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Design and Simulation of Closed Loop DC/DC Synchronous SEPIC Converter using PID Feedback Controller

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Abstract - *This paper proposes the Design and simulation of closed loop DC/DC synchronous SEPIC (Single Ended Primary Inductance Converter) using PID feedback controller. SEPIC converter is utilized to defeat the restrictions of conventional buck-boost converter like inverted output, pulsating input current, high voltage stress makes it unreliable for wide range of operation. The synchronous SEPIC converter permits the voltage at its yield to be higher than, less than or equivalent to that at its input. The synchronous converters are more favourable than the any other converters because of its reduced current ripple and better efficiency. In synchronous SEPIC converters the diode in the converter is supplanted by a PWM controlled switch to make the working better by avoiding the discontinuous conduction mode and saving the diode's inverse voltage. A PID feedback controller is utilized for the closed loop control of synchronous SEPIC converters. MATLAB simulation is being utilized to validate the method and show the viability of the design of a closed loop synchronous SEPIC converter.*

Key Words: DC-DC Converter, synchronous SEPIC Converter, PWM, PID feedback controller

1. INTRODUCTION

An electronic circuit is a circuit that coverts the source of DC from one voltage level to another. A DC to DC converter is a sort of electric power converter, In that there are numerous types of DC-DC converters such as Buck converters can only reduce the voltage, boost converters can only increase voltage and buck-boost, Cúk and synchronous SEPIC converters can increases or reduces the voltage. Buck-boost converters can be less expensive that they just require a single inductor and a capacitor. This regularly makes the buck-boost inefficient. Cúk converters solve both of these problems by using an extra capacitor Both Cúk and buck-boost converter operation cause large amounts of electrical stress on components, this can bring about gadget failure or overheating. Synchronous SEPIC converters tackle both of these issues. The single-ended primary-inductor converter (SEPIC). is such a DC/DC converter which allows the electrical potential (voltage) at its yield to be higher than DC/DC converters. In like manner, in the closed loop the SEPIC converter provides positive controlled constant output voltage for the given input voltage unlike the buck-boost converter which gives negative regulated output voltage. series coupling capacitor provides the isolation which protects the converter when short circuit happens. Duty cycle controlls the yield of the SEPIC converter. The conventional power converter such as buck, boost and buck-boost converters cannot keep up a wide operation range with high efficienctiveness, especially if step up and step down voltage conversion has to be accomplished.These qualities can be obtained in a SEPIC, likewise SEPIC provides positive regulated output voltage to the given input voltage.[1]. Synchronous SEPIC are more favourable than the other different converters due to its decreased current ripple and better efficiency. The main Scope of this project is concentrated on the synchronization of the circuit which is investigated in the non-synchronous circuit, that is the swapping of the diode by switch(MOSFET) becomes the synchronous SEPIC converter. Therefore positive controlled output voltage is produced for the given input voltage which can be lower, constant or higher than the input.

1.1 synchronization of SEPIC converter

Generally the synchronization of the circuit is investigated in the non-synchronous circiuit. Thus swapping the diodes by switch becomes the synchronous SEPIC converter as shown in Fig 2 and Fig 3. The term synchronization came from synchronizing the pulses of the MOSFET switch. The requirement for synchronization is to create continuous conduction mode and the inverse voltage of the diode can be removed. [8], [9]

2. BLOCK DIAGRAM

Fig.1 shows basic block diagram of DC-DC SEPIC Converter. It is mainly consists of DC input, Synchronous SEPIC converter, PWM controller, R-Load, PID feedback controller

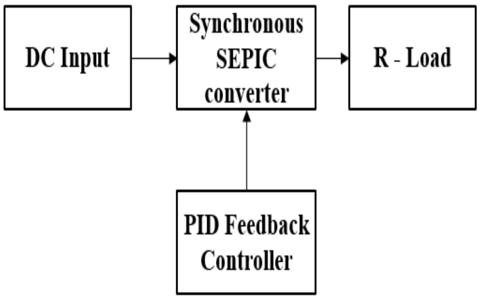

Fig -1: Block diagram of synchronous SEPIC converter using PID feedback controller

The DC Input is provided for the synchronous SEPIC converter. In this the SEPIC converter acts like a non-inverting buck boost converter. hence it is almost similar to a conventional buck-boost converter. DC to DC SEPIC is controlled through PID Feedback controller, the SEPIC converter is capable to either reduce or raise an input voltage. The PID feedback controller takes the input from the output of the SEPIC converter. Thus the Duty cycle is directly controlled by using PID feedback controller. By controlling the duty cycle, the pulse is given to the MOSFET of the synchronous SEPIC converter to increase or decrease the voltage. The output of the PID controller is given to the synchronous SEPIC converter. Thus SEPIC converter produces the DC output and given to the R-Load.[3]

3. CIRCUIT ANALYSIS OF PROPOSED TECHNOLOGY

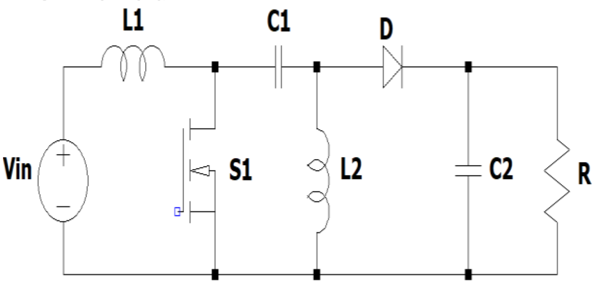

Fig -2: Basic SEPIC converter

Fig.2. shows the circuit diagram of a SEPIC converter (Non-synchronous)

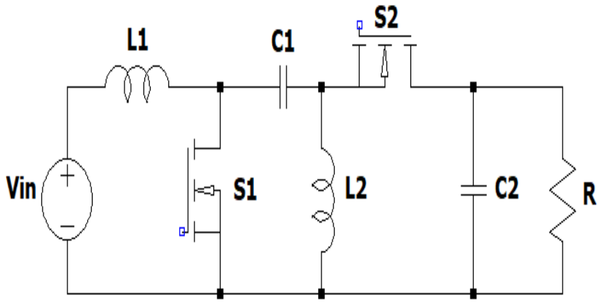

Fig -3: Synchronous SEPIC converter

Fig 3. shows the circuit of synchronous SEPIC converter.

Vin be the input voltage of the converter, Vo be the output voltage, L1 is the inductor associated at the input end. L2 is connected in corresponding to the load. The switch S1 is associated in parallel with the input voltage. S2 is associated in series with C1. The switch can be made ON and OFF during the operation. C1 and C2 is the coupling capacitor and output capacitor respectively, which stores the voltage. R is the resistance load which is connected parallel to C2.

4. MODE OF SYNCHRONOUS SEPIC CONVERTER

Continuous Conduction Mode (CCM):

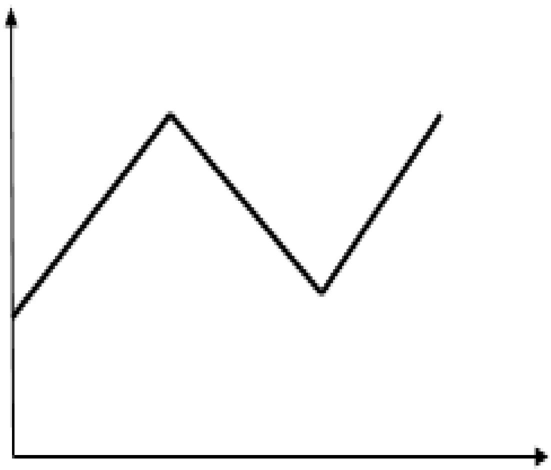

Fig-4: Continuous conduction mode

A SEPIC is supposed to be in continuous conduction mode ("continuous mode") if the current passes through the Inductor L1 never tumbles to zero. During a SEPIC's steady state operation, the typical voltage Across the capacitor C1 (Vc1) is identical to the input voltage(Vin).

Since capacitor C1 blocks the DC, the normal current across it(Ic1) is zero, making Inductor L2 the only source of load current. Therefore, the normal current through inductor L2 is identical as the normal load current and hence independent of the input voltage.[11].

5. WORKING PRINCIPLE OF SYNCHRONOUS SEPIC CONVERTER

The single-ended primary-inductance converter (SEPIC) is a step-down/step-up DC/DC converter circuit that provides a steady 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. To make the converter operate in its continuous conduction mode, it must be synchronized. The proposed strategy is to replace the diode D by another switch S2 and this is to avoid any shift and also to save the inverse diode voltage. Those two switches, S1 and S2 are controlled by two complementary PWM signals produced in the driving circuit using PID feedback controller. In this continuous conduction mode synchronous SEPIC has two working modes when "S1 is ON, S2 is OFF" and "S1 is OFF, S2 is ON".

MODE 1: When S1 is ON and the S2 is OFF the current flows across the inductor L1 and therefore L1 and L2 are charging and the capacitor C1 is discharging.

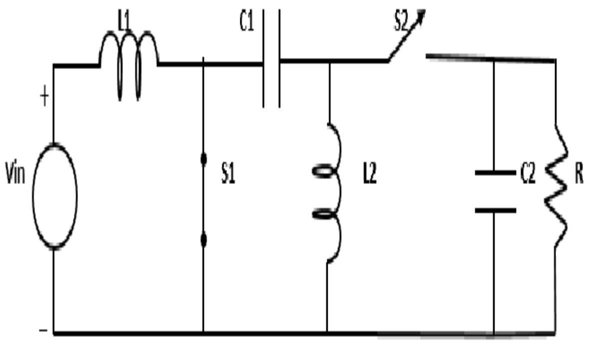

Fig-5: Synchronous SEPIC converter when 'S1' is closed and 'S2' is open

MODE 2: when S1 is OFF and S2 is ON the inductor L1 and L2 discharges then the capacitor C1 charges

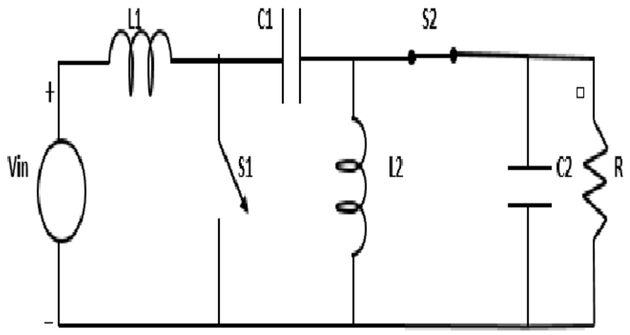

Fig-6: Synchronous SEPIC converter when 'S1' is open and 'S2'is closed

6. CLOSED LOOP SIMULINK MODEL

The SEPIC converter is simulated In matlab/simulink using the basic circuit diagram of SEPIC converter

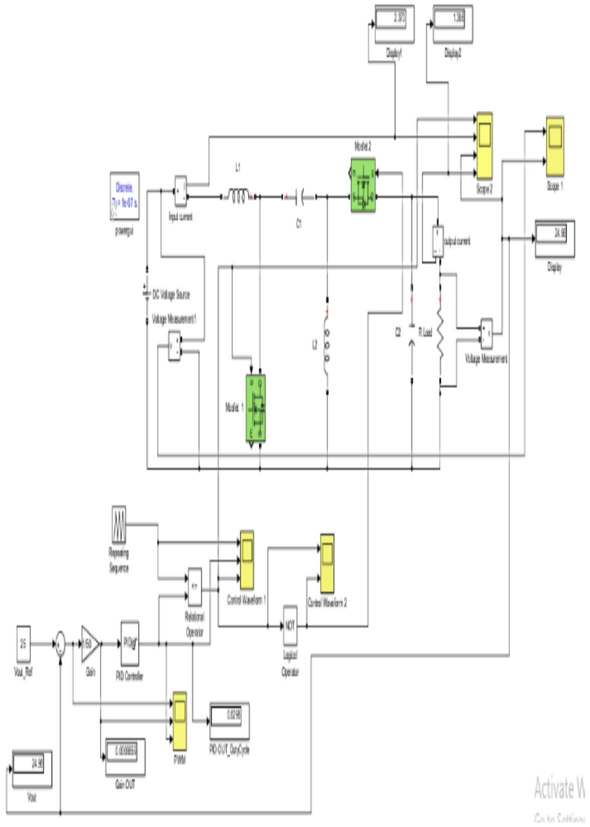

Fig-7: proposed simulink model

Fig. 7 shows the closed loop simulation model of proposed converter, Which consists of DC input, synchronous SEPIC converter, R-Load, and PID Feedback controller. It is ideally a non- inverting synchronous buck boost converter. Here the input voltage is 15V DC, Which comprises of PID feedback controller for gate pulse generation for proposed SEPIC converter. With respect to the positive reference voltage the positive output voltage is developed, that might be higher or lesser or equivalent to that of the input voltage. Here the switching frequency is 50kHz. Pulses are generated with the help of closed loop model by using PID feedback controller. The produced controlled output from the PID feedback controller is a input to the gate pulse generation model. Fig 8. shows the output voltage of proposed closed loop SEPIC converter. Here the output voltage is 25V DC.

7. DESIGN PROCEDURE:

1. Duty Cycle Consideration:

For a SEPIC converter working in a continuous conduction mode (CCM), the duty cycle is given by

$$D = \frac{Vo}{Vo + Vin}$$

D- Duty cycle

2. Output voltage:

Output voltage of the synchronous SEPIC converter is given by

$$Vout = Vin * \frac{D}{1-D}$$

$Vout$ be the output voltage

3. Output current:

The output current of the synchronous SEPIC converter is given by

$$Iout = \frac{Vin*Iin}{Vout}$$

Where $Iout$ be the output current,*vin* be the input voltage, *Iin* be the input current

4. Inductor consideration:

A decent guideline for deciding the inductance is to permit the peak-to-peak ripple current to be roughly 40% of the maximum input current at the minimum input voltage. The ripple current flowing in equal values of Inductors L1 and L2 is given by

$$L1 = L2 = \frac{Vin(min) * Dmax}{2*\Delta IL*fsw}$$

5. Ripple current:

One of the initial steps in designing any PWM switching controller is to decide how much inductor ripple current, ΔIL, to permit. A lot of builds EMI, while too little may bring about unstable PWM operation. A general rules is to use 20 to 40% of the input current. The ripple current is given by

$$\Delta IL = 40\% * Iin$$

6. Output current:

The output current of the SEPIC converter is given by

$$Iout = \frac{Vin*Iin}{Vout}$$

7. SEPIC Coupling Capacitor Selection:

The selection of the AC coupling capacitor is as follows

$$Cc(min) = \frac{Iout*D}{\Delta VCS*f}$$

The peak-to-peak ripple voltage on Cs is given by

$$\Delta Vcs = \frac{Iout*Dmax}{Cs*fsw}$$

8. SEPIC output capacitor selection:

The output capacitor is given by

$$C(out) = \frac{Iout * D}{\Delta Vripple * f}$$

where the ripple voltage is taken as 2% of the output voltage and is given by the equation as follows

$$\Delta Vripple = 2\% * Vout$$

8. SIMULATION RESULTS

Fig 7. Shows the proposed system simulation model which is designed for Fig 3. It shows the simulated model of gate pulse generation for proposed SEPIC converter. Here the switching frequency is 50kHz. Pulses are generated with the help of closed loop model by using PID feedback controller. The generated controlled output from the PWM controller is a input to the gate pulse generation model.

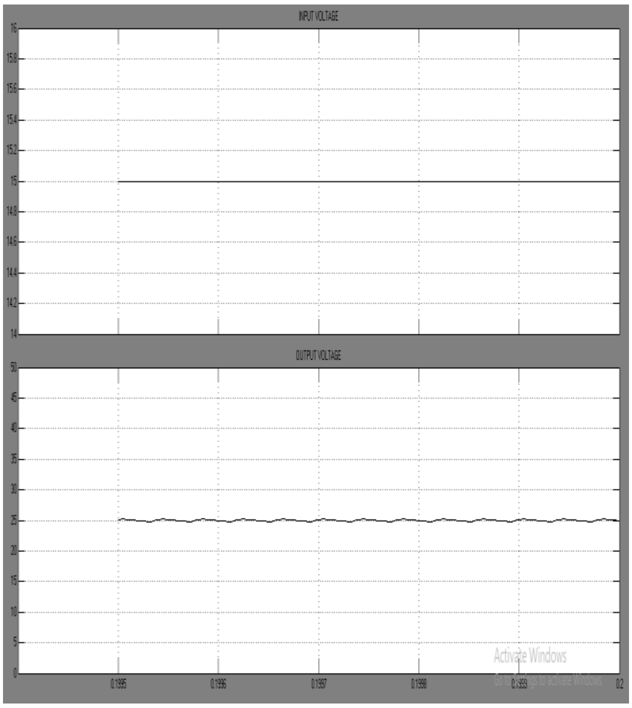

Fig-8: Input and output voltage waveform

Fig 8 shows the input and output voltage waveform of the synchronous SEPIC converter.

Fig 9 a) b) c) d) shows the waveforms of synchronous gate output, Inductor current ripple, Output voltage ripple, and Load current ripple waveforms respectively.

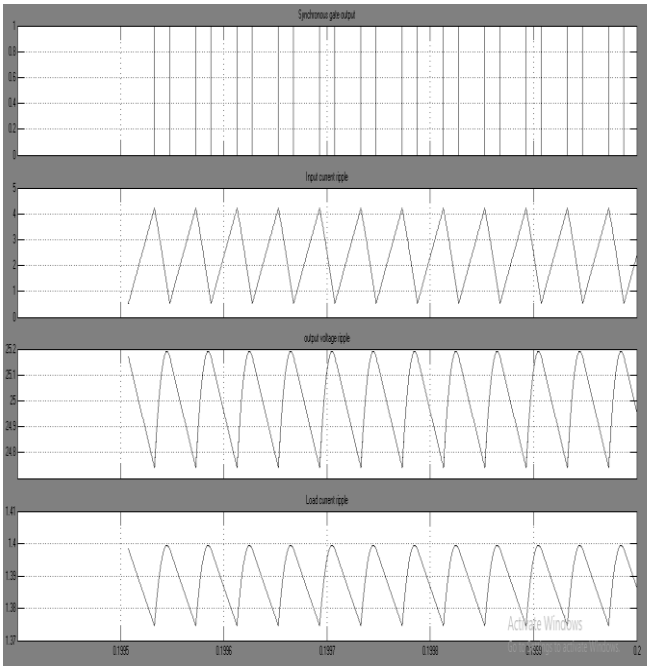

Fig-9: Waveforms of a) Synchronous gate output, b) Inductor current ripple, c) Output voltage ripple, d) Load current ripple waveforms.

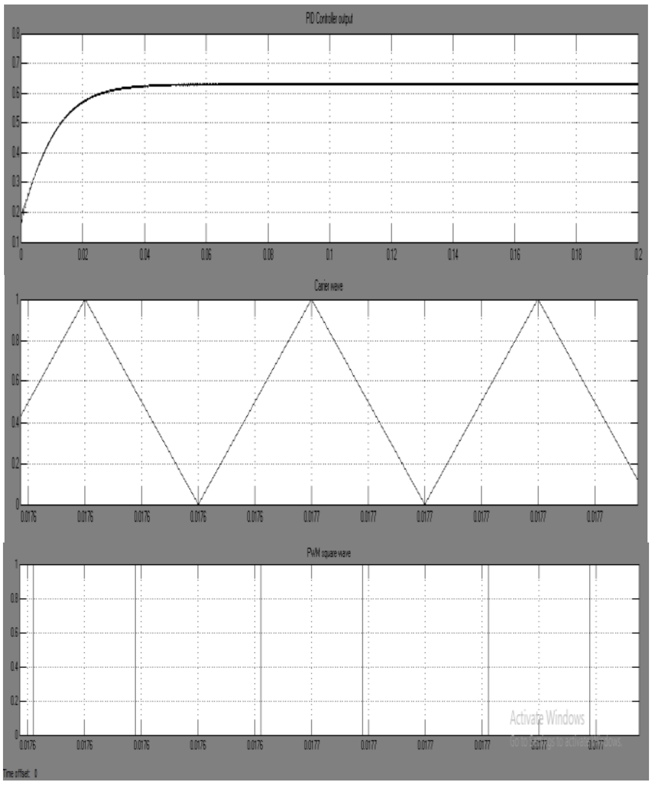

Fig-10: Waveforms of a) Carrier wave b) PID controller output c) PWM square wave

Fig 10 a) b) c) shows the waveforms of Carrier wave, PID controller output, PWM square wave respectively.

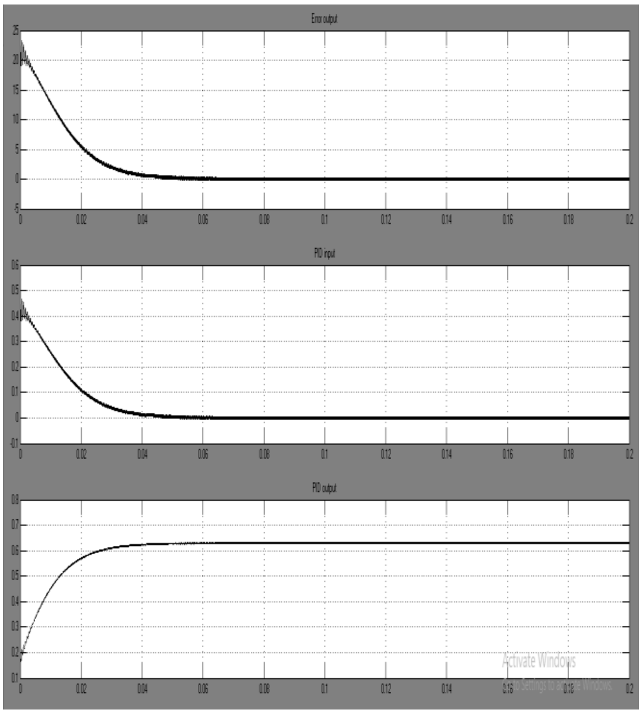

Fig-11: Waveforms of a) error output b) PID Input c) PID output

Fig 11 a) b) c) shows the Waveforms of a Error output , PID Input and PID output respectively

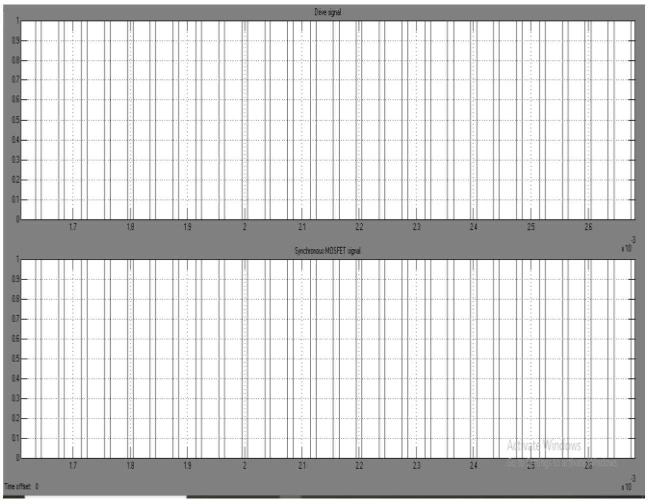

Fig-12: Waveforms of a) Drive Signal b) Synchronous MOSFET Signal

Fig 12 a) b) c) shows the Waveforms of Drive Signal and Synchronous MOSFET Signal respectively.

9. CONCLUSION

In this paper SEPIC DC-DC converter is controlled by PID feedback controller signals which is designed for closed loop synchronous SEPIC converter. This converter was simulated using the MATLAB/ Simulink software. 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 PID feedback controller. However, the function of this converter keeps up its output voltage higher , lower or constant than input voltage, which can improve the efficiency of the converter. Output voltage is continuously estimated and compared with reference voltage.

Table -1: Converters parameters and components

Components	Parameters
Input voltage	15V
Output voltage	25V
Switching frequency	50kHz
Inductance	L1=100µH, L2=100µH
Capacitance	C1= 10µF C2= 70µF
R-Load	18Ω

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