

USING A PV ARRAY, AN OFF-BOARD ELECTRIC VEHICLE BATTERY CHARGER

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ABSTRACT

The automobile industry has prospered as a result of the development of electric vehicles during the past 10 years (EV). The infrastructure for battery charging is crucial to the growth of EVs. When an EV battery is charged from the grid, it requires more load. This motivates the recommendation of an off-board photovoltaic (PV) array-based EV battery charging method in this study. Using a backup battery bank in addition to the PV array allows for the constant charging of the EV battery independent of solar radiation. The boost converter and a bidirectional DC-DC converter used in the suggested approach allow the EV battery to be charged in both sunny and cloudy conditions. The backup battery makes it easier to charge the EV battery during the hours when it isn't sunny and charges it simultaneously when it is sunny. The recommended charging system is simulated using Simulink in the MATLAB software, and the results are presented in this work.

Keyword : - Electric Vehicle, Charging Station, Fast Charging, Photovoltaic Array, DC-DC Converter.

1. INTRODUCTION

The environmental, scientific, and financial potential of EVs have inspired previously unimaginable levels of integration between the transportation and electrical power sectors. The primary connection between the two areas is the battery charge, which supplies the traction, control, lighting, and air conditioning systems for electric vehicles. However, using the electrical grid to charge the EV puts additional strain on the utility, particularly during periods of high demand.

The intermittent nature of the PV array necessitates the usage of power converters to recharge the EV battery. Multiport converters (MPCs) are preferred over other converters in the onboard chargers of hybrid EVs because they can connect power sources and energy storage elements like fuel cells, ultra capacitors, super capacitors, and PV arrays with the loads in EVs like motors, lights, power windows and doors, radios, amplifiers, and mobile phone chargers. The MPCs have the drawback of making the EV heavier, more expensive, and more difficult to maintain as all the sources are built into the EV itself.

Additionally, the complexity of controller implementation increases in these converter-based EV battery charging systems. Therefore, an off-board charger is recommended in this study, with the EV battery being placed inside the vehicle unit and the PV array and backup battery bank located in the charging station or parking station. A variety of converter topologies for off-board charging systems are presented in the literature.

Due to its ability to function in boost mode, the boost converter is the most widely used converter topology. Additionally present are the benefits of same input and output voltage polarity, minimal EMI, and low input current ripple. In order to recharge the electric vehicle battery when there is little sunlight and it is dark outside, an auxiliary storage battery bank is required. This backup battery bank needs to be charged in a forward direction and discharged in a backward way depending on the solar radiation. Therefore, a converter that is bidirectional and capable of power transmission in both directions is required.

Because of its advantages, such as higher efficiency in discontinuous conduction mode, low inductance value, and decreased ripple current as a result of multiphase interleaving technology, bidirectional DC-DC converter (BIDC) is a preferred non-isolated bidirectional converter topology. The snubber capacitor across the switches reduces turnoff losses and the inductor current parasitic ringing effect is further reduced by employing zero voltage resonant soft switching technique. [18–20] provides a list of the extra advantages of this bidirectional converter.

2. PROPOSED SYSTEM

The proposed PV-EV battery charger in Fig. 1 consists of a PV array, a boost converter, a bi-directional dc-dc converter, an EV battery, a backup battery bank, and a controller. To keep the output voltage at the dc link constant, the boost converter receives gate pulses from the controller. Gate pulses are also generated in order to operate the bidirectional dc-dc converter in boost mode, charging the backup battery from the PV array, and in buck mode, charging the EV battery from the backup battery. Additionally, the controller sends gate pulses to the auxiliary switches Sa, Sb, and Sc.

During periods of high solar radiation, all auxiliary switches are activated to interface dc links with the EV battery, dc links with the backup battery, and dc links with the PV array via boost converter and bi-directional dc-dc converter, respectively. When solar irradiation is low, Switch Sa is turned OFF to separate the PV array and boost converter from the dc link. Switch Sc is turned OFF to disconnect the bidirectional dc-dc converter and the backup battery from the dc connection when the solar power is insufficient to charge them. In this part, the proposed system's three operational modes—mode 1, mode 2, and mode 3—are explained.

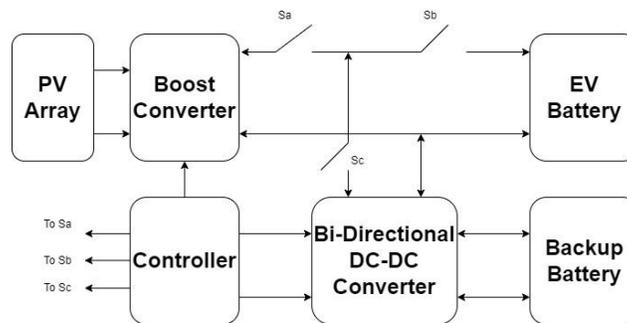


Figure 1: Block Diagram of the proposed system

Mode 1:

In order to charge the backup battery and the electric vehicle battery from the PV array at the same time utilizing boost converters and bi-directional dc-dc converters, respectively, all auxiliary switches are turned on during peak sunlight hours, when the PV array power generated is at its highest. The backup battery is charged in this mode by the bi-directional dc-dc converter, which increases the dc link voltage.

Mode 2:

Under low solar irradiation conditions and during the hours when it is not sunny, the output of a PV array is insufficient to charge an EV battery. Thus, when switches Sb and Sc are set ON to disconnect the PV array from the dc link, the bi-directional dc-dc converter links the EV battery to the backup battery. The bi-directional dc-dc converter steps down the backup battery voltage while it is in this mode to charge the electric car battery.

Mode 3:

When the electricity generated by the PV array is sufficient to charge solely the EV battery, switches Sa and Sb are switched ON and switch Sc is turned OFF to disconnect the bi-directional dc-dc converter and backup battery bank from the dc connection.

2. DESIGN OF THE CONVERTERS

Now, we are going to calculate the battery side parameters.

Specifications of the converter for battery side capacitors and inductors are:

$$V_{in} = 800 \text{ V}$$

$$V_{out} = 360 \text{ V}$$

$$f_{sw} = 5 \text{ kHz}$$

$$V_{ripple} = 0.36 \text{ V}$$

$$I_{ripple} = 3 \text{ A}$$

$$L = \frac{V_{out} * (V_{in} - V_{out})}{I_{ripple} * F_{sw} * V_{in}}$$

$$L = \frac{360 * (800 - 360)}{3 * 5000 * 800} = 13\text{mH}$$

$$C = \frac{I_{ripple}}{(8 * F_{sw} * V_{ripple})}$$

$$C = \frac{3}{8 * 5000 * 0.36} = 20\mu\text{F}$$

4. DESIGN OF CONTROLLERS

The proposed charger's controller is coupled to the boost converter, bi-directional dc-dc converter, and three auxiliary switches via gate pulses. The method that turns the auxiliary switches ON and OFF is shown in Fig. 2. if the power of the PV array exceeds the rated power of the EV battery, PR, power will be generated simultaneously from the PV array. If the PV array power is less than the rated power of the EV battery but greater than the minimum required power, the PM, switch Sc is turned OFF to disconnect the backup battery from the charging system, and switches Sa and Sb are switched ON to charge the EV battery solely from the PV array.

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In a bidirectional dc-dc converter, two switches are used. Gate pulses that are 180 degrees out of phase with one another must be received by the two switches in the. The controller in the suggested system generates two gate pulses for the bi-directional dc-dc converter, depending on the power of the PV array. If the PV array power exceeds the PR, gate pulses are generated to the BIDC switches to operate it in boost mode, raising the dc link voltage to charge the backup battery bank. If the PV array power is less than PM, the gate pulses are correctly generated to operate the bi-directional dc-dc converter in buck mode, producing a step down voltage at the dc link sufficient to charge the EV battery by the backup battery.

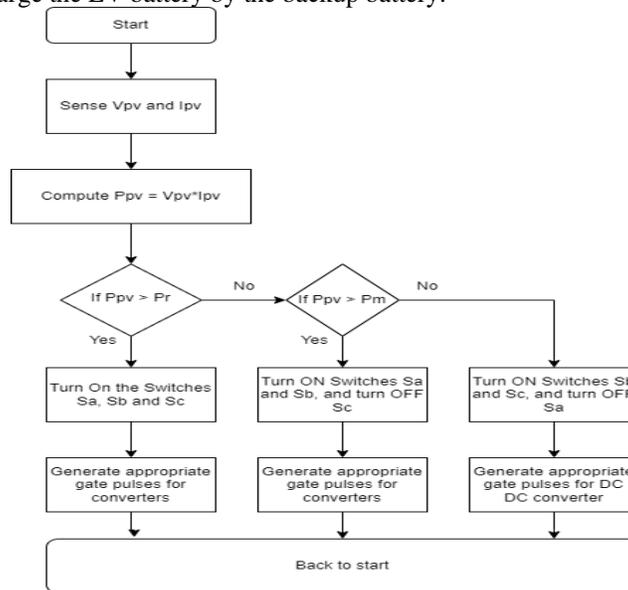


Figure 2: Flow chart of the control system

5. SIMULATION AND RESULTS

The MATLAB software's Simulink is used for the simulation investigations of the proposed system. It is modelled using the PV array's classical equation [21, 22]. The boost and bi-directional dc-dc converters are modeled using power MOSFETs, inductors, and capacitors from the SimPower Systems Blockset in the Simulink library. The controller is built using the PWM generator, pulse generator, logic gates, comparator, multiplier, and PI controller from the Simulink library. The battery models that are already included in the Simulink library are combined with the boost converter and bidirectional dc-dc converter that have been built in order to create the suggested charging system shown in Figure 3.

The dynamic response of the system was investigated using the developed simulation model for PV array irradiation of 1000, 750, and 100 W/m² in modes 1, 2, and 3, respectively. The simulation results are shown in Fig. 5-10, together with the gate pulses to the auxiliary switches and the voltage and current waveforms of the PV arrays. The waveform of the radiation is seen in Figure 4.

This method simultaneously charges the EV battery and the backup battery. As PV power is insufficient to charge the EV battery at low irradiation of 100 W/m², the gate pulses of the auxiliary switches V_b and V_c are strong, whereas the gate pulse of V_a is moderate. In this mode, the EV battery is charged while the backup battery bank is discharged via a dc-dc converter.

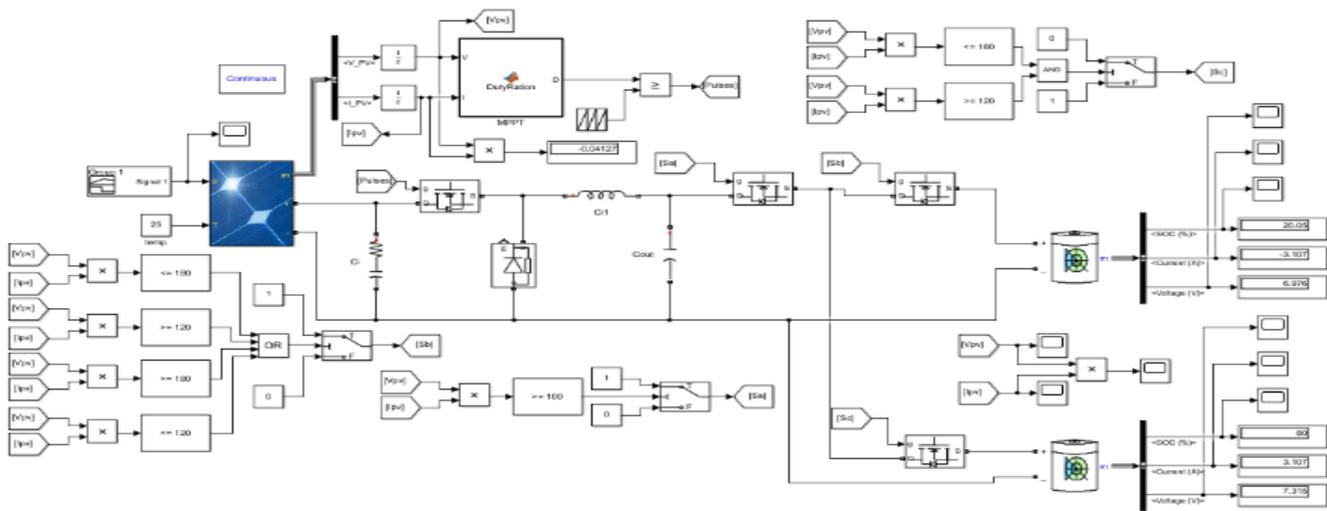


Figure 3: Mathematical Model of the simulated system

Using the created simulation model for PV array irradiation of 1000, 750, and 100 W/m² in modes 1, 2, and 3, respectively, the dynamic response of the system was explored. Fig. 5-10 depicts the simulation results, which illustrate the voltage and current waveforms of the PV arrays in addition to the gate pulses to the auxiliary switches. Figure 4 displays the radiation waveform. In this method, the EV battery and the backup battery are charged simultaneously. As PV power is insufficient to charge the EV battery at low irradiation of 100 W/m², the gate pulses of the auxiliary switches V_b and V_c are strong and the gate pulse of V_a is low. In order to charge the EV battery in this mode, the backup battery bank discharges using a dc-dc converter.

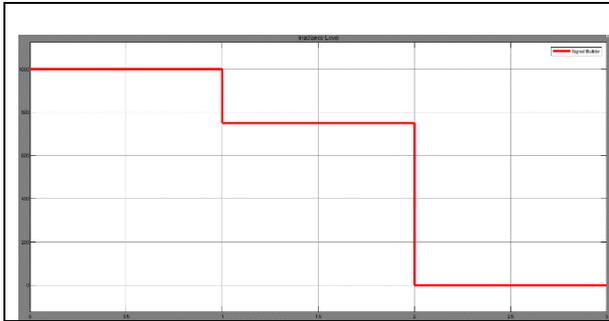


Figure 4: Irradiance level of PV array

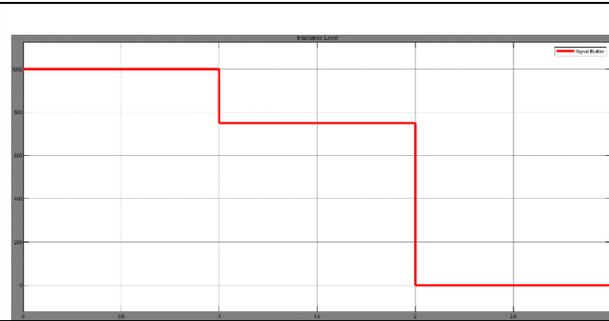


Figure 5: PV Current

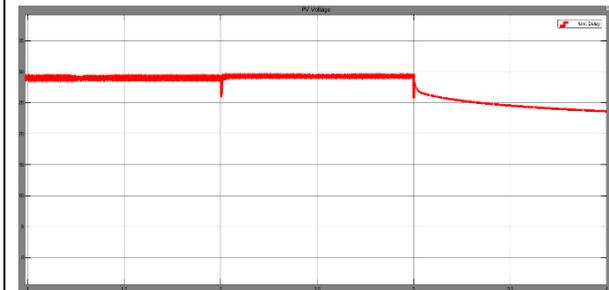


Figure 6: PV Voltage

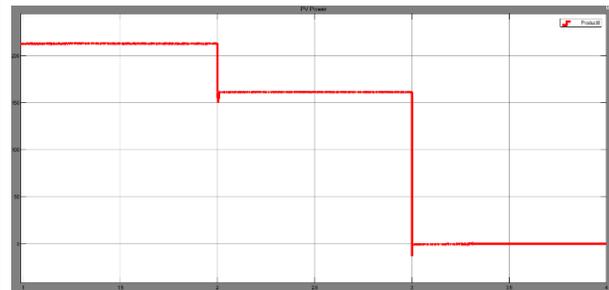


Figure 7: PV Power

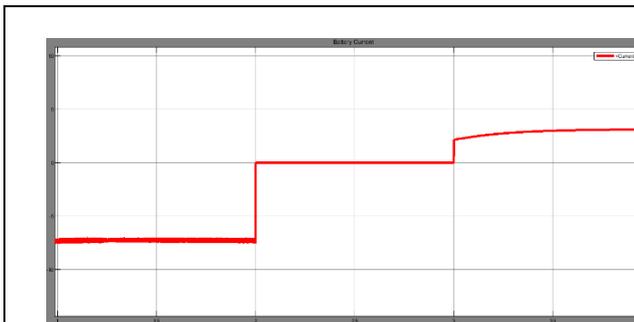


Figure 8: Current waveform for Backup Battery

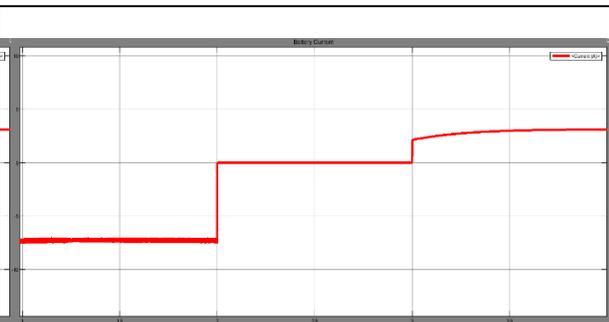


Figure 12: Voltage waveform for Backup Battery

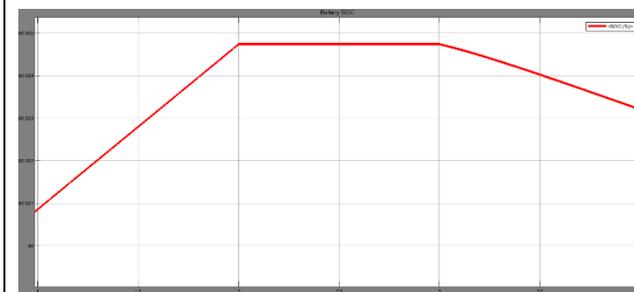


Figure 13: State of Charge for Backup Battery



Figure 14: Current waveform for EV Battery

6. CONCLUSION

In this work, a PV-powered off-board EV battery charging system is suggested. This study examines the system's adaptability to continuously charge the EV battery regardless of the irradiation circumstances. The Simulink environment of the MATLAB software is used to develop and simulate the system. The simulation's outcomes highlight the viability of the suggested charger.

VII. REFERENCE

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