VEHICLE TO GRID INTEGRATION –THE BILATERAL IMPACT

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Abstract*— Due to simultaneous and intermittent charging events of plug-in electric vehicles(PEVs) the distribution system is greatly affected. As the V2G(Vehicle to Grid) penetration increases, the unpredictable nature of load demand becomes more considerable. Since the increase in the number of electric vehicles is not steep but gradual hence the utilities can plan the upgrades in the infrastructure to prevent unstability in the power system. Not only the grid side but the battery is also affected by a considerable amount. As the battery operating condition and its service time vary the performance of battery changes. In this paper we have investigated the bilateral impact i.e. impact posed by PEVs on grid system and how the batteries of PEVs got affected when its connected to the distribution network.

***Index Terms*— PEVs, V2G penetration, Unstability.**

I. INTRODUCTION

With advent of electric vehicles(EVs) the transportation system has become a lot easier. The main feature of this technology is zero pollution. These vehicles possess conversion efficiency of about 80 to 90% in converting electrical energy into forward motion, thereby reducing fossil fuel consumption and toxic gas emissions in the course. This new era of electric vehicles (EV) is also vital for the future of auto industry as they share the common perspective of its importance and are banking on the electrification of vehicles. But as the penetration of plug-in electric vehicles(PEVs) increases in the distribution system, several problems are encountered by both grid side and battery side. Usage of V2G technology with low or high penetration level at the distribution level of power system with high charging level produces acceptable distortion in voltage[1]. It also put an additional load on existing distribution system. One of the challenging issue is adverse effect of EV charging on peak demand in which distribution network see a shift in typical load profile.

In the case of PEV, or large rechargeable battery packs on wheels, the requirement of high power connections to the distribution gird is necessary to recharge in a timely manner. This creates a problem for the distribution network as well as industry where peak demand is a relevant issue. Peak demand is a crucial issue for energy distributors as sudden overloads would reduce power quality and increase cost on the low voltage (LV) distribution network.[2]

Studies have suggested that even low penetrations of PEV at 10% can have a dramatic impact on peak demand. In recent years the penetration of PEVs has increased since the ongoing initiative for electrification of transportation sector has gained significant momentum. The reasons for the growing popularity of PEVs are several economic and environmental concerns, such as rising fuel costs, depletion of fossil fuel reserves and greenhouse gas emissions. Thus, it is almost certain that the level of PEV penetration into our power grids will keep on rising[3].

The important characteristic of an electric vehicle is that its electrical energy would be used efficiently to power the electric motors and the other parts of the battery powered electric vehicle. Since EVs are categorized as a system with higher efficiency of engine and no emission of harmful gases and pollutants through tailpipe it is also came to known as zero emission vehicle. From the system point of view, electric vehicles may be considered as: (a) Simple loads drawing a continuous current from the grid, (b) loads which are flexible and that may allow an aggregator company to coordinate their charging procedure and (c) storage devices that may allow an aggregator company to even request power injection from batteries back to the grid which is known as V2G(vehicle to grid).V2G mode will affect the life of the battery pack, and reduce the cycle life of the battery pack which will greatly enhance the cost of electric vehicle owners, thus affecting the course of the electric car market[4].

II. IMPACT ON GRID SIDE

When we talk about V2G integration it means we are connecting a large number of electric vehicles to the electrical network. The basic concept of V2G or G2V is that, as electrically powered road vehicles become more common, their need to be regularly connected to the grid system in order to have their batteries charged can be deployed by regarding them as both a load and a source. By ensuring that vehicles are connected to the grid whenever possible and by arranging for the immediate future requirements of each car to be specified (next journey time, next journey distance), suffice electricity can be stored in the batteries. At times when demand exceeds the available generation capacity, energy can be drawn from the batteries, provided each individual vehicle has sufficient charge remaining at the stated time for its next departure to complete that journey.

Mostly the charging of electric vehicle have the impact on the power system mostly in terms of power quality, line loss increase, charging behavior will bring the voltage over limited to the distribution network, power quality decline, life span of distribution transformers decreases, harmonic and fault current increase and other bad effects. Result have shown that a certain number of electric vehicle charging will lead to a substantial aging of distribution transformers and shorten its life[4,5].

If smart charging techniques are not deployed the random and uncoordinated charging of plug-in electric vehicles can increase the peak load demand of power system. Generally the integration of electric vehicles takes place on low voltage distribution system significant overload conditions of distribution lines and transformer can be experienced due to the charging load of PEVs. In [3] two smart charging strategies has been proposed in which a combined G2V and V2G charging framework, for optimal integration of PEVs in workplace car parks is incorporated. The above charging strategies are based on an economic and a technical objective, namely minimization of PAR and minimization of total daily cost, respectively. The design of the charging strategies allows inclusion of all the PEVs (having either positive/negative/zero energy requirement) for providing V2G services and takes into account constraints related to charging infrastructure, PEV batteries and the distribution system infrastructure.

Reference [4] studied the impact of electric vehicle charging when the transformer at low penetration, although this impact is negligible, but an increasing number of electric vehicles will increase the transformer losses.

Integration with Renewable Resources

Practically wind, solar and other renewable resources, and the occurrence of conventional power plants generally mismatch electricity demand. The main reason is discontinuous operation of renewable generation resources, and this can be overcome by discharge of electric cars connected into network which can play a significant role in regulating power supply and demand balance. We can charge electric vehicles when the grid load is in low ebb in the future, making it become distributed power to store electrical energy; when the power grid load is peak, the electric vehicles connected into network and discharge can feedback electrical energy to the entire grid system; achieve this two-way interaction of electric vehicles and the grid, which is calledV2G mode[4].

For this to be done a charging stratregy needs to be formulated for the sake of EV owner. When formulating a charging strategy, the priority is given to EV owner. The owner will want to minimize the costs of driving its vehicle. This includes the cost of the energy used and the cost of battery degradation. Though[6] EVs are powered by electric batteries, these batteries age, and a rapid charging and discharging accelerates their detriorating process. Therefore, when V2G scheme is considered, where the battery might be charged and discharged frequently, it is essential to consider the cost of an accelerated degradation. Taking this into account, it is expected from the EV owner that he/she might require some economic compensation to agree on participating in the V2G scheme if it results in an accelerated ageing of the battery.

In reference [7] battery wearing cost has been calculated for 85 kWh battery package consisting of Sanyo UR18650E cells. Its results indicate that V2G will provide an economical frequency regulation for power grid and generate profit for electricity network operators and electric car owners.

Power Quality Issue

There is always an uncertainity in the charging behavior of electric vehicles and the behavior of the car users which results in a kind of randomness in the charging load of electric vehicles which increases the difficulty of controlling the grid, and have an hostile effect on the reliability of the whole grid system. Simultaneously, charging of PEVs will cause problems of power quality and aspects of the economic operations. This type of discontinuous charging will increase peak load demand of grid, so it needed additional capital investment on generating power and transmission capacity.

For conventional power generation, even in an proper orderly charging strategy, will have some negative impact on the grid upto some extent. However ordered charging strategy can ousted some extent intermittent for new energy generation, resulting in positive impact. The charging of electric vehicle pose following impacts on the power system namely load capacity, power quality, grid economy and environmental effects. Similarly discharging of electric vehicles also have some positive effects on the power system[4].

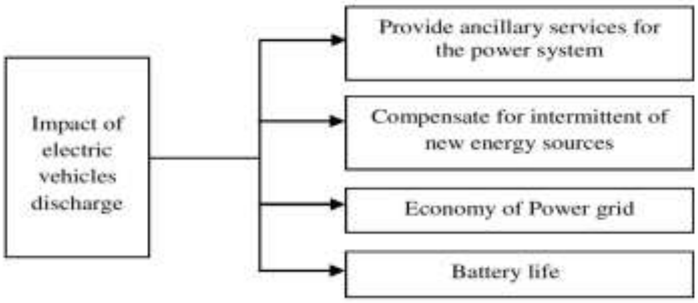

Fig.1. Discharging impact of EV

III. IMPACT ON BATTERY USE

The V2G scheme affects the life of the battery pack, and reduce the life cycle of the battery which in turn greatly increase the cost of electric vehicle owners, thus affecting the course of the electric car market. From[6] the experimental data obtained, two parameters are identified to have the main influence on deterioration of the battery cell: depth-of-discharge (DOD) or its inverse state of charge (SOC) and temperature. The state of charge (SOC) can directly affect the lifetime of the battery. Battery wearing increases inner resistance, capacity and power loss as well as change impedance spectra. Battery wearing depends on temperature, SOC, cycling depth and charge power [7]. Ageing rates increases to twice when temperature rise 10 ºC.

Nowadays, the power battery of EVs is classified into five main configuration: lithium battery, fuel cell battery, lead-acid battery, nickel-metal hydride(NiMH) battery and super-capacitor. Out of these lithium-ion battery has the best application in EVs industry and are commonly used due to their better performance as compared to other batteries. The reason behind this being the high energy density and power density, especially Lithium iron Phosphate ($LiFePO_4$). However[8] Lithium batteries have some serious disadvantages such as the overcharged cell which has a risk of explosion, the undercharged cell eventually reduces the life cycle of the battery, and unbalanced charge in series battery gradually reduces overall charge capacity. The operating temperature for Li-ion battery is -20°C to 60°C when charging and -50°C to 60°C when discharging. If the temperature is too high, the charge and discharge efficiency will be affected.

Improvement of the lifecycle is important to extend the calendar life of a battery. Batteries for electric vehicles should last as long as the lifetime of the vehicle. Otherwise replacement of the car battery is necessary within the lifetime of the car. This will increase the price of driving a BEV(Battery Electric Vehicles). The efficiency of a battery is given by the energy losses that occur when charged and discharged. The amount of energy that is available to power the wheels represents the efficiency of the battery.

After the battery capacity drops below a certain critical value, it is stated as unfit or declared worn out. At this situation, individual components like the printed circuit boards, copper bus bars, steel enclosures, plastics etc. can be salvaged. However, the cells cannot be reused. Reusing materials found in battery packs has environmental benefits, as it reduces the amount of mining required, as well as economic benefits as it reduces the amount of material that needs to be imported. Lithium, is a vital component in EV batteries, however, it is not currently competitive for recycling companies to extract lithium from slag, or competitive for the (Original Equipment Manufacturer)OEMs to buy at higher price points from recycling companies[9].

Even after the terminals are physically disconnected self-discharge reduces stored energy in the battery. The proposed model[10] represents the effect of self-discharge as a reduction in the SOC of battery. Self-discharge rate is different for each battery technology. A Li-ion battery discharges at 5% in the first 24 hours and then at a rate of 2-3% per month. In this paper a combination of electrical and thermal model of battery including the effect of self-discharge is presented.

IV.MODELS AND RESEARCHES

In [11], derivation of a thermo-electrical analytical model of a lithium ion battery is done and has been simulated. The temperature effects on the battery can be easily simulated by this model. It provides a way to estimate the discharge characteristics over a range of battery temperatures, which is beneficial for the thermal analysis of battery packs in hybrid electric vehicles(HEVs).

The impacts of increasing integration of PHEVs into the distribution grid are analyzed in [12], and the controlled charging method to coordinate the V2G operation of PHEV is proposed. In the proper charging condition, the grid operator has a great deal of flexibility in coordinating charging decisions given the needs and limitations of both sides. When the strategy is uncontrolled, PHEV charging will increase the peak load.

In [13] the author has described mathematical formulation for incorporating V2G into the distribution network. The 3-Phase current injection formulation of Newton Raphson iterative method was mainly used to provide basis for the study of the impact of V2G on the voltage profile of the power system. Results show that voltage profile is improved in 3-phase spot integration and system-wide V2G integrations than in 1- phase integrations. It can be analyzed from the study that V2G in charging mode results in decreasing bus voltages, while injecting of kW or kVAr power improves the voltage profile.

[14] deals with the integration of electric vehicles into the smart grid by making their flexibility accessible to a third party. After a discussion of the term flexibility in the context of EV, a general map of grid integration aspects has been drawn, consisting of the battery system and its management, power quality, charging technology, communications and energy management.

For electric vehicle (EV) applications a novel battery charge equalization algorithm among lithium-ion battery cells has been presented in [8]. The proposed charge equalization algorithm is able to equalize and modulate the battery charge in order to improve the efficiency, reliability and safety issues of the battery drive system.

Reference paper [15] analyzed the impact of grid disturbances on grid-connected EV batteries. Authors finding indicate that the battery charge current gets affected by power quality events which causes serious disturbances that transfer through the EV charging system in the G2V(Grid to Vehicle) mode. However, in V2G mode the charger is effectively immune to the grid disturbances. This concludes that there is a difference in performance of charging system and that dc/dc and ac/dc converter stage protection is required essentially for the G2V mode.

In [16] the author has developed a method that the receiving power and the electricity bills can be reduced in the facility by using a battery mounted on electric and hybrid electric vehicles. This paper presents a method of creating charge and discharge schedules of electric vehicles with help of mathematical programming that has been formulated as constraints of models of a battery mounted on EV and PHEV and a connection and disconnection state and objective function to minimize electricity bills in the facility has been proposed.

In [17] the method of managing the power transaction in the parking lot has been developed as an optimization problem and solved using genetic algorithm. Satisfying V2G owners alongwith gaining maximum profit form parking lot was the main objective of this problem. For the case study, a parking lot with 40 parking spaces was considered and the sensitivity of profit gained by parking lot to variation of some parameters of vehicles like charge and discharge efficiencies and the battery capacity were examined.

In [18] a method has been presented to reduce power fluctuations and its performances under varying communication delay and number of vehicles in V2G pool.

V.CONCLUSION

Various models and researches have been invetigated in this paper. The impacts of both grid side and battery side have investigated. From above we can conclude that if the penetration of PEVs in the distribution network or grid system is upto a tolerable amount then its impact on the grid will be negligible. However if the amount of penetration is greater than what is desired then power system will experience some serious problems like increase in peak load demand, increase in distribution losses , effect on substation available capacity, maloperation of SVR in the distribution circuit, grid instability problems by leading to large swings in peaks and troughs, large voltage drops and branch congestions. Therefore, an EMS[Energy Management System] is necessary to properly manage the behavior of PEVs while considering benefits of both PEV owners and the grid.

SUGGESTION AND FUTURE SCOPE

Although a lot of work has been done in this field but still there is always a scope of improvement. However V2G integration impose problems on both grid and battery but if proper communication and intelligent information technologies are used then this technology can aid to power system. EVs as an energy storage devices can reduce our dependence on other energy storage devices. The peak demand problem can be overcome by using smart chargers and controllers. Battery life can be optimized by testing different chemical composition for inner materials. However Li ion batteries are best suited for electric vehicle purpose but other this cadmium is also an better alternative for grid scale appications. Further research can be done on battery material and make them suitable for EV purposes.

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