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Single Phase Based on UPS Applied to Voltage Source Inverter and Z- Source Inverter by Using Matlab/Simulink

V. Ramesh[1], P. Anjappa[2], P.Dhanamjaya[3]
K. Reddy Swathi[4], R.Lokeswar Reddy[5],E.Venkatachalapathi[6]
PhD Scholar EEE Department, Department of Electrical Engineering, K L University, A.P, India[1]
HOD & Associate Professor Department of Electrical Engineering, GVIC Engineering, Madanapalli, A.P, India[2]
Assistant Professor Department of Electrical Engineering, GVIC Engineering, Madanapalli, A.P, India[3456]

Abstract:** Uninterruptible power supplies (UPSs) are widely used to supply critical loads, such as airline computers and life-support systems in hospitals, providing protection against power failure or anomalies of power-line voltage. In general, there are two types of traditional single phase UPSs. The first one couples a battery bank to a half or full-bridge inverter with a low-frequency transformer. In this type of UPSs, the ac output voltage is higher than that of the battery bank; thus, a step-up transformer is required to boost voltage. .The second one couples a battery bank to a dc/dc booster with a half or full bridge inverter. In this type of UPSs, the additional booster is needed, leading to high cost and low efficiency. The controlling of the switches in the booster also complicates the system. Due to the presence of the step-up transformer, the inverter current is much higher than the load current, causing high current stress on the switches of the inverter The dead time in the pulse width-modulation (PWM) signals to prevent the upper and lower switches at the same phase leg from shooting through has to be provided in the aforementioned two types of UPSs, and it distorts the voltage waveform of the ac output voltage. In order to overcome the above problems in the traditional UPSs, new topology of the UPS is proposed by using a voltage source inverter and Z-source inverter. With this new topology, the proposed UPS offers the advantages over the traditional UPSs such as the dc/dc booster and the inverter have been combined into one single-stage power conversion and the distortion of the ac output-voltage waveform is reduced in the absence of dead time in the PWM signals. The effectiveness of the proposed method is implemented by using MATLAB/SIMULINK software.

Index Terms: **MOSFET, UPS, VSI, ZSI, PIC Controller, MATLAB/SIMULINK software**

I. INTRODUCTION

A. GENERAL INTRODUCTION

This project deals with the designing of a uninterruptible power supply (UPS) by using a Z-source inverter, where a symmetrical LC network is employed to couple the main power circuit of an inverter to a battery bank. With this new topology, the proposed UPS can maintain the desired ac output voltage at the significant voltage drop of the battery bank with high efficiency, low harmonics, fast response, and good steady-state performance in comparison with traditional UPSs.

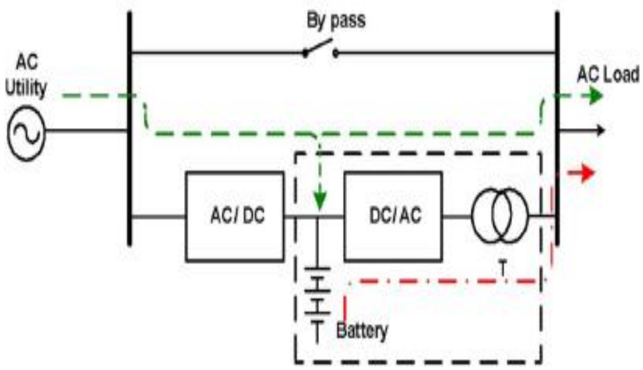

Fig 1 UPSs using low frequency transformer

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The second one couples a battery bank to a dc/dc booster with a half or full bridge inverter is as shown in Fig.2. In this type of UPSs, the additional booster is needed, leading to high cost and low efficiency [1]-[3]. The controlling of the switches in the booster also complicates the system. Furthermore, the dead time in the pulse width-modulation (PWM) signals to prevent the upper and lower switches at the same phase leg from shooting through has to be provided in the aforementioned two types of UPSs, and it distorts the voltage waveform of the ac output voltage.

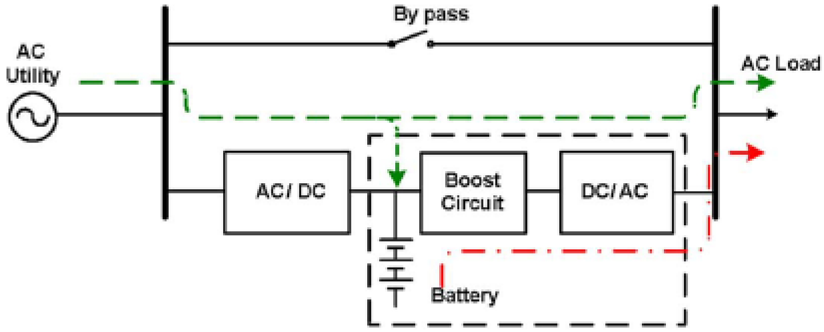

Fig 2 UPSs using boost circuit

B. *OBJECTIVE*

The objective of the project is:

- To design and simulate uninterruptible power supply (UPS) by using a Z-source inverter, where a symmetrical LC network is employed to couple the main power circuit of an inverter to a battery bank.
- To design the UPS is proposed by using a Z-source inverter.

C. *ORGANIZATION*

In Section 1 is a brief introduction of the project that it deals with the designing of a Single-Phase Uninterruptible Power Supply Based on Z-source Inverter ,this chapter comprises of the literature survey, objective and the organization of thesis. In chapter 2 In this chapter the comparison between the traditional inverters and Z-source inverter are discussed and also the Z-source operating principle and its mathematical analysis is described. In chapter 3 In this chapter the different pulse modulation schemes are described and advantages of pulse width modulation is explained[2]-[5]. In this chapter 4 the single phase pulse modulation schemes briefly described and single phase Z-source inverter PWM scheme is demonstrated with reference to voltage source inverter PWM. In this chapter 5 the simulation model of both voltage source inverter and Z-source inverter is performed with different modulation index and results are discussed. In chapter 6, the hardware and experimental result of a Single-Phase Uninterruptible Power Supply Based on Z-source Inverter, power supply, control circuit, driver, MOSFETs and power circuit are explained [8]. In chapter 7 gives the conclusion of the project and reference to the project.

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II. TRADITIONAL SOURCE INVERTERS

Traditional source inverters are voltage source inverters and current source inverters. The input of voltage source inverter is a stiff dc voltage supply, which can be a battery or a controlled rectifier (both single phase and single phase voltage source inverter) [7]-[8]. The switching device can be a conventional MOSFET, thyristor or a power transistor. Voltage source inverter is one in which the dc source has small or negligible impedance. In other words a voltage source has stiff dc source voltage at its input terminals. A current source- fed inverter or current source inverter is fed with adjustable dc current source. In current source inverter, output current waves are not affected by the load.

A. Voltage source inverter [VSI]

The traditional voltage-source inverter input is a dc voltage source supported by a relatively large voltage source can be a battery, fuel-cell stack, diode rectifier, and/or capacitor. Four switches are used in the main circuit; each in traditionally bidirectional current flow and unidirectional voltage blocking capability. The V-source inverter is widely used however; it has the following conceptual limitations. The traditional three phase leg voltage source inverter is as shown in Fig. 3

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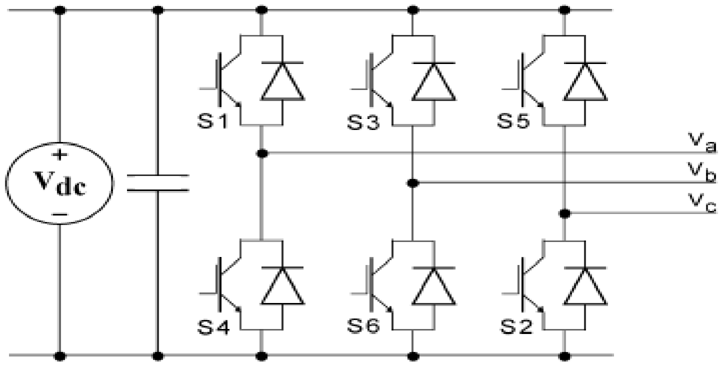

Fig. 3 Voltage-source inverter

Limitations of voltage source inverter

The V-source inverter is buck (step down) inverter for dc-to-ac power conversion. For applications where over drive is desirable and the available dc voltage is limited, an additional dc-dc boost (step up) stage is needed to obtain a desired ac output. The additional power converter stage increases system cost and lowers efficiency. The upper and lower devices of each phase leg cannot be gated on simultaneously either by purpose or by EMI noise. Otherwise, a shoot-through would occur and destroy the devices[5]. The shoot-through problem by electromagnetic interference (EMI) noise's misstating-on is a major killer to the inverter to the inverter's reliability. Dead time to block both upper and lower devices has to be provided in the V-source inverter, which causes waveform distortion, etc. An output LC filter is needed for providing a sinusoidal voltage compared with the current-source inverter, which causes additional power loss and control complexity.

B. Current source inverter [CSI]

The traditional current-source inverter input is a dc current source feeds by the main converter circuit. The dc current source can be a relatively large dc inductor fed by a voltage source such as a battery, fuel-cell stack, diode rectifier, or thyristor converter. Four switches are used in the main circuit; each is traditionally composed of a semiconductor switches device with reverse block capacity such as gate-turn-off thyristor (GTO) and SCR or a power transistor with a series diode to provide unidirectional current flow and bidirectional voltage blocking. The traditional three phase leg current source inverter is as shown in Fig. 4

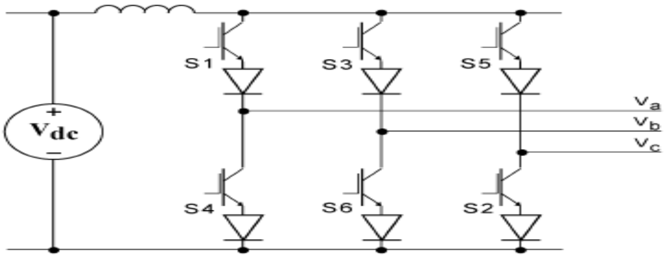

Fig.4 Current-source inverter

However, the current-source inverter has the following conceptual barriers and limitations.

Limitations of current source inverter

The ac output voltage has to be greater than the original dc voltage that feeds the dc inductor or the dc voltage produced is always smaller than the ac input voltage. For applications where a wide voltage range is desirable, an additional dc-dc boost stage is needed. The additional power conversion stage increases system cost and lowers efficiency. At least one of the upper devices and one of the lower devices have to be gated on and maintained on at any time. Otherwise, an open circuit of the dc inductor would occur and destroy the devices. The open-circuit problem by EMI noise's misgating-off is a major concern of the converter's reliability. Overlap time for safe current commutation is needed in the I-source converter, which also causes waveform distortion. The main switches of the I-source inverter have to block reverse voltage that requires a series diode to be used in combination with high-speed and high performance transistors such as insulated gate bipolar transistors (IGBT). This prevents the direct use of low-cost and high performance IGBT modules.

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III. PULSE MODULATION SCHEMES

A. PULSE-AMPLITUDE MODULATION

In PAM the successive sample values of the analog signal *s*(*t*) are used to effect the amplitudes of a corresponding sequence of pulses of constant duration occurring at the sampling rate. No quantization of the samples normally occurs (Fig.5 *a*, *b*). In principle the pulses may occupy the entire time between samples, but in most practical systems the pulse duration, known as the duty cycle, is limited to a fraction of the sampling interval. Such a restriction creates the possibility of interleaving during one sample interval one or more pulses derived from other PAM systems in a process known as time-division multiplexing (TDM).

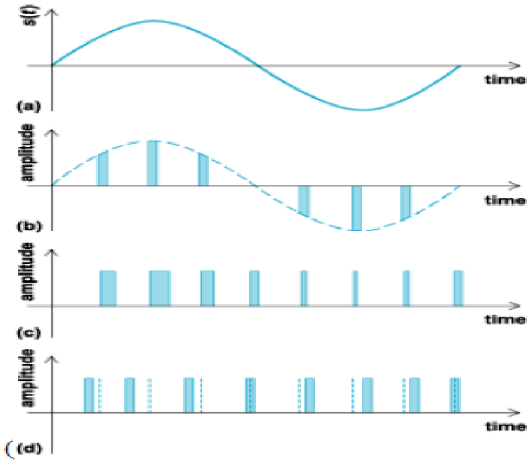

Fig. 5 *(a)* Analog signal, *s*(*t*). (*b*) Pulse-amplitude modulation. (*c*) Pulse-width modulation. (*d*) Pulse position modulation

B. PULSE-WIDTH MODULATION

In PWM the pulses representing successive sample values of *s*(*t*) have constant amplitudes but vary in time duration in direct proportion to the sample value. The pulse duration can be changed relative to fixed leading or trailing time edges or a fixed pulse center. To allow for time-division multiplexing, the maximum pulse duration may be limited to a fraction of the time between samples.

C. PULSE-POSITION MODULATION

PPM encodes the sample values of *s*(*t*) by varying the position of a pulse of constant duration relative to its nominal time of occurrence. As in PAM and PWM, the duration of the pulses is typically a fraction of the sampling interval. In addition, the maximum time excursion of the pulses may be limited.

IV. SINGLE PHASE UPS BASED ON Z-SOURCE INVERTER

A. PULSE WIDTH MODULATION OF Z-SOURCE INVERTER

As described in Section 2, the unique feature of a voltage-type Z-source inverter is that it allows the shooting-through of an inverter phase-leg, which in turn gives rise to an ac output voltage boost, controlled by varying the duty cycle (To\T) . This section now presents an analysis on how to introduce phase-leg shoot-through appropriately to the modulation of a simple H-bridge Z-source inverter. Fig 6 shows the topology of a voltage-type Z-source inverter with phase-legs (2 for H-bridge, 3 for three-phase-leg, and 4 for four-phase-leg inverters), where a dc voltage source and a conventional voltage Z-source converter with two, three, or four phase-legs, are connected at opposite ends of the Z-source impedance network. (Note that an optional diode can be connected in series with the power source to block the reverse flow of current, if required.) Voltage-type Z–source inverters are considered here because voltage-type inverters are generally more established and can conveniently be constructed using low-cost, high performance insulated gate bipolar transistor (IGBT) modules (with integrated anti-parallel diode) or intelligent power modules. With the use of the same topology as that of a conventional VSI, a voltage-type Z-source inverter can assume all active (finite output voltage) and null (0 V output voltage) switching states of VSI as shown in the Table 1. But unlike the conventional VSI where dead-time delays are inserted to the complementary switching of the two switches of a phase-leg to prevent short-

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circuiting of the phase leg, a voltage type Z-source inverter has the unique feature of allowing both power switches of a phase-leg to be turned ON simultaneously (shoot-through state) without damaging the inverter.

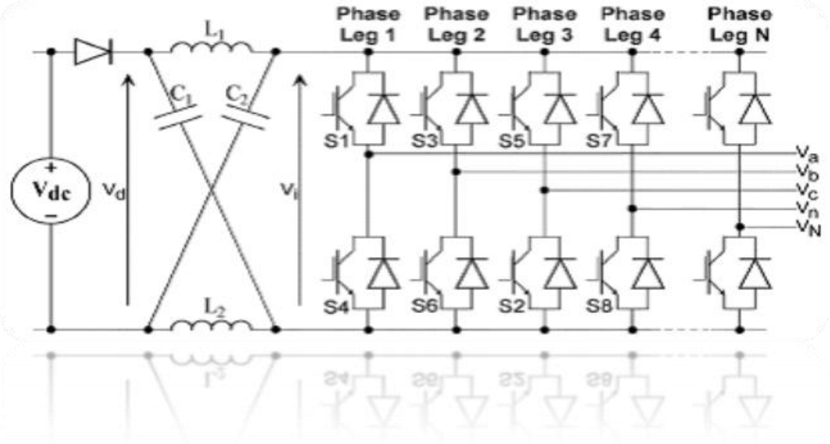


Fig. 6 Voltage type Z-source inverter

Table 1 Switching states

State (Output Voltage)	S_1	S_4	S_3	S_6
Active {10} (finite)	1	0	0	1
Active {01} (finite)	0	1	1	0
Null {00} (0V)	0	1	0	1
Null {11} (0V)	1	0	1	0
Shoot-Through H1 (0V)	1	1	S_3	$!S_3$
Shoot-Through H2 (0V)	S_1	$!S_1$	1	1
Shoot-Through H3 (0V)	1	1	1	1

The impact of this phase-leg shoot-through on the inverter performance can be analyzed by considering the equivalent circuits shown in Fig.4.2. When in a shoot-through state during time interval T_0 , the inverter side of the Z-source network is shorted as in Fig. 7.

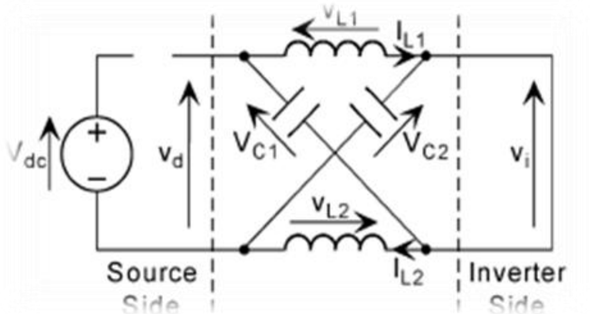


Fig. 7 voltage type Z-source inverter in shoot through switching state

Therefore, (assuming $L_1 = L_2= L$ and $C_1= C_2= C$)

$$V_{C1}=V_{C2}=V_C;\ V_{L1}=V_{L2}=V_L \quad (4.1)$$

$$V_L=V_C;\ V_d=2V_C;\ V_i=0 \quad (4.2)$$

Alternatively, when in a non shoot-through active or null state during time interval T_1 , current flows from the Z-source network through the inverter topology to the connected ac load. The inverter side of the Z-source network can now be represented by an equivalent current source, as shown in Fig. 8. This current source sinks a finite current when in a non shoot-through active state and sinks zero current when in a non shoot-through null state. From Fig 7, the following equations can be written

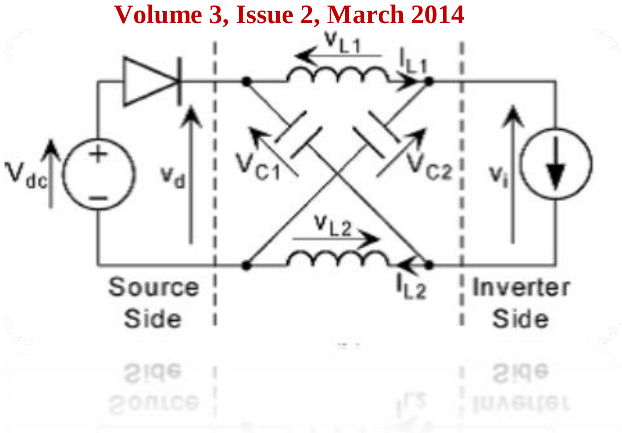


Fig. 8 voltage type Z-source inverter in non-shoot through switching state

From Fig. 4.3, the following equations can be written

$$V_I=V_{dc}-V_C \ \& \ V_d=V_{dc} \tag{4.3}$$

$$V_i=V_C-V_L=2V_C-V_{dc} \tag{4.4}$$

Averaging the voltage across a Z-source inductor over a switching period of $T = T_0+T_1$ then gives

$$V_C/V_{dc}=T_1/(T_1-T_0) \tag{4.5}$$

Using (4.3) and (4.5), the peak dc voltage V_i across the inverter phase-legs and the peak ac output voltage can be written as V_S

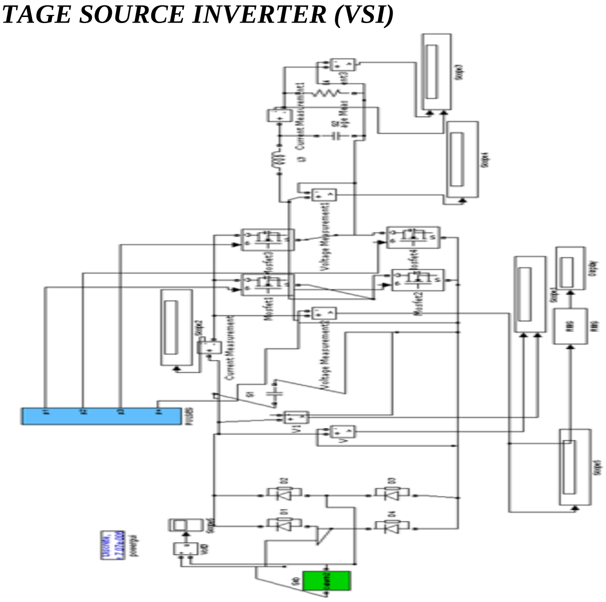
$$V_i=B_b\ V_{dc} \tag{4.6}$$

$$V_S=M.BV_{dc}/2 \tag{4.7}$$

Where B_b is the boost factor introduced by the shoot-through state, M is the modulation ratio commonly used for conventional VSI modulation, and the term in {} in (4.4) gives the ac output of a conventional VSI. Obviously, equation V_S shows that the ac output voltage of a Z-source inverter is boosted by a factor of B_b , which is always greater than 1, which cannot be achieved with a conventional VSI (assuming no additional dc–dc converter is used)..

V. SIMULATIONRESULTS

A. SINGLE PHASE VOLTAGE SOURCE INVERTER (VSI)



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For Modulation index =0.4

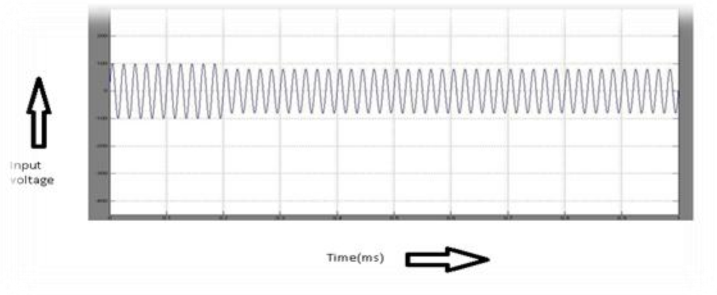


Fig 9 Input Voltage Vs Time(ms)

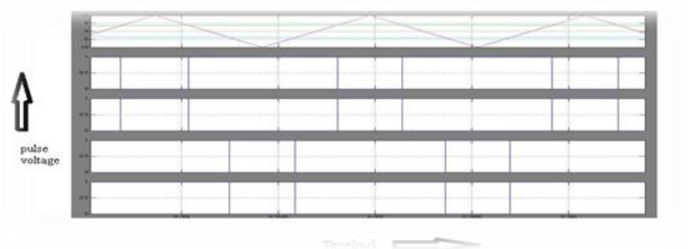


Fig 10 Pulses for voltage source inverter Vs Time (ms)

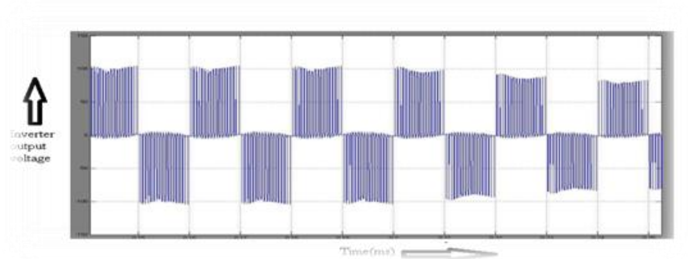
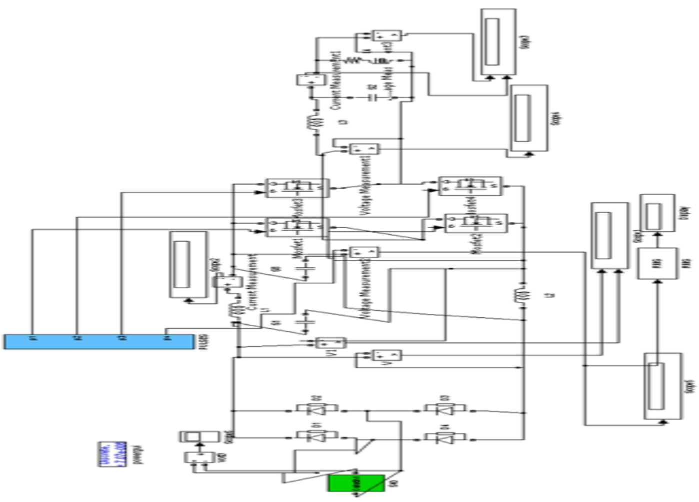


Fig 11 Output voltage of VSI Vs Time (ms)

B. SINGLE PHASE UPS BASED ON Z - SOURCE INVERTER (ZSI)



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Modulation index =0.4

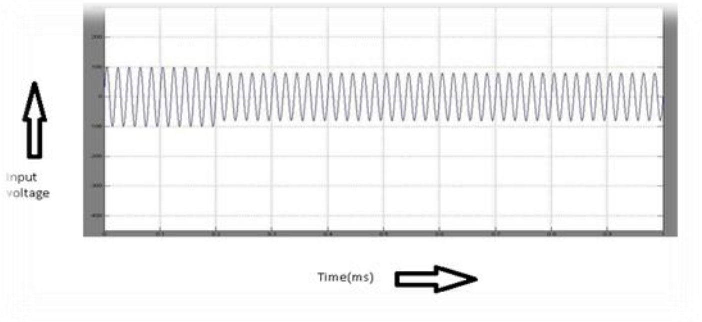


Fig 12 Input Voltage Vs Time (ms)

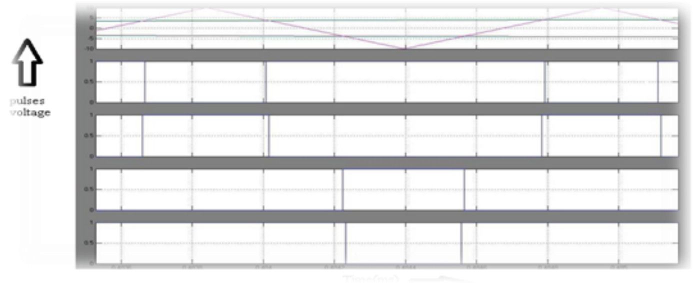


Fig 13 Pulse for Z-source inverter at Duty Ratio (D0) of 0.3.

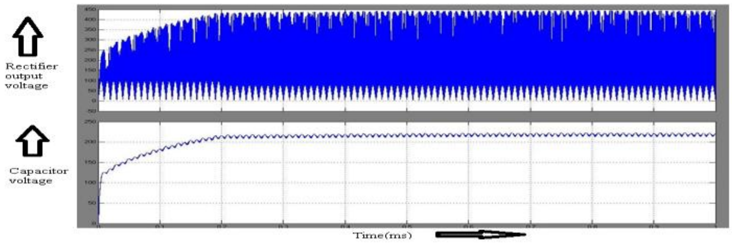
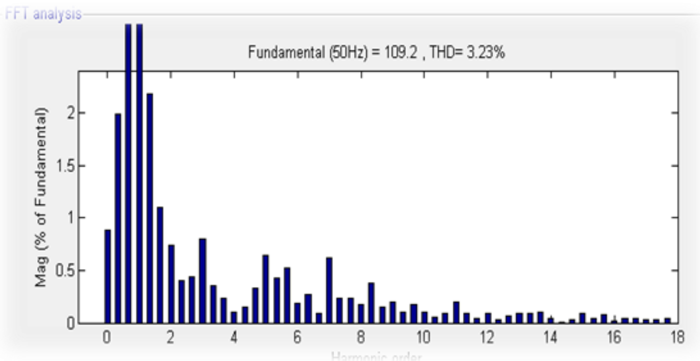


Fig 14 Rectifier output voltage and Capacitor voltages Vs Time (ms)

FFT Analysis



VI. CONCLUSION

A new type of inverter for UPS application has been proposed and corresponding simulated waveforms are verified. The proposed single phase Z-source inverter provides ride-through capability during voltage sags and reduces total harmonic distortion when compared to traditional voltage source inverter. The proposed Z-source based UPSs provide the both buck and boost operation of dc link voltages, this operation done by pulse width modulation. Which both operations are not observed in traditional voltage source inverters .Compared with

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traditional UPSs, the proposed UPS shows the strong regulation capability to maintain the desired ac output voltage at 25% voltage sag of the battery bank with low harmonics, fast response .The presented method is implemented by using MATLAB/simulink software and simulation results are presented. The Z-source inverter is practically implemented and the hardware results obtained.

SCOPE FOR FUTURE WORK

In the present work the superiority of Z-source inverter is evaluated and compared with the conventional voltage source inverters for different Modulation index. In the present work open loop analysis of UPSs based on Z-source inverter is performed with open loop analysis. In future studies, closed loop analysis of the UPS based Z-source inverter can be performed.

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