A PCS-based bi-directional battery charger for electric vehicles

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ABSTRACT

This study proposes a novel idea for a bi-directional battery charger for PHEV/EV with photovoltaic production system and battery charger system operation algorithm. The functions of solar power conversion and battery charging/discharging are built into a unique battery charger system. Additionally, four instances with different load situations are used to analyze the operation algorithms of the system while taking into account sensitive photovoltaic sources in relation to the environment, grid, and battery characteristics. It is also used to charge batteries using a hybrid constant current constant voltage control algorithm that combines the advantages of both constant current control and constant voltage control. For performance verification, informative simulation using PSIM and experimental results utilizing a 3.3kW lab-prototype set are presented.

Keyword *—**DC-DC Converters, Electric Vehicle, PI Controller, Renewable Energy**.*

1. INTRODUCTION

Battery chargers are one of the primary mechanical and electrical components of EVs and PHEVs that regulate the system's overall energy balance. On-board chargers for slow charging and off-board chargers for quick charging have both recently been created. Battery chargers have power ratings of approximately 50kW for off-board chargers and 3.3kW for on-board chargers. Therefore, if the utility grid is used to supply the charger's principal power, the existing grid's total power rating needs to be increased, and a number of safety and reliability issues need to be taken into account [1]. For this reason, renewable energy sources are viewed as an alternative to the utility grid's limited power capacity for EV and PHEV applications. among renewable energy As a result, the PFC circuit of the charger can be removed if PV PCS and a standard battery charger are used together, leaving only a bidirectional dc-dc converter connected to the PV PCS's dc-link capacitor bank. In this study, a novel idea for a PV PCS-based bidirectional battery charger for EV and PHEV is put forth. According to the PV power generation state and the load power demand condition, the proposed system can function in four different modes. Additionally, a hybrid constant current constant voltage charging/discharging algorithm is proposed in order to address the long charging time issue [5] . that is a drawback of both constant current control and constant voltage control. 3.3kW lab-prototype experimentation and informative simulation are conducted.

1.1. ANALYSIS OF THE PROPOSED BATTERY CHARGER

A. System Configuration

A PV generation system featuring a dc-dc converter for increasing PV array output, maximum power point tracking control (MPPT), and a dc-ac inverter for synchronising output ac voltage with grid voltage is shown in Fig. 1(a). The typical battery charger can be linked to the grid using this PV system and is shown in Fig. 1(b). The traditional battery charger, as depicted in Fig. 1(b), is made up of a boost converter for power factor correction and a dc-dc converter to charge the battery. The boost converter and dc-dc converter should be replaced by a PWM ac-dc converter and a bi-directional dc-dc converter if the battery power is discharged and provided to the grid.

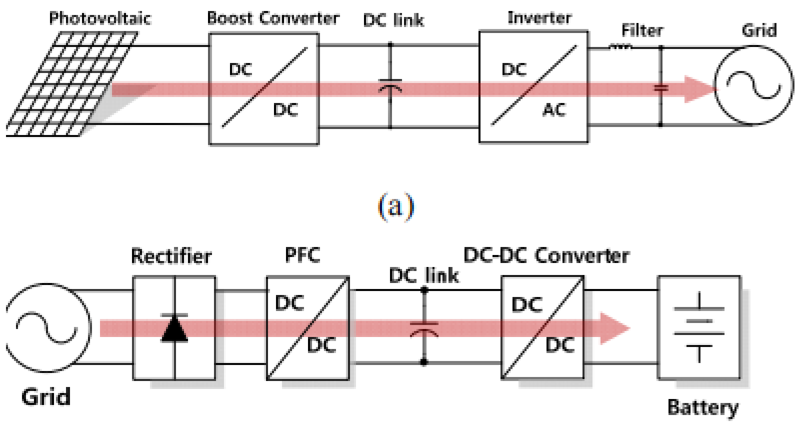

Fig. 1. (a) General PV generation systems and (b) conventional battery charger system.

These two power stages can be merged in the proposed battery charger system as depicted in Fig. 2, and only one bi-directional dc-dc converter is added to the PV PCS in parallel with the PV PCS's dc-link capacitor bank.

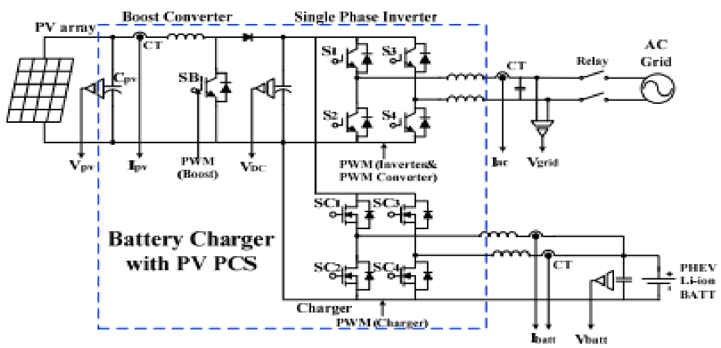

Fig. 2. Proposed battery charger using PV PCS.

1.2. Phase Interleaving Bi-directional Converter

The switching strategy for a bi-directional dc-dc converter is shown in Fig. 3. The switching method employs a two-phase interleaving mechanism with a 180° phase variation between each phase. The benefit of the interleaving technique could alter the ripple in the input and output currents based on the duty ratio [6]. Equation (1) illustrates the relationship between input current ripple and duty ratio. Similar to input current ripple, output current ripple also varies. o in on swing V T I N ND d L N (1)

where N is the phase number, T is the switching period, and _Non switch is the number of switches that are turned on throughout the time. According to duty ratio, the input current ripple varies in Fig. 4. In the case of two-phase, input current ripple is maximised at duty ratios of 0.25 and 0.75 while it is minimised at 0.5. As a result, at a 0.5 duty ratio, output current is also kept to a minimum in order to reduce battery charging current ripple and achieve this reduction at 0.35–0.65 duty ratio. As a result, we could reduce battery deterioration at certain duty ratios. Bidirectional dc-dc converter is regulated by current sharing algorithm to address the current imbalance.

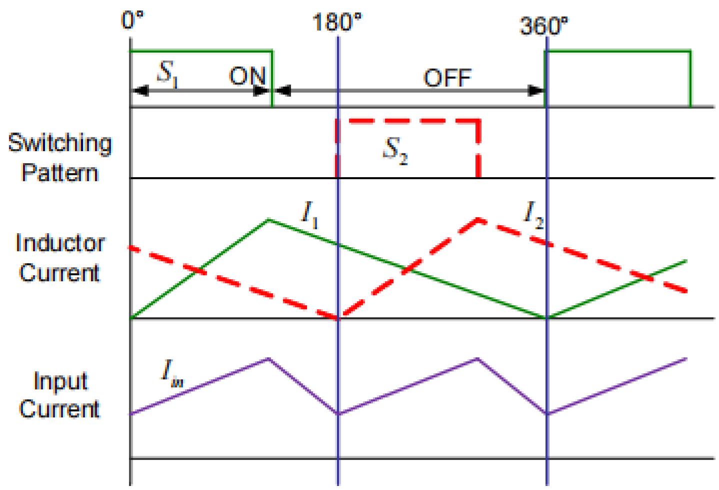

Fig. 3. 2-Phase interleaving technique.

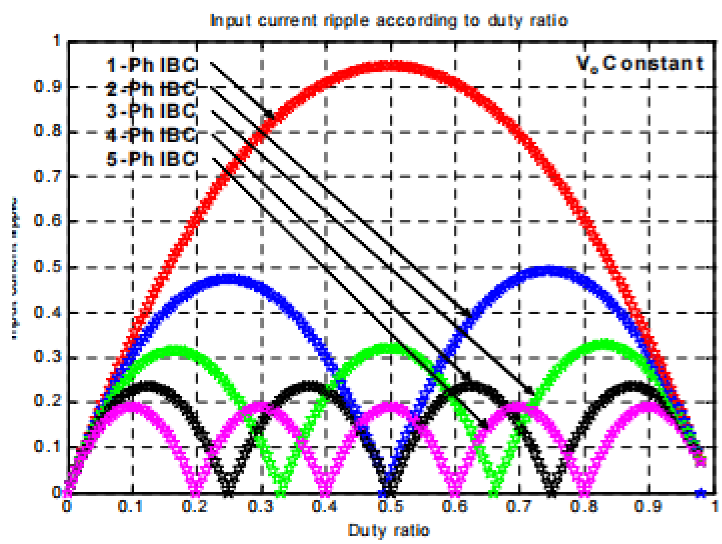

Fig. 4. Variation of input current ripple according to duty ratio.

2. Control algorithm and operation modes

In this paper, based on photovoltaic, dc link, battery and inverter power, operation mode and control algorithm is divided. Equation (2)~(5) shows the photovoltaic, inverter, battery charger and dc link power

$_{PV\,PV\,PV}PVI = \times(2)$

$_{INV\,INV\,INV}PVI = \times(3)$

(4) CH CH CH PVI

DC (5) DC DC PVI

Photovoltaic power is equal to dc link power in equation (6). In , the inverter power and battery charger power are added to create the dc link power. The multiplier inverter (grid voltage) and current are displayed by inverter power. Grid voltage is constant in equation (3), while grid current varies, affecting the inverter's power. The power of the battery charger fluctuates greatly depending on the charging current. Therefore, the power of the inverter and battery charger is what causes the power variation of the dc link. It is seen in by changing the dc link voltage. In other words, we may generate each current reference and sense the power variation in the dc link voltage.

PV DC P P=(6)

DC INV CH PPP = (7)

DC DC di V C= *dt*(8)

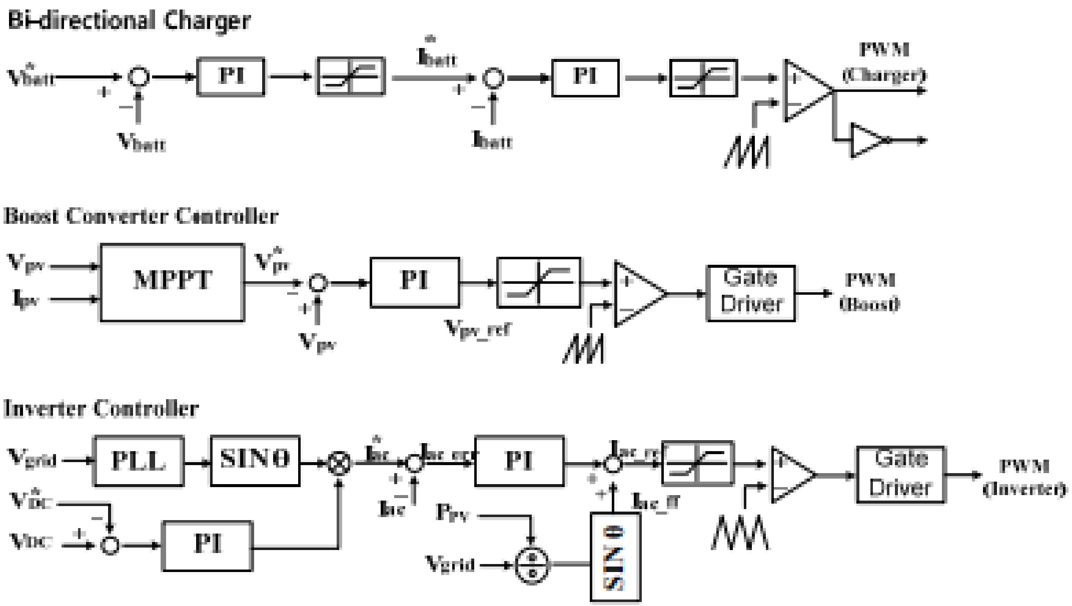

Fig. 5. System control block diagram.

The proposed block diagram for the system's control is shown in Fig. 5. The suggested method operates naturally in response to source and load conditions. Equations through depict the algorithm that could operate in PWM converter and organic inverter modes. Without changing the programme, this algorithm is run in two different modes.

DC err DC DC V VV (9) _
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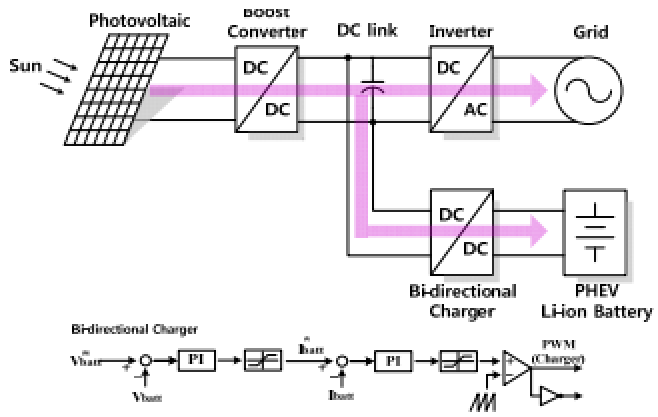
The operational modes of the proposed battery charger can be divided into four modes according to the source and load conditions as shown in Fig.



(a) Mode I

2.1 Operation Modes

Mode I
PV PCS produces the necessary ac voltage and feeds the electricity into the grid. PV electricity is used to provide the battery when it begins to charge on a low power level, and any extra PV power is sent to the grid. Mode I can say that solar power is more than battery charging power.

•Mode II
When the amount of power needed for the battery exceeds the amount of power generated by the PV system, all of the PV power is transferred to the battery, and the grid supplies the energy gap between the battery and PV systems. In this scenario, the grid power flow is negative and the dc-ac inverter's operating mode is changed to pwm ac SIN dc converter..

•Mode III

The bi-directional dc-dc converter is not used when the battery is fully charged; instead, just the PV PCS is used, transferring all of the PV's power to the grid. This style of operation for PV generation systems can be considered standard.

•Mode IV
All battery power is supplied from the grid when PV cannot generate electricity, such as at night, during periods of low radiation, and during inclement weather. Additionally, it is occasionally necessary to deplete the battery's power. In the charging mode, the bi-directional converter charges the battery while the dc-ac inverter operates as a PWM ac dc converter to obtain the dc-link voltage. However, in the case of discharging mode, power is sent to the grid via a bi-directional dc-dc converter and dc-ac inverter.

3. SIMULATION AND EXPERIMENTAL RESULTS

Fig. 7 shows the simulation platform and consists of power part and controller part.

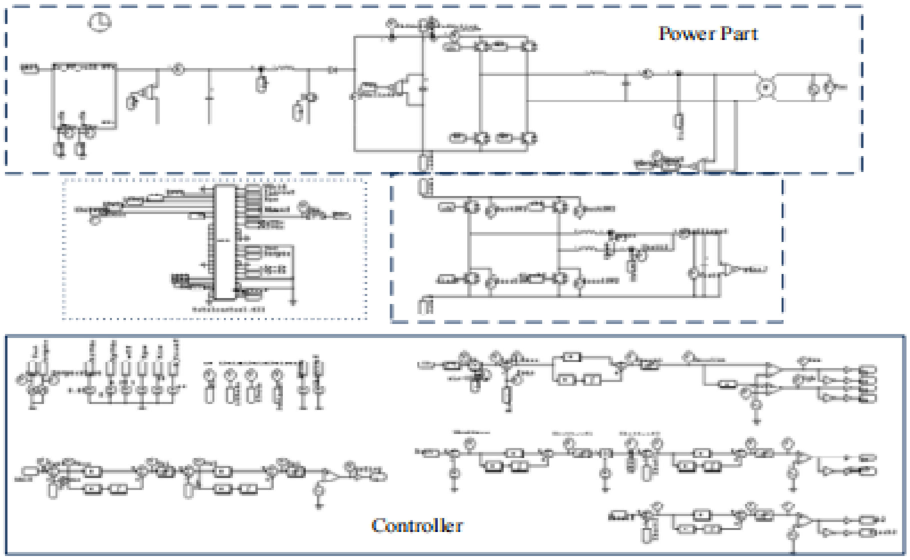
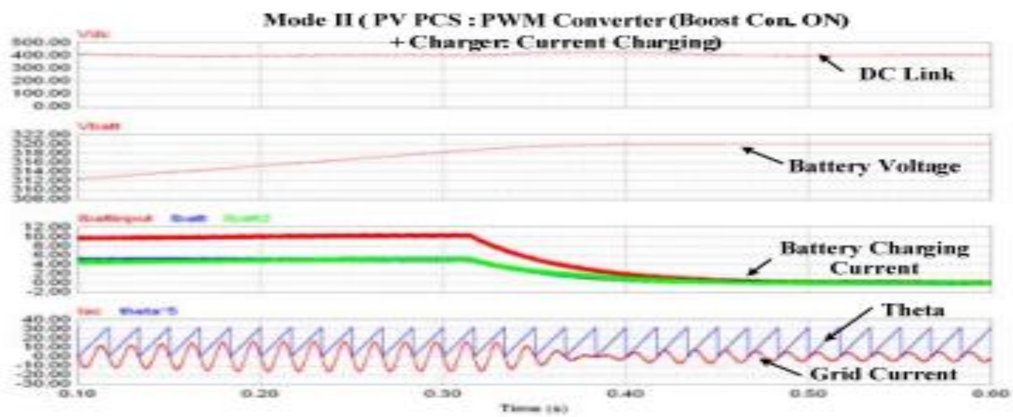
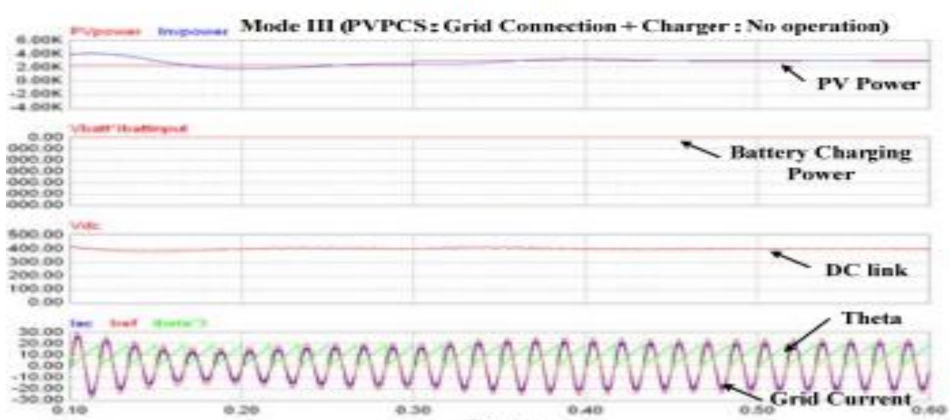


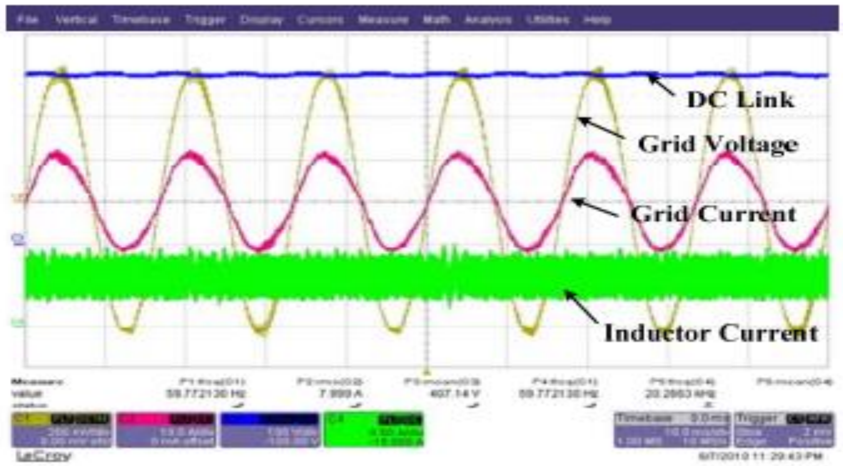
Fig. 7. Simulation platform.



(b) Mode II



(b) Mode II



4. CONCLUSION

An innovative idea for a bi-directional battery charger for PHEV/EV with a solar generation system and a battery charger system operation algorithm is put forth in this work. Four scenarios of the suggested methods are also thoroughly examined in terms of load and source characteristics. Battery chargers also employ the interleaving technique to lessen the ripple in the current used to charge batteries.

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