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Vehicle-to-Grid (V2G) Technology Integration

Vasundhara K Patil[1], Jeevan V Wankhade[1]

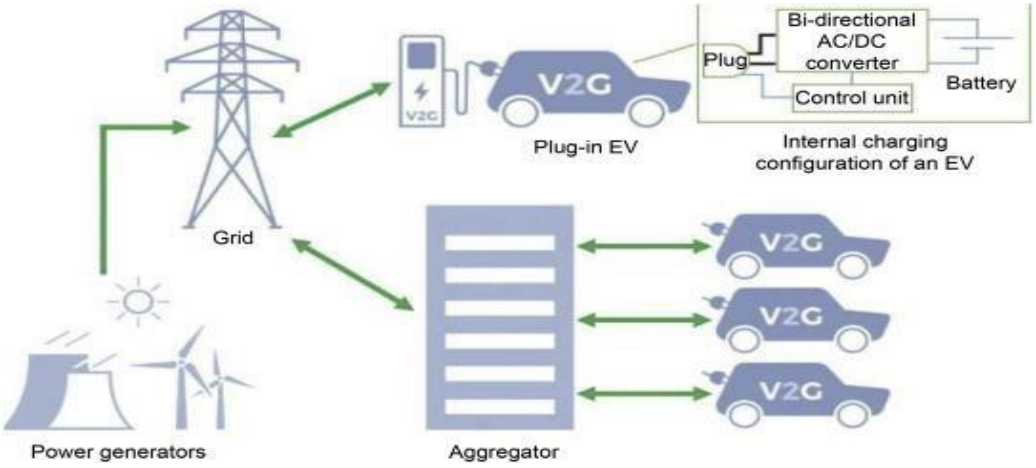
[1]Government Polytechnic, Hingoli, India

Abstract. The increasing global concern on climate change caused due to vehicular greenhouse gas emission and depletion of natural resources is the driving force towards the adoption of alternate clean fuel technology. Electric vehicles (EV) are an alternate green and clean technology which can enable the efficient transition to sustainable low- carbon emission transportation system. So, plug-in hybrid electric (PHEVs) vehicles are in the spotlight now. As most of the these customer-owned PHEVs stay parked more often than they are driven, it offers an opportunity to utilize their stored on-board energy to provide additional functionalities while they are idle. When the EV is parked, energy can be drawn out or supplied to the EV through the grid depending upon the requirements of the grid and the vehicle's battery SoC. Vehicle to Grid (V2G) is a technology that allows for bidirectional energy flow between EV and electricity grid. The features, advantages, future scope of V2G along with the challenges to implement it are presented here.

Keywords: Vehicle-to-Grid (V2G),Plug-in hybrid electric (PHEVs),Aggregators.

Introduction

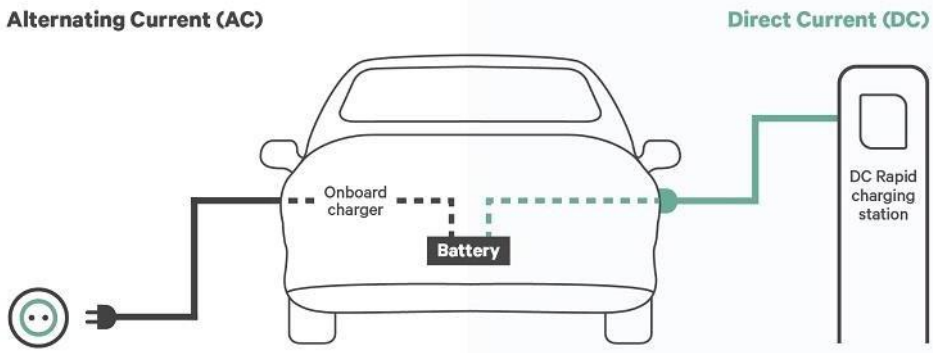
The Increasing environmental concerns due to vehicular emissions and depletion of natural energy resources led to search for a more efficient and clean vehicle. The Plug-in hybrid electric (PHEVs) vehicles are being seen as the future of transportation as well as on-board energy storage systems to cater additional functionalities. This energy storage systems on board in an electric vehicle allow bidirectional power flow to take power from or supply power to a connected power grid. The Vehicle-to-Grid (V2G) technology based on this principle. It enables energy stored in EV batteries to be pushed back to the electricity grid. The fundamental idea is to modulate the charging and discharging of EV batteries in accordance with the owner's needs and the requirements of the grid.



Vehicle to Grid Technology

Vehicle to grid (V2G) technology is a system in which capable to control bi-directional flow of electric energy between a vehicle and the electrical power grid. The on board energy stored in any electric-drive vehicle can be usedto meet the power requirements of power grid.. It has been calculated during the peak hours of power demand almost 92% of the total vehicles remain parked. So when a vehicle is idle, the on-board battery can be connected to a nearby electrical grid via appropriate smart communication devices. The idea is to use the

power from the idle electric vehicles to facilitate peak shaving. The vehicle batteries can be fully charged during off-peak hours of demand and discharged at any time according to the power requirements of grid. This can be implemented through smart grid concept, where an electricity network is capable of managing the electricity flow between grid and the users to fulfill varying power demand by continuous communication with the devices in the network.



For charging an EV, alternating current (AC) from the grid is converted to direct current (DC), which is stored in vehicle's battery. For the reverse flow, the DC electricity has to be converted back to AC to feed back to grid. This can happen on-board the vehicle or off-board at the level of the charge point/ station depending on the kind of charger used. In the on-board vehicle, AC with the V2G charger placed in the EV itself and can be connected to the grid using a cable. Off-board V2G setups uses DC current, and the hardware required for bidirectional flow is installed at the charge point/ station. Both setups have their own pros and cons. A vast majority of V2G setups are off-board DC setups using the CHAdeMO protocol.

Scope and Potential for V2G

Analysis by Precedence Research (2020) shows that the global V2G market will give revenue worth USD 17.43 billion and grow at a CAGR of 48% during 2020-27. India is targeting a share of 40 per cent for its renewables in its power system by 2030, with a total installed capacity of 450 GW.According to analysis by the India Energy Storage Alliance, the EV market in India is projected to grow at a CAGR of 44% and the annual battery demand is expected to grow by 32% from 2020 to 2027. This is a growth opportunity for India in this sector. The recent V2G pilot projects

also have shown promising results in the field. One case study by TERI is given below with outcomes and lessons to be learned.

Objective : The study simulated a V2G model for a typical summer day in Delhi to assess its utility to promote peak shaving/ shifting through time-of-day/ differential tariff mechanism, demand response (DR) and demand side management (DSM), integration of solar rooftop, and potential for emergency back-up applications.

Outcome : EV can be used to supply power to the grid during peak hours and be charged back during off-peak hours or when output from renewable sources is in excess.

Lessons to be learned: i) Aggregated models can help charging stations and EVs save on high storage costs. ii) Time of Day (ToD) tariff help to manage peak hour demand and vehicle ownersshould be encouraged to participate in V2G by providing financial incentives. iii) V2G could also help to achieve higher grid integration of renewables, enhanced fuel security by larger penetration of EVs, and a transition to a low-carbon path towards growth.

There are diverse and varied imperatives of V2G as

1. **Peak shaving:** V2G is well suited for peak shaving. The EV batteries can charge during off-peak hours,

thus filling the valleys in the load curve and can be discharged when there is peak in demand. Thus, V2G can help utilities manage their daily load and meet the peak demand efficiently as well as costeffectively.

2. **Arbitrage opportunities:** V2G makes it possible for the EV market users to trade on the power markets. When electricity prices are low, energy can be bought and stored by charging the vehicles. When the prices become high, the stored energy can be sold on the power market. Variable tariffs such as Time-of-Day (ToD) or Time-of-Use (ToU) tariff Structure can also be provided so tbat individual EV owners and fleet aggregators can take advantage of these differentials

3. **Frequency regulation:** The power grid frequency is set up at 50 Hz. When there is a supply - demand mismatch, then there will be variations in frequency, causes impact on the grid stability. Since EV batteries can quickly (within a few seconds) respond to the changes, this will be a much more efficient solution compared to sluggish mechanical spinning reserves. So V2G enabled EVs can be competitive for frequency regulation in the ancillary service market. Following table shows examples of revenue estimates associated with frequency regulation from studies over the past years.

Examples of Revenue Estimates from Frequency Regulation Services		
Study Location , year	**Calculation for**	**Net Revenue Estimate (USD/vehicle-year)**
Kempton and Tomic ,2003	Single Toyota RAV_4EV	USD 2250 for the 10KW chargepoint, USD 3320 for the 10KW chargepoint
Agarwal et al.Singapore,2012	10,000 private light duty vehicles	USD 1508
Ercan et al.United states,2014	School buses and Fleet Transit	USD 17384 for school buses USD 6170 for transit bus

All the above mentioned estimates for financial gains are based on anumber of assumptions such as the availability of sufficient EVs to be plugged into the grid; the willingness of EV owners to schedule their usage according to the need of the utilities

and the presence of communication mechanisms for efficient linkages between the EV, the charging station and the grid.

4. **As an RE storage unit :** EVs can be charged directly by RE sources (e.g. solar photovoltaic (PV),wind etc) when there is not sufficient demand but high volume of renewable energy is available in the grid. Thus the EVs can then store the energy and supply it when there is an increase in power demand.

Challenges for V2G

While V2G having wide range of applications and advantages, but there are certain implementationchallenges invovled that also have to be addressed**.**

1. **Existing EV scenario**

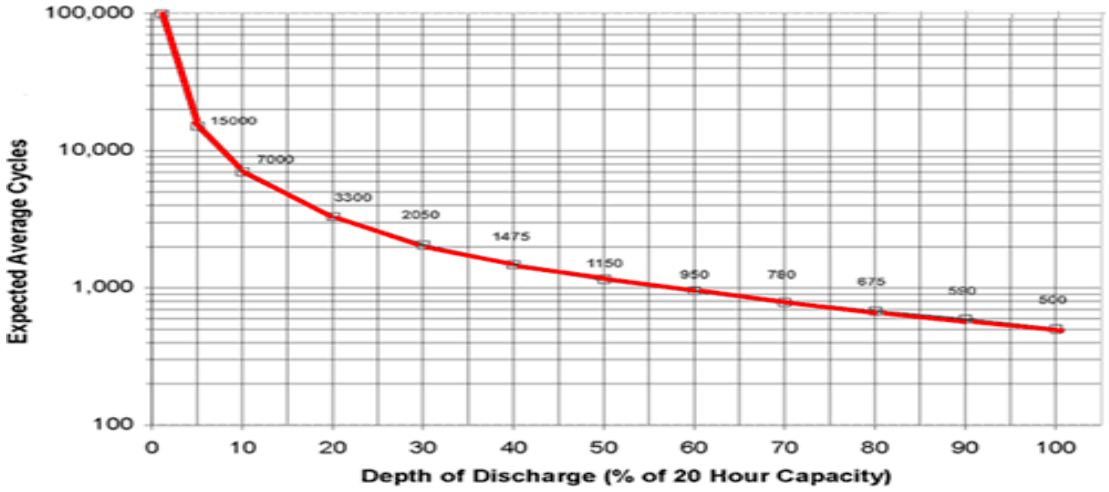
Current EV penetration level in India is less than 1% of the overall automobile market. Out of 230 million registered motor vehicles ,less than 1 million are registered EVs in the country.The majority of which are e-2Ws and e-3Ws, having limited practical utility for V2G due to their small battery sizes.

2. Lack of communication networks and protocols for grid and EVs linkages

V2G requires a real-time bidirectional communication between the utility grid and the charging station and also between the charging station and the individual EV owners.

3. Degradation of bateery life

The rate of degradation is often depends on how the battery is used, which is characterized by ageing stress factors including: capacity throughput (*CTP*), temperature (*T*), State of Charge (*SoC*), swing in State of Charge (Δ*SoC*) and the magnitude of both charging and discharging current. As the depth of discharge (DOD) increases, the life of the battery reduces significantly. This Reduced battery life further adds cost to the owner for participating in V2G.



Conclusion

The V2G technology provides a wide array of possibilities for reliable power generation and storage. It promises a more sustained approach where the environment is a major concern while fulfilling future power demands. Analysis by Precedence Research (2020) shows that the global V2G market will give revenue worth USD 17.43 billion and grow at a CAGR of 48% during 2020-27. This is a growth opportunity for India in this sector. The recent V2G pilot projects also have shown promising results in the field. The Government of India also has aggressively pushing mainstreaming of electric vehicles (EVs) through various policy instruments, which include the second phase of the Faster Adoption and Manufacturing of Electric Vehicles in India (FAME-II) scheme, production-linked incentive (PLI) scheme in advance chemistry cell (ACC) battery manufacturing, National Mission on Transformative Mobility and Battery Storage, and the Phased Manufacturing Programme (PMP) for setting up export-competitive integrated batteries and cell-manufacturing giga plants. According to analysis by the India Energy Storage Alliance, the EV market in India is projected to grow at a CAGR of 44% and the annual battery demand is expected to grow by 32% from 2020 to 2027. As and when more durable batteries and cost efficient grid management will become common, thesmart grid technologies supporting V2G have the latency to meet up the future power demand.

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