IMPLEMENTATION OF PV BASED ELECTRIC VEHICLE BATTERY CHARGER WITH V2G CAPABILITY

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ABSTRACT:

As an environmental friendly vehicle, the increasing number of electrical vehicles (EVs) leadsto a pressing need of widely distributed charging stations, especially due to the limited on-board battery capacity. However, fast charging stations, especially super-fast charging stations may stress power grid with potential overload at peaking time, sudden power gap and voltage sag. This project discusses the detailed modeling of a multiport converter based EV charging station integrated with PV power generation, and battery energy storage system. In this project, the control scheme and combination of PV power generation, EV charging station, and battery energy storage (BES) provides improved stabilization including power gap balancing, peak shaving and valley filling, and voltage sag compensation. An ANN based controller is designed for regulating performance of multi-mode power converter.

INTRODUCTION

The continuous rise in gasoline prices along with the increased concerns about the pollutions produced by fossil fuel engines are forcing the current vehicle market to find new alternatives to reduce the fossil fuel usage. Along with the research on bio-fuel driven engines; different electric vehicles and hybrid electric vehicles are evolving as viable alternatives to replace, or at least reduce, the current fleet of fossil fuel driven vehicles. Although current manufactured electric/hybrid vehicles are being marketed as a way to reduce fossil fuel usage, several promising technologies are being demonstrated that can utilize power electronics to charge the battery from the utility using plug-in vehicles or act as a distributed resource to send power back to the utility with vehicle-to-grid capabilities. In this paper, different plug-in vehicle topologies are described to review the power electronics required for them. The newly evolving V2G technology is also discussed along with economics and compliance requirements to allow the vehicle to be connected to the grid. Before going into the details of power electronics required for the electric/hybrid vehicles, the common formsof these vehicles are described next to get accustomed with the terminologies.

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Electric Vehicles

A typical electric vehicle (EV) has a battery pack connected to an electric motor and provides traction power through the use of a transmission. The batteries are charged primarily by a battery charger that receives its power from an external source such as the electrical utility. Also during regenerative braking, the motor acts as a generator which provides power back to the batteries and in the process slows down the vehicle. The primary advantage of an EV is that the design is simple and has a low part count. The primary disadvantage is that the driving range of the vehicle is limited to the size of the battery and the time to re-charge the battery can be from 15 minutes to 8 hours depending on how far the vehicle was last driven, the battery type and battery charging method.

Hybrid Electric Vehicles

The components that make up a typical hybrid electric vehicle (HEV) include a battery pack, motor controller, motor/generator, internal combustion engine, transmission and driveline components. The batteries are charged through the use of the on-board internal combustion engine and generator. In a plug-in hybrid electric vehicle (PHEV), the batteries can also be charged through the use of a battery charger that receives its power from the utility. The best PHEV design will allow the vehicle to operate on electric power only reducing the amount of time that the engine runs. When the vehicle is not operating, the battery can be charged through the use of a battery charger that is "plugged in" to the electrical utility or other energy sources. A PHEV normally has a larger battery pack than a HEV. The advantage of a PHEV over an HEV is that due to external battery charging, the vehicle can run longer on electric power which in-turn reduces engine fuel consumption.

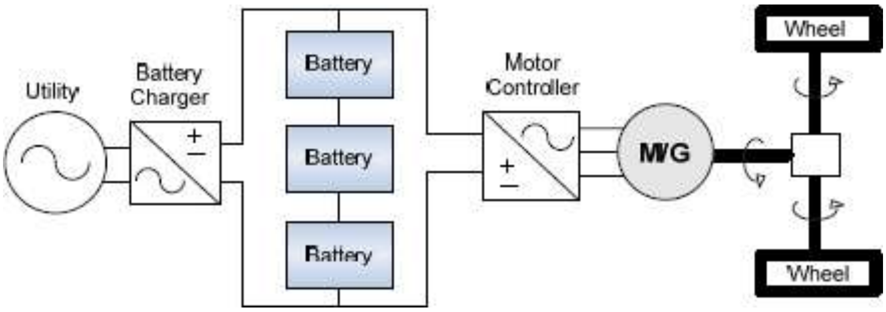

Figure 1: Typical EV configuration

Plug-In Vehicles:

According to the Electric Power Research Institute (EPRI), more than 40% of U.S. generating capacity operates overnight at a reduced load overnight, and it is during these off-peak hours that most PHEVs could be recharged. 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% increase in capacity) will be required

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[2]. 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. 1. 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 magnetelectric 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 stoppedquickly 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, 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 Toyota Prius HEV configuration is given in Fig. 2. The Prius design uses two permanent magnet motors/generator, one of 10kW and the other of 50kW. The battery is connected toa booster and inverter before feeding to the motor/generators. The power electronics are bidirectionaland 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 [3], [4]. The batteries can also be charged using regenerative braking of the large motor/generators. There is no provision to charge the batteries externally. For plug-in hybrid electric vehicles, batteries are charged when they are not being driven. This is normallyaccomplished 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.

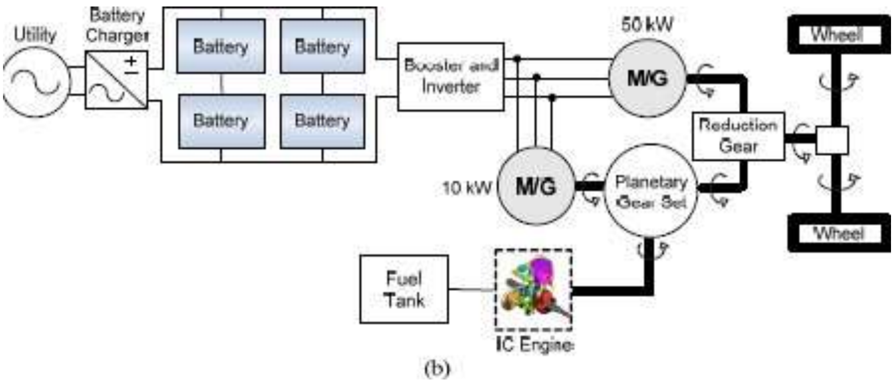

Figure 2: Configurations converted PHEV

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Plug-in Electric Vehicle Charger Topology

The desirable characteristics for the charger are power bi-directionality (V2G and G2V), power factor equal to one, capability of performing power control, low PQ impact, construction and topology simplicity, and regular 16 A single-phase plug compatibility [6]. This charger does not allow performing fast charge, being 2.3 kW (10 A, 230 V) the advisable maximum power for a single-phase household-type plug. This power range is defined based on EU standards and power grid restrictions, since higher power ranges could represent a negative impact on the low voltage (LV) grid in terms of PQ and EMS requirements [22]–[24]. Regarding the voltage level of the battery pack, the proposed design is focused on L-category vehicles (two-, three- and four-wheel vehicles such as motorcycles, mopeds, quads, and minicars), as the one studied in [25], but could be extended to other voltage levels.

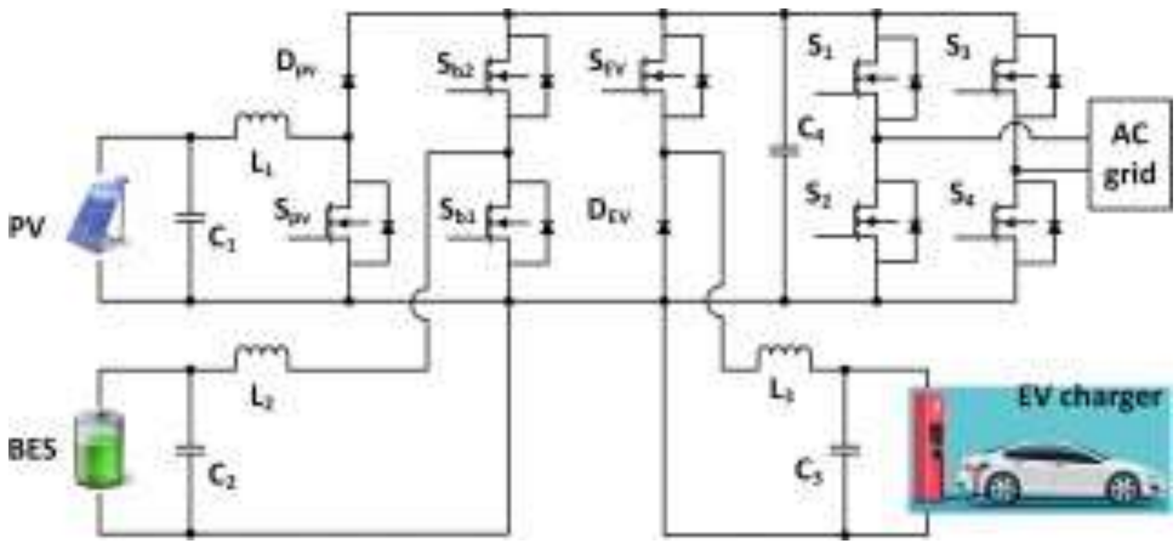

Figure 3: PEV charger topology

TOPOLOGY AND DESIGN:

The topology of the proposed MMPC consists of four Insulated Gate Bipolar Transistors (IGBTs) with antiparallel diodes connected as shown in Fig. 4. Q1, Q3 constitute the upper pair and Q2, Q4 constitute lower pair IGBTs. The selection of different modes of operation can be achieved with switches denotedas K1, K2 and K3 in figure 4. VL is the low DC voltage at Auxiliary battery side and VH is the high voltage DC at the primary battery.

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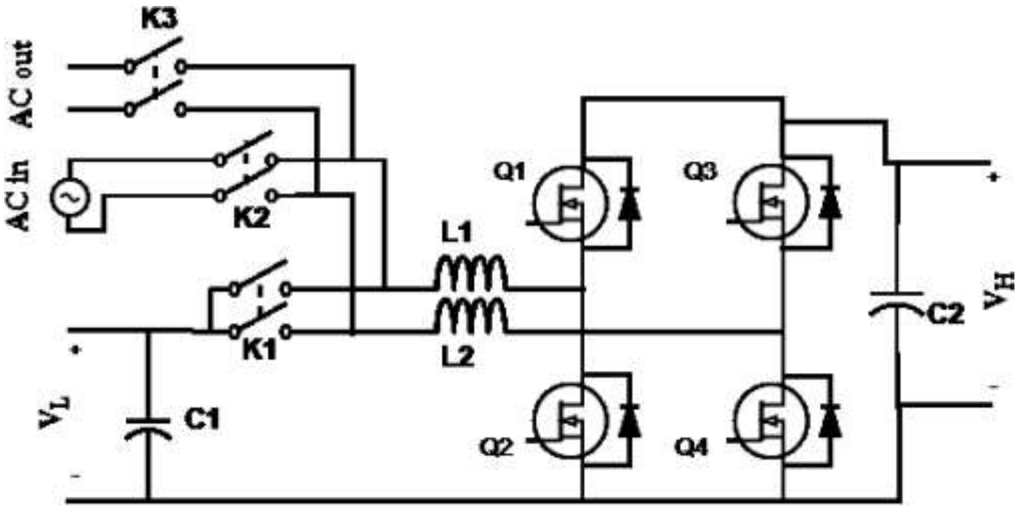

Figure 4: Proposed MMPC Topology

Switch K1 is turned on to make the MMPC work as a bidirectional DC-DC converter. During this operation Switch, K2 and K3 will be in the off state. The model with interleaved topology is havinga pair of buck and boost converters. Buck converter operation is when the upper pair IGBT is acting as switches and the lower pair IGBT conducting as diodes. Similarly, the upper and lower IGBT acts as diodes and switches respectively for the boost converter. As working in AC – DC converter mode, Switch K1, K3 are off and K2 is on. During this mode the primary battery can be charged from AC mains, and the system work as a full bridge rectifier. Switch K3 is turned on keeping K1, K2 off and the energy flows from the battery to residential grid/AC loads when the system working as DC – AC converter. Charging mode and V2H mode are selected manually by the user. Table I shows the complete switching sequence for the MMPC.

TABLE I. SWICTHING SEQUENCE OF MMPC

Switch Operation			*Gate Pulses to IGBTs*				*Operation modes*
K1	K2	K3	Q1	Q2	Q3	Q4	
OFF	ON	OFF	OFF (Diodes are conducting)				Charging EV (AC - DC)
OFF	OFF	ON	PWM pulse				V2H (DC - AC)
ON	OFF	OFF	Pulse	OFF	Pulse	OFF	DC – DC Buck
ON	OFF	OFF	OFF	Pulse	OFF	Pulse	DC – DC Boost

EXPERIMENTAL RESULTS:

The experimental results have been obtained using a reduced scale setup (with power levels 5 times lower than the full scale). It is important to note that in this reduced scale setup the DCBUS voltage was stabilized around 108 V and PMax was ±460W, being the "Advisable Energy Levels" used for sizing, simulation and further full-scale implementation.

Artificial Neural Networks:

Figure 5 shows the structure of an ANN, in which fixed node indicated by a circle, an adaptive node indicated by square. In this structure hidden layers are presented in between input and output layer, these nodes are functioning as membership functions and the rules obtained based on the if-then statements is eliminated [7]. For simplicity, we considering the examined ANN has two inputs and one output. In this network, each neuron and each element of the input vector p are connected with weight matrix W. The hybrid learning algorithms are implemented for obtaining the values of system parameters. These learning algorithms is a function of linear and non-linear parameters. These explanations are implemented in Matlab/Simulink software.

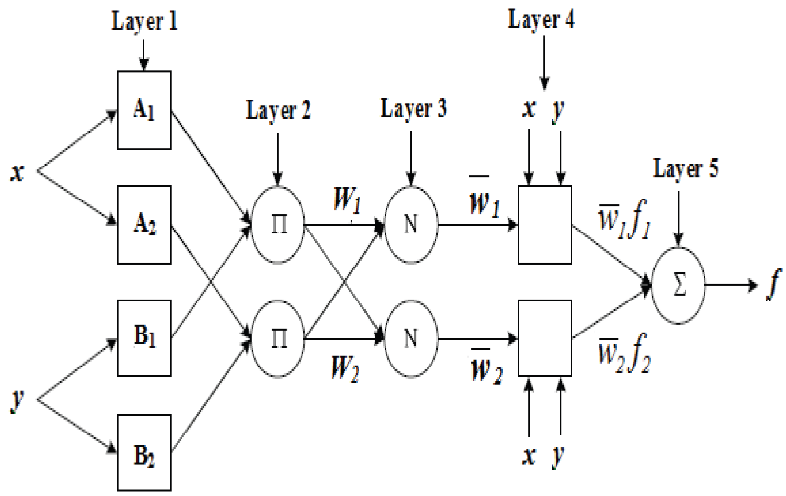

Figure 5 ANN architecture for a two-input multi-layer network

Where the two crisp inputs are x and y, the linguistic variables associated with the node function are Ai and Bi. The system has a total of five layers are shown in Fig 5.

Algorithm for Neuro Controller:

1. Assume the inputs and outputs in the normalized form with respect to their maximum values and these are in the range of 0-1.
2. Assure the No.of input stages given network.
3. Indicate the No.of hidden layers for the network.
4. Design the new feed forward network based on the system parameters 'transig' and 'poslin'.

5. Assume the learning rate be 0.02 for the given network.

6. Identify the number of iterations for the system.

7. Enter the goal.

8. Train the network based on the given input and outputs.

9. for the given network Generate simulation with a command ‘genism’

SIMULATION RESULTS:

The MMPC system designed is for a voltage ripple of 2% and current ripple of 20%. In order to achieve these requirements in all modes of operations, the inductance and capacitance need to be matched with MMPC design.

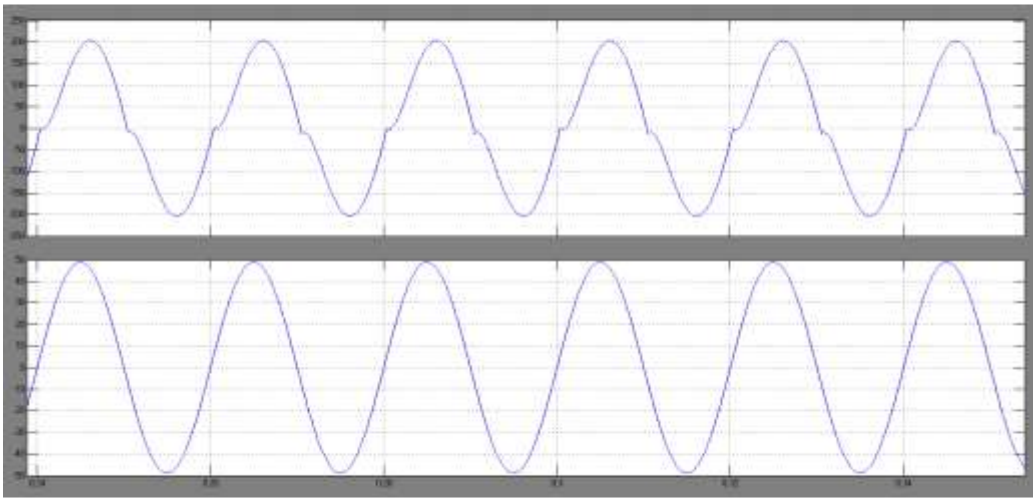

Figure 6: Simulation waveforms for Grid voltage and current under AC-DC Mode

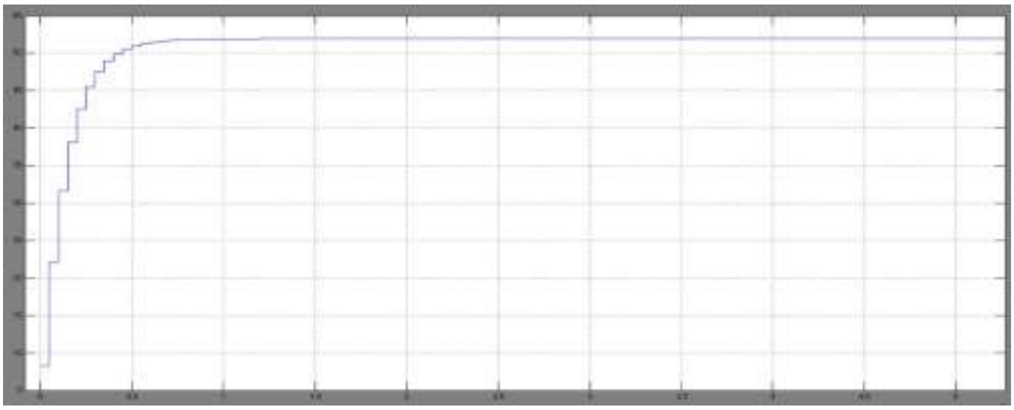

Figure 7: Simulation waveforms for output voltage under DC-DC Boost Mode

CONCLUSION

In this project, a multiport converter based EV charging station with PV and BES is proposed. A BES controller is (a) (b) Figure. Comparison of the power device losses between the Si converters and SiC counterpart, at various load percentage and different operating modes (PV to EV, PV to BES, and BES to EV), (a) conduction losses, (b) switching losses with the same labels and orders as in (a). Figure. Comparison of the peak efficiency between the Si converters and SiC counterpart, at various load percentage and different operating modes (PV to EV, PV to BES, and BES to EV). developed to regulate the voltage sag, and balance the power gap between PV generation and EV charging demand. With the proposed control design, BES starts to discharge when PV isinsufficient for local EV charging, and starts to charge when PV generation is surplus or power grid isat valley demand, such as during nighttime. As a result, the combination of EV charging, PV generation, and BES enhances the stability and reliability of the power grid. Different operating modesand their benefits are investigated and then, simulation and thermal models of the multiport converter based EV charging stations and the proposed SiC counterpart are developed in ANSYS Twin Builder. Simulation results show that the efficiency can be improved by 5.67%, 4.46%, and 6.00%, respectively, for PV-to-EV mode, PV-to-BES, and BES-to-EV mode at nominal operating condition, compared to Si based EV charging stations under the same operating conditions.

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