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HIGH STEP UP DC-AC CONVERTER WITH REDUCED SHOOT THROUGH STATES FOR PV ARRAY BY USING ANN CONTROLLER

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Abstract— *The voltage-fed quasi-Z-Source Inverter (qZSI) are used to realize both DC voltage boost and DC to AC inversion in single stage with a reduced number of power switching devices and improved reliability. But its voltage boost property could be a limiting feature in some applications where very high input voltage gain is required .This paper presents about a high step up dc-ac converter of the qZSI used for Distributed Generation (DG), such as Photo Voltaic (PV) array. Step-up dc/ac converter with a dual Stage (two stages) quasi-Z-source network could be derived by the adding of one diode, one inductor, and two capacitors to the traditional qZSI. The proposed dual stage qZSI inherits all the advantages of the traditional solution (voltage boost and buck functions in a single stage, continuous input current, and improved reliability). Moreover, as compared to the conventional qZSI, the proposed solution reduces the shoot-through pulses at the same input voltage. Capacitor voltage control method is proposed in a two-stage control manner (dc side and ac side control). The main objective is to increase efficiency and minimum switching stress on devices can be achieved by choosing a proper capacitor voltage reference by using Artificial Neural Network (ANN) controller. The proposed method performances are validated using simulated results obtained in MATLAB/Simulink.*

Keywords— ***Artificial Neural Network Controller, DC to Dc-DC to AC converter, Distributed Generation, Photo voltaic Array, Quasi-Z-source inverter.***

I. INTRODUCTION

The voltage-fed quasi-Z-source inverter is suitable for different renewable power applications such as fuel cells solar panels, wind power generators. The qzsi is voltage boost and buck functions in a single stage [1] and it can boost the input voltage by introducing a special shoot- through switching state,

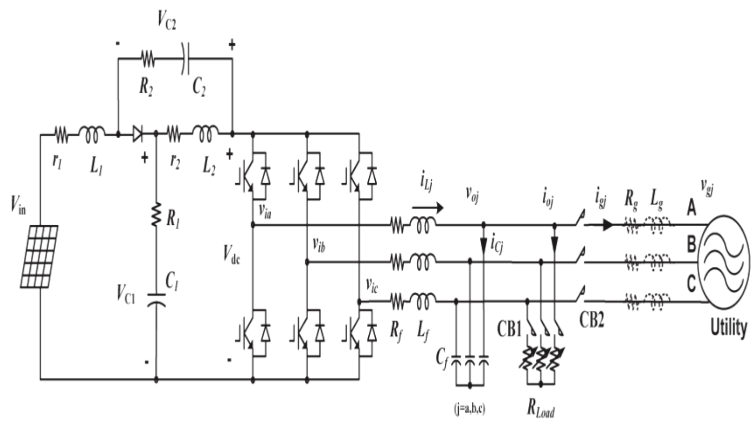


Fig. 1. Single stage Voltage fed qZSI for PV Array

which is the simultaneous conduction (cross conduction) of both switches of the same inverter's phase leg [1],[4]. This switching state is forbidden for the traditional Voltage Source Inverters (VSIs) because it causes the short circuit of the dc-link capacitors. In the qZSI, the shoot through states are used to boost the magnetic energy stored in the dc-side inductors *L*1 and *L*2 without short circuiting the DC capacitors *C*1 and *C*2. The voltage boost based on Pulse Width Modulation (PWM) method to simple boost control. It's the voltage boost and buck functions in a single stage. This increase in magnetic energy provides to boost the voltage on the inverter output. If the input voltage is high enough, the shoot-through states are eliminated, and the qZSI begins to operate as a traditional VSI. The ZSI can deal with input voltage fluctuation in a wide range, which is conventionally achieved by a two-stage dc–dc converter cascaded by dc–ac structure [1].The figure 1 shows the single stage voltage fed qzsi for PV array.

1.1.STEP-UP DC/AC CONVERTER WITH DUAL STAGE qZS-NETWORK

The figure 2 shows the basic block diagram of the dual stage quasi z source inverter for PV array by using the artificial neural network controller. This paper deals with an the dual (two-stage) qZS inverter is by the adding of one diode (*D*2), one inductor (*L*3), and two capacitors (*C*3 and *C*4) to the traditional qZSI, as shown in Fig 1.

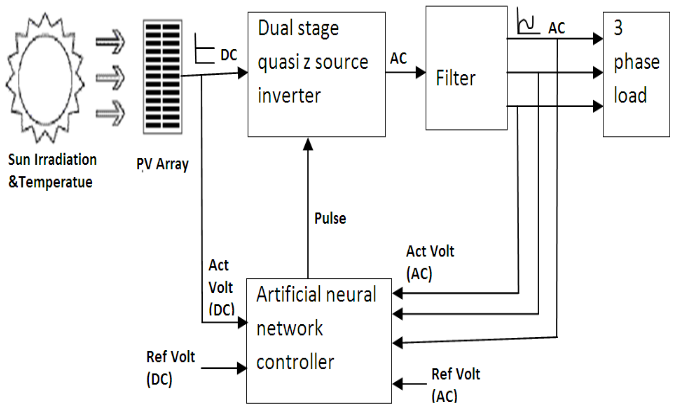


Fig 2 Basic block diagram of proposed method

A Dual stage voltage-fed qZSI for PV array as shown in figure 3. Proposed figure 1 for PV Array. The low voltage from the energy source first passes through the front-end step-up dc/dc converter afterward, the output dc voltage is inverted in the three-phase inverter and filtered to comply with the imposed standards and requirements (second dc/ac stage).step-up dc/dc converters provides a very high voltage gain.

The dual stage voltage fed qZS-network and continuous input current, ripple filter, and load .The ZSI for use in several applications, such as DG, uninterruptible power system, fuel cell vehicles, PV or wind power conversion, and electronic loads [1].

To regulate the varying input voltage, the qZSI has two different operating modes: shoot through and non shoot through. When the output voltage of a PV array reaches its maximum it's operated an non shoot

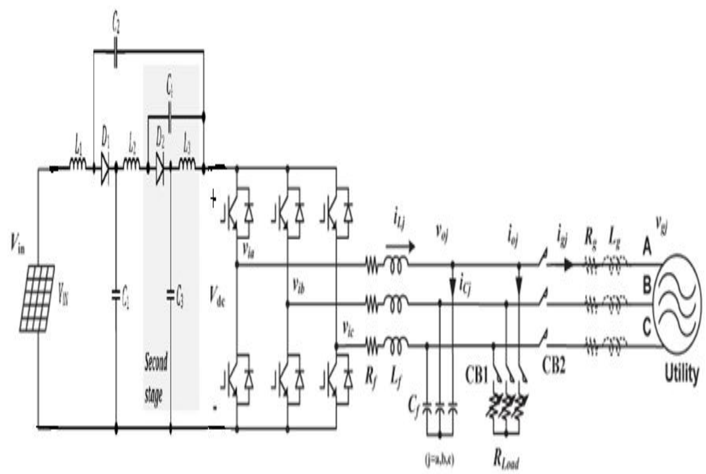


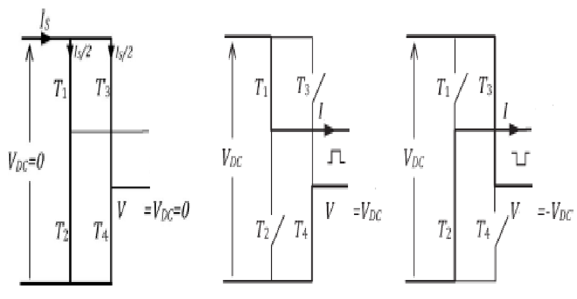
Fig.3.Dual stage Voltage fed qZSI for PV Array

through mode in this mode performs only the voltage buck function. The inverter is controlled in active states when one and only one switch in each phase leg conducts. When the input voltage drops below some predefined value, the qZSI starts to operate in the shoot-through mode. To boost the input voltage during this mode using a special pulse PWM inverter control [4]. Table 1 shows the Switching states sequence per one period of PWM.

Table 1.Switching states sequence per one period of PWM

	Top side		Bottom side	
	T1	T3	T2	T4
Active state	1	0	0	1
Zero state	1	1	0	0
Shoot-through	1	1	1	1
Zero state	1	1	0	0
Active state	0	1	1	0
Zero state	1	1	0	0
Shoot-through	1	1	1	1
Zero state	1	1	0	0

During the shoot-through states, the inverter short circuit via any one phase leg [4],[2] combinations of any two phase legs, and all three phase legs. This shoot-through stat is forbidden in the traditional VSIs because it causes a short circuit of dc capacitors and destruction of power switches [4]. The dual stasge qZS network makes the shoot-through states and its effectively protecting the circuit from damage [14]. The shoot through states are used to boost the magnetic energy stored in the dc-side inductors *L*1, *L*2, and *L*3 without short circuiting the dc capacitors *C*1, . . . , *C*4. This increase in the magnetic energy provides the boost of the voltage seen on the the transistors in the full-bridge configuration are controlled alternately in pairs (*T*1 and *T*4 or *T*2 and 3, Fig.3. with 180◦-phase-shifted control signals [4]



(a) (b) (c)

Fig. 4. Equivalent circuit of the inverter during the (a) Shoot through state, Non-shoot-through (active) states: (b) positive and (c) negative half-cycles

The equivalent circuit of the two-stage qZSI during non-shoot-through (active) states is shown in Fig.4. inverter output during the active states. The equivalent circuit of the two-stage qZSI during the shoot through states is shown in Fig.5.

1.1.1. Mode 1 operation

The fig 5 shows the mode 1 operation of dual stage ZSI .This mode will make the inverter short circuit via any one phase leg, combinations of any two phase legs, and all three phase legs which are referred to as the shoot-through state. As a result, the diode D is turned off due to the reverse-bias voltage. At the shoot-through state the inductor in charging condition and the voltage drop across the capacitor the capacitors transfers their electrostatic energy into magnetic energy it's stored in the inductors. During this time interval voltage boosting operation takes place.

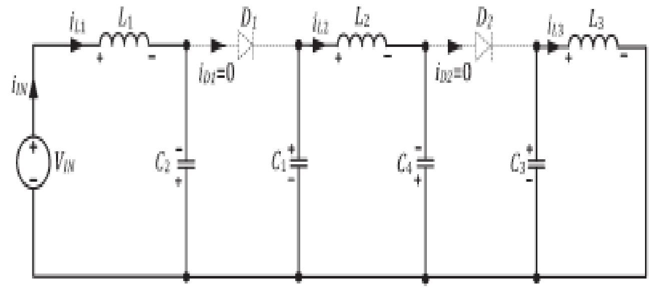


Fig.5. Mode 1operation

When the inverter is in the shoot-through state for an interval to during a switching cycle T, the following voltage equations [2] can be described from Fig 5 as

$$V_{C1} = V_{L1} \quad (1)$$

$$V_{C2} + V_{in} = V_{L2} \quad (2)$$

$$V_{out} = 0 \quad (3)$$

1.1.2. Mode 2 operation

The fig 6 shows that mode 2 operation. At the non-shoot-through states the dc power source, as well as the inductors, charge the capacitors and power the external ac load, boosting the dc voltage across the inverter bridge. Here diode is conduction stage, so the capacitor voltage Vc1 is appears across the inverter bridge .In this mode the DC voltage is Fig 6 converted to an AC voltage.

When the inverter is in the active state for the interval T1, during the switching cycle T, the voltage equations are as follows

$$V_{L1} = V_{C1} - V_{out} = -V_{C2} \quad (4)$$

$$V_{L2} = V_{in} - V_{C1} = V_{in} - V_{out} + V_{C2} \quad (5)$$

$$V_{out} = V_{C1} + V_{C2} \quad (6)$$

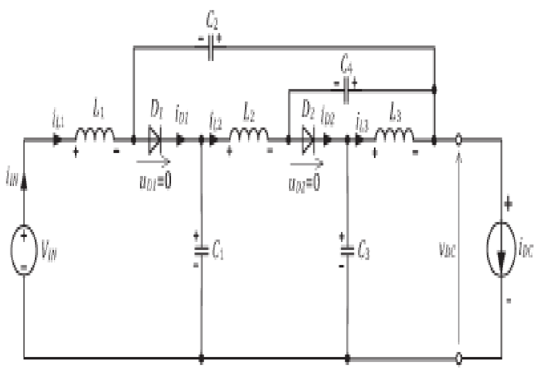


Fig.6 Mode 2 operation

II TWO-STAGE CONTROL METHODOLOGY FOR QZSI-BASED FOR PV ARRAY

The Fig.3.shows the proposed dual stage qZSI, where *Lf, Rf* , and *Cf* are the inductance, capacitance, and stray resistance of the filter, respectively, and *voj, iCj, vij, iLj, ioj* , and *igj* are the load voltage, capacitor current of the filter, output voltage of the inverter, inductor current of the filter, load current, and grid current, respectively, all in three phases (*j* = a*a, b, c*). CB stands for circuit breaker. CB1 is ON and

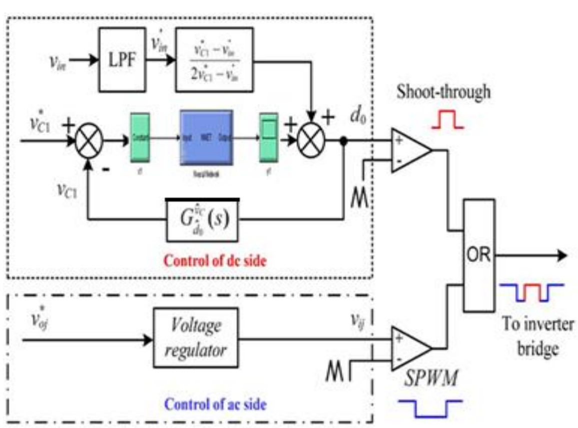


Fig. 7. Two-stage control method of the qZSI for output voltage control.

CB2 is OFF when the qZSI works under voltage control mode, and CB1 is OFF and CB2 is ON when the qZSI is under current control mode [1].

Pulses generated by the dc-side controller (for voltage boost) and the ac-side controller (for dc–ac conversion) are combined together by logical OR to fire six insulated-gate bipolar transistors, assuming "1" is ON and "0" is OFF[1].For the dc-side control, capacitor voltage V_{c1} is measured and fed back. Based on the nonlinear approximation, a Artificial Neural Network (ANN) controller assisted with a two layer feed forward network. The network will be trained with levenberg marquardt back propagation algorithm. This controller is used to give the constant steady state output.

Fig.7. shows the proposed diagram of the two-stage control method of qZSI, where pulses from control of dc side and that of ac side are combined in the same manner as in the output voltage control mode. For the ac-side control, capacitor voltage V_{C1} is measured and fed back. The magnitude of the grid current reference *Ig** is generated through a ANN controller according to the error signal of *vC*1. In the case that $V_{C1}{*}- V_{C1}$ is positive, power injected into the grid should be reduced to maintain a constant V_{C1}.

III PV ARRAY SPECFICATION

The condition for simulation of PV array using qzsi is the Module type : Canadian solar cs5p-220m,Number of series-connected modules per string 5, Number of parallel strings 66, Module specifications under STC [Voc-59.26, Isc-5.09, Vmp-48.13, Imp-4.54], Model parameters for 1 module [Rs-0.248, Rp-235.76, Isat-1.443, Iph-5.098, Qd-1.5],phase-3,frequency-50hz,sampling time-20khz.

3.1. Energy Conversion Efficiency

$$\eta = \frac{Pm}{E*A} \qquad (7)$$

The equation (7) expressed as, Energy conversion efficiency η is the percentage of power converted (from absorbed light to electrical energy. When a solar cell is connected to an electrical circuit. This term is calculated using the ratio of maximum power divided by input light irradiance E in W/m^2 under Standard Test Conditions (STC) and A is area of the solar cell.

3.2. Maximum Power

The load for which the cell can deliver maximum electrical power at the level of irradiation. The equation (8) states P_m is maximum power, V_m is maximum voltage, and I_m is the maximum current

$$P_m = V_m I_m \qquad (8)$$

3.3. SOLAR MODULE AND ARRAY MODEL

A typical PV cell produces less than 2W at 0.5V approximately the cells must be connected in series-parallel configuration on a module to produce enough high power. A PV array is a group of several PV

$$I = NpIph - NpIs\left[\frac{q\left(\frac{v}{Ns}+\frac{IRs}{Np}\right)}{kTcA} - 1\right] \qquad (9)$$

The equivalent circuit is described on the following equation (10) is

$$I = NpIph - NpIs\left[q\left(\frac{v}{NskTcA}\right) - 1\right] \qquad (10)$$

Where, Ns - is series number of cells for a PV array. Np - is parallel number of cells for a PV array.

IV SIMULATION RESULTS

Dual stage zsi for PV module by using ANN controller has been simulated using MATLAB/Simulink. The simulation diagram of proposed controller is shown in figure.8.Simulation results are shown in fig.9. and fig.10 &11. Simulation are performed in the proposed control method the system parameters in the experiment as follows: $L1 = L2 = 500\ \mu$H, $C1 = C2 = 400\ \mu$F, $Lf = 5$ mH, $Cf = 60\ \mu$F, system output frequency $f = 50$ Hz, and switching frequency $fs = 20$ kHz which is also the sampling frequency of the controller.

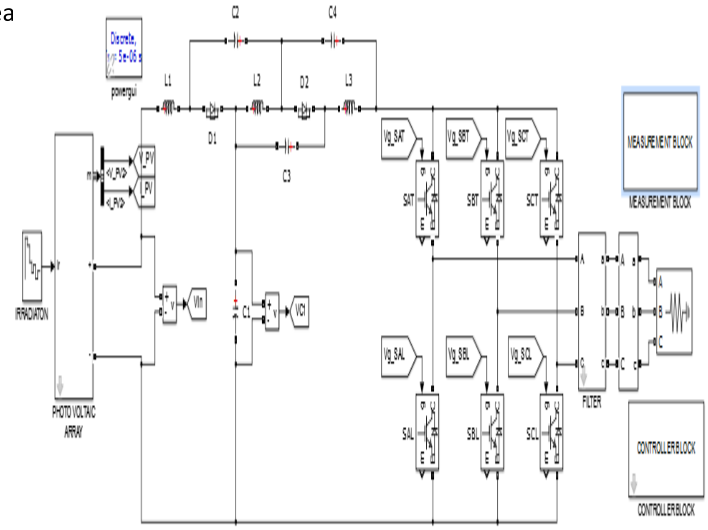


Fig .8. Simulation circuit for Dual stage Quasi Z source inverter with PV module By using ANN controller

4.1. Single stage qzsi &PI controller output waveforms

The fig .9. (a,b,c,d,e) shows the waveforms of an input voltage,DC capacitor voltage, Three phase grid current,Three phase grid voltage , shoot through pulses of an single stage qzsi. Here PI controller is used for linear approximation. This waveforms are comes under in the 300v input voltage.Even if the input voltage is 170v means it's does not give the constant steady state output and Generating shoot through pulses are high and it produces the steady state error in the output by using the single stage qzsi and PI controller. These pulses are reduced by using dual stage Z source inverter.

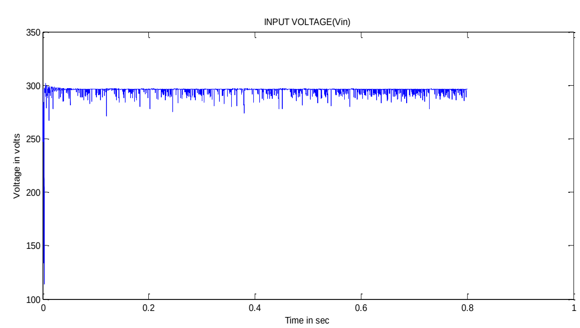


Fig.9.(a).Waveform of Input Voltage

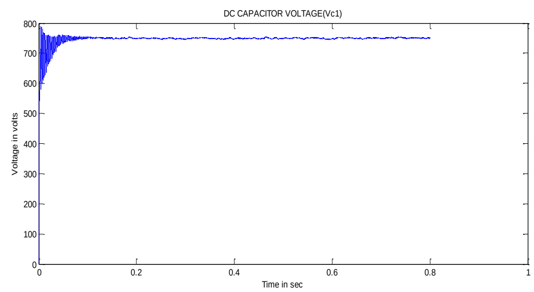


Fig.9.(b)Waveform of DC Capacitor voltage

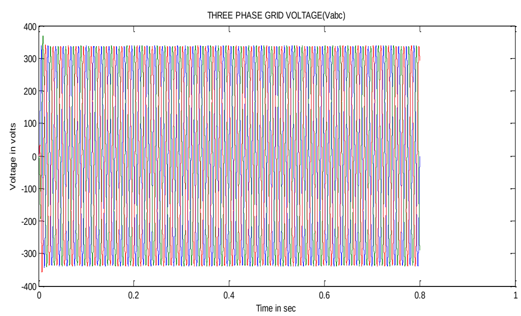


Fig.9.(c).Waveform of Three phase Grid voltage

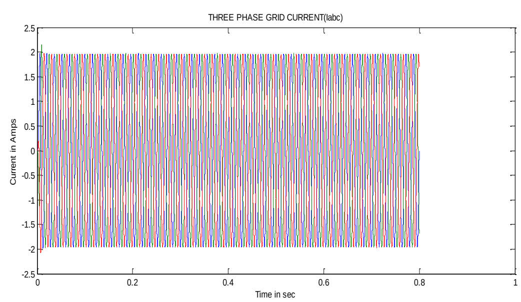


Fig.9.(d).Waveform of Three phase grid current

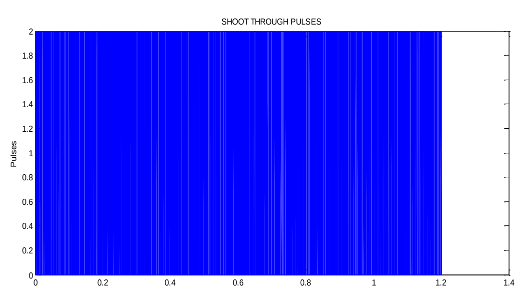


Fig.9.(e).Waveform of Shoot Through Pulses

4.2. Dual stage qzsi & ANN controller output waveforms

The fig 10(a,b,c,d,e)is an waveform of an input voltage, Dc capacitor voltage, Three phase grid current, Three phase grid voltage , shoot through pulses of an proposed method. Here ANN controller is used for nonlinear approximation and it reduces the steady state error in the output and it gives as the steady state output. The Figure 10(a) represents the waveform of input voltage. Here the input voltage is 300v .This input voltage is an output voltage from PV. When the output from the PV is low the shoot through state enables to boost the input voltage to required level. The fig 10(b) shows the waveform of DC Capacitor voltage. Here the DC capacitor voltage is 750v. The fig 10(c) shows the waveform of three phase grid voltage. Here three phase grid voltage is represented by per phase rms peak is 338v.This is the per phase voltage. This voltage is given to three phase load.

The figure 10(d) shows the waveform for three phase grid current .Here the three phase grid current value is 1.9 A. Here the load is fixed at 1KW and the voltage is varied depends upon the photo voltaic output. Voltage is proportional to the current for fixed load. The figure 10(e) shows the shoot through pulses in the proposed method. Here the shoots through pulses are reduced by using dual stage Z Source inverter. These shoots through pulses are less compared to the conventional method.

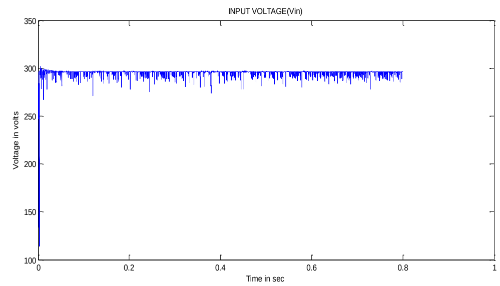


Fig.10.(a).Waveform of input voltage

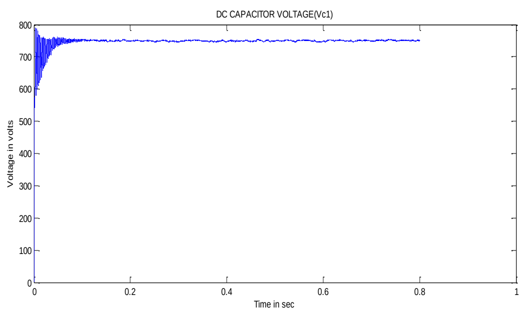


Fig.10.(b).Waveform of DC capacitor voltage

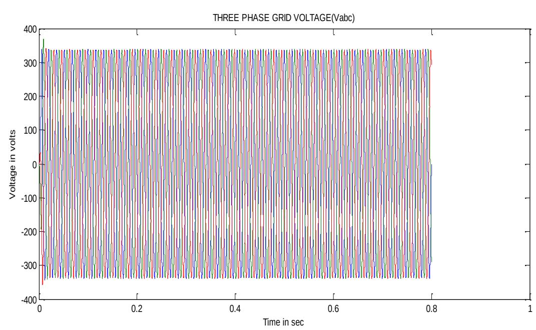


Fig.10.(c).Waveform of three phase Grid voltage

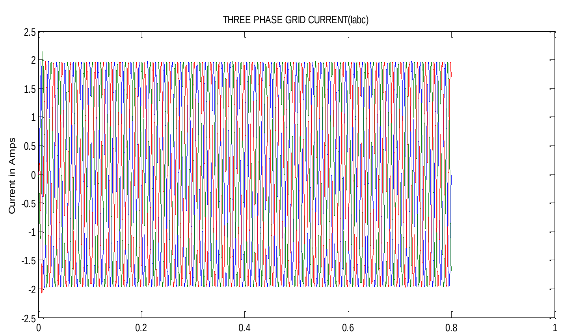


Fig.10.(d).Waveform of Three phase Grid Current

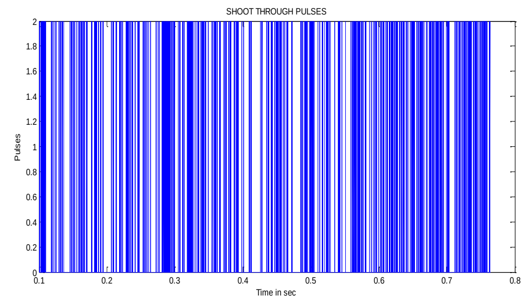


Fig.10.(e).Waveform of Shoot through pulses(proposed method)

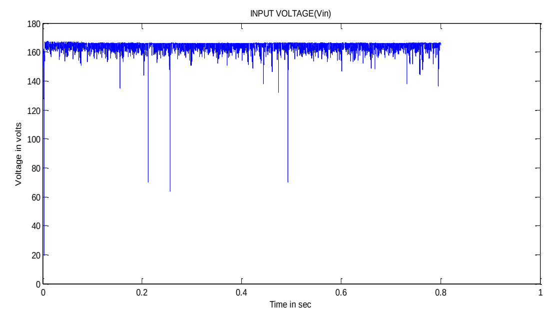


Fig.11.Waveform of Input Voltage (170V)

In the proposed method dual stage qzsi with ANN controller is used for an nonlinear approximation. The fig 11 shows the waveform of an input voltage in the value of 170V. It gives the same steady state output even if the input voltage varies.

V.CONCLUSION

This paper deals with a Dual stage qZSI-network, one diode, one inductor, and two capacitors were added to the conventional voltage-fed qZSI. The voltage-fed qZSI with the dual stage qZS-network reduced the shoot-through Pulses by over the conventional qZSI. The proposed Dual stage qZSI can be applied to almost all dc/ac, ac/dc, ac/ac, and dc/dc power conversion schemes. It further decrease the shoot-through pulses, the number of stages of the qZS-network could be increased. The Dual stage qZSI-network ensures continuous input current of the converter during the shoot-through operating mode, thus featuring the reduced stress of the input voltage source. ANN controller is used gives the constant steady state output in the waveform. The theoretical analysis and simulations results presented in this paper clearly demonstrated.

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