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ELECTRIC VEHICLE SOLAR PV BATTERY CHARGER BASED ON SEPIC CONVERTER AND BIDIRECTIONAL CONVERTER (BIDC) WITH A FOPID CONTROLLER

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Abstract: The main objective of this research, which is explained in detail in the following article, is to develop a PV array battery charger for electric vehicles using a sepic converter and a bidirectional DC-DC converter with a Fractional Order PID (FOPID) controller. In this study, the battery charging process is examined in great detail, focusing on batteries and electric vehicles. An electric vehicle's battery may be recharged via the grid, although this increases the system's demand. This study proposes an off-board photovoltaic (PV) charging solution. A backup battery bank is utilised in combination with a solar array since the EV battery has to be charged at all times. A three-phase bidirectional DC–DC converter with a FOPID may be used to charge the EV battery utilising both solar and non-solar hours. As long as the sun isn't shining, both batteries may be charged. When it's not sunny, the backup battery charges the EV. MATLAB's Simulink is used to model the proposed charging procedure.

Keywords: Photovoltaic (PV), Battery, Electric Vehicle (EV), SEPIC converter, Bidirectional DC–DC converter, Fractional Order PID (FOPID)controller

I.INTRODUCTION

Carbon dioxide (CO2) and other greenhouse gases (GHG) are produced by traditional internal combustion engines (ICEs) (IC engines). As a consequence, electric vehicle sales are on the rise (EVs). Vehicles powered by electricity may have to use alternative energy sources, even if it is more convenient. RESs, which are abundant and pollution-free, may be used to recharge an electric vehicle's battery. Electric cars powered by renewable energy sources are referred to as "green mobility" (RES). Solar power, a potential renewable energy source, may simply be used to fuel the batteries of electric automobiles. The PV array may be used to charge an electric vehicle's battery using a variety of power converters. It is not uncommon to see lithium ion batteries in electric vehicles owing to their compact size and high energy density. To extend battery life, these batteries may benefit from their low self-discharge rate and rapid charging capabilities.

Explosion is unlikely, even if they're overloaded or shorted. Using these batteries for charging necessitates voltage management. Recharging an electric vehicle's battery involves the use of voltage controls and power electronic converters. Power converters are required to recharge the EV battery since the PV array is intermittent. When it comes to hybrid electric car on-board chargers, many power sources and energy storage components may be connected to a broad variety of electric vehicle loads, including radios and amplifier systems, mobile phone charging ports, and electric windows or doors. On the down side, MPCs add weight, cost and upkeep to your car since everything is contained inside them. The widespread use of converters in electric vehicle battery charging systems makes controller integration more difficult. According to the results of this research, EV batteries and backup power banks may now be kept at a charging station or parking lot utilizing a novel off-board charger. [14–16] Off-board charging systems may use a broad range of converter topologies. For this reason, the sepic converter is preferred over alternative converter topologies. Additional advantages include reduced electromagnetic interference (EMI) and low input current ripple... A few more instances of this may be found in [17 and 18]. When the sun isn't shining or irradiation is low, a backup storage battery bank keeps the electric vehicle's battery completely charged. Charging and discharging the battery bank should be done in accordance with how much solar power it generates. A converter is required because electricity may flow in either direction.

There are both non-isolated and isolated converters available for purchase. Isolated converters are more expensive, heavier, and bulkier because of the transformer's isolation. Non-isolated bidirectional converter topologies like this one are preferred over others because of the advantages in inductance and discontinuous conduction efficiency they provide. Ripple currents are also reduced by using the multiphase interleaving approach. [20]. Because parasitic ringing in inductor currents is reduced with resonant soft switching, switching losses are also minimized. Benefits of using a bidirectional converter are also available. A bidirectional DC–DC converter may be used to recharge the battery while the electric automobile is parked. To power the electric car's dc load, the battery must be drained. If feasible, it is best to recharge an electric vehicle's battery during the daytime. There will be no interruptions in charging with the use of a PV array, a sepic DC–DC converter, and a backup battery bank in one charger.

II.PROPOSED SYSTEM

An EV battery charger block schematic is depicted in the figure.1 below. An electric car battery and a backup battery bank as well as the controller are all schematically depicted in the picture.In order to run a SEPIC converter with a consistent dc link output voltage, a controller may be used. To charge the backup battery as well as the electric vehicle battery using the PV array's gate pulses, pulses for the BIDC switches' gate pulses are required. auxiliary switches Sa, Sb, and Sc receive gate pulses from the controller. All of the backup batteries, electric vehicle batteries, and PV array auxiliary switches are turned on in times of strong solar irradiation to provide a direct current connection. Sa must be turned off when solar radiation is low so that the PV array and sepic converter are not linked to the dc connection. When the backup battery cannot be charged by solar power, the BIDC and backup battery are unplugged from the dc power source. Modes 1 through 3 of the system's functioning will be covered in this section.

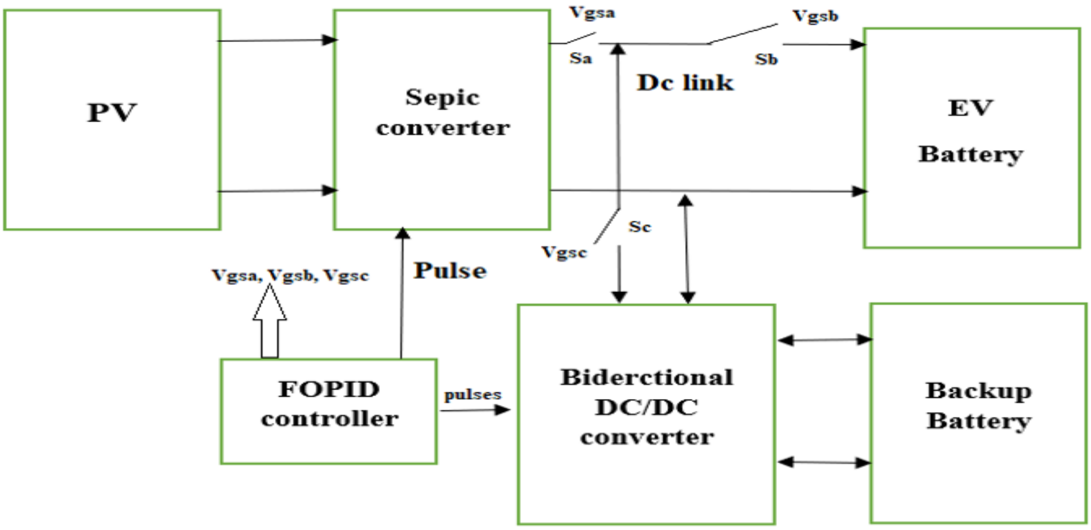

Fig.1 The proposed EV battery charger's block diagram

Mode 1

The EV battery and the backup PV array battery are both charged at the same time when all of the auxiliary switches are turned on during the hottest parts of the day. When the BIDC is charging the backup battery, it increases the voltage on the dc link, which in turn recharges the battery.

Mode 2

When the sun isn't shining or it's cloudy, PV array electricity is insufficient to recharge an electric vehicle's battery. Switch Sa is turned off and switches Sb and Sc are turned on, resulting in the loss of DC link between the PV array and backup battery. BIDC reverses its operation to lower the backup battery voltage to charge the EV battery.

Mode 3

All of the PV array's output powers Sa and Sb, while Sc shuts off when it's enough to charge the EV's battery entirely.

A)SEPIC CONVERTER

The duty ratio of the sepic converter is adjusted by the PI controller to maintain a constant output voltage regardless of the PV array voltage. Two capacitors and two inductors form the core of the sepic converter. Sepicconverters have the following benefits: Because it does not employ a buck-boost or cuk converter to invert the output voltage polarity, the voltage it produces has the same polarity as the voltage applied to it. Here is the formula for a sepic converter's voltage gain.

$$\frac{V_{\mathrm{dc}}}{V_{\mathrm{PV}}} = \frac{D}{1-D} \tag{1}$$

For this equation to work, you'll need these three variables: D, VPV, and Vdc (sepic converter duty ratio). The values of the inductors and capacitors used in the sepic converter are set in accordance with (2)–(4):

$$L_a = L_b = \frac{V_{\mathrm{PV_{min}}} D_{\mathrm{max}}}{2\Delta i_{\mathrm{PV}} f_{\mathrm{sw}}} \tag{2}$$

$$C_1 = \frac{I_{\mathrm{dc}} D_{\mathrm{max}}}{\Delta V_{C1} f_{\mathrm{sw}}} \tag{3}$$

$$C_2 = \frac{I_{\mathrm{dc}} D_{\mathrm{max}}}{\Delta V_{\mathrm{dc}} f_{\mathrm{sw}}} \tag{4}$$

There are four variables in this equation: voltage potential, current potential, and frequency of the switching waveform in the solar array (Idc).

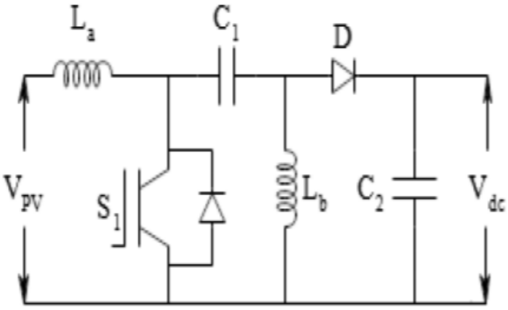

Fig. 2Sepic converter schematic diagram

voltage ripple of the capacitor C1, output voltage ripple of Vdc, and maximum duty ratio Dmax are all computed as follows: current, VC1, Vdc, and Dmax.

$$D_{\mathrm{max}} = \frac{V_{\mathrm{dc}} + V_D}{V_{\mathrm{PV_{min}}} + V_{\mathrm{dc}} + V_D} \tag{5}$$

where VD is voltage drop of the diode

B)INTERLEAVED DC–DC CONVERTER WITH BIDIRECTIONAL OPERATION

As seen schematically in Fig. 6.5, a BIDC is part of the proposed charging system. The converter is linked to a high-voltage battery bank through a low-voltage dc connection. When the converter is moving backwards, the boost mode is utilized, and the buck mode is used when it is moving forward. When in boost mode, the three switches SL1, SL2, SL3 are all active, whereas the three switches are all active when in buck mode. Snubber capacitors and diodes guard the converter's switches. Inductors L1 through L3 utilize a low-pass filter, whereas inductors L4 through L7 use a boost inductor. CL and CH capacitors serve as energy buffers in this converter. Current ripple is reduced by using interleaved inductors. [20] demonstrates how a single-leg converter works. (6) and (7) represent the voltage conversion ratios of the BIDC while in buck mode (7)

$$\frac{V_{\text{BackupBatt}}}{V_{\text{dc}}} = \frac{1}{1 - D_{\text{Boost}}} \tag{6}$$

$$\frac{V_{\text{dc}}}{V_{\text{BackupBatt}}} = D_{\text{Buck}} \tag{7}$$

Voltage backup battery, BIDC boost mode duty ratio, and BIDC buck mode duty ratio are all referred to as VBackupBatt. The inductance values of the inductors are less when the converter is operating in discontinuous conduction mode to improve efficiency.

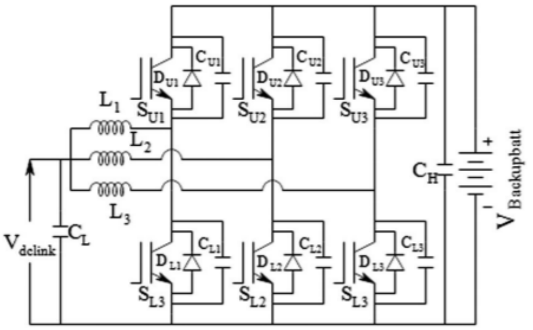

Fig. 3Diagram of a half-bridge BIDC circuit

Equations (8) and (9) can be used to determine the critical inductance in the boost and buck modes (9).

$$L_{\text{cric}} = \frac{3V_{\text{BackupBatt}}^{2} D_{\text{Boost}} (1 - D_{\text{Boost}})^{2}}{2Pf_{s}} \tag{8}$$

$$L_{\text{cric}} = \frac{3V_{\text{dc}}^{2} (1 - D_{\text{Buck}})}{2Pf_{s}} \tag{9}$$

where P denotes the backup battery's power.The low and high voltage side BIDC capacitor values are calculated using the calculations below

$$C_{H} = \frac{D_{\text{Boost}} P}{2 f_{s} V_{\text{BackupBatt}}^{2}} \tag{10}$$

$$C_{L} = \frac{V_{\text{BackupBatt}} D_{\text{Buck}} (1 - D_{\text{Buck}})}{8 f_{s}^{2} L \Delta V_{\text{dc}}} \tag{11}$$

C)DESIGN OF CONTROLLER

Three more switches, BIDC and sepic converter, receive gate pulses from controller of proposed charger. Fig. 4 depicts the procedure for turning on and off the auxiliary switches.

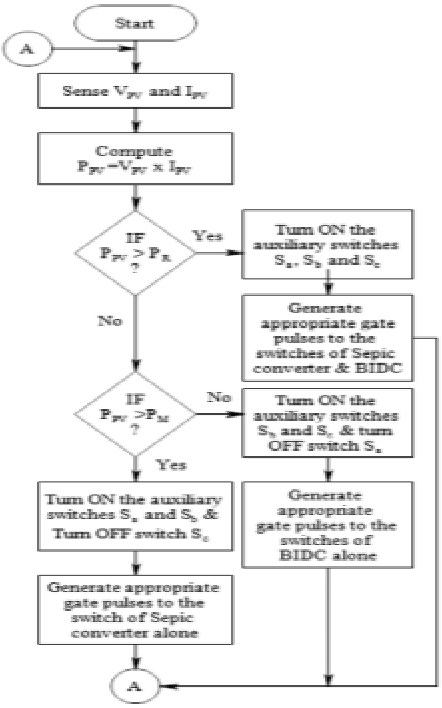

Fig.4Diagram illustrating the procedure for generating gate pulses for auxiliary switches

III. PROPOSED CONTROL ALGORITHM

Voltage and current measurements may be used to determine the output of a PV array. If all other switches can be switched on, the batteries in an electric automobile and a battery backup bank may be charged at the same time. For battery charging, Sa and Sb are used when the PV array power is less than the battery capacity, but greater than the minimum needed power. To prevent overcharging, a switch is triggered when the PV array's power dips below PM. The electric vehicle's backup battery can now be charged thanks to the activation of Sc and Sb. The sepic converter's dc connection can be controlled with a FOPID controller to maintain a consistent voltage. There are two switches per leg of the BIDC. The gate pulses transmitted to the two switches on a single leg must have a 180-degree phase difference.

FOPID CONTROLLER

Industrial control systems often use a universal feedback control loop method. When a consistency process variable deviates from its intended set point, the PID controller develops and executes corrective actions. The following diagram depicts the transfer function of an integer-order PID controller.

$$G_c(S) = K_p + K_s s^{-1} + K_d s \tag{12}$$

Integral and derivative time constants (Ki and Kii) are two PID controller time constants (Kd). The PID algorithm is built on these three variables. One way the Integral affects a mistake's reaction is by keeping track of the number of recent errors and how quickly they change. An device like a control valve or warming element may be utilized to guide the process when these three processes are combined. Closed-loop control utilizing a PID controller can be seen in Figure.6.

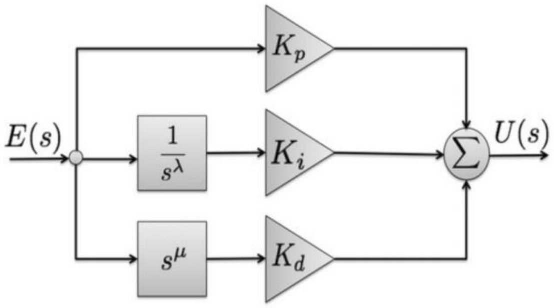

Fig. 5A closed-loop process control system based on a FOPID controller.

IV. SIMULATION RESULTS

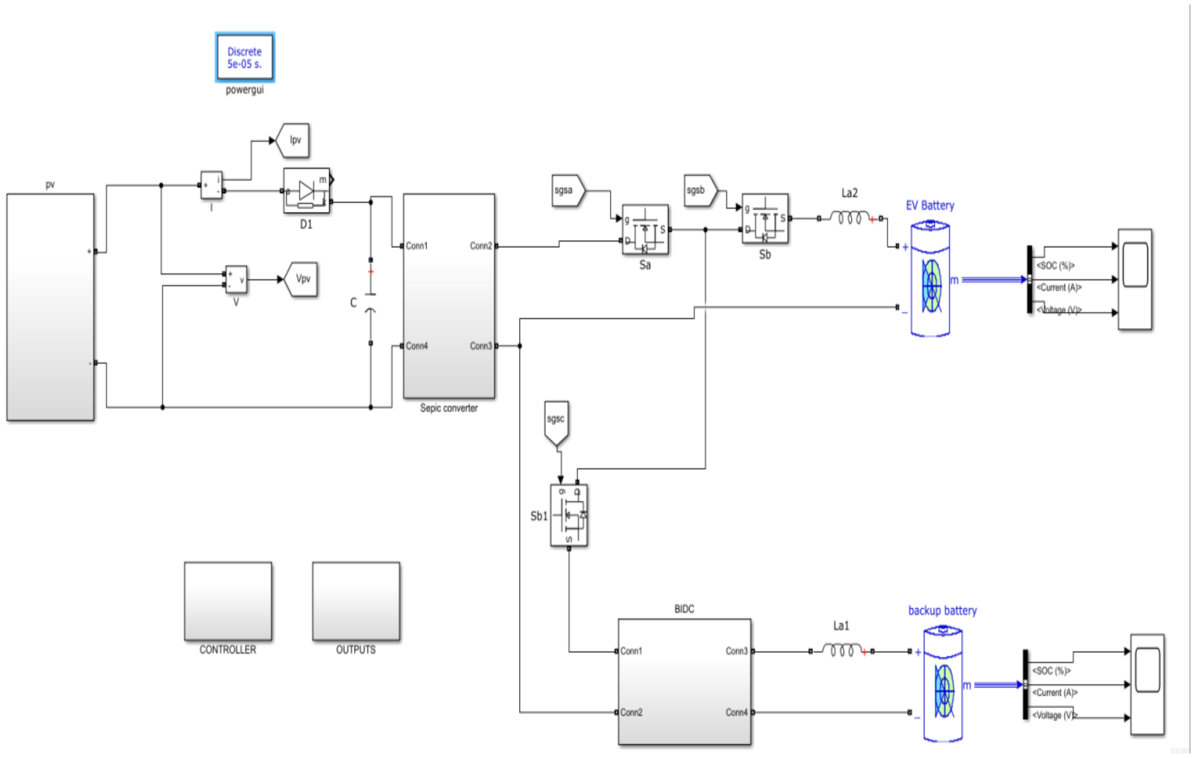

Fig.6 MATLAB/SIMULINK circuit diagram of the proposed charger

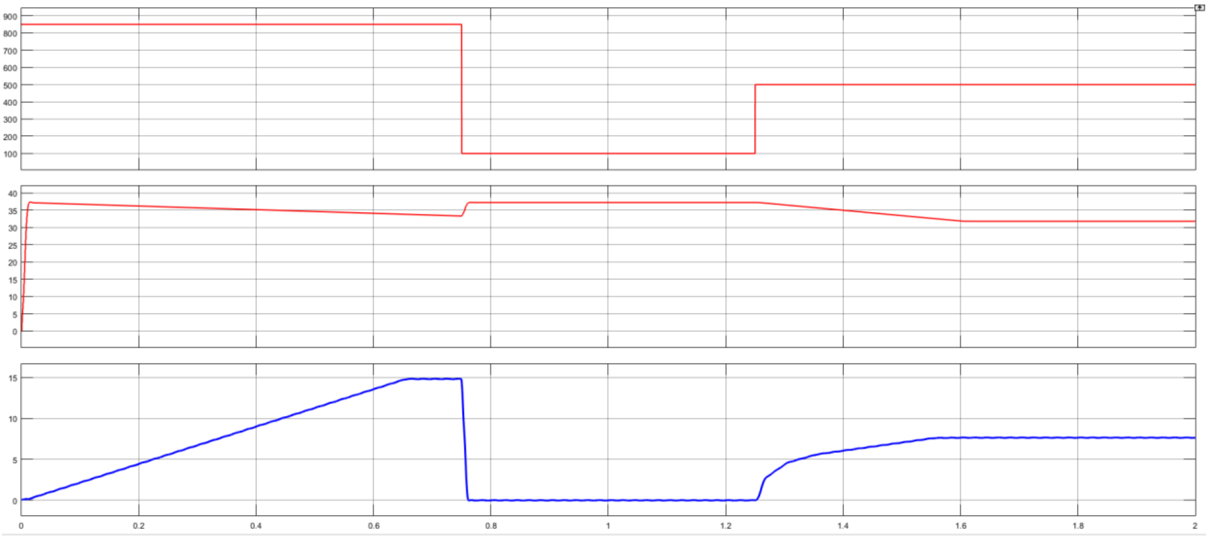

Fig 7 Irradiance, PV array voltage and currenr

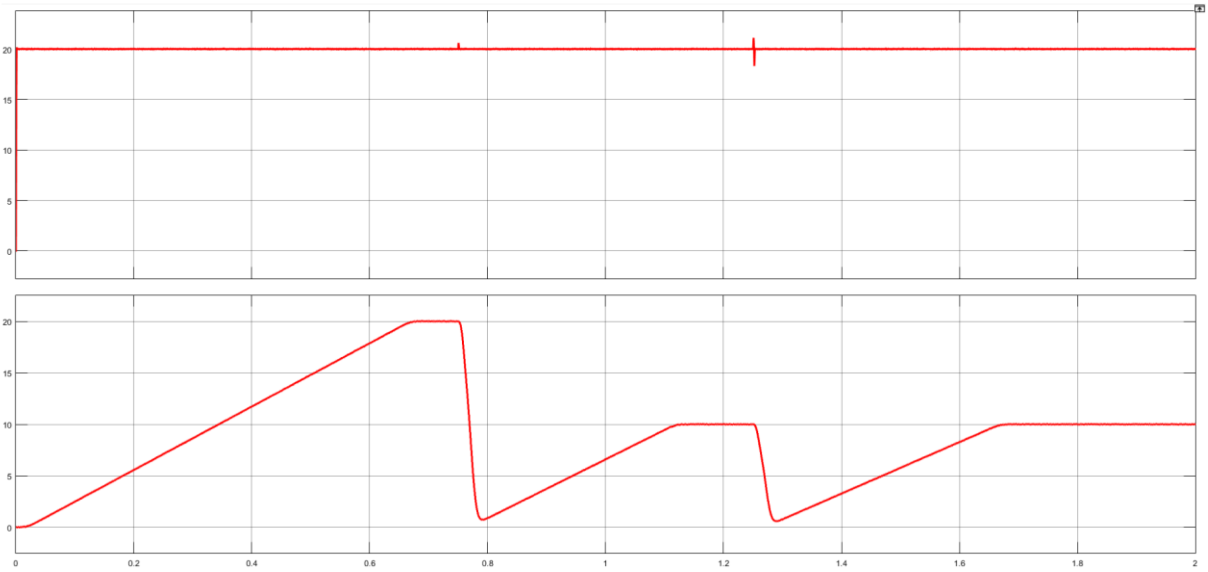

Fig .8Voltage and current of DC link (Existing)

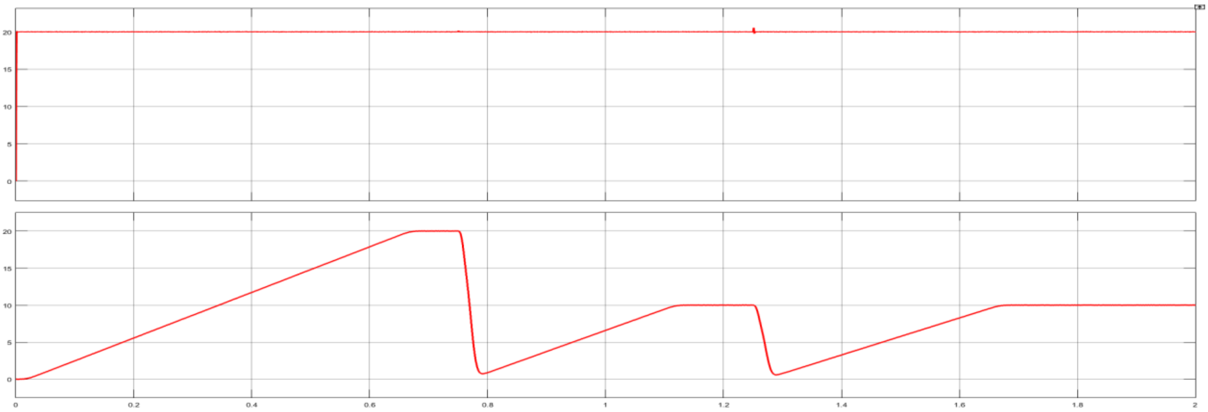

Fig.9Voltage and current of DC link (Extension)

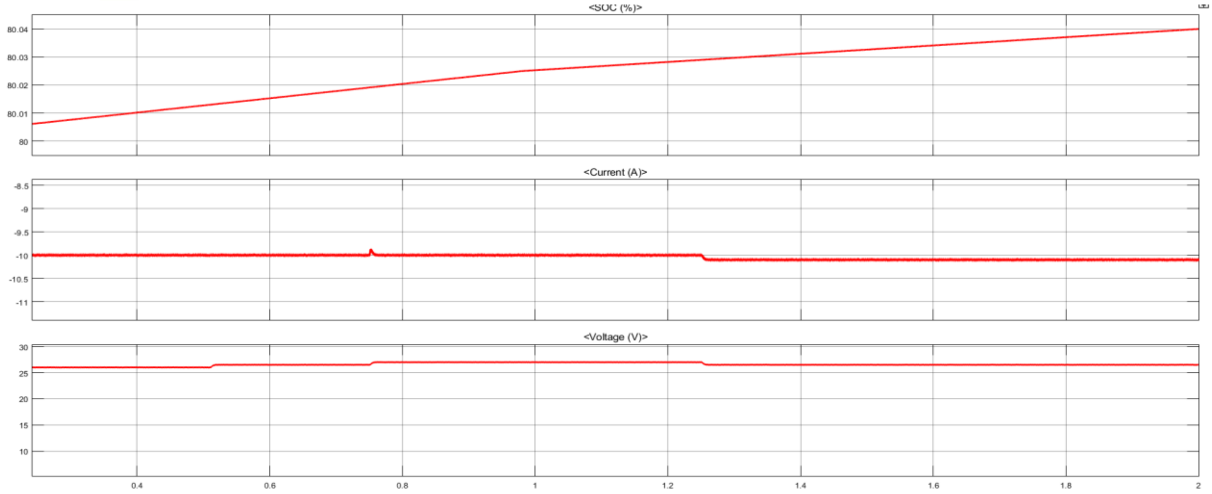

Fig.10State of Charge, Voltage and Current of EV Battery (Existing)

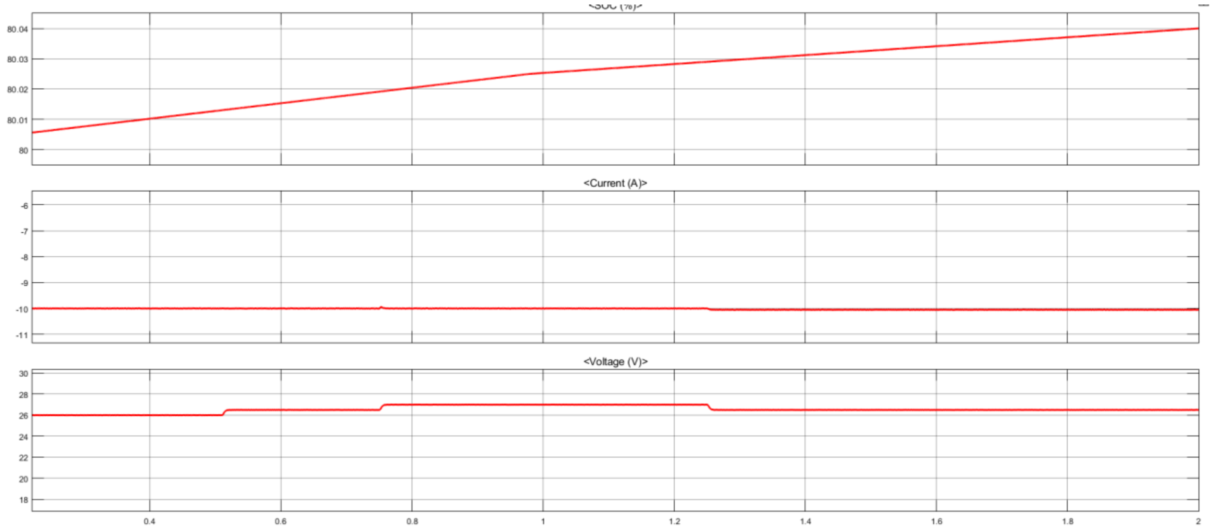

Fig.11State of Charge, Voltage and Current of Backup Battery (Extension)

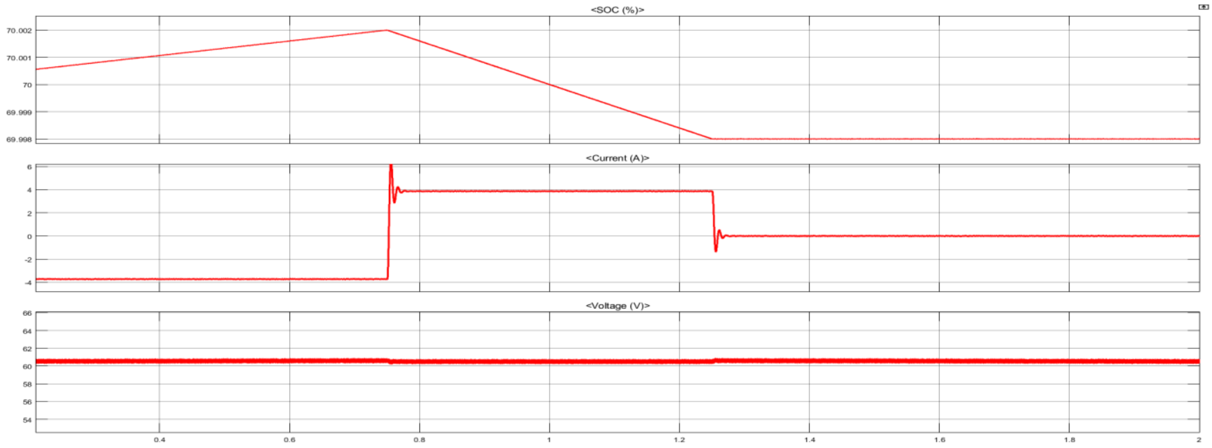

Fig.12State of Charge, Voltage and Current of EV Battery (Existing)

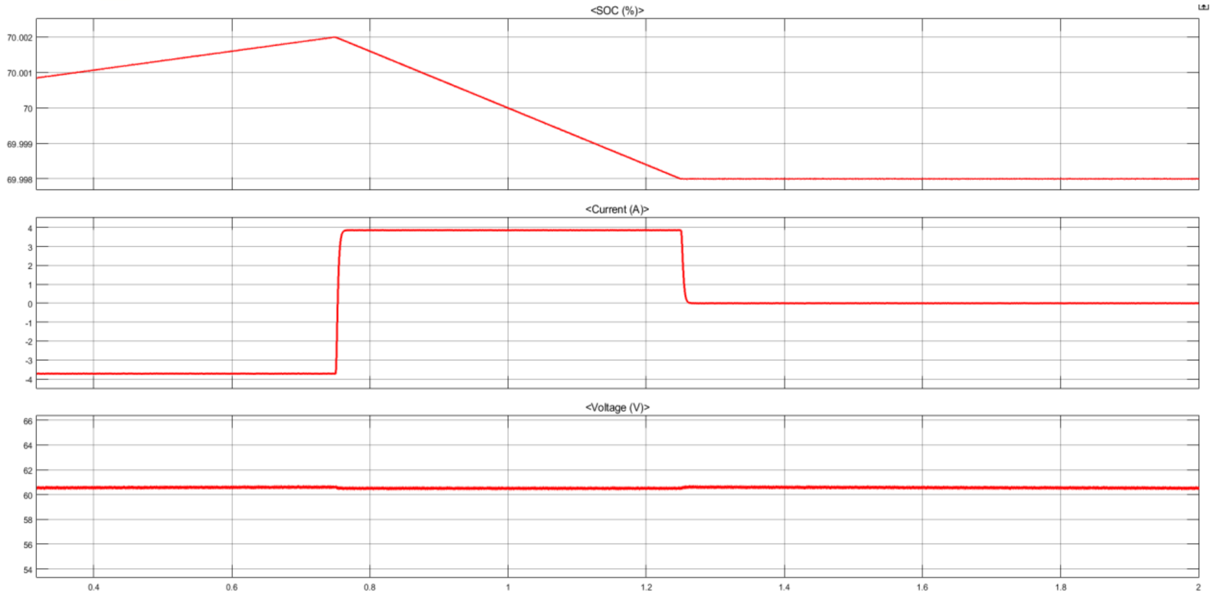

Fig.13State of Charge, Voltage and Current of Backup Battery (Extension)

CONCLUSION

Using a sepic converter and a bidirectional DC-DC converter with a FOPID controller, a battery charger for an electric vehicle is presented. This article examines the system's adaptability to continuously charge the EV battery no matter what the irradiation circumstances are. MATLAB's Simulink platform is used to develop and simulate the system. The suggested charging system's three modes of operation are examined and compared to current findings. The ripples are reduced by replacing the PI controller with a FOPID controller in the expansion.

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