Modelling and Implementation of SEPIC Converter for Electric Vehicle Application

Chava Sunil Kumar[1], Udayini Vanga[1], Srilekha Akula[1]

[1]Department of Electrical & Electronics Engineering, BVRIT HYDERABAD College of Engineering for Women, Hyderabad, Telangana – 500090, India
Email: sunilkumar.ch@bvrithyderabad.edu.in

Abstract.

Converter is an important electronic component and plays a vital role in working of electric vehicle. Among all the converters Single-Ended Primary-Inductor Converter (SEPIC) has a unique feature that is, it gives constant output voltage irrespective of the varying input voltage because of this it is used for LED lightening system in electric vehicle. It also provides better voltage control, provides low input current ripple because of which harmonics can be reduced and large capacitor design is not required, it also has lesser electrical stress when compared with any other converter. This paper presents the design and implement of SEPIC converter for LED lightening system of electric vehicle by simulating it using MATLAB software. The proposed design technique is effectively validated using MATLAB/Simulink and implemented in hardware.

Keywords. SEPIC converter, PI controller, Electric vehicle.

1. INTRODUCTION

Converters are mostly used to enhance or buck voltage in response to demand. The resultant output voltage falls within the input voltage range of the SEPIC Converter. A converter that alters voltage is appropriate in this situation. Since buck-boost converters only need one inductor and one capacitor, they are less costly [1]. These converters do, however, contain a considerable amount of input current ripple. In many buck-boost converter applications, these ripples produce harmonics. A big capacitor LC filter is used to filter out these harmonics from the converter. However, this results in the converter becoming costly or ineffective. The fact that the output voltage is inverted by the buck boost converter complicates the use of the device further. The Cuk converter, however, overcomes these issues by including an extra capacitor and inductor. Cuk and buck-boost converter operation, however, put a lot of electrical strain on the parts, which might cause failure or overheating of the device. Both of these problems are addressed by SEPIC converters.

e-ISBN: 9788770229647 https://doi.org/10.13052/rp-9788770229647.028

2. SYSTEM CONFIGURATION

Figure 2.1 depicts a simple SEPIC's schematic design. By stepping up or down the input voltage in accordance with the demand, a SEPIC converter takes a variable input and produces a constant output voltage. The amount of energy transported is controlled by switch Q1, which is frequently a transistor like a MOSFET [2]. Compared to bipolar junction transistors (BJTs), MOSFETs have a substantially higher input impedance and a smaller voltage drop. Additionally, they do not need biassing resistors since, unlike BJTs, the switching of MOSFETs is controlled by a voltage difference rather than a current difference.

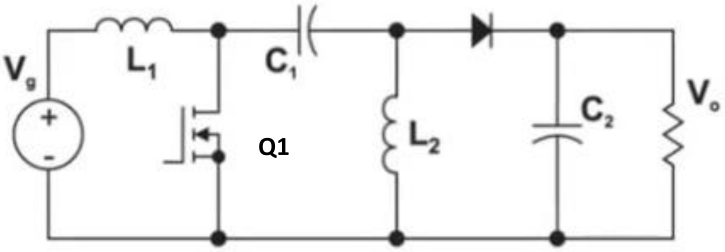

Figure 2.1. Schematic of SEPIC Converter

The converter shown in figure 2.2 contains an input capacitor, output capacitor, two inductors, a coupling capacitor, a control switch (MOSFET is considered here), an uncontrolled (Diode is considered here). The input terminal of SEPIC is connected to one terminal of the first inductor another terminal of L_{1A} is connected to capacitor Cp and drain of Q1. Second terminal Cp is connected to second inductor and anode of diode D1.Here L_{1A} is the first inductor and Cp is the coupling capacitor. The cathode of diode D1 is connected to the output capacitor. A PWM signal is given to gate of the Q1 and remaining terminals of the components are grounded as shown in figure 2.2.

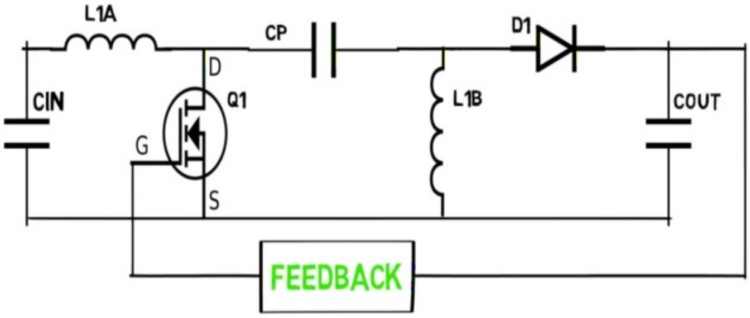

Figure 2.2. Schematic of SEPIC Converter with feedback.

e-ISBN: 9788770229647 https://doi.org/10.13052/rp-9788770229647.028

3. ANALYSIS OF SEPIC DESIGN

Input Voltage consideration [3, 4, 8]

$$V_{IN} = V_{L1} + V_{C1} + V_{L2} \tag{3.1}$$

Where V_{L1} is the voltage across first inductor.

Inductor Selection

A good general rule of thumb for calculating inductance is to allow the peak-to-peak ripple current to be around 40% of the highest input current at the lowest input voltage. Given by: The ripple current passing through inductors L1 and L2 of equal amplitude.

$$\Delta I_L = I_{IN} \times 40\% = I_{OUT} \times \frac{V_{OUT}}{V_{IN(min)}} \times 40\% \tag{3.2}$$

The inductor value is computed as follows:

$$L1 = L2 = L = \frac{V_{IN(min)}}{\Delta I_{IN} \times f_{sw}} \times D_{max} \tag{3.3}$$

The switching frequency is f_{sw}, and the duty cycle at the minimumV_{in} is D_{max}. To guarantee that the inductor does not saturate, the peak current is provided by:

$$I_{L1\,(peak)} = I_{OUT} \times \frac{V_{OUT} + V_D}{V_{IN(min)}} \times \{1 + \frac{40\%}{2}\} \tag{3.4}$$

$$I_{L2\,(peak)} = I_{OUT} \times \{1 + \frac{40\%}{2}\} \tag{3.5}$$

Coupling Capacitor Selection

The SEPIC capacitor, Cs, is chosen based on the RMS current, which is provided by:

$$I_{Cs\,(rms)} = I_{OUT} \text{ x } \sqrt{\frac{V_{OUT} + V_D}{V_{IN(min)}}} \tag{3.6}$$

The peak-to-peak ripple voltage on Cs:

$$\Delta V_{Cs} = \frac{I_{OUT} \times D_{max}}{Cs \times f_{sw}} \tag{3.7}$$

4. CONTROL STRATEGY

To regulate the SEPIC voltage, a control strategy for regulating the switch S1. Closed loop control is achieved with PI controllers. The following are the steps involved in tuning PI controllers:

1) Linearizing the plant
2) Identifying the new plant
3) Simulate data
4) Plant identification.

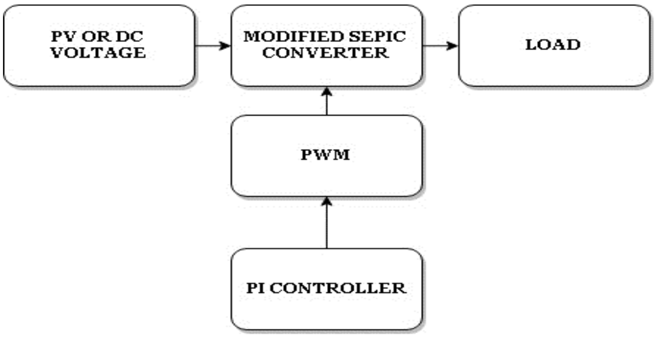

Figure 4.1. (a) Block diagram of PV system

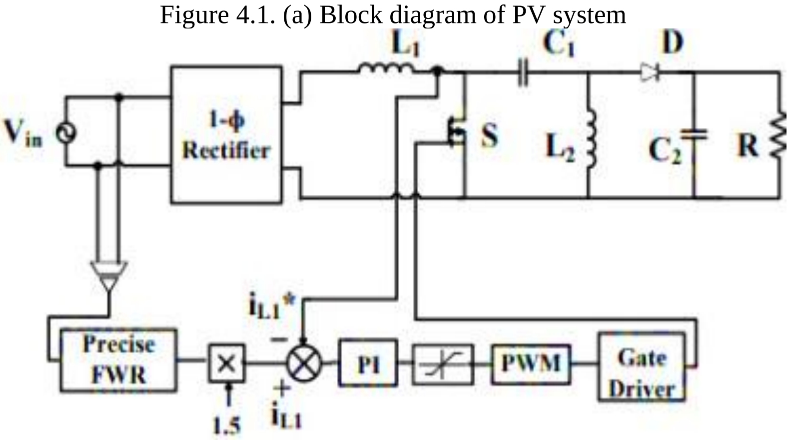

Figure 4.1. (b) Control diagram.

The control strategy for closed loop SEPIC converter is shown in figure4.1. (a) & (b)In this configuration PI (Proportional Integrator) Controller is used to compare the output voltage with the required voltage. In closed loop configuration some part of the output is taken from the output and is given to a comparator. Reference signal as reference voltage is also given to comparator. The output of comparator is given to PI controller. The output of SEPIC is obtained by tuning the PI Controller (using plant identification method). According to the required output we get the output voltage.

5. SIMULATION RESULTS

The findings of the SEPIC converter employing the PI control scheme are shown in this part for two test scenarios. Table.1 shows the nominal parameters for the simulation research. MATLAB is used to implement the complete model. The following sections illustrate the two operational situations for a step change in source and load [5].

Table 1: Nominal Parameters for Simulation study

S. No	Parameters	Value

1	Input Voltage (V_{in})	20 V
2	Inductance (L_1& L_2)	1.43mH
3	Capacitance (C_1& C_2)	150 µF
4	Resistance (R)	6.5 Ω

A. Source Voltage Step Change:

The simulation results for step change in source voltage for PI control schemes are shown in Fig. At t=0.2sec, source voltage increases from 10V to 20V and bring back to 10V at t=0.6sec. Due to sudden increase in source voltage results surge in load voltage. The load voltage is regulated in 3msec and 10msec at 0.2sec and 0.6sec respectively.

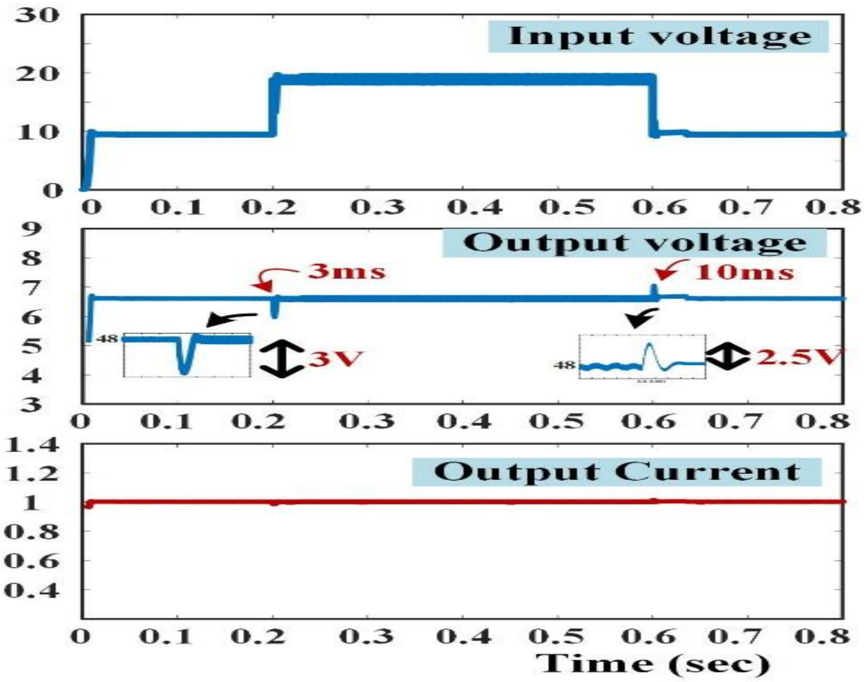

Figure 5.1. Results of simulation for a step change in source voltage

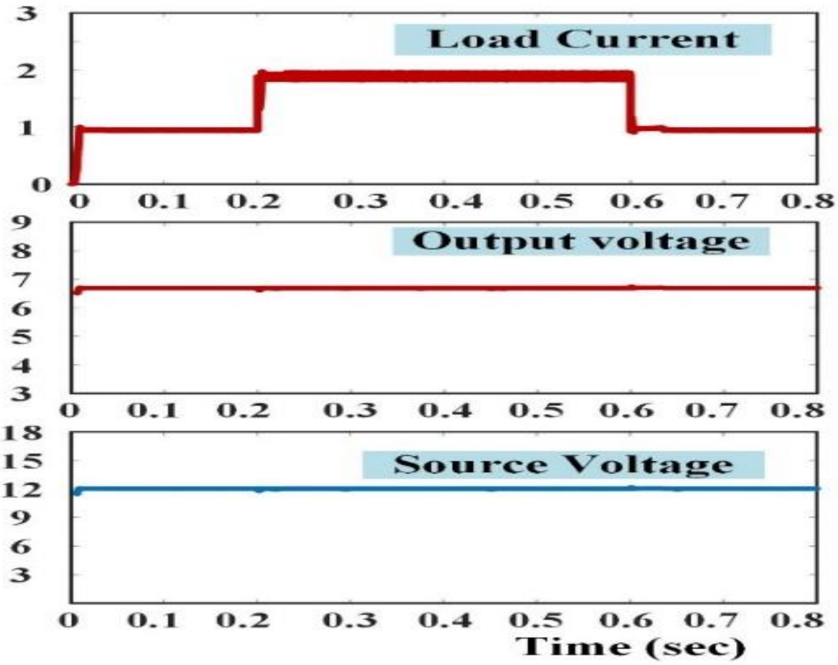

Figure 5.2. Simulation results for a load step change

B. Simulation results for step change in load:

The simulation results for PI control methods for a step change in load are shown in Fig. At t=0.2sec, load current increases from 1A to 2A and bring back to 1A at t=0.6sec. Due to sudden increase in load demand results surge in load voltage. The load voltage is regulated 6.5V.

6. HARDWARE IMPLEMENTATION

The TMS320F28069 controller board has been used in the development of the suggested method. The method is created in MATLAB with Simulink blocks. For the creation of high-speed, multi-variable digital controllers and real-time simulations in a variety of sectors, the TMS320F28069 controller board was created particularly. It is a whole real-time control system powered by a 250MHz, 603 PowerPC floating point processor. A/D and D/A converters are also available to handle analogue feedback signals. Users may debug the application, adjust settings, and track execution outcomes in real-time depending on the PC and DSP's connection capabilities.

There are two cases in the hardware output of SEPIC Converter they are:

i)When the headlight of electric vehicle glows with a bright light

The figure 6.1 shows the headlight that is used in the electric vehicles glowing with a bright light because of the output obtained from the closed loop SEPIC Converter which has a duty ratio of 0.4 with input voltage as 20 volts and output voltage of 12 volts using LAUNCHXL- F28069M board and subsequently firing pulses are generated [6, 7].The pulses generated are given to MOSFET in the hardware circuit built. The constant output voltage obtained from the hardware circuit is given to headlight of electric vehicle.

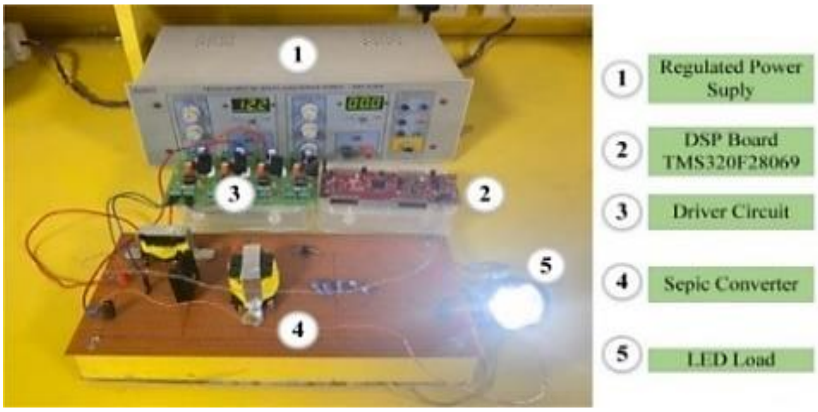

Figure 6.1. Hardware setup for bright light

ii) When the headlight of electric vehicle glows with a dim light

The figure 6.2 shows the headlight that is used in the electric vehicles glowing with a dim light because of the output obtained from the closed loop SEPIC Converter which has a duty ratio of 0.1 with input voltage as 20 volts and output voltage of 8 volts.

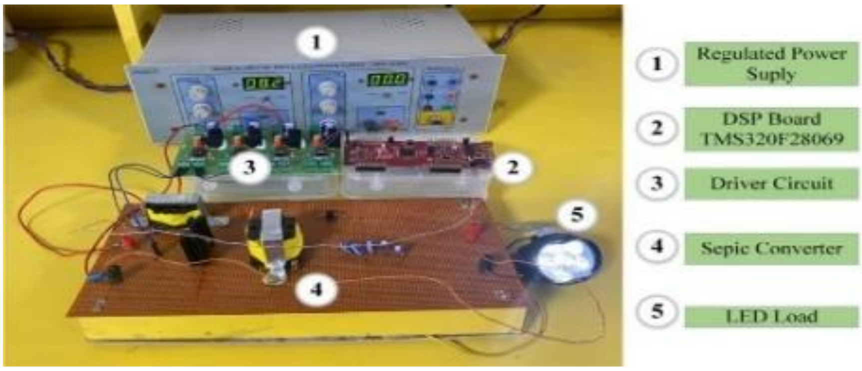

Figure 6.2. Hardware setup for dim light

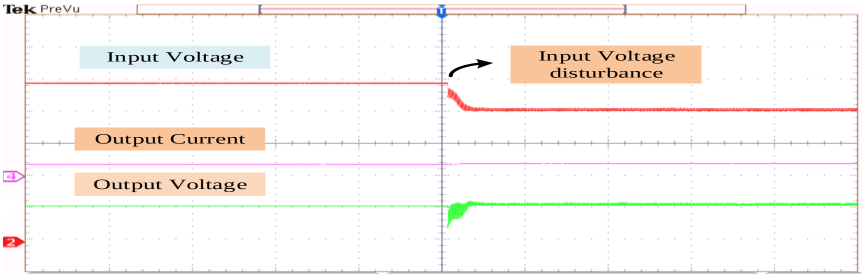

Figure 6.3 (a) Source side disturbances

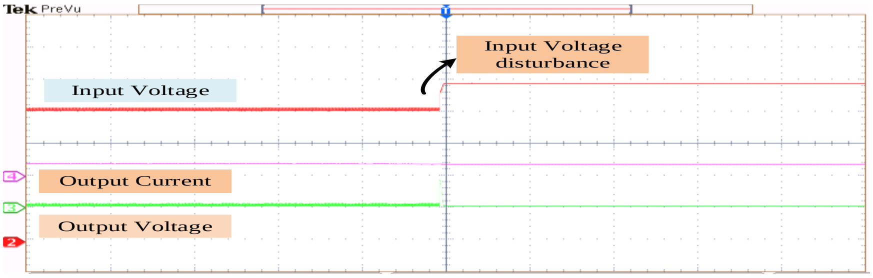

Figure 6.3(b) Source side disturbances

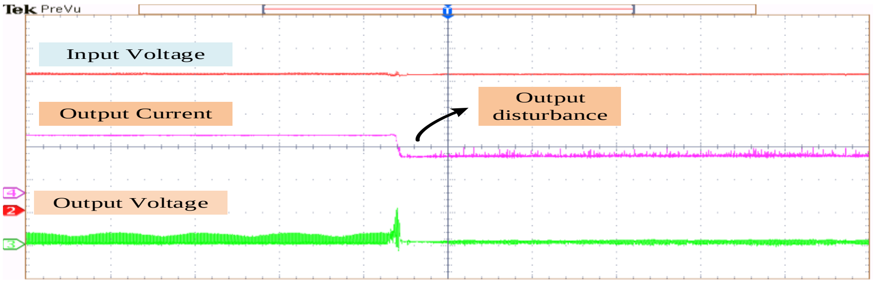

Figure 6.4 Load Side disturbances

The constant output voltage obtained from the hardware circuit is given to headlight of electric vehicle. Figure 6.3(a,b) and 6.4 shows the source and load disturbances.

7. CONCLUSION

The SEPIC may operate with input voltages that are more or lower than the output voltage's regulation. The SEPIC design has minimal active components, a straightforward controller, and clamped switching waveforms for low noise operation in addition to being able to function as both a buck and a boost. The simulation results for closed loop control show that the duty cycle may be adjusted to regulate DC output voltage as necessary. For the hardware implementation of the SEPIC Converter for the electrical vehicle lighting application from TEXAS instruments, the Simulink model of the SEPIC Converter with closed loop and open loop is completed and the results are seen.

REFERENCES

[1] Reeto Jose. K, Anisha Shivanandan, Vani Venugopal and Kshemada Devi, 2015. V, DC-DC SEPIC Converter Topologies, Int. Jnl. of Research in Engg. and Technology, 04(05): 20-23.

[2] Venkatanarayanan, S. and M. Saravanan, 2014. Proportional-integral Control for SEPIC Converter, Research Jnl. of Applied Sciences, Engineering and Technology, 8(5): 623-629.

[3] Wael A. Salah, Dahaman Ishak, Basem Abu Zneid, Amir Abu Al Aish, Mohd Shawal Jadin and Anees Abu Sneineh, 2015. Implementation of PWM control strategy for torque ripples reduction in brushless DC motors, Electr Eng., 97: 239-250.

[4] Antonietta De Nardo, Nicola Femia and Walter Zamboni, 2012. Designing a mixed electrolytic/ceramic filter capacitor in DC-DC converters, Analog Integr Circ Sig Process, 73: 3-45.

[5] Yuh-Shyan Hwang, An Liu, Chia-Hsuan Chen, Yi Tsen Ku, jiann-Jong Chen and Cheng - Chieh Yu, 2014. A Continuous condition mode low-ripple high- efficiency charge-pump boost converter, analog integer Circ Sig process,79: 355-369.

[6] Uma maheswari, M.G., G. Uma and L. Annie Isabella, 2014. Analysis and design of digital predictive controller for PFC Cuk converter, J Comput Electron,13: 142-154.

[7] Dewei Jia, Yubo Duan and Jing Liu, 2009. Emerging technologies to power next generation mobile electronic devices using solar energy, Front. Energy Power Eng. China, 3(3): 262-288.

[8] Anbu kumar Kavitha and Govindarajan Uma, 2010. Control of Chaos in SEPIC DC-DC Converter, Int. Journal of Control, Automation and System,8(6):132.

e-ISBN: 9788770229647 https://doi.org/10.13052/rp-9788770229647.028