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Design of Modified Z-Source DC-DC Converter

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ABSTRACT

Sustainable energy application like Solar cells and fuel cells have low output voltage than required load demand. High gain dc-dc converters are used to boost the solar cell output voltage. The z source converter can also use to boost the PV panel voltages. This proposed system presents the modified Impedance source converter topology. The proposed converter gives high voltage gain with low duty ratio, high efficiency and positive polarity for output voltage. Therefore, this converter is good choice for high step up applications. The performance analysis of modified impedance source converter is analyzed by MATLAB/Simulink platform to validate their performance. The time domain simulation results demonstrate that the proposed converter gives improved voltage gain compared to conventional impedance source converter.

KEYWORDS: *DC-DC power converter, Impedance source, MATLAB/Simulink, Voltage gain.*

I. INTRODUCTION

Carbon emissions and high rate of oil cost are one of the drawbacks of using non-renewable energy sources So, therecent reaches are about renewable energy sources [1]. Some issues caused by combustion of fossil fuels are

- Non-renewable energy source
- Global warming
- The pour of oil has to lead water pollution and wildlife damage.

The renewable energy sources are used for long-term and they are cost effective and highly efficient. The renewable energy source like solar energy are increasingly employed to produce electrical energy [2]. But the solar cells output voltage is lesser than the load demand. So high gain dc-dc converters employed to boost the output voltage of renewable energy sources [3].

The solution of the above problem has been rectified by connecting several photovoltaic cells in series. Anyhow, some cells may be shaded and mismatch in photovoltaic modules cause high power dissipation and decrease the output power [4]. Using dc-dc converters are one of the best methods to boost the output voltage [5]. However, this converter has several switches and high switching stress.

The converters use high turn ratio transformer to obtain the large voltage gain [6]. The use transformer causes large leakage inductance.

The boost converters give large dc gain voltage but practical implementation of this converter give low efficiency and give large diode reverse recovery problem [7]. On the other hand, to boost this low output voltage Super lift converters are used. But these converters main switch duty cycle must be high to reach required output voltage. On the other hand, boost converter with coupled inductors may be used to obtain large output voltage. Anyhow, they unstable and inefficient [8].

Conventional impedance source converter has been proposed by Xupeng Fang in the year of 2002. It is used to obtain large dc voltage gain in comparison to the common dc-dc converters [9]. In this paper, an innovative impedance source converter is proposed, based on conventional Z source topology [10]. The main benefits of the proposed converter are

- Switch voltage stress is reduced.
- They do not have reverse recovery problem because the output diodes are turned on and off softly.
- The proposed converter has larger dc voltage gain, in comparison to the conventional Z source converter.
- In low switch duty ratio high voltage gain can be obtained.

II. EXISTING Z SOURCE CONVERTER CONFIGURATION

The conventional Z source converter has two modes of operation. They are voltage fed and current fed. When the power supply is dc voltage source then it is voltage fed converter. When the power supply is dc current source then it is current fed converter.

To simplify the analysis, we consider the power flow direction in only source to load. The impedance source converter is nothing two port network which consist of two capacitors and two inductors. The impedance source is a symmetrical converter so the inductors L, L_1 and L_2 have the same values and the capacitors C, C_1 and C_2 have same values. The conventional Z source converter is shown in Fig.1.

$$V_{C1}=V_{C2}=V_C \text{ and} \quad (1)$$

$$V_{L1}=V_{L2}=V_L \quad (2)$$

The converter has two patterns of operation. They are

1. S is ON
2. S is OFF

When the switch S is ON, the diode D is reverse biased so the source doesn’t give any power to the circuit. At that time the capacitors discharge the energy and inductors charges through the capacitors. The mode the time interval of the converter is D.T.

$$V_c=V_L \quad (3)$$

$$V_0=0 \quad (4)$$

When the switch S is OFF, the diode D is forward biased. At that time the capacitors C_1 and C_2 are charged. The inductors L_1 and L_2 are discharge the

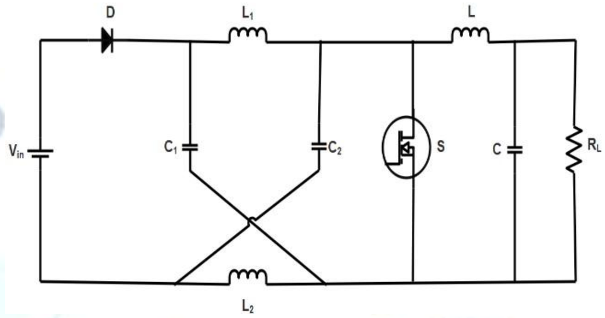

Fig.1 schematic Z source convert

energy and the current flow through the load. This mode the time interval of time is (1-D). T

$$Vc=V_i-V_L \quad (5)$$

$$V0=V_i-2V_L \quad (6)$$

Where,

V_i = Input voltage
V_0 = Output voltage
D = Duty ratio
V_L= Inductor voltage
V_C= Capacitor voltage

The average output voltage of the converter,

$$V_0 = Vc = \frac{1-D}{1-2D} V_i \quad (7)$$

III. PROPOSED IMPEDANCE SOURCE CONVERTER

The proposed converter has DC voltage source in series with diode and two port impedance networks is shown in Fig.2. The two-port network have two inductors and two capacitors. Then the network connected to the switch and filter circuit. The switch is controlled by using PI controller. The output of switch voltage is given to the load. The proposed converter has two patterns of operation.

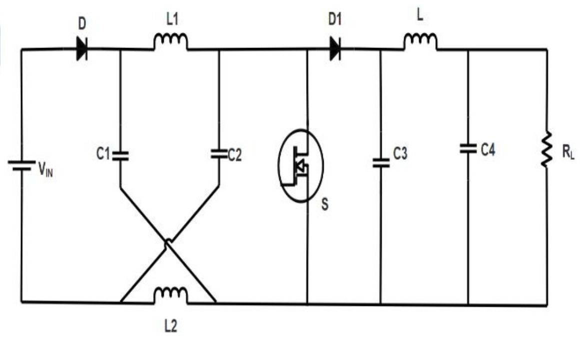

Fig.2 proposed converter topology

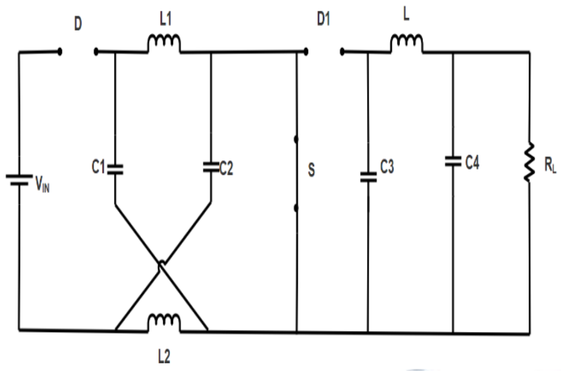

Fig.3 proposed converter-When S is ON

MODE 1: when S is ON

This operation mode is started when the switch, S, is turned on. In this operation the diode D is turned off. That time the input diode D voltage is,

$V_D = 2.V_C - V_i$ (8)

This mode of operation is shown in Fig.3. The capacitors C_1 and C_2, voltage is applied across the inductors L_1 and L_2. At that time inductors charges energy and the current are increased linearly. The diodes D1 is conducted in reverse direction. The inductor L charge the energy from the capacitor C_3. The capacitor C_4 discharge the energy. So, the current flows to the load.

MODE 2: When S is OFF

In this operating mode is started when the switch, S, is turned off. That time, the voltage across the input side increasing until the input diode D is turned off. The voltage is applied across the inductors L_1 and L_2. This mode is shown in Fig.4.

$V_{L1} = V_{L2} = V_I - V_C$ (9)

In this time the capacitors C1 and C_2 are charging. The diode D1 is forward biased because the inductors L1 and L2 changing the polarity due to the Len's Law. In that the inductors L charging and the current flow, the load through the capacitor C.

$V_O = -V_c$ (10)

IV. GAIN EQUATION OF PROPOSED CONVERTER

The converter output voltage gain is calculated by using Volt-second balance equation is applied across inductors L1 and L. The equations can consider based on volt-second balance principle:

$\int_0^{DT} V_L(t)dt = -\int_{DT}^{T} V_L(t)dt$ (11)

At inductors L1 and L

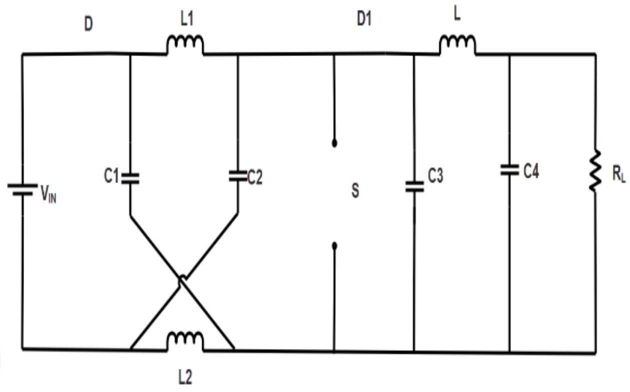

Fig.4 Proposed converter- S is OFF

$L_1 = D.T.V_c = -(1-D).T.(V_1 - V_c)$ (12)

$D.T.V_c = (-V_1.T + V_1.D.T + V_cT - V_c.D.T)$ (13)

$2V_c.T.D = (-V_1 + V_1.D + V_C)T$ (14)

$V_c(2D-1) = V_1(-1+D)$ (15)

$V_c = \frac{V_1(1-D)}{1-2D}$ (16)

For L,

$L = D.T.V_c = -(1-D).T.(V_1 - 2V_c - V_0$ (17)

$D.T.V_c = (-V_1.T + V_1.D.T + 2V_cT - 2V_c.D.T + V_0T - V0D.T$ (18)

$-V_1 + DV_1 + 2V_1\left(\frac{1-D}{1-2D}\right) - 2V_1D\left(\frac{1-D}{1-2D}\right) + V_0 - V_0D = V_0D$ (19)

$V_1(-1 + D + \left(\frac{2-2D}{1-2}\right) - \left(\frac{2D-2D^2}{1-2D}\right)) = V_0$ (20)

$\frac{V_1(-1+2+D+2D+2D-2D-2D^2+2D^2)}{1-2D} = V_0$ (21)

$\frac{V_1(1+5D-2D)}{1-2D} = V_0$ (22)

$\frac{V_1(1+3D)}{1-2D} = V_0$ (23)

Where,

V_1= Input voltage
V_0= Output voltage
D= Duty cycle
V_L=Inductor voltage
Vc= Capacitor voltage

V. SIMULATION RESULTS AND DISCUSSION

The simulation work is starts at conventional Z source. The Z source converter consists of two inductors and two capacitors. The Z-source dc-dc converter is symmetrical, that means, the inductors L_1 and L_2 and capacitors C_1 and C_2 have the same inductance (L) and capacitance (C), respectively. Here the input voltage is 24V and the duty cycle is 40%. The simulation diagram of the proposed converter is shown in Fig.5. The input voltage and input diode D waveforms are shown in Fig.6 and 7.

The closed loop of proposed converter uses the PI controller to control the output voltage of the converter. The controller output is compared to repeating sequence which is given to the switch.

The converter output is compared to reference block and it gives the error output which is 0.4 shown in Fig .8. Then the error value is compared to repeating sequence which gives the switching frequency of the converter. The repeating sequence values are [0 0.002 0.001].The compared output gives the PWM signal. Then the compared output is given to the switch which is used to turn ON and turn OFF the switch. The main switch waveform is given in Fig.9.

The converter output is compared to set point. The set point is constant value. The constant value corresponds to converter expected output voltage. Then this value is compared to actual output voltage which gives the error value then the error value is compared to repeating sequence block. The output of the feedback loop is given to the gate pulse of the switch.The output voltage waveform is given in Fig.10. The table I shows the parameters of the modified converter.

Table-I: Important characteristics of proposed converter

S.NO	PARAMETERS	VALUE
1	Input voltage	24V
2	Duty ratio	40%
3	Inductances L_1,L_2,L_3 and L_4	200µH
4	Capacitances C1,C_2,C_3 and C_4	47µF
5	Load Resistance	1kΩ
6	Output Voltage	264V
7	Output Current	0.26Amps
8	Switching frequency	20kHz

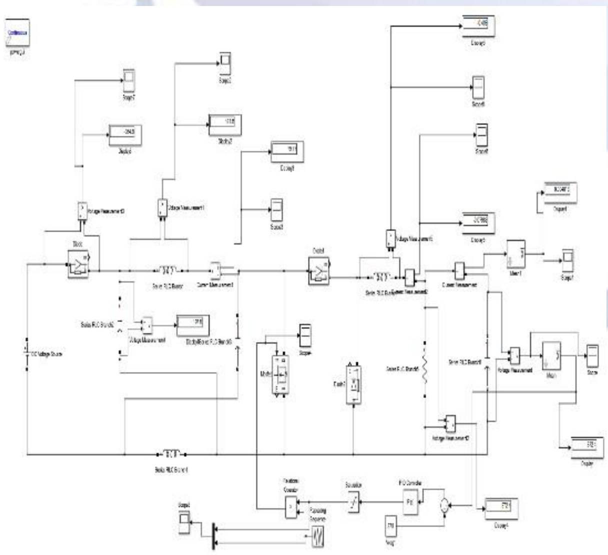

Fig.5 Proposed converter in Simulink

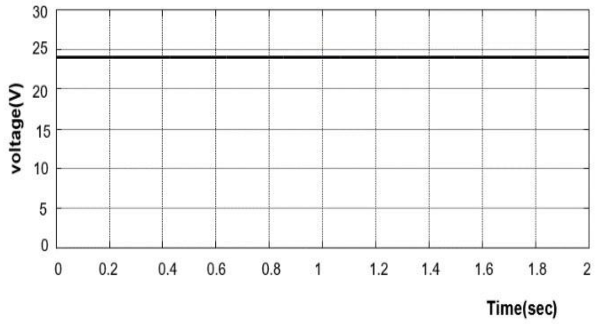

Fig.6 Input voltage waveform

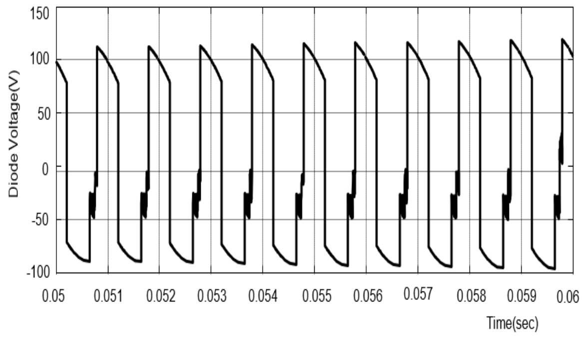

Fig.7 Diode voltage waveform

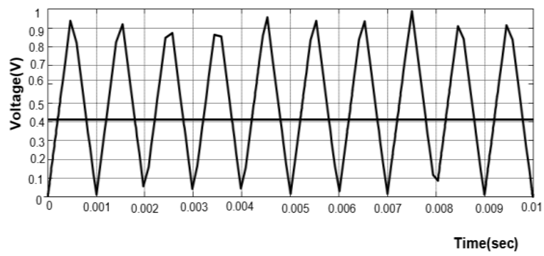

Fig.8 Controller waveform

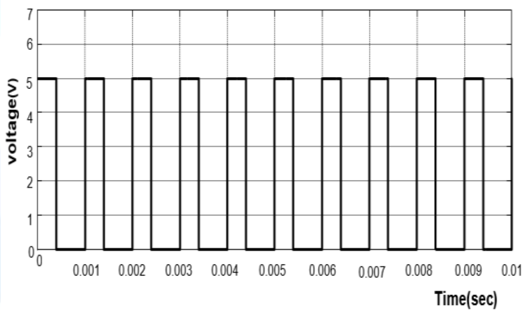

Fig.9Main switch voltage waveform

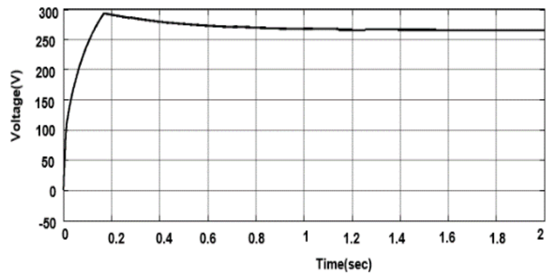

Fig 10: Output voltage waveform

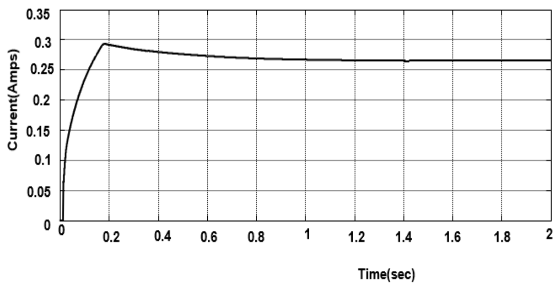

Fig.11 Output current waveform

VI. CONCLUSION

This paper presented a design and implementation of modified Z source DCDC converter. The different modes of converter are analyzed. The proposed converter gives larger output voltage gain compared to conventional impedance source dc-dc converter. This converter eliminates the problem of complexity and large duty ratio. This is achieved by choosing proper inductor and capacitor values. The proposed converter gives the input of 24V converted to any desired value up to 400V (closed loop). The digital simulations are carried in MATLAB/Simulink platform to validate the performance of the converter.

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