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# Modelling and Simulation of Three Phase Quasi-Z Source Inverter using SBPWM at Varying Shoot through Duty Ratio

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***Abstract*— The inverter studied and simulated in this paper is a 3-phase-quasi-z-source inverter. It is preferred due to certain qualities like its simple structure and because of having a continuous input current, common ground and shoot through state. Traditional inverters don't have the shoot-through condition. If both the switches are operated at a time, short circuit occurs and circuit gets damaged. So we need to give dead time in traditional inverters. This results in more total harmonic distortion.**

**In this paper we have studied a topology of Quasi-z-source inverter (qZSI) to analyse the effect of Shoot-Through Duty Ratio (D) variation on the output voltage. The results are obtained using MATLAB/SIMULINK, suitable plots and waveforms are drawn using the said results to investigate the change in output voltage with the change in shoot-through duty ratio.**

**The advancement in quasi Z-source topology will be continuously improving the performance of electronic equipments in various applications because of its buck boost ability with least components and less cost. The fields on which it has maximum influence include aerospace, home appliances and power generation (solar, wind, etc).**

***Index Terms*— quasi z source inverter, photovoltaic, voltage-source-converter, pulse width modulation.**

## I. Introduction

### *A. Background*

Power electronics is one of the emerging fields in the systems employing power electronics for energy transformation in areas like renewable power system, home equipments, aerospace systems etc. With the increase in power demand there is an increase in the demand of power electronic equipments having low cost and high performance. The concept of z-source has advanced the research areas in power electronics and it has been modified in many ways to feed the needs in power system. Since z-source inverters have buck boost capabilities, new topologies are tried to lower the cost and improve performance with least components for different fields like solar, thermal and wind power generation. Traditionally, we have two types of converters that is voltage source inverter, and current source inverter and both have their limitations that does not allow economical and efficient solutions. Traditional inverters don't have the shoot-through condition. If both the switches are operated at a time, a short circuit occurs and the circuit gets damaged. So we need to give dead time in traditional inverters. However,

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this results in more total harmonic distortion. Therefore, in applications where we need boosted voltage, the z-source converter is considered as a possibility.

*B. Literature Review*

Traditional inverters have the major limitation of non-shoot-through state that means shoot-through can't happen in these inverters. At a time only one switch of the leg can be operated but in 2002 Professor F.Z PENG came up with a new solution to the limitations of traditional VSI/CSI i.e z source inverter. In z source inverter shoot-through is possible but it has the limitation of drawing discontinuous input current. These limitations were covered in quasi z source inverter proposed by Dr. Sang Zang in 2009.
The concept of z-source converters was presented in 2002[1]. It is different from conventional voltage source converter and current source converter as it is an impedance network consisting of diodes, capacitors and inductors where capacitors and inductors are connected in X form to buck or boost the voltage[2].
Conventional 3-phase VSI has 6 active states and two zero states where as in ZSI by gating the switches extra zero states are possible which provide unique buck-boost feature. ZSI too has some limitations like no common ground is present and it draws discontinuous input because of which input stress increases. These limitations were eliminated by the concept of qZSI[3].

*C. Motivation of present work*

Quasi z source inverter is a major area of research lately. The main problem with the conventional inverters is that shoot-through state is not present and to operate the alternate switches at a time, we need to give dead time which increases total harmonic distortion. Quasi z source inverter reduces the total harmonic distortion by Shoot-through state. It also boosts the output voltage. So analysis of results at different shoot through duty ratios is required.

*D. Problem Statement*

In traditional inverters the voltage cannot be boosted and output voltage has more distortion. To overcome this, ZSI is used but in ZSI the circuit draws discontinuous current due to which there is more input stress and common ground is also not present. To overcome these problems quasi z source inverter is used as it boosts the output voltage. The output voltage in this case depends on the shoot-through duty ratio. Therefore, the work presented here studies the effect of shoot-through duty ratio on the output voltage using simple boost pulse width modulation (SBPWM) topology.

*E. Quasi-z source inverter*

The equivalent circuit of qZSI is shown in fig.1, which explains its operation. From fig.1 it can be observed that its operation is similar to ZSI but it draws continuous input which reduces input stress. This makes it well suited for solar generation applications[4–12].
qZSI has the buck- boost capability making it the most preferred inverter in the field of renewable energy[13].
qZSI has the major advantage of eliminating the lower harmonics so the output voltage obtained are better than conventional inverters[14].

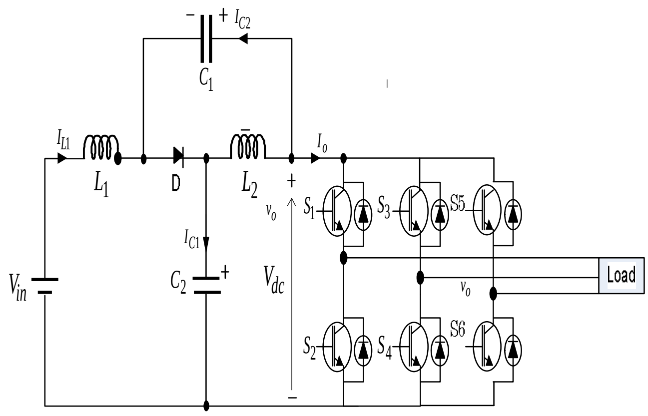
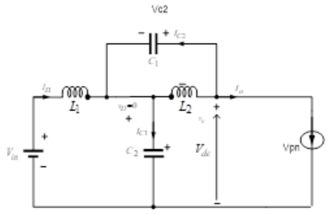



Figure 1. quasi z source inverter

qZSI have two operational states (shoot-through and Non- shoot-through) explained through the Fig 2 and Fig 3 respectively given below [15].



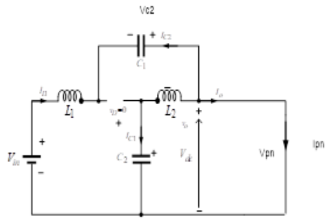
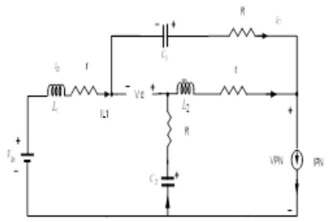




Figure 2. Non-Shoot-through state Figure 3. Shoot through state

The pwm technique discussed in this paper is simple boost pwm method. In the simple boost method[16] , two constant reference lines are used to apply the shoot-through duty ratio[17].

## II. Modeling Of Voltage-Fed Quasi Z Source Inverter

The equivalent circuit of voltage fed qZSI is given in fig.4 and 5. After solving the circuit we get the equations which are solved to design the inverter. The rating of components used is shown in Table II.



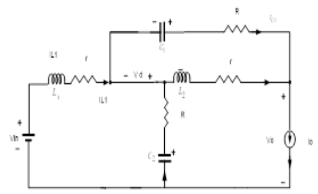




Figure 4. Equivalent circuit of qZSI Shoot through state Figure 5. Equivalent circuit of quasi-ZSI for non - Shoot through state

The state-space equations for fig.4 are [9]

$$=\begin{bmatrix} L1 & 0 & 0 & 0 \\ 0 & L2 & 0 & 0 \\ 0 & 0 & C1 & 0 \\ 0 & 0 & 0 & C2 \end{bmatrix}\begin{bmatrix} Il1(t) \\ Il2(t) \\ Vc1(t) \\ Vc2(t) \end{bmatrix} = \begin{bmatrix} -(R+r) & 0 & 0 & 1 \\ 0 & -(R+r) & 1 & 0 \\ 0 & -1 & 0 & 0 \\ -1 & 0 & 0 & 0 \end{bmatrix}\begin{bmatrix} Il1(t) \\ Il2(t) \\ Vc1(t) \\ Vc2(t) \end{bmatrix} + \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{bmatrix}\begin{bmatrix} Vin(t) \\ Ipn(t) \end{bmatrix} \quad (1)$$

which is written as FX = A1X + B1U

The state space equations for the circuit in fig.5 are

$$=\begin{bmatrix} L1 & 0 & 0 & 0 \\ 0 & L2 & 0 & 0 \\ 0 & 0 & C1 & 0 \\ 0 & 0 & 0 & C2 \end{bmatrix}\begin{bmatrix} Il1(t) \\ Il2(t) \\ Vc1(t) \\ Vc2(t) \end{bmatrix} = \begin{bmatrix} -(R+r) & 0 & -1 & 0 \\ 0 & -(R+r) & 0 & -1 \\ 0 & 0 & 0 & 0 \\ -1 & 1 & 0 & 0 \end{bmatrix}\begin{bmatrix} Il1(t) \\ Il2(t) \\ Vc1(t) \\ Vc2(t) \end{bmatrix} + \begin{bmatrix} 1 & R \\ 0 & R \\ 0 & -1 \\ 0 & -1 \end{bmatrix}\begin{bmatrix} Vin(t) \\ Ipn(t) \end{bmatrix} \quad (2)$$

which is written as FX = A2X + B2U.

Solving above equations we get

$$V_{C1} = \frac{1-D}{1-2D}V_{in} - V_{22}$$

$$V_{C2} = \frac{1-D}{1-2D}V_{in} - V_{22};\ V_{22} = \frac{(1-D)(r+2\,DR)}{(1-2D)^2}V_{Pn}\ ;\ I_{L1} = I_{L2} = \frac{1-D}{1-2D}I_{Pn} \quad (3)$$

TABLE I. THE MODEL DESIGN PARAMETERS OF THE QZSI

| S.NO | COMPONENT | RATING |
|---|---|---|
| 1. | Inductor (L1) | 3mH |
| 2. | Inductor (L2) | 3mH |
| 3. | Capacitor (C1) | 470µf |
| 4. | Capacitor (C2) | 470 µf |
| 5. | Load Resistance | 100Ω |
| 6. | Modulation index | 0.9 TO 0.5 |
| 7. | D | 0.1 TO 0.5 |

III. SIMULATION

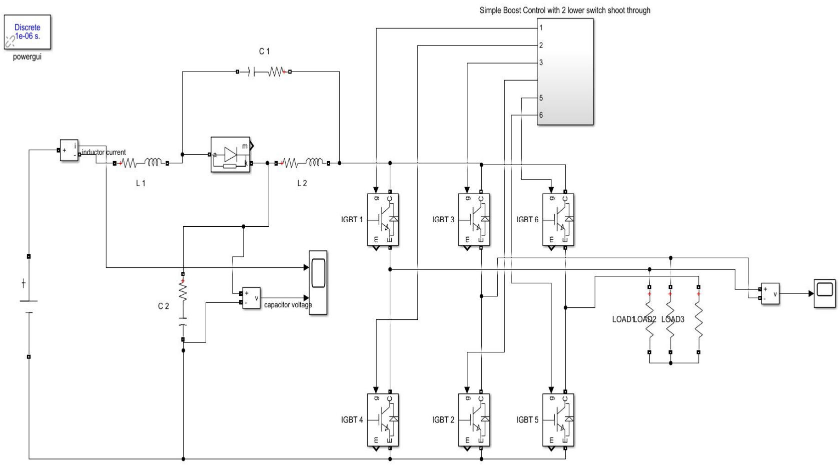



Figure 6. Simulink Model of three phase quasiZSI

Fig.6 shows the Simulink model of a 3-phase quasiZSI full bridge inverter. In this topology, the inductors L1 and L2 and capacitors C1 and C2 represent the quasi Z source impedance network which stores energy during shoot-through period and releases it during non-shoot-through period which results in voltage boost at output. The diode isolates the dc source during shoot-through period and conducts normally during non-shoot- through period. The H-bridge consists of 6 IGBT which turns ON and OFF according to the switching pulses generated by firing circuit. The load considered here is a simple R load.

The Simulink model of firing circuit shown in fig.7 is used to generates the switching pulses, which are fed to the gate terminals, to turn ON and OFF IGBT in a proper sequence. It also generate the shoot through pulses for the IGBT according to SBPWM technique, which is the main advantage of quasiZSI resulting into voltage boost at the output of the network.

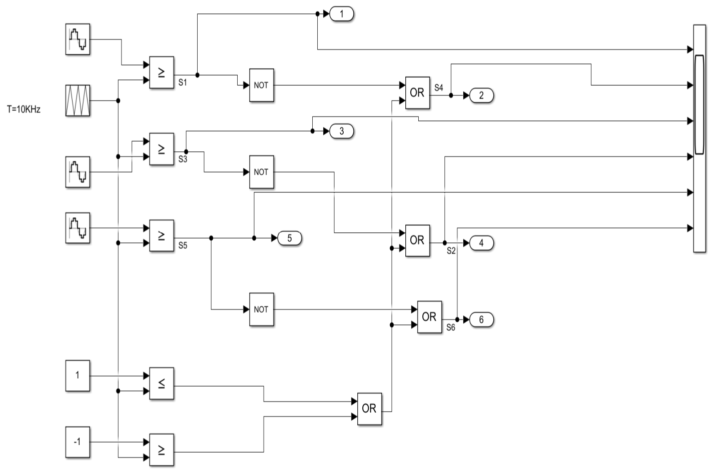



Figure 7. Simulink Model of simple boost PWM

## *A. Generation of pulses*

The switching sequence is generated with SBPWM. The graph for switching cycles and of PWM is shown in fig.8. PWM generator shown below is used to control turn ON and turn OFF times of DC supply voltage. The time of turn ON and OFF is estimated by comparing the voltage of Triangular wave (carrier) and voltage of modulating wave.

The PWM generator produces switching states for IGBT's which are considered for the shoot through time simulation

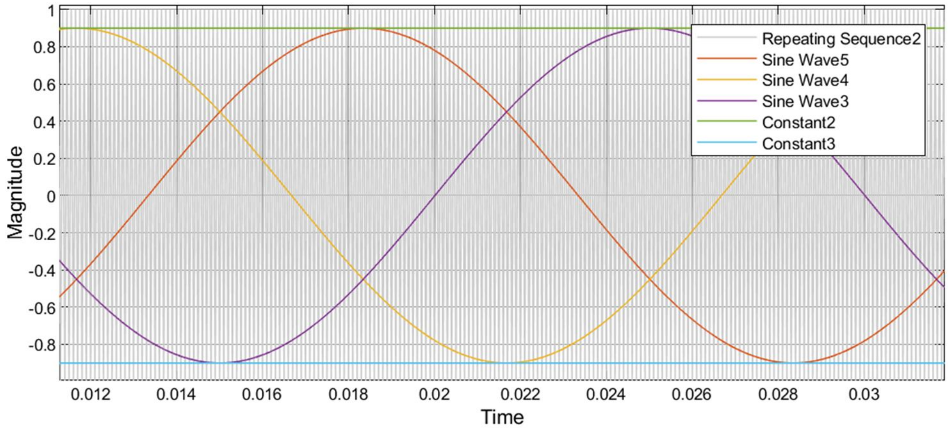



Figure 8. Simple boost PWM waveform

The gating pulses produced in the simulation are shown in fig.9. The figure shows the switches operating at a particular time.

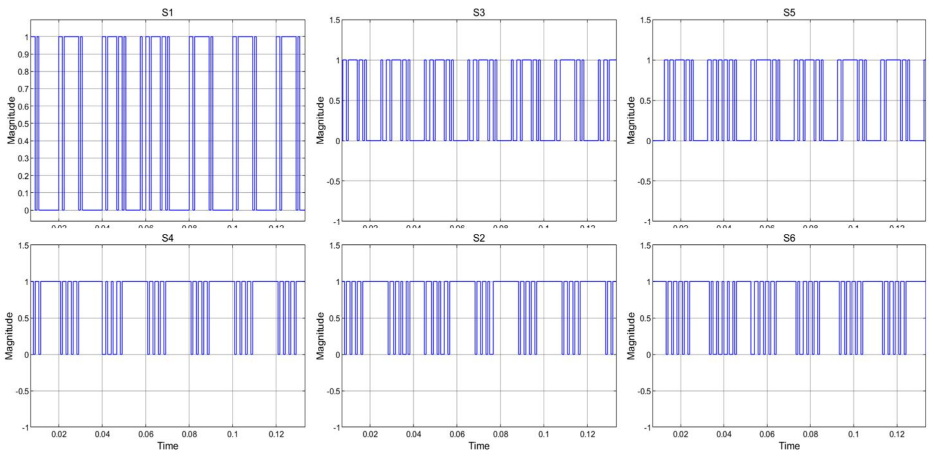



Figure 9. Gating pulses

## IV. Simulation Results

The values of inductor currents for the inductors L1 and L2, capacitor voltages for capacitors C1 and C2, output voltage and output current for the different values of modulation index (M) and shoot-through duty ratio (D) obtained from simulation are given in Table II.

TABLE II. SIMULATION RESULTS

| M | D | L1 (A) | L2 (A) | C2 (V) | C1 (V) | Vout (v) | Output current (A) |
|---|---|---|---|---|---|---|---|
| 0.9 | 0.1 | 0.71 | 0.71 | 104.62 | 4.8 | 110 | 1.12 |
| 0.8 | 0.2 | 1.8 | 1.8 | 120.51 | 20 | 160 | 1.14 |
| 0.7 | 0.3 | 3 | 1.11 | 140 | 40.5 | 190 | 1.75 |
| 0.6 | 0.4 | 5.05 | 5.05 | 189.33 | 88 | 290 | 2.19 |
| 0.5 | 0.5 | 18 | 18 | 300 | 200 | 480 | 2.25 |

The waveforms shown in fig.14-15 are obtained at shoot through duty ratio 0.1 and 0.5 respectively. The output voltage, capacitor voltage and inductor current waveforms for the different shoot-through duty ratio are shown these figures.

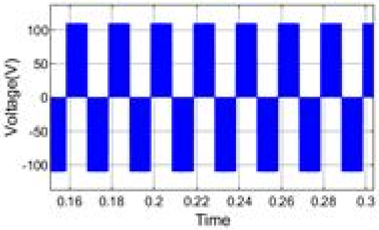



Figure 10. Waveform of output voltage of R load QZSI with D = 0.1 input voltage 100

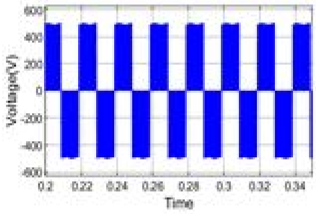



Figure 11. Waveform of output voltage of R load QZSI with D = 0.5 input

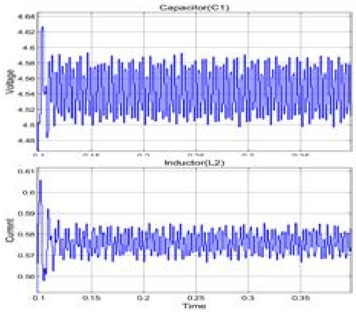



Figure 12. Waveform of inductor 2 and capacitor 1 of R load QZSI with D = 0.1 input voltage 100v

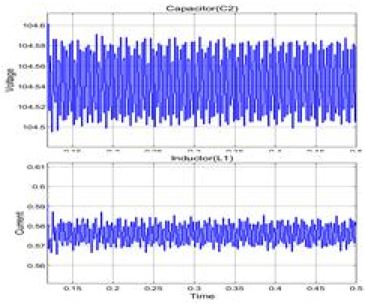



Figure 13. Waveform of inductor 1 and capacitor 2 of R load QZSI with D = 0.1

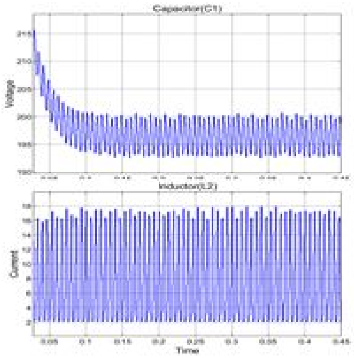



Figure 14. Waveform of inductor 2 and capacitor 1 of R load QZSI with D = 0.5

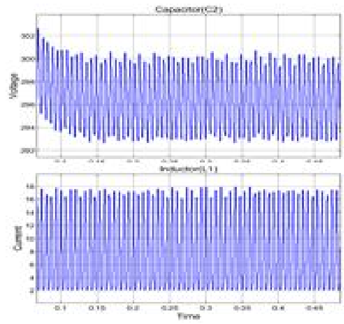



Figure 15. Waveform of inductor 1 and capacitor 2 of R load QZSI with D = 0.5 and input voltage 100v

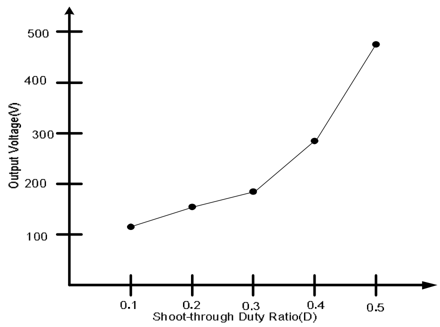



Figure 16. Output voltage at different shoot-through duty ratio

Fig.16 shows a plot between the output voltage (Y-axis) and D (X-axis). It is observed that when D is increased from 0.1 to 0.5, the measured output voltage also increases from 110V to 480V.

## V. CONCLUSION

In this work, the effect of different shoot-through duty ratios on the output voltage through SBPWM is studied. From the simulation, it was observed that on decreasing the modulation index the shoot-through duty ratio increases and because of it, the output voltage increases.

The effect on the capacitive voltage and inductance current on varying the shoot through duty ratio is also studied in this paper. It was found that with the increase in duty ratio, capacitive voltages increase and inductance currents also increase.

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