SOLAR POWERED INTEGRATED EV CHARGER WITH BIDIRECTIONAL POWER FLOW FEATURE

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Abstract - *This paper includes a solar powered single stage based integrated power electronic converter with bidirectional power flow feature for plug-in electric vehicles (PEVs). This examines the opportunity of charging electric vehicle batteries with clean energy using renewable assets. Proposed converter achieves all the modes of operation, i.e plug-in charging, pv based plug-in charging, propulsion and regenerative braking. Within the conventional way, separate power electronics converters are needed for charging and discharging of the battery. The proposed converter has least additives in comparison to the existing converters that have stepping up and stepping down functionality in all modes. Hence reduced quantity of switches and inductors result in higher power density, low cost, size and weight reduction.*

***Key Words*: PV System, Buck/Boost Converter, MATLAB Simulation**

1. INTRODUCTION

The electric vehicles or plug-in electric vehicles (PEVs) are now a promising approach to reduce the air pollution that uses pollution-free battery power to produce clean energy for the vehicle. Latest statistics shows that the fossil fuel reserve of the world would get completely depleted before this century. Therefore, the shift towards alternative sources of power is the needed. The aggregate of EV and PV offers a completely unique possibility for sustainable charging of electric vehicles. DC-DC converters in an EV may be classified into unidirectional and bidirectional converters. Bidirectional DC-DC converters are used where regenerative braking is required. During regenerative braking the power flows back to the voltage bus to recharge the batteries. The bidirectional converter in conventional structure is included with the on-board charge. In the conventional way, separate converters are needed for charging and discharging of the battery. But in proposed way single power electronic converter is needed for two independent operations. Because the switching frequency is higher, the passive components are smaller and lower losses simplify thermal management. The energy stored can be transformed to output voltages that can be smaller than the input (buck), greater than the input (boost). As a result, it is concluded that buck/ boost operation of converter is possible in every mode of operation. The block diagram of entire system is shown in Fig.1.

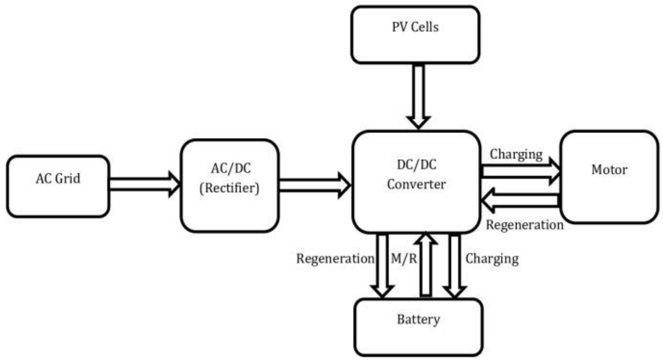


Fig. 1: Basic block diagram of proposed system

2. PHOTOVOLTAIC SYSTEM

Renewable strength resources will be an increasingly vital part of electricity era. Among the renewable energy resources, the energy through the photovoltaic effect can be considered the most essential and sustainable resource because of the abundance, and sustainability of solar radiant energy. To obtain the energy by the photoelectric effect, there shall be a directed motion of photoelectrons. All charged particles move in a directed motion under the influence of electric field. The electric field in the material itself is located in semiconductors, precisely in the impoverished area of PV junction. Cavities occurs whenever the valence electron turns into a free electron, and this process is called the generation, while the reverse process, when the free electron fills the empty spaces a cavity, is called recombination. If a consuming device is connected to such a system, the current will flow and we will get electricity.

3. ZETA-SEPIC BASED INTEGRATED CONVERTER

A single-stage-based integrated power electronic converter has been proposed for plug-in electric vehicles (PEVs) as shown in Fig.2.

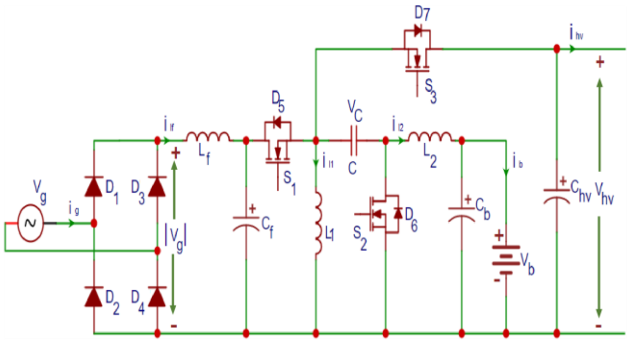


Fig. 2: Proposed ZETA-SEPIC integrated converter

The ZETA converter topology provides a positive output voltage from an input voltage that varies above and below the output voltage. SEPIC is also a type of dc-dc that allows the electrical potential at its output to be greater than, less than, or equal to that at its input. SEPIC has continuous input current, so less reflected ripple, less conducted emissions. ZETA has continuous output current, less ripple to the load. The proposed ZETA-SEPIC-based integrated converter for PEVs which has buck/boost capability in each mode of operation.

3.1 Modes of operation

The proposed integrated converter operates in different modes. In the following section, operation of converter is discussed in detailed manner.

1) Plug-in charging mode:

The plug-in charging mode of vehicle is possible only when vehicle is in rest condition and then charger plug is connected to single phase supply socket to charge the battery. In this mode switch S_1 is pulse width modulation gated while switch S_2 and S_3 are kept in OFF-state. When switch S_1 is turned ON, inductor L_1 stores energy through Vg-L_f –S_1- L_1-Vg and inductor L_2 stores energy through V_g- L_f- S_1-C- L_2- V_b- V_g as shown in Fig.3.

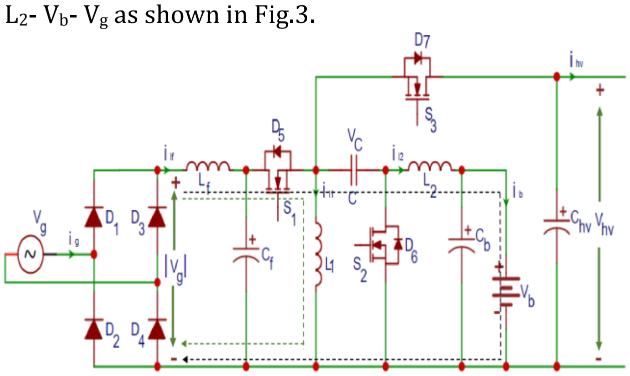


Fig. 3: Equivalent circuit of plug-in charging mode when S_1 is on

When switch S_1 is turned OFF, inductor L_1 discharges to the capacitor C, and voltage across capacitor gradually increases. While inductor L_2 supplies stored energy to the output stage as shown in Fig.4.

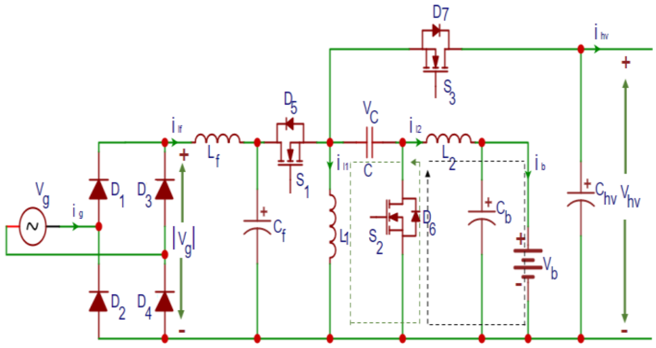


Fig. 4: Equivalent circuit of plug-in charging mode when S_1 is off

2) PV based plug-in charging mode:

This mode is possible only when vehicle is in rest condition and then charger plug is connected to charge battery with help pf pv cells. S_1 is pulse width modulation gated while switch S_2 and S_3 are kept in OFF-state. When switch S_1 is turned ON, inductor L_1 stores energy through the path V_{pv}- L_f –S_1- L_1-V_{pv} and inductor L_2 stores energy through the path V_{pv}- L_f- S_1-C- L_2- V_b- V_{pv} as shown in Fig.5.

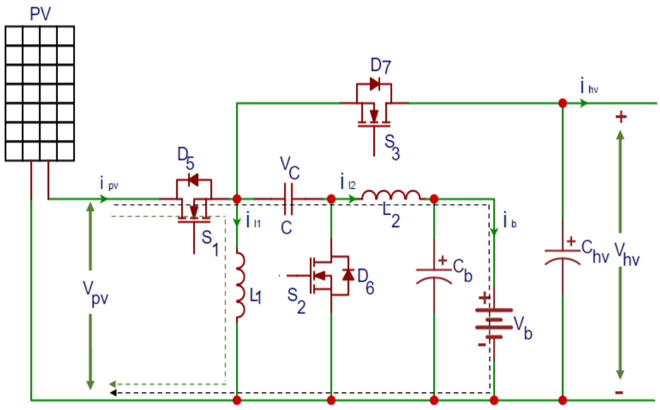


Fig. 5: Equivalent circuit of pv based plug-in charging mode when S_1 is on

When switch S_1 is turned OFF, inductor L_1 discharges to the capacitor C, and voltage across capacitor gradually increases. While inductor L_2 supplies energy to the output stage as shown in Fig.6 and current through L_2 decreases linearly.

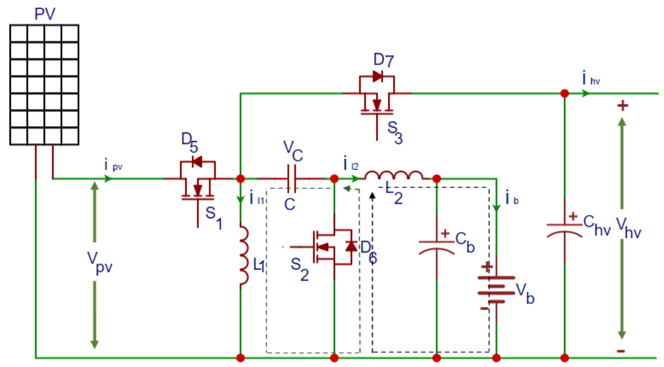


Fig. 6: Equivalent circuit of pv based plug-in charging mode when S_1 is off

3) Propulsion mode:

In this mode, switches S_1 and S_3 are kept in OFF, and switch S_2 is gated through PWM signal. When switch S_2 is turned ON, inductor L_2 stores energy through the path V_b-L_2-S_2-V_b, and inductor L_1 stores energy from capacitor C as shown in Fig.7 and inductor current through L_1 is linearly increasing.

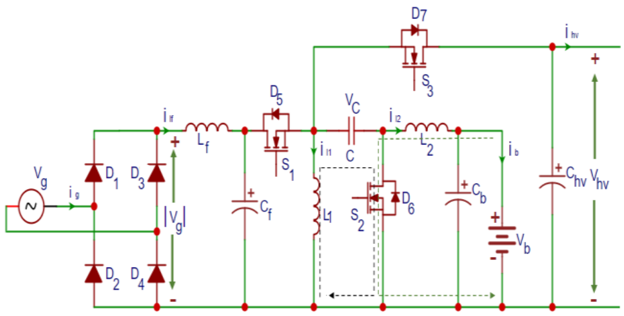


Fig. 7: Equivalent circuit of propulsion mode when S_2 is on

When S_2 is turned OFF, inductor L_2 transfers its stored energy in the capacitor C and dc-link capacitor C_{hv} through the path V_b-L_2-C-D_7-V_{hv}-V_b and capacitor C is charged to the battery voltage. The inductor L_1 transfers its stored energy to the dc-link through the path L_1-D_7-V_{hv}-L_1, as shown in Fig.8.

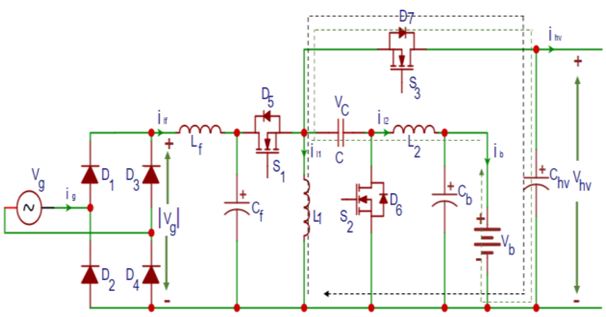


Fig. 8: Equivalent circuit of propulsion mode when S_2 is off

4) Regeneration mode:

During regenerative braking the power flows back to the voltage bus to recharge the batteries. In this mode switch S_3 is turned ON, inductor L_1 stores energy through the path V_{hv}-S_3-L_1-V_{hv} and inductor L_2 stores energy through the path V_{hv}-S_3-C-L_2-V_b-V_{hv}, as shown Fig9.

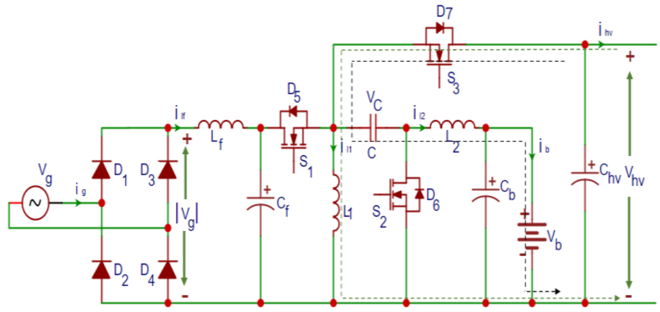


Fig. 9: Equivalent circuit of regeneration mode when S_3 is on

When S_3 is turned OFF L_1 transfers its stored energy to the capacitor C through the path C-L_1-D_6 as shown in Fig.10.

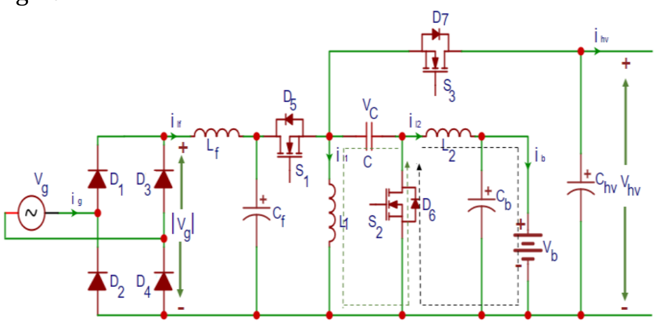


Fig. 10: Equivalent circuit of regeneration mode when s3is off

4. SIMULATION RESULTS AND DESCRIPTION

For the simulation of proposed scheme, the simulink model of proposed converter in plug-in charging mode, pv based plug-in charging mode, propulsion mode and regenerative braking mode are to be developed individually. Simulation parameters for integrated converter is given in Table1. An input voltage V_{in} of 220 V gives an output V_{out} of 12 V in Plug-in charging mode. In pv based plug-in charging mode, an input voltage V_{in} of 270 V gives an output voltage of V_{out} of 300 V. In propulsion mode, an input voltage of V_{in} 12 V gives an output voltage V_{out} of 24 V and in regeneration mode an input voltage V_{in} of 36 V gives an output voltage V_{out} of 12 V.

Table -1: Simulation parameters

PARAMETERS	VALUES
Grid Voltage (V_g)	220 V
Battery Nominal Voltage (V_b)	12 V/300 V
Line Frequency (f_L)	50 Hz
Nominal Charging Power (P_b)	1 KW
$C_{hv}/C/C_b/C_r$ (µF)	550/10/2200/1 µF
Switching Frequency (f_s)	20 kHz
$L_1/L_2/L_f$ (mH)	2/2/1.5 mH

4.1 SIMULINK MODEL OF CONVERTER IN PLUG-IN CHARGING MODE

The integrated DC-DC converter in plug-in charging mode is simulated in MATLAB/SIMULINK by choosing the parameters listed in Table 1 and simulink model is shown in Fig.11 and simulation results are shown in Fig.12.

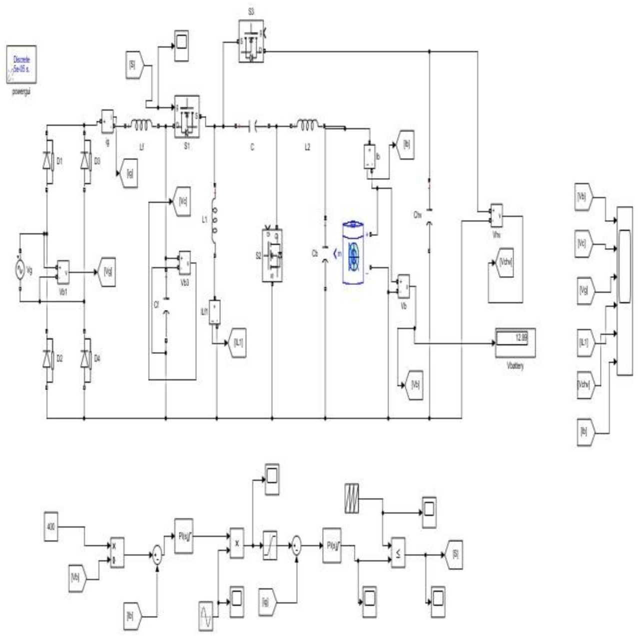
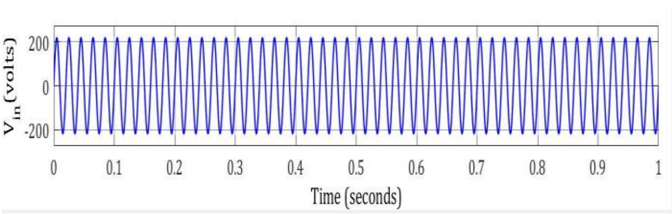


Fig. 11: Simulink model of plug-in charging mode



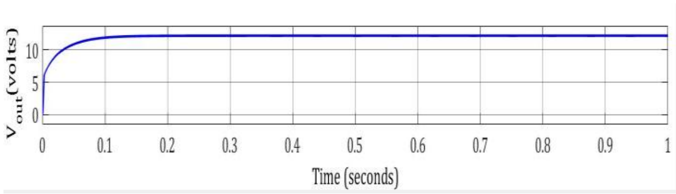


Fig. 12: Simulink result: (a) Input voltage and (b) Output voltage

4.2 SIMULINK MODEL OF CONVERTER IN PV BASED PLUG-IN CHARGING MODE

The integrated DC-DC converter in pv based plug-in charging mode is simulated in MATLAB/SIMULINK by choosing the parameters listed in Table 1 and simulink model is shown in Fig.13 and simulation results are shown in Fig.14.

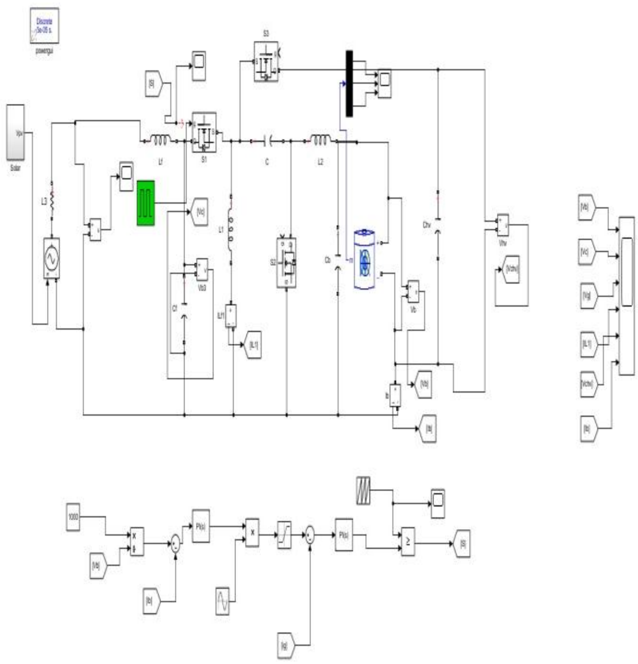
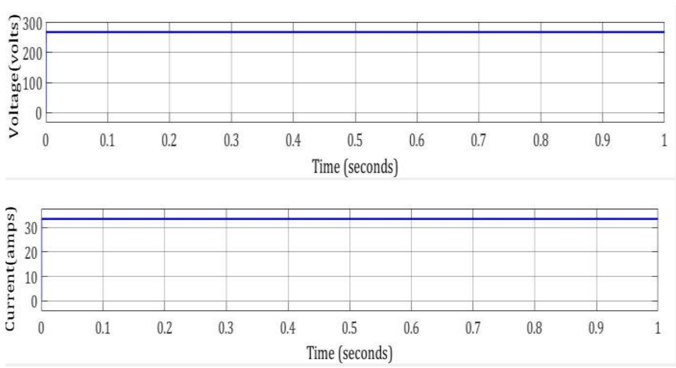


Fig. 13: Simulink model of pv based plug-in charging mode



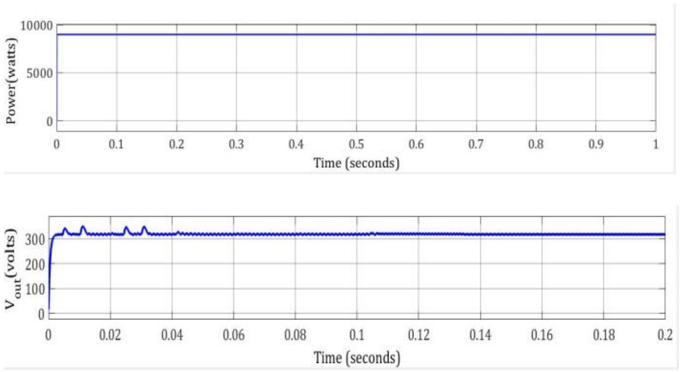


Fig. 14: Simulink result: (a) PV voltage (b) PV current (c) PV power and (d) Output voltage

4.3 SIMULINK MODEL OF CONVERTER IN PROPULSION MODE

The integrated DC-DC converter in propulsion mode is simulated in MATLAB/SIMULINK by choosing the parameters listed in Table 1 and simulink model is shown in Fig.15 and simulation results are shown in Fig.16.

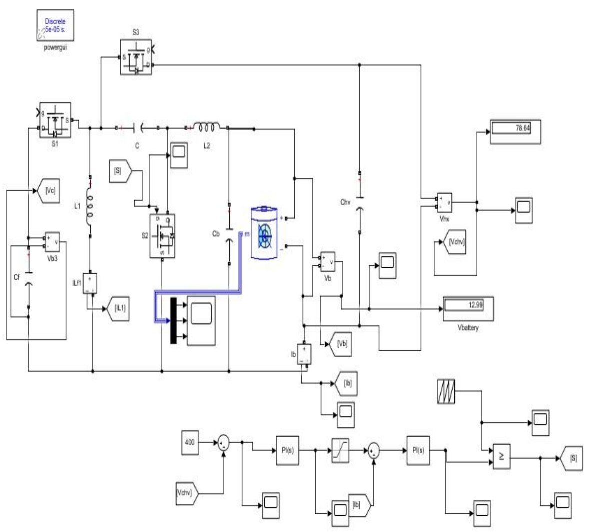


Fig. 15: Simulink model of propulsion mode

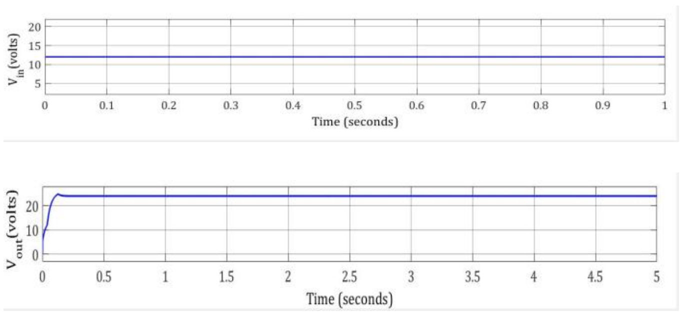


Fig. 16: Simulink result: (a) Input voltage and (b) Output voltage

4.4 SIMULINK MODEL OF CONVERTER IN REGENERATION MODE

The integrated DC-DC converter in regeneration mode is simulated in MATLAB/SIMULINK by choosing the parameters listed in Table 1 and simulink model is shown in Fig.17 and simulation results are shown in Fig.18.

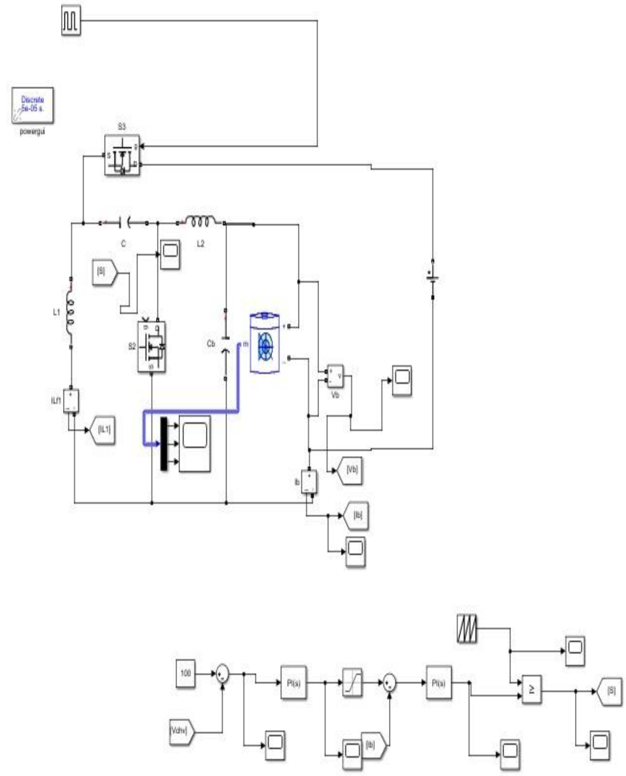


Fig. 17: Simulink model of regeneration mode

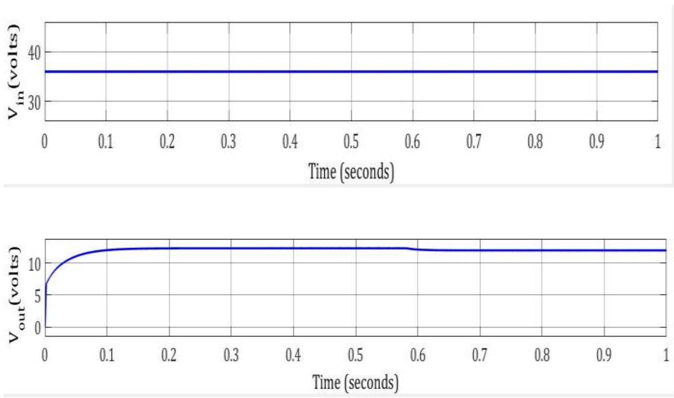


Fig. 18: Simulink result: (a) Input voltage and (b) Output voltage

5. CONCLUSION

Solar energy is becoming more prevalent as its cost is becoming more competitive with traditional power sources. Main contribution of this paper is to propose design 3-Port, bidirectional converter for direct charging of EV from PV. In this paper, we successfully simulated the proposed integrated converter. The simulations of the converter in different modes were accomplished with MATLAB. Hence implementation of solar powered integrated power electronic converter with bidirectional power flow feature energy achieved effectively.

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