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A Closed Loop Model of Modified SEPIC Converter with Magnetic Coupling and Output Diode Voltage Clamping

Kshemada Devi V[1], Anooja V.S[2]

PG Student [PE], Dept. of EEE, VAST, Thrissur, Kerala, India[1]

Assistant professor, Dept. of EEE, VAST, Thrissur, Kerala, India[2]

ABSTRACT: In harnessing renewable energy sources, where the voltage of the electric generators has wide variations and low voltage, a dc-dc high gain voltage converter is required. A Single-Ended-Primary-Inductor converter (SEPIC) is a solution to such applications. To maintain the output voltage constant in spite of changes in input voltage a feedback closed loop control is necessary. This paper gives the design, simulation, and fabrication of a closed loop SEPIC converter with a voltage gain of twenty.

KEYWORDS: SEPIC Converter, Voltage Multiplier, Magnetic coupling.

I.INTRODUCTION

Power electronics is an engineering study that deals with conversion of electrical power from one form to another. Power electronics contributes a large part of engineering. It has close connection with many areas of engineering such as solid state physics, circuit theory, systems and control theory, signal processing, electronics, electromagnetics, power systems, electric machines, simulation and computing etc. Now a days power electronics can be considered as a rapidly expanding field as the scope of the technology covers a wide area. A power electronic system consists of power electronic switching devices, controllers, filters, sensors, electromagnetic devices etc. Power electronics plays a vital role in todays life. Somehow, it is connected with our daily life as its application covers almost all areas. It has got application in residential, commercial, industrial, transportation, utility systems, aerospace, telecommunication etc.

For converting electrical power from one form to another, a power converter is used. Actually 'converter' is a general term which denotes all kinds of converters. In rectifier mode of operation, electrical power is converted from ac to dc. The converters used for such conversions are called ac-dc converters. Power conversion from dc to ac is made in inverter mode of operation, and the converters used are dc-ac converters. Besides, there are dc-dc and ac-ac converters.

Hence, for renewable energy system and arising demand of this technology for varied applications, dc-dc converters plays an important key role. So the development of a dc-dc converter with high step-up has got its own importance and hence it is an important research area.

A Single-Ended-Primary-Inductor(SEPIC) Converter is a kind of dc-dc converter which allows the electrical potential(voltage) at its output to be greater than, less than, or even equal to that of its input. SEPIC is controlled by the duty cycle of the control switch. It has got the advantages of having true shutdown and non inverted output. It is possible to achieve a high voltage gain with this converter . SEPIC converters are mainly used in industrial applications. This converter operates at a fixed switching frequency and duty ratio. This converter has got a good response speed too.

SEPIC converters are suitable for those applications that require high voltage step-up . Due to its varied applications it would be beneficial if the voltage gain of the converter has increased to some high value effectively.

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Various methodologies are now available for voltage gain improvement. One method is the use of voltage multiplier cell. Use of voltage multiplier is a good choice for having high voltage gain. It could act as a non dissipative clamping circuit. It could also help in reducing the voltage across output diode. Moreover, it could increase reliability and reduce the size and cost. Another is making use of coupled inductor technique. With this technique it is possible to achieve a high voltage gain. It is a good solution to achieve low voltage stress on the active switch. So with this it is possible to achieve high step-up. Arrangement with numerous magnetic elements connected through semiconductor devices is the other method for voltage gain improvement. It is possible to achieve large voltage step-up with this. But, the converter complexity increases and efficiency decreases with increase in no. of processing stages. Also high control techniques would be required as it requires so many switches. Use of switched capacitors is another technique. It offers the feature of high voltage step-up. This topology could provide substantial savings in size and weight in those applications that require high output voltage. It could also help in reducing the electromagnetic interference with other circuits and supply networks.

And this project work is aimed at improving the output voltage step-up. To achieve desirable characteristics modification of the classical circuit is essential. In this paper, the proposed converter 'A closed loop model of modified SEPIC converter with magnetic coupling and output diode voltage clamping' is considered.

II.LITERATURE REVIEW

The development of step-up dc-dc converters is an important research area due to the crescent demand of this technology in various applications, especially those which are supplied by low dc output voltage sources. It has got greater demand as it is inevitable for renewable energy sources such as low power wind, photovoltaic (PV) modules. And, the power trains of hybrid electric vehicles(HEV), electric vehicles(EV) and fuel cell vehicles(FCV) makes use of the different energy storage components such as batteries, fuel cells and ultra capacitors. But the voltage levels of these energy storage elements will be usually low, and the motors of the vehicles require higher voltages. So, those cases also make use of step-up dc-dc converters. Also the telecom, computer industry, automotive headlamps using the high-intensity discharge lamp ballasts uses step-up dc-dc converters to boost the low voltage level of to a higher voltage as per its requirement. The other fields of its application include portable electronic equipment, uninterruptable power supply, battery powered equipments, some medical equipments etc.

A brief note on the study related to certain step-up dc-dc converters is as mentioned.

Even though, conventional boost converters have simple circuit structure, the practical considerations limit output voltage to approximately six times of applied voltage. Inorder to have high output voltage extremely high dutycycle ratios are required. But the problem is that the extreme duty cycle causes small off times which in turn results in severe diode reverse-recovery current and increased electromagnetic interference(EMI) levels. Also, it induces the power device conduction losses and turn-off losses with high step-up conversion, as the current ripples of the power devices are large. Besides as no room is left for control to compensate changes in a load or a line, extreme duty cycle is not desirable. For this converter, the voltage stress of the switch and the diode are equal and it is almost equal to the output voltage. And with no doubt, the voltage stress would be large in high output voltage applications. Moreover it requires high-current and high voltage rated MOSFET. There by it necessitates the use of high cost switches. So, certain modifications were experimented on such converters to have desirable and better characteristics. For a three level boost converter has double the voltage gain and half the power device voltage stress when compared with conventional boost converter. There by it reduces circuit cost and the conduction losses. This makes it more suitable in low input voltage high output voltage applications. Severe output diode reverse recovery problem is one of the major drawback of this converter. It is possible to achieve improved performance with passive lossless three level boost converter. Requirement of many necessary passive components, increased voltage stress or current stress of the power devices are some of the drawbacks of this converter. Another modified boost converter say boost converter with switched inductor uses only one power stage. It has got simple structure too. But it is associated with the drawback, that the existance of three power devices in the current flow path during the switch-on period and two power devices during the switch-off period. Also, it has got high voltage stress voltage stress on the active switch; almost equal to output voltage. Step-up switch mode converter with a switched capacitor is meant to provide a good voltage gain. Here, the

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capacitor itself can be taken as another voltage source. However, the circuit complexity and system cost is high as it requires a lot of power devices. Besides, it is suitable only for the development of low-power converters.

It is because of the reason that high peak currents appear through the semiconductors as a result of charging dynamics on the switched capacitors. Moreover, it requires many capacitors as it produces high-voltage stress across the switches. Step-up converters with inductor and switched capacitor provides extended voltage gain. In this converter the switch voltage stress is reduced by the switched cell. But, requirement of increased number of magnetic omponents and large conduction losses are the major drawbacks for this converter.

Conventional flyback converters are meant to provide high voltage gain. The high voltage gain is achieved by adjusting the turns ratio of the transformer. This converter can provide electrical isolation too. But its limitation is that the leakage inductor of the transformer can cause energy losses and high voltage spikes on power devices. With boost flyback converter it is possible to achieve a good static gain with reduced voltage stress across the switches. But for this converter as the input current is pulsed, need of LC input filter is inevitable.

The transformerless dc-dc converters include the cascade boost type, the quadratic boost type, the voltage-lift type, the capacitor-diode voltage multiplier type, and the boost type integrating with switched-capacitor technique. It is possible to achieve a good voltage gain with this converter and it uses only one power stage. This converter has got two inductors with the same level of inductance. And those inductors charges in parallel during the switch-on period and are discharges in series during the switch-off period. Voltage stresses on the active switches are lower than the output voltage. The other benefit of this converter is that under the same operating conditions, the current stress on the active switch during switch-on period is equal to the half of the current stress on the active switch during switch off . However they are all complex and of higher cost.

Cascade boost converters can meet the demand of high output voltage. This converter can be operated at high switching frequency. But, the major drawback of this solution is its structural complexity and higher cost; as it requires two power switches.Also, it is associated with severe output diode reverse recovery problem. Its switch voltage stress equals the the high output voltage. Stability problem is yet another important issue of this converter. Clamp mode coupled inductor boost converter uses diodes and coupled windings and it is somewhat similar to active switches. It is possible to recycle the leakage energy with this converter. The output rectifier reverse recovery problem could be limited with this converter. The induced current in the secondary winding of the coupled inductor is meant to discharge the clamp capacitor. With this converter it is possible to have good step-up voltage gain. Eventhough, the converter is severe in its structural complexity and cost.

A Quadratic converter could provide large step-up voltage conversion ratios. But, the switch voltage stress of this converter is higher and it is almost equal to the output voltage. In short, it has no any advantage over the conventional boost converter. So, as a modification quadratic boost converter with coupled inductor is considered. In this converter, the energy stored in the leakage inductor of the coupled inductor is recycled to the output capacitor. This converter can achieve good voltage gain. It has got the added advantage of having low voltage stress on the power switch with appropriate duty ratio. The quadratic boost converter with a nondissipative soft switching cell operate with a somewhat higher voltage scale. It requires no any isolation between power and the control stages. But the problem is that it produces conduction losses due to the series association of switch with diode.

Luo-voltage lift converters have improved voltage gain. Also the ripples of this converter are comparatively lower. But it is quite expensive. Another converter called Single switch nonisolated step-up dcdc converter provides good voltage transfer gain with reduced switch stress. It uses hybrid switched-capacitor technique for achieving high voltage gain. It has low turn-on losses. Further it reduces switching and conduction losses. But the converter is of less reliablility. Single switch three diode dcdc pulsewidth modulated converters are meant to operate at constant frequency and duty cycle with a provision of good voltage gain with small output voltage ripples. Moreover it has lower voltage stress on the semiconductor devices, specially on the diodes which allows the use of Schottky diodes, for alleviating the reverse-recovery current problem and conduction losses. However, the presence of parasitic resistances makes it difficult to achieve high voltage conversion ratio.

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An interleaved boost converter is meant to achieve a good voltage gain. The key merits of interleaved boost converter are current ripple cancellation, fast transient response, reduction in the size of passive components and high reliability. But it is associated with certain disadvantages in high step-up dc-dc applications, such as extremely large duty ratio, conduction losses, turnoff losses, voltage stress of the switches, severe output diode reverse recovery problem and also the serious electromagnetic interference(EMI) noise. These drawbacks makes it unsuitable for low voltage high performance devices. Some modified step-up interleaved dc-dc converter clamp the voltage stresses of all the switches to a low voltage level. Here, the leakage energies are collected in a clamp capacitor and recycled to output. The recycling of the leakage energies, reduces losses and reverse recovery problem of output diode to a certain extend. An interleaved boost converter with magnetically coupled voltage doubler circuit requires almost the same number of semiconductor devices compared with conventional interleaved boost. This converter produces a good voltage gain. The voltage stress on the switches can be reduced with different turns ratio of the coupled inductor. With this converter it is possible to reduce output diode reverse recovery problem and switch stress. The higher output voltage is due to the additional coupled inductors. The major drawback of this converter includes duty cycle limitation, need of a soft start and initial charge at output capacitors. A switched capacitor interleaved dual boost converter is suitable for high step-up applications. But it requires large number of switched-capacitors to realize the high voltage gain. Also, current through the capacitors is too much high. And the interleaved boost converter associated with an isolated transformer could provide good performance. But it contributes high weight and volume.

A Single-Ended-Primary-Inductor(SEPIC) Converter is a kind of dc-dc converter which allows the electrical potential(voltage) at its output to be greater than, less than, or even equal to that of its input. SEPIC is controlled by the duty cycle of the control switch. It has got the advantages of having true shutdown and non inverterd output. It is possible to achieve a high voltage gain with this converter . SEPIC converters are mainly used in industrial applications. This converter operates at a fixed switching frequency and duty ratio. This converter has got a good response speed too.

A brief note on certain SEPIC converter topologies are presented here.

A conventional SEPIC converter exchanges energy from the capacitor and inductors for converting one voltage to another voltage. Where the switch control the sum of energy exchanged. MOSFET has lower voltage drop than BJT. It could provide comparatively higher voltage gain . However, at a very high switching frequency, conventional SEPIC converter suffers deficiencies and associated losses. This drawback can be reduced by Resonant SEPIC converter by offering large operating range, small size and acceptable performance. In this topology, capacitance parallel with the switch and the diodes along with the resonant inductor in series with the coupling capacitor provides desired performance. But, it limits the response speed. So, a new quasi-resonant SEPIC topology is introduced to overcome forementioned drawback and to achieve good performance. This converter also requires minimal component count. The resonant SEPIC converter consists of two subsystems and they are Resonant inverter and Resonant rectifier. There is a resonant tank circuit for a resonant rectifier. It consists of resonant inductor and capacitance and it is an additional parasitic junction capacitance from the diode. The resonant SEPIC converter makes use of two resonant inductors. Where, one inductor resonates with the net switching capacitance for resonant inversion and the other inductor resonate with the rectifier capacitance for resonant rectification. With this method it is possible to achieve a good response speed but the system is slightly expensive.

So, SEPIC converters are suitable for those applications that require high voltage step-up . Due to its varied applications it would be beneficial if the voltage gain of the converter has increased to some high value effectively.

Various methodologies are now available for voltage gain improvement. One method is the use of voltage multiplier cell. Use of voltage multiplier is a good choice for having high voltage gain. It could act as a non dissipative clamping circuit. It could also help in reducing the voltage across output diode. Moreover, it could increase reliability and reduce the size and cost. Another is making use of coupled inductor technique. With this technique it is possible to achieve a high voltage gain. It is a good solution to achieve low voltage stress on the active switch. So with this it is possible to achieve high step-up. Arrangement with numerous magnetic elements connected through semiconductor devices is the other method for voltage gain imrovement. It is possible to achieve large voltage step-up with this. But, the converter complexity increases and efficiency decreases with increase in no. of processing stages. Also high control techniques

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This comprehensive review of the literature outlined various step-up dc-dc converters specifically SEPIC converter; its merits and negative impacts. The review also focussed on dc-dc step-up voltage gain improvement techniques.

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III. A CLOSED LOOP MODEL OF MODIFIED SEPIC CONVERTER WITH MAGNETIC COUPLING AND OUTPUT DIODE VOLTAGE CLAMPING

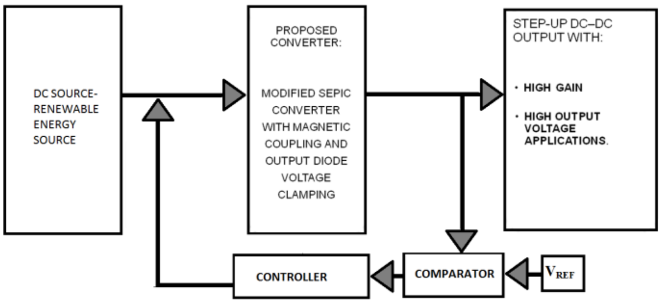

Fig. 1. Block Diagram – A Closed loop model of modified SEPIC converter with magnetic coupling and output diode voltage clamping

The block diagram of proposed converter, A closed loop model of modified SEPIC converter with magnetic coupling and output diode voltage clamping is shown Fig 1. It utilizes low input voltage to produce high static gain and high efficiency with low switch voltage. It is hence meant especially for high output voltage applications. The basic circuit diagrm of closed loop system of modified SEPIC converter with magnetic coupling and output diode voltage clamping is as shown in Fig 2.

The modified open loop SEPIC converter with magnetic coupling and output diode voltage clamping. is ultimately achieved by adding a diode D_{M1}, a capacitor C_M and voltage multiplier cell. Also by making the inductor, L_2 a coupled one.

Here, the inductor winding turns ratio (n) increases the output voltage. The D_{M2}-C_{S2} acts as voltage multiplier cell.The importance of voltage multiplier cell lies in:

1.Increasing the converter static gain.

2.Reducing the voltage across the output diode to a value lower than output voltage.

3.Transferring the energy stored in the leakage inductance to output.

4.Creating a non dissipative clamping circuit for the output diode.

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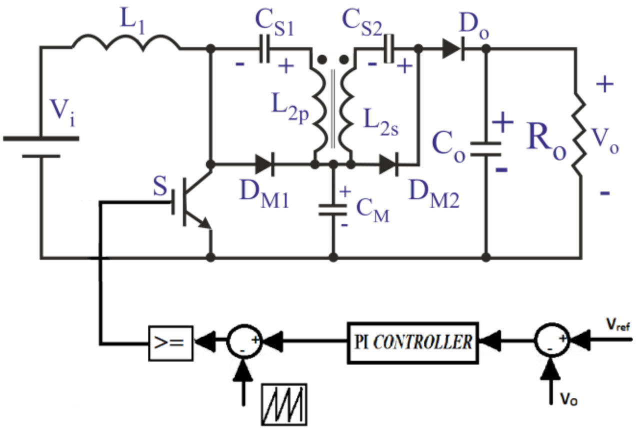

Fig. 2. Circuit Diagram - A Closed loop model of modified SEPIC converter with magnetic coupling and output diode voltage clamping.

In open loop converters, output has no effect on input to control a process. But the key features to be satisfied by a converter is to monitor, measure and control a process. So in order to control a process for having a desired response, the actual output should be compared with the desired one and thus generated quantity can be used as input to the converter. And the same happens in a closed loop converter. There by it could act as an automatically controlled system. And the control depends on output in one or another way. In short, the actual process that occurs in a closed loop converter is, the error signal which is the difference between input and feedback signal(output or a function of output)is given to the controller to obtain the output at a desired value. So it is well clear that the main disadvantage for an open loop system is the output voltage variation along with the input voltage changes. Hence it would be difficult to limit the output voltage as per our intention. In order to limit the output voltage to a desired value(say fixed voltage) it is better to use a closed loop system. Which makes the system suitable for a particular application. Moreover it has got so many advantages over an open loop converter such as to reduce the converter's sensitivity towards the external disturbances, to produce repeatable performance which is reliable too, to improve stability etc.

IV. MODES 0F OPERATION AND THEORETICAL WAVEFORMS

A. Modes of operation:

A brief idea regarding the operation of proposed converter is possible from the following session.The circuit operates through five stages. First of all the assumptions made need to be considered .

Assumptions:

- All capacitors are considered as voltage sources.
- All components including semiconductors are considered as ideal ones.

- ***Stage 1:*** This stage is from t_0-t_1 and it is shown in Fig 3.During this stage the switch S is in closed state .At that time the current flows through V_i,L_1,S and the inductor L_1 stores energy. In the magnetically coupled part the current flow will be through L_{2S},D_{M2},C_{S2}.Thus the charging of capacitor C_{S2} happens. It is the leakage inductance which limits the current and energy transfer that occur in a resonant way. The output diode D_o is blocked during this time and the maximum voltage across it is V_o-V_{CM} .At the end(i.e,at t_1),the energy transfer to the capacitor got completed and hence the diode D_{M2} goes to blocked state.

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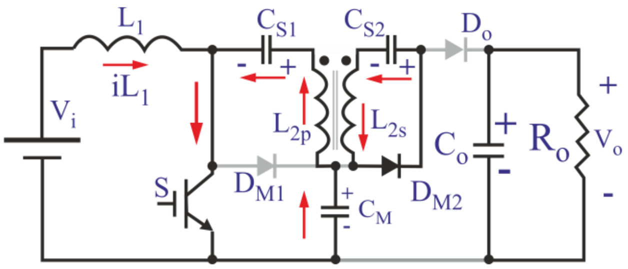

Fig. 3. Mode I

- ***Stage 2:*** This stage is from t_1-t_2 and it is shown in Fig 4.In this stage also the switch S is in closed state. Initially the diode D_{M2} is blocked. The current flows through V_iL_1S and charging of inductor L_1 occurs . And the inductor L_2 charges through $C_ML_{2p}C_{S1}$.Finally the switch is turned off at t_2.

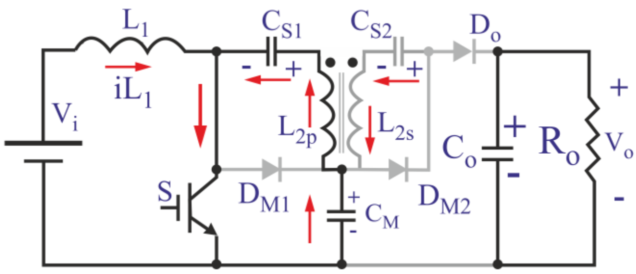

Fig. 4. Mode II

- ***Stage 3:*** This stage is from t_2-t_3 and it is shown in Fig 5.In this stage the switch S is in open state. So during this period inductor L_1 discharges to capacitor C_M. And the energy transfer to output occurs through the path C_{S1},L_2,C_{S2},D_O.

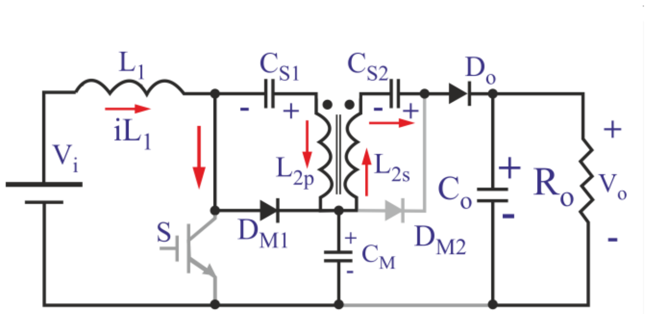

Fig. 5. Mode III

- ***Stage 4:*** This stage is from t_3-t_4 and it is shown in Fig 6.In this stage the switch is in open state itself.At t_3 the diode D_{M1} goes to blocked condition because of the positively charged capacitor C_M .Energy transference to the output occurs until t_4.And at t_4 the switch is turned ON again.

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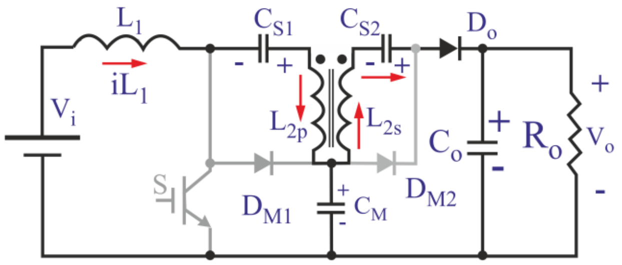

Fig. 6. Mode IV

- ***Stage 5:*** This stage is from t_4-t_5 and it is shown in Fig 7.In this stage the switch turned to closed state again..During this period the current of output diode, D_O linearly decreases and ultimately the D_O returns back to blocked state. And the first operation stage continues.

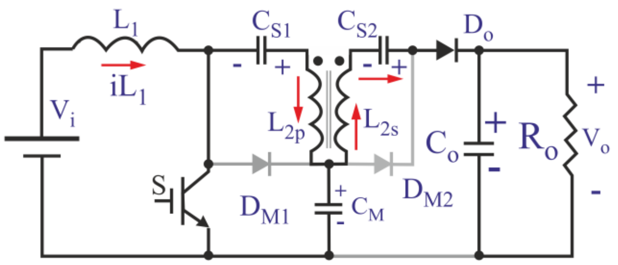

Fig. 7. Mode V

- The above five modes describes the working of proposed converter. And feed back will take decision on the triggering pulse to be provided for the switch S. For that, obtained output voltage is compared with the reference voltage. It is then given to PI controller which decides on duty ratio. And the switching pulse is generated by considering the duty ratio and a reference wave.The feed back is as shown in Fig 2.

B. Theoretical Waveforms:

Fig 8 depicts the main theoretical waveforms of the proposed converter. From that it can be easily understood that the voltage across all diodes as well as the switch voltage is lower than the output voltage. Also the switch turn ON happens at zero current which will help to minimize the switching losses considerably. The coupling inductor leakage inductance helps in limiting the current variation ratio of diodes and thereby reduces the negative effects of diode reverse recovery.

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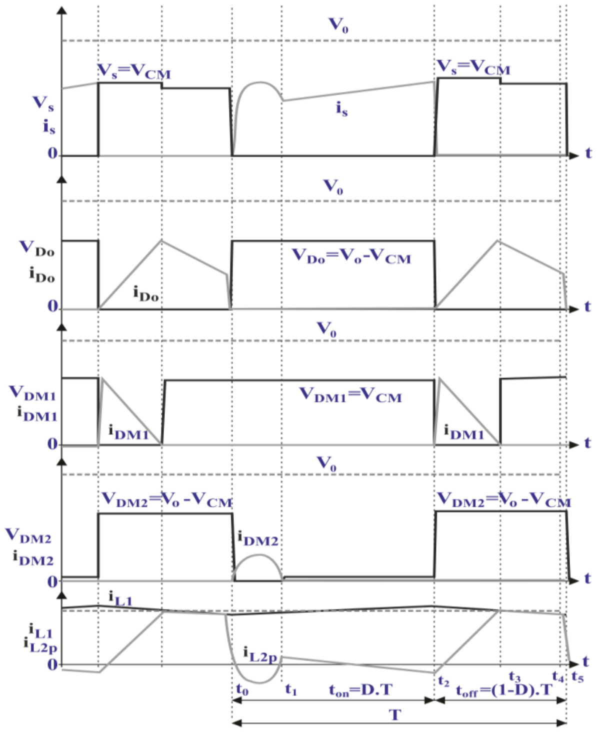

Fig. 8. Theoretical Waveforms

V. DESIGN

The design part of the proposed converter is presented here.The assumptions made here are:

a. Input Voltage, V_i=5V
b. Output Voltage, V_O =100V
c. Switching frequency, f=24kHz

- ***Switch Duty Cycle:***

  Consider,

  a. Static gain=20
  b. Inductor winding turns ratio(n)=2.6

  Hence the converter duty cycle(D),

  $$D = 1-([Vi/V_o]\,(1+n)) = 1-([5/100]\,(1+2.6)) = 0.82. \qquad (1)$$

- ***Diode and Switch Voltage:***

  Here the switch voltage (V_S) ,voltage across the diode D_{M1} and the voltage of the capacitor C_M(V_{CM}) are equal.

  $$V_S = V_{DM1} = V_{CM} = [V_i/1\text{-}D] = [5/1\text{-}0.82]=27.778\ V. \qquad (2)$$

  Also, the voltage of diode D_{M2}(V_{DM2}), voltage of the output diode D_O(V_{DO}) are equal.

  $$V_{DM2} = V_{DO} = V_O - V_{CM} = [nV_i/1\text{-}D] = [2.6 \times 5/1\text{-}0.82] = 72.22\ V. \qquad (3)$$

- ***Inductance L_1 and L_{2p}-L_{2S}:***

  Consider the current ripple of inductors L_1 and L2 be same as Δi_L. And assume it as 5 A.

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Now,
The average current through inductor L_1=Input current.
The average current through inductor L_2=Output current.
Inductor current ripple (Δi_L)= $[V_i D/Lf]$
From that, $L=[V_i D/\Delta i_L f]$

$$L_1 = L_{2p} = L = [5 \times 0.82 / 5 \times 24 \times 10^3] = 34.1667\mu H. \quad (4)$$

The secondary winding,

$$L_{2s} = (n^2) \times (L_{2p}) = (2.6^2) \times (34.1667) = 230.9669\ \mu H. \quad (5)$$

- ***Capacitors C_S and C_M:***

Consider the voltage ripple of both the capacitors C_S and C_M be same as ΔV_C. And it is equal to 15% of nominal voltage capacitor C_M voltage.

i. e, ΔVC = 15% of nominal voltage of capacitor C_M = $[5/1\text{-}0.82] \times [15/100] = 4.1667V$. (6)

Also,
The capacitor voltage ripple $\Delta V_C = [nI_O/cf]$
From that $C = [nI_O / \Delta V_C f]$
Where,

$$I_O = [P_O/V_O] = [33.33/100] = 0{:}333A. \quad (7)$$

Now,

$$C = [nI_O/\Delta V_C f] = [2.6 \times 0.333 / 4.1667 \times 24 \times 10^3] = 8.6657\mu F. \quad (8)$$

$$C_{S1} = C_M = C = 8.6657\mu F.$$

- ***Semiconductor current effort :***

Average current of all diodes=Output current.
$I_{DO} = I_{DM1} = I_{DM2} = I_O = [P_O/V_O] = 0{:}333A.$

$$R_O = [V/I] = [100/0.333] = 300.0300\Omega. \quad (9)$$

VI.SIMULATION

Circuit simulation is done to verify the design. It could also provide an overall idea regarding the behaviour of converter when implemented.

Figure 9 is the simulation circuit of proposed closed loop model of modified SEPIC converter with magnetic coupling and output diode voltage clamping. Figure 10 and figure 11 gives the simulated switch and output voltage waveforms respectively.

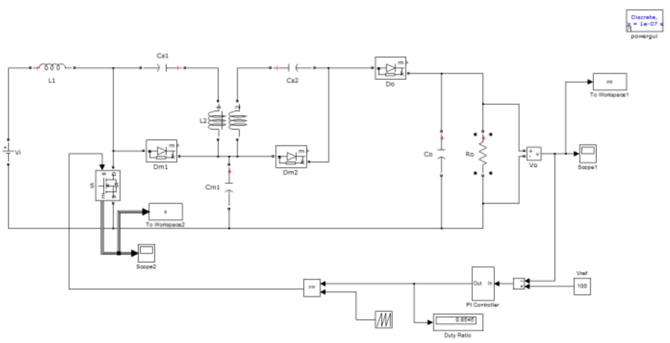

Fig. 9. Simulation Diagram of proposed closed loop converter - Closed loop model of modified SEPIC converter with magnetic coupling and output diode voltage clamping.

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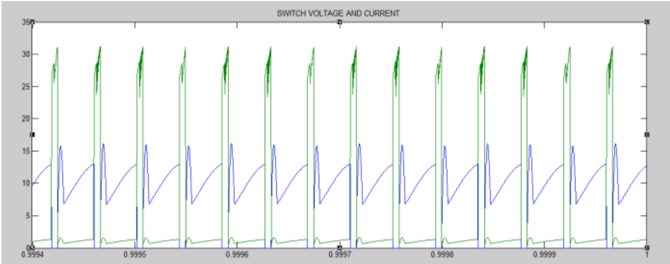

Fig. 10. Closed loop converter - (V_S,i_S) versus time (t)

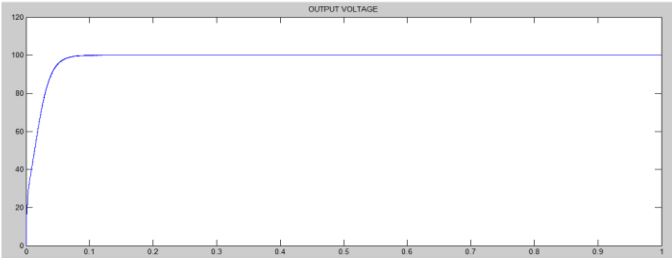

Fig. 11. Closed loop converter - (V_O,i_O) versus time (t)

VI. HARDWARE ASSEMBLING AND TESTING

A. Hardware Modules:

The hardware for the closed loop model of SEPIC converter with magnetic coupling and output diode voltage clamping can be developed as three modules. It includes:

1. Control Circuit
2. Drive Circuit
3. Power Circuit

Power circuit is the main circuit part. The gate signal required by the power circuit is provided by the control circuit. Normally, the control circuit output voltage is of 3V- 5V. But the threshold voltage of MOSFET switch will be greater than or equal to 10.6V. Inorder to amplify the signal from control circuit and to isolate the control circuit and power circuit, a driver circuit can be used in between.

1. CONTROL CIRCUIT

Function of the control circuit is to generate a switching pulse of required frequency. The most important part of a control circuit is its PIC. The name PIC initially referred to Peripheral Interface Controller. It has got memory for program with a provision of erase and rewrite. The PIC used here is dsPIC30F2010.

For programming the PIC to have a pulse as per our requirement, a code generation program file needs to be created. The code generation program for dsPIC30F2010 can be done in MPLAB.

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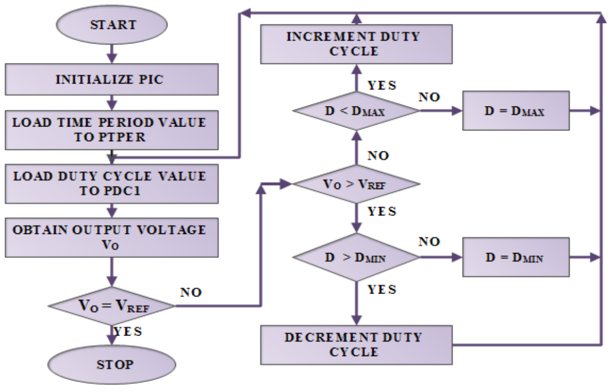

Fig. 12. Closed Loop Program Flow Chart

Figure 12 shows the flow chart of closed loop program.Figure 13 shows the hardware of control circuit and Figure 14 shows the controller output waveform.

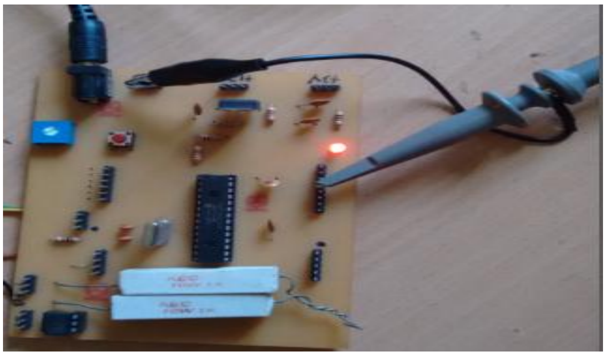

Fig. 13. Hardware-Control circuit

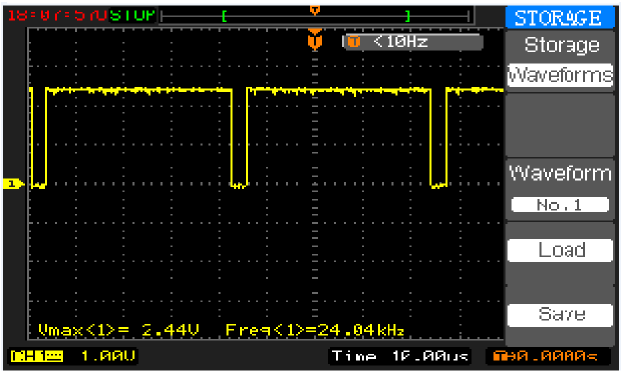

Fig. 14. Output waveform from the control circuit

2. DRIVER CIRCUIT

The output from the control circuit will be of low voltage around 3V-5V. But the power MOSFET requires a gate signal greater than or equal to 10.6V. Drive circuit is used to boost voltage level of the switch signal generated by control circuit to enable it to turn on MOSFET. Here, TLP250 is used as the driver IC.

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Figure 15 shows the hardware of drive circuit. And figure 16 shows the output of drive circuit. It depicts that a pulse signal of a magnitude greater than 10.6V and 24 kHz switching frequency, suited for this application is possible to obtain from the drive circuit.

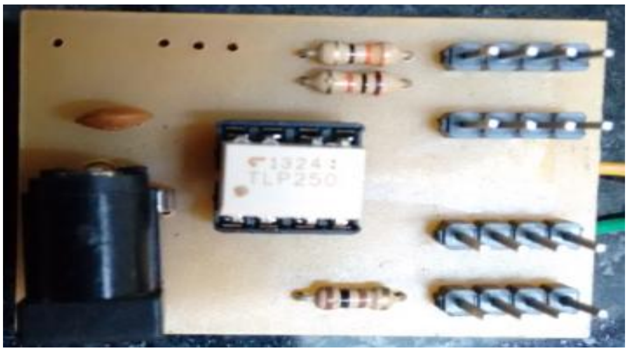

Fig. 15. Hardware-Drive circuit

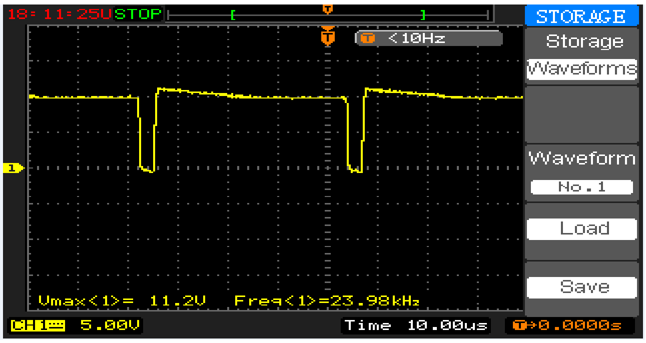

Fig. 16. Output waveform of the drive circuit

3. POWER CIRCUIT

Power circuit is the main circuit part of hardware implementation. Figure 17 shows the experimental set-up for the closed loop converter with magnetic coupling and output diode voltage clamping. From the picture it can be understood that the closed loop converter produces an output dc voltage of 100V for an input dc voltage supply of 5V. Figure 18 shows the switch voltage waveform of closed loop converter. It shows the switch voltage as 40.2V. Figure 19 shows the output dc voltage waveform.

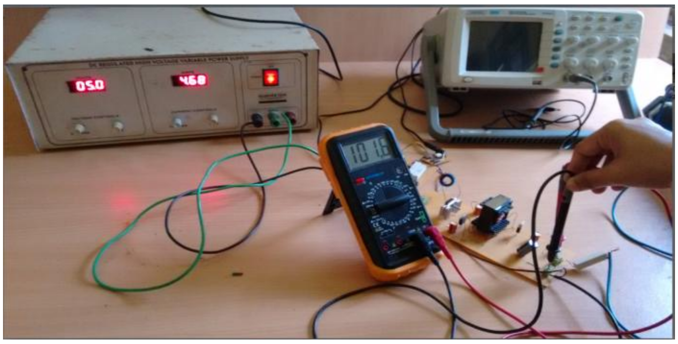

Fig. 17. Experimental set-up:A closed loop model of SEPIC converter with magnetic coupling and output diode voltage clamping

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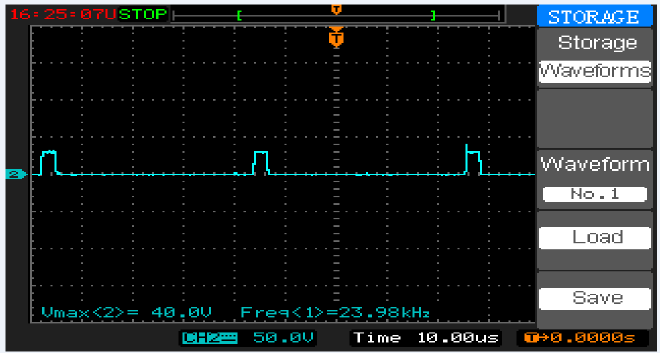

Fig. 18. Switch voltage waveform of the proposed converter

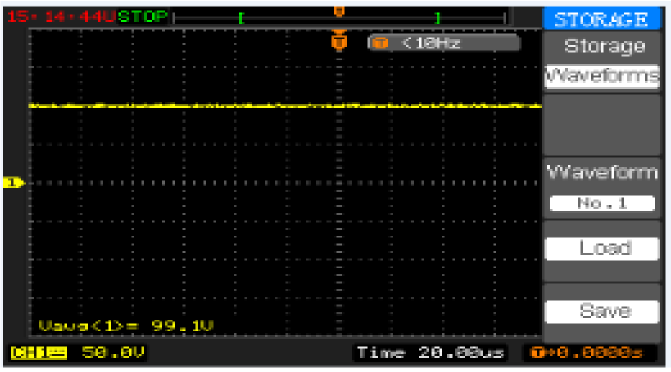

Fig. 19. Output voltage waveform of the proposed converter

B. Observation:

Output voltage is observed for a sample set of values; both simulation and hardware of the proposed closed loop converter. Figures 20 to 23 shows the correspondingly plotted graphs.

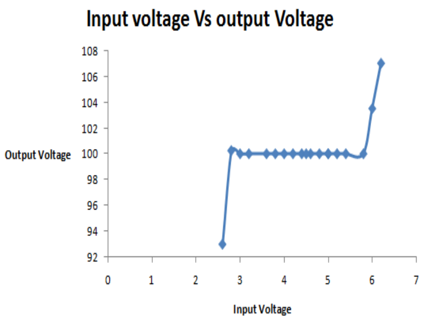

Fig. 20. Closed loop Simulation at constant load

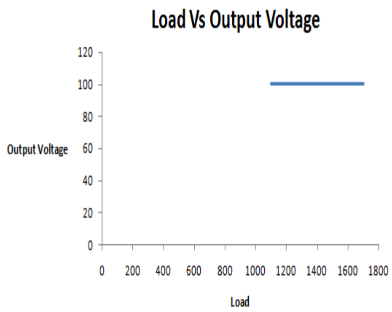

Fig. 21. Closed loop Simulation at constant input

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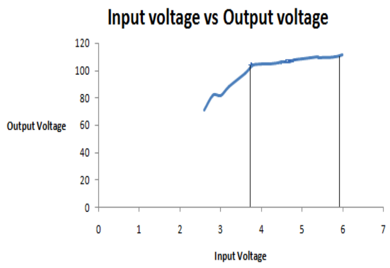

Fig. 22. Closed loop Hardware output at constant load

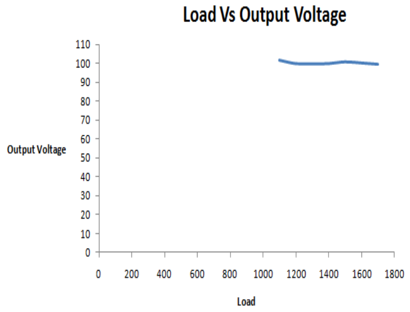

Fig. 23. Closed loop Hardware output at constant input

The obsevation shows that the results obtained from simulation and hardware are satisfactorily matching.

C. Result:

Line regulation is a measure of the ability of the converter to maintain its output voltage with given changes in the input line voltage. And load regulation is the capability of the converter to maintain a constant output voltage(or current) level despite changes in the converter0s load(such as a change in resistance value connected across the converter).

Table 1 and table 2 respectively shows the permissible values of line and load regulation for this converter.

TABLE I. INFERENCE TABLE FOR LINE REGULATION

OUTPUT REQUIREMENT	LOAD	LOWER LIMIT OF INPUT VOLTAGE	UPPER LIMIT OF INPUT VOLTAGE
100V	AT 300Ω	4.2 V	11.6 V
	AT 500Ω	3.8 V	9.5 V
	AT 750Ω	3.4 V	8 V
	AT 1000Ω	3.2 V	7 V
	AT 1700Ω	3 V	5.8 V

TABLE II. INFERENCE TABLE FOR LOAD REGULATION

OUTPUT REQUIREMENT	INPUT VOLTAGE	LOWER LIMIT OF LOAD	UPPER LIMIT OF LOAD
100V	AT 5V	300Ω	1750Ω

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VI. CONCLUSION

In this work development of high gain dc-dc converter is taken. The voltage gain of around twenty is required. A modified SEPIC converter is the basic circuit. To maintain the output voltage constant inspite of changes in input voltage a closed loop control is provided.

Here a model of SEPIC converter with magnetic coupling and output diode voltage clamping is designed. Simulation is carried out using MATLAB and verified the design. The designed circuit is assembled and tested. And obtained results were found satisfactory.

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