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Analysis and Design of Solar Power Fed DC-DC SEPIC Converter

K.Uthira[1], R.Sandhiya[2], P.Iraianbu[3], R.Srinivasan[4]

Assistant Professor, Dept. of EEE, Muthayammal College of Engineering, Rasipuram, Namakkal, Tamilnadu, India[1,2,3,4]

ABSTRACT: Photovoltaic system as a renewable source offers several advantages like abundant availability, free from pollution, more reliable and less maintenance. The power generated by the PV panel changes with the intensity of solar radiation and operating temperature. It is important that PV panel must operate with maximum output power for high reliability. So in this project, with the help of maximum Power point Technique(MPPT),output power will be maximized. Here, the solar power fed DC-DC Single-ended primary inductor converter(SEPIC) is used which will provide the output voltage without polarity inversion.In order to realize the performance of the solar power fed DC-DC SEPIC converter, the entire system is constructed and simulated using MATLAB/SIMULINK software tool. Simulation results reveal that the proposed converter can provide regulated output voltage in the presence of load and parameter variation.

KEYWORDS: Photovoltaic panel(PV),Maximum Power Point Tracking (MPPT), Direct Current(DC),Single ended primary inductor converter(SEPIC),Incremental conductance(IC).

I.INTRODUCTION

The depletion of fossil fuels and global warming caused by the green house gas emissions led to the development of non-conventional energy sources.These sources of energy are also called renewable energy. Solar energy,wind energy,bio-energy,bio-fuels,hydropower are some of the examples of renewable energy sources.Solar energy is the most available source of renewable energy.The advantages of solar energy is inexpensive,free from pollution,it is freely available and abundant in nature.Simple applications such as calculators and other low power consuming devices can be powered by solar energy effectively.Solar panels requires less maintenance.The installation of solar panels is not complex.

In solar photovoltaic conversion, photovoltaic devices or solar cells converts sunlight into electricity. An array of solar cells called solar PV panel converts solar energy into usable amount of direct current (DC).Photovoltaic cells provide an additional method of acquiring energy, converting sunlight directly into electricity through the use of semiconductors.

PV systems have been extensively used for low power electrical generation and have applications such as electrification for domestic applications, water pumping, air condition in rural and isolated areas. The proposed system comprises of photovoltaic array, DC-DC SEPIC converter feeds DC load.

Maximum power point tracking is used for extracting maximum available power from PV module. The point at which PV module can produce maximum power is called „maximum power point‟(or peak power voltage).Maximum power point tracking is used to maximize the efficiency of the photovoltaic module.

The major principle of MPPT is to extract the maximum available power from PV module by making them operate at the most efficient point (maximum power point).

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II.LITERATURE SURVEY

LITERATURE SURVEY-I

T Alex Stanley Raja,R Senthil Kuma,A Nandhakumar, K V Santhosh kumar Volume: 04 Issue: 10| Oct-2017

ABSTRACT: There has been an increase in demand for clean and sustainable energy sources, and solar energy is currently considered to be one of the most valuable and abundant yet low-maintenance clean sustainable energy source. Photovoltaic solar energy systems require DC-DC converter in order to regulate and control the varying output of the solar panel. The single ended Primary inductance Converter topology performs the operation of a buck-boost converter but with no voltage polarity reversal. This paper suggests a converter design that will ensure high performance and cost efficiency. The converter has been simulated in MATLAB and the hardware was done by choosing the design values appropriately. This design aims to have lower losses for higher switching frequencies, and maximize the added advantages of the proposed converter,such as low ripple, highefficiency and low electrical stress on the components.

III. SYSTEM OVERVIEW

Figure 1 illustrates the schematic diagram of closed loop control of DC-DC SEPIC converter system. This system

comprises of solar panel,DC-DC SEPIC conveter,MPPT,Voltage sensor,PI controller,Non-linear carrier control,load.

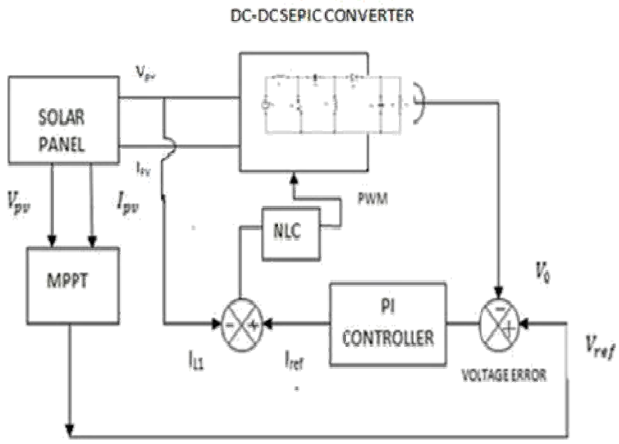

Figure 1 Block diagram of proposed system.

A. PHOTOVOLTAIC CELL

An array of solar cells called solar PV panel,converts solar energy into a usable amount of direct current(DC) electricity.Figure 3 represents the cell photocurrent.R_{sh} and R_s are the intrinsic shunt and series resistances of the cell respectively.PV cells are grouped in larger units are further interconnected in a parallel series configuration to form PV array.

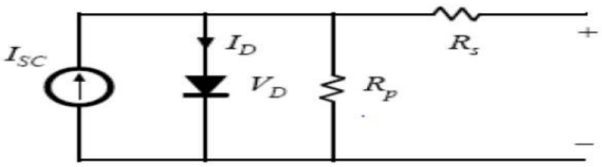

Figure 2 Equivalent circuit of a solar cell

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Vol. 7, Issue 10, October 2018

B. Maximum power point tracking

MPPT is used for extracting the maximum available power from PV module under certain conditions.The voltage at which the PV module can produce maximum power is called maximum power point.Maximum power point tracking is used to maximize the efficiency of the photovoltaic module.

C. Incremental conductance

IC was designed based on the observation of P-V characteristic curve.IC tries to improve the tracking time and to produce more energy on a vast irradiation changes environment.The MPP can be calaculated by using the relation between dI/dv and –I/V.The slope of the PV array power curve is zero at the MPP,increasing on the left of the MPP,and decreasing on the right hand side of the MPP.Figure 3 represents the incremental conductance method.

DC-DC SEPIC converter is capable of operating in either step up or step down mode and widely used in battery operated equipment by varying duty cycle of gate signal of MOSFET.It can step up or step down voltage.For duty cycle above 0.5 it will step up and below 0.5,it will step down the voltage to require value.SEPIC has the advantages of a continuous input and output currents due to the presence of input and output inductors.Advantage of SEPIC converter is that it provides a positive regulated output voltage from an input voltage that varies above to below the reference voltage.The SEPIC converter is chosen because the output voltage is higher or lower than the input voltage,also the input and output sides are isolated.

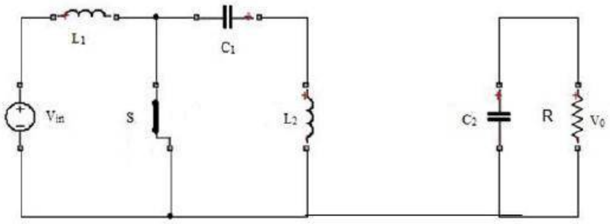

Figure 5 SEPIC converter

MODES OF OPERATION

SEPIC ON-STATE

When switch Q is turned on,current I_{L1} increases and the current I_{L2} increases in the negative direction.The energy to increase the current I_{L1} comes from the input source.Since switch(S) is a short while closed,and the instantaneous voltage V_{C1} is approximately V_{IN} the voltage V_{L2} is approximately V_{IN}.Therefore,the capacitor C_1 supplies the energy to increase the magnitude of the current in I_{L2} and thus increase the energy stored in L_2.

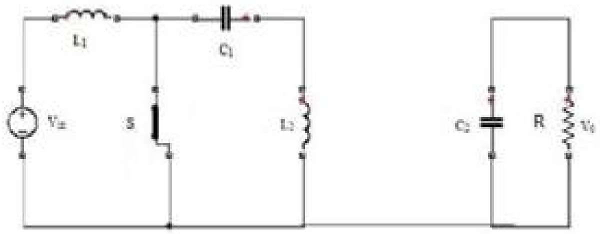

Figure 6 SEPIC on-state

When the switch Q1 is turned off,the current IC1 becomes the same as the current IL1,as the inductors will not allow instantaneous changes in current.Current IL2 will continue in the negative direction,infact it never reverse direction.It

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can be seen that a negative IL2 will add to the current IL1 to increase the current delivered to the load.By using Kirchoff's law

$$I_{D1}=I_{C1}-I_{L2} \qquad (4)$$

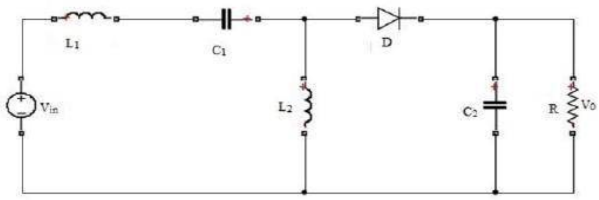

Figure 7 SEPIC off-state

So while Q_1 is off,power is delivered to the load from both L_2 and L_1.Coupling capacitor(C_1),is charged by L_1 during this OFF cycle,and will recharge L_2 during the on cycle.The boost/buck capabilities of the SEPIC are possible because of capacitor C_1 and inductor L_2..Inductor L_1 and switch(S) create a standard boost converter,which generates a voltage(V_S) that is higher than V_{IN}.Since the average voltage across C_1 is V_{IN},the output voltage(VOUT) is

$$V_{OUT}=V_S-V_{IN} \qquad (5)$$

If V_S is less than double of V_{IN},then the output voltage will be less than the input voltage.If V_S will be greater than double of V_{IN},then the output voltage will be greater than the input voltage.

G.Non-Linear Carrier Control

The non-linear carrier control is based on sensing the inductor current and comparing the signal derived from the inductor current with a periodic non-linear carrier waveform. The non-linear carrier controller generates the pulses from the comparison of the non-linear carrier waveform and the sensed inductor current signal.At the beginning of a switching period,a short clock pulse sets the flip-flop(FF),which turns on the power switch.If the comparator output goes high and resets the flip-flop(FF),thus turning off the power switch.The process is repeated in each switching period.

Using the NLC controller,input voltage sensing,error amplifier in the current-shaping loop,and the multiplier/divider circuitry in the voltage feedback loop are eliminated,The simple high-performance controller is well suited for integrated-circuit implementation.Non-linear carrier control can be applied to current-programmed boost rectifiers,as well to other rectifiers based on the buck-boost,SEPIC or other topologies,with either integral charge control or peak-current-programmed control.

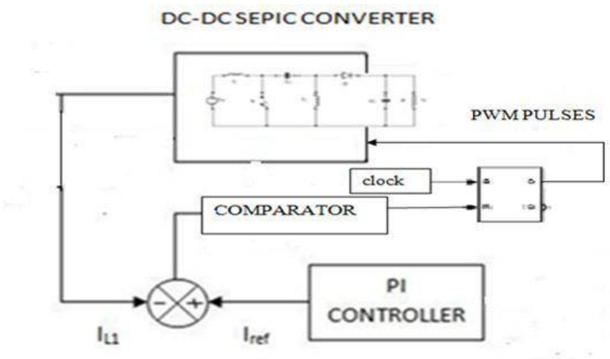

Figure 8 Non-Linear Carrier Control

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Vol. 7, Issue 10, October 2018

IV. SIMULATION RESULTS AND DISCUSSION

The simulation results of this section are generated using MATLAB/Simulink simulation software.

The voltage and current from the solar panel is V_{PV} and $I_{PV.}$This voltage and current are given to the MPPT.With the help of MPPT,output power will be maximized.In this work,incremental conductance algorithm is used to generate

$V_{ref.}$The task of MPPT algorithm is to calculate thr reference voltage.Reference voltage from MPPT is 48V.The proposed system employs a PI controller.PI controller is used to implement closed loop control.The outer control loop uses PI controller to generate inductor reference current.

PI controller output added with the non-linear carrier waveform and it is given to the comparator.Inductor current from the SEPIC converter is also given to the comparator.The non-linear carrier control is based on sensing the inductor current and comparing the signal derived from the inductor current with a periodic non-linear carrier waveform.

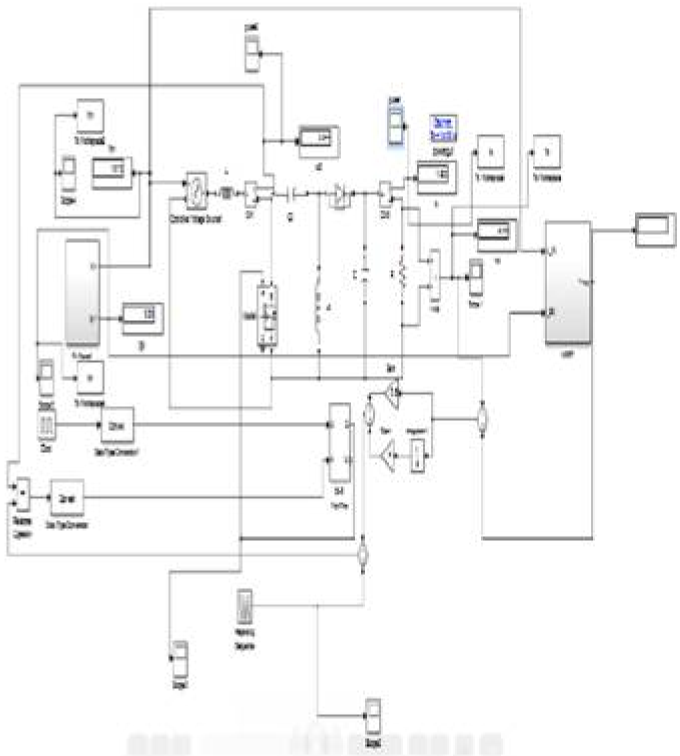

Figure 9 Closed loop control of solar power fed DC-DC SEPIC converter

V.RESULTS

The output voltage and current from the solar panel is 18.6V and 5.35A.Figure represents the output current waveform of SEPIC converter.Figure represents the waveform of SEPIC converter output voltage.

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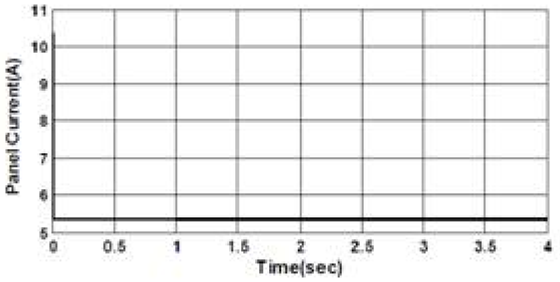

Figure 11 Waveform of solar panel current

The output voltage and current from the SEPIC converter is 48.17V and 2.0A.

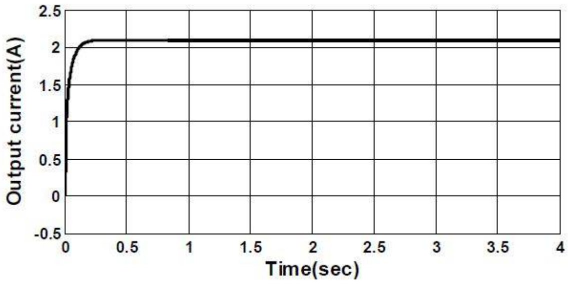

Figure 12 Waveform of SEPIC converter output current

Non-linear carrier control is used to generate the PWM pulses for triggering the MOSFET switch in the DC-DC SEPIC converter to attain the regulated output voltage.

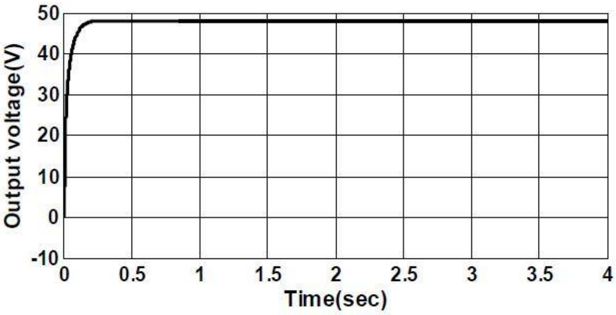

Figure 13 Waveform of SEPIC converter output voltage

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PARAMETER VARIATION

Table 2 shown the output voltage for the variation in PI controller parameters.Results shows the proposed converter can provide a regulated output voltage irrespective of parameter variations.

Table 2 Parameter variation

S.NO	K_p	K_i	OUTPUT VOLTAGE(V)	LOAD CURRENT(A)
1	0.3	3	47.09	2.048
2	0.4	4	47.7	2.074
3	0.5	5	47.93	2.084
4	0.6	6	48.04	2.089

VI.CONCLUSION AND FURURE SCOPE

In this work,the closed loop control of solar power fed DC-DC SEPIC converter have been carried out by using MATLAB/SIMULINK software tool.Here,the solar power fed DC-DC SEPIC converter is used to provide the output voltage without the polarity inversion.In order to realize the performance of the solar power fed DC-DC SEPIC converter was analysed.Future work may include implementation of solar power fed DC-DC SEPIC converter.

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