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Examining the Potential of Renewable Energy Sources to Help Promote the Adoption of Electric Vehicles in A Smart Grid Setting.

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Abstract: - Transportation-related energy use is currently second only to global industrial consumption. Transportation driven entirely by renewable energy allows for a significant decrease in the consumption of fossil fuels, which reduces greenhouse gas emissions. Electric vehicles (EVs) can be used as an option to reduce pollution in transportation. Power supply networks face increasing electricity demand as a result of widespread EV adoption. By using renewable energy sources (RESs) for electric vehicle charging, this issue may be solved. Coordination of EV charging with other demands and renewable generation is challenging since RESs are unpredictable. Power oscillations in the electric grid may be mitigated by employing EVs as energy sources. This article provides an overview of current findings in the area of smart grid-based integration of renewable energy sources with electric cars (EVs). Systems that integrate smart grid technology with electric cars must deal with a number of problems relating to grid infrastructure, control, and communication. Section 2 discusses the viability of integrating solar and wind energy sources with electric automobiles. EVs integration into the electric grid and Vehicle to grid services are the two categories into which the available research publications in this field are divided. Section 3 investigates the role of V2G in the electrical market as well as its management issues. In addition, the future potential of integrating electric cars with renewable energy sources and the Smart grid is underlined, along with the research needs in this area.

Keywords: Renewable Energy Sources, Electric Vehicle, V2G Services, EV - Grid Integration, Green Transportation, RES - EV integration, Smart charging.

INTRODUCTION:

The depletion of fossil fuel supplies, climate change, and greenhouse gas (GHG) emissions must all be addressed if a sustainable ecosystem is to be ensured. Since the transportation sector is the second-largest producer of hazardous pollutants, electrification of transportation is seen as a practical solution. The commercial apex of EV technology occurred around the year 1900, however it has been around for over a century.

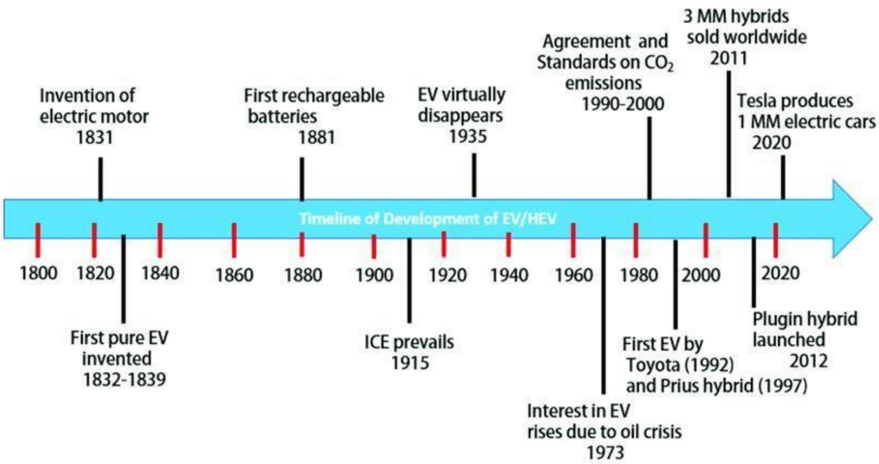

Figure 1. development of electric cars (EVs)

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Figure 1 displays the advancement of electric cars. By reducing reliance on petroleum imports, transportation electrification increased energy security. The adoption rate of electric cars is still low [1] because of problems such a costly initial investment, battery degradation, a lack of convenient charging locations, range anxiety, and other factors. Governments all around the globe have introduced a variety of initiatives and financial incentives to promote the usage of electric cars and complete the switch to electric transportation. The International Energy Agency's "Global EV Outlook" report estimates that by the end of 2030, there may be up to 130 million electric cars worldwide [2].

Single-phase loads are moved by electric vehicles. As a result, in any of the three phases, they can be connected to distribution networks. As a result, compared to the other two phases, which are not loaded, one phase's electrical components, such as a transformer, overhead line, or power supply cable, may be overloaded [3]. It is difficult to manage EVs as new loads while upholding grid security and dependability because to their erratic scheduling. When residential demand peaks coincide with EV home charging, additional system peaks result.

A further large source of dangerous pollutants is the traditional electricity sector, which relies on fossil fuels. In order to minimize emissions in the electricity sector, renewable energy sources (RES) like solar and wind are frequently used. Because renewable energy is unpredictable and is impacted by location, time, weather, and other variables, using an energy storage system (ESS) is necessary to prevent voltage instability and grid dependability problems [4]. Furthermore, if non-renewable sources are utilized to charge EVs, the advantages of lower emissions brought on by electric vehicles cannot be assessed. In areas where fossil fuels are the main energy source, EV emissions have been demonstrated to increase [5]. Electric car charging using RES lowers GHG emissions [6]. The relationship between both the EV-PV system and the distribution system has been examined in several papers in the literature. The reference [7] explores solar electric car charging with a focus on control systems, algorithms, and the underlying economics. The impact of EV charging circuits on power quality and the grid is covered in reference [8]. An overview of EV modelling techniques, with an emphasis on EV load & charging station modelling, isprovided in References [9].

A graphical representation of the number of articles on the integration of electric cars and renewable energy sources is shown in Figure 2. Based on their degree of contribution to the field, almost 70 research papers were selected and analyzed out of nearly 224 papers.

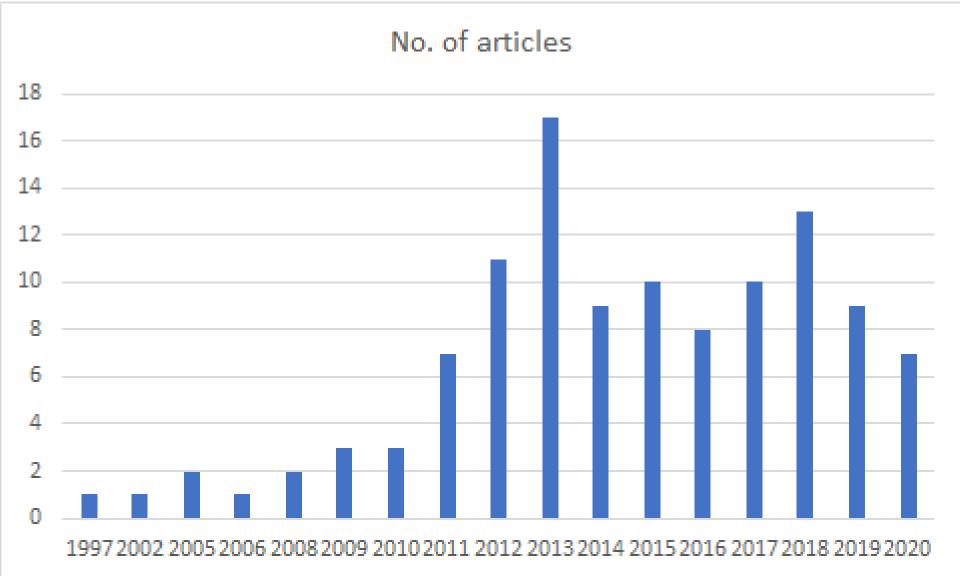

Figure 2. articles that planned to years

The following is how the document is structured: Section 2 of the study explains how EVC is integrated into the electric grid. The Section 3 report details the V2G services. Open questions, future research directions, and concluding remarks are discussed in Section 4.’

ELECTRIC VEHICLE - GRID INTEGRATION

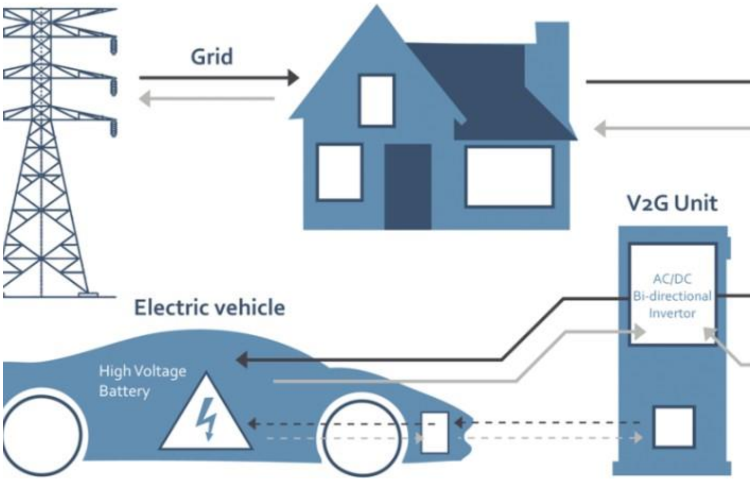

Figure 3. EV and electric grid integration

A significant issue that will require thorough analysis and monitoring in light of economic consequences, control, and operation benefits under ideal circumstances is the integration of a significant number of electric vehicles into the power grid. Numerous studies have looked at howelectric vehicles affect the power grid [10], while others have focused on specific uses. A grid- connected electric car is shown in Figure 3. (EV). V2G is a method that allows energy to flow in both directions between the grid and electric vehicles. The modelling of EV connection with distribution network showed a change from unidirectional to bidirectional mode.

Rising energy and demand are making the technical challenges associated with EV penetration—such as higher system costs, system imbalance, poor stability, and poor power quality—more obvious. The research has looked into the G2V mode (unidirectional approach) in terms of smart charging [11], safety [12], and control features [13]. These studies seek to reduce the associated costs with pricing [14] or the impact on the distribution system [15].

Electric vehicles function as a distributed producing and storing system as well as a grid load while in reversible mode. Peak load shaving, or the concept of storing energy in the batteries of electric vehicles and transferring it to the grid during peak hours, is an idea that has been around for a while. Coordination of the charging and discharging processes is a significant difficulty when using electric vehicles as a storage system because each has a small battery. It is necessary to have a basic understanding of the characteristics of EV battery energy consumption in order to do the analysis of G2V and V2G modes. *Equation* (1) gives the average EV battery pack energy consumption.

Battery pack energy usage on average

Eavg = (Ep + Emax) (2 – np) Wh/Km. ....(1)

Ep stands for energy used for propulsion.

Eaux stands for "energy usage for auxiliary loads."np stands for the powertrain's efficiency.

The battery pack total energy needed is provided by

Ebp = Eavg * Dv Watt hours .... (2)

Where Dv = Vehicle range in km

The formula for how many battery cells are connected in a string in series is

$$Ncs = Ubp/Ubc \quad \text{(3)}$$

Where Ubp = Nominal battery pack voltage (V)

Ubc = Voltage of each battery cell (V)

This is how a string's energy content is calculated:

$$Ebs = Ncs * Ebc \text{ Watt hours} \quad \text{(4)}$$

Where Ebc = Energy of a battery cell (Wh)

The battery pack's overall string count is computed using

$$Nsb = Ebp/Ebs \quad \text{(5)}$$

You may recalculate the battery pack's total energy using the formula

$$Ebp = Nsb * Ebs \text{ Watt hours} \quad \text{(6)}$$

The battery pack's capacity Cbp is determined as follows:

$$Cbp = Nsb * Cbc \text{ (Ah)} \quad \text{(7)}$$

Where Cbc is the capacity of the battery cell (Ah) The battery pack Ncb's total cell count is indicated by

$$Ncb = Nsb * Ncs \quad \text{(8)}$$

Peak current of the battery pack

$$Ibpp = Ispc * Nsb \text{ (A)} \quad \text{(9)}$$

Where Ispc = string peak current (A)A battery pack's maximum power

$$Pbpp = Ibpp * Ubp \text{ (W)} \quad \text{(10)}$$

In the earlier, V2G was limited to electric car to distribution infrastructure energy transfer. On the other hand, two innovative energy transfer modes that have been created as a consequence of technology breakthroughs are V2H and V2V.

As a result, there are currently three subcategories of energy transmission from an EV: 2(a) Vehicle-to-grid (V2G): Energy transfer from an EV to the electrical grid

Vehicle-to-house or building (V2H/V2B): Energy transfer from an EV to a building or home. 2(c) Vehicle-to-vehicle (V2V): Energy exchange between two electric vehicles.

Table I compares V2G, V2H, and V2V schemes based on their features and functionalities.

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, LessFlexible
	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 ancillaryservices	Act as a home backup generator and a controllableload	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 pricedpeak time	Sell excess energy back to the grid at high priced peaktime	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 micro grid	Coordinate control of EVs
	Coordinate with renewable energies		Reactive power support
	Reactive power support		
	Stabilize the grid for short periods		

EV Smart Charging with Grid and RES

Numerous studies have looked at the advantages of solar charging systems for electric vehicles. Reference [16] lists the advantages of recharging EVs using solar power, showing how this promotes higher PV and EV penetration. Electric cars can help reduce excessive PV generation [17]. Reference [18] claims that solar-powered charging of electric vehicles is more economical and produces less CO2 than grid-powered charging. The use of solar energy and the deployment of electric cars as energy storage units are taken into consideration in reference [19] in order to lower grid peak demands. These studies demonstrate the benefits of solar energy over grid-based EV charging for electric vehicles [20]. All of the research on smart charging focuses on specific EV grid integration elements such slow/fast charging, market participation, and auxiliary services [21]. References [22,23] provide earlier research on systems that integrate a number of areas that are frequently researched independently.

In conjunction with V2G technology, smart charging increases PV self-consumption while reducing peak demand [24]. Sequential charging, which dynamically varies the number of Electric Vehicles undergoing constant power charging so that the PV generation is followed by net charging power [25], might reduce unpredictability. Numerous cases are examined in reference [26] to demonstrate that sequential charging performs better than concurrent chargingin terms of solar power utilisation under stochastic settings.

Using renewable energy sources in conjunction with electric vehicles.

It is thrilling to see how the power system will change when more renewable energy sources (RES) are integrated. The current power infrastructure receives an erratic and unreliable supplyof electricity from these sources, primarily wind and PV solar energy [28]. The majority of studies concluded that it is relatively feasible to integrate photovoltaic solar systems and wind energy conversion systems (WECS) into the electrical grid [29]. To balance the grid's RES-basedpower generation, stationary energy storage systems (ESS) or controlled dispatch loads [30] maybe deployed. Stationary energy storage systems store electricity when there is a surplus and release it when there is a shortage [31]. Through a variety of charging mechanisms, EVs may usethe extra energy generated by RES or provide electricity to the grid during periods of low energy output, levelling grid operations [32]. [33] asserts that increasing renewable energy sources and implementing EVs that can provide V2G services are two practical ways to ensure energy security. Figure 4 shows how the power grid with EVs integrates solar and wind energy. Electric cars are put together at a charging station and utilised in the V2G mode to reduce power fluctuations from these RES [34].

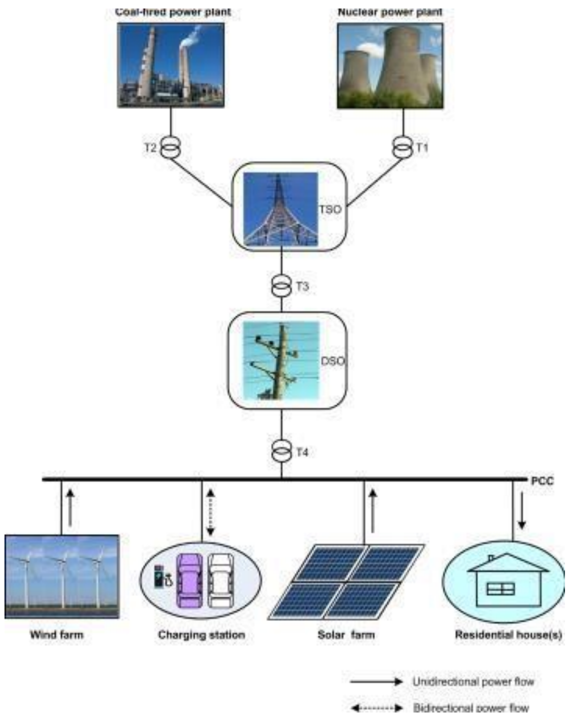

Figure 4. Electric vehicle integration with grid and renewable energy sources

Integration of solar photovoltaic energy with electric vehicles: Possibility

In order to sustain the grid and charge EVs, solar PV electricity is anticipated to become more and more common as electric vehicles gain in popularity. Numerous studies have shown how exciting it would be to install solar panels on parking lot rooftops to charge electric automobiles [35]. Fig. 5 depicts a solar parking lot charging station with a bidirectional DC to AC power converter connected to the electrical grid. How many charging stations may be connected to the power grid is shown in the diagram? On the other hand, electric cars with a bidirectional DC charger may absorb extra power and are connected directly to the PV controller. In times of high demand when solar power is scarce, it can also restore battery-stored power. The study on the widespread usage of rooftop PV panels with electric cars is described in [37]. EVs can lessen the load on the power distribution grid by using V2G services. [38] details a research on the installation of solar panels on parking lots for cars in the Swiss city of Frauenfeld. The findings suggest that PV systems on parking lots might supply 15% to 40% of EV energy needs in the future [39].

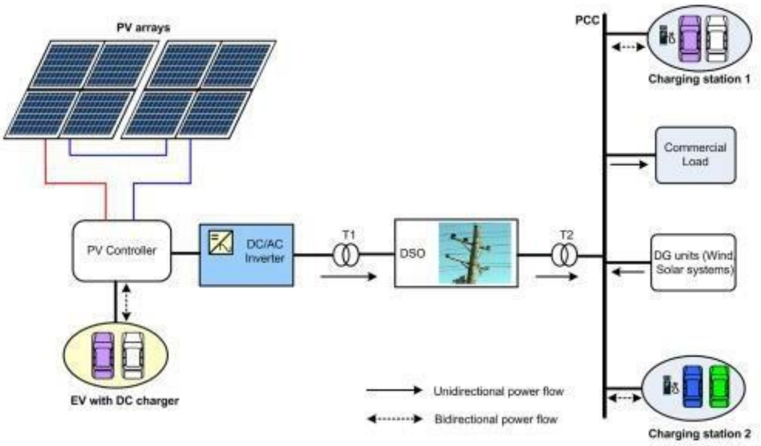

Figure 5. Solar-powered grid-connected parking lot with EV charging station

Integration of wind energy with EVs: Achievable

Energy conversion systems (WECSs) based on wind farms are a well-established and practical solution for producing power. To assess their impact and feasibility on the electric grid, numerous studies have examined the interaction between WECSs and EVs in diverse contexts [40]. examines how electric cars may be used in the US energy market to deliver ancillary services and voltage control using WECSs. Between the years of 2015 and 2030, [41] conducted an intriguing research on the extensive use of renewable energy sources (especially wind) in the North-Eastern Brazil power system using plug-in hybrid electric cars. [42] Investigated the extensive use of PHEVs to integrate wind energy conversion systems into the microgrid (MG). Atwo-stage stochastic unit commitment model was used by Liu et al. [43] to account for the interconnections between large-scale wind farms, plug-in hybrid electric cars, and thermal powerplants.

3. V2G SERVICES*: Vehicle to Grid*

The main purpose of the batteries in electric cars is to transform electrical energy into mechanical energy for propulsion. Another characteristic of V2G is the ability to feed energy back into the grid to improve grid stability and dependability [45]. [46] predicts that by 2030, there will be 56 million electric vehicles actively being utilised on the road, with batteries averaging 120kWh. Since cars spend the majority of their time in parking lots, the SG may utilise them effectively while they are parked [47]. To better comprehend V2potential G's uses inthe SG, its role in the power market as well as its management issues are explored [43].

Services for Voltage and Frequency Regulation

Automated generation control, which balances supply and demand to change the voltage and frequency of the system, is the focus of regulation services. The market is perfect for EVs due to the stochastic character of the regulation and its temporal sensitivity [48]. Voltage regulation was the main focus of the investigation into V2ability G's to make up for reactive power in [49]. AGstypically need contracts with the SG to determine their service capacity and deliver frequency regulation service [50]. Due to EV mobility and limited service capacity, service capacityestimate is a new topic of study. [51] uses an AG model-based estimation technique to track and anticipate EV frequency control capacity every quarter-hour. As the Regulation Up may cause worries about battery depletion and range anxiety [52–57], the main objective of a centrally regulated schedule is to optimise EV revenue [48].

V2G Services Energy Management

There are three basic types of V2G operation depending on the scheduling goal. Vehicle-to-home(V2H) mode is activated when home appliances are powered by electric vehicles (EVs) that utilise renewable energy sources. When electric cars (EVs) are parked at businesses or leisure centres and are being charged in the parking lot, vehicle-to-building (V2B) discharge is conceivable. V2G clearly provides a wide range of services, from a single residential residenceto a substantial microgrid.

Demand Side Management (DSM)

The demand profile can be flattened by using EV energy to serve variable loads during peak hours while electric vehicles discharge through aggregators. The grid operator normally managesthe EV scheduling in DSM mode from a centralised location. The scheduling of V2G may therefore be seen as an optimization challenge for reducing the scheduling cost.

Flattening a load

One of the main V2G services in DSM is load flattening. It is accomplished by using EV energy to meet the surplus demand. Due to the lengthy peak demand, the majority of electric cars will require this service. The SoC status at the time of each EV's arrival and required departure, however, varies, needing flexible scheduling and rewards to encourage them to discharge [58]. As a result, while calculating the scheduling aim, the cost of battery use is considered [59].

Outage Control

Electric cars can serve as energy sources when the regional grid is undergoing maintenance. Maintaining service continuity during a residential power loss is the major objective of V2G scheduling [60–62]. Electric cars must be used for outage management. A high number of parked EVs [63, [64]] or big-capacity EVs, such as electric buses [65], can be used to meet the energy demand. It has been shown that using electric vehicles may lessen power outages, guarantee the consistent operation of an island microgrid, and reduce line loss.

RES Integration

To lessen the consequences of increased greenhouse gas emissions, a large number of RES-DGs can be added to the SG as a green energy supplement. The system's dependability may be compromised by the output unpredictability brought on by environment-dependent power generation [64]. EVs can serve as potential energy storages that reduce RES fluctuation when linked to the SG and RES. They can store surplus energy and fill in the energy gap when necessary. Renewable energy sources may be integrated into the smart grid as a secondary choice in any residential structure, offering end-users two advantages [66-69]. First off, using renewable energy at peak times reduces the demand for retail electricity, resulting in reduced total electricity prices [70]. Second, in the case of a power outage, RES helps with the provision of household appliances. Demand response that is too slow might waste energy for RES installed as a high-power rating farm. In these situations, EVs can deliver renewable energy to the place that needs it [71].

3.3. V2G Services' Functions and Challenges in the Electricity Market

The base power, spinning reserve, peak power, and regulatory markets are the four submarkets that make up the electrical market in terms of control mechanisms. A smooth shift from energy consumers to loads, however, may be hampered by the movability and range anxiety issues with EVs [72, 73]. The following things need to be taken into account while managing V2G services:

1. The mobility of EVs increases the unpredictability and probable delay of the V2G service. While in certain cases, internet generations can help to lessen the harm.
2. Electric vehicle depth-of-discharge (DoD) circumstances and trip needs should be considered for the best V2G scheduling.
3. Because V2G services have such a broad range of energy needs and reaction requirements, it is challenging to design data/command communication between mobile EVs, SG, and AGs [74].

4. OPEN ISSUES AND DIRECTIONS FOR RESEARCH

This part addresses three major unresolved issues related to how electric cars interact with renewable energy sources.

Integration of a large number of RESs into the grid

The differences between RES-producing facilities and conventional power plants are significant [75]. The distinctions between RESs and conventional generators provide substantial obstacles totheir integration into the electrical grid. The local power system is impacted by problems with voltage management, fault current, flicker, and harmonic distortion. A progressive revamp of the power system and its operating procedures may be required in order to accommodate the widespread integration of renewable energy sources into conventional power systems.

Battery use for RESs interaction in EVs

A excess of RES-generated power may be stored in an EV battery. In the event of a power outage, an electric vehicle's battery can be drained to generate electricity. This will result in a longer charging-discharging cycle for the battery. Lithium-ion batteries are used in nearly all of the electric vehicles now on the market. The power and capacity of Li-ion batteries will sharply decrease as the number of charging-discharging cycles increases. As a result, the battery's useful life will be reduced.

Potential for V2G to allow interaction with RESs

The majority of EVs currently on the market do not support V2G technology. The phase-out of internal combustion engines is the primary objective of EV adoption in the transportation sector. For V2G to be successful, several difficulties need to be thoroughly addressed. To use the V2G capability, EVs initially need to have bidirectional power converters and contemporary communications equipment. Second, the charging station has to include smart charging connectors that can interface to the control system of the electric car. Finally, the complexity of grid operators' control tactics will increase as the number of electric vehicles (EVs) increases. Electric cars are largely used in V2G as a kind of energy storage or as an energy source. Since EVs are moving, it is impossible to anticipate with precision how they will be distributed. The ability of the power distribution network to schedule electricity between EVs, RES, and chargingstations may suffer as a result [76].

5. SUMMARY AND FUTURE WORK

This study provides a detailed analysis of the interactions between electric cars and smart grid infrastructure. It has also been emphasised on the use of electric cars to embrace renewable energy sources into the smart grid. Reactive power support, frequency and voltage control, and other subsidiary grid services have reportedly been provided by electric cars in order to increase operational effectiveness, reduce operating expenses for the power system, and safeguard the electric grid. The study discovered that it would be feasible to link EVs to the smart grid system using advanced communication, control, and metering technology. However, further research is needed to support the V2G framework's superiority to alternative energy storage strategies. The final section discusses unresolved issues and potential future study topics. The goal of this study is to educate academicians and engineers on the state of the field today so they can advance it.

Conflicts of Interest: The authors say they have none.

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