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Advanced Management of Electric Vehicle Charging Conditions Utilizing a Photovoltaic-Based Multi-Mode Converter System

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ABSTRACT

The surging popularity of electric vehicles (EVs) as an environmentally friendly mode of transportation has heightened the need for conveniently situated charging stations, since EVs have limited range on their internal batteries. Fast charging stations, especially super-fast charging stations, may strain the power infrastructure owing to the risk of overload during peak hours, sudden power interruptions, and voltage drops. This work examines the detailed modeling of a direct current (DC) power generation and battery energy storage system integrated into a multiport converter-based electric vehicle (EV) charging station. This project assesses the feasibility of utilizing Plug-in electric vehicles (PEVs) in Vehicle to Home (V2H) scenarios as a means of residential battery storage or backup generator during power outages or distribution system faults, which are typically of shorter duration. Both the simulated and experimental results validate the feasibility of PCMM and demonstrate its capacity to accomplish the design objective. The charger has been designed and its operation validated using a space vector modulation technique and a simulation analysis. The simulation findings indicate that the proposed charger and a compatible autonomous EMS would interact well in a typical residential setting.

1. INTRODUCTION

It is possible that renewable energy technology will play a large role in the future of the power system throughout the globe. This is because there are growing worries about the pollution of the environment. Because grid extension is often impractical due to economic and technological constraints, a stand-alone power system that is powered by renewable energy may be a particularly attractive and cost-effective option in the event that power delivery systems are required to be provided to remote and isolated locations. Despite the fact that PV integration is becoming more important, studies usually evaluate it as a relatively modest component of the overall power supply for electric vehicle charging stations. As photovoltaic (PV) generation becomes more widespread throughout the day, it helps to reduce the amount of electricity that is wasted during peak hours, which is when there is the greatest need for rapid acceleration of charging. As a result of the intermittent nature of solar power, battery energy storage (BES) may be used to manage the voltage of the DC bus or load, equally distribute power gaps, and smooth out the output of PV. A multi-port DC/DC converter was selected for the electric vehicle charging station described in this article rather than three individual converters. This decision was made due to the high power density and efficiency of the converter.

There are two separate AC bus and DC bus designs for charging stations, according to all of the research that have been discussed above. In this instance, a DC bus charging station is used to maximize the utilization of solar energy while simultaneously minimizing the many expenses and losses connected with converters, both financially and environmentally. Sources of direct current (DC) may be seen of as both the output of PV and the BES. Additionally, non-isolated multi-port converters, which often originate from buck or boost converters, have the potential to provide enhanced mobility, power density, and efficiency in comparison to their isolated counterparts.

2 . ELECTRIC VEHICLES

The majority of electric vehicles (EVs) make use of transmissions in order to transport energy from a battery pack to an electric motor, which subsequently supplies the vehicle with the traction power it needs. The majority of the responsibility for recharging the batteries lies with a battery charger, which obtains its power from a source other than the batteries themselves, such as the electrical grid. In the event that the speed of the vehicle is slowed down by the use of regenerative braking, the motor functions as a generator, therefore redirecting energy back into the batteries. The straightforward and low-parts-count design of electric vehicles is a significant advantage of these vehicles. The most significant disadvantage is that the driving range is restricted by the size of the battery, and the amount of time it takes to recharge the battery may vary anywhere from fifteen minutes to eight hours, depending on the distance traveled during the previous drive, the kind of battery that was used, and in addition to other considerations. along with the process of charging the battery.

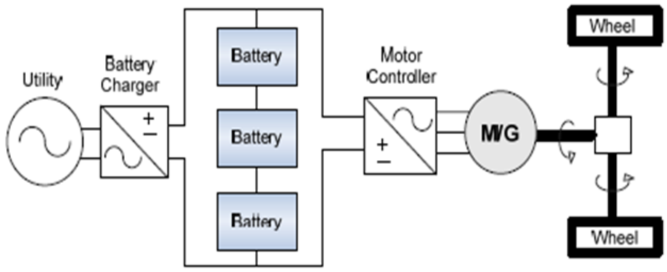

Figure 1: Typical EV configuration

Plug-In Vehicles:

Over 40% of U.S. producing capacity works at decreased load overnight, and most PHEVs may be recharged during these off-peak hours, as reported by the Electric Power Research Institute (EPRI). Recent research shows that replacing half of the cars on the road with PHEVs by 2050 will only need an 8% increase in electricity output (a 4% increase in capacity) [2]. Many modern plug-in electric cars include their own on-board battery chargers that may be used to recharge the vehicle's batteries from a standard wall outlet. Plug-in electric vehicles (PEVs) are seen in their most basic form in Fig. 1. Power is supplied from the battery pack through the motor controller to the motor, which in turn drives the wheels. Many modern electric vehicles have a permanent magnet electric motor that doubles as a generator to keep the batteries charged. In regenerative braking, the motor is reversed so that it generates electricity to charge the vehicle's batteries as it slows down. When stopping the car rapidly is necessary or the batteries are fully charged, friction brakes are deployed. Electric batteries, a motor controller, a motor/generator, an internal combustion engine, a transmission, and a driveline are the main parts of a typical HEV. The permanent magnet motor receives three-phase power from the main power electronics, which consist of a DC-AC motor controller. In Fig. 2, we see the Toyota Prius in its HEV version. Two permanent magnet motor/generators, one 10kW and one 50kW, are used in the Prius's architecture. In order to power the motors and generators, the battery is hooked up to a booster and an inverter. The power electronics may both charge the battery and provide power to the motors. A planetary gear system receives power from the gasoline engine and motor/generators. Transmission ratio is dynamically set by power flow between the battery, motor/generators, and gasoline engine in a continuously variable transmission (CVT) mode [3, 4]. Battery power may be replenished by regenerative braking of the massive motor/generators. The battery packs cannot be charged via an external source. In order to keep the batteries of a plug-in hybrid EV charged, the vehicle must sit idly for long periods of time. Typically, this is accomplished by utilising a utility-connected AC-DC converter to draw DC power from the grid. A DC-DC converter can be used to charge the batteries directly from a solar resource, and an AC-DC converter can be used to charge the batteries from a wind resource. As power is drawn from the grid in order to replenish the batteries, there is no two-way exchange of energy..

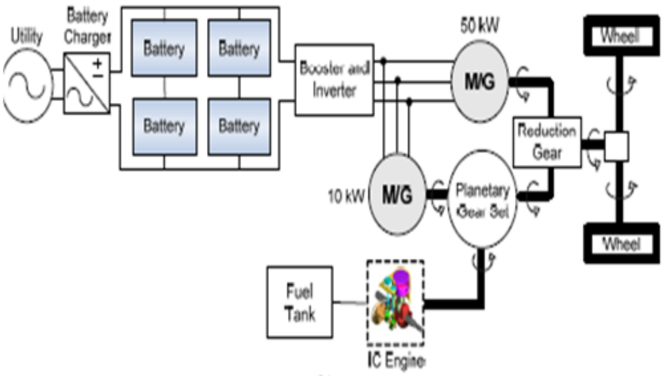

Figure 2: Configurations converted PHEV

3. PLUG-IN ELECTRIC VEHICLE CHARGER TOPOLOGY

With a power factor of 1, the charger should be able to give power in both directions (V2G and G2V), it should be able to execute power management, it should have a minor influence on power quality (PQ), it should have a clear design and topology, and it should be compatible with standard 16 A single-phase plugs [6]. Due to the fact that the highest safe output for a single-phase wall outlet connector is only 2.3 kW (10 A, 230 V), this charger does not have the capability to provide rapid charging. This range is chosen based on EU legislation and power grid constraints. This range is calculated because bigger power ranges have the potential to have a detrimental affect on the low voltage (LV) grid in terms of power quality and energy management system (EMS) needs [22]-[24]. The design that has been proposed gives priority to L-category vehicles, which include motorcycles, mopeds, quads, and minicars, *a.*
among other two-, three-, and four-wheel vehicles *b.*
However, if it is deemed essential, it might be *c.*
generalized to include other voltage levels.

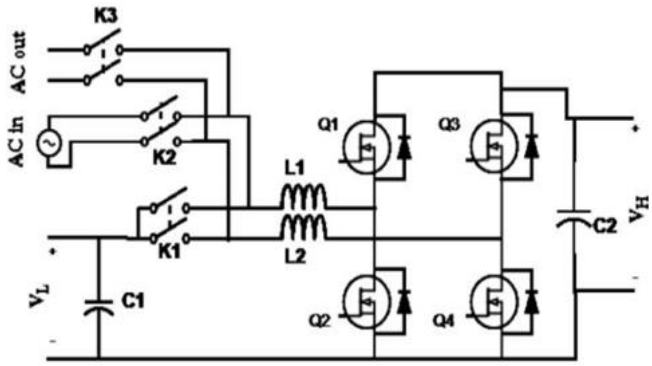

Figure 3: Proposed MMPC Topology

In MMPC, this is fixable by an interleaved boost Power factor Correction (PFC) method. It is possible to gate lower pair IGBTs for PFC circuit functioning during AC - DC operation. When the bottom pair of IGBTs in an MMPC circuit is functioning as a boost converter, it receives continuous input current from the AC mains. As demonstrated in Figure 4, the average current mode may be used to regulate the input current.

When water droplets are charged, they release a measured quantity of gas. Thus, the battery electrolyte is kept in a state of constant mixing, ready to provide a complete charge.

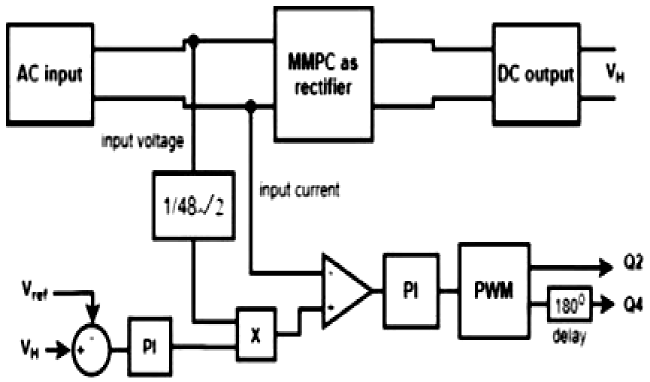

Figure 4: Average current mode control for PFC

This feedback loop will be activated when harmonics are present in the input current. Inner and outside controls are included. DC voltage at the output was measured and sent to the feedback circuit. In the inner loop, the current drawn from the input AC inductor is shaped to match the amplitude and phase of the input voltage. Q2 and Q4 receive 1800-phase-delayed PWM output pulses.

Photovoltaic Array Modeling:

The cell is an integral component of the PV electrical phenomena network. To increase the necessary current, high power, and potential difference, a PV show uses solar cells and their respective regions connected in a non-current or parallel mode. Each cell functions similarly to a diode in real life, with the intersection defined by the semiconductor material. Light weight, when absorbed by the electrical wonder sway at the place of junction, delivers the streams instantly. Figure 5 displays the (current-voltage) and (power-voltage) characteristics of the PV exhibit at completely random star intensities, and power diagram 5 depicts the ubiquitous presence of a single electrical outlet on each output.

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

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

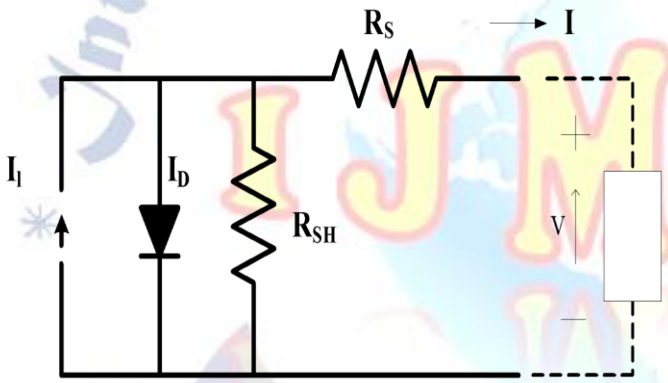

Figure 5: PV Electrical Equivalent circuit

4. SIMLATION DIAGRAM AND RESULT ANALYSIS FOR MMPC:

Four Insulated Gate Bipolar Transistors (IGBTs) are used in MMPC, and they are coupled in anti-parallel with diodes. The IGBTs Q1, Q3 are the top pair, while the Q2, Q4 are the bottom pair. The switches K1, K2, and K3 in figure 6 allow the user to decide between several operating modes. The Auxiliary battery side has a low DC voltage (VL), whereas the Primary battery side has a high DC voltage (VH).

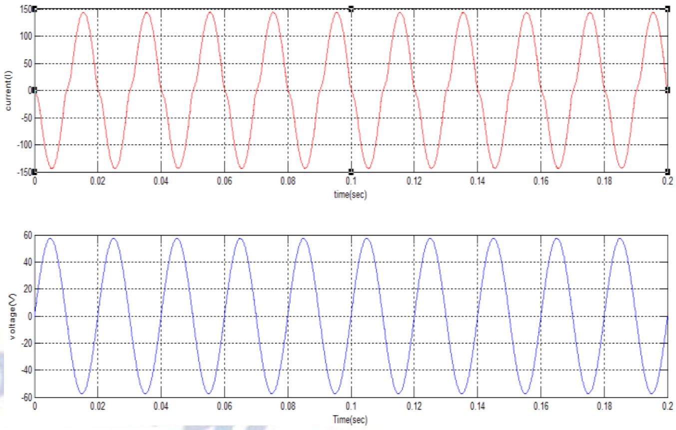

Figure 7: Input Voltage and Current Wave Forms for Ac-Dc Mode

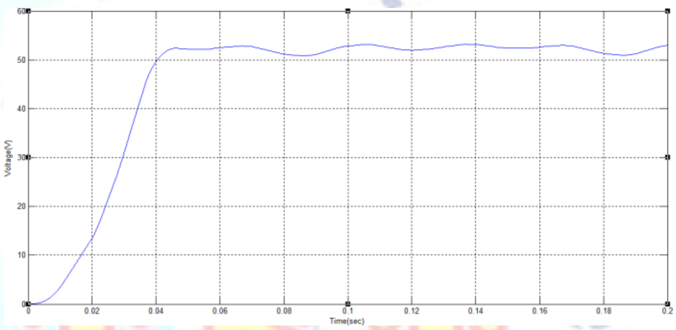

Figure 8: Output Voltage Waveform for Ac-Dc Mode

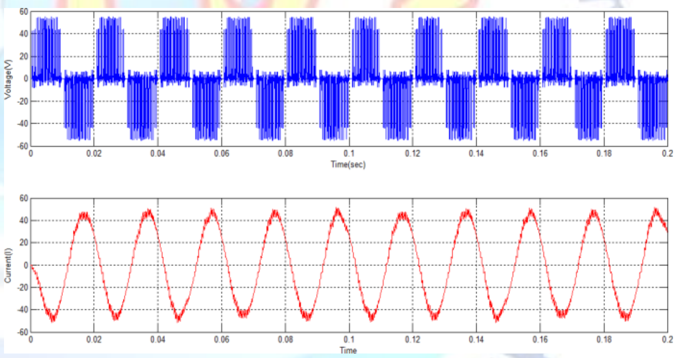

Figure 9: Output Voltage and Current Waveforms for Dc-Ac Mode

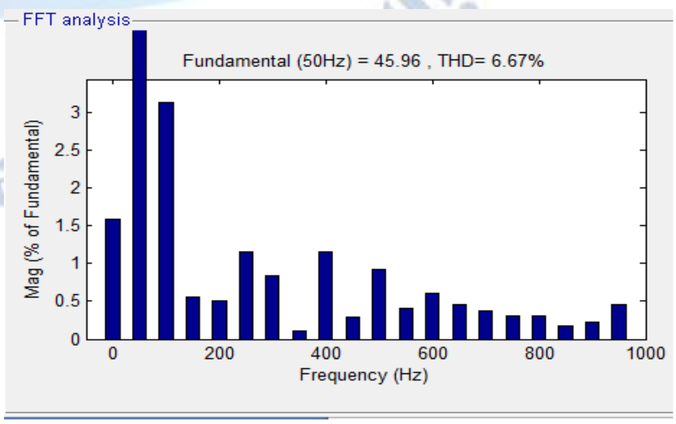

Figure 10: Thd Analysis of Output Current Waveform

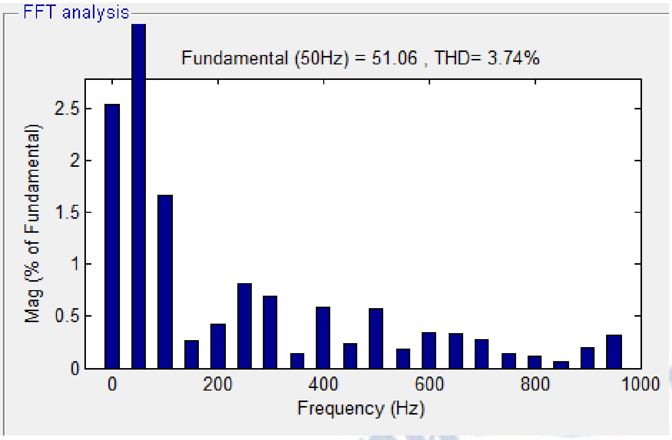

Figure 11: Thd for Output Current in Ac-Dc Mode

Table 1: RESULTS COMPARISION TABLE

S.no	MODES	PARAMETERS	PWM	Hysteresis Control
1.	AC-DC MODE	Output Voltage	54V	76V
2.	DC-AC MODE	Output Voltage	55V	62V
3.	DC-AC MODE	THD for Current	6.67%	3.74%
4.	BUCK MODE	Output Voltage	12V	26V
5.	BOOST MODE	Output Voltage	72V	140V

5. CONCLUSION

The rapid charging stations, particularly super-fast charging stations may stress power grid with probable overload during peaking time, unexpected power gap and voltage sag. In this the comprehensive modelling of a multi port converter based EV charging station integrated with DC power generating, and battery energy storage system has been built. The studies of the capabilities for Plug-in electric cars (PEVs) in Vehicle to Home (V2H) scenarios, for which the vehicle works as a domestic battery storage system and/or a backup generator during a grid outage or more frequent short duration distribution system problem has been done. Both the simulated and experimental data confirm PCMM's viability and prove it can achieve the design goal. This charger has been constructed utilising a simulation study using a Hysteresis Control PWM approach to confirm its functioning. In order to ensure that the suggested charger and an appropriate autonomous EMS can interact in a normal domestic context, simulated results are performed.

Conflict of interest statement

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

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