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Design and Simulation of Closed Loop SEPIC DC-DC Converter for a Stand-alone Photovoltaic System

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ABSTRACT: In this paper designed and simulated a SEPIC converter by using photovoltaic system. The extraction of the solar power from the solar panel is a straight progression but obtaining high efficiency from the solar panel is really a challenging process. In order to obtain high efficiency and stable output a boost converter should be used. The synchronous converters are now becoming more advantageous than the other converters due to its reduced current ripple and better efficiency. The synchronous single-ended primary inductance converter (SEPIC) is analysed with different parameters.The diode in the converter is replaced by a PWM controlled switch to make the operating better by avoiding the discontinuous conduction mode and saving the diode's inverse voltage. The converter is simulated in mat lab/Simulink platform.

KEYWORDS: SEPIC converter; DC-DC converter; PWM control;

I.INTRODUCTION

The renewable energy resources are becoming a boon to the developing world where the necessity of electrical energy is increasing day by day. There are many types of renewable energy resources among them the solar energy is the superlative. Though photovoltaic (PV) cell has some limitations of high capitation cost, lower conversion efficiency, partial shading and seasonal energy production, it has seized the attention of many researchers because of its special virtues. The special virtues include costless source and maintenance free system. These systems are also pollution free that is environmental contamination is reduced to the minimum of zero percentage.

Circuits run best with a steady and specific input. Controlling the input to specific sub circuits is crucial for fulfilling design requirements. AC-AC conversion can be easily done with a transformer; however dc-dc conversion is not as simple. Diodes and voltage bridges are useful for reducing voltage by a set amount, but can be inefficient. Voltage regulators can be used to provide a reference voltage. Additionally, battery voltage decreases as batteries discharge which can cause many problems if there is no voltage control. The most efficient method of regulating voltage through a circuit is with a dc-dc converter.

Solar photovoltaic conversion is based on the photovoltaic effect to transform a part of energy of the sun to electricity. This technology requires little maintenance but it needs a good implementation of the DC –DC or/and dc-ac converter to obtain high efficiencies. There are many researches made in the field of photovoltaic conversion and propose new converter, amongthem [1] a sliding mode controlled SEPIC converteris designed; [2] presents modelling and simulation of closed loop controlled buck converter for solar installation; other papers deal with dc-dc buck-boost converter[3];in [4] a boost converter in detailed; [5] introduces a synchronous cuk converter which is simulated in Mat lab Simulink.

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II. THE STAND -ALONE PHOTOVOLTAIC SYSTEM

Fig. 1 shows the photovoltaic system's block diagram to be discussed. The system consists of a photovoltaic generator composed by two modules assembled in parallel, a synchronous DC/DC SEPIC converter controlled by PWM technique, and a bank of batteries.The input quantities acting on the photovoltaic generator are the irradiance and the temperature; the controller parameters are the pulse width modulation (PWM) signals that control the converter's switches by introducing the right duty cycle.A photovoltaic array is made with combined series/parallel combinations of PV solar modules, which are composed of combinations of PV cells usually assembled in series.

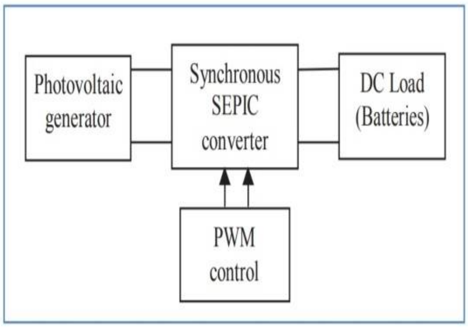

Fig.1. Block diagram of the stand-alone PV system

The expression of cell current is given by,

$$I = I_{ph} - I_S \cdot \left[\exp\left(\frac{q(V + R_S I)}{nkT}\right) - 1\right] - \frac{V + R_S I}{R_{sh}}$$

Where:
I: cellcurrent (A);
I_{ph}: light generated current (A)
I_S: Diode Saturation Current (A)
q: Charge of electron=1.60×10^{-19}(Coulomb)
V: Cell Output Voltage (V)
R_S: SeriesResistor(Ω)
K: Boltzman constant=1.380662×10^{-23}(j/K)
T: cell Temperature (K).
Rsh: Shunt resistor (Ω)

III.WORKING PRICIPLE OF SEPIC CONVERTER

The single-ended primary-inductance converter (SEPIC) is a step-down/step-up DC/DC converter circuit that provides a constant positive output voltage from a positive input voltage which can be lower or higher than the output. This Kind of DC/DC converter is very important when the output voltage has to be maintained constant, it can be used in open loop without any IP controller.

Fig.2. shows the basic electrical scheme of the SEPIC converter, consisting of an input capacitorC_{in}, out capacitor Cout and ; an AC coupling capacitor C_C, An coupled inductor L1 &L2; a diode D and a switchQ1.

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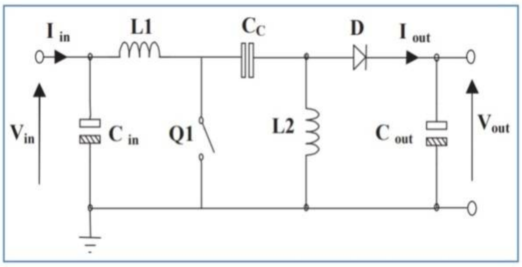
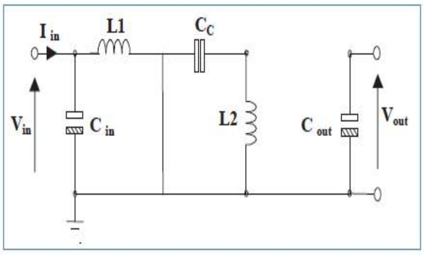


Fig2. SEPIC converter electrical scheme.

To make the converter operate in its continuous conduction mode, it must be synchronized. The proposed methodis to replace the diode D by another switch Q2 and this is to avoid any shift and also to save the inverse diode voltage. Those two switches, Q1 and Q2 are controlled by two complementary PWM signals produced in the driving circuit using saw tooth generator.in this 2 continuous conduction mode,SEPIC has two operating modes"Q1 on, Q2 off" and "Q1 off, Q2 on".



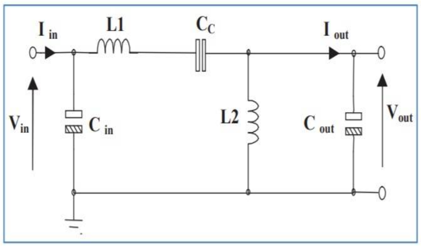


Fig.3.first mode "Q1 on, Q2 off" Fig.4.second mode "Q1 off,Q2 on"

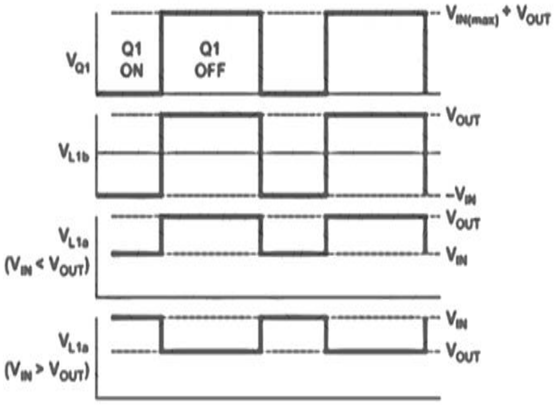


Fig.5 voltage waveform during CCM

To understand the voltages at the various circuit nodes.it is important to analyse the circuit at dc when Q1 is off and not switching.During steady state CCM. Pulse width modulation (PWM) operation and neglecting ripple voltage, capacitor C_p is charged to the input voltage.

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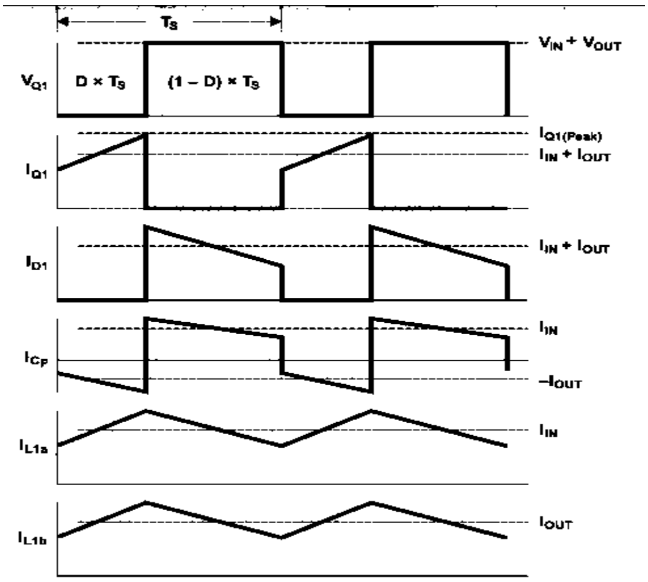

Fig. 6 current waveform during CCM

The current flowing through various circuit components are shown in fig 6.When Q1 is on, energy is being stored in L1 from the input and L2 from C_C. When Q1turns off L1 current continuous to flow through C_c and D, and into $C_{out}$and the load.

IV. DESIGN

Assuming the duty cycle of SEPIC converter operating in CCM is given by

$$D = \frac{V_{OUT} + V_{FWD}}{V_{IN} + V_{OUT} + V_{FWD}},$$

One of the first steps in designing any PWM switching regulator is to decide how much inductor ripple current, ΔIL, to allow. Too much increases EMI, while too little may result in unstable PWM operation. A rule of thumb is to use 20 to 40% of the input current, as computed with the power-balance equation,
The ripple current across both inductors,L1 and L2 is given approximately:

$$\Delta I_L = 30\ \% \ \times I_{in(\max)}$$

The values of L1 and L2 are as next:

$$L1(\min) = L2(\min) = \frac{V_{in(min)} \times D}{2 \times \Delta I_L \times f}$$

The AC coupling capacitor is

$$C_C(\min) = \frac{I_{out} \times D}{\Delta V_{C\,ripple} \times f}$$

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The capacitor ripples voltage as related to the output-capacitor current. When Q1 is on, the output capacitor must provide the load current

V.RESULT AND DISCUSSION

5.1 Modelling of closed loop design of SEPIC dc-dc converter for Stand Alone photovoltaic systemusing MATLAB.

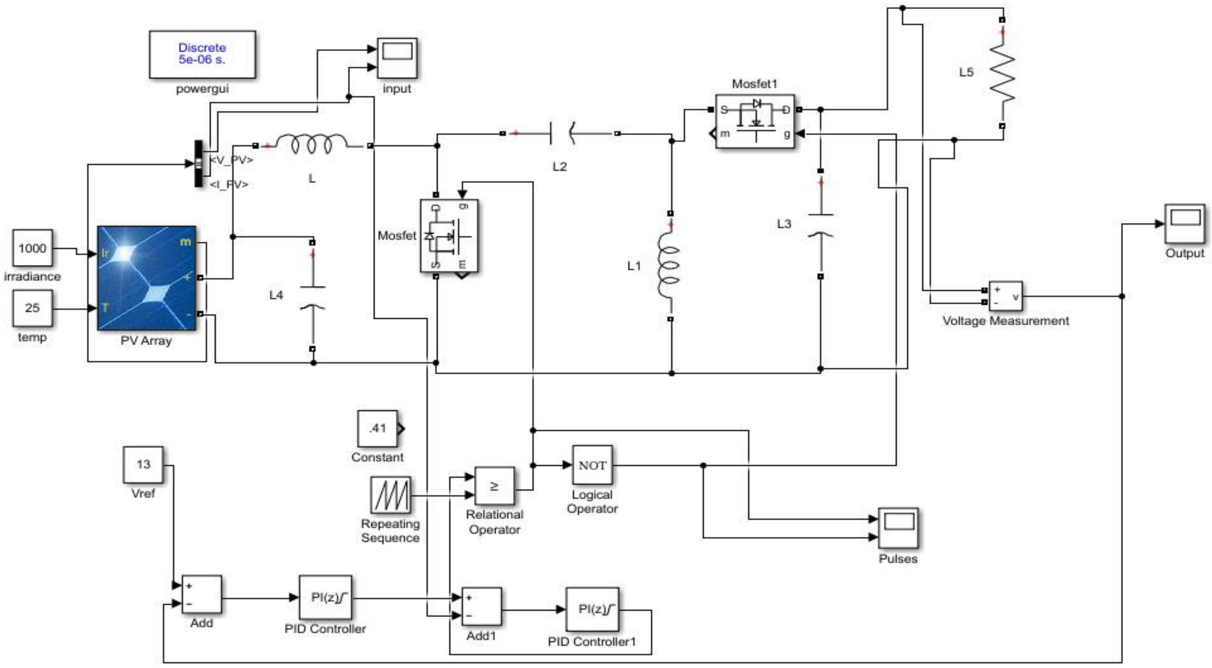

Fig. 7.Proposed closed loop model of SEPIC DC/DC Converter for stand-alone PV System

Fig. 7 shows the closed loop simulation model of proposed SEPIC DC-DC converter for stand-alone PV system. Here the input voltage is 22V DC.

Fig. 8 shows the simulated model of gate pulse generation for proposed SEPIC converter. Here the switching frequency is 40K Hz. Pulses are generated with the help of closed loop model by using PWM controller. The generated controlled output from the PWM controller is input to the gate pulse generation model.

Fig. 11 shows the output voltage of proposed closed loop SEPIC converter for stand-alone PV system. Here the output voltage is 12V DC.

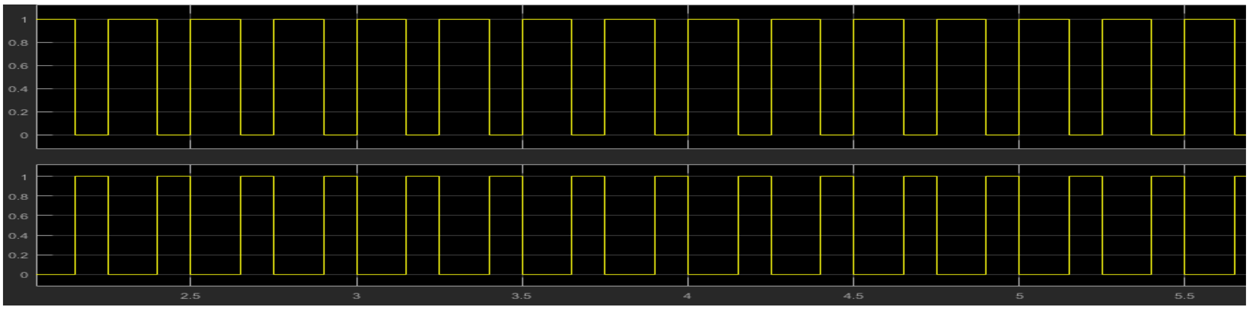

Fig 8. PWM 1 curve and PWM 2 curve respectively.

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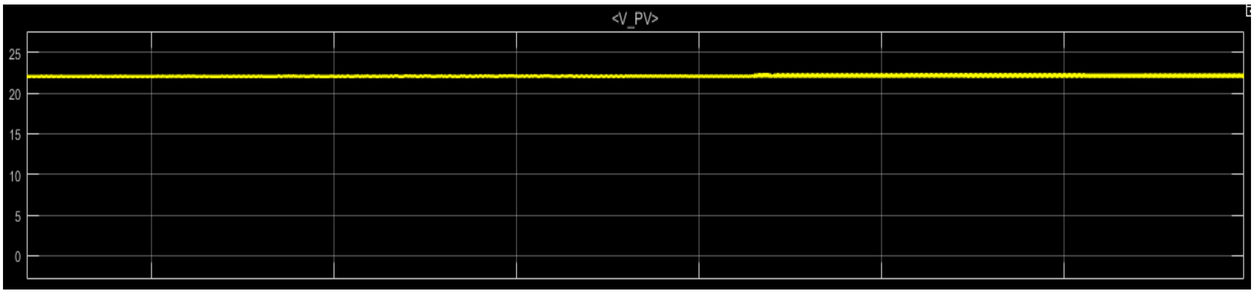

Fig 9. Input voltage curve

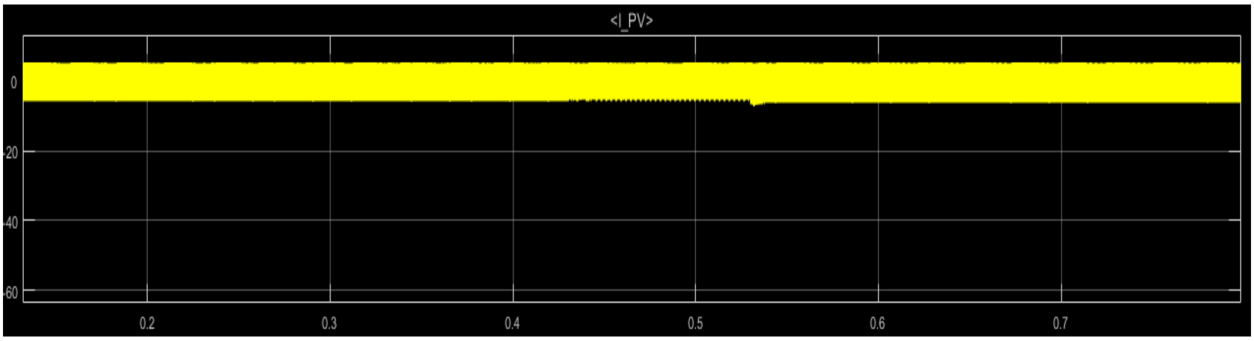

Fig. 10 input current waveform

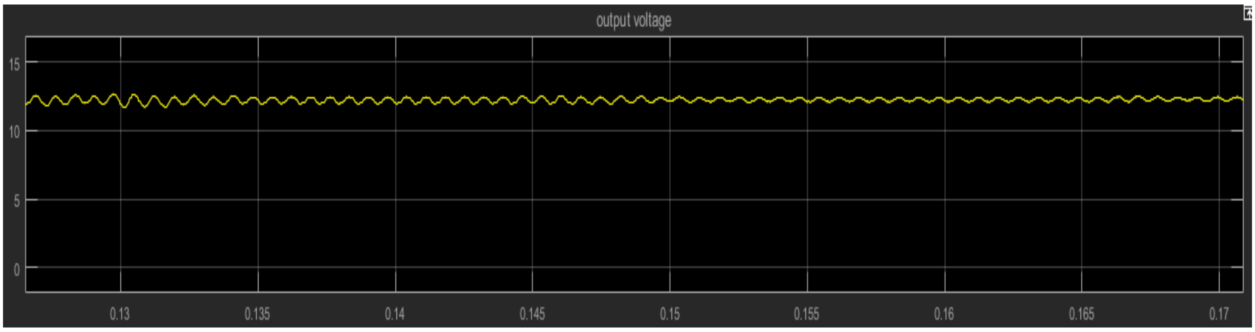

Fig.11 output voltage curve

VI. CONCLUSION

This paper SEPIC DC-DC converter controlled by PWM signals designed for stand- alone photovoltaic systems. This converter was simulated using the MATLAB / Simulinkplatform. The simple in operation where it only has two states of operation, so the discontinuous conduction mode has been avoided and the inverse voltage of the diode is eliminated by replacing it with another switch controlled by PWM. However, the function of this converter maintains its output voltage constant which can improve the efficiency of the photovoltaic system and ensure a good transfer of energy.

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