QUASI-Z-SOURCE INVERTER BASED PHOTOVOLTAIC POWER CONDITIONING SYSTEM

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ABSTRACT

The quasi-Z-source inverter (QZSI) is a single stage power converter derived from the Z-source inverter topology, employing an impedance network which couples the source and the inverter to achieve voltage boost and inversion. A new carrier based pulse width modulation (PWM) strategy for the (QZSI) which gives a significantly high voltage gain compared to the traditional PWM techniques is implemented. This technique employs sine wave as both carrier and reference signal, with which the simple boost control for the shoot-through states is integrated to obtain an output voltage boost. The conventional triangular wave carrier used in simple boost control technique is replaced by sine wave, which improves the shoot-through duty ratio for a given modulation index. The conventional perturb and observe maximum power point tracking algorithm is modified for QZSI and used along with the PWM technique for tracking the maximum power from PV. All the simulations are done using MATLAB. Hardware implementation and Microcontroller programming are done.

Keyword*: QZSI, PWM, simple boost, perturb and observe, shoot-through*

I.INTRODUCTION

Inverter denotes a class of power conversion circuits that operates from a DC voltage or DC current source and converts it into AC voltage or current. Static power converters are constructed from power switches and the AC output waveforms thus take discrete values. However this waveform is not sinusoidal. By employing a modulation technique that controls the time and sequence of the power switches used, the output voltage waveform obtained is more sinusoidal with less harmonic distortions. The modulating techniques mostly used are Sinusoidal pulse width modulation, space vector technique and selective harmonic elimination technique. Inverters are classified into two types namely, Voltage source inverter (VSI) and Current source inverter (CSI).

1.1 VOLTAGE SOURCE INVERTER

The simplest voltage source for a VSI may be a battery bank which may consist of many cells in series – parallel combination. Figure 1 shows the power topology of a full bridge VSI. A set of large capacitor is required because the current harmonics injected by the operation of the inverter are lower order harmonics. It is clear that both the switches Q1 and Q2 cannot be on simultaneously because a short circuit across the DC link voltage source E would be produced. In order to ensure that short circuit does not occur , the modulating technique must be in such a way that either the top or the bottom switch of the inverter leg is ON.

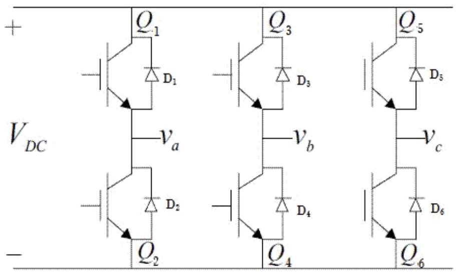

Fig 1: Three phase Voltage source Inverter

Figure 2 depicts the conventional PWM technique. It can be seen that the output voltage will be definitely less than the input voltage. The boost operation cannot be performed as the voltage is less than the input. So VSI cannot be used for the operation of hybrid electric vehicles which require both buck and boost operation

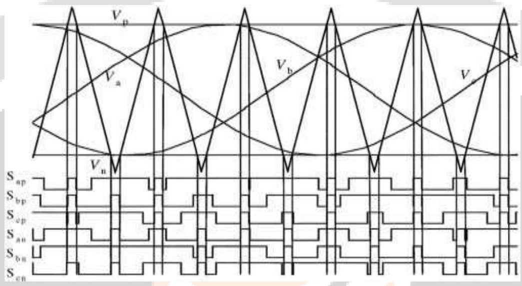

Fig - 2 Sine and Triangular PWM

1.2 Z – SOURCE INVERTER

Figure 3 shows the general Z – source inverter. The network employs a unique impedance circuit to couple the converter main circuit to that of the power source in order to obtain the unique features that cannot be achieved using conventional VSI or CSI. The Z-source inverter (ZSI) has been reported suitable for residential PV system because of the capability of voltage boost and inversion in a single stage.

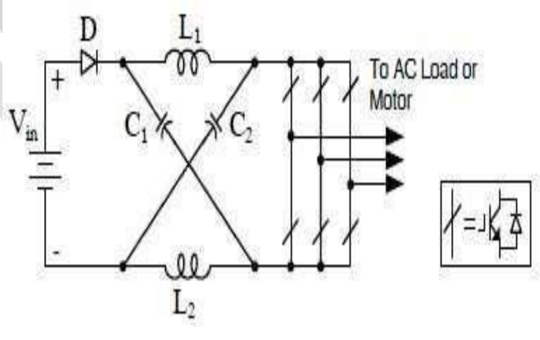

Fig - 3 Z-source inverter topology

The unique feature about Z- source inverter is that the output voltage can be anywhere from zero to infinity. The inverter can perform both buck and boost operation and provide a wide range of output voltage which is not possible in conventional voltage source and current source inverters. The Z-source inverter has nine permissible switching states which has an extra state compared to the conventional inverters. The extra switching state arises from the shoot through state of the network in which two switches of the same leg is switched ON and conduct simultaneously which is not possible in conventional inverters.

2. OPERATION OF CONVERTER

2.1 BLOCK DIAGRAM

Fig 4 illustrates the fundamental diagram for PV power injected to the load. The PV power is quasi z-source network.. With the help of PIC controller driver circuit applying the PWM to the qZSI to boost the voltage. The boosted voltage given to load.

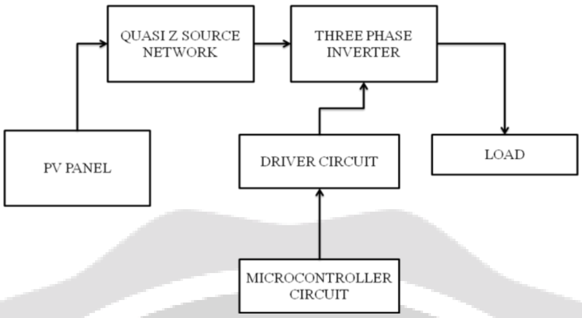

Fig - 4 Block diagram of QZSI PV Power Conditioning System

2.2 CIRCUIT DIAGRAM

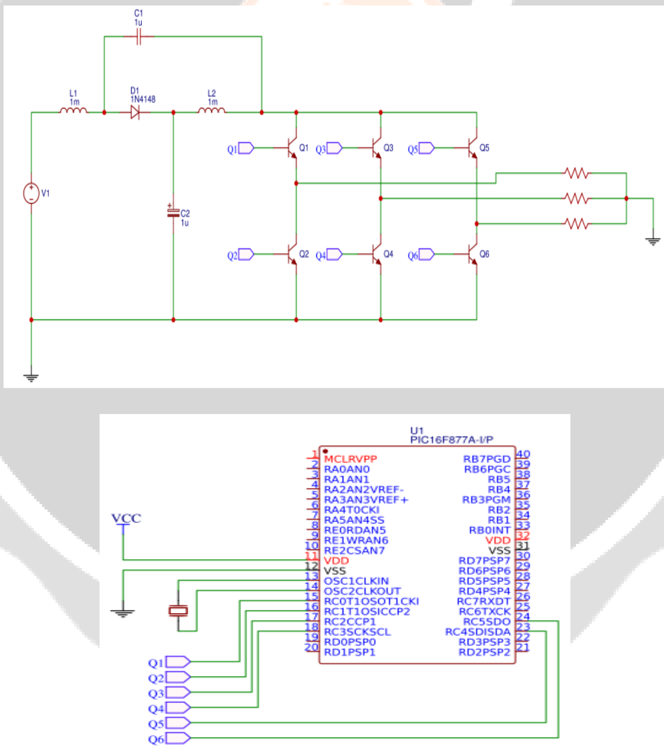

Fig - 5 Circuit diagram for QZSI PV Power Conditioning System

2.3 QUASI-Z-SOURCE INVERTER

The quasi z-source inverter (QZSI) is a single stage power converter derived from the Z-source inverter topology, employing a unique impedance network. The conventional VSI and CSI suffer from the limitation that triggering two switches in the same leg or phase leads to a source short and in addition, the maximum obtainable output voltage cannot exceed the dc input, since they are buck converters and can produce a voltage lower than the dc input voltage. Both Z-source inverters and quasi-Z-source inverters overcome these drawbacks; by utilizing several shoot-through zero states. A zero state is produced when the upper three or lower three switches are fired simultaneously to boost the output voltage. Sustaining the six permissible active switching states of a

VSI, the zero states can be partially or completely replaced by the shoot through states depending upon the voltage boost requirement.

Quasi-Z-source inverters (QZSI) acquire all the advantages of traditional Z-source inverter. The impedance network couples the source and the inverter to achieve voltage boost and inversion in a single stage. By using this new topology, the inverter draws a constant current from the PV array and is capable of handling a wide input voltage range. It also features lower component ratings, reduces switching ripples to the PV panels, causes less EMI problems and reduced source stress compared to the traditional ZSI.

2.4 QZSI NETWORK

The QZSI circuit differs from that of a conventional ZSI in the LC impedance network interface between the source and inverter. The unique LC and diode network connected to the inverter bridge modify the operation of the circuit, allowing the shoot-through state which is forbidden in traditional VSI. This network will effectively protect the circuit from damage when the shoot-through occurs and by using the shoot-though state, the (quasi-) Z-source network boosts the dc-link voltage.

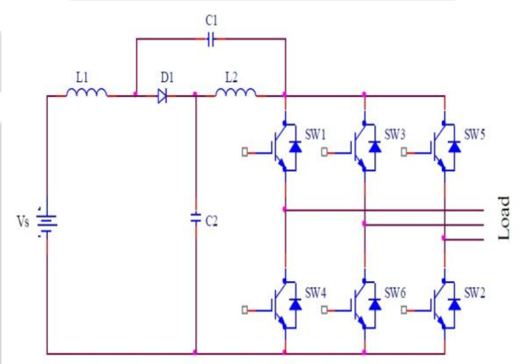

Fig - 6 Quasi Z source inverter

The impedance network of QZSI is a two port network .It consists of inductors and capacitors connected as shown in fig. This network is employed to provide an impedance source, coupling the converter to the load. The dc source can be a battery, diode rectifier, thyristor converter or PV array. The QZSI topology is shown in the figure 6.

3. MODES OF OPERATION

3.1 ACTIVE MODE

In the non-shoot through mode, the switching pattern for the QZSI is similar to that of a VSI. The inverter bridge, viewed from the DC side is equivalent to a current source. , the input dc voltage is available as DC link voltage input to the inverter, which makes the QZSI behave similar to a VSI.

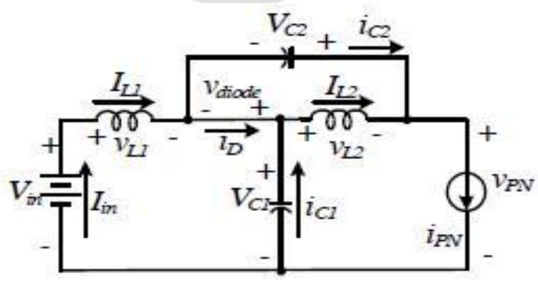

Fig - 7 Equivalent circuit of QZSI in Active mode

3.2 SHOOT THROUGH MODE.

In the shoot through mode, switches of the same phase in the inverter bridge are switched on simultaneously for a very short duration. The source however does not get short circuited when attempted to do so because of the presence LC network, while boosting the output voltage. The DC link voltage during the shoot through states, is boosted by a boost factor, whose value depends on the shoot through duty ratio for a given modulation index.

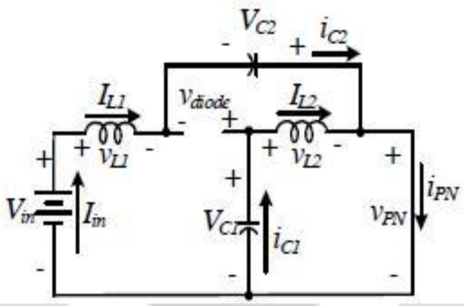

Fig - 8 Equivalent circuit of QZSI in Shoot through Mode

4. SIMULATION AND HARDWARE RESULTS

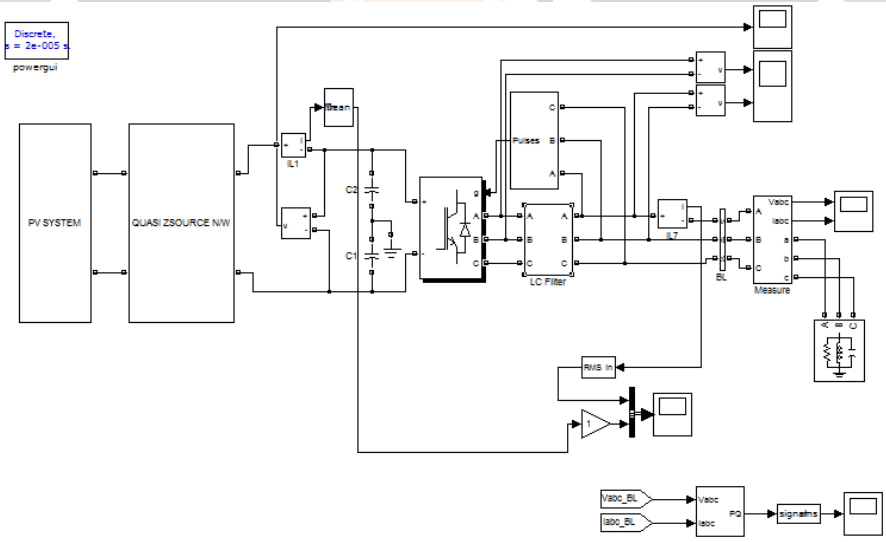

Fig - 9 Simulation diagram of QZSI PV Power Conditioning System

The qZSI output is compared with the PWM and energy balance is to be maintained during continuous conduction. In the qZSI output is possibly connected to the load as shown in fig 9.

4.1 WAVEFORM FOR QZSI OUTPUT

The output from qZSI is as shown in fig 10. The output is measured and the 3 phase supply is not directly coupled through the load, due to the energy disparity is carried from the PV power. This may be optimized throughout the shoot-through state. Now the PV power may be controlled by the duty cycle. The inverter output is controlled by modulation index for stable, even and to augment the massive power.

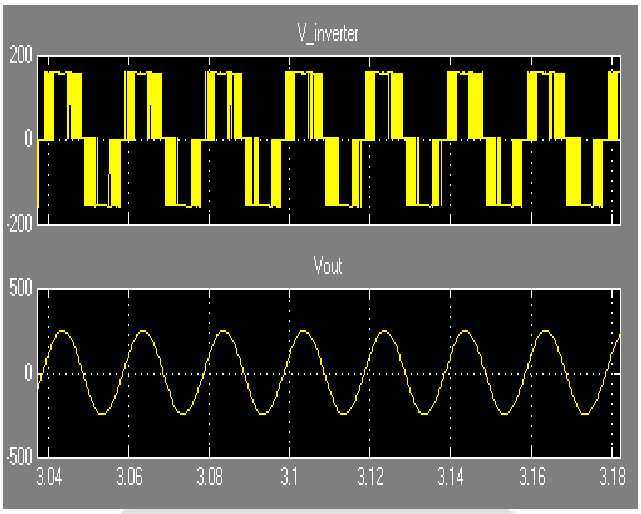

Fig - 10 Inverter voltage & Output voltage

4.2 WAVEFORM FOR LOAD CURRENT AND VOLTAGE ACROSS LOAD

The load current and voltage waveform is shown in fig 11

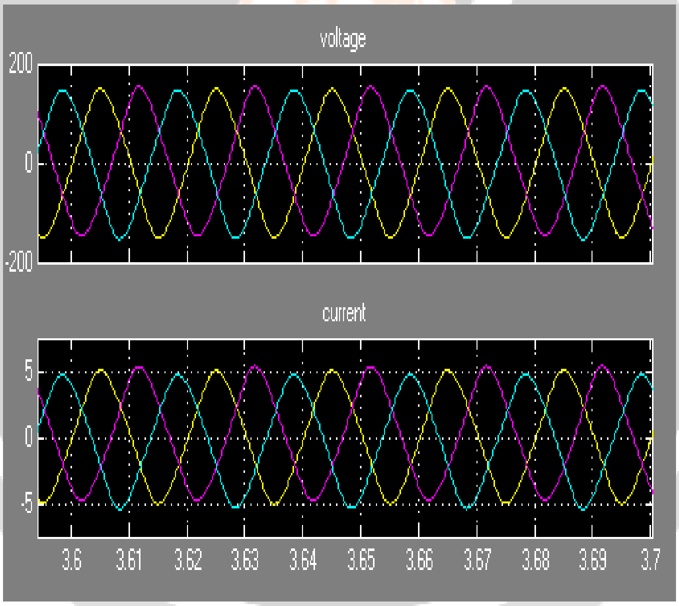

Fig - 11 Load voltage and current

4.3 PROGRAMMING IN PIC

The programming has been done in MPLAB using its C18 compiler. The program code is done in C and saved in a (.C) file. The header files (p18f4550.h and delays.h) and library file (p18f4550.lib) and linker file (18f4550.lkr) are included. The source file is a (.C) file and the workspace is stored as a (.mcw) file. The source code is built using pickit2 and the source code is loaded in the PIC for generating pulses.

4.4 HARDWARE DESIGN OF QZSI POWER CONDITIONING SYSTEM

Fig - 12 Hardware design of qzsi pv power conditioning system

5.CONCLUSION

PV array has been simulated and integrated to the QZSI with maximum power point tracking algorithm (perturb and observe method).QZSI has been simulated with sine carrier and triangular carrier and the results have been compared and the individual harmonic contributions have been analyzed. The proposed QZSI inherits all the advantages of the ZSI and features its unique merits. It can realize buck/boost power conversion in a single stage with a wide range of gain that is suited well for application in PV power generation systems. Furthermore, the proposed QZSI has advantages of continuous input current, reduced source stress, and lower component ratings when compared to the traditional ZSI. The voltage gain with sine carrier is greater than the voltage gain with triangular carrier. The hardware implementation of power and control circuits has been implemented. Switching pulses are generated using PIC18f4550.

5.1 SCOPE FOR FUTURE WORK

A grid-connected PV power generation system is one of the most promising applications of renewable energy sources. The proposed QZSI based PV power generation system is intended as a grid connected system and transfers the maximum power from the PV array to the grid by maximum power point tracking technology. QZSI is best suited interface for photovoltaic power generation system and could prove to be highly efficient, when implemented with the improved control techniques proposed.

APPENDIX

PIC PROGRAM

```
#include<p18f4550.h>

#include<delays.h>

#pragma config FOSC = INTOSCIO_EC,FCMEN = OFF,IESO = OFF,PWRT = OFF,BOR = OFF,WDT = OFF,LVP = OFF,MCLRE = OFF,STVREN = OFF,CP0 = OFF,CP1 = OFF,CP2 = OFF,CP3 = OFF,CPB = OFF,CPD = OFF,WRT0 = OFF,WRT1 = OFF,WRT2 = OFF,WRT3 = OFF,WRTC = OFF,WRTB = OFF,WRTD = OFF,EBTR0 = OFF,EBTR1 = OFF,EBTR2 = OFF,EBTR3 = OFF,EBTRB = OFF
```

```
Void main (void){
TRISB=0x00;
OSCCON=0x77;
while (1){
LATB=0x85;
Delay10TCYx (23);
Delay1TCY();
LATB=0xAF;
Delay10TCYx(30);
Delay1TCY();
Delay1TCY();
Delay1TCY();
LATB=0x85;
Delay10TCYx(46);
LATB=0xAC;
Delay10TCYx(50);
LATB=0xA8;
Delay10TCYx(18);
Delay1TCY();
Delay1TCY();
LATB=0xAF;
Delay10TCYx(31);
LATB=0xA8;
Delay10TCYx(46);
LATB=0xAC;
Delay10TCYx(35);
Delay1TCY();
Delay1TCY();
LATB=0x85;
Delay10TCYx(9);
LATB=0xAF;
Delay10TCYx(10);
```

```
LATB=0x85;
Delay10TCYx(40);
Delay1TCY();
Delay1TCY();
Delay1TCY();
Delay1TCY();
Delay1TCY();
Delay1TCY();
LATB=0xAC;
Delay10TCYx(12);
LATB=0xA8;
Delay10TCYx(3);
Delay1TCY();
Delay1TCY();
LATB=0xAF;
Delay10TCYx(38);
Delay1TCY();
Delay1TCY();
Delay1TCY();
LATB=0xA8;
Delay10TCYx(46);
LATB=0xA1;
Delay10TCYx(37);
Delay1TCY();
LATB=0x85;
Delay10TCYx(6);
LATB=0xAF;
Delay10TCYx(1);
LATB=0x85;
Delay10TCYx(46);
LATB=0xA1;
Delay1TCY();
```

```
Delay1TCY();
Delay1TCY();
Delay1TCY();
Delay1TCY();
Delay1TCY();
Delay1TCY();
Delay1TCY();
Delay1TCY();
Delay1TCY();
Delay1TCY();
Delay1TCY();
LATB=0xA8;
Delay10TCYx(11);
Delay1TCY();
Delay1TCY();
Delay1TCY();
Delay1TCY();
Delay1TCY();
LATB=0xAF; } }
```

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