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SVM Based Multiport Converter for Electric Vehicle Charging Station with PV and Battery

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ABSTRACT

Although EVs are better for the environment than traditional cars, the growing demand for them necessitates the installation of charging stations in convenient locations. The electrical system might be put under unnecessary strain by fast charging stations, particularly super-fast charging stations, which could cause an overload during peak hours, a rapid drop in power, and a voltage drop. Space vector modulation to multiport converter based electric vehicle charging station with PV power production and battery energy storage system is discussed and modelled in this research. In this study, we show that combining solar photovoltaic (PV) power production with an electric vehicle (EV) charging station and a battery energy storage (BES) system improves stability in a number of ways. Matching daily charging demand with sufficient daytime PV output, thus, reduces the impact on the power system. We show simulation results confirming the proposed multiport EV charging circuits' advantages at various modes using the PV-BES configuration and the SVM approach. The EV charging station also makes use of SiC devices to boost efficiency.

INTRODUCTION

The contemporary automobile market is being forced to discover new alternatives to lower the amount of fossil fuel that is used as a result of the persistent rise in the price of gasoline as well as the growing worries about the pollutions created by engines that run on fossil fuels. Along with research being conducted on engines that are powered by biofuels, a variety of electric cars and hybrid electric vehicles are now being developed as potential replacements for, or at the very least reductions in, the present fleet of vehicles that are powered by fossil fuels. Although currently manufactured electric and hybrid vehicles are being marketed as a way to reduce the use of fossil fuels, a number of promising technologies are currently being demonstrated. These technologies can utilise power electronics to charge the battery from the utility using plug-in vehicles, or they can act as a distributed resource to send power back to the utility using vehicle-to-grid capabilities. Both of these technologies have the potential to reduce the use of fossil fuels. In this work, many topologies for plug-in vehicles are discussed in order to examine the power electronics that are necessary for each of those topologies. The rapidly developing technology known as V2G is also covered in this article, along with the economics and regulatory criteria that must be met before a vehicle may be linked to the grid. In order to familiarise yourself with the terminology before delving into the specifics of the power electronics that are necessary for electric and hybrid cars, the most prevalent types of these types of vehicles will now be discussed.

RELATED WORK

Fuzzy controller for voltage-frequency control technique for microgrid in islanding operation was given by Singaravelan and Kowsalya [1]. The fuzzy-based voltage-power/frequency-active power (VP/FQ) method that has been presented uses the microgrid's actual power output to control the voltage, and it uses the microgrid's reactive power output to regulate the frequency. This supervisory control technique makes it possible for the voltage source converter (VSC) to work in islanding mode during the instantaneous synchronisation operation by using a conventional inductor interface and dqframe current management. The findings indicate that the suggested method works well and has some value for the regulation of inverters in microgrids. Hung-I Hsieh and colleagues [2] came up with the idea for a high-frequency photovoltaic pulse charger for lead-acid batteries. This charger would be directed by a power increment-aided incremental-conductance maximum power point tracking algorithm. The purpose of the PV-PC that is created by a boost current converter is to prevent sulfating crystals from forming on the electrode plates of the LAB and to extend the life of the battery. The BCC that is connected to the PV module is designed in order to optimise the amount of energy that is charged to the battery while still maintaining maximum power transmission. In order to drive the BCC when it is functioning at MPP in opposition to the random insulation, a duty-control that is directed by the PI-INC MPPT has been created.

A unique Maximum Power Point Tracking (MPPT) method was suggested by Arash Shafie et al. [3] primarily for use in battery charging applications, which were considered constant voltage type loads. The primary contributor to this success was increasing the output current. This method has a number of features, including a very simple current controller and an independence from the circuit architecture. This results in a high efficiency for the conversion of energy at a low cost, making it suitable for applications that need low power and cheap cost. In order to better simulate real-world conditions, a brand-new hybrid PV model was developed. In conclusion, the results of the simulation that were run will be shown, which will validate the method. Jannik Schafer [4] proposes a novel multi-port multi-cell (MPMC) topology, which allows for the overcoming of the arising design challenges for converter systems in applications with highly different input and output voltage levels. This topology is able to accomplish this by utilising a set of cells that are connected in parallel. The use of an MPMC topology has a number of benefits, one of which is the reduction of the cell-internal port voltage ratios, which ultimately results in advantageous characteristic impedances for the converter ports.

G. Sowmmiya [5], suggested a multiport rapid charger for electric vehicles that is planned and built based on the idea of an active power electronic transformer. This idea provides the following advantages: power control; voltage control (compensation of voltage sags and peaks); current control (short-circuit current limitation). The multiport topology enables the reduction of power losses as well as the complexity of the power circuit, which results in an increase in power density. Energy is supplied to the multiport converter component by the grid converter, which also performs the function of a synchronous rectifier. Highest power point tracking is carried out so that the voltage that is collected from the PV module may generate the maximum amount of electricity.

ELECTRIC VEHICLES

A standard electric vehicle (EV) consists of a battery pack that is linked to an electric motor and a transmission that is used to transfer the power generated by the electric motor to the wheels. The battery charger, which gets its electricity from an external source such as the electrical utility, is the primary device responsible for the process of charging the batteries. In addition, while using regenerative braking, the motor performs the function of a generator, sending power back to the vehicle's batteries while simultaneously reducing the vehicle's speed. The fundamental benefit of an electric vehicle is that its design is straightforward and has a limited number of components. The primary drawback is that the driving range of the vehicle is restricted to the capacity of the battery, and the amount of time required to recharge the battery can range anywhere from fifteen minutes to eight hours, depending on how far the vehicle was driven the previous time, the type of battery, and the method for charging the battery.

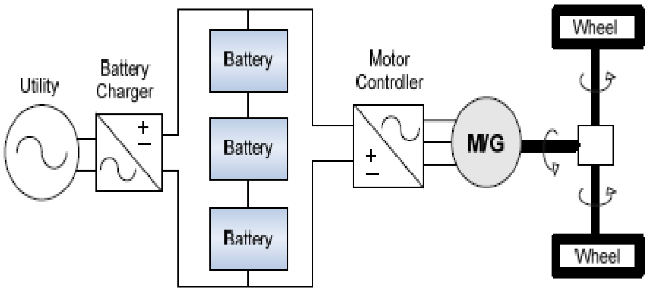

Figure 1: Typical EV configuration

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 [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 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, 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 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 [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 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. A Toyota Prius configuration with PHEV conversion is shown in Fig. 2. 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.

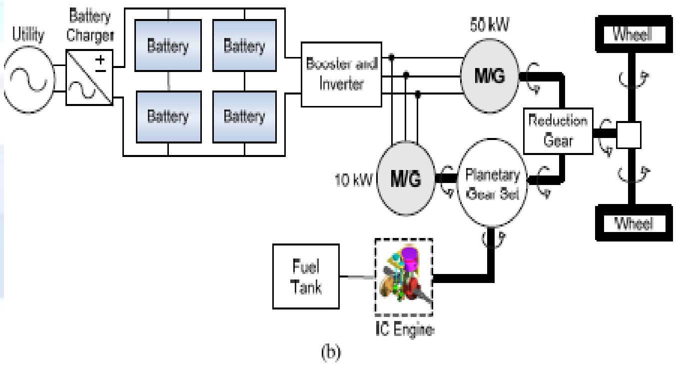

Figure 2: Configurations converted PHEV

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.

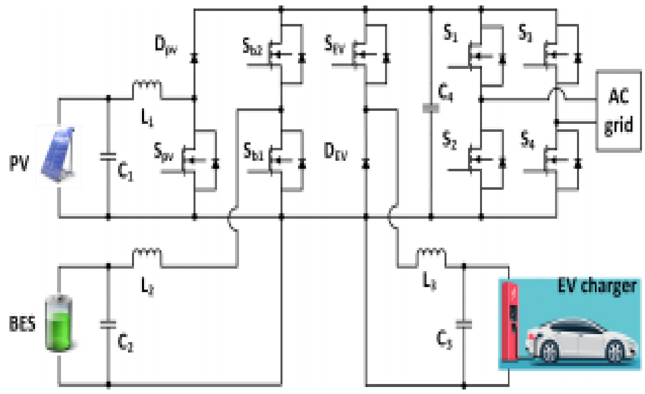

Figure 3: PEV charger topology

Photovoltaic Array Modeling:

In the PV network of electrical phenomenon, cell is the necessary part. For the raise in appropriate current, high power and potential difference, the sunlight dependent cells and their region unit joined in non-current or parallel fashion called as PV exhibit are used. In practical applications, each and every cell is similar to diode with the intersection designed by the semiconductor material. When the light weight is absorbed by the electrical marvel sway at the point of intersection, it gives the streams at once. The (current-voltage) and (Power-Voltage) attributes at absolutely unpredictable star intensities of the PV exhibit are represented in figure 4, whereas the often seen existence of most electrical outlet on each yield is shown in power diagram 5.

$I = I_{ph} - I_D - I_{sh}$ (1)

$I = I_{ph} - I_o [\exp (q V_D / nKT)] - (v_D / R_S)$ (2)

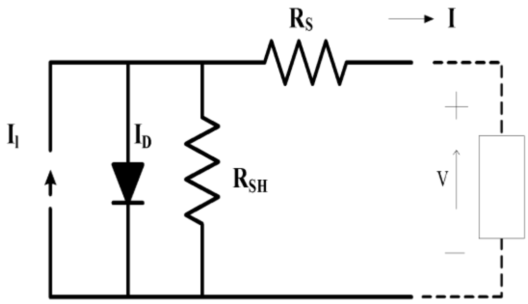

Figure 4: PV Electrical Equivalent circuit

Operation of Multi Stage Converter:

Mode 1: PV to EV:

In this mode, the switches Spv, Sb1, and Sb2 are turned off while SEV is turned on. Therefore, PV directly delivers power to the load, as shown in Figure. The differential equations in this stage can be expressed as follows:

$$i_{PV} = C_1 \frac{dv_{C1}}{dt} + i_{EV}$$

$$C_2 \frac{dv_{C2}}{dt} = \frac{v_{Bat} - v_{C2}}{r_b} - i_{L2}$$

$$i_{EV} = C_3 \frac{dv_{C3}}{dt} + \frac{v_{EV}}{R_{EV}}$$

$$v_{C1} - v_{C3} = L_3 \frac{i_{L3}}{dt}$$

$$L_2 \frac{i_{L2}}{dt} = -v_{C2}$$

Mode 2: BES to EV

When Spv and SEV are turned on while Sb1 and Sb2 are turned off, BES is discharged to the EV load, as shown in Figure. The differential equations in this mode can be expressed as follows:

$$i_{PV} = C_1 \frac{dv_{C1}}{dt}$$

$$L_2 \frac{i_{L2}}{dt} = v_{DC} - v_{C2}$$

$$v_{DC} - v_{C3} = L_3 \frac{i_{L_3}}{dt}$$

$$C_2 \frac{dv_{C2}}{dt} = \frac{v_{Bat} - v_{C2}}{r_b} - i_{L2}$$

$$i_{EV} = C_3 \frac{dv_{C3}}{dt} + \frac{v_{EV}}{R_{EV}}$$

SVM TECHNIQUE FOR TWO-PHASE INVERTER

In the SVM technique of three-phase inverter. A reference voltage vector V* is realized by computing the duty ratio for two space vectors which are adjacent to V* and by adjusting the switching time of two zero space vectors.

In this paper, the realization method for SVPWM technique of two-phase inverter is proposed without zero space vectors. Figure 5 shows the model sectors to determine the switching times for the reference vector V^* by adjusting four voltage space vectors.

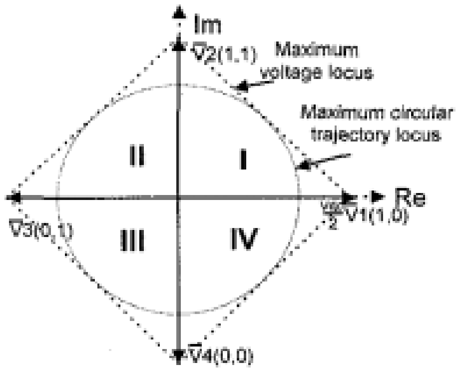

Figure 5: SVM Four possible space vectors

SIMULINK RESULTS

The experimental findings were acquired via the use of a set up with a smaller size (with power levels 5 times lower than the full scale). In this reduced scale arrangement, the DCBUS voltage was stabilised at approximately 108 V, and the PMax was around 460 W. These values are the "Advisable Energy Levels" that were used for sizing, simulation, and subsequent full-scale implementation. It is crucial to note that these values were employed. In addition, a PWM control and data logging purpose is employed, together with several other pieces of laboratory equipment and electrical components, as shown in Figure 5.

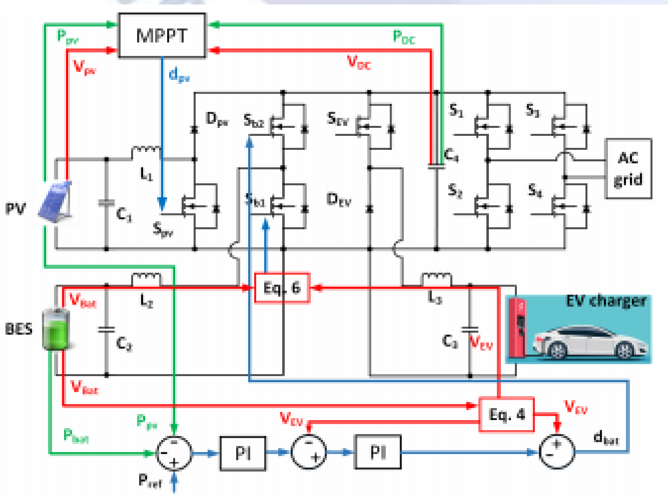

Figure 6: Simulation Diagram for PV based V2G System

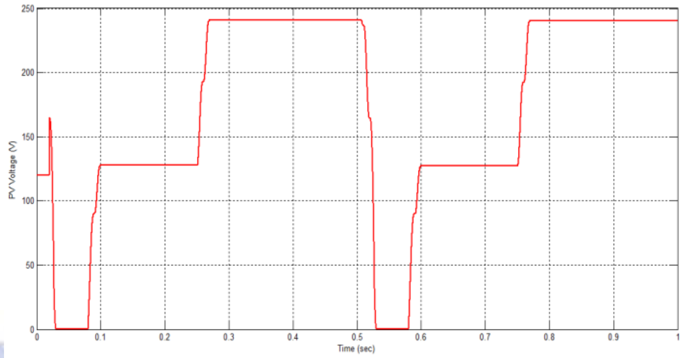

Figure 7: Simulation Waveform for PV Voltage

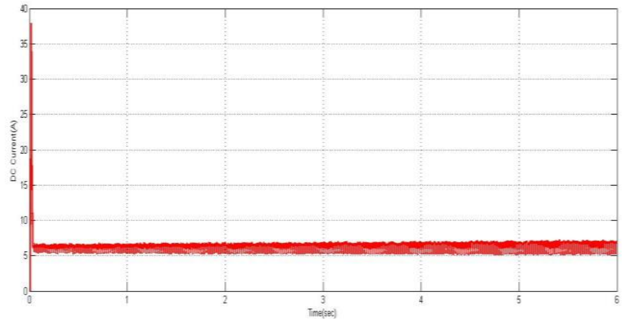

Figure 8: Simulation Waveform for PV Current

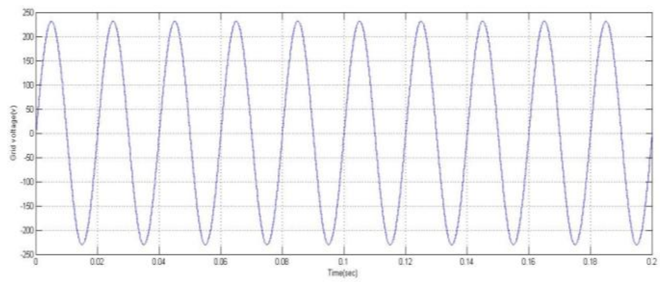

Figure 9: Simulation Waveform for Grid Voltage

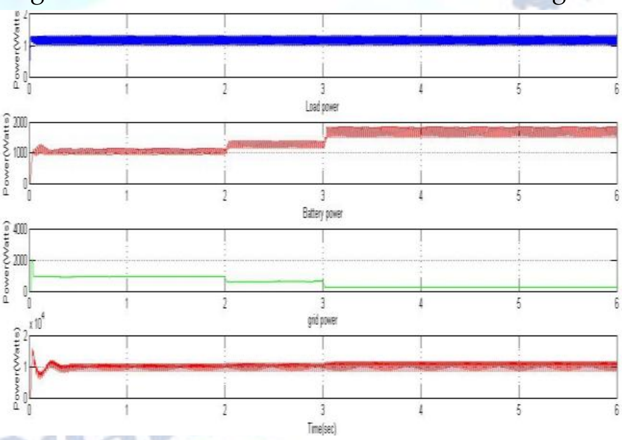

Figure 10: Simulation Waveform for System Powers at different Load Conditions

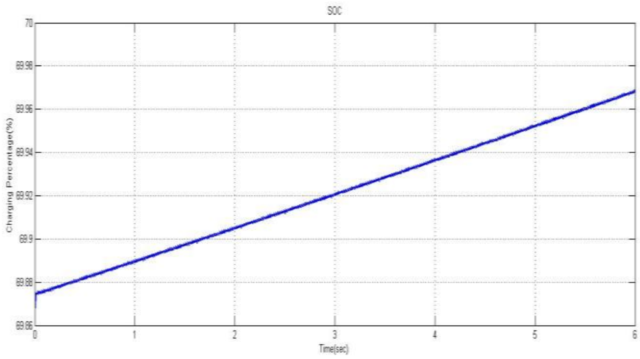

Figure 11: Simulation Waveform for Battery SOC

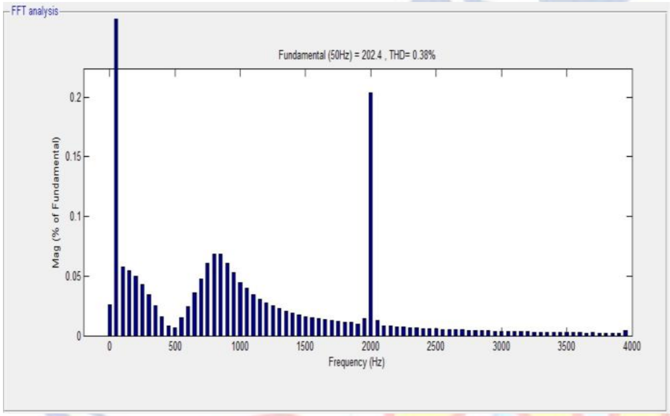

Figure 12: Simulation Waveform Inverter Voltage THD

CONCLUSION

A space vector modulated multiport converter-based electric vehicle (EV) charging station with photovoltaic cells and battery energy storage was presented . A BES controller is the suggested control architecture. A BES begins discharging when photovoltaic (PV) production is inadequate for local electric vehicle (EV) charging, and a BES starts charging when PV output is in excess or the power grid is at low demand, such as during the evening. Because of this, the integration of PV generating, EV charging stations, and BES systems results in an increase in the power grid's stability and dependability. Next, simulation and thermal models of the multiport converter-based EV charging stations and the suggested SiC equivalent are constructed in Matlab/Simulation. This is followed by an investigation into the various operating modes and the advantages associated with them. The results of the simulation demonstrate that the efficiency can be enhanced for the PV-to-EV mode, the PV-to-BES mode, and the BES-to-EV mode while operating at the nominal condition. This is in comparison to the efficiency of Si-based EV charging stations when running under the same circumstances.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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