International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

http://ijpsat.ijsht-journals.org
Vol. 30 No. 1 December 2021, pp.220-228

Exposure of Electrically Driven Vehicles and Smart Vehicle-to-Grid Technology

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Abstract — Electric vehicles are considered as an asset to the smart grid to maximize economic and environmental performance under a variety of operating conditions. It is more important to maintain network resiliency during emergency conditions and disruptive events. This paper discusses the impact of smart grid-to-vehicle (G2V) and vehicle-to-grid (V2G) implementation on distribution systems and examines current scenarios. The V2G system has a strong impression on the main factors of the utility network such as the efficiency, reliability, loss of lines, and durability of the system. The paper also highlights the economic merits of the V2G concept that heavily doped on the scheme of charging/discharging and vehicle participation. The use of artificial intelligence techniques would also increase the performance of network connectivity soon. Moreover, the V2G technology is incorporated in the charging scenarios to convalesce the payback program of the existing solar grid system.

Keywords— electric vehicle (EV); energy management system; microgrids; smart grids, optimization.

I. INTRODUCTION

When an electric vehicle (EV) has adequate power electronics devices, intelligent connections to the grid, and proper rapid charger control, then it acts as a stored energy source including assistance by way of storage for unanticipated outages. Due to continuous climate change and growing concerns of greenhouse gases, there is a dire need to establish a standard fast-charging station to combat diminishing fossil fuel resources. For this stability, charging time and battery chemistry are areas that have to be solved. South Asia is expected to be the largest solid-state car battery worth 661,724 units by 2030. The growth of the battery technology and related market is influenced by factors such as increasing demand for electric vehicles around the world, higher battery capacity and EV range using solid-state car batteries, and other features of SSB's like higher battery life, higher energy density, and better safety features compared to presently used lithium-ion batteries [1]. Countries such as China, Japan, India, South Korea, and Thailand are considered under the Asia Pacific for market analysis. China is the largest contributor to the global market, accounting for a share of more than 95%. Chinese EV manufacturers, who have access to cheaper parts and components, are providing electric vehicles at lower prices. Today, many researchers give their ideas and company install them at different places. Moreover, the photovoltaic system, in terms of labor and fossil fuel is nearly free of cost. Fast charging stations (FCS) present a topology that is normalized by the IEC 61851-1. A fleet of EVs charging at different modes requires an appropriate management strategy to combat it. An Electric vehicle charging station (EVCS) generally relies on local regulators and a decentralized approach for renewable energy sources. In addition, the supervisory rule-based scheme, energy management scheme based on optimization techniques, or fuzzy logic scheme is required to monitor and supervise the power flow from renewable resources to electric vehicles without the necessity of a communication interface [2]. The application of the DC bus facilitates the allowance of the charging criterion by integrating new elements such as other renewable sources and storage systems for fast charging EVs, as the management strategy does not need to be changed [3].

To gain more revenues, vehicle to grid technology can also be accumulated employing a bi-directional DC-to-DC power changer connecting to a DC-operated Bus where owners of EVs can realize control of request between intake and outgoing modes. Large storage bank by a fleet of EVs and quick reaction for the utility grid; system intended (and paid) for electric mobility; aid cheaper grid supervision, sustainable and stable power; move current peak capacity to baseload as a great opportunity for car fleet owners. In paper [4] the authors recommend that battery-powered vehicles be very suitable to supplement wiring reserves and regulation services since the connection to the grid is already paid for the leading market in Brazil (the photovoltaic). In some particular hours, the tariff increase sharply; thus if exist surplus energy from the vehicles standing long hours in parking space, then energy can be injected from the EV into the grid. This is done through the bi-directional DC-to-DC charger and inverter. The scenario is marked in Fig. 1.

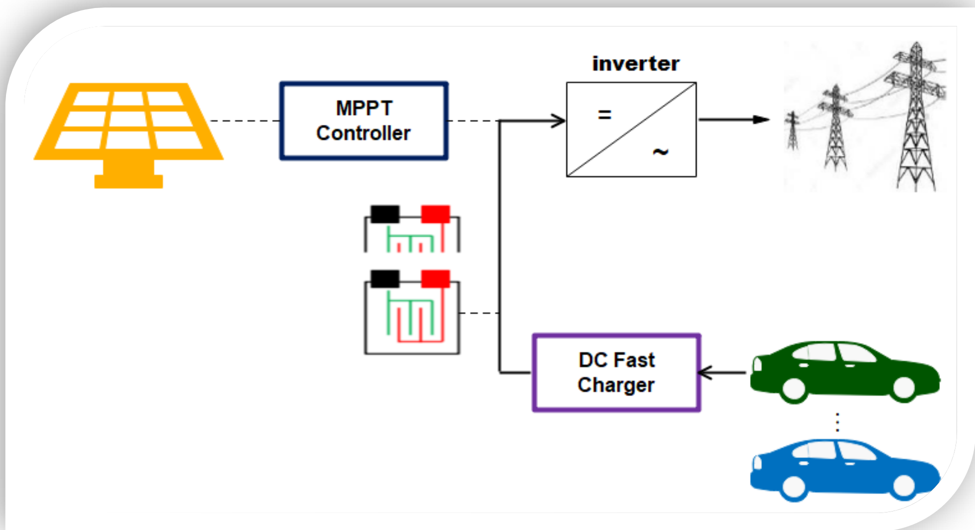

Fig.1. A fleet of electric vehicles to charge a grid.

The organization of the paper is divided as; in Section 2 configuration and modeling of the EV rapid charging facility. Section 3 covers the exposure and the emergence of V2G. Section 4 is dealing with the barriers and blockades of acceptance of vehicles to the grid. Section 5 gives the solutions and remedial actions and section 6 with concluding remarks and future directions.

II. Modelling Of Fast-Charging Stations

The DC charging stations will provide surplus improvements by tallying remarkable drive to the worldwide vehicle market. By the year 2027, the EV refueling stations' market is ramped to cross the US 28 billion dollars from the planned amount of the US 2.5 billion dollars in the last twenty years. V2G induction can help speed up the service of a national network depending on system performance, rapid power distribution, net stability, and system reliability. Since electrically driven vehicles can act as a consumer and simultaneously can serve as a local distributed buffer storage device. When a fleet of vehicles is linked to distribution systems, then battery-driven vehicles are used to inject power to the utility, particularly at the peak time of load congestion, and hence improve the reliability and get momentary gains. The V2G technology possesses different key highlights like controlling of real and imaginary powers, high load shaving and valley area fillings by load matching, harmonics mitigation related to voltage and current waveforms, better power factors, the lesser gross cost of service including utility operating price, make income, solution for the renewable intermittency issues and minimized green emissions [6, 7]. EVs equipped with V2G provide a backup resource for renewable alternatives. Such prominent features may permit ancillary facilities like control of voltage/frequency parameters and provision of spinning reserves [8]. The inclusion of EVs with micro-grids and smart grids by employing artificial intelligence (AI) techniques is also a promising area for the near future [9, 10].

A. Modeling of PV Module

An equivalent model of a photovoltaic cell consisting of a single diode model is selected for this configuration. It consists of a current source in parallel with a diode along with parallel and series resistances. A tandem PV cell equivalent model is displayed in Fig. 2.

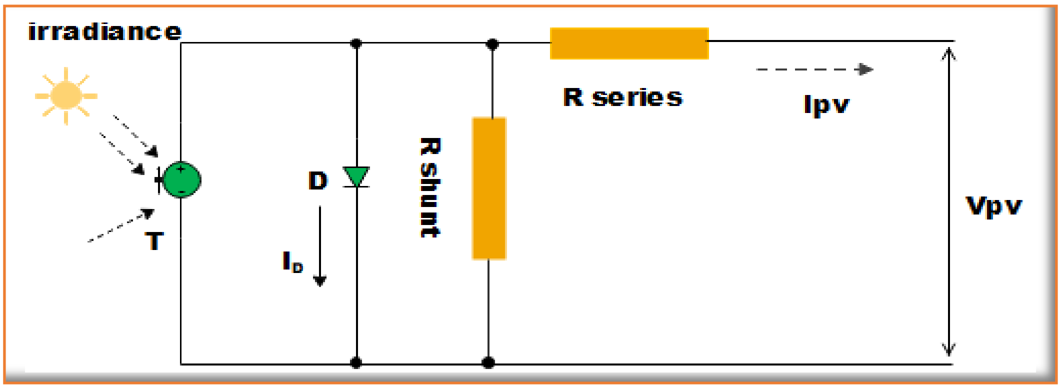

Fig.2. Sight model of a tandem photovoltaic cell.

If I_D is the diode current, I_{pv} and V_{pv} are the output current and voltage of the tandem solar cell, T is the temperature and G represents irradiance, then the equations used for calculating the output current are;

$$I_{PV} = I_{ph} + I_{sat}\left(e^{q\left(\frac{V+I_{PV}*R_S}{NKT_{PV}}\right)}\right) - \frac{V + I_{PV} * R_s}{R_{sh}} \quad (1)$$

$$I_{ph} = I_{pho}(1 + k_0(T - 300) \quad (2)$$

$$I_{sat} = k_1 T^3 e^{\frac{-qV_g}{KT}} \quad (3)$$

Where,

I_{ph} − solar-induced current;

I_{pho} − solar-induced current at 300 ^{0}C

I_{sat} − saturation diode current

V_g − voltage at diode terminals; k_0, k_1 constants

N − diode ideality quality factor

q − 1.602×10^{-19} Coulomb, charge related to an electron

R_{sh} *and* R_s − denotes the shunt and series resistances

K − Boltzmann value (1.38×10^{-23} Joules/Kelvin)

T_{PV} − Operating temperature of photovoltaic

B. International Standards for Electric Vehicles

Different standard organizations are enlisted; National Electric Code, U.S. NEC, the IEEE-Engineers, and the Society of Automotive Engineers (SAE). They upgrade the standards to maintain the presence of harmonics. The SAE defined the standards J1772, J2293, J2836, J2894, J28487 relevant to EVs charging [11]. The infrastructure working council (IWC) is also functioning to develop multiple codes and standards concerned with the grid code interface. A pictorial view of de-facto charging standards of EVs is shown in Fig. 3.

Fig.3. Defacto standards of electric vehicles.

III. Emergence Of Grid To Vehicle (G2V) And Vehicle To Grid (V2G) Technologies

The fast adoption of G2V demands huge electric power via grids, thus power grids like HVDC and super grids are required in the near future [12, 13]. On the other hand, the merits gained by the V2G technology include the less power utility, regulation of real and virtual power provision, improved load curves, lessening of current harmonics, peak load shaving, valley filling by load equilibrium, the low running cost of infrastructure, improved greenhouse gas emissions, and the mass addition of renewable energy generation [10], [14]-[16]. The countries like India, Korea, Malaysia, Thailand, Indonesia, the Philippines, and Vietnam are generally chosen based on EV market penetration, efforts to promote local manufacturing, and the amount of research available on their policies [17]. Fig. 4 displays some of the features of the V2G.

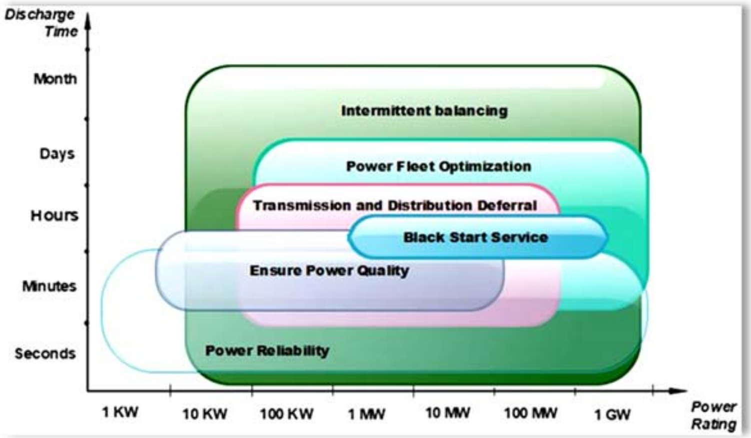

Fig.4. V2G relies on the power rating and discharge rate.

A. Adjuvant services

Reliability of utility grid, balance in between power provision and consumer demand, the accurate transaction of power from buyer and supplier, all these can be controlled by adjuvant services that are obligatory in a power network. When the V2G system is two-directional, it can raise higher-quality ancillary facilities, superb voltage regulation, and adaptive control of frequency by using swarm optimization, catering the peak power, effective load management, and protection schemes by using supervisory control and data acquisition (SCADA) systems along with the use of artificial intelligence (AI), and capable spinning reserves [11, 18].

B. Regulation of voltage and frequency

Voltage and frequency regulation helps to balance real and virtual energy supply and demand. This can be achieved in modern grid systems by employing flexible alternating current transmission systems (FACTS) controllers [19]. EV batteries provide fast charge/discharge rates in the V2G method, producing an effective alternative for frequency control. Voltage control can be incorporated by using the battery charger. The electrical charger may help in compensation of leading and lagging imaginary powers by selecting appropriate current phase angles [20]. The estimations for all the relevant parameters can be obtained by using some professional simulation software, before the commencement of the real hardware components [21].

C. Target Load Leveling

A V2G scheme can handle the electrical demand by providing the stored battery energy to the power grid during the peak time and recharging the battery while the demand is lower in the grid. The V2G can use excess energy from EV-powered batteries to grant active power support to the grid. A smart load schedule offsets the load curve and helps in managing the peak load. The main targets are to reduce the power losses, level the high loads, and flatten the local load profile having peak loads [22].

D. Go for Renewable Resources

EVs equipped with a V2G system provide a backup source for renewables, for example, solar and wind, thus providing AC power. If electricity generation from renewable energy sources is very high, to return to equilibrium, centralized power plants should minimize generation or reduce the number of distributed generators (DG). EVs may store surplus energy from renewable sources to drive or provide electricity to the national grid when demand is greater [14, 23, 24]. Fig. 5 shows various applications of vehicle technology.

Fig.5. Vehicles to everything.

Table 1 marks the importance of V2G technology.

TABLE 1. POWER OF V2G TECHNOLOGY

Types	**Availability**	**Fitness Function**	**Constrains of EV**
Uni-D →	Voltage regulation Grid regulation Spinning reserve Load leveling Frequency regulation.	Minimize power losses, emission, cost & increase profit.	Battery SoC; Battery capacity; EV availability; Battery energy exchange limit; energy price.
Bi-D ↔	Demand Response Load leveling Peak shaving Voltage regulation Improve system reliability Spinning reserve Grid regulation.	Maximize RES, minimize error, rest same as uni-directional.	Battery SoC; Battery capacity; EV availability; Battery energy exchange limit; energy price, elevate system efficiency.

IV. Barriers For Vehicle Acceptance

The degradation of the battery over time, overall setup change, communication costs between the EVs and the grid station, distribution channels and their placements, losses that occur during distribution, and many other technical hurdles are the major cost contributing factors when one talks about V2G implementation. The battery life is affected by the constant charging/discharging and the storage of the battery is affected as well as the concerning time. Economical solutions are available to avoid these issues which include the usage of more efficient batteries. These can be developed by constructing a structure that passes all the standards used by operators and manufacturers. It is evident that the number of EVs which will penetrate the grid is on the rise, but on the other hand, the grid is not being upgraded for the high number of EVs that are coming in its way. Another dilemma faced by the grid is a different number of batteries with different charging needs.

EVs are produced in a way that they can be charged at residence or they can be charged at charging stations. During the charging process of batteries, EVs put on new challenges and demands on the transmission and distribution systems.

A. Degradation of Battery

The total power is drawn and the rate at which it is drawn directly affects the degradation of the battery where the major contributors are frequency of cycle and the depth of the discharge. Moreover, the occurrence of ripple currents, deep-discharging, reversed flow, overcharging, shock loadings, vibration resistance, and the subjection of external corrosion are the issues that arise in battery handling [25].

B. Potential Road Blockade in Electric Vehicles Journey

The transition to electric vehicles from the conventional ones will not be a smooth one. Although a huge rise is seen in the demand for electric vehicles, the road towards the global adoption of electric vehicles is laden with many obstacles that need to be overcome. A few of the obstacles are discussed below [26].

i. The Surge in Electricity Demand

The surge in the electricity demand is expected as the forecast of electric cars is whopping 2 billion electric vehicles. This will eventually put a sharp decline in the demand for crude oil, hence making oil a favorable option for power grid companies to produce electricity. In this way, the contribution of electric cars towards the generation of CO_2 emissions can be traced.

ii. Battery Disposal and Recycling

A total of 11m tons of used lithium-ion batteries are expected to come from recycling. This is the total volume of batteries expected between now and 2030. At the moment out of the total waste of lithium-ion batteries, only 5% are being recycled hence the waste of Li-ion batteries is on the rise [27].

iii. Charging Infrastructure

One factor which seems to be the fundamental barrier to the adoption of electric cars is the lack of charging stations. At the moment, there is a total of 16,000 charging stations in the US, but most of them face issues such as slower charges and traffic. A sound infrastructure for electric vehicles needs to be developed soon which will resolve consumer issues such as easy access to stations, fast charging, and convenience.

iv. Battery Technology

As the demand for electrically driven vehicles is on the rise, manufacturers are running out of cobalt and lithium, which are the primary materials for the manufacturing of the battery. This has led to an impulsive rise (as much as double) in the price of lithium.

v. Customer Adoption

Not many customers are interested in electric car purchases as they found it difficult to comprehend. Added issues such as battery lifetime, availability of charging stations, the anxiety of running out of charge, and initial investments hinder the purchase and acceptance of electric cars [28]. The mainstream adoption of electric vehicles is barred for the following reasons, according to the customer's point of view:

- The infrastructure for charging vehicles is still not very developed,
- The high price of the battery as per the customer budget,
- The need for an enhanced vehicle mileage range that would minimize the cost of possession.

V. REMEDIAL ACTIONS

A. The impact of electric cars on the economies and value chain of automotive

The global world is currently stringent on their policies regarding the carbon footprints and CO_2 emissions from vehicles, which have eventually affected manufacturers of the automotive sector and they compel to adopt electric vehicle projects.

B. Solutions of V2G

Power can be derived from the grid during charging (and vitality is cheap and abundant), and a system is developed where power is fed into the grid when needed. Likewise, smart building management technology is adopted by bigger residential areas by diverting the 'unused power from buildings during off-peak timings which are usually daytime during weekdays or late nights. This unused power is fed to electric vehicle charging points. In this way during the peak times, mostly early evenings the unused power is available for utilization.

VI. FUTURE PERSPECTIVE & CONCLUSION

The use of solid-state car batteries which are lightweight, less volume independent of chemical reaction dominates EV fleets to act as a producer. Integrating alternate renewable energy resources like fuel cells, supercapacitors into V2G technology will eventually cut down the burden and also solely depend on a single energy source. The listed charging techniques which are dynamic in nature can be adopted, which will eventually lessen the battery degradations and the initial cost of the expenditure. The application of AI techniques would also enhance grid connectivity performance shortly.

This article extricates the gems of vehicle2grid from the latest collection of V2G literature. The innovation gives the two-directional control scheme that charges at the lowest request period and is released when the control is required. The challenges faced in the emerging technology of V2G technology are mentioned in the manuscript.

VII. ACKNOWLEDGMENTS

The scholars would like to thank you for the full support given by the Islamia University of Bahawalpur, Pakistan, and the HEC of Pakistan. Besides, the authors are also grateful to the Electrical Engineering Department (SKE), University Technology Malaysia (UTM) for providing excellent research infrastructure and facilities.

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