MODIFIED Z SOURCE FED SEPIC DC-DC CONVERTERS FOR HIGH GAIN APPLICATIONS

[1]P.Ganesan, [2]K.Rajaraman,
[1]Associate professor, [2]Assistant professor,
[1]Department of Electrical and Electronics Engineering,
[1]Governement college of engineering, Srirangam, Trichy,India

Abstract : This paper presents the performance verification and suitability of Modified Z Source Fed SEPIC DC-DC converter for modern photovoltaic applications. Most of the renewable energy resources are generally produces low voltage. Hence it is important to boost the low voltage obtained from the renewable source to the voltage suitable for the required applications. In this context, Simulink models of the Z Source, Modified Z source, and Modified Z Source Fed SEPIC system are designed. Simulation results during steady-state and transient operating conditions demonstrates the performance and suitability of these converters for different applications.

***IndexTerms* - Boost converter, Z source, SEPIC, impedance source network, DC-DC converter, Photovoltaic (PV), power converters.**

I. INTRODUCTION

Increase in emission levels, continuous depletion of traditional natural resources and rapidly rising demand in energy consumption has been a major concern for many years. Investigations towards solving this concern lead to harvesting green renewable sources such as Photovoltaic (PV), wind energy using wind turbine and hydro power. Photovoltaic is a source of renewable energy that offer many advantages such as fuel-Less, Pollution-Less, low maintenance costs and Noise-Less. To avoid Energy crisis and increase of pollution in environment renewable energy sources are widely used.

Generally, a dc-dc converter is used to step-up the voltage to the required level. In theory, the traditional boost converter can realize infinite voltage gain when duty cycle is equal to 1.Due to the maximum duty cycle is limited due to the parasitic resistances. The economic, efficient and high-voltage-stressed diodes and switches are required to get better performances. The efficiency of the traditional interleaved-boost converter is relatively low. In this paper a modified converter with conventional Z-source network fed to a SEPIC converter stage has high voltage gain compared to the traditional Z source dc-dc converters and low THD levels. It gives a common ground between the dc supply source and load output. The impedance network acts as a bridge connecting the source and the converter. Since the voltage stress on the switches and diodes are less when compared to the traditional boost dc converters, the efficiency is improved. The cost and size of the modified converter is reduced. Sinusoidal based pulse width modulation (PWM) technique is used in the inverter and PID Controllers are used in simulation. Thus, this converter is desirable for PV power generation systems, hybrid electric vehicles, HID lamp ballast etc.

High gain converters which employ voltage multiplier techniques to extend their voltage gain offers lower commutation losses and lower electromagnetic interference (EMI) [2] has the limitation of production of di/dt. Boost converter with interleaved configuration has high voltage gain, less voltage and current stresses [3] and the cascaded dc-dc converter gives high gain with reduced current ripple [4] has the very complicated circuit results in increase in overall system cost and size. The switched inductor technique gives a large gain beyond a large duty ratio [5] has very bulky switched-inductor, which makes the converter size big and expensive.

The impedance network can be used for the dc-dc power conversion. This impedance network can be utilized for various converter configurations like buck, boost, buck-boost, unidirectional, bidirectional etc. have been found in the literature [7], [8]. The network has efficient power conversion and can be employed in a broad area of electric power transformation applications.In this paper we are anlysing the benefits of the proposed modified z source fed SEPIC network in comparision with the conventional Z source and the modified Z source network[10].

II. Z SOURCE DC-DC CONVERTER

For the simplified analysis, the conditions assumed are given below:

All the components are ideal.$L_1 = L_2 = L$, $C_1 = C_2 = C$. Current through L_1, L_2 and voltage across C_1, C_2 varies linearly. The converter performs two states of operation, shoot-through and non shoot-through states.

2.1 Shoot through mode:

Inductors L1 and L2 are getting charged . The output of AC circuit is not influenced by the input of DC.

2.1 Non Shoot through mode:

To the contrary, the inductors L1 and L2 are discharged when the inverter works on the non-shoot-through zero state, the inductors provide energy to the inverter with the main energy provider-voltage source E. In this way, the input voltage of the inverter bridge is boosted. V_L =E-V_C, V_S =E, V_i =V_C -V_L =2V_C – E.

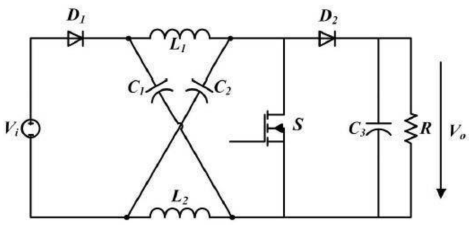

Fig 2.1 Circuit Diagram of conventional Z Source converter

When the Z-source network is added with the three-phase voltage-source inverter, during the shoot-through zero state that there is chance of load terminals are shorted which is a dis advantage of conventional Z source converter. We can use the general PWM,if the DC voltage is high .If it is not high we can go for the modified PWM to boost voltage to get desired output voltage.

$$Gain = \frac{Vo}{Vi} = \frac{1}{(1-2D)} \qquad (2.1)$$

III. MODIFIED Z SOURCE CONVERTER

For the simplified analysis, the conditions assumed are given below:
All the components are ideal.$L_1 = L_2 = L$, $C_1 = C_2 = C$. Current through L_1, L_2 and voltage across C_1, C_2 varies linearly.

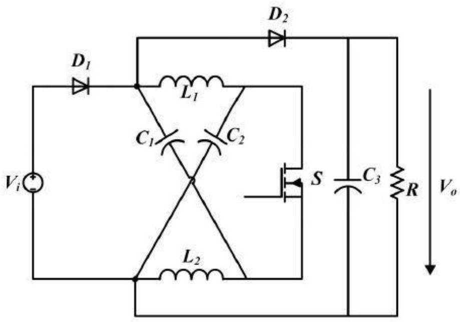

Fig 3.1 Circuit Diagram of Modified Z Source converter

The converter performs two states of operation, state 0 and state 1.

3.1 Mode 0

Switch S and diode D_2 are in ON condition, diode D_1 is in OFF condition during this state. T_0 = DT represents the interval for state 0 in switching cycle (T). This state has two loops. L_1, S and C_1 (or L_2, C_2) consist of loop (1). C_1 or C_2 discharge energy to L_1 or L_2. C_2, S, C_1, D_2, C_3 and R consist of loop (2). C_1 and C_2 discharge energy to R and C_3.

3.2 Mode 1

Here D_1 is ON, Switch S and D_2 are OFF. $T_1 = (1 - D)T$ is interval of state 1 in switching cycle T. This state consists of two loops. L_1, C_2 (or L_2, C_1) and D_1 consist of loop (1). Energy from V_i, L_1 or L_2 is discharged to C_2 or C_1. Duty cycle limit is $0 < D < 0.5$.

$$Gain = \frac{Vo}{Vi} = \frac{2(1-D)}{(1-2D)} \qquad (3.1)$$

IV. MODIFIED Z SOURCE FED SEPIC CONVERTER

It combines the effect of modified Z source converter and a SEPIC converter.It has extra inductor L3 and capacitor C4 for SEPIC configuration in comparision with the modified Z source.Hence it acts as a multi stage conversion.

For the simplified analysis, the conditions assumed are given below:

All the components are ideal.$L_1 = L_2 = L$, $C_1 = C_2 = C$. Current through L_1, L_2 and voltage across C_1, C_2 varies linearly.
The converter performs two states of operation, state 0 and state 1.

4.1Mode 0

During this state Switch S and diode D_2 are in ON condition, diode D_1 is in OFF condition during T_{0N} = DT represents the interval for state 0 in switching cycle (T). This state has Four loops. L_1, S and C_1 , L2,S and C2 consist of loop (1 and 2). This is state of discharging where C_1 or C_2 discharge energy to L_1 or L_2. Third loop consist of C_2, S, C_1, C4, D2, C_3 and R consist of loop (2). C_1 and C_2 discharge energy to R and C_3. . Third loop consist of C_2, S, C_1, C4, L3 and C_1, C4 discharge energy to L3.

4.2 Mode 1

During this mode, D_1 is ON, Switch S and D_2 are OFF. $T_{off} = (1 - D)T$ is interval of mode 1 in switching cycle T. This state consists of two loops. Vi, D_1, L1, and C_2 and Vi, D_1, L2 and C_1. Energy from V_I, L_1 or L_2 is discharged to C_2 or C_1. Duty cycle limit is $0 < D < 0.5$. When the duty cycle is closer to 0.5, voltage gain will be $M > 2$

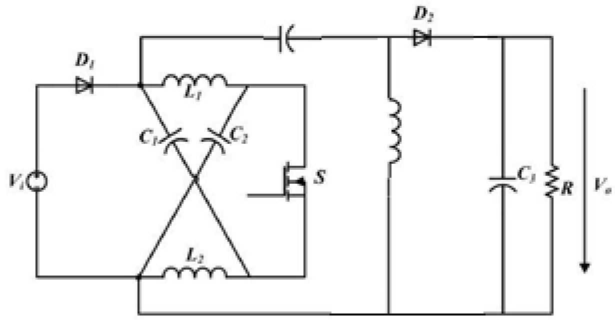

Fig 3.1 Circuit Diagram of Modified Z Source fed SEPIC converter

$$Gain = \frac{Vo}{Vi} = \frac{2(1-D)}{(1-2D)(1-D)} \qquad (4.1)$$

V. SIMULATION RESULTS AND DISCUSSION

MATLAB software is used for performing simulation. Simulation has been done for the existing Z source and modified Z source and compared with the Modified Z source fed SEPIC converter. First simulation is done with PID controllers with constant output voltage of 50V.Second simulation done for constant duty cycle of 0.3.

5.1 Simulation using PID Controller

The parameters are selected as follows:

$V_i = 12V$; $C_1 = C_2 = 47uF$; $C_3 = 3300uF$ $L_1 = L_2 = 180uH$; $R = 100\Omega$ switching frequency, f = 5KHz,Controller =PID

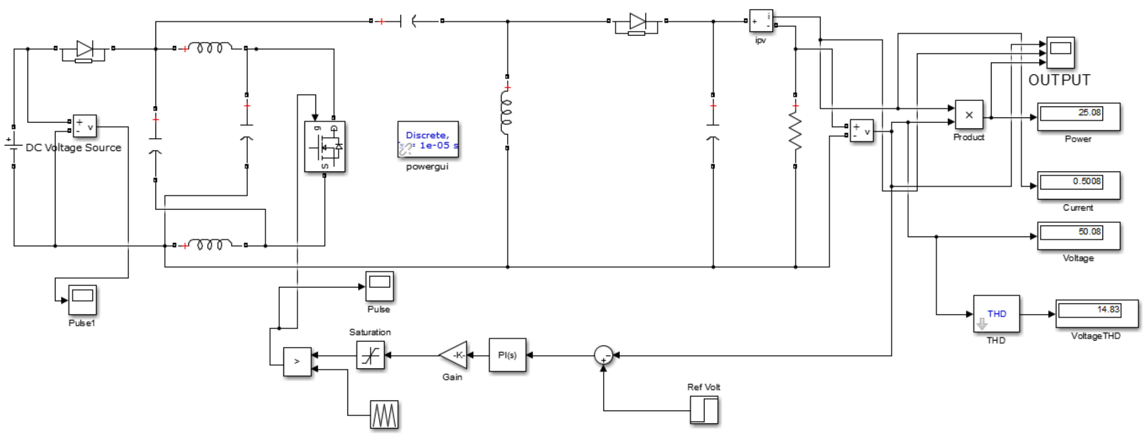

Fig 5.1.1 MATLAB simulation of Modified Z Source fed SEPIC converter with PID controller

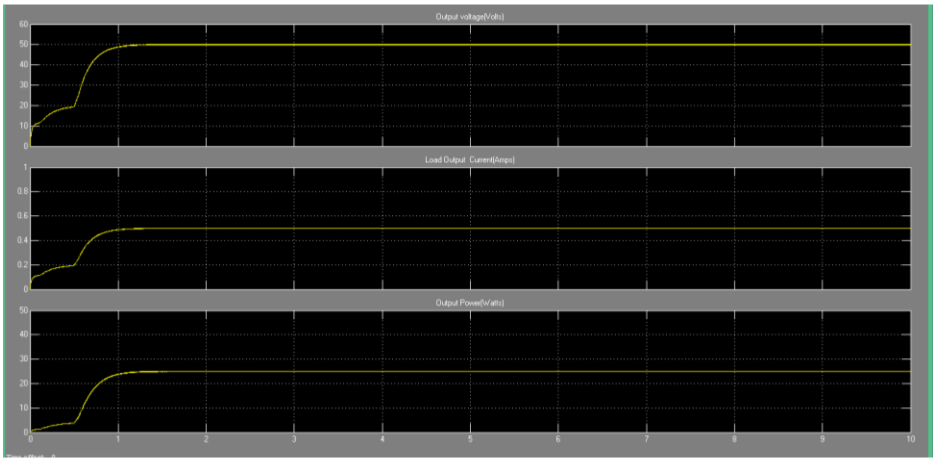

Fig 5.1.2 Simulated Output (V, I, POWER) of Modified Z Source fed SEPIC converter with PID controller

5.2 Simulation using constant duty cycle

The parameters are selected as follows:

V_i = 12V ; $C_1 = C_2$ = 47uF ; C_3 = 3300uF $L_1 = L_2$ = 180uH ; R = 100Ω switching frequency, f = 5KHz, duty cycle=0.3

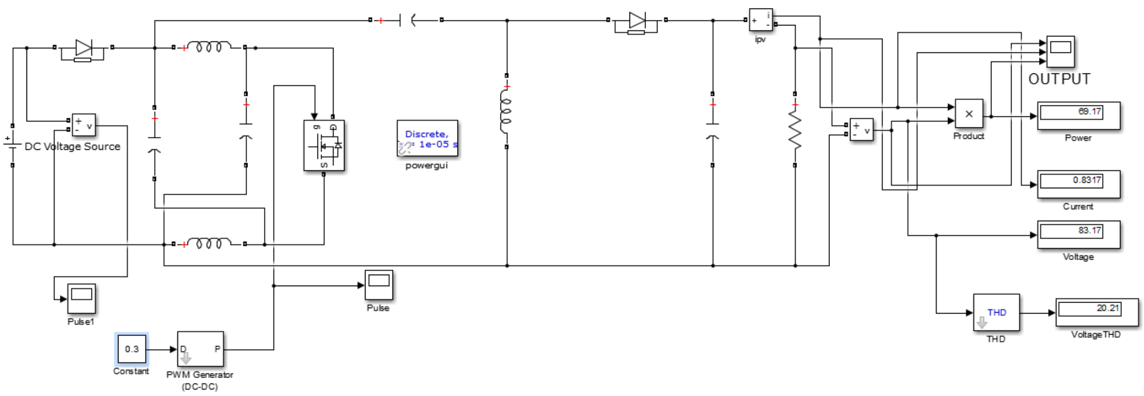

Fig 5.2.1 MATLAB simulation of Modified Z Source fed SEPIC converter with PID controller with duty cycle 0.3

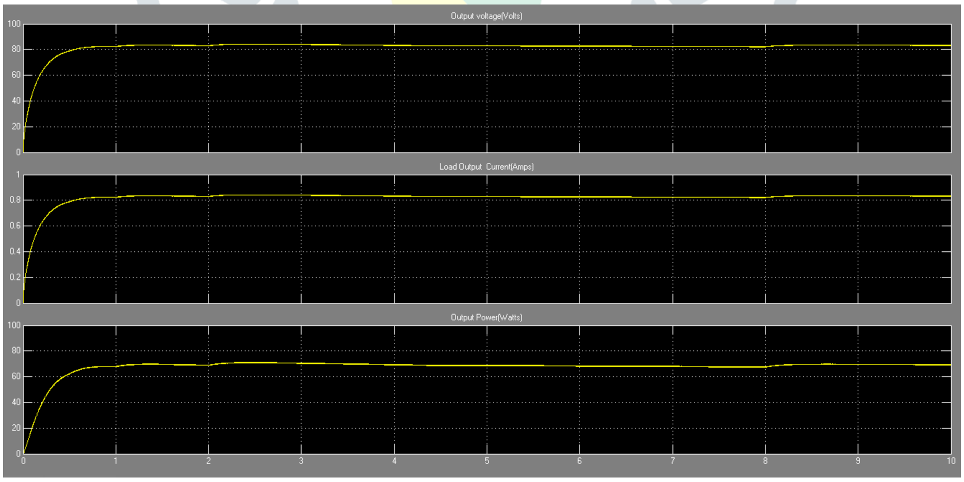

Fig 5.2.2 Simulated Output (V, I, POWER) of Modified Z Source fed SEPIC converter with duty cycle 0.3

Table 5.1: Descriptive Statics

Simulated Converter name	Duty cycle for 50V(calculated)	I/P Voltage	THD for 50V using PID controller	O/P Voltage using constant duty cycle
Z source	0.43	12 V	15.48	66.61 V
Modified Z Source	0.34	12 V	15.03	69.35 V
Modified Z source fed SEPIC	0.26	12 V	14.83	83.17 V

Table 5.1 second column is the calculated value of dutycycle using equation 3.1, 4.1 and 5.1. For the input voltage of 12V, using the MATLAB simulation as per fig 5.1.1 done and the respective desired output of 50V is achieved through the PID controller.However for each controllers the Total harmonic distortions is calculated by the simulation and was listed in column 4 of Table 5.1.THD is minumum in modified Z source fed SEPIC converter.The output of voltage, current through 100Ohm resistor and power drawn from the converter is shown as per the fig 5.1.2

For the input voltage of 12V, using the MATLAB simulation as per fig 5.2.1 done and the respective output is achieved for the constant duty cycle of D=0.3. Each controller the output voltage is calculated by the simulation and was listed in column 5 of Table 5.1.Output voltage is maximum in modified Z source fed SEPIC converter.On the contrary, modified Z source fed SEPIC converter uses less duty cycle to achieve the same voltage. The output of voltage, current through 100Ohm resistor and power drawn from the converter is shown as per the fig 5.1.2.

Hence higher gain with less duty ratio of the switches with less distortion is achieved by the modified Z source fed SEPIC converter.

VI HARDWARE RESULTS AND DISCUSSION

A Prototype model of in modified Z source fed SEPIC converter as per the block diagram fig 6.1 was made using the below compnents.Hardware setup consists of RPS of V_i = 12V and 5V, Z source components of C1 = C_2 = 47uF; L_1 = L_2 = 180uH; Load resistance = 100Ω Output capacitance of C_3 = 3300uF. PIC controller PIC16F877 is used for PID controlled PWM Generator. Output is shown through the display board.

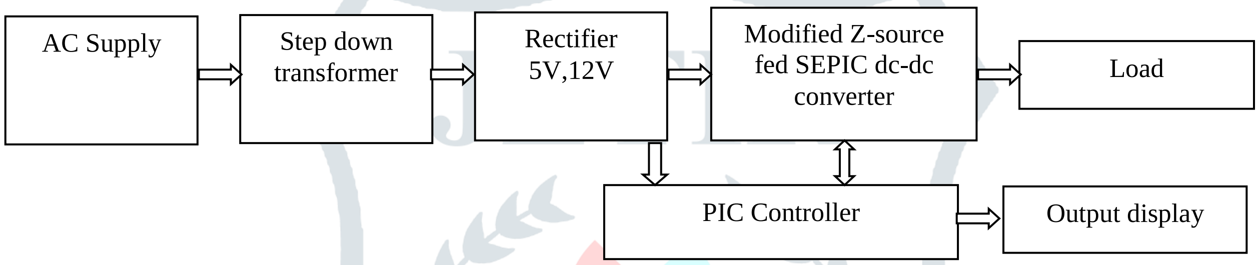

Fig 6.1 Hardware block diagram of Modified Z Source fed SEPIC converter with PID controller

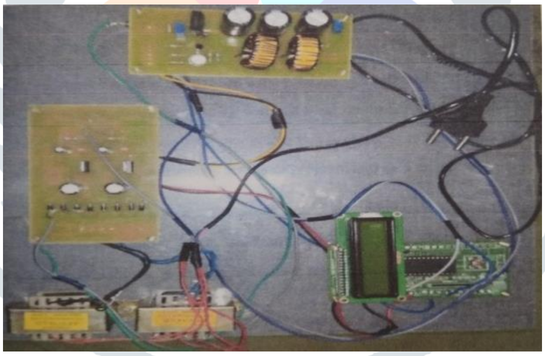

Fig 6.2 Hardware prototype of Modified Z Source fed SEPIC converter with PID controller

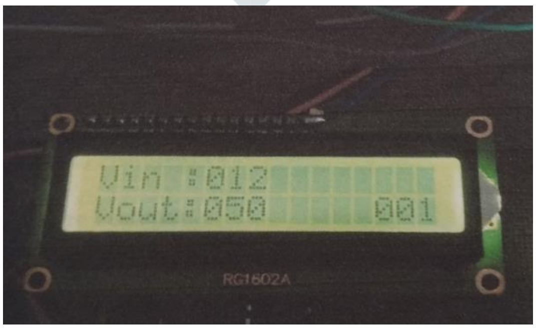

Fig 6.3 Output of prototype of Modified Z Source fed SEPIC converter with PID controller

The output voltage of 50v from the input of 12 V using the prototype of Modified Z Source fed SEPIC converter with PID controller is achieved and the results are inline with the simulated anlysis.

VI Conclusion

The modified Z-source fed SEPIC dc-dc converter has been presented in this paper. This DC converter has various advantages over the traditional boost dc converters. It provides higher voltage gain when compared to traditional Z-source dc boost converter. The configuration provides common ground between the output and input without any additional elements. This reduces cost and size of the dc converter. Simulation and prototype hardware results reveal that modified Z-source fed SEPIC converter gives a higher voltage gain without large duty ratio. Hence it is an efficient and reliable dc boost converter with higher voltage gain. We can include a multilevel inverter with this dc converter to get a sinusoidal ac output voltage to be used in normal household applications. Also the analysis shows the decrease of harmonic content in voltage; hence less filter requirement is needed. As a result the overall system cost gets minimized. Also as a result of low voltage stresses on the semiconductor devices, both efficiency and reliability of the converter is improved. Hence it is desirable for PV power generation systems, hybrid electric vehicles etc.

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