

Modified Trans Quasi Z-Source DC-DC Converter with Dual Output

Meenakshi Thillainayagam
Department of EEE, Jansons Institute of
Technology, Coimbatore, India
mechand22@gmail.com

SuthanthiraVanitha Narayanan
Department of EEE,
Knowledge Institute of Technology, Salem, India

Abstract— This paper presents a new topology of Quasi Z source DC –DC converter with dual output using the resources of transformer replacing the inductor in the Z impedance network. The dual output is obtained across the main load connected to the impedance network and the secondary of the transformer. The proposed converter can be applied for photovoltaic systems in the front end and the boosted dual output voltage can serve as input for multilevel inverter thus reducing the source requirements. Simulation study of the proposed inverter is carried in MATLAB and the results are presented.

Keywords— Converter; Z source; Transformer; Dual output; Photovoltaic systems

I. INTRODUCTION

DC-DC converters generate controlled variable DC from fixed DC voltage that are step up or step down voltage depending on the circuit configuration adopted by the system. Various classifications of the converters were devised based on the operation like buck, boost and buck-boost converters [1-2]. The primitive converters yield only single output and for applications that require multiple source, the circuit becomes bulky. Hence Single Inductor multiple output DC-DC converters were proposed in literature to obtain multiple output from a single circuit for various electronic applications [3-4]. This circuitry uses additional switches to share the inductor current between the multiple output voltages. This circuitry generally holds good for low power applications.

High power DC-DC converters are used as power conditioners for renewable energy sources and are applied for DC drive applications [5-6]. Few special type of DC-DC converters used for high power applications are Cuk, fly back, sepic and Quasi Z source DC-DC converter [7]. All these converters are designed to give single output with the aid of energy storage elements.

An attempt is made to convert the aforesaid converter to produce dual output with a simple modification in the circuitry. The converter of interest is Quasi Z source DC-DC converter [8]. The advantage of this converter includes high boost value with reduced stress on the components. The new modified trans quasi Z source DC-DC converter uses mutually coupled devices like transformer to produce dual output. The secondary are connected in series aiding

fashion which in turn feeds the load. This forms one output. The other output is tapped from the load connected to primary of the transformer. The output is controlled by the switching device switched at high frequency. This is different from Trans Z source topology where the primary and secondary of the transformer forms the inductive device in the circuit, The proposed circuit produces dual output voltage with a reasonable boost. The circuit is built in MATLAB Simulink environment to validate the theoretical findings. The simulation results very well follow the described nature of the circuit and the results are presented.

II. DC-DC CONVERTERS

A. Types of Converters

DC-DC converters are exclusively used as a power conditioning unit for renewable energy sources. They convert fixed DC to variable DC by continuous switching ON and OFF of the switching device. Depending on the operation, the DC-DC converters are classified as buck, boost and buck-boost converters.

B. Buck Converter

The basic operation of the buck converter has the current in an inductor controlled by two switches (usually a transistor and a diode). In the idealized converter, all the components are considered to be perfect. In this system the converter outputs reduced voltage compared to the input.

C. Boost Converter

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current by creating and destroying a magnetic field. In a boost converter, the output voltage is always higher than the input voltage.

D. Buck-Boost Converter

In the buck-boost converter during the On-state, the input voltage source is directly connected to the inductor (L). This results in accumulating energy in L. In this stage, the capacitor supplies energy to the output load. During Off-state, the inductor is connected to the output load and capacitor, so energy is transferred from L to C and Special types of converters are Cuk Converter and Impedance Converter. All these converters produce a single output.

III. Z SOURCE DC-DC CONVERTER

Quasi Z-Source DC-DC converter is a special type of converter which uses a LC impedance network to buck and boost the input voltage depending on the duty ratio. The energy storage action helps to boost the input voltage and this provides only one output. The circuit diagram of the Z source DC-DC converter is shown in Fig. 1.

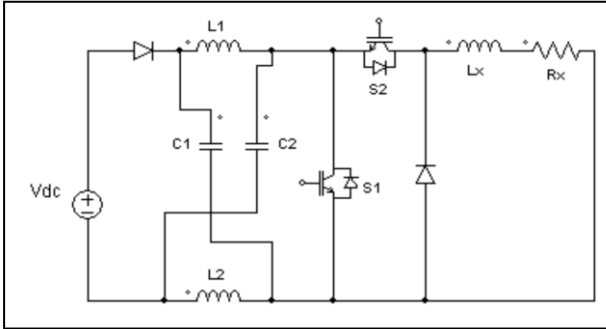


Fig. 1. Circuit diagram of Z Source DC-DC converter

The proposed converter is a new version of Z-source DC-DC converter which aims at producing dual output voltage from a single circuit. This is obtained by replacing the inductor by transformer in the impedance network. The mutual induction induces voltage in the secondary of the transformer which is taken as the secondary output.

A. Circuit diagram of the proposed trans Quasi Z DC-DC converter

In the conventional method of DC-DC converter, inductance is used. Single output is obtained from the inductance network of the converter. To obtain an additional output from the converter, the inductor is replaced with the transformer. The circuit diagram of the converter is given in Fig. 2.

In this circuit, inductor is replaced with transformer. Dual output is obtained in this impedance network. The output is rectified by a diode rectifier and the output is obtained as pure DC voltage. The diode D1 is a reverse protection diode which prevents the reverse flow of the current. The capacitor C1 and C2 are the components of the LC network which aids in energy storage. The duty cycle of the switching device controls the buck boost operation of the converter. Both the voltages are boosted which depends on the turns ratio.

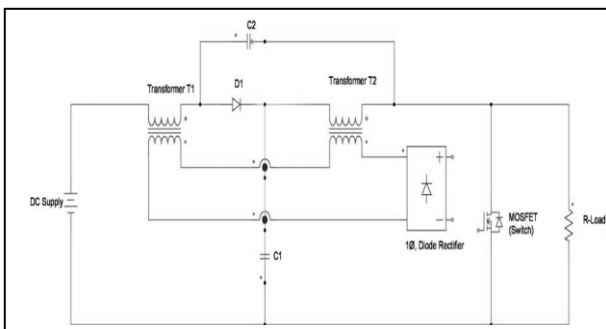


Fig. 2. Circuit diagram of proposed Trans Quasi Z DC-DC converter

B. Modes of Operation

There are two modes involved in the operation of the converter. They are

- T-ON MODE
- T-OFF MODE

• T-ON Mode

T-ON mode is during the conduction of the switching device. The switch acts as a short circuit during ON condition and hence the load is isolated. During closed condition, the DC supply energizes the transformer and capacitors C1 & C2 get charged. The load remains inactive. The operating flow under ON state is figured in Fig. 3. Hence the energy storage operation is performed in T-ON mode.

• T-OFF Mode

This mode is during the OFF state of the switch. Now the voltage appears across the load. During Open condition, the voltage across the load is the algebraic sum of the supplied voltage and capacitor voltage. MOSFET action under this condition is well observed from the Fig. 4. The energy discharge operation is performed. Hence the secondary of the transformer also discharges its output to the rectifier unit. Hence dual output is obtained from the proposed circuit. The output voltage from the secondary of the transformer is rectified and obtained as a pure DC voltage. The output from the primary is filtered with the capacitor filter and pure DC is obtained.

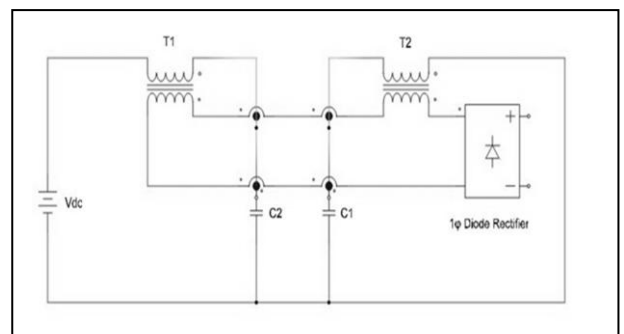


Fig. 3. Equivalent circuit during the T-ON state

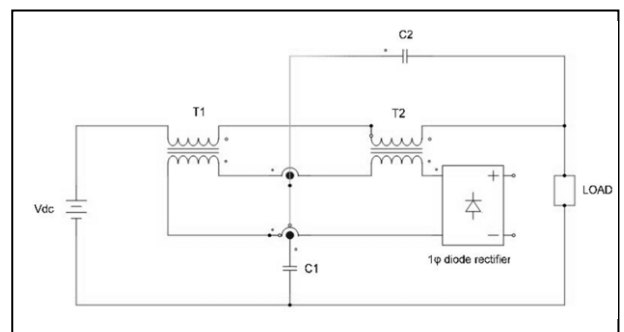


Fig. 4. Equivalent circuit during the T-OFF state

C. Mathematical Analysis

The analysis of Trans Quasi Z Source DC-DC Converter with dual output is performed under T-ON and T-OFF state. Basic Kirchoff's Voltage Law (KVL) equations are used for the analysis. The equations obtained in the T-ON state is given by (1) and (2)

$$V_{dc} - V_{T1} + V_{C2} = 0 \quad (1)$$

$$-V_{T2} + V_{C1} = 0 \quad (2)$$

During the T-OFF state, the output is presented to the load. The governing equations are given by (3) and (4)

$$V_{dc} - L_1 \frac{di_1}{dt} - M \frac{di_2}{dt} - V_{C1} = 0 \quad (3)$$

$$L_2 \frac{di_2}{dt} + M \frac{di_1}{dt} = -V_{ph} + V_{C1} \quad (4)$$

The equations obtained from the equivalent circuit on the secondary of the transformer is given by (5)

$$L_2 \frac{di_2}{dt} + M \frac{di_1}{dt} = -V_{C2} \quad (5)$$

On solving the above equations, the capacitor voltage is obtained as (6) and (7)

$$V_{C1} = \frac{T_1}{T_1 - T_0} V_{dc} \quad (6)$$

$$V_{C2} = \frac{T_0}{T_1 - T_0} V_{dc} \quad (7)$$

IV. RESULTS AND DISCUSSION

The simulation of the proposed Trans Quasi Z DC-DC converter is performed in MATLAB Simulink with the following parameters. The input voltage fed to the system is 18V. The primary and the secondary inductance of the transformer is 105mH, 650mH and mutual inductance is 47mH. Fig. 5. shows the simulation model of the proposed converter. The switching frequency is 10kHz .

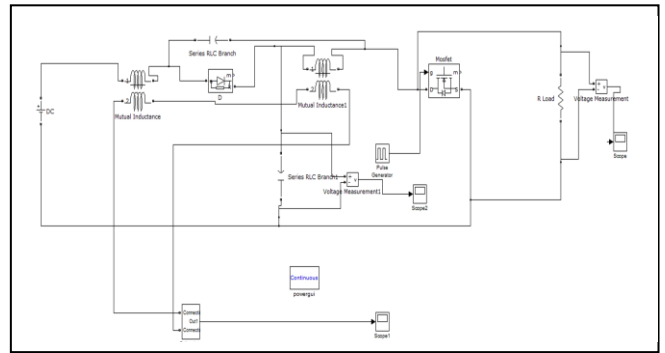


Fig. 5. Simulink model of the proposed Trans Quasi Z DC-DC converter

The input voltage fed to the SIDO Z converter is 18V. Fig. 6. shows the simulated waveform of the input voltage. The pulse produced at a frequency of 10 kHz is shown in Fig. 7. The duty ratio of the pulse is 0.65. On applying the gate pulse to the switching device, the output voltage is obtained across load 1 and load2. The voltage across the load1 is boosted to 42V for a duty ratio of 30%. The boost factor is 3.5. The voltage across the Vload2 is obtained as 32V . Fig. 8. and Fig. 9. Show the output voltage obtained across load 1 and load 2 respectively. It is very well seen that boosted voltage is obtained across both the output.

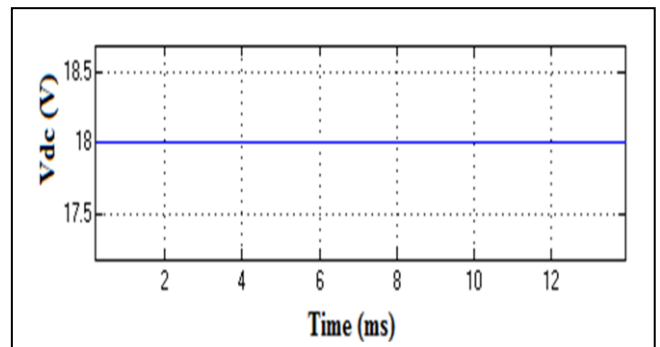


Fig. 6. Input voltage of the proposed Trans Quasi Z DC-DC converter

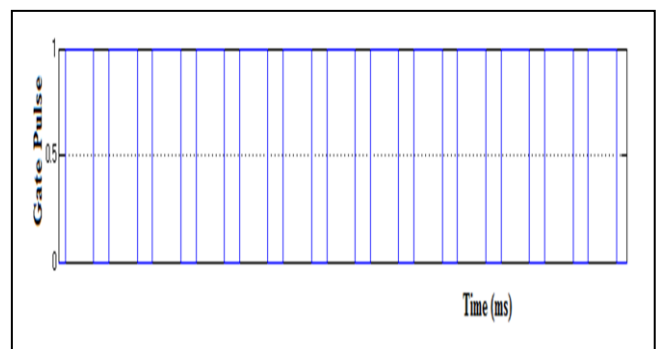


Fig. 7. Gate pulse fed to the proposed Trans Quasi Z DC-DC converter

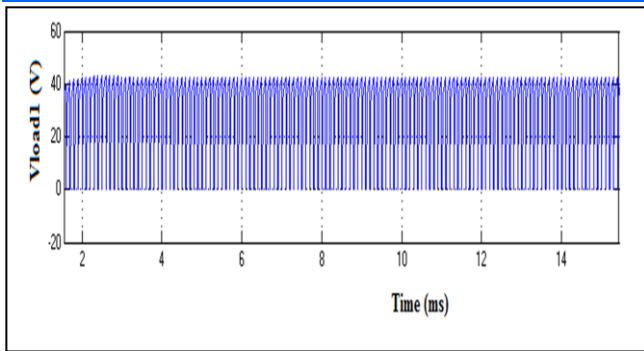


Fig. 8. Simulated waveform of voltage obtained across Vload1

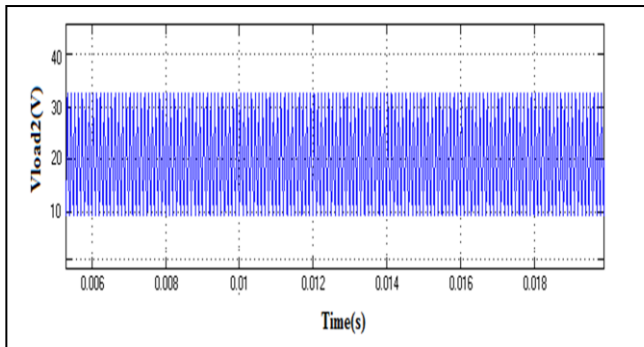


Fig. 9. Simulated waveform of voltage obtained across Vload2

Sequence of simulation was conducted to study the effect of duty ratio on the output voltage across load1 and load2. The converter exhibits the features of boost converter for increasing duty ratio. The voltage obtained across the load for different duty ratio is given in Fig. 10. It is observed that for increasing duty ratio, the output voltage increases in both the load. The voltage across load1 is comparably higher than voltage across load2. This is because the Vload2 depends upon the voltage rise and fall of the inductor current. The capacitor voltage obtained is given by Fig. 11.

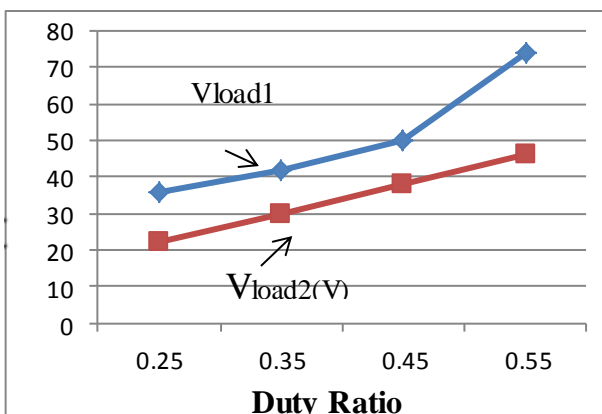


Fig. 10. Effect of duty ratio on output voltage

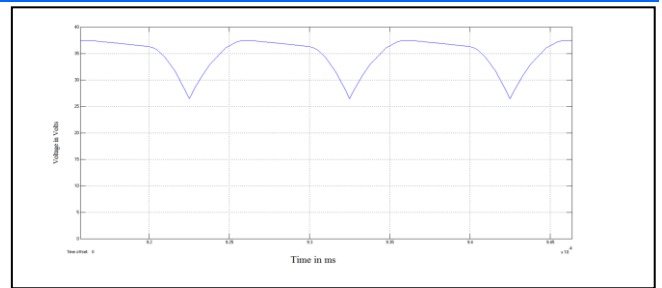


Fig. 11. Simulated waveform of capacitor voltage

V CONCLUSION

The current work proposes the new trans Quasi Z DC-DC converter with dual output for renewable energy systems. The input voltage is shared between the coupled device and dual output voltage is obtained. The quasi network boost the input voltage, thus boosted voltage is obtained. This voltage serves as input to the multilevel inverter. Continuous current is featured by the converter and the ripple in the input current is reduced.

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