[NC-Rase 18]
DOI 10.5281/zenodo.1489849

ISSN 2348 – 8034
Impact Factor- 5.070

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

V2G INTERACTION: A SMART GRID TECHNOLOGY

Priyanka Arvind Dinde[1] & A.R. Thorat[2]
Undergraduate Student[1], Assistant Professor[2], Electrical Engineering Department
Rajarambapu Institute of Technology, Islampur

ABSTRACT

Electric vehicle is an promising solution for transportation option to the conventional vehicle due to energy crisis and environmental issues. Recently, integration of electric vehicle to grid is an advanced technique to deal to energy crisis and environmental issues. This technology provide so many services to power grid. Vehicle to grid is vast area of study. This paper discuss on concept, services, barriers to V2G technology .Finally, paper suggest ways of EV connectivity to grid, EV charging schemes during implementation of V2G technology, solution for the challenges of V2G to increase the implementation of V2G technology.

Keywords: *Bidirectional charger, Electric Vehicle [EV], vehicle to grid interaction [V2G], Renewable energy.*

I. INTRODUCTION

For transportation sector and power generation industry, fossil fuels are dominant sources of energy. Because of depletion of fossil fuels it is necessary to find alternative energy sources .So for this electric vehicle is promising solution. Today the worlds energy consumed by the vehicles is 30% and it is responsible for 27% of total greenhouse gas emissions.[5] The increasing demand of energy will lead to carbon dioxide emission and energy crisis

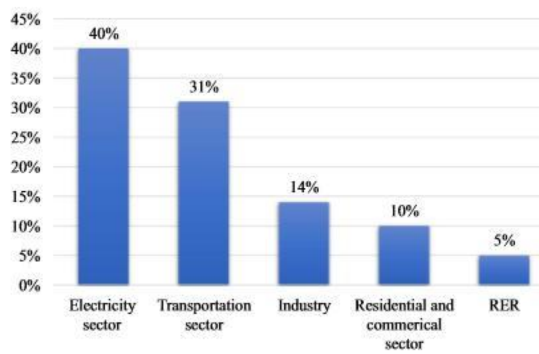

Fig.1 .Various sector wise emission of GHG [7]

So to eliminate the emissions originated, grid connected vehicle is an effective solution. Some of the studies reveal that most of the vehicles parked for 95% of time, so they can available in this time to connect to grid and ready to deliver their battery energy to grid

For improving power system operation, V2G technology is best smart technology. V2G concept allows electric vehicle and power grid interaction for energy exchange.

The EV technology provide number of benefits or services such as peak power shaving, spinning reserve, voltage frequency regulation to support the power grid [1].To increase the profit ,to reduce losses the optimization techniques are adopted.

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II. METHODS AND MATERIAL

2.1 Vehicle to Grid concept

V2G technology take power from charged local EV fleet and provide the energy to the power grid using control and management of aggregator . [2]When EV integrate into grid it act as var EV can be integrated into power system and operate as the active load(that is draws power from the power grid) or active ESS (that is energy to grid)

It is interaction between electric vehicle and power grid. [2]

In V2G technology power transfer is in two way :

Unidirectional
Bidirectional

1. Unidirectional power flow

Unidirectional V2G is one way power transfer that is EV can be act as a active load and draws power from power grid . Grid provide energy to charge the EV and also manage the charging rate of the EV battery

Only ancillary services provide by unidirectional V2G to power grid, such as power grid regulation and spinning reserve, because of this services power grid can be easily modified [2]

It can reach increase in profit and reduction in emission by using optimization technique

2. Bidirectional power flow

Bidirectional power flow is the two way power transfer between EV and the power grid to reach so many advantages to power grid. A bidirectional EV charger consists of AC/DC rectifier and DC/DC chopper

The AC/DC rectifier provide DC power to EV by rectification process for charging purpose and also it act as a inverter and fed AC power to power grid . DC/DC chopper act as a step down and step up chopper during charging and discharging mode.[2]

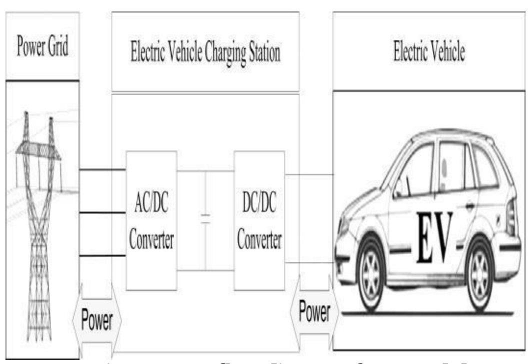

Fig2. Power flow diagram for V2G [2]

To improve power system operation the bidirectional(two way power flow) V2G provide more flexibilities and possibilities . It provide services like active power support , reactive power compensation, improve power factor and give assistance for the integration of renewable energy resources[2]

2.2 EV Integration with Grid

For EVs integration into the electric power system it requires an intensive evaluation and examination in words of economic influence, operation and control advantages at optimal conditions. The pillar of this framework is of two folds, that is, the electric vehicle possessors and profitable body (utility entity).[1]

Essentially within power grid, there is no storage provision (other than its 2.2% capacity in pumped storage), so for matching the customer changing or fluactuating load demand, generation and transmission must be managed without any interrupt[3].Vehicles is in the nature of roadway driving, so it is designed to have large and frequent power fluctuations. Due to high capital cost of large generators it has high use (average 57% capacity factor). By contrast, as personal vehicles are cheap per unit of power and they are utilized only 4% of the time for transportation.so remaining 96% of time of vehicle is used for secondary function .

There are three types of EDV
1.battery-electric vehicle: This vehicles can be charge during off peak periad and discharge when peak demand

[4] Fuel cell vehicle: this vehicle converts liquid or gaseous fuel into power

[5] plug-in hybrid: it can operate in both mode. During driving purposes it uses fuel energy without using battery charging and when connected to grid provide power through battery

For integration purpose, each vehicle must have three essential components (1) for electrical energy flow there must be connection to the grid (2) for communication with grid operator control or logical connection necessary and (3) on-board charging type vehicle [3]

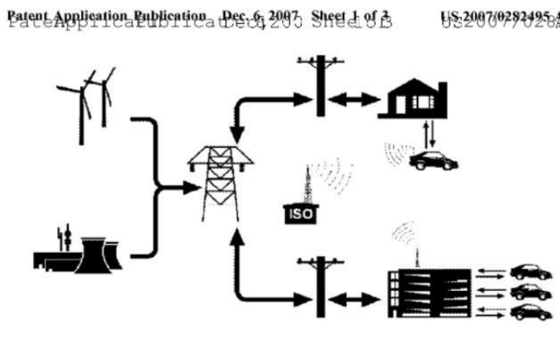

Fig 3[3]

The fig3.shows the interaction between electric vehicle and power grid connections. Electricity flows in one-direction from generators to the electricity user through the grid. From electric vehicle, or with battery electric vehicle power fed back to the grid, the flow is in both direction (FIG. 3 shows the two way power flow). Broadcast radio signal, or through a cell phone network, direct Internet connection, or power line carrier are the control signals transmitted by the grid operator. The signal may go directly to each individual vehicle, or to the office of a fleet operator, when grid operator, demand power for grid ,during peak load which in turn controls vehicles in a single parking lot, schematically shown in the lower right of FIG. 3 or through a third-party aggregator, is the central incharge who co-ordinates all the required operational activities like communicating with distribution system operator (DSO), transmission system operator (TSO), and energy service providers. The link between energy market and EV owners.is maintain by aggregator

Due to the—limited energy storage, less device lifetimes, and more energy costs per kwh electric vehicle cannot provide base load power demand ,also it can not exploiting their strengths—quick response time, low standby costs, and low capital cost per kW.[3]

Due to continuously charging and discharging cycles , the battery lifespan is extremely affected in vehicle to grid application. The Peterson et al.[1]

conducted the study on the capacity fade characteristics of the lithium-iron-phosphate (LiFePO4) battery cells . The study reveals this type of battery handle continuous charging discharging cycle with less capacity loss. Guenther et al.[1] Conducted a study to examine the battery degradation characteristics of the Li-ion battery based on the aging model. The results show that V2G transactions reduce the battery lifetime for nearly 3 years because of the prolonged discharging cycles and greater cycle depths. However, the battery life can be extended by adopting intelligent charging schemes

2.3 EV Charging Schemes

The performance of power grid is affected by charging and battery management since charger type, charging level, and charger connections of EV's have significant effects on the grid . There are two ways by which ,battery status can identified: State Of Charge (SOC), means current state of battery in use and State Of Health (SOH) means is a figure of merit of condition of battery compared to its ideal condition. The State of health and the State of charge of the battery is affected by the time required for charging , the rating of , temperature parameter of battery, and the control design.[4]

State Of Charge =Remaining Capacity/ Rated Capacity

The following are the common used charging methods for electric vehicle

1. Multistep Constant Current [CC]-

In this method, by managing or controlling the voltage of the battery the constant current is maintained. During charging the SOC level increases linearly. It provide charging of EV battery in much shorter time with longer cycle life and high energy efficiency. The charging termination is sometime decided by the range of voltage , charging time, increase in temperature etc.[4]

2. Constant Voltage [CV]-

This is simplest and most common charging method in which battery act as a voltage source. Charging current varies over the time, during the charging period .At the initial stage the current is high, at that time state of charge is at the low level .However, the

ISSN 2348 – 8034
Impact Factor- 5.070

charging current goes to minimum over the time, and the state of charge reaches its maximum level. The high amount of current is draws by using this method.[4]

3. Combination of CC and CV-
In this method combinations of CC and CV are used .At initial stage the battery is charged slowly with constant current and then current increases. A cut off value is set for the state of charge and if the SOC reaches that value the charging is moved to constant-voltage mode which is maintained until the maximum level of the SOC.[4]

Parameter	CC	CV	Combination of CC-CV
1.Charging time	Short time	More	Fast charging rate
2.Efficiency	More efficient than CV	Less efficient	More efficient than CC
3.Lifeof battery	Enhances the life	Overheating ofthe battery reduces life	Increase life span of battery
4.O/P Impedance	High	Low	High

For deciding the state of charge and charging stoppage time following methods are used:

[8] Voltage limit: A boundary level of the battery voltage is set and once the voltage reaches that level the charging is ended .This method generally implemented in the CC charging method

Voltage drop: When SOC level of the battery reaches 100%, in some types of batteries, the temperature starts rising due to the chemical reaction, and this chemical reaction drops the voltage and if voltage drop reaches a pre-set value the charging will stop

c. Change in voltage rate (dV/ dt) : Over the time , if voltage change is not observed or if it goes to a negative value (−dV /dt), then the charging process will stop

d. Minimum current level (Imin): when charging current reaches the predefined lowest current range ,charging process terminates .This method generally applicable in the CV charging scheme .

e. Change in temperature rate: when rate of temperature change reaches defined safety range ,then system terminates the charging process .

2.4 V2G Services

1. Ancillery services:
By controlling the EV charging rate the primary services is provided by unidirectional power exchange scheme

It is categorized into two service a.power grid regulation:
To balance the generation and load demand, frequency modulation is provided by power grid regulation. In regulation down mode, the fixed load increases so EV charging rates are reduced to remain at same preference operating point. EV charging rates are rises in regulation up mode due to a minimization of fixed load.[1]

b. Standby reserve or Spinning Reserve: It is an extra generation to compensate the power outage. It provide quick response within 10 min

2. Active power support:

The bidirectional vehicle to grid service provide the active power support to grid by utilizing excessive EV energy The grid load outline is flatten by

a.Peak load balancing:
In the peak load balancing concept, to balance the load the V2G provide power by valley filling (charging at night when demand is low) and peak shaving (sending power back to grid when power demand is high to shave off the load)

b. load levelling
It can enable utilities new way to provide regulation services (keeping voltage and frequency stable) and provide spinning reserve (meet sudden demand for power)

It reduces the stress on power system, reduces losses in system by maintaining power system operating capacity at lower level, prevent additional equipment upgrade cost

3. Reactive power compensation:
Voltage regulation in power grid is provided by reactive power compensation. It also improve the power factor ,as power factor improves it reduces current flow and losses in line .Capacitive reactive power is required for power grid compensation .In V2G is able to provide reactive power compensation service due to presence of capacitor in EV bidirectional battery charger[1]

4. Increases uses of renewable energy sources
The energy production in renewable energy sources is totally depend on environmental factor .So by utilizing the EVs fleet as energy reserve or energy storage the intermittency issue of RES can be solved. The economics of renewable energy generation industry is improved by EV. The future power grid will be cleaner and sustainable due to interaction between EV and renewable energy [1]

2.5 V2G challenges

1. Battery Degradation
The continuous charging and discharging cycle of the battery, will deteriorate the battery cell . Guenter et al [1] studied about the battery degradation characteristic of lithium ion battery, the study revealed that the battery lifetime is reduced by nearly 3 year due prolonged charging discharging cycle. Battery lifetime is the operating system lifetime

Due to the irreversible chemical action, the battery internal resistance is increased [2] and minimize the battery life and usable capacity. To predict the battery life cycle the ESR (Equivalent Series Resistance) parameter is used. The battery ESR is increased due to battery frequent charging discharging cycle and battery DOD (Depth of Discharge).

So to minimize increase in battery ESR, the battery cycle should be maintained around the middle range of SOC. Battery DOD is lesser than 60% to maintain the battery life cycle so the usage life drops between 30% SOC to 90% SOC[2].

2. Maintenance
As the EV are powered by battery, especially lithium ion battery, so there is increasing concern about their safety availability, and recycling process. The extraction lithium from salt water is under research. In V2G grid supply power to EVs, so aim of achieving clean energy is not being fulfilled [4]

3. High Investment Cost
In V2G technology to reinforce the grid and for charging facilities tremendous investment will be needed To upgrade the power system the high cost is required .For transferring power in V2G ,for each EV the bidirectional charger is needed which is a complex controller

The frequent charging discharging cycles are required in V2G implementation and in this process energy conversion process involves which will directly proportional to more losses and more losses is proportional to additional cost. Also in the power system the EVs fleets denote serious losses

4. Connectivity
Using V2G technology the EVs can be charged it creates a power quality degradation problem such as voltage drop, increasing peak load, saturating transformer, frequency drop [4]. Power balancing is affected due to fast charging. At the evening the fast charging occurs, which is significant challenge to manage since it is coinciding with grid's peak demand.

5. Social Barriers
For V2G implementation there is crucial requirement of large number of EVs. Public acceptance and awareness of the V2G technology is prevented due to social barriers, which is a big challenge for V2G implementation. Taking part into V2G technology requires EVs owner to share the EV batteries energy with power grid which not ensure guaranteed amount of energy for emergency to EVs owner which create range anxiety among EV owners. This is due to lack of charging facility [2] To reduce this barrier a neat planned EV charging infrastructure is needed

III. CONCLUSION

The conventional vehicle emits the carbon dioxide which create environmental issues .Also it requires energy from fossil fuels which are dominant sources. Electric Vehicle is one of the promising solution to mitigate all issues. Integrating electric vehicles into grid is one of the smart grid technology which provide numerous services to power grid. There are methods for integrating vehicle to grid such as by using fleet of EV, through aggregator, by interacting with individual EV owner etc.

This report discusses about the concept, services, charging schemes, integration of V2G technology and challenges faced by the technology. Replace the fossil fuels from powering the conventional internal combustion engine is the primary goal of this technology .V2G technology provide so many benefits to grid such as ancillary services, managing the peak load demand, load balancing, reactive power compensation and solution for intermittency issue of renewable energy sources.

Having a neat planned charging infrastructure and related technologies, is the initial requirement of this technology. Despite of that notable improvement, future researches are enhances in this area.

ISSN 2348 – 8034
Impact Factor- 5.070

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