Potentially Affect Of A Vehicle To Grid On The Electricity System

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Abstract- As many electric vehicles (EVs) are continuously on the market, Vehicle to Grid (V2G) technology has been successfully taken into consideration. The EV can be used to take part in such a load change in the electricity network as external storage gadgets. This article makes it much easier for researchers to understand the philosophy of V2G and its measurable influence on the electricity system in order that included all of the details for the integration of renewable energy sources. In the field of well-mannered and battery degradation, bi-directional charger and charging stations, a configuration for V2G and the critical aspects involved with V2G become analyzed by means of concentrated battery system management and control throughout this work. The challenges, benefits and technologies related to V2G are also addressed, in addition to the financial revenues and expenses of both EV holder as well as the energy infrastructure. For standardized test systems, the influence of a vehicle on the grid on the electrical grid has been examined in this work.

Keywords- Smart charging, Vehicle to Grid (V2G), EV

1. INTRODUCTION

As the years are passing, advancement in Vehicle to Grid (V2G) are getting closer to become reality and implement throughout the world [1]. V2G technology has its own advantages, it consists basically the bi-directional flow of electricity from vehicle to grid or vice versa according to demands. The major equipment required is EV’s battery, Charging stations, Power Grids, Aggregator etc. This technology made into use according to the requirement of energy. The main object of V2G is to give maximum power i.e. EV owners charge their vehicle on low cost and discharge the vehicles when it requires on high cost, this make the EV owners in huge benefits being connected to V2G project.

We can take the advantage of EVs to reduce the increasing energy crisis and environmental pollution. Electric vehicles effectively emit no air contamination at the location where they are used and create comparatively lesser noise pollution to internal ignition automobiles, regardless of if they are moving or not. Emission of pollutants such as carbon dioxide (CO2) or other pollutant for example: NOx, CO, PM and NMHC are not appear in Electric vehicle in the area of utilization [2].

In this paper discuss the issues and challenges regarding V2G transfer and impact of V2G on power system, technology required for V2G, economics and modelling of V2G by various computational analyses.

2. INSIDE OF VEHICLE TO GRID

For the unidirectional power transfer in EVs, G2V (Grid to Vehicle) and V1G technologies comes into effects. But for the power to be transferred bi-directionally among EVs and power grids, we have to introduce V2G. Chargers with AC-DC converter circuit as well as DC-DC connector have been typically used in bi-directional power transmission to increase the power factor and control the charging and discharging rate of the battery [3].

V2G technology has so much ability that it can possibly advantageous for both the owner and supplier of power. Smart city possible block diagram of V2G system is shown below in Fig. 1.
2.1 Technology Required for V2G

The development of electric vehicles (EVs) would be a strong benefit for the growth of sustainable energy in the world and in particular, for the development of renewable energy sources. This would be true for a number of purposes. Perhaps notably, including a transformation in the transport sector, EVs present a feasible chance of introducing even larger numbers of renewable energy into the ultimate electricity production.

EVs will require a lot of extra power. This can be met for all intents and purposes and cost benefits with renewable, including sunlight based and wind energy delivered to the grid. These advancements offer a tempting prospect – especially for urban communities – to decarbonizes transport while noise pollution and contaminate air, decreasing dependency on fuel and embracing new ways to deal with urban portability.

2.2 Smart charging:

Owing to the probability that more than 159 million EVs will have been added into the power system by 2030 and that significant numbers would have been relocated to some terrestrial areas with unregulated charging, the nearby grid would have been disrupted by extreme traffic. Support for the local grid is important to maintain a strategic distance from such a situation. In general, such predictions can be held away by using smart charging. In general, smart charging will be integrated with slow charging in the low-voltage distribution network [6].
The top priority of Mobility field is to diminish the expenses of smart charging associated with fast and ultra-fast chargers. However, to improve the flexibility of system, slow charging is most appropriate. However, arrangements such as high-storage charging stations and battery interchange technologies will help maintain a strategic distance from maximum demand from fast and super charging to reinforce local power grids. Dissimilar to uncontrolled charging, it diminishes concurrence and brings down peak demand.

2.3 Advantages of V2G

For power grid applications
Structures capacity to adjust their energy demand with V2G charging stations also assists the power grid for an enormous scale. This will prove to be useful when the measure of sustainable power source in the grid, delivered with wind and sun based, increments. Without vehicle-to-grid innovation, power must be purchased from reserve power plants, which rise power costs during peak time, since striking up these additional power plants is an expensive methodology. V2G empowers energies organizations to play ping pong with power in the grid.

Work as a virtual generating station
In this approach, the entire V2G electricity grid functions as a virtual power plant (VPP). This point of view could be widely used for the evaluation of the V2G limit near to the generation and transmission components and in the enormous reach of the power grid. VPP can be assessed together to minimize the generation and change the power supply and demand of power stations and moreover, to replace costly generation units, especially during peak load times. In addition, EVs power dispatch is not included in this application and all capacity batteries are required for the SO to set up conceivable grid services. In fact, the VPP plan is expressed in the small and irregular limit of EVs. From this viewpoint, it tends to be used at all stages of the power system alongside other existing properties. The concept of a VPP must therefore be considered in small grids and isolated islands for the assessment of energy resources in particular as a reinforcement of the low and discontinuity quality of renewable energy resources [7].

Environment friendly
Electric vehicles essentially do not discharge air pollution at the location where they are operating. It is also generally easier to build contamination management frameworks in centralized power stations than to retrofit vast quantities of vehicles. Another advantageous position is that electric vehicles typically have less noise emissions than internal ignition motor vehicles, regardless of whether they are moving or not. Emissions of gasses such as carbon dioxide (CO$_2$) or other contaminants, for example: NOx, CO, PM and NMHC, do not occur in the usage area of Electric Vehicles.

To the vehicle owner
The use of V2G would help that both grids provider and the automobile owner. In addition, there will be points of interest for the environment in the future. Energy is stored in EVs at night time-when the cost is low-and is removed during peak hours-when the cost is high, EVs serve as a pump storage unit. As a result, the vehicle owner will receive income from the expense distinction and repay some component of the early investment [2].

2.4 Challenges of V2G

Degradation of battery life
EVs store electricity from the grid in electrochemical cells. The lead-acid batteries were the least expensive decision, however as of now lithium-ion (Li-ion), hydride of Nickel Metal based batteries and polymer of lithium-metal show up progressively serious attributable to their long cycle lives, littler size and lower weight. To charge the batteries, they require to be connected to the grid.

In the ongoing report at Tantung College, Taiwan, the capacity limit of the industrial 18650 Li-ion cell involved in composite cathode LiNi0.5Mn0.3Co0.2O2 (NMC) and Li1.1Mn1.9O4 (LMO) and graphite anode at different Depths-of-Discharge (DoDs) and temperature was examined. The results show that the fading potential is highly affected by the temperature of the capacity and is unmistakable at temperatures above 45°C [8].
First the schedule life of the EV battery was evaluated utilizing the battery life model. With no use of the battery, the EV battery would gradually degrade and after around 17 years the battery limit would have dropped to 75% of its actual limit.

**Expense of charging stations and storage**

V2G setup requires the foundation of basic measures for installment of grids. The charging and discharging procedure can't be done without solid connections among EVs, charging stations, and the smart grid.

The equipment of technology expected to effectively make V2G storage with their expenses are:
- Plug-in Electric Vehicle, Public Electric Vehicle Supply Equipment (EVSE) ($6,440 per charger)
- Private EVSE, Grid Control Indicators (GCI) and smart meters ($188 per meter)
- Home Energy Management Gateway (HEM) ($100 per house or building)
- Software ($100 per ESVE)
- Driver Communication Device.

To compute the complete cost, need to discusses first expect two EVSE for one EV (at work and at home), a smart meter associated with every charger, one HEM for each EV, and programming per EV. In this way, the overall cost of the energy framework per electric vehicle would be as follows:

\[
\text{Cost per vehicle} = [2 \times \text{Cost of EVSE}] + [2 \times \text{cost of smart meter}] + [\text{cost of HEM}] + [2 \times \text{cost of software}]
\]

\[
= [2 \times $6440] + [2 \times $187.5] + [$100] + [2 \times $100]
\]

\[
=$13,555 \text{ per vehicle}
\]

It is estimated that 30 million vehicles in India, at that point the total expense for introducing the charging station in India is $406,650 Billion.

**Note:** The above data (except no. of cars) is based on estimation of Texas Triangle (USA).

**Effects of harmonics**

Vehicle-to-Grid (V2G) is an evolving use of plug-in electric vehicles that connect with the power grid to produce electricity. Power quality improvement is one of the potential advantages of V2G frameworks. V2G is assessed as a way to improve distribution network power quality by means of harmonic suppression.

The Analysis of Harmonics for the odd harmonics from the third up to 25th on 11kV transport bar for 33kV/11kV substation as depicted in Fig. 3

![Harmonic distortion at 11kV bus bar](image)

**Fig.3** Harmonic distortion at 11kV bus bar at the main substation

**Energy cost due to losses**

A normal EV battery has a capacity of around 25 kWh and a lifetime of 2000 cycles and expenses about $10,000. Despite the fact that it has a limit of 25 kWh, its depth of discharge is typically restricted to around 80% to improve its life. This implies when it is completely energized, it has just 20 kWh of
accessible vitality. The expense of charging the battery isn't only the expense of the 20 kWh of energy in the battery since there is normally a productivity loss of 10% in the charger used to change over the AC from the manufacture company to DC used to charge the battery. Along these lines the client needs to buy 22 kWh of energy to give the 20 kWh of accessible energy. With power costing ten pennies for every kWh at the purpose of utilization, it costs just $2.20 to charge the battery for a day's driving, and this is the income gotten by the power producing utility.

We see that the main expense of charging the EV is $2.20 for one time, considering the inverter effectiveness, the client has just 18 kWh of accessible energy which cost $7.20, longer than a month the charging cost is so high.

2.5 Economics of V2G

The maximum capacity of the V2G system based upon advancement of technology also, since organization of EVs in explicit markets is vital to accomplishing a critical mass for offering types of assistance.V2G is co-operated by numerous EV proprietors; it is not the work of single identity. For receiving the economical rewards of V2G technology, it is crucial to create and convey reasonable plans of action taking factors, for example, state of-charge (SoC), least bid size, participating capacity and so on into consideration. So as to make a beneficial plan of action inside this area, it is necessary that the service provider make an incentive for the three principle partners grid, aggregator, and EV proprietor [9].

Revenue and cost of V2G

The Economic value of V2G can be estimated as the difference between revenue and expense.

- Revenue equations:

  The revenue formula depends on the market into which power is to be sold.
  Revenue is just the product of energy dispatch and price for the markets that pay only for energy, i.e. base load power and peak power [10].

  TR = \( r_{el} E_{disp} = r_{el} \times P_{disp} \times t_{disp} \)  

  \( TR \) – Total revenue usually in 
  \( r_{el} \) – Electricity market rate in $/kWh
  \( P_{disp} \) – Dispatched power in kW
  \( t_{disp} \) – total time to dispatch power in hours

  For V2G, capacity is disbursed just if EVs are accessible and parked. Calculate revenue from either regulation services or spinning reserve, in which the terms included are energy payment and capacity payment.

  \( TR = \left( r_{cap} \times P \times t_{plug} \right) + \left( r_{el} \times E_{disp} \right) \)  

  \( r_{cap} \) - capacity rate in $/kWh
  \( r_{el} \) – electricity rate in $/kWh
  \( P \) – Contracted Power Capacity
  \( t_{plug} \) – time the EDV is plugged-in in hours
  \( E_{disp} \) – energy dispatched in kWh

  For spinning reserves, the method of computing \( E_{disp} \) is:

  \[ E_{disp} = \sum_{i=1}^{N_{disp}} \left( P_{disp} \times t_{disp} \right) \]  

  \( N_{disp} \) = Dispatch Number
  \( P_{disp} \) = Power of dispatch
  \( T_{disp} \) = duration of each dispatch in hours
Furthermore, a run of the dispatch is ten minute, so the all-out $E_{\text{dis}}$ will be fairly low. There can be 400 dispatches for regulation services every day, changing in power ($P_{\text{dis}}$). On rearranging equation (3):

$$E_{\text{dis}} = R_{d-c} \times P \times t_{\text{plug}}$$

(4)

where, $R_{d-c} = \frac{E_{\text{dis}}}{P_{\text{contr}} \times t_{\text{contr}}}$

$P_{\text{contr}}$ – contracted power capacity
$t_{\text{contr}}$ – contract Duration

For estimating Regulation Services Revenues (in which energy becomes estimated, not recorded); Eqn (4) and Eqn (2):

$$TR = E_{\text{dis}} = \left( \rho_{\text{el}} \times R_{d-c} \times P \times t_{\text{plug}} \right) + \left( \rho_{\text{cap}} \times P \times t_{\text{plug}} \right)$$

(5)

- **Cost equations:**

The Obtain energy, wear and capital expenses are used to calculate the cost of V2G. The capital expense is that of extra hardware required for V2G however not for operating Vehicles [10].

For yearly basis, usually the common expression of cost is:

$$C = C_{\text{ac}} + C_{\text{en}} \times E_{\text{disp}}$$

(6)

$C_{\text{ac}}$ – Total per year cost
$C_{\text{en}}$ – er energy unit cost
$E_{\text{disp}}$ – energy dispatched in the year
$C_{\text{ac}}$ – yearly capital cost

For spinning reserves, we must make use of eqn. (6) and eqn. (3) again to calculate total cost. Placing eqn. (4) into eqn. (6). To provide regulation, the total annual cost is:

$$C = C_{\text{ac}} + C_{\text{en}} \times R_{d-c} \times P \times t_{\text{plug}}$$

(7)

Purchased electricity concept as well as equipment failure terminology are included in the $C_{\text{en}}$ equation.

$$C_{\text{en}} = \frac{C_{\text{pe}}}{\eta_{\text{conv}}} + C_{d}$$

(8)

$C_{\text{pe}}$ – cost of energy purchased
$C_{d}$ – Equipment degradation expense in $/kWh

$C_{\text{pe}}$ includes the cost of hydrogen, electricity, gasoline and $\eta_{\text{conv}}$ is the efficiency to convert fuel into electricity and vice versa.

$C_{d}$ is measured as V2G wear attributable to overrun period on a hybrid engine or fuel cell, or extra battery cycle. In the case of a hybrid operating in the engine-generator mode or a fuel cell vehicle, the cost of degradation can be measured as:

$$C_{d} = \frac{C_{\text{engine}}}{L_{h}}$$

(9)

$C_{\text{engine}}$ – capital cost of engine in ($/kWh)
$L_{h}$ – lifetime of engine or fuel cell.

For vehicles Battery,

$$C_{d} = \frac{C_{\text{bat}}}{L_{\text{ET}}}$$

$C_{\text{bat}}$ – capital cost in $
$L_{\text{ET}}$ – battery lifetime throughput energy in kWh

if the Engine’s life is greater than Vehicle’s life, battery life or fuel cell, the cost of degradation is zero.

$C_{d}=0$

(10)
3. DATA ANALYSIS

3.1 Peak power and peak demand Analysis and its Results: A case study on Delhi EV charging

In the beginning of August 2020, Delhi government announced a policy ‘Delhi Electric Vehicles Policy, 2020’. It gives the maximum importance on replacement of public transport, two wheelers and private four-wheelers with Electric Vehicles (EVs).

The primary aim is to reduce the air pollution and to be less dependent on Internal Combustion Engine (ICE). Delhi government aims at least 5, 00,000 EVs in next five years. This policy also offers road tax, subsidies and registration fee waiver for the advent of EVs in capital.

Out of 11 million registered vehicles in Delhi, 83,000 are EVs, out of which 75,500 are e-rickshaws, 900 private EVs and around 3700 e-two-wheelers at present. Also Delhi government sets plan to install 300 more vehicles in next six months.

Energy Efficiency Services Limited (EESL) undertaking a project to install charging stations across the capital. As of now, New Delhi Municipal with the state-run firm has installed 55 DC-001 15 kW public charging stations in the city. Apart from it, the firm also installed 305 chargers in Delhi, in which 203 are AC-001 chargers and 102 are DC-001 fast chargers.

Delhi’s Energy Consumption and peak demand in 2018 was 33,625 MUs and 5,745 MW respectively. According to the ‘Long term Electricity Demand Forecasting [11]’ by Central Electricity Authority, the Energy Consumption and Peak demand in 2030 are forecasted to be 68,860 MUs and 7797 MW respectively. The growth of it from 2015 to 2030 is shown in figure 4.

3.2 Idle EV charging station Estimation: A case of Delhi

To analyze the status of EV charging stations, the total capacity available for V2G is estimated. Total EV charging capacity \(C_{\text{cap}}\) can be computed by using number of charger \(C_n\) and the power consumed by a charger \(C_p\).

\[
C_{\text{cap}} = C_n \times C_p ~ (11)
\]

If the charging capability of the EV charger is expected for being 80 kW (up from its current value i.e 15 kW) and the number of chargers in the city is projected to be about 5020 in 2030, the total charging ability of the EV can be measured at 4.01.600 kW in Delhi.

For each year, the idle station capacity \(S_{\text{cap}}\) is simply the remaining capacity subtracting the EV charging power at peak time \(P_{\text{total}}\).

\[
S_{\text{cap}} = C_{\text{cap}} - P_{\text{total}} ~ (12)
\]
The year wise total idle station capacity is depicted in between the area of two plots in given Fig. 5 below. At peak time, Delhi’s charging power estimated as 58,272 kW in 2030. Hence, the total idle station capacity calculated is 3,43,328 kW. It can be concluded that, it is correct to say that maximum of 85% chargers are available for V2G operations during peak time.

4. CONCLUSIONS

The recent study concerned the overview of V2G and its major impacts on Power system. The primary object of this paper was to discuss various problems, limitations and challenges in V2G transfer. The Economics of V2G is also highlighted in which we obtain the cost equations and revenue equations. The final part of the paper is Data analysis on peak demand and peak power and estimation of idle station capacity based on Delhi EV charging system in which we use the forecasted data by Central Electricity Authority. From this analysis, it winded up that during peak time, we can use maximum of 85% chargers that are available for V2G.

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