A Review Of Plug-In Hybrid Electric Vehicles As New Storage And Transportation System For Smart Grid

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Abstract

Plug-in Electric Vehicles (PEVs) will be an integral part of smart grids in the near future. Reduction in green house gas emissions, increase in oil prices and dependency on foreign oil are major incentives to the development and deployment of Plug-in hybrid electric vehicles. As fossil fuels prices climb higher, the search for alternative modes of transportation intensifies. One other possible solution is the transformation of current hybrid electric vehicles into larger capacity plug-in hybrid electric vehicles (PHEVs). The plug-in hybrid electric vehicle fleet is expected to increase the base electric load and add constraints on the reliable operation of a power system. With larger battery storage, the PHEV has the ability to run in all-electric mode for Commuters, switch to conventional gasoline engine for longer trips, and provide support to the power grid needed in emergency situations. This paper describes the economic implication of charging the vehicle or sending power back to the utility in brief, advantage of PHEV for grid, impact of PHEV on grid. A new parking facility as an energy exchange station called "Smart Garage" and Smart Metering for PHEV is also discussed.

*Key word- **Plug in hybrid vehicle, Hybrid electric vehicle, smart grid, vehicle to grid, Ancillary Services, Smart garage, Demand side management, Outage management.***

1. Introduction

Due to excessive usage of fuels and the continuously depleting amount of these resources, reduction in green house gas emissions, increase in oil prices and dependency on foreign oil a newer option has emerged in the past few years, the plug in HEV (PHEV). The only difference between a standard hybrid and a PHEV is an increase in the capacity of the battery pack, a connection to charge from an electrical outlet, and modifications to the power electronics. PHEVs have a new advantage of running in all-electric-mode for longer distances, typically 30-60 miles, and could become a new source of energy storage for the bulk power grid. HEVs charge their batteries from the car's internal combustion engine or regenerative breaking and deplete their energy while the car is stationary or during acceleration. This method is referred to as *charge-sustaining* since the batteries will maintain a set state of charge, typically 70% - 80%. The major change in a PHEV is the use of a *charge-depleting* strategy where the car batteries will be steadily used while driving to maximize fuel efficiency and the state of charge will decrease over time, typically as low as 30%. The car will also be connected to the power-grid while not in use to provide energy to the batteries from the grid and/or provide support to the grid in emergency situations. During PHEV charging time, the plug-in vehicle more than doubles the average household load. Hence, for PHEVs, a major concern is the impact on the grid, since they can be plugged in for charging at any point in the distribution network regardless of time. The PHEV will be always close to the energy demand, and efficiency of stored energy in EV´s batteries is potentially significantly higher than the energy stored in hydrogen and in fuel cells hydrogen cars. Moreover the hydrogen cars have just limited capacity to provide ancillary services to the grid in comparison to EV.

2. The types of electric vehicle

In common usage, electric vehicle refers to an automotive vehicle in which the propulsion system converts electrical energy stored chemically in a battery or other power source into mechanical energy to move the vehicle. There are three types of electric vehicles in current market: battery electric vehicles, hybrid electric vehicles, and fuel-cell electric vehicles.

A. Battery electric vehicles

Battery vehicles store energy electrochemically in the batteries, with lead-acid currently cheapest but with nickel metal-hydride (NiMH), lithium-ion, and lithium-metal polymer batteries becoming more competitive due to longer cycle life, smaller size and lower weight. Operationally, they plug in to charge their batteries and unplug to drive. Battery vehicles must have grid connections for charging, so the incremental costs and operational adjustments to add V2G are minimal. Because of the increased duty cycle, electric-vehicle batteries can deliver 85% of their charge without damaging the batteries or shortening their useful life.

B. Hybrid electric vehicles

A hybrid has one power system with large energy storage and a second with high power output and discharge-recharge capability— for acceleration and regenerative braking. Contemporary hybrid vehicles use an internal combustion (IC) engine whose shaft drives a generator. A small battery buffers the generator and absorbs regenerative braking. The battery and generator power one or more electric motors that drive the wheels; possibly in conjunction with direct shaft power from the IC engine. A hybrid electric vehicle has more than one source of power. The first hybrid vehicle is credited to an Italian, Count Felix Carli. In 1894, Carli constructed an electric-powered tricycle that had a system of rubber springs which could release a short burst of additional power when needed.

C. Fuel- cell electric vehicles

In this electrochemical device, the reaction between a fuel, such as hydrogen, and an oxidant, such as oxygen or air, converts the chemical energy of the fuel directly into electrical energy. The fuel cell is not a battery and does not store energy, although the fuel cell also has two electrodes separated by an electrolyte. When fuel cells are the primary power source in a hybrid vehicle, batteries provide secondary power. Fuel cells do not provide immediate output during a cold start. Until the fuel cells reach operating temperature, which may take about 5min, a battery pack supplies the power for initial start-up and vehicle movement.

3. Valley filling approach

Electric infrastructure is designed to meet the electricity demands most of the times. The system reaches its maximum capacity only 5% of the time in the year. If this system is utilized optimally it can provide enough power if 73% of the nation's vehicles are to be replaced by their plug in counterparts (PHEVs). In order to achieve this target Pacific Northwest National Laboratory (PNNL) has put forth the concept of Valley Filling. The various plant type categories are the nuclear plants, Coal fuelled plants, Natural gas combined and conventional steam plant, conventional hydro power plants, renewable energy generation plants and the peaking plants. These plants are used at various points depending on the demand. Nuclear power plants are used as a base load plant while coal fuelled plants have capabilities to ramp up and down generation. The difference between the above methods for generating the load requirements and the capacity of the grid can be utilized for charging the PHEVs. Figure 1 show the existing generation by the plants as well as the capacity of the system.

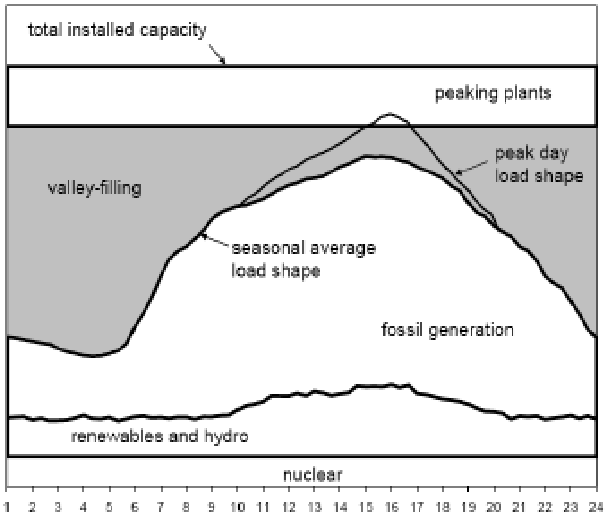

Fig.1 Valley filling concept showing margins between installed system capacity and system load. It also shows various fuel generation margins

4. Vehicle to Grid (V2G) Concept

In the vehicle to grid (V2G) concept, parked PHEVs when plugged in can either be charged or can provide power to the grid. The vehicle can provide power to the Grid by charging the battery whenever the brake is applied and later providing this power to the Grid during the peak times. Two cases can be considered in which (i) charging or supplying power to the grid shall take place only once or (ii) This cycle can take place any number of times. Case (i) would result in the increase in the net power while in case (ii) the net profit would increase, but the net power would decrease because of reduction in efficiency due to multiple charging and discharging cycles. This happens because the efficiency drops at the charger (which charges the battery of the vehicle) as well as the inverter (which provides the power to the grid). To implement such a concept the design of the Energy Storage Unit (ESU) would be a very important part as it would improve overall quality, efficiency, reliability, cost effectiveness, and flexibility of the electric utility system. Energy Storage Units (ESUs) connected to the power grid can mitigate this problem this helps improve the efficiency and reliability of the power grid and helps stabilize the power generation rate to a more cost effective value. Moreover, ESUs can be employed to store energy produced by intermittent sources like solar and wind energy, to be used during peak demand hours. ESUs used in the power grid have been stationary units such as batteries, flywheels and ultra capacitors. For V2G implementation, three elements are required: 1) power connection for electrical energy flow from vehicle to grid, 2) control or logical connection, needed for the grid operator to determine available capacity, request ancillary services or power from the vehicle, and to meter the result, and 3) precision certified metering on board the vehicle. For fuelled vehicles (fuel cell and hybrid), a fourth element, a connection for gaseous fuel (natural gas or hydrogen), could be added so that on board fuel is not depleted. In relation to V2G, the plug-in hybrid has a grid connection for its transportation function and a large enough battery to provide V2G from the battery alone. The plug-in hybrid can provide V2G either as a battery vehicle (that is, not using the IC engine when doing V2G), or as a motor-generator (using fuel while parked to generate V2G electricity). All these fuel cell vehicle, Hybrid vehicle and plug in hybrid electric vehicle can generate clean AC power at power levels from10kW to 200kW. When connections are added to allow this electricity to flow from cars to power grid, we call it "vehicle to grid", or V2G. The V2G vehicles for distributed energy applications can provide voltage and frequency regulation, spinning reserves, and electrical demand side management. If used in large numbers, V2G vehicles have the potential to absorb excess electricity produced by renewable sources, such as wind power, when the grid is operated at low load conditions. Studies show that V2G vehicles could be a significant enabling factor for increased penetration of wind energy.

5. PHEV battery technology and battery Charger requirement

Energy storage capacity of current PHEV batteries may fall in the range of 15-20 kWh for a 60 km all electric driving range. PHEV batteries are required to have high power capability and high energy density. Typical battery requirements for PHEV applications are shown in Table 1

Range (km)	32	64
Max. Weight (Kg)	120	120
Peak Power (kW)	65	50
Power Density (W/kg)	540	400
Storage Capacity (kWh)	6	12
Energy Density (Wh/kg)	50	75

Table 1.PHEV battery requirement

A. Nickel Metal Hybrid Battery

A five cars field test, performed by EPRI, have proven that Nickel Metal Hybrid (NiMH) batteries lifetimes exceed five years and are expected to meet the 130,000 – 150,000 mile vehicle life time requirements due to improvements in charge acceptance and retention at high temperatures. however, NiMH technologies still faces significant challenges before reaching large scale deployment due to the battery relatively large weight and volume and insufficient power/energy performance compared with alternative solutions.

B. Lithium Ion Battery

For the same specifications, Li-Ion batteries are considerably lighter than NiMH ones. But, although Li-Ion batteries meet the requirements of PHEV batteries, deep cycling capabilities of these batteries are yet to be proven. The major challenges with Li-Ion batteries are high capital cost, energy and temperature management, and, at this stage of development, absence of field validation data proving deep cycle capabilities.

There are different levels of battery chargers depending on the application and the connection. Charger types include residential charger (typically single-phase or phase-to-phase) and rapid charger. The latter allows unidirectional power flow and will not be discussed further in this work. Table.2 displays operating electrical range of different types of PHEV battery chargers. For residential charger applications, full charge is to be achieved within 6 hours. However, for higher energy capacity batteries, longer periods may be required. The charger must be safe, convenient and efficient. Table 3. Summarizes the residential charger requirements. Operational requirements include battery temperature management, cooling, converter control, communication means, diagnostic capabilities, vehicle lifetime durability and a user friendly interface.

PHEV Charger	Current (A)	Voltage (Vac)	Power (kW)
Single Phase Level 1	15	120	1.8
Single Phase Level 2	30	120	3.6
Public Level 2	32	208	6.6
Larger Residential	40	240	9.6
Public Level 3	80	208	16.6

Table2. Different Levels of PHEV Battery Chargers

	Min	Max
Peak Power	2.4 kW	3-4 kW
ac Voltage	120 V	240 V
dc Voltage	280 V	450V
Efficiency	90%	95%

Table3. Residential Charger Electrical Requirement

6. PHEV and HEV configuration

Recent studies show that if PHEVs replace one-half of all vehicles on the road by 2050, only an 8% increase in electricity generation (4% increases in capacity) will be required. Most of the electric vehicles that are of plug-in type, utilize on-board battery chargers to recharge the batteries using utility power. The simplest form of a plug-in electric vehicle is shown in Fig.2 this configuration consists of a battery system and a motor controller that provides power to the motor, which in turn supplies power to the wheels for traction. Many of today's EVs use a permanent magnet electric motor that can also act as a generator to recharge the batteries when the brakes are applied. During regenerative braking, the motor acts as a generator that provides power back to the batteries and in the Process slows down the vehicle. Friction brakes are used when the vehicle must be stopped quickly or if the batteries are at full charge. The components that make up a typical HEV include a battery pack, motor controller, motor/generator, internal combustion engine, and transmission and driveline components. The primary power electronics include a DC-AC motor controller which provides three-phase power to a permanent magnet motor. The typical HEV is shown in fig.3 design uses two permanent magnet motors/generator, one of 10kW and the other of 50kW. The battery is connected to a booster and inverter before feeding to the motor/generators. The power electronics are bidirectional and used for both charging the battery and powering the motors. The motor/generators and gasoline engine feed into a planetary gear set. The system operates in a continuously variable transmission (CVT) mode where the gear ratio is determined by the power transfer between the battery, motor/generators and gasoline engine. The batteries can also be charged using regenerative braking of the large motor/generators. There is no provision to charge the batteries externally.

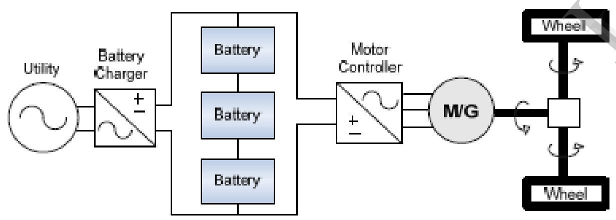

Fig.2 Typical EV configuration

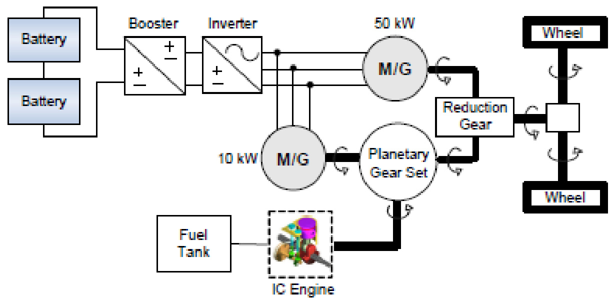

Fig.3 Typical HEV configuration

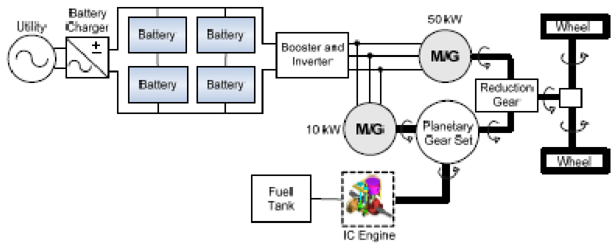

Fig.4 Typical HEV configuration

For plug-in hybrid electric vehicles, batteries are charged when they are not being driven. This is normally accomplished through a utility connected AC-DC converter to obtain DC power from the grid. The batteries can also be charged directly from a solar resource using a DC-DC converter or from a wind source using an AC-DC converter. Energy flow is unidirectional as power is taken from the utility to charge the battery pack. The battery voltage for most converted PHEVs are maintained at the same level as the original design (typically 200-500 VDC) and battery modules are added in parallel to increase the energy capacity of the battery pack, thus allowing the electric motor to run more often than the original HEV design. Some of the PHEV conversion companies include: CalCars Energy CS, Hymotion, Electrovaya, and Hybrids Plus, and most of them use lithium batteries.

7. Benefits of using PHEV'S in power system

It is expected that V2B operation will improve the reliability of the distribution system, provide extra economic benefits to the vehicle owners, and reduce the home or building electricity purchase cost based on the demand side management (DSM) and outage management (OM) programs with customer incentives.

Benefits of operating PHEV as distributed storage-

A. Electric Utility Benefits

The stored battery energy can be used to serve a portion of the local demand on a feeder thus contributing to peak shaving. Secondary advantages of peak shaving include reducing transmission congestion, line losses, delay transmission investments and reduce stressed operation of a power system. In a deregulated market, load serving entities purchase electric energy through long-term contracts with generation companies and short-run spot electricity markets. During periods of high demand or peak load periods, the electricity prices reach their highest. Peak shaving applications of PHEV fleet reduces the cost of electricity during peak periods. The avoided electricity purchase could be used to develop incentive programs to promote the purchase of PHEV and their use for grid support applications. PHEVs offer the power system with a flexible controllable load and could provide load levelization during off-peak periods.

B. Ancillary Services

The ability of PHEV to provide ancillary services leads to a more stable operation of the power system, a reduction in the operation of protection relays and possibly a reduction of the impact of some contingencies. Although these services can be attributed to improving social welfare, the extended service of demand will increase the yearly load payment. PHEV can either be deployed as a power supply or as a load in order to regulate the frequency.

Benefits of operating PHEV for vehicle owners-

A. Demand Side Management (DSM)

For electric utility, DSM is defined as “the planning, implementation, and monitoring of distribution network utility activities designed to influence customer use of electricity in ways that will produce desired changes in the load shape”, which includes peak clipping, valley filling, load shifting, strategic conservation, strategic load growth, and flexible load shape [8]. However, for utility end-user (customer), DSM is often understood to include two components: energy efficiency (EE) and demand response (DR). EE is designed to reduce electricity consumption during all hours of the year; DR is designed to change onsite demand for energy in intervals and associated timing of electric demand by transmitting changes in prices, load control signals or other incentives to end-users to reflect existing production and delivery costs. By cooperative activities between the utility and its customers to utilize DSM, it will provide the benefits to the customer, utility, and society as a whole, which is summarized in Table1

Customer benefits	Societal benefits	Utility benefits
Satisfy electricity demands	Reduce environmental degradation	Lower cost of service
Reduce / stabilize costs	Conserve resources	Improved operating efficiency.
Improve value of service	Protect global environment	Flexibility of operation
Maintain/improve lifestyle and	Maximize customer welfare	Reduced capital needs

Table2.DSM benefits for customer utility and society.

In the V2B option, the owners will plug in their vehicles during the day at their final destination for a given time frame. As an example, this may be either at their workplace (central business district) or at the place of their study (university). The destinations, either parking lots or parking garages, are assumed to be equipped with a bi-directional charger and controller. The parking facility should allow either charge or discharge mode for the car batteries when necessary. The idea is that the parking facility can offer an aggregation service for charging the batteries when the building demand is lower than its peak load and discharge the batteries to partially supply the building to reduce the peak demand during a high demand. This mode will be considered as DSM by V2B. Considering the electricity rate when the vehicle batteries were charged is lower than when the batteries are discharged, the battery storage may be used to offset high cost during the peak demand.

B. Outage Management (OM)

Another important benefit of V2B is using the battery energy storage in BEVs/PHEVs as an emergency back-up power for the commercial facility/building, which increases the reliability of the power supply for that load An outage is typically caused by several unplanned events and a timely detection and mitigation of such situations is a real concern for the utility. Outage management system helps the operators to locate an outage, repair the damage and restore the service. Outage management must be performed very quickly to reduce outage time. Recently completed project proposes an optimal fault location scheme which will help the operator to find the faulted section very quickly. In this paper we will focus mainly on the restoration strategy under an outage.

a) *Outage beyond the distribution system*:

These may be caused by generator failure, fault in transmission line or substation busbar. Usually spinning reserves are kept for these circumstances. PHEVs can be a candidate solution for spinning reserves (as the traditional fastest acting spinning reserve generators are highly costly while PHEV qualifies for fast response with lesser cost).

b) *Outage in distribution system*:

These may be caused by fault inside the distribution system and can be mitigated by precise spatial adjustment of PHEV generation that may be fed locally during and after outage. To propose the restoration strategy where PHEV is used to mitigate an outage condition, we need to correlate the information about events (where the fault is located and how the impact will propagate) and the location of the storage. The restoration strategy can be executed in the following steps:

1) Detect a fault;
2) Estimate the location of the fault;
3) Analyze the amount of generation required and the availability of BEV/PHEV that can provide an alternative generation support in the vicinity of the faulted area until the faulted section is repaired.

C. Peak power

Peak power is typically generated by power plants that can be switched on for short periods. Since peak power is typically needed only a few hundred hours per year, it is economically sensible to draw on generators that are low in capital cost, even if each kWh generated is more expensive. V2G peak power may be appropriate for this purpose. The required duration of peaking units can be 3–5 h, which for V2G is possible but difficult due to on-board storage limitations. Vehicles could overcome this energy-storage limit if the vehicles are aggregated, or if there were refuelling. Electric vehicles can afford power in peak period while consume power in off-peak period. This action can reduce the difference between the maximum and minimum of the power load.

8. Smart garage and Charging/Discharging Infrastructure for PHEV

Commercial and public parking garages in a central business district (CBD) provide thousands of parking spaces for commuters and visitors. After penetrating the conventional vehicle market, owners of PHEVs will be using these parking garages, which may provide an aggregated service to act as an electric power source or storage. Fig.5 shows a simple transportation network with smart garage building. As a smart garage is constructed, PHEV drivers have two options: proceed to final destination directly or park at the smart garage and walk to the destination along walking links. Drivers in transportation network select parking garage based on the location and financial incentives (less parking fee), which can be modelled as traffic assignment problem. Demand of smart garage (number of parked BEVs/PHEVs) calculated from the traffic assignment problem would vary by the location and incentive of the smart garage.

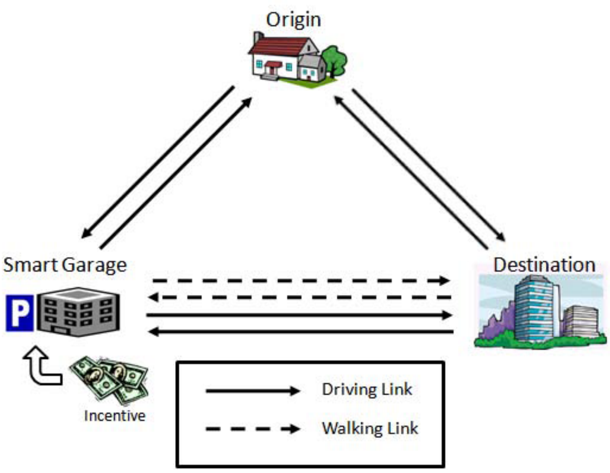

Fig.5 Simple transportation with Smart Garage

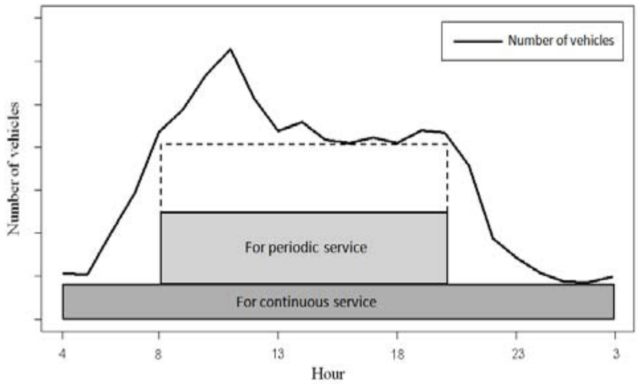

Fig.6 Demand of Smart Garage for the day

Electric power capacity of smart garage is estimated based on demand of smart garage. Demand of smart garage building is not constant. Generally, the demand of smart garage building during the day would be higher than during the night, similar to the demand structure for a conventional garage as shown in Figure6. Due to the versatility, electric power capacity needs to be defined in two parts: for periodic service and for continuous service as in Figure 6. The available electric power estimated based on the demand of smart garage can be used for determining the support service that can be provided during outage management and demand side management in vehicle-to-building (V2B) mode.

9. Impact of PHEV on the distribution grid

Uncoordinated charging of the batteries of PHEVs has a no negligible impact on the performance of the distribution grid in terms of power losses and power quality. Both power quality and power losses are represented in Table.3 for three cases: without PHEVs, uncoordinated and coordinated charging. The power quality is given as the average of 1000 samples of the maximum load, voltage drop and line current for the IEEE 34-node test feeder during winter season for a penetration degree of 30%. The power losses are the ratio of the power losses to the total load. With respect to uncoordinated charging, the coordination of the charging reduces the power losses. Power quality is improved to a level which is similar to the case where no PHEVs are present. Because the extra loads for charging PHEVs remain in the case of coordinated charging, additional losses are still higher. The coordination of the charging can be done by a smart metering system. The distribution grid must be enforced to cope with the increased loads and voltage drops caused by charging PHEVs if this coordination system is not applied. Both scenarios will introduce extra costs for the distribution system operators and eventually for the customers.

Parameters	Without PHEVs	Uncoordinated charging	Coordinated charging
Peak load [kVA]	23	36	25
Line current [A]	105	163	112
Node voltage [V]	220	217	220
Power losses [%]	1.4	2.4	2.1

Table3 .Power Quality and losses for Grid

10. Smart Grid's smart metering for PHEV

A smart metering system must be implemented to control the coordination and communication between the PHEVs individually, the distribution system operator and the transmission system operator (TSO). The vehicles could also be grouped and represented by a fleet manager to communicate with the DSO and TSO. Smart metering will lead to opportunities to make PHEVs a controllable load, to apply the vehicle-to-grid concept and to combine PHEVs and renewable energy. This technology is available for implementation, but capital investments by the utilities are necessary. For the implementation of smart metering, also other incentives, such as real-time pricing and integration of renewable energy, are important. Less grid enforcements are necessary with the coordination system. The maximum load is lower because the vehicles are not charging if the household loads are peaking. Therefore, the voltage drops, line currents and power losses are considerably reduced. The cost of upgrading the grid must be compared with the cost of the execution of smart metering. In both cases, the cost for the implementation and the possible additional power production will be passed on to the customers. In practice, it would be no difference for the DSOs which technology is implemented, as they are allowed to have a fair rate of return in a cost plus mechanism. With this mechanism, the DSOs are not strongly pushed towards the use of the most efficient technologies. The tariffs and the performance of the grid are more important in a price cap mechanism. The realization is favourable if the smart metering system helps a significant deferral of grid investments compared to the enhancement of the grid.

11. FUTURE SCOPE

PHEVs have the prospect of entering to the electrical grid, but whether they ever do so in large numbers will depend in part on their relative economics compared with more conventional transportation choices as well as their impact on utility economics, which likely would affect the prices charged for their fuel (plug-supplied electricity) and arrangements made by utilities to accommodate their recharging. The economics for both the prospective vehicle owner and the electric utility are promising and that more detailed analysis could more completely identify and evaluate opportunities. Moreover, as volatile renewable power sources such as wind and solar enter the generation mix, batteries of PHEVs have the potential to interact with the grid as distributed storage to help maintain network reliability and increase the capacity factors of these renewable power sources.

12. Conclusion

PHEV play a major and important role to integrate transportation, power system and communication infrastructure. PHEV allow customer to charge their vehicle from grid as well as from renewable energy system such as wind and solar which shows flexibility for consumer. As a component of smart grid, it can provide ancillary service (including spinning reserves and regulation) and peak power; PHEV are expected to significantly increase in numbers over the next few years.
From various aspects, the advantages, the scheme and the simulation modes, this paper reviews the contents of PHEV and its influence, advantage, impact on the power system. Future enabling technologies in the area include communication between the vehicle and the energy management centre bidirectional charging units and bi-directional meters (on board or off board) , intelligent on board power management unit and intelligent energy management centre. All of the above technologies will be an integral part of the future vision of the smart grid.

13. References

[1] C. Pang, P. Dutta, S. Kim, M. Kezunovic, and I. Damnjanovic, "PHEVs as Dynamically Configurable Dispersed Energy Storage for V2B Uses in the Smart Grid.
[2] Steven L. Judd and Thomas J. Overbye An Evaluation of PHEV Contributions to Power System Disturbances and Economics".
[3] Vincenzo Marano and Giorgio Rizzoni, *Center for Automotive Research- The Ohio State University,"* Energy and Economic Evaluation of PHEVs and their Interaction with Renewable Energy Sources and the Power Grid.
[4] W. Shireen, *Senior Member, IEEE*, and S. Patel, " Plug-in Hybrid Electric Vehicles in the smart grid environment.
[5] Tu yiyun ,Li Can , Cheng Lin ,Le Lin," Research on Vehicle-to-grid Technology.
[6] Ahmed Yousuf Saber, *Member, IEEE*, and Ganesh Kumar Venayagamoorthy, *Senior Member, IEEE, "*Plug-in Vehicles and Renewable Energy Sources for Cost and Emission Reductions"
[7] M. Musio , P. Lombardi , A. Damiano," Vehicles to Grid (V2G) concept applied to a Virtual Power Plant Structure.
[8] Bill Kramer, Sudipta Chakraborty, Benjamin Kroposki ," A Review of Plug-in Vehicles and Vehicle-to-Grid Capability ".
[9] M. El Chehaly, *Student Member, IEEE*, Omar Saadeh, *Student Member, IEEE*, C. Martinez, *Student Member IEEE*, G. Joos, *Fellow, IEEE,"v* Advantages and Applications of Vehicle to Grid Mode of Operation in Plug-In Hybrid Electric Vehicles"
[10] Kristien Clement-Nyns, Edwin Haesen, *Student Member, IEEE*, and Johan Driesen, *Member, IEEE,"* The Impact of Charging Plug-In Hybrid Electric Vehicles on a Residential Distribution Grid."