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DESIGN AND SIMULATION OF SEPIC CONVERTER

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Abstract:

This topic presents a SEPIC (Single-Ended Primary Inductor Converter) Converter and Control method suitable for dc-dc Power Conversion. SEPIC is chosen since it has positive voltage gain and higher characteristics than any other converter. The proposed design provides high efficiency over a wide range of input and output voltage ranges, up & down voltage conversion, small size and excellent transient performance. The Converter regulates the output using an ON-OFF control scheme modulating at a fixed frequency and duty ratio operation. This control method enables a fast transient response.

Key words: *DC-DC Converter, Synchronous SEPIC Converter, PWM, PID feedback controller*.

1. INTRODUCTION:

Transformations of a DC voltage to some other DC voltage level giving a regulated output are called choppers. In chopper circuits switch operates as an electronic switch i e; by completely ON or completely OFF. The DC component of the output voltage can be unflappable by adjusting the duty ratio D.

First basic converter is the buck converter. It always brings down (bucks) the input voltage.

Boost converter is the next basic converter. It boosts the input voltage [5].

Suppose if I have an application where I need both bucking and boosting operation. When these two converters are connected in series the above need can be fulfilled. For this, two separate controllers and switches are required. The single converters which gives both buck and boost operations is SEPIC (Single ended primary inductance converter) [1]. It is greatly used in switching circuits and PFC (Power Factor Correction) circuits because it has:

1) Input and output voltage polarities are identical.
2) Inductor ripple current is less.
3) Bucking and Boosting operation.
4) Many outputs can be taken.

Power electronic circuits have more nonlinear characteristics. Operation of the circuits is mostly by on-off switch control.

This report introduces a single-ended primary inductor conventional (SEPIC) converter, its open loop simulation results (5MHz), simulation of SEPIC converter with PID controller, its simulation results.

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2. BLOCK DIAGRAM:

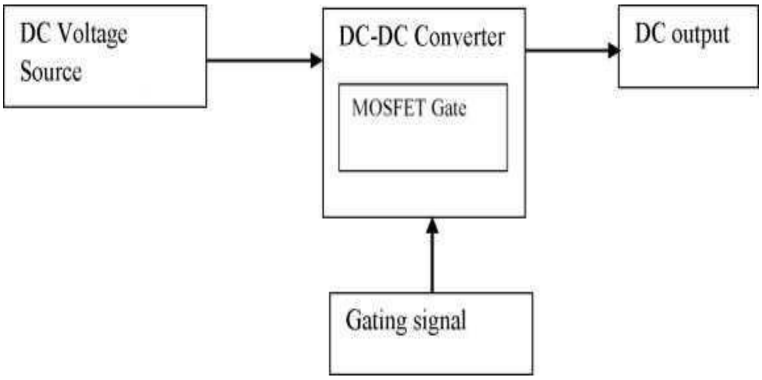

Fig1: Block diagram of SEPIC converter

Input source: Input of 12V fed to the DC-DC Converter.

Converters: one of the type of a DC-DC Converter is used. It is a SEPIC Converter. It is a single circuit which performs both the operations of stepping up and stepping down of Voltage at a constant frequency at a particular duty cycle [2][4]. Here the switch used is a MOSFET [5]

Gating Signal: The gating signals to the MOSFET is given using a PWM technique which contains LM555 Timer, a low pass filter and a comparator which compares the filter output with a constant 5V DC Voltage. The switching frequency is 50 KHz.

DC Output: The output obtained depends on the Duty Ratio 'D' [3], if Duty ratio above 0.5 condition the circuit will boost the voltage if Duty ratio below 0.5 condition the circuit will buck the voltage [4]. The load used in the DC Output is a Resistive Load.

3. CIRCUIT ANALYSIS OF CONVENTIONAL SEPIC CONVERTER:

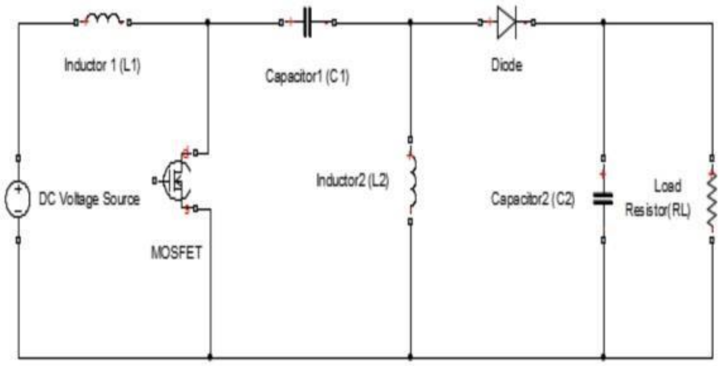

Fig2: Conventional SEPIC converter

The conventional SEPIC converter design with various elements such as an input supply voltage (Vin), duty ratio with switch (D), a diode, capacitors (C1 & C2), Inductors (L1 & L2) along with a load resister (R_L). For better understanding in the circuit only R load is used here. Based on the requirements different types of loads can be used. Thus, the required response can be obtained. Ideal elements are assumed. The inductors elements current to be assumed continuous.

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4. WORKING PRINCIPAL OF SEPIC CONVERTER

SEPIC is a circuit, which can either buck or boost output voltage. In the SEPIC converter the switching devices present in it is controlled by the duty ratio for obtaining the required output voltage. The equivalent circuits of SEPIC converter during its switching status (closed and open) are shown [5][7].

4.1. WHEN SWITCH IS CLOSED:

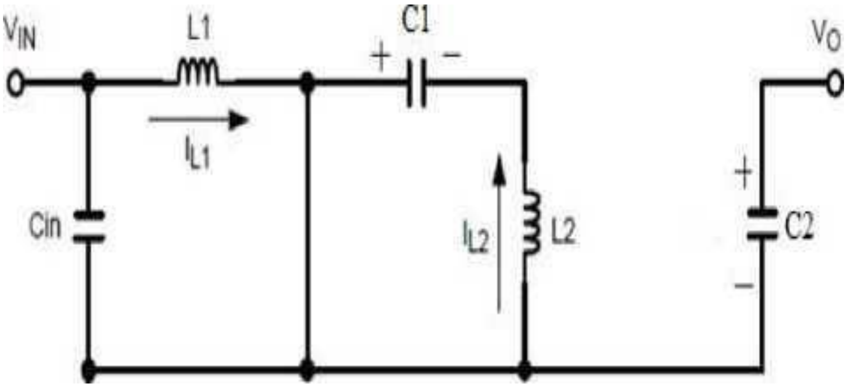

Fig3: SEPIC (Switch-Closed)

The inductor element L1 stores the energy in it. During this condition the input voltage is equal to the inductor voltage. Thus, transferring the energy stored in capacitor C1 to the other inductor element L2. The capacitor C2 supplies the energy to the load [6] as shown in Fig3

4.2. WHEN SWITCH OPEN:

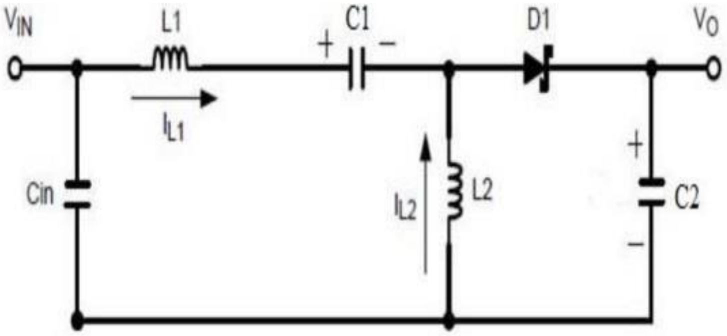

Fig4: SEPIC (switch-open)

Inductor L1 is the energy storing element which transfers the energy to the capacitance C1 during open condition. Similarly, through diode D the inductor L2 is the energy storing element which transfers its energy to capacitance C2.and supplies the require energy to Load [6].

5. SEPIC CONVERTER WITH PID CONTROLLER

In this will see about the basics of PID controller and SEPICs block diagram with the controller.

5.1. BASIC PID CONTROLLER:

There are 3 basic behavior types or modes in PID Controller. They are P - Proportional mode, I - Integrative mode and D - Derivative mode [5].

- In P mode, controller output is proportional to steady state error. It gives us an offset error and large time is required to get the steady state.
- In I mode the output of controller is varied at such a rate that it becomes proportional to error signal. It removes offset but acts slowly.
- Error elimination is done by PI Controller.
- PID controller has all above features:

Response of system is very fast in Derivative mode, makes error zero -Integrative mode and elimination of oscillations- P mode.

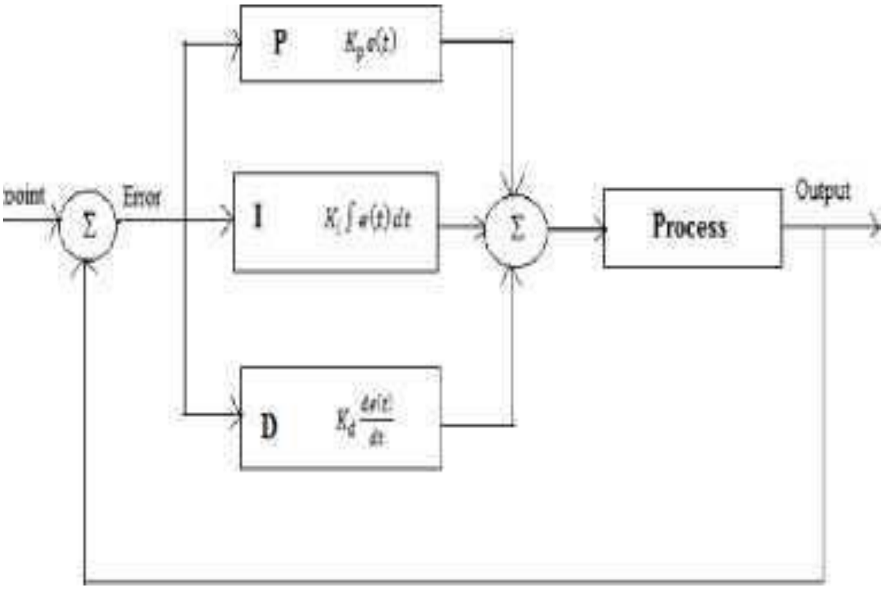

Fig5: PID Controller

5.2. BLOCK DIAGRAM OF CONVERTER WITH CONTROLLER

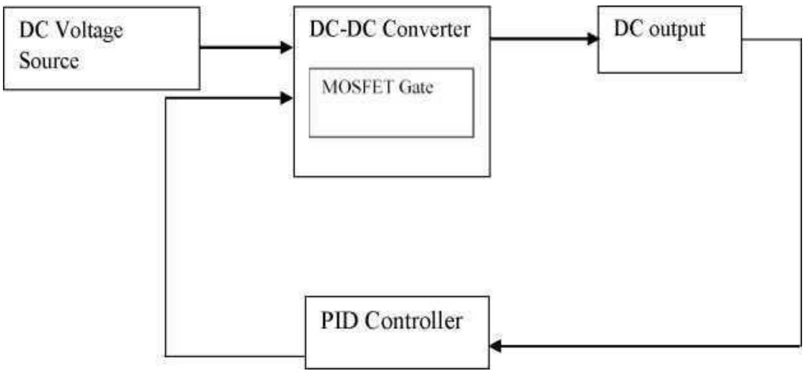

Fig6: Block diagram of converter using controller

DC Voltage Source: A DC Voltage source is fed to the DC-DC Converter.

DC-DC Converter: DC-DC Converter used here is a SEPIC Converter. It is a single circuit which performs both the operations of Stepping up and stepping down of Voltage at a constant frequency at a particular duty cycle [7]. Here the switch used is a MOSFET

Gating Signal: The gating signals to the MOSFET is given using a PWM technique

DC Output: The output obtained depends on the Duty Ratio 'D' ,

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The boost operation happens if D > 0.5

The buck operation happens if D < 0.5 The load used in the DC Output is a Resistive Load.

PID Controller: Output error from the DC is fed to the PID Controller. The PID Controller circuitry is a combination of 3 controllers namely, Proportional controller, Integrator controller and Derivative controller [5]. By selecting suitable values of Kp, Ki, Kd we control the transient and steady state response of the system.

6. SIMULATION OF A CONVENTIONAL SEPIC CONVERTER IN MATLAB/ SIMULINK

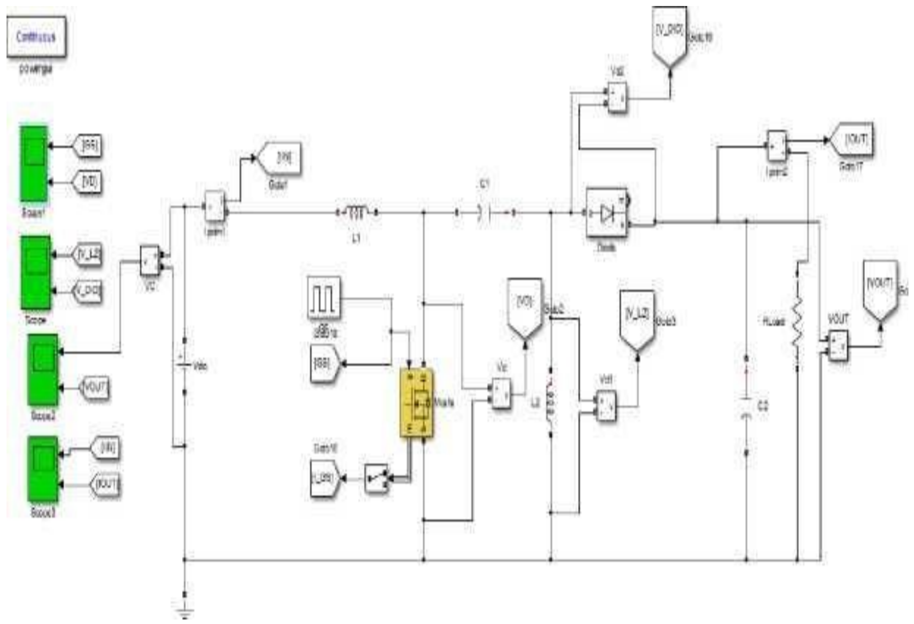

Fig7: Simulink diagram of convention SEPIC converter

f = 5MHz

Vin = 3.6V

L1 = L2 = 64.89 micro-H.

C1 = 10 micro-F

C2 = 39.144nF

D = 30%

R_L = 50 ohm

Forward voltage of diode = 0.8V

Simulation time = 0.01s

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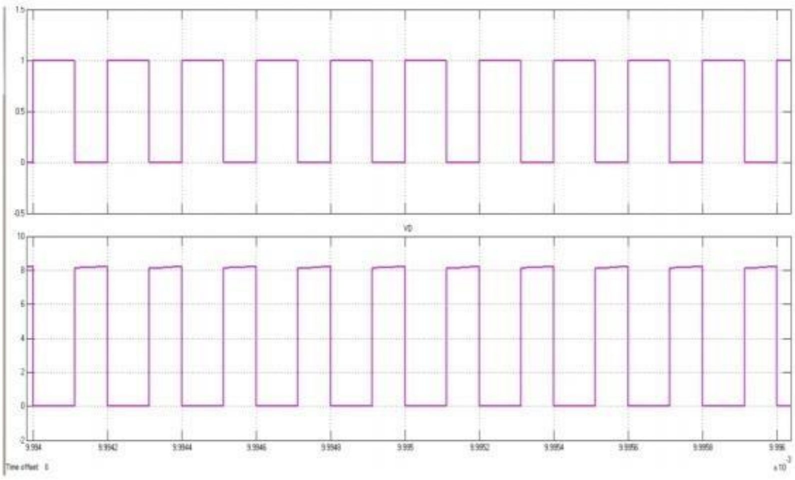

Fig8: Getting pulses of switch, internal diode of MOSFET

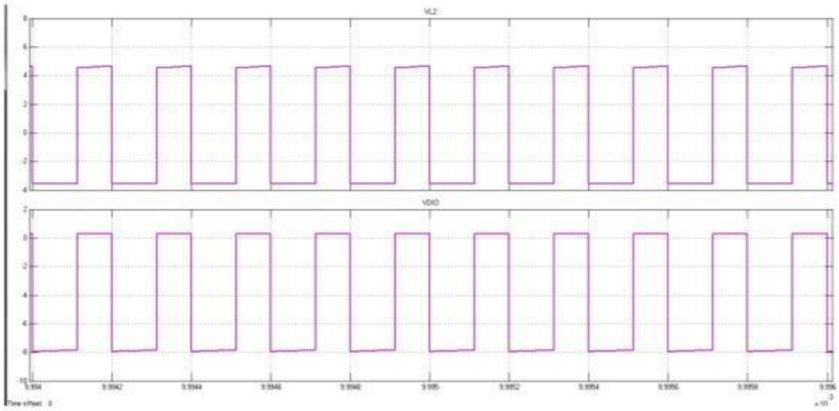

Fig9: Voltage across L2 and diode

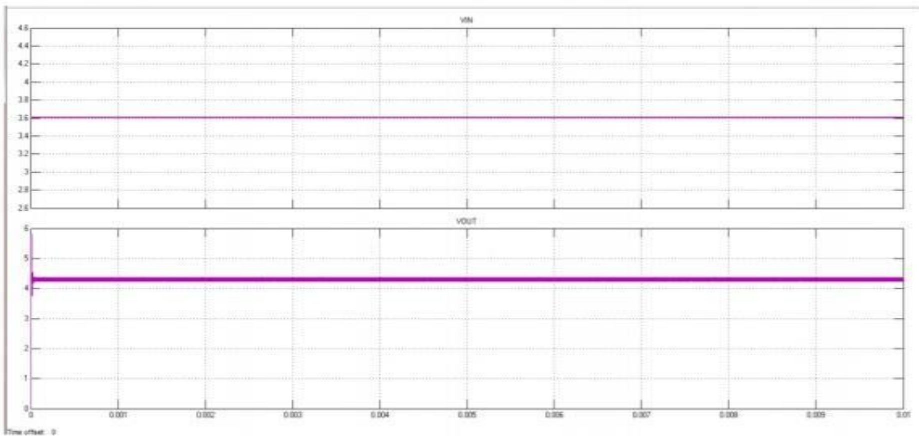

Fig10: Input voltage and output voltage waveforms

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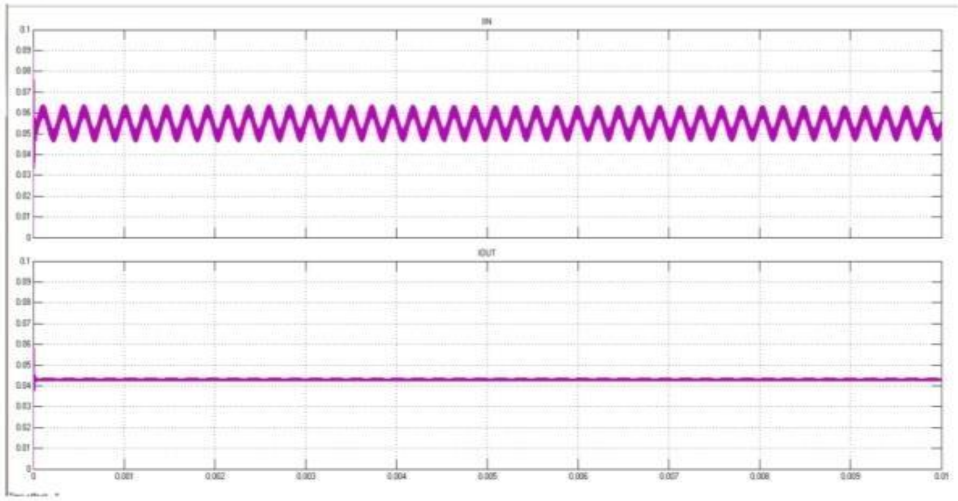

Fig11: input current and output current waveforms

7. SIMULATIN OF SEPIC WITH PID CONTROLLER

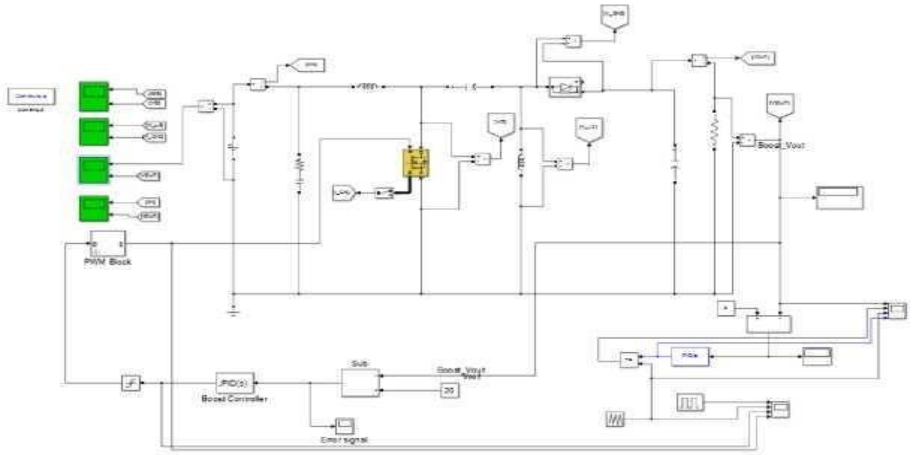

Fig12: Simulation diagram of SEPIC Converter with PID Controller

f = 5MHz, Vin = 5V, L1 = L2 = 64.89micro H, C1= 10 µ F, C2 = 39.144 n F, D = 56%, RL=100 ohm, Forward voltage of diode = 0.8V, Simulation time = 0.005s, Vref = 9V, Kp = 0.001, Ki = 0.95, Kd = 0, Filter coefficient = 100.

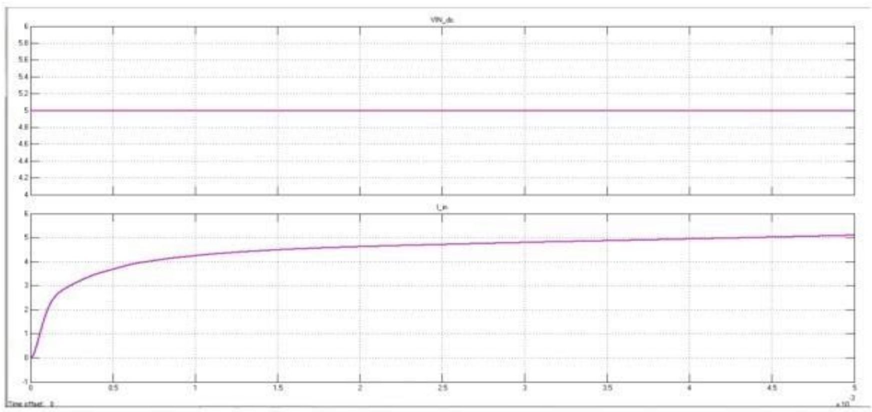

Fig13: Input voltage and input current of SEPIC using PID Controller

8. CONCLUSION:

The single ended primary inductor converter (SEPIC) is able to function both buck and boost output voltage. By the switching devices present in it is controlled by the duty ratio `D` to get required output voltage. The boost operation happens if D > 0.5. The buck operation happens if D < 0. 5 and PID controller is also used. Converter is operated in two modes (switch is open & closed) only. In which it can step-up or step-down the output voltage. This converter was simulated using MATLAB or Simulink software.

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