A Modified Single-Phase Quasi z source converter

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***Abstract* —** *Power Electronic devices plays an important role to control and convert electrical power from one form to another. The system which performs the power processing is called a converter. Converter can perform the function of rectifying (AC to DC), inverting (DC to AC), boosting (DC to DC), and frequency conversion (AC to AC). The device which is used to convert DC to AC is called inverter. Inverters are classified into two types, current source inverter (CSI) and voltage source inverter (VSI). The demerits of CSI and VSI can overcome by using the proposed concept. The proposed concept gives voltage boost and it provides short circuit protection. Two different methods are used to boost the output voltage, simple boost control method and fuzzy logic control method. The obtained output voltage of QZSI and total harmonic distortion (THD) are compared and analysed. The proposed concept is used for the applications of grid connected photovoltaic systems, electric vehicles and adjustable speed drives.*

Keywords —*current source inverter (CSI), voltage source inverter (VSI), total harmonic distortion (THD), QZSI-quasi z source inverter.*

I. INTRODUCTION

Quasi z source inverter is a single stage power converter and it is derived from the impedance source inverter topology. The traditional voltage source and current source inverters suffers from the limitation of triggering two switches in the same leg or phase leads to a source short circuit and the maximum obtainable output voltage cannot exceeds the DC input and can produce a voltage lower than DC input voltage. Both z-source and quasi z-source inverter overcome these drawbacks by utilising the several shoot through zero states. Shoot through zero state is produced when all the upper switches or lower switches are fired simultaneously to boost up the output voltage.

The impedance network couples the source and the inverter to achieve voltage boost in a single stage. Different topologies of z source inverter are Quasi-z-source inverter, semi-Z-source inverter, Trans-Z-source inverter, Y-source inverter, X-source inverter, etc.

Z-source and its derived topologies could be applied in many application areas such as fuel cell, photovoltaic and wind power generation system, hybrid electric vehicle, etc. and they could also be applied in ac power supply due to their buck-boost function. The main circuit uses voltage-fed quasi-Z-source inverter structure. This system is suitable to wide range of load, from no-load, light load to heavy load.

Compared with the traditional voltage source inverter-based ac power supply with the same capacity, its efficiency is more. The major difference between impedance source inverter and quasi impedance source inverter is, the QZSI draws a continuous constant DC current from the source due to input inductor while ZSI draws a discontinuous current. QZSI has higher reliability and it requires simple control strategy. Since the QZSI draws constant current, stress on the inverter switch is less.

II. CIRCUIT DIAGRAM OF THE PROPOSED QZSI

QZSI circuit differs from that of conventional ZSI in the LC impedance network interface between source and inverter. This network protects the circuit from damage when shoot through occurs and by using the shoot through state, QZSI network boosts the DC link voltage. The circuit diagram contains diodes front end, filter capacitors, impedance network, inverter switches and load.

The DC source can be taken as a battery, diode rectifier, thyristor converter or PV array. Here, diode rectifier is used for the DC source. The input AC supply is converted to DC by using the diode bridge rectifier. The circuit involves impedance network having inductances L_1, L_2 and capacitances C_1, C_2 and the inverter module contains IGBT switches with an anti parallel diodes. Voltage of capacitor C_4 is near to constant DC voltage, since the AC input voltage is rectified by the diode bridge rectifier and filtered by the capacitors C_3 and C_4.

The controllable device VT_5 is used to deal with the discontinuous operation condition when the load is light, it could be an IGBT or a Power MOSFET. Here VT_5 is chosen as IGBT device. IGBT part is turned ON when the inverter operates in non shoot through state i.e. in the active state and traditional zero state. IGBT part is turned OFF when inverter operates in shoot through zero state.

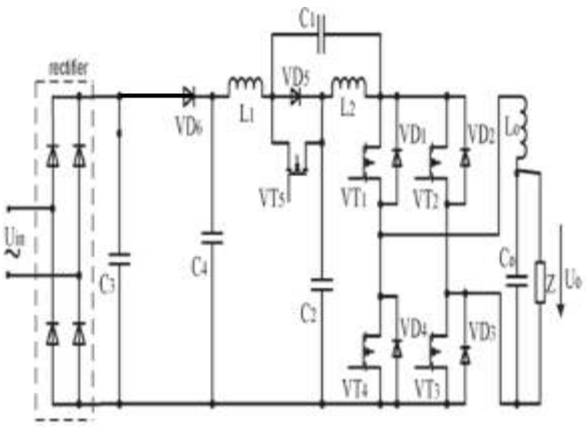

Fig. 1 Circuit Diagram Of Proposed QZSI

III.MODES OF OPERATION OF QZSI

In traditional voltage source inverter, the operation involves in two modes: a) active state mode b) zero state mode. It has two active states and two zero states. In QZSI, the operation involves in three modes: a) active state mode b) zero state mode and c) shoot through mode. It has two active states, two traditional zero states and three shoot through zero states.

Active states: One of the upper switches and one of the lower switches of different legs are turned on and power flow to load.

Traditional Zero states: Upper or lower two switches are turned on and power does not flow to load.

Shoot through states: The switches of same leg or total switches are turned on.

Circuit Operation during different modes are given below:

Active State:

During this mode, capacitor voltage is equal to input voltage. No voltage across the inductor since only pure DC current is flowing through inductor. Single-phase QZSI has two active states.

Traditional Zero State:

During this mode, inductor current decreases linearly and voltage across the inductor is difference between input voltage and capacitor voltage. Single-phase QZSI has two traditional zero states.

Shoot-Through Zero State:

During this mode, inductor current increases linearly and voltage across inductors is equal to voltage across capacitors. These capacitors charge the inductors and current through the capacitor is equal to the current through the inductor. Single phase QZSI has three shoot through states.

TABLE I
OPERATING STATES FOR SINGLE PHASE QZSI

STATE	VT_1	VT_2	VT_3	VT_4
Active state	ON	OFF	ON	OFF
	OFF	ON	OFF	ON
Traditional zero state	ON	ON	OFF	OFF
	OFF	OFF	ON	ON
Shoot through zero state	ON	OFF	OFF	ON
	OFF	ON	ON	OFF
	ON	ON	ON	ON

IV.CONTROL METHODS

Simple Boost Control Method

In simple boost control method, two constant voltage signals which are compared with the high frequency carrier wave. Whenever the magnitude of carrier wave becomes greater than or equal to positive constant signal or lesser than or equal to the negative constant signal, pulses are generated and they control the shoot through duty ratio. Simple boost control method used to control the shoot through duty ratio. The shoot through duty ratio is given by D.

$$D=\left(\frac{T_0}{T_1+T_0}\right) \qquad (4.1)$$

From equation 4.1, duty ratio is the ratio of on time to the total time. For simple boost control, the obtainable shoot through duty ratio decreases with the increase of modulation index. The maximum shoot through duty ratio of simple boost control is limited to (1-m), where m is the modulation index.

Voltage gain is given as:

$$\frac{U_0}{U_i} = mB$$

Where B is the Boost factor and it is given as:

$$B=\left(\frac{1}{1-2D}\right)$$

$$\frac{U_0}{U_i} = mB = m\left(\frac{1}{1-2D}\right) = \frac{m}{2m-1}$$

Fuzzy Logic Control Method

In bi valued logic, it contains only two possible values as 0/1, yes/no, right/wrong etc. Fuzzy logic is a multi valued. It has relative values like yes, not, not so much, a little bit etc. Fuzzy control system is based on fuzzy logic. Steps involved in fuzzy logic control method are given in below:

Step 1: Identifying the input, output, and process tasks.
Step 2: Identifying the linguistic variables used and define fuzzy sets and membership functions.
Step 3: Forming procedural rules.
Step 4: Determining the defuzzification .
Step 5: Test the system and modify if necessary.

V. SIMULATION RESULTS AND ANALYSIS

In the fig 5.1, it shows the Simulink model for single phase quasi z source inverter. The parameters taken for the system are given in below table 5.1

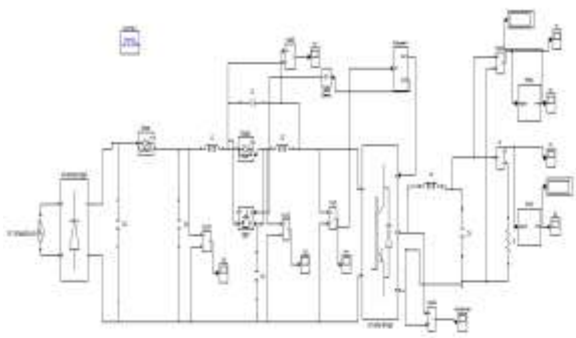

Fig 5.1 Simulink model for the single phase quasi z source inverter

PARAMETERS FOR SIMULINK MODEL

TABLE 5.1
SYSTEM PARAMETERS

S.NO	Parameter	Parameter values
1.	input AC voltage	150v
2.	Z network components C_1=C_2 L_1=L_2	 1000µF 2mH
3.	Output filter components L C	 1mH 10 µF

Fig 5.2 shows the rectified and filtered DC voltage for single phase QZSI and fig 5.3 shows the input voltage of QZSI. Output voltage and output current of single phase QZSI are shown in fig 5.4 and 5.5 respectively.

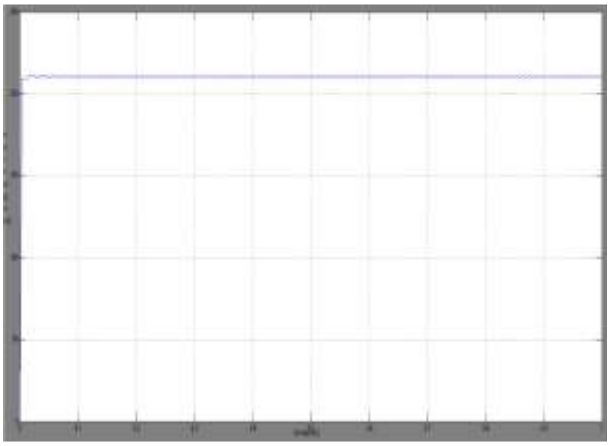

Fig 5.2 Rectified and filtered DC voltage

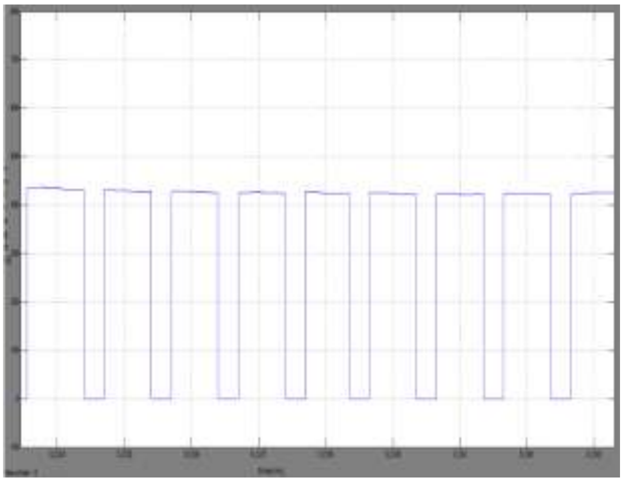

Fig 5.3 Quasi z source inverter input voltage

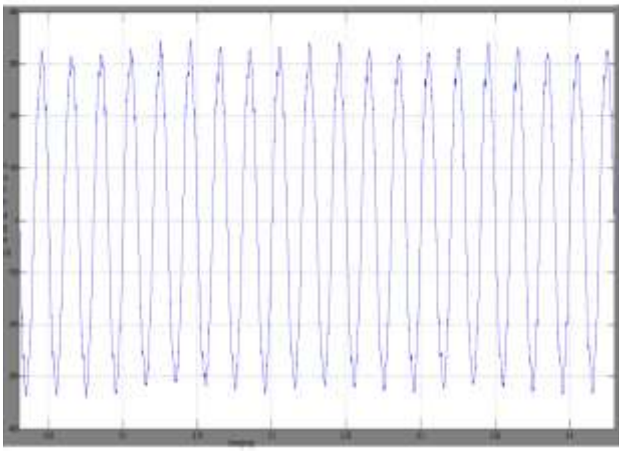

Fig 5.4 Output voltage of the single phase QZSI

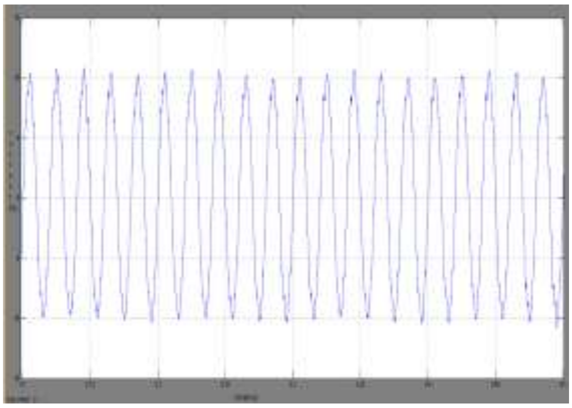

Fig 5.5 Output current of the single phase QZSI

Fuzzy input, output, membership functions, fuzzy rules are shown in below figures. The obtained output voltage from fuzzy logic control is also shown in below figure. Obtained simulation results are tabulated in table 5.2.

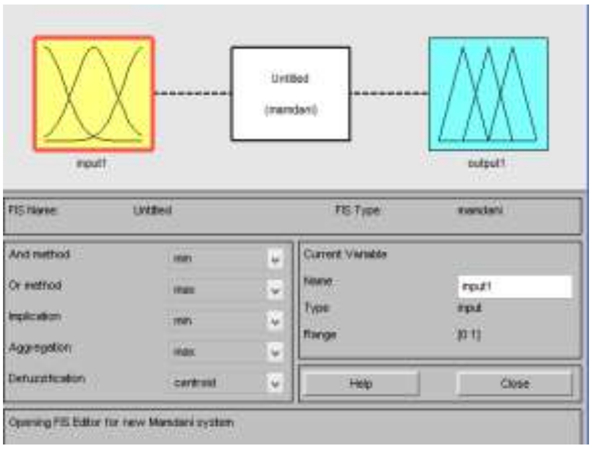

Fig 5.6 Opening FIS editor for Mamdani System

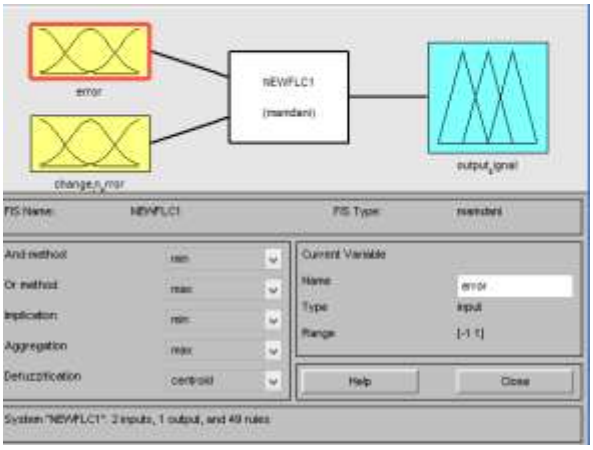

Fig 5.7 Input and Output for Fuzzy Logic System

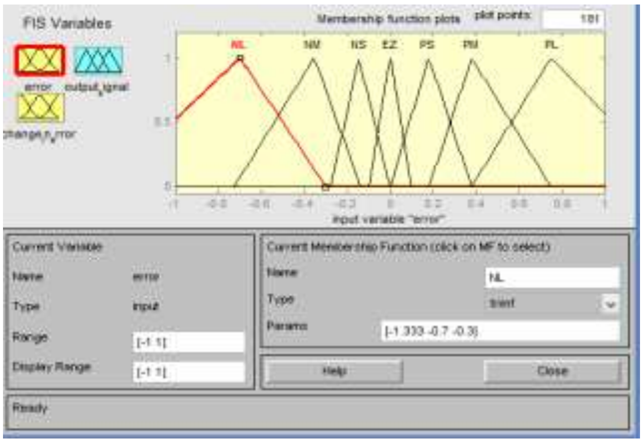

Fig 5.8 Membership Functions for Error

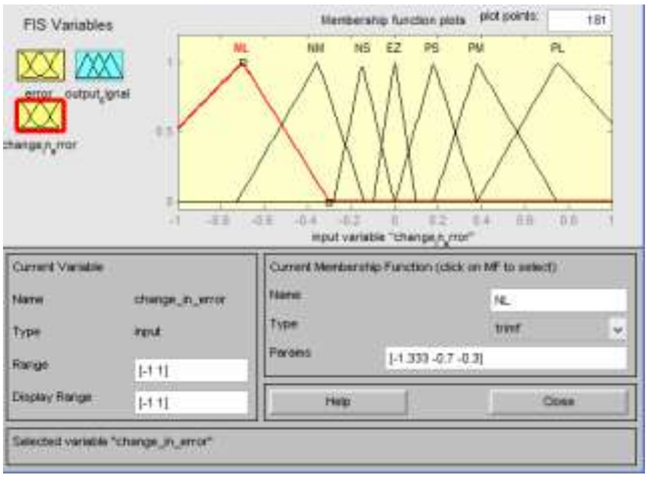

Fig 5.9 Membership Functions for change in Error Input

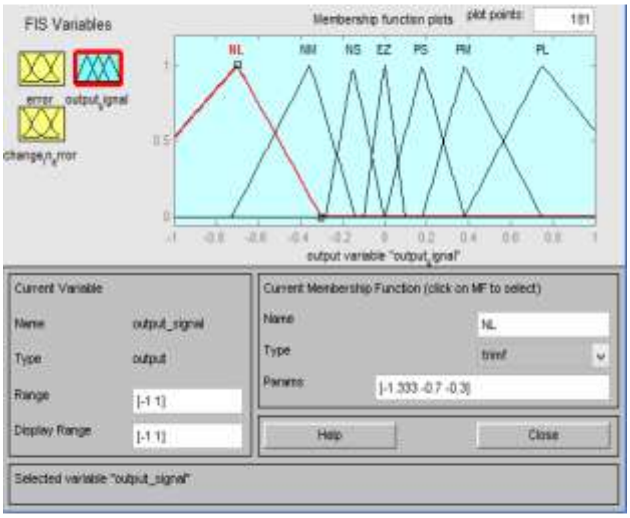

Fig 5.10 Membership Function Plots for Output Signal

Fig 5.11 Fuzzy Logic System Rules

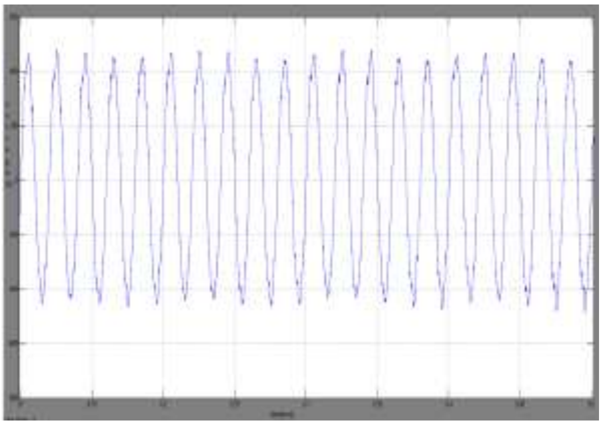

Fig 5.12 Output Voltage of QZSI with Fuzzy Logic Control

VI. MATHEMATICAL EQUATIONS OF QZSI

The Average voltage of the quasi z source network inductors should be zero in a switching period T. Let T_1 be the duration of active and traditional zero state, T_0 be the duration of shoot through zero state, T be the switching period.

$$U_{L1} = [T_1 (U_i - U_{C2}) + T_0 (U_i - U_{C1})]/T \qquad (6.1)$$

$$U_{L2} = [T_1 (U_{C2} - U_{inv}) + T_0 (U_{C2})]/T \qquad (6.2)$$

Now, make the average voltage of the quasi z source network inductors zero in a switching period T:

$$U_{L1} + U_{L2} = 0 \qquad (6.3)$$

After simplification the obtained input voltage of Inverter Bridge is,

$$U_{inv} = \left(\frac{T_1 + T_0}{T_1 - T_0}\right) U_i \qquad (6.4)$$

Shoot through zero state Duty cycle is given by:

$$D = \left(\frac{T_0}{T_1 + T_0}\right) \qquad (6.5)$$

U_{inv} can be written in terms of duty cycle is as follows:

$$U_{inv} = \left(\frac{1}{1-2D}\right) U_i \qquad (6.6)$$

$$U_{inv} = B\, U_i \qquad (6.7)$$

Where B is Boost factor, $B = \left(\frac{1}{1-2D}\right)$

Peak value of the output voltage U_0 is given by:

$U_0 = mU_{inv}$

$U_0 = m\, BU_i$

Where m is the modulation index.

Average voltage of the quasi z source network capacitors C_1 and C_2 are as follows:

$$U_{C1} = -U_i \left(\frac{T_0}{T_1 - T_0}\right)$$

$$U_{C2} = U_i \left(\frac{1 - T_0}{T_1 - T_0}\right)$$

U_{C1} and U_{C2} can be written in terms of duty cycle is as follows:

$$U_{C1} = -U_i \left(\frac{D}{1-2D}\right)$$

$$U_{C2} = U_i \left(\frac{1-D}{1-2D}\right)$$

The value of shoot through zero state duty cycle D is depends on the control method of the inverter. The control methods for the quasi z source inverter are simple boost control and maximum boost control.

In simple boost control method, m+D=1 and duty cycle D is a constant value.

From the above equations voltage gain of simple boost control is given by:

$$\frac{U_0}{U_i} = mB = m\left(\frac{1}{1-2D}\right) = \frac{m}{2m-1} \qquad (6.8)$$

Voltage buck or boost depends on modulation index and shoot through zero state duty cycle D. Modulation index is chosen as large as it can be to decrease the voltage stress of the power switches. For the output voltage, a larger modulation index will correspond to a lower boost factor and this will decrease the voltage stress of the power switches.

TABLE 6.1

OBTAINED SIMULATION RESULTS

	V_0 (V)	I_0 (A)	THD (%)
Single phase QZSI	320	10	5.73
Three phase QZSI	315	6	5.03
Fuzzy control QZSI	450	15	5.46

VII. CONCLUSION

This paper describes a new single-phase AC power supply topology based on the single-phase quasi-Z-source inverter. it concerns the light load and heavy load conditions. When a higher output voltage is required or when the line voltage suffers with lower voltages, the shoot –through zero states are employed to boost the dc capacitor voltage. By controlling the shoot-through zero state intervals, desired DC voltage can be maintained. By designing the circuit mechanism, the reliability, safety and efficiency of the system are improved. It could suit to all kinds of load, such as resistive, inductive and capacitive, and has good load characteristics.

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