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MATLAB/SIMULINK ANALYSIS OF A RIPPLE FREEHIGH EFFICIENCY BUCK-BOOST TYPE CONVERTER FOR EV CHARGING AND CONTROLLING APPLICATIONS

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Abstract - *DC-DC conversion is the central stem of power electronics and is advancing quickly. Many newtopologies are still created every year. The most common design of DC-DC converters is typically, a converter with high gain, in orderto increase the output voltage of the photovoltaic and to obtain a high conversion efficiency. The SEPICconverter is a converter topology which is used to provide a regulated output voltage from an input voltage that varies above and below the output voltage. However, comparing to conventional DC-DC converter topologies, SEPIC converters can increase by 5 times of the input voltage. A SEPIC converter of type is designed and evaluated in this paper. Conventional DC-DC SEPIC Buck-Boost type converter is utilized forindustrial applications like DC motor control, LED light drives, etc., SEPIC converter is much suitable for high- voltage applications. The DC-DC SEPICconverter is controlled to extract the maximum power from a Source to charge (or) control the Load. The SEPIC converter will operate in Continuous Conduction Mode in order to increase the Efficiency of the Converter. Analysis is made for both Open-Loop and Closed-Loop of theConverter in MATLAB/Simulink.*

Key Words*: *Converter, SEPIC Efficiency, High-Voltage Application, Pulse Width Modulation, CCM, DCM, Buck-Boost, Closed loop.

1. INTRODUCTION

These days, there are many purposes behind the advancement of electric vehicles (EVs). The most important reasons are increasing of fuel cost, lacking in energy resources and reduce the greenhouse gas emission. The advantages of using the EVs can be stated as, being a source of the clean energy, having high efficiency when compared to the conventional vehicles and producing less noise than the conventional vehicles. The EVs that are widely used in worldwide, can be either a hybrid EVs or battery EV's. Many researches had proposed many converters for charging & controlling applications of EV. Some of them are listed below;

Piyush Choudhary and Som Nath Mahendra has proposed a DC-DC cuk converter [1] for solar photovoltaic array which has an inductor current of 20% and 50% more. An efficiency of 90% and more is achieved. They both has made the calculations and analysis, in CCM mode operation, transfer function, state space analysis, simulation of cuk converter are done.

Danila Shirly.A.R, Sudhilaya M, Priyadharshini Y, Shamni J and Poorani J has proposed a paper which predominantly focuses on the design and implementation of efficient landsman DC-DC converter [3] with power loss minimization using particle swarm optimization (PSO) a hybrid soft computing technique. But, the boosting of output voltage is only 2 times of the input voltage.

P.Ramesh Babu, S.Ram Prasath and R.Kiruthika has putforth a paper of simulation and performance analysis of CCM zeta converter [2] with PID controller. They have designed, analyzed, simulated, close loop, continuous conduction code of zeta converter in their paper. The converter works in continuous current mode (CCM) as it were. But, The boosting of input voltage isn't unreasonably much high. In any case, the converter has lower Output voltage Ripple and has high productivity.

Alia M. Khatab, Mostafa I. Marei and Hadi M. Elhelw has proposed a paper of an electric vehicle battery charger [4] based on zeta converter fed from a PV array. This paper proposes a battery charger for an electric vehicle (EV) in view of zeta converter. The perturb and observe (P&O) maximum power point Tracking (MPPT) technique is used to obtain the maximum power from the PV array. The proposed P&O technique is used for generating the duty cycle for the zeta converter is working properly. But The output current has high ripple.

H.Suryoatmojo, I.Dilianto, Suwito, R.Mardiyanto, E.Setijadi and D.C.Riawan have proposed a paper named design and analysis of high gain modified SEPIC converter for photovoltaic applications. The proposed converter has the advantage of the SEPIC converter, like consistent input current. The proposed circuit structure likewise works on the elements, like high voltage gain and high conversion productivity. The proposed converter only applicable for 100W devices only. This converter has 2 more storage elements comparing to proposed converter.

Faizan Hameed, Khalid Iqbal both has Proposed a paper of ZETA Converter based charge controller for efficient use of solar energy in street lighting system. Purpose of circuit's designed is to charge the battery between upper and lower voltage limits in addition to continuous checking the status of battery charge to add or release current accordingly. This proposed converter only applicable for low power rated devices only. The converter has high output current ripple. Principal contrast between the strategy utilized in the proposed system and different methods utilized in the past is that ZETA converter itself will go about as charge regulator what's more with this, specific properties of ZETA converter will be used to optimize street lighting system to reduce the power losses and cost.

Suraj S, Jijesh J J, Sarun Soman has proposed a converter analysis of dual phase dual stage boost converter for photovoltaic applications. The converter discussed in this paper is derived by combining the concept of interleaving and cascading of boost converters. The converter is intended for a power rating of 200W with yield voltage of 192V for an input voltage of 12V got from photovoltaic source at an exchanging frequency of 50KHz. This results exhibit that this converter achieves a predominant performance over other dc-dc boost converters by offering improved efficiency and voltage gain, while having lower input current ripple.

SEPIC converter has a lot of advantages which can be summarized as follows, it has a simple design, which composes from four energy storage elements; two inductors and two capacitors. The result current can be constant and liberated from the ripples because of the presence of an inductor at the result side. Operating as a buck-boost converter means that, the SEPIC converter has the ability to increase and decrease the output voltage than input voltage. When compared to the conventional buck-boost converter, the output voltage is not inverted. It has little settling time, low exchanging pressure and it tends to be associated with high frequency transformers.

2. CIRCUIT CONFIGURATION

The circuit configuration of the proposed DC-DC converter is shown in figure 1. It operates in a input voltage of 16 - 24 V. The power circuit strategy is presented with two inductors, two capacitors,one DIODE and one MOSFET switch operating at a switching frequency of 30 kHz.

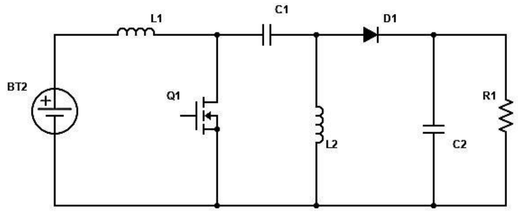

Fig –1: DC-DC SEPIC Converter

The proposed converter is designed for 300W applications. The regulated output voltage and output current will be 60 V and 5 A respectively.

3. DESIGN OF DC – DC SEPIC CONVERTER

The design specifications of the proposed converter are shown in

The equation to find the duty cycle D is,

$$\frac{Vo}{Vin} = \frac{D}{1-D}$$

The equation to determine the inductors L1 and L2 is,

$$L_1 = \frac{D \times Vo}{f \times \Delta Io}$$

$$L_2 = \frac{D \times Vin}{2f \times \Delta Io \times \Delta Vin}$$

The equation to determine the capacitor C1 is,

$$C_1 = \frac{Io}{f \times \Delta Vo}$$

Where,

ΔI_o= 2% of output current,

ΔV_{in}= 5% of input voltage,

ΔV_o= 5% of output voltage

So, these are the design equation of this proposed converter. Using this equations the components values are derived.

Table -1: Design Specification of The Converter

PARAMETERS	VALUES
Supply Voltage (V_{in})	16 V– 24 V
Inductor (L_1)	540μH
Inductor (L_2)	2.7μH
Capacitor (C_1)	93μF
Capacitor (C_2)	4700μF
Output Power (Po)	300W
Output Voltage (Vo)	60V
Output Current (Io)	5 A
Switching frequency (f_s)	30 kHz

4.1 Open loop simulation of DC-DC SEPIC Converter

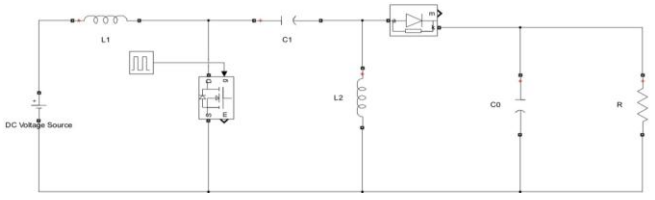

Fig -2: Open loop simulation diagram of DC-DC SEPIC converter

Figure 2 shows the open loop simulation diagram of the proposed converter. This has pulse generator which gives the gate pulse to the MOSFET switch of proposed converter. The duty cycle of the switch controls the output voltage. So by varying the duty cycle, The output voltage can be varied.

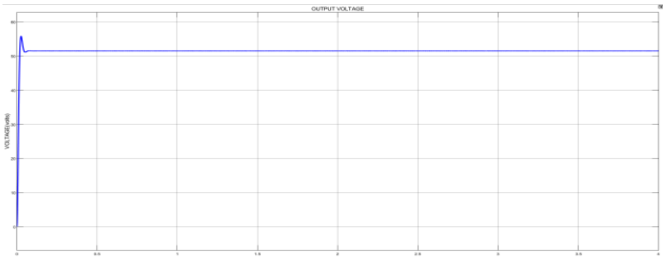

Fig-3: Output voltage waveform of open loop DC-DC SEPIC converter

Figure 3 shows the output voltage waveform of the DC-DC SEPIC converter under open loop. The desired output voltage of 60V is not obtained in open loop control, instead an output voltage of 51.5V is obtained.

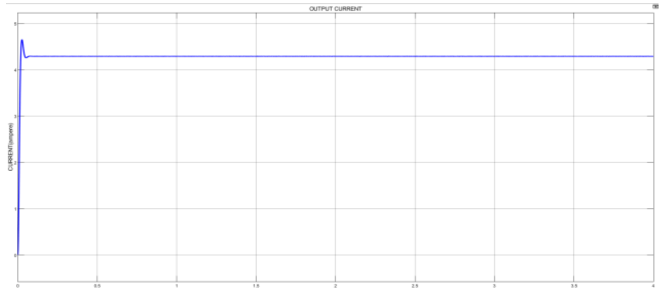

Fig-4: Output current waveform of open loop DC-DC SEPIC converter

Figure 4 shows the output current waveform of the DC-DC SEPIC converter under open loop. The desired output current is 5A. But in open loop 4.5A of current is only obtained.

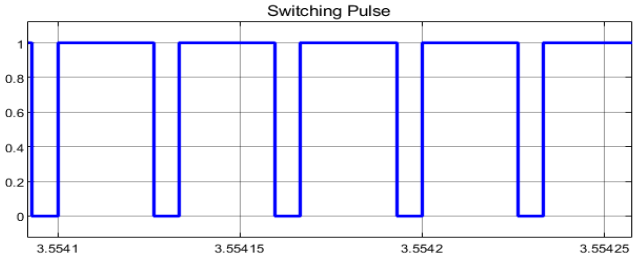

Fig-5: Switching Pulse Waveform of DC-DC SEPIC Converter

Figure 5 shows the switching pulsewaveform of the proposed DC-DC SEPIC converter which is generated by pulse generator. Here the switching frequency(fs) is 30KHz. The duty cycle of is given by this pulse generator.

4.2 Closed Loop Simulation of DC-DC SEPIC Converter using PI Controller

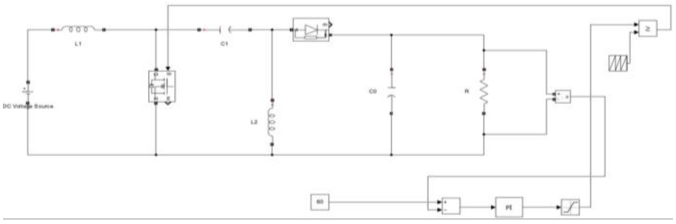

Fig-6: Closed Loop Simulation Diagram of DC-DC SEPIC Converter using PI Controller

Figure 6 shows the closed loop simulation diagram of the proposed converter. In open loop, the expected outputs are not obtained. So, moving to closed loop system. This circuit has a feedback circuit, which is controlled by PI controller. The PI controller is the most commonly used in closed loop systems because of its performance in terms of simplicity. It produces an error signal by comparing the desired output signal with the actual output signal.

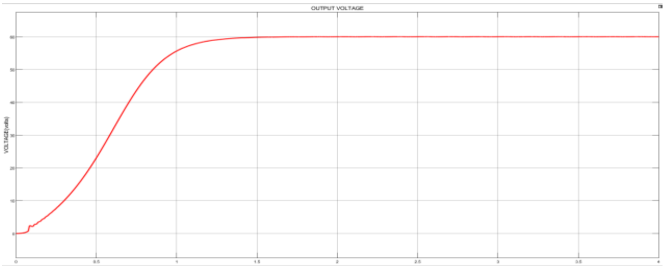

Fig -7: Output Voltage Waveform of Closed loopDC-DC SEPIC Converter

Figure 7 shows the output voltage waveform of the DC-DC SEPIC Converter under Closed loop. The desired output voltage of 60V is obtained at 1.5 seconds. Then the output voltage becomes stable and constant in closed loop system. The allowable ripple voltage of DC converters is 5% of output voltage. In this proposed converter, it is very minimum which less than its 1% of output voltage.

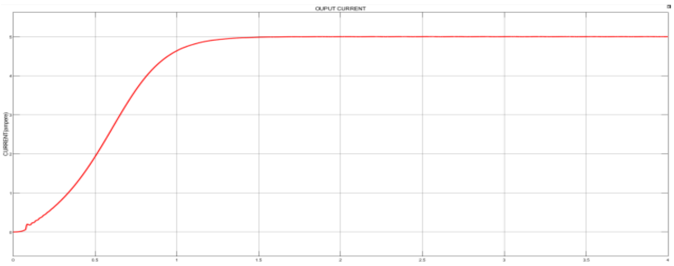

Fig -8: Output Current Waveform of Closed loopDC-DC SEPIC Converter

Figure 8 shows the output Current waveform of the DC-DC SEPIC Converter under Closed loop. The desired output Current of 5A is obtained in Closed loop control. The allowable ripple current of DC converters is 2% of output current. In this proposed converter, it is very minimum which less than its 0.5% of output current. So by this, the converter is justified as a ripple free converter.

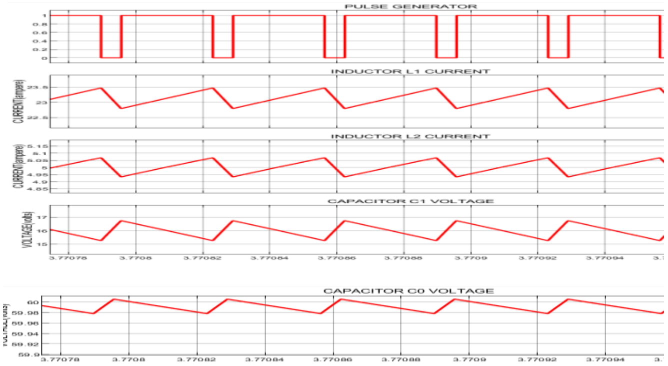

***Fig -9:** Waveforms of Switching pulse, InductorL1 Current, Inductor L2 Current, Capacitor C1 Voltage, Capacitor C2 Voltage under Closed loop*

Figure 9 shows the waveforms of switching pulse, inductor L_1 current, inductor L_2 current, capacitor C_1 voltage, capacitor C_2 voltage of DC-DC SEPIC converter. When, MOSFET switch is turned ON, the inductor L1 and L2 are charging and the capacitor C_1 and C_2 are discharging. When, MOSFET Switch is turned OFF, the inductor L1 and L2 are discharging and the capacitor C_1 and C_2 are getting charged. This proposed converter operates in continuousconduction mode (CCM) when simulated under closed loop.

Table-2: Open-loop analysis of constant input voltage-variable duty cycle

V_{in}	I_{in}	V_{out}	I_{out}	D	Efficiency
16	0.07851	3.201	0.2668	20	67.99%
16	0.2162	6.04	0.5033	30	87.87%
16	0.5661	9.807	0.8172	40	88.48%
16	1.285	15.04	1.253	50	91.65%
16	2.875	22.62	1.885	60	92.72%
16	6.782	34.52	2.876	70	91.49%
16	18.15	54.1	4.509	80	84.02%

Table.2 gives the analysis of constant input voltage and variable duty cycle under open-loop condition. The input voltage is kept constant 16V then varying the duty cycle by pulse generator the output voltage is varied. The output voltage is both less and greater than the input voltage corresponding to the duty cycle. By this table, the proposed converter achieve the both buck and boost operation.

Table -3: Closed-loop analysis of variable input voltage – constant output voltage

V_{in}	I_{in}	V_{out}	I_{out}	Efficiency
16	22.97	60	5	84.58%
18	19.43	60	5	85.38%
20	16.98	60	5	87.48%
22	15.11	60	5	89.88%
24	13.61	60	5	91.18%

Table.3 gives the analysis of Variable Input Voltage and Constant Output Voltage under Closed-loop. The input voltage is varied from 16 - 24V and the output reference voltage is 60V that is kept constant. By varying the input voltage, the efficiency of the proposed converter is also varied. There is a gradual increase in efficiency when the input voltage is increased gradually. The input current is reduced, as increase in input voltage.

Table -4: Closed-loop analysis of constant input voltage -variable output voltage

V_{in}	I_{in}	V_{out}	I_{out}	Efficiency
16	13.64	48	4	88.91%
16	17.83	54	4.501	84.34%
16	22.97	60	5	84.58%
16	29.28	66	5.5	77.09%
16	33.86	72	5.928	72.13%

Table.4 gives the analysis of constant input voltage and variable output voltage. The input voltage is kept constant and the output reference voltage is varied. The proposed converter is provide the expected output voltages. But, above the designed output voltage (60V) the efficiency of the converter is reduced. The input current is also increased by increasing the output reference voltage.

Table -5: Closed-loop analysis of constant input voltage - constant output voltage - variable Load

V_{in}	I_{in}	V_{out}	I_{out}	Efficiency	% of resistive load
16	50.71	60	8.283	63.98%	60%
16	37.56	60	7.143	72.02%	70%
16	30.82	60	6.25	76.68%	80%
16	25.76	60	6.00	78.89%	90%
16	22.97	60	5	84.25%	100%
16	19	60	4.287	84.78%	120%
16	16.7	60	3.837	85.40%	130%
16	15.33	60	3.572	86.35%	140%

Table .5 gives the analysis of closed loop constant input voltage and constant output voltage with variable resistive load. The input voltage and output voltage both are kept constant. The resistive load is only varied. The full load resistance value is 12Ω. The converter is also tested in overloaded condition. Here up to 140% of full load is tested, which is 16.8Ω. The converter works properly and gives the expected output voltage and efficiency is also slightly increased.

5. CONCLUSIONS

In this paper, the Design, Analysis and Simulation of DC-DC SEPIC Converter have been carried out for (16-22V) input and 60V output. Both open loop and closed loop analysis have been done for the designed converter. The proposed converter not able to achieve the expected voltage and current in open loop system. So, moving to closed loop system. The closed loop system gives the required voltage (60V) and current (5A). The efficiency of the proposed converter is 85%. By taking varies analysis, the proposed converter can able to operate in both buck and boost operation. The proposed converter can able to do both step up and step down the input voltage. The Proposed converter operates in Continuous Conduction Mode (CCM). The output Current has low ripple and This converter has high Efficiency.

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