A Study on V2G Technology Incorporation with the Smart Grid Station

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Abstract- *For electrical power industry, Smart Grid (SG) is one of the hot topics in national news and professional conferences from last few years. Its success is depending on the customer need, which is measured in terms of reliability. But in present SG systems, there is always an energy scheduling problem for source and the demand side, as electrical energy demand is growing rapidly. This gives an alarming situation not only for providing sustainable energy but also preservation of environment worldwide. Therefore, in this paper, the vision for futureSG is further articulated by Vehicle-to-Grid (V2G) implementation, so that monitoring and controlling of that electrical power will be possible. Also, the Electric Vehicle (EV) has become integral part of the grid operation. This offers an opportunity to utilize EV's stored energy, when they are in idle (parking) condition means if demandneed is low and sending power back to the grid if demand need is high. This way, flaw less and error less continuous supply is imaginable for the consumers. To get the maximum benefit of this V2G technology, it is enforced to merge the complementary strengths of the EV's and needs of the power grid. This paper will also shed some light on economic impact, advantages and scope of V2G technology.*

Keywords: Smart Grid (SG), Electric Vehicle (EV), Vehicle-to-Grid (V2G), Renewable Energy Sources (RES), Energy Management System (EMS), IoT (Internet of Things).

I. INTRODUCTION

In present times, **Electricity** is considered as the heart of the modern technology and become so vital now and also the whole world is depending on it [1-2].On the other side, electrical energy demand is increasing rapidly so it's not only become the challenge for its production but also for its distribution. This rising demand introduces some complexities in power grids by the amplified need of reliability, security, efficiency and environmentalconcerns [3]. The transport sector is the largest user of oil and also the second largest source of CO2 emissions, therefore the utilities offer the discountedelectricity prices to encourage the grid-friendly charging. As per a recent report, Niti Aayog supportsthe Electric Vehicle (EV) and discourages the privately-owned petrol and diesel-fuel vehicles, therefore this EV market is quickly growing these days [4].

a. Overview on Smart Grid Stations

"Smart" means smart devices and Smart Grid (SG) concept is first implemented in 1997. SG is nothing but the innovation in the electric grid system. Conventional Grids were just to transmit and distribute the power and also lacking in monitoring and real time control, which creates an interesting opportunity for SG stations to act

as a real-time solution. For electricity, if considering from generation to consumption point then SG station is defined as an electrical system which uses information, any communication technology and computational intelligence in a combined way across generation, transmission, substations, distribution and consumption to attain a system, which is clean and clear, safe and secure, effective and reliable andsupportable [5].

Fig. 1 Working concept of Smart-Grid Station

In America, SG station goal is to address the aging of distribution network, improve service levels, and enhance user interaction. Similarly, in Europe focusis to promote Renewable Energy Sources (RES), so that power industry meets the environmentally approachable requirements [6-7].

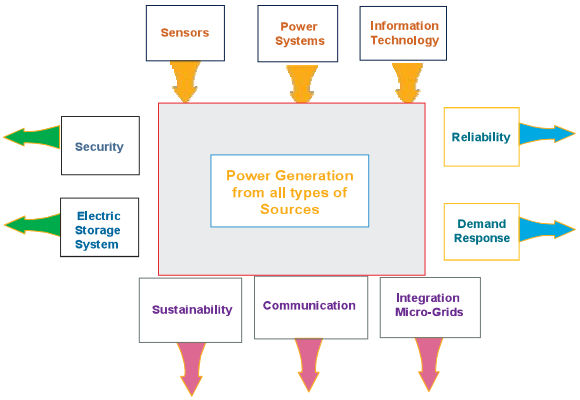

Fig. 2 Smart Grid Architecture

Observation says, SG station even take the decisions according to the situation to maximize the throughput of the system and reduce the energy consumption. Its hugeness and dependency increase by its stakeholders as shown in Fig.1.

It is basically convergence of industry sectors like electrical power, telecommunication infrastructure and information technology (Smart meters and Sensors) [8]. In this, monitoring and controlling are the crucial roles to make it self- healing, self-organizing and self-configuring. It provides its shareholder a chance to maximize the efficiency, reliability, economic performance and security of their electrical network. An overview of its architecture is shown in Fig.2.

a. Brief Idea of Vehicle-to-Grid (V2G) Technology

The V2G concept was first introduced by Willet Compton of the Delaware University. The Indian Government had announced the National Electric Mobility Mission Plan 2020 (NEMMP) in 2012, along with Faster Adoption and Manufacturing of EV's (including Hybrid EV's) in India (FAME) guidelines in 2015 to provide incentives to EV's. Also, Norway has the world's highest share of Plug-in EV's per capita. All these things highlighted that by 2030, EV's may take up to 86% of the new light-vehicle sales, as they are promoting night time charging in a very fine way.

The EV basically has three major components and they are *Energy Storage Unit, Control Unit and Propulsion Unit*. **In the first one**, it stores power by ultra-capacitor, battery and hydrogen fuel cell. **The second one,** it modulates the power, decides in what way power must be used and also acts as a converter, which converts power from DC to AC. **The later one**, it has 2 motors, one is for **Power** to accelerate or propel the vehicle to attain a good speed and other is for **Energy** to travel the vehicle for long distances i.e., 200 to 300 miles. The success of any EV highly depends on the type of battery used and its life is measured in terms of cycle stability. It means how many numbers of times a battery can be charged and discharged before being degraded to 80% of its original full charge capacity [9]. Lithium battery offer high energy density if compared to other non- toxic rechargeable batteries. Presently Li -Ion battery is little costly but expected to reduce with increase in cell production volume and improvement in manufacturing technology. These days **Battery Swapping** is also possible, where discharged battery can be directly swapped to a fully charged one, where one can eliminate the waiting period for charging the battery. The EV's battery charging will put an extra burden or load on distribution grid but at the same time EV's positively having the potential to support the grid under various conditions. **Reversible Battery Chargers** are significant, as power flows in both the directions between the EV and the Grid by using V2G technology [10]. According to authors in [11], SG is a cost saving option, so to maintain data safe between generation, consumer and also to maintain integrity to avoid improper function & destruction, security is always needed. In [12], Monitoring, Detection & Classification is needed for the future development topics related to transmission, distribution, commercial, DG & EV to reduce the synchronization problem. So that the computational speed of security algorithms will increase while preserving a high detection accuracy & a low rate of false alarms. In [13], V2G implementation by Genetic Algorithm gives the best solution in terms of energy efficiency & energy consumption. In [14], authors ensure the charge-discharge effect in V2G system, which improves the power quality by using Active Power Filter and also eliminating the harmonics by some Active Measures to get the smooth power. The remainder of the paper is organized as follows: Section II talks about the challenges faced by the SG stations, proposed method i.e. V2G technology is briefly explained in Section III, economic impact of the proposed system is summarized in Section IV then advantages and scope of this V2G technology incorporation is discussed in Section V, finally the conclusions and future work are given in Section VI.

II. Challenges And Limitations In Smart Grid (SG) Station

Good power quality supply at load side, power network to transmit additional energy and cut greenhouse emissions to save the surroundings in spite of having these many advantages in SG station, it is still facing some challenges [15]. Its prime objective is to improve its capacity to use more electricity but at cheaper cost, towards the power developments in the standard-of-living of all the people on this Planet. For the development of our country, our focus should be on the growth of SG by considering its "self-healing" feature, which will protect the grid as a strong grid. The grid is generally designed for the unidirectional power flow, so for returning the power anti-islanding scheme is used which again needs some additional investment. SG station has a lot of challenges in its implementation too like investment, business model, consumer education, and cyber security. Whatever may be the challenges facing by it, it should not be an obstacle to upgrade the existing grid to a best Smart Grid [16].

Some changes must be incorporated into the nature of electricity supply, as the demand is growing rapidly and traditional resources are exhausted. Energy Management System (EMS), IoT, Big Data and SG with EV's are some new technologies in it. If energy demand exceeds the base load power plant capacity, then peak load power plant must be utilized as the power grid itself has not that much enough electrical energy storage [17]. Report says, if the EV's are charged in non-peak hours (6pm-6am) then it would decrease the burden on SG station and its output and efficiency will be improved. And for this, V2G has four

general groups: base load power (station power that is running most of the time), peak shaving (occurs at highest power demand hours), spinning reserves (responds if equipment or power supplier fails), and regulation. The utility pays spinning reserves and regulation sources for just being available and base load and peak shaving are paid per kWh generated [18].

III. INCORPORATION OF V2G TECHNOLOGY WITH SG STATION

Motivation behind this study is to use the battery and chargers in EV's (100 kW or more power capacity) for the grid storage, create a second use when the car is parked which brings a payment to the EV owners. It will balance the power during peak and off-peak hours of the day by introducing RES also in electric markets to provide >> 50% of electricity. Already known to us conventional vehicles are powered by fuels like diesel, petrol and natural gas. Energy conversion efficiency of a fuel is only around 14%– 30% depending on the distance covered, remaining energy is either lost or inefficiencies or used by the power accessories [19].

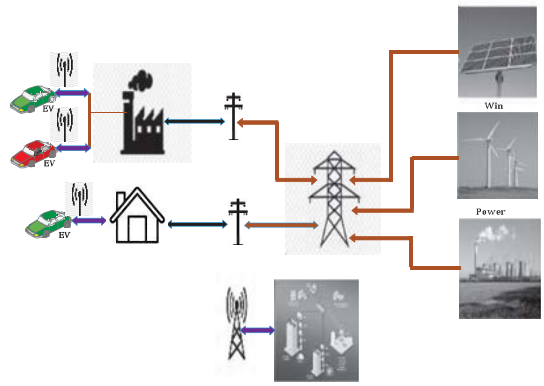

Fig. 3 V2G Technology incorporation with the Smart Grid Station (Solar Energy Management System)

The research on V2G Technology mainly focuses on feasibility analysis, overall structure and the function of each component. The aim is to improve efficiency, reduce cost, volume and weight including the minimization of Total Harmonic Distortions (THD). The most important gradient for V2G to work is the two-way communication between EV and the grid. V2G concept stands on this principle and it works on balance the 'off-peak' and 'peak' demand, only if it is provided at correct time in the correct way. And there is a difference in demands between peak and off- peak times. Three elements are mainly needed for the V2G incorporation: **Power Connection** (energy flow from vehicle to grid), **Logical or Control Connection** (grid operator finds available capacity, request additional services and meter the result) and **Precision Certified Metering** (on board the vehicle)[20].

This technology also needs monitoring to sense the grid status, whether the vehicles should be providing or drawing the electricity at any given time. The idea is to just set up an exchange system between the grid and a vehicle with some energy storage capabilities to help both the involved parties. This is presented all together in pictographic form as shown in Fig.3. In this technology, the vehicle batteries can be fully charged during low-demand hours and flow can be reversed at any time according to the requirements. Therefore, the complete benefit can be taken from the idle vehicles power to provide load-shedding and peak shaving and other tasks. By using some advanced techniques like IoT (Internet of Things), the state of charge of battery in EV can be monitored and controlled easily during the bi- directional power flow between the SG and EV and it will be maintained through EMS [21].

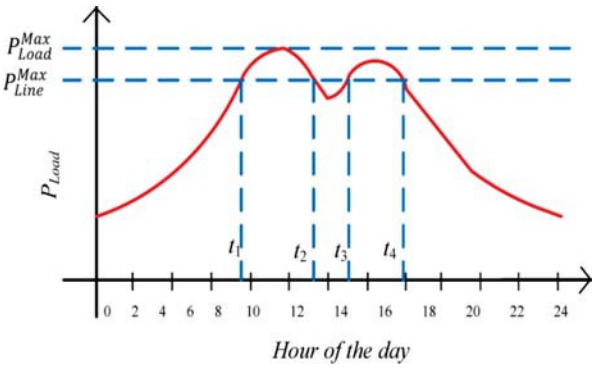

Fig. 4 Load curve and feeder capacity

To calculate the amount of energy needed for peak shaving, an example of commercial load required for peak shaving, is demonstrated in Fig.4.

During peak load period, constraint for "$n-1$" security is the line power flow (P_{Line}) does not exceed the line capacity (P^{Max}),

$$P_{Line} \leq P^{Max} \quad \text{------(1)}$$

EV's are providing power to reduce P_{Line} (assumption), then EV must deliver the difference between maximum power demand (P^{M}) and maximum line power flow (P^{Max}),

$$P_{EV}^{Max} = P_{Load}^{Max} - P_{Line}^{Max} \quad \text{------(2)}$$

where, P^{Max} is maximum required injection power by EV to meet electrical system reliability.

Peak loads may drop below line capacity for a period of time and during this time, EV battery can be recharge from grid until total load exceeds line capacity again. Charging EV during this time, results reduction in number of EV's required. EV energy rating is calculated by integrating desired power overtime as:

$$E_{EV}^{Max} = \int_{t1}^{t2} \{(P_{Load}) - (P_{Line}^{Max})\}dt + \int_{t2}^{t3} \{(P_{Load}) - (P_{Line}^{Max})\}dt + \int_{t3}^{t4} \{(P_{Load}) - (P_{Line}^{Max})\}dt \quad \ldots\ldots(3)$$

E^{Max} is energy that EV must deliver for peak shaving. The number of EV's needed to supply the power needed to reach the top of a particular condition must satisfy the following inequality,

$$E^{Max} < n_1 E_{EV} \quad \text{------(4)}$$

where, n_1 is number of vehicles to provide needed energy during peak shaving and also these vehicles should satisfy the following equation.

$$P^{Max} < n_2 P_{EV} \quad \text{------(5)}$$

where, n_2 is number of vehicles to provide peak power during peak shaving. Finally, the minimum required vehicles (n) can be found as follows:

$$n = Max\,(n1, n2) \quad \text{------(6)}$$

From the above equation (6) it is concluded that by adding minimum number of EV's to the grid, peak load demand can be reduced during peak load hoursand it also reduces the burden on the distribution system.

IV. Economic Impact of V2G Technology

Any new product or if there is some development then it has a factor called Economic Impact Analysis (EIA), which examines the effect of the new thing oneconomy in an area, which may range from a specificarea to the global world. The latest report talks about the requirement of EV's and also the importance of its charging and discharging points all over the globe. The Government is employing "polluter pays principle" in the car tax system, which says high taxes for high emission cars and lower taxes for lowand zero emission cars and it impacts the economic revenue. **Social Impact** says, energy bills will be reduced for citizens and the public authorities therefore, quality of life will be improved by creatinglocal jobs. Also, there is an improvement in air quality. According to **Technical Impact on the Power Grid**, EV integration into distribution grid tells there is no substantial impact on the grid voltages in residential, commercial and mixed feeder. Conventional thinking advises that all Plug-in Electric Vehicles (PEV) would plug in at night or early in the morning hours for the next day driving, but this outlook is limited now, and also misses a factthat vehicles are parked on an average 75% of the time. From this logic, if every car is pluggable then power available is much larger than the current generation capacity by the proposed system and it also helps the Utility Companies to meet the peak demand without the necessity of constructing expensive new power plants. In such power flows, the major stakeholders are: vehicle owners and manufacturers, firms to provide power and the society as a whole. **The Vehicle Owner-** must be waged for the firm touse the vehicle to offer grid services and must be confident that vehicle will be definitely available for the personal use if needed. **The Vehicle Manufacturer-** must be able to charge V2G capability so that customers will be ready to pay. **The Firm-** must originate enough profit from the vehicles to compensate that additional cost for monitoring and controlling the vehicle-grid interactions, paying owners, and system administration. This way, the proposed method will be the intelligentway for the bulk storage and also economically attractive for the vehicle owners [22]. For Ex. (bi-directional flow/two-way electricity flow between vehicle and grid)- A customer can take his car, plug it into the grid, send power back to the electrical company during peak demand (at high price) and charge his car during off-peak demand (at low price) thus making his own profit from his car only, exactlylike the stock market buy low sell high. Fig. 5. shows the EV can be charged or discharged According to theneed so that it will be benefitted for both

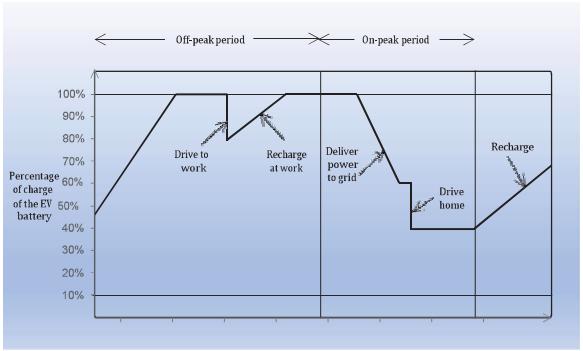

Fig. 5 EV Strategy during off-peak and on-peak periods

the user and power system and it becomes a routine, which wouldincrease efficiency and reliability.

V. V2G System Advantages and Scope

V2G is a new emerging technology which balances the power on generation and consumption side by receiving the power in off-peak hours and sending the same power back to the system in peak hours, where charging stations will behave as grid connecting points [23]. This system is giving benefits to both power grid operators and the vehicleowners along with the clean and clear environment as the emissions are reduced by EV's, which will enhance the efficiency and reliability of overall system. This way, reliance on foreign oil supplies will be reduced by promoting the Energy Security (ES), which favors the growth of EV's. Also, EV batteries that have already reached to the end of theirlife could be given a second chance to reuse them. Finally, it reduces the total distribution losses and voltage drops and protective relay tripping will also be avoided. Electric school bus is

best example for V2G application, as it is having large battery capacity and long parking period too.These days most of the segments are concentrating on V2G technology as it improves the mobility of consumption. The requirements, costs, and benefits for this technology must be balanced, so that it increases the overall productivity. In this, EV's can power small houses or offices by Uninterrupted Power Supply (UPS) as they are having great capacity. Now, it becomes fairly easy to shift from the conventional to non-conventional sources of energy from the stability point of view. Economic analysis says that, now it becomes easier to establishgood relationships between the users and the grid as it is contributing back to the grid.

VI. CONCLUSION

SG station is offering an opportunity to improve the quality and reliability of the power system and it is having the potential to meet the future power demand, which will support the V2G technology. It is really surprizing that how this technology brings positive change in reliability factor for the system. Its features meet both consumer and the utility requirements, where the environment is also a major concern. It is a more constant approach, in which high efficiency and low cost are the important developments. This paper describes the study of V2G technology with SG station in brief way, with which this can be implemented in India. By this study it is concluded that this technology can bring visible benefits from relevant to economical aspect, but still in research a lot of basic work to be explored.

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