Solar Powered Electric Vehicle Battery Charger With Battery Backup

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Abstract:
Over the past few years, the development of electric vehicles (EVs) has driven the growth of the automotive industry. Battery charging mechanisms are very important for the advancement of electric vehicles. However, charging the EV battery from the grid increases the demand on the system, ultimately increasing the cost of electricity for EV owners and requiring the use of alternative energy. Renewable energy sources (RES) can be used to charge electric vehicle batteries because they are unlimited and do not pollute the environment. Solar photovoltaics are an easy-to-use renewable energy source with promising potential for powering electric vehicle batteries. If solar photovoltaics are used in conjunction with a DC-DC converter, a backup battery, and a three-phase bidirectional converter, the EV battery will be continuously charged even when the sun is not shining. Therefore, in this study, a solar photovoltaic array with a high-efficiency SEPIC dc-dc converter and a widely used lithium-ion battery was selected. The plan has the ability to charge electric vehicle batteries in any weather conditions.

I. Introduction:
In today's world, cities and towns are growing all over the world, the demand for automobiles is increasing every year, and the demand for automobiles is increasing in every aspect of life. So we hope to find a way to solve this problem, which is necessary and beneficial, and charging the electric battery from electric power when the electric car can contribute will eliminate and end the need for the electric grid. The increasing cost of electricity for electric car users necessitates the use of all other energy sources. There are actually renewable energy sources (RES) that can be used as alternative energy sources to charge energy storage. Solar energy is the most efficient and rapidly growing form of renewable energy.

Since photovoltaic arrays are not the same, the energy converter must charge the electric car battery. Multiport converters are good for onboard hybrid electric vehicle battery chargers because they can be connected to the mains power supply and energy storage such as photovoltaic arrays. Electric vehicle charging system requires DC/DC bidirectional conversion, which is crucial for reliable operation and efficient distribution during the period when there is no sunlight. The unidirectional DC/DC converter is the parent of the bidirectional DC/DC converter, which allows power to be converted in both directions. But another DC/DC converter (usually an amplifier) is needed to convert the power. Solar photovoltaic power is converted into a constant DC output used to charge the electric vehicle battery

Sepic converter is the most commonly used converter scheme as it can operate in both stepdown and stepup modes. In the case of conventional SEPIC converters, the input voltage stabilizes as the output voltage fluctuates from high output voltage to low output voltage. The stepdown booster is similar to the generator and has the advantage of not having a reverse voltage. The duty cycle of the switch is also used to control the output voltage. They have two inductors and switching voltage connected together. To convert one voltage to another, the sepic converter transfers energy between a capacitor and an inductor. Switches are usually MOSFET like transistors that help control the amount of power s witched.

Unlike bipolar junction transistors (BJTs), which are controlled by current difference rather than volt age, MOSFETs now switch based on voltage difference, so there are no adverse effects. A second battery is needed to charge the electric car's battery when the sun is not shining or there is not enough s unlight outside. This spare BB needs to go out for different charging depending on solar energy. A bi directional converter is needed to send power in both directions. Bidirectional DC/DC generator has wide application and many researches, and reduces the weight and volume of power equipment. Bidirectional interleaved DC/DC converters (BIDC) have been adopted among different nonisolated bidirectional converter topologies due to their advantages such as higher efficiency and lower current. Lithiumion batteries make them the choice for electric vehicles. In addition, these batteries can be charged quickly and can work for a long time. There is also less risk of breakage when overcharged or short circuited. Therefore, it is used to charge electric car batteries when there is no sunlight.

According to the above, in the current study on electric vehicle battery charging, SEPIC converters are installed using nonelectric devices from solar energy and battery backup for more power. EV batteries are charged during the day using a solar panel with the help of a SEPIC converter. Additionally, the backup battery (BB) is charged using BIDC when there is no sunlight.

The proposed methodology operates in three different modes:

a) Mode-I: Initially, both EV battery and the battery bank (BB) are being charged by the solar panel during sunny hours.

b) Mode-II: Secondly, the EV battery is only charged by PV and the BB will disconnect from solar charging system during less sunny hours.

c) Mode-III: The EV battery is charged by BB and BIDC where, solar PV is disconnected from the source during low sunny hours.

II.Proposed work:

According to Figure 1, the proposed EV charging station consists of a solar panel, a SEPIC converter, a battery pack (BB) such as an EV battery, and various accessories. The SEPIC converter receives gate pulses from the controller to have a stable output of 24V. Additionally, the BIDC switching pulses are designed to drive the BIDC in stepup and stepdown modes to charge the BB and EV batteries respectively. Similarly the controller generates pulses for R1, R2 and R3. For boost mode, the 24V DC bus voltage is increased to 64V (voltage on the BB) and for discharge mode, 64V is decreased to 24V to charge the EV battery. During peak solar energy, all switches are on for DC link to E V battery, DC link to BB of BIDC and DC link to PV array. When solar energy is average, switch R 3 is open to cut off BIDC and BB from charging the EV battery. During low solar power, switch R1 is open, isolating the PV and switching the SEPIC converter from the DC link. However, EV batteries are covered by BB and BIDC.

III. Design of proposed system:

A. Solar PV system:

The use of solar photovoltaics has increase significantly since the last decade. Among nonrenewable energy sources, solar energy is the most widely used and efficient energy source in the environment. Using the sun, direct electricity is produced that can be used for many purposes. The solar generator is easy to install and is sturdy and stable. As the output power increases, more photovoltaic cells are connected in series, forming a photovoltaic module. Manufactured in standard photovoltaic module sizes including 36cell, 60cell and 72cell modules. The system consisting of several photovoltaic mod ules is called a photovoltaic array. Using one or more circuits connected to the junction box, they can be connected together to create a single DC output. Table 1 gives the characteristics of solar photo voltaic parameters.

Input Irradiance	1000W/M^2,600 W/M^2,200 W/M^2
Input Temperature	25□C
Modules in Parallel	2
Modules in Series	4
Maximum Power	2000W
Open Circuit Voltage (V_{oc})	40V
Cells per Module	60
Short Circuit Current (I_{sc})	8.75A
Maximum Power Point Current (I_{mp})	8A
Maximum Power Point Voltage (V_{mp})	33V

Table 1. Parameters of Solar Cell

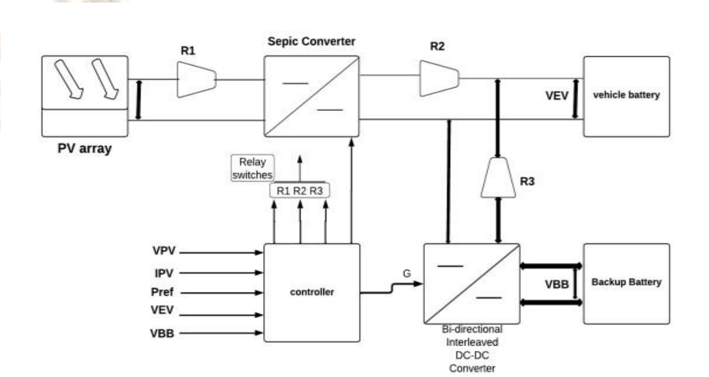


Figure 1.Block Diagram of proposed model

B. Design of converter:

Due to the continuous nature of the photovoltaic array, the DC/DC converter can provide constant output power regardless of the input power to charge the EV battery. As stated in the literature, sepic converters are best to get the best performance from solar photovoltaics.

1)Sepic converter:

Regardless of solar power, the SEPIC converter can maintain the same output voltage on charging demand by using a MPPT controller to adjust its duty cycle.This converter has 1 MOSFET, 1 diode, 3 capacitors and 2 inductors as shown in Figure 2. SEPIC converters have two main advantages over buck-boost and cuk converters:

a) Depending on the duty cycle, the converter will operate in both boost and buck mode.

b) It also provides similar voltage input and output

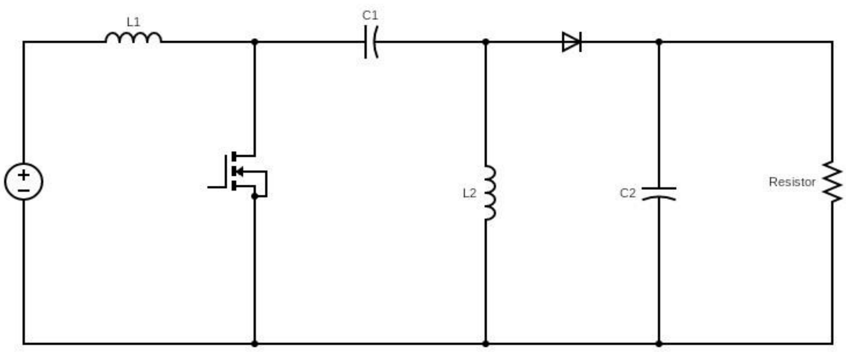


Figure 2.Sepic Converter

PARAMETER	VALUES
Duty cycle (D)	0.15
Inductance(L1)	$453\mu H$
Inductance(L2)	$823\ \mu H$
Capacitance(C1)	$199\ \mu F$
Capacitance(C2)	11mF
Output Voltage (Vo)	24
Fs	5000

Table 2. Parameters of Sepic Converter

The following formula gives the Duty cycle of Sepic converter:

$$D = \frac{Vdc}{Vin+V0}$$

Where, V_{dc}= dc - junction voltage, V_{in} = photovoltaic array Voltage, D = converter duty cycle. Inductor and capacitor values are shown below.

1.Inductance

$$L_1 = \frac{V_{dc} * D}{\triangle I_{l1} * Fs}$$

2.Inductance

$$L_2 = \frac{V_{dc} * D}{\triangle I_{l2} * Fs}$$

3.Capacitance

$$C_1 = \frac{D}{R*\left(\frac{\Delta Vc1}{Vo}\right)*Fs}$$

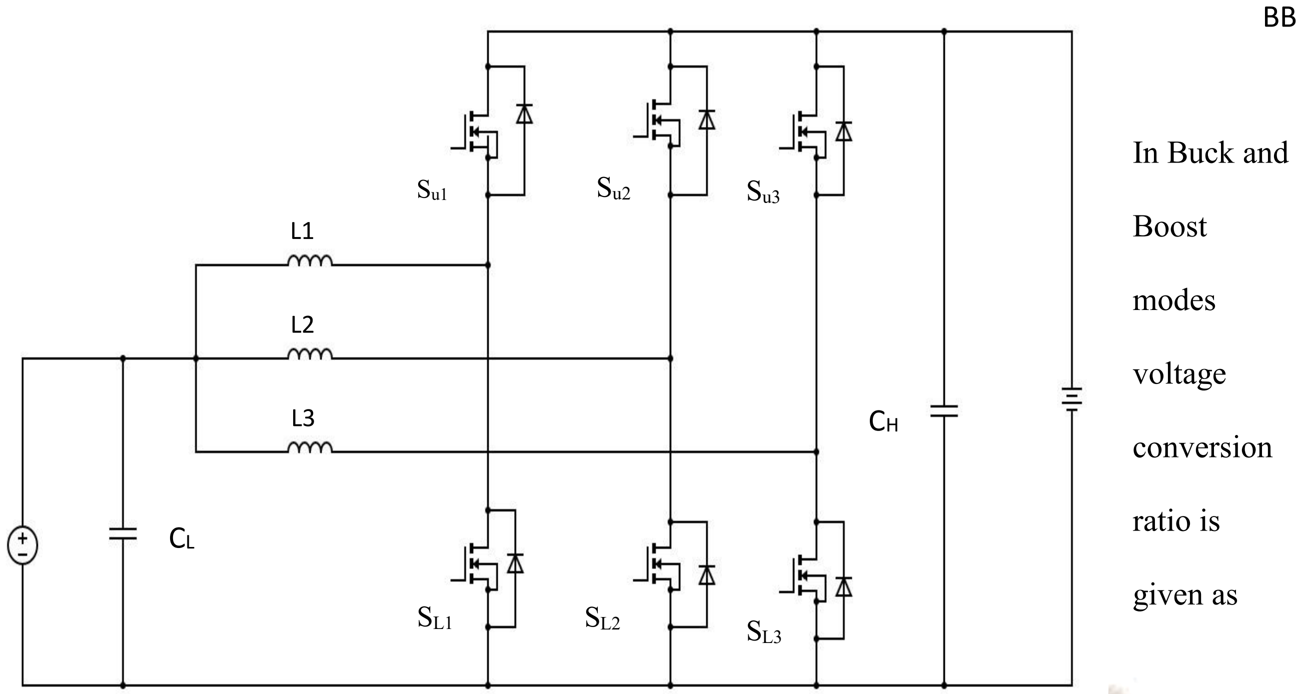
4.Capacitance

$$C_2 = \frac{D}{R*\left(\frac{\Delta Vc2}{Vo}\right)*Fs}$$

2) Bidirectional Interleaved DC-DC Converter:

Fig. 3 displays the graphic illustration of the BIDC employed in the suggested charging method. The backup BB is connected on the high voltage side of the converters, while the dc bus is installed on its low voltage side. Both boost and buck modes are used by this converter whether moving forward or backward. Switches S_{U1}, S_{U2}, and S_{U3} are functional in buck mode, whereas switches S_{L1}, S_{L2}, and S_{L3} are functional in boost mode.

The L1, L2, and L3 inductors serve as boost inductors. these are also function as low-pass filters in buck mode but as boost inductors in boost mode. Capacitors (C_L) and (C_H) serve as the converter's smoothing energy buffers. Current ripples are reduced by interleaving inductor currents. By taking into account the functioning of a single leg converter as described in the literature, the converter’s modes of operation are examined.



In Buck and Boost modes voltage conversion ratio is given as

Figure 3.Interleaved Bi-directional dc-dc converter

1. $D_{buck} = \frac{Vpv}{Vbatt}$

2. $D_{Boost} = 1 - \frac{Vpv}{Vbatt}$

3. Inductance $L_{min} = \frac{Vinmin*Dmax}{Iripple*Fs}$

4.capacitor $C_H = \frac{Dboost*Po}{2*Fs*(Vbb)^2}$

5. Capacitor $C_L = \frac{VBB*Dbuck(1-Dbuck)}{8*Fs^2*L*\Delta Vdc}$

Parameters	**Values**
D_{buck}	0.375
D_{boost}	0.625
L_{min}	150 μH
C_H	5 μF
C_L	25 μF
F_s	25000

Table 3. Parameters of Interleaved Bi-directional dc-dc converter

3) EV Battery and Backup Battery:

EV Battery with a rating of 24V,35Ah and for backup battery 64V,100Ah

IV. Controller in the proposed charger:

The suggested charger's controller creates gate pulses that are routed to the switches included inside the

a) Sepic converter
b) BIDC and
c) generates the signals to operate the three switches, R1, R2 and R3.

a) Controller for Sepic converter

MPPT is a technique used with variable power sources to maximize energy extraction as conditions vary. The technique is most commonly used with photovoltaic (PV) systems, but can also be used with wind turbines. Incremental conductance MPPT(Maximum Power Point Tracking) is used in proposed model.

Incremental conductance can determine the maximum power point without oscillating. It can perform MPPT under rapidly varying irradiation conditions with higher accuracy than P&O. However, this method can produce oscillations and can perform erratically under rapidly changing atmospheric conditions. The sampling frequency is decreased due to the higher complexity of the algorithm compared to P&O. Figure 4 shows the flowchart of incremental conductance method.

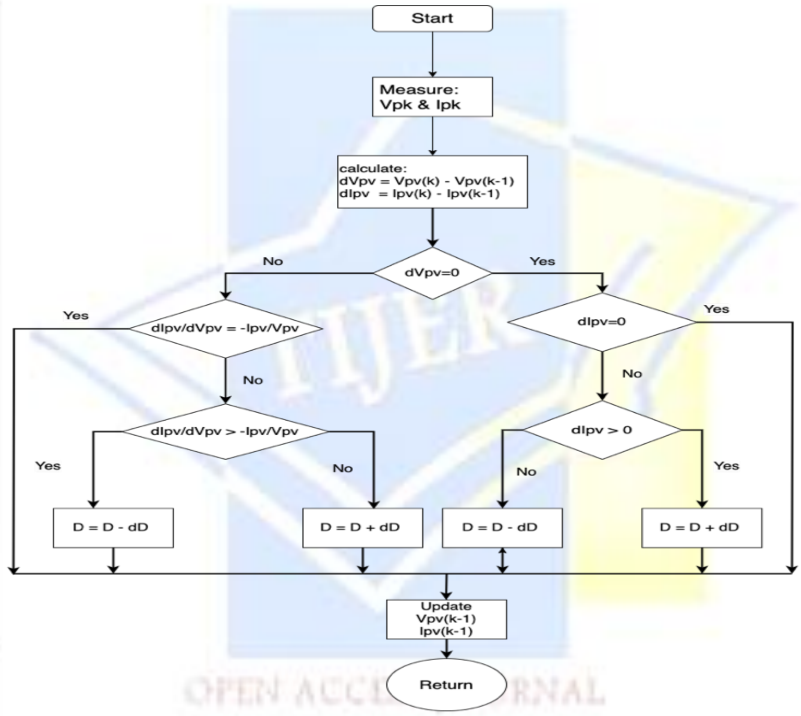


Figure 4.Flow chart of incremental conductance

b) Bidirectional interleaved dc-dc converter:

BIDC has three branches with two switches each. Two switches on the same channel must receive gate pulses that are 180 degrees out of phase with each other. The controller in the planning process generates control signals S_{Boost}, S_{Buck} and S_{off} according to the photovoltaic array power, as shown in Figure. If the photovoltaic array power P_{PV} exceeds the power P_U upper limit, the S_{Boost} control signal can be used and make the BIDC operate in boost mode and increase the DC bus voltage so that the backup battery can be charged in the PV-EV and BB mode, as shown in Figure 5.

As shown in Figure , the gate pulse is generated by the BIDC switch. In this mode, the controller recognizes the battery backup voltage $V_{BackupBatt}$ and compares it to the battery backup voltage V_{BB} and sets the leg 1 switch to phase 0 and the leg 2 switch to switch at a phase shift of 120 and leg 3 shift with a 240 degree phase shift. The S_{Buck} control signal is valid and the BIDC is converted to gate pulses to operate in buck mode, thus creating a pv voltage. If P_{PV} is less than P_L, the BB of the DC bus Sufficient to charge EV batteries in BB-EV mode.

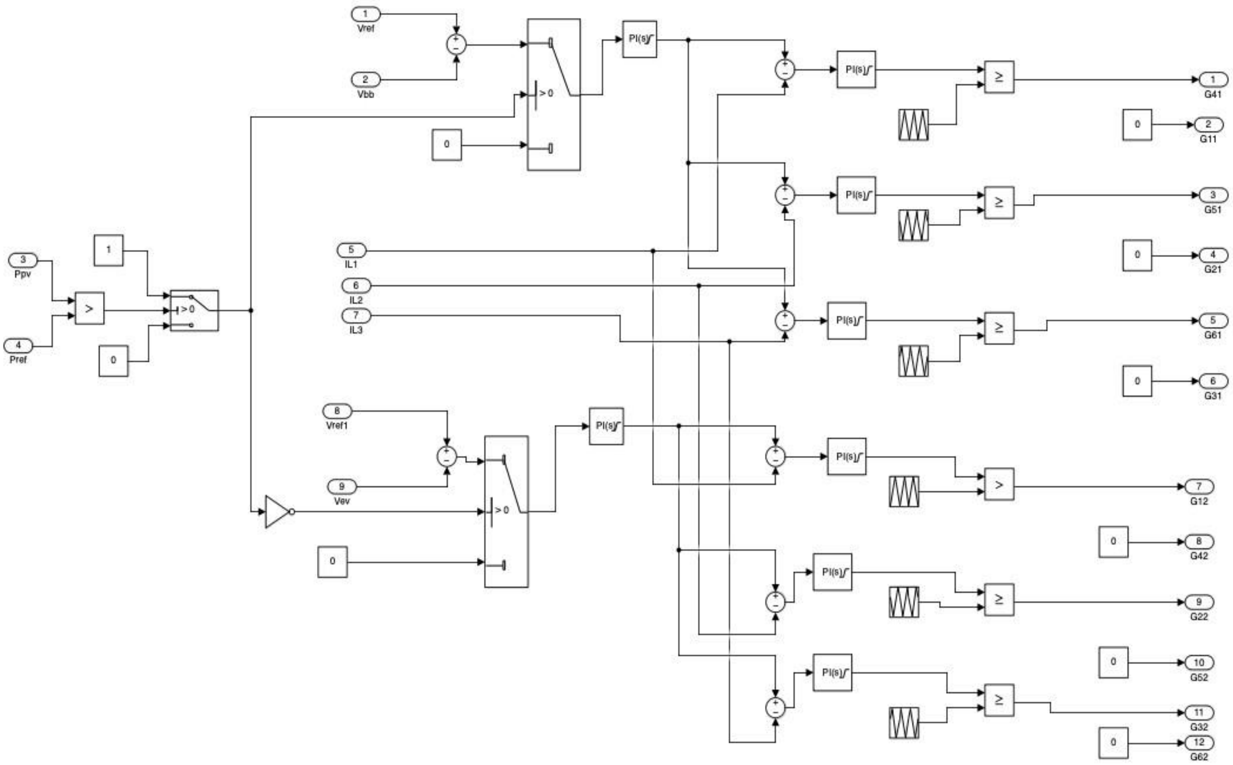


Figure 5.Control of BLDC Converter Simultaion Circuit

c) **Controller for the switches R1, R2 and R3**

To determine the power of the photovoltaic array, the controller measures the voltage and current of the system. If the power of the photovoltaic generator is more than the upper power consumption (P_U), the controller generates a signal to close all switches (R1, R2, R3) and charge the EV an dBB battery simultaneously. When the photovoltaic power is greater than low power consumption (PL) but less than (PU), switches R1 and R2 are closed only to charge the batteries from the photovoltaic array, while switch R3 is open for isolation, prevents the backup BB from being charged.

If the PV system has less power than(PL), switch R1 is open to remove the PV system from the battery charger. Switch R2 and R3 are open for BB to charge the EV battery. The controller recognizes Vbatt and matches it to the preset EV battery full load charging voltage to prevent tricking the EV battery. If Vbatt reaches full charge, turn on R3. The control diagram of each of the three switches is shown in the figure 6.

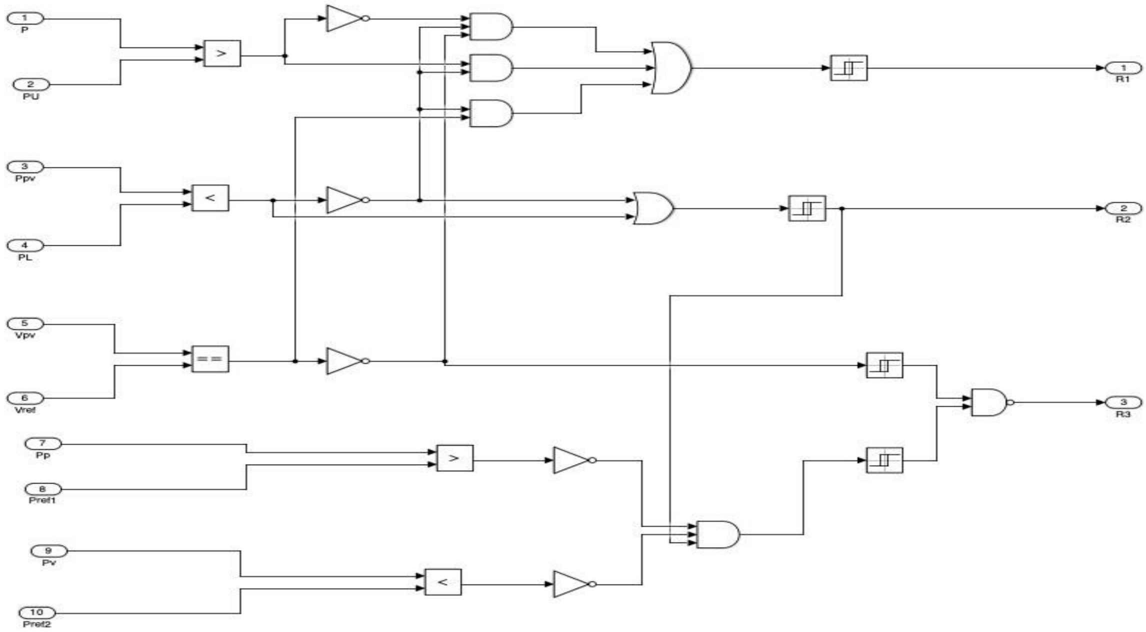


Figure 6.Simultaion circuit of controlled Switches R1,R2&R3

V. Results:

The proposed system was examined using MATLAB/Simulink software. Sim Power Systems in the Simulink software package is used to model SEPIC and BIDC converters. Simulink libraries, pulse generators, comparators, circuits, logic gates and MPPT controllers are used in the design of the controller. To design the charging system, the battery model in the Simulink library was integrated with the SEPIC converter model and the BIDC and photovoltaic array model. The projection model is shown in Figure 1. Using the developed simulation model, the situation was analyzed for 1000 W/m2, 600 W/m2 and 200 W/m2 mode1(PV-EV&BB), mode 2 (PV-EV) and mode 3 (BB-EV) respectively. Simulation results are shown in photovoltaic array irradiance and power waveforms in Figure 6. From this figure, it can be seen that when the radiation of the photovoltaic array is 1000 W/m2, the pow er is greater, so all relays are closed. Therefore, in this mode called (ModeI), the EV battery and the s pare BB are charged simultaneously. During 600 W/m2 radiation, relay R3 opens, while relays R1 and R2 close, isolating the BB from the system. Since in this mode the power of the photovoltaic array is only sufficient to charge the battery, it is called (Mode-II).
When at a low irradiance level of 200 W/m2, switches R2 and R3 are off, on and off, and R1 is on because the PV power is not enough to charge the EV. Therefore the backup BB charges the EV battery from the BIDC, called (Mode III).

A. Mode – I operation(PV-EV-BB):

The Figure 7(c),7(d) depicts the simulated dynamic waveform of soc, voltage, current of EV battery and backup BB for the equivalent irradiation values. In mode I (PV-EV & BB), the PV power is, 2000W as per Figure 7(a) and the V_{PV} is 120V. which is decrease to V_{DC} of 24 V by SEPIC converter as shown in Figure 7(c). So, the relay R1,R2&R3 are in on position.

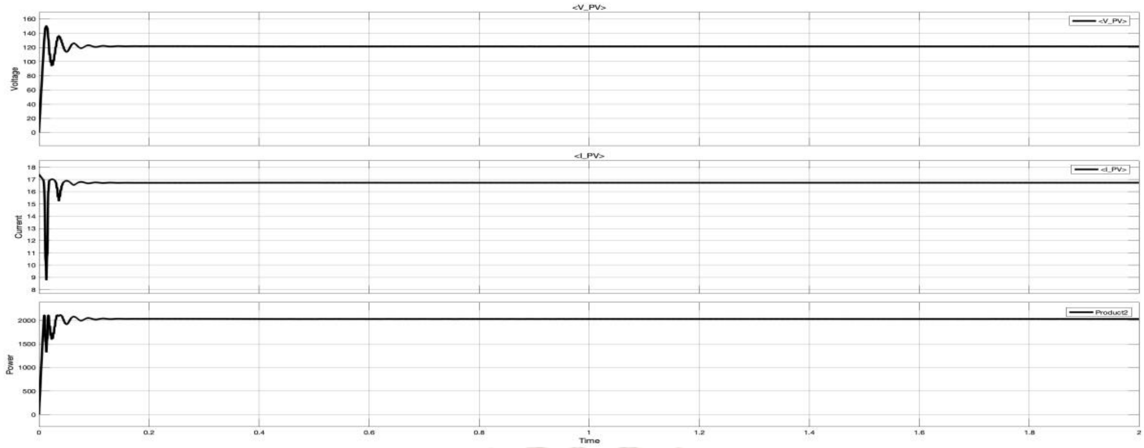


Figure 7(a): Solar panel output voltage, current, power during Mode-I

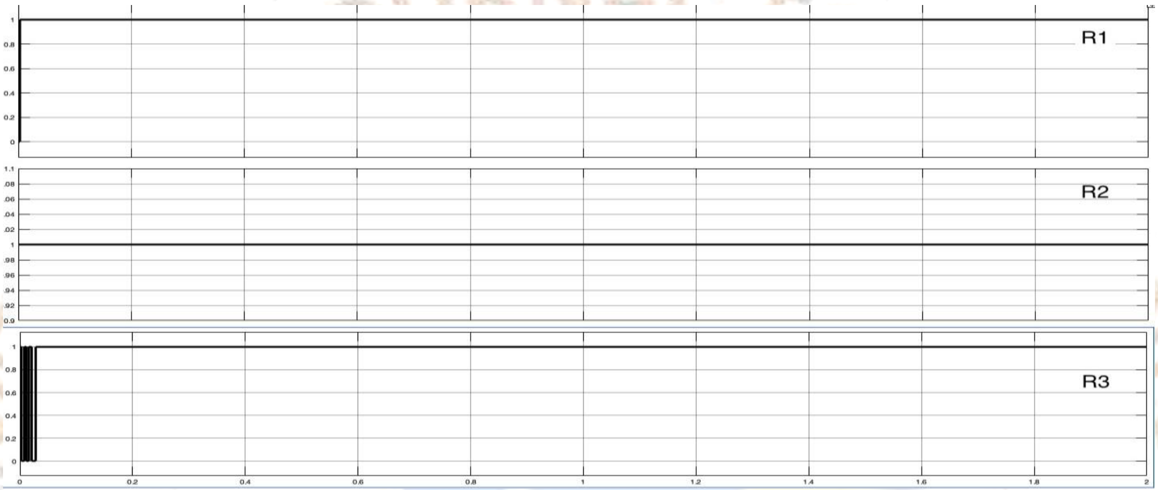


Figure 7(b). State of switches during mode-I

The value of Soc of EV battery is increasing and its current is negative, shown in below figure 7(c), indicate that the EV battery is charging.

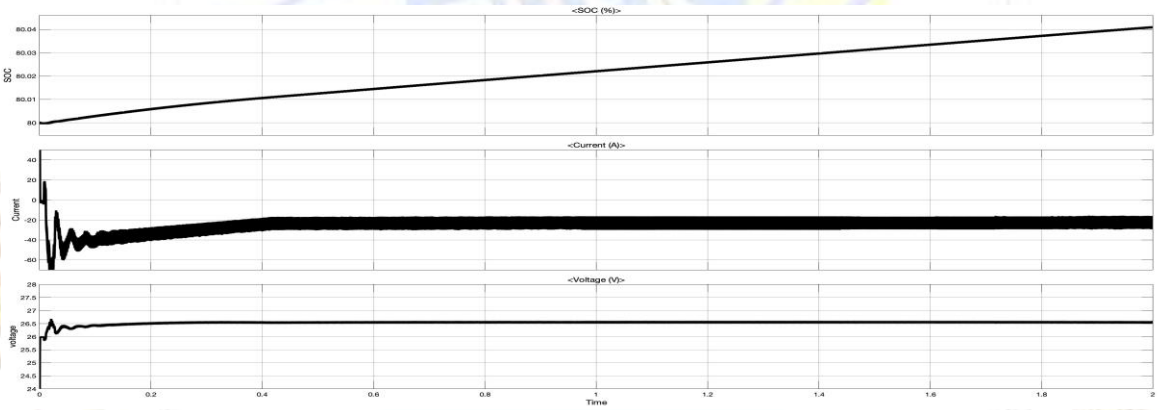


Figure 7(c).EV battery voltage, current and Soc waveforms during mode-I

BIDC operates as a boost converter in forward direction and boost the dc bus voltage, Vdc of 24V to 64V to charge the backup battery. It is shown in figure 7(d) with an increase in Soc.

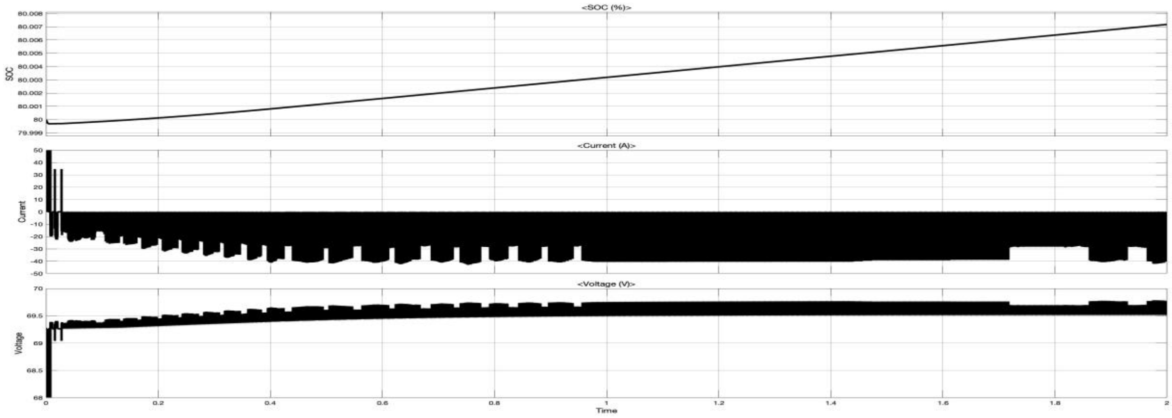


Figure 7(d).Backup battery voltage, current & Soc waveform during mode-I

B. Mode-II operation(PV-EV):

In this mode as the irradiation is 600 W/m2, and the power is 1200W as per Figure 8(a), which is not enough to charge the EV battery and backup BB.

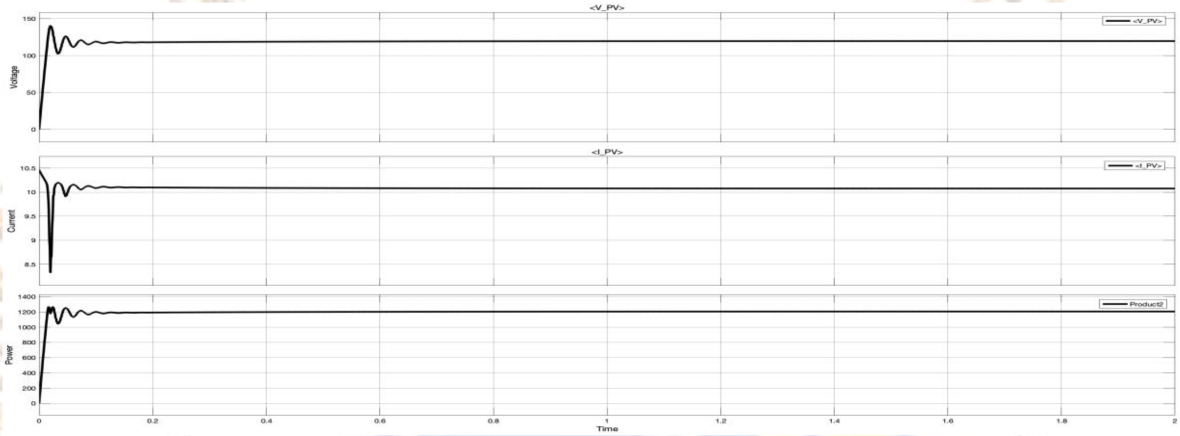


Figure 8(a): Solar panel output voltage, current, power during Mode-II

The power is below the value of P_U So, switches R1 and R2 are closed and switch R3, is open, separating backup BB from the system, Shown in figure 8(b).

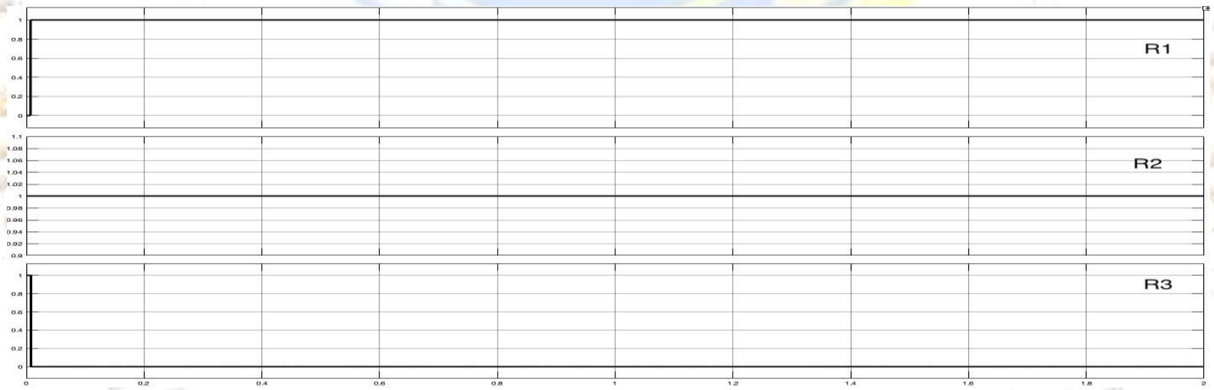


Figure 8(b): State of switches during mode-II

From the Figure 8(c) that the SOC of an EV battery is increasing and its current is negative, so, it is charging.

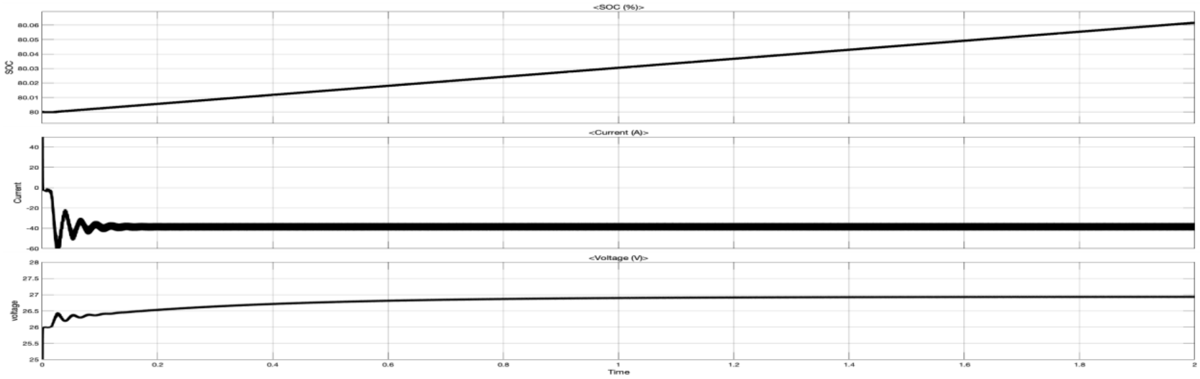


Figure 8(c): EV battery voltage, current and Soc waveforms during mode-II

In Figure 8(d) it is seen that the SOC of BB is constant and its current is zero. That means that the BB is cut-off from solar PV.

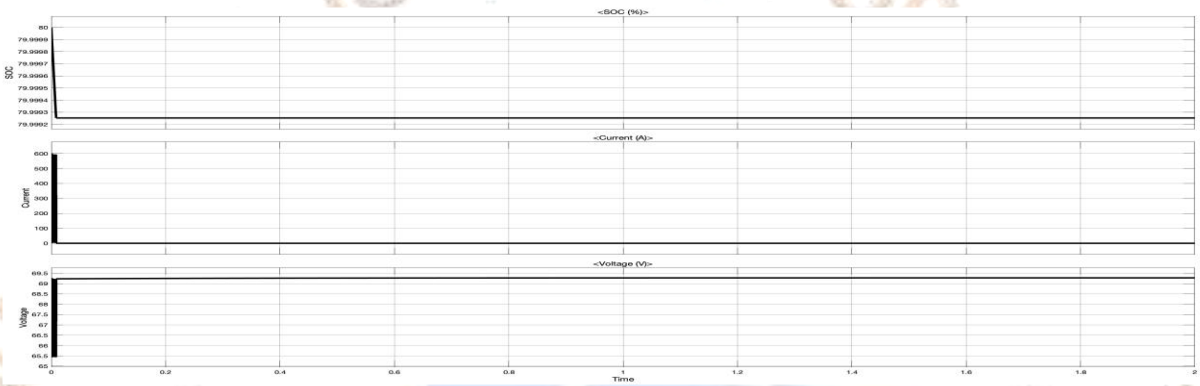


Figure 8(d): Backup battery voltage, current & Soc waveforms during mode-II

C. Mode-III operation(BB-EV):

During non-sunshine hours, PV array output power(360W) is less than P_L so relay R1 is in open position to disconnect the solar PV from SEPIC converter and R2&R3 are closed to charge the EV battery with Backup battery. The power output of solar PV and the waveforms of switches shown below figure 9(b).

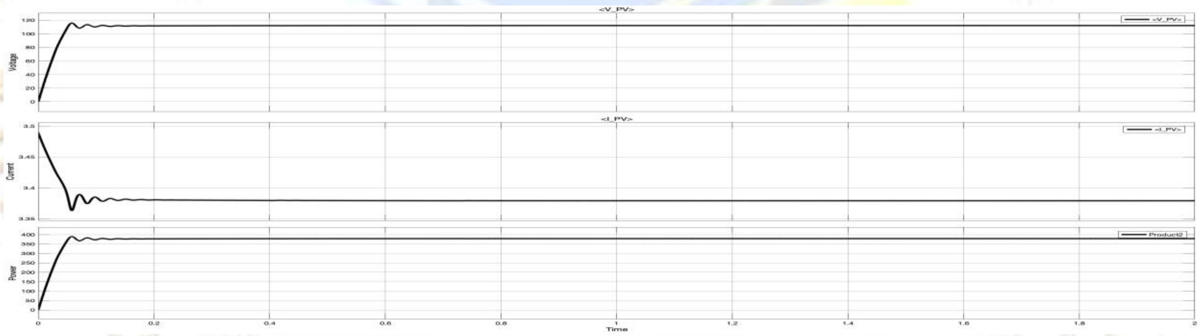


Figure 9(a): Solar panel output voltage, current, power during Mode-II

Figure 9(b): State of switches during mode-III

The Soc of EV battery is increasing is shown in figure 9(c), the current is negative which is shown below means the EV battery is charging.

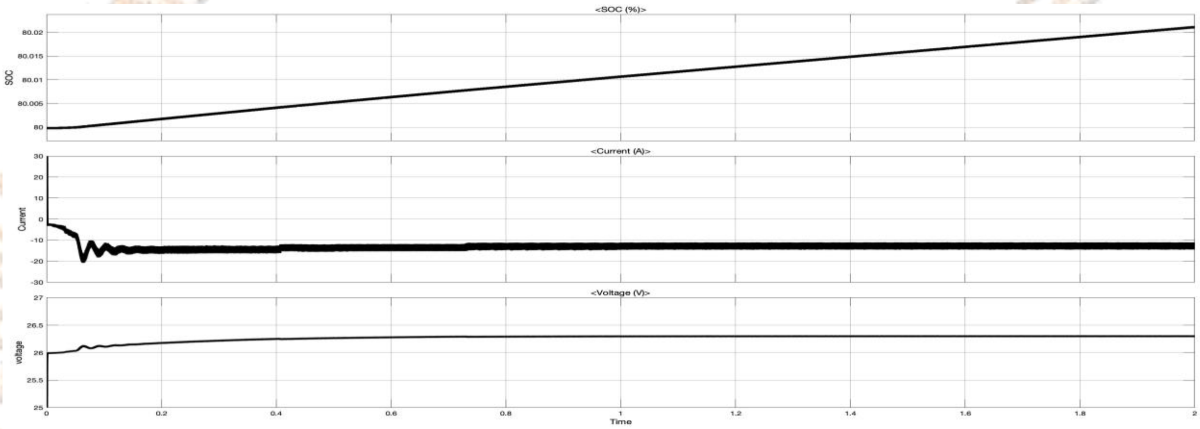


Figure 9(c) EV battery voltage, current and Soc waveforms during mode-III

The Soc of Backup battery is decreasing, the current of battery is positive which means the backup battery is discharging is shown in below figure 9(d).

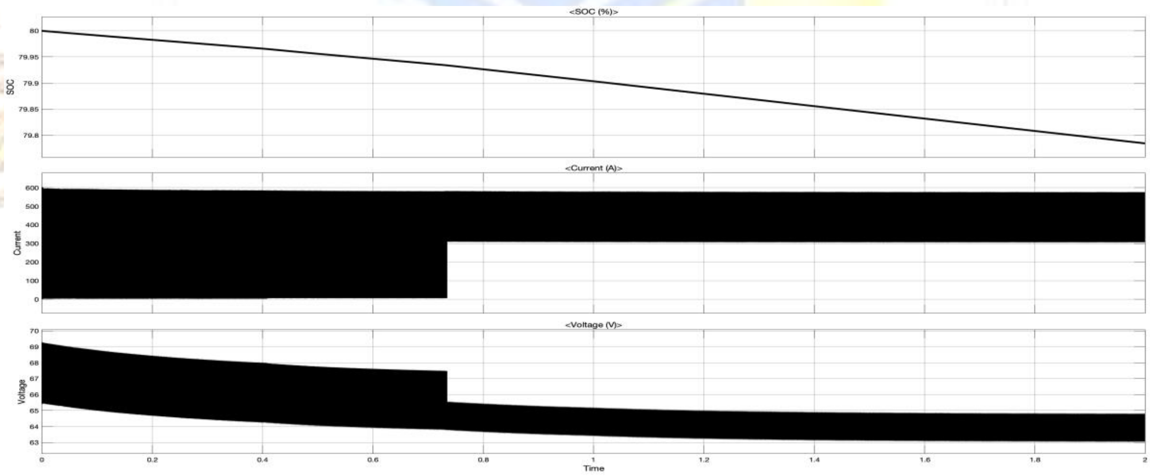


Figure 9(d):Backup battery voltage, current &Soc waveforms during mode-III

Vi. Conclusion:

In this study, suitable methods for continuous charging of electric vehicles independent of solar energy were examined. The proposed model was developed and evaluated in simulations in MATLAB software. The results show that solar panels can charge electric car batteries and batteries when the sun is shining. However, in cases where daylight is short, charging the EV battery is supported by the backup battery. Additionally, research results show that the SEPIC converter can provide sufficient DC output to charge electric vehicle batteries during periods of bright sunlight and low power.

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