids. The article in [73] explored both the promise and the possible pitfalls of the PHEV and V2G concept, focusing first on its definition and then on its technical state of the art. PEV and battery implementation enable nonlinear programming of energy storage devices, maximization of market benefit, optimal generation scheduling, and daily energy loss minimization [74]. A mathematical model was proposed [75] to determine the best EV distribution that maximizes system user total income and V2G profits through daily EV charging/discharging schedules. The best distribution of quick-charging locations based on grid effects and economic benefits was reported in [76].

6.2. Auxiliary Facilities

EVs are becoming increasingly integrated into the electrical grid, which opens up the possibility of using battery chargers and PEVs as distributed energy resources to offer subordinate services. Ancillary facilities are essential for grid resilience, balancing supply and demand, and transferring electricity from the seller to the buyer. The primary purpose of incorporating PEVs as fast-responsive storage is to provide ancillary services in urban areas. Incapable of engaging in the regulatory power markets, the parking lots might group to establish PEV clusters and enter into bilateral agreements with WtE-CHP [77]. A comprehensive control strategy for a bidirectional isolated charger for EVs with the capacity to provide ancillary services has been proposed [78].

6.3. Frequency and Voltage Regulation on Grids

The bi-directional power between the grid and the vehicle and vice versa can regulate the frequency and voltages. The authors in [79] showed that EV batteries can control the frequency in a microgrid utilizing G2V and V2G operating modes. The successful simulation in the research indicated that the EV combined with V2G technology decreases the grid frequency fluctuations. In the following research works, [64,80], the authors presented techniques and strategies for controlling frequency fluctuations and voltage regulations to stabile the grids. Since fast-charging/discharging battery packs for PEVs quickly release battery capacity, V2G ESS might be an approach for controlling frequency. Voltage regulation that balances demand and supply controls reactive power. PEVs are outfitted with control functions independent of one another to react quickly to regulating signals. The charger can compensate for generated capacitive or inductive reactive power by properly selecting the current phase angle. EV charging may stop if grid voltage drops below a particular point and may resume if grid voltage increases above that point [15,81]. Overall, the frequency, voltage regulations, reliability of the EV and grid systems, stability, and grid security can be achieved by implementing modern G2V and V2G.

7. Issues, Pitfalls, Limitations, and Challenges for G2V and V2G

7.1. G2V and V2G Issues

EVs's integration with grids has several advantages and operational flexibility. However, these bi-directional-based EV technologies currently being implemented have not yet matured. The sudden rising EV integration in grids has caused many serious issues, such as technical, socio-economical, and environmental issues, that must be passed on to optimize the EV integration with grids [82]. According to the available data, an effective G2V and V2G power distribution plan can reduce the demand for further electricity infrastructure investments while minimizing the requirement for new energy. If EVs can schedule and control their stored energy, the ever-increasing stress must be reduced. Scheduling all the G2V, V2G, and other generation electricity generation production units is a major issue with this project. Larger-capacity units are typically utilized to meet critical load demand in the grid system, while smaller-capacity units are typically used to regulate peak demand. The availability of renewable energy necessitates the proper reactive and active power requirements and the required quantity of V2G devices to establish the cost for G2V and V2G units. As a result, G2V and V2G aim to reduce the grid's reliance on large-scale generators while also cutting back on active and reactive correction devices depending on grid load situations. In this sense, two different strategies might be used to address the problems. A grid-connected electric car is connected to the electricity grid, other power generation facilities, and EV charging stations.

7.1.1. Temperature Issues

Temperature rise in EV batteries is a constant issue because of the chemical reaction. High temperatures destroy the battery pack. A temperature control system is needed for the secondary lithium battery. Generally, the battery must be utilized in high and low temperatures. The dynamic parameters of temperature, the charging and discharging current, and the battery's capacity to take care of restrictions are all attributed to the slowed-down pace of synthetic responses and preparation. An increased battery temperature leads to various challenging conditions that result in unexpected chemical behavior and a battery explosion. By triggering the reactions, the Arrhenius influence limits some power, but more current results in warmer run-overs and a higher temperature due to positive temperature feedback. Fundamental improvements must be made if the battery's heat is to be controlled. Some improvement of the temperature of rechargeable batteries should be in the charging and discharging power during the current feed [83].

7.1.2. Economic Issues and Benefits

Figure 9 [84] depicts the link between daily V2G profit and driving distance. Up to 130 km of driving, the V2G profit in B1 mode is constant before it progressively decreases. When the travel distance is less than 130 km, the BEV battery's energy can complete the trip and still have enough left to take part in the V2G for two hours at total capacity. Because the discharge power and discharge time are the same when the driving distance is less than 130 km, the energy returned to the power grid is also the same. The amount of energy that can be returned to the power grid reduces when the driving distance surpasses 130 km. The BEV battery's remaining energy cannot discharge at total capacity for 2 h. As a result, V2G's profit declines as well.

The energy control methods used in H1 mode and B1 mode are nearly identical. In other words, a V2G discharge can only be considered if the PHEV battery has enough electric energy to power the return trip. As a result, the PHEV's V2G profit trend is the same as the BEV's. The PHEV's comparable V2G profit in the H1 mode is at 30 km shorter. After then, V2G gradually begins to make money and drops until 80 km has been covered. The battery sizes are mostly blamed for the profitability gap between BEV and PHEV.

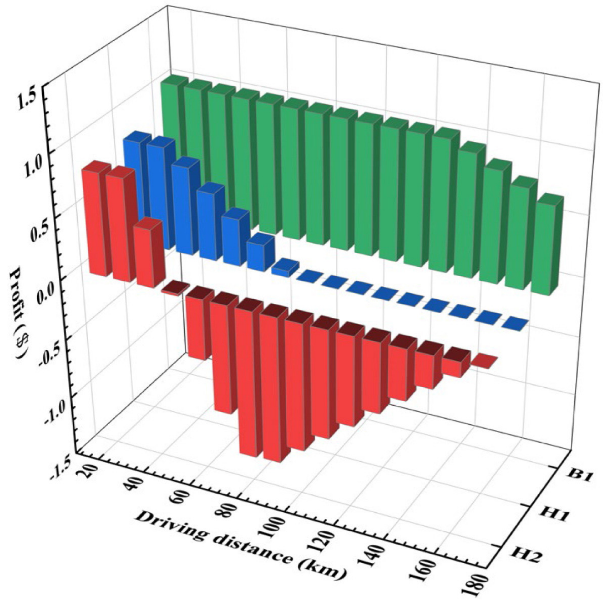

Figure 9. V2G energy scheduling mode with driving distance [84].

A BEV with a replaceable battery may travel farther and produce more energy for the grid. The feed-in energy of a BEV is double that of a PHEV within the same period. That is because the discharge power of a BEV is 7 kW, whereas that of a PHEV is 3.5 kW. Within 30 km, a BEV's profit is not twice that of a PHEV. The difference is that, whereas PHEVs employ less expensive lithium iron phosphate batteries, BEVs use more costly NCM lithium-ion batteries. In Figure 9, the profit in the H2 mode is lower compared to the H1 mode at greater distances, despite the fact that it has similar profitability as the H1 mode at distances of 30 km or less. The value of the H2 mode is diminished if the distance traveled is less than 50 km.

7.2. G2V and V2G Pitfalls

Adopting G2V and V2G has numerous possibilities for environmental issues and positive outcomes economically. The battery life, network security, and social barrier deterioration are some of the greatest issues impeding the growth potential of V2G, in addition to the obvious economic difficulties. In G2V and V2G technology, EVs are frequently regarded as dynamic distributed RES that support the grid. Numerous studies have demonstrated the superiority of this idea and established that it is the better option for the above-described future power system paradigm. It improves the management of the electrical grid, and this has been done numerous times previously. City public services use various technologies, such as flywheels, battery storage systems, and pumped hydroelectric storage. The developing G2V and V2G sectors compete directly with the existing G2V and V2G industries. In addition, G2V and V2G systems have some limitations toward adopting wide applications since they have system losses such as efficiency and fast-charging issues.

7.3. G2V and V2G Limitations

Recently, a helpful remedy for the energy industry has been seen in the G2V and V2G models. The main goal of global EV adoption is to minimize the need for traditional internal combustion engines and reduce carbon emissions. The advent of G2V and V2G transfers is a signal for infrastructure enhancements related to EVs to enable this novel usage in the power sector. Recent technological breakthroughs include bi-directional power conversions, more advanced connections, and smart meters. Most future EVs with enhanced technology that can produce electricity by G2V and V2G relationships have not yet been introduced. Owners must choose whether they want to participate in future contracts. An EV with bidirectional power flow capabilities is significantly expensive have some limitations due to additional technology parts inclusions [82,85,86]. Studies and research are required to close the uncertainty gap and provide manufacturers and customers with a viable option for energy market contributors.

7.4. G2V and V2G Challenges

The peak capacity of the grid offers a hurdle to EV adoption, which poses a bigger issue. Electricity demand grows to peaks that may happen more frequently since they depend on the power demand [87]. The grid is put under more strain due to extreme weather events. We might reduce these peaks caused by bidirectional V2G charging by adopting semiconductor technology, which could benefit everyone. Today's semiconductor-based devices can support the grids to power from storage batteries and modern EVs. Improving power load management, power management, sensor, and connection technologies with broadband gaps can increase grid reliability [88]. Several expenditures are involved with V2G development because there are so many challenges to its execution. For instance, battery deterioration, infrastructure modifications, and improved EV–supply grid connections mostly affect the distribution network or its characteristics, energy loss, or other technological problems [89,90]. Frequent charging/discharging degrades battery storage capacity and its life cycle. Batteries can remove these obstacles with more cost-effective and effective construction, acceptable to producers and operators. The distribution network is less affected by introducing V2G thanks to cooperation between aggregators and operators. Figure 10 summarizes the challenges regarding G2V and V2G bi-directional power transmission.

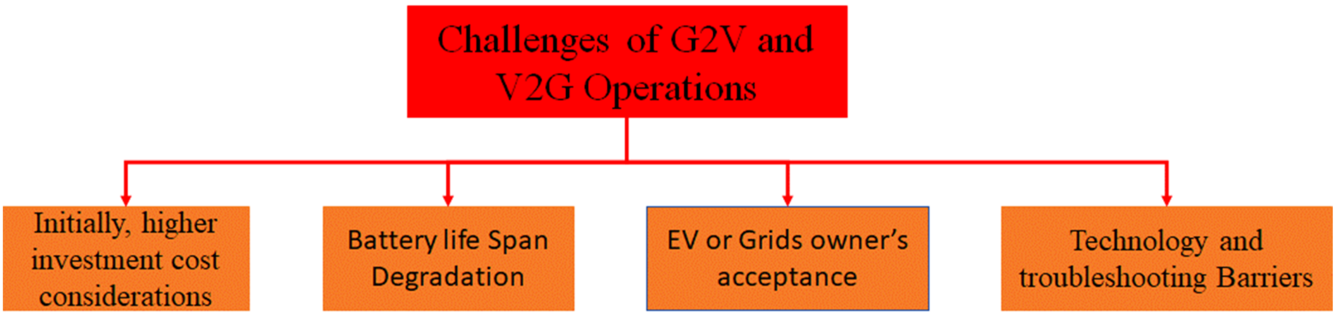

Figure 10. Challenges toward EV adoption.

7.4.1. Higher Investment Cost

The initial and ongoing investment expenditures by the EV or the power grid owners are a key disadvantage of the bi-directional EV installation. The fundamental V2G and G2V system architecture's appropriate completion is the initial stage in the execution of EV adoption. To support the higher conductivity of EVs and, thus, the rescheduling of various smart technologies on the end user side, the power system has to be altered in some technical elements relating to the software and hardware architecture. Each EV participating in the bi-directional energy transfer applications in the power grids will need a rapid EV charging system that includes intricate power converters, controllers, high current, high-tension cabling, and upholding of safety regulations [82]. G2V and V2G could increase power losses, which is another important problem that needs to be reduced, as it can result in losses in money. Advanced converter designs are necessary for an EVs' regular charging/discharging cycle for conversion and switching losses at various distribution system stages.

7.4.2. Battery Life Span Degradations

The EV battery's material composition can be impacted by frequent charging and discharging cycles. If the batteries are continuously charged and discharged, the internal series-equivalent cell resistance can increase and reduce overall efficiency. The EV battery's life span can decrease with increasing age of the batteries and constant burnout from the regular rate of the charging/discharging state, the depth of discharges, and the temperature of batteries [91,92]. Lithium-ion batteries (LIBs) have experienced a tremendous increase in demand due to the proliferation of EVs. The main concern is how to dispose of such massive retired LIBs. The echelon use of retired LIBs is gradually taking over as a research hotspot. The echelon usage of large-scale retired power LIBs can be resolved, which has enormous economic and environmental benefits. The difficulties are now faced while using retired power LIBs in a cascade [93,94].

7.4.3. EV or Grid Owner's Acceptance

The acceptance of EVs is still not ubiquitous for consumers and grid owners due to updated versions of technologies from both ends. The grid owners and EV owners hesitate to dispose of old systems or upgrade with new bidirectional EV technologies and have trouble with ability to provide funds. On the other hand, the high initial cost of ownership and adaptation to EV-focused driving and charge/discharge cycles could be a significant deterrent in preventing consumers from quickly adopting EVs, in place of conventional ICE-based vehicles, in the future large-scale adoption of EVs. To combat consumer concerns, consumers should know regular and planned expenses.

7.4.4. Technology and Troubleshooting Barriers

As EV technologies are new to consumers and grid owners, they have some obstacles for both sides. There is a lack of competent technical hands for the grid owners, and, at the same time, it is difficult to find available service stations for consumers if their EVs face any troubles. People have fears about adopting new modern EVs because of ownership expenses, available charging points, and maintenance costs regarding adopting EVs.

7.4.5. System Loss

Connecting the V2G and G2V bidirectional EV charger in series with the grid reduces switching losses and system efficiency. Batteries fall under this category since their continuous charging and discharging are necessary for control. A specific bidirectional charging control approach for EVs that considers the SoC of the batteries and synchronous voltage and frequency management is essential in this regard. Almost 470 TWh of electricity, with a lower carbon intensity, would need to be provided to EV batteries during off-peak hours to accomplish these increased power savings and account for energy losses. Additionally, higher energy loss from the V2G and G2V technologies may result in a loss of money. More energy conversion losses are often necessary when charging and discharging because these operations produce energy conversions.

8. Conclusions and Recommendations

Improved G2V and V2G technology can transfer power bi-directionally. The EV owners and grid owners can benefit simultaneously by adopting these technologies. Moreover, the EV owners may be able to build an additional source of income by selling energy at a higher price during the grid's peak hours. In this paper, the G2V and V2G impacts are presented in more depth, namely, the opportunities, improvements in strategies, operation, control, issues, and new technology adoptions. In this research work, the article emphasizes reviewing the possibilities in bringing advancements in EV technology, smooth operations between grids and EVs, fast bidirectional charging and discharging scopes, control of grids and EVs structures, issues, benefits, pitfalls, challenges, and recommendations. Overall, this paper shows the influences of upgraded G2V and V2G technology and bi-directional fast energy transmission topology, issues, benefits, and challenging factors of adopting these modern EVs. The following is a compilation of several essential and in-depth recommendations for the advancement and future research direction of V2G technology:

- Designate a V2G strategic strategy, increase V2G fundamental research, and consider additional hardware and operational circumstances when building the SG.

- Research of reactive, dynamic, steady-state behavior, capacity estimates, V2G modeling, and other studies in related domains.
- Encourage EV users to participate in the V2G system while considering the social effects of implementing electric transportation, especially the V2G system.
- Effective charging scheduling techniques for the V2G application must be developed to improve system performance.
- Further research is necessary because a complete economic justification for smart chargers has not yet been shown. While there are clear financial benefits to employing dispersed ESSs like EVs to absorb excess RE, this issue still needs more research.

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