Grid Connected PV system based on Z-source Inverter with Phase shifted PWM Technique

G. Chakradhar*,B. M.manjunath**,
(PGstudent, RGMCET)* ,(ASST .Professor, RGMCET)**,
Chakri.212@gmail.com*,manjunath_bm@in.com**.

ABSTRACT: ***The traditional grid-connected photovoltaic systems contain voltage source inverter and the current source inverter. They are buck converter but not a buck–boost converter. Their obtainable output voltage range is also limited. The common problem in traditional inverter is that the two switches of any phase leg can never be turned on at the same time otherwise a short circuit (shoot through) will occur and it may damage the inverter. In this paper photovoltaic(PV) power conditioning systems based on neutral clamped multilevel Z-source inverter is considered. Using Z-source network, the system can work over the wide range of PV array Output voltage when compare to conventional converter. It allows the use of the shoot-through switching state for boosting the input voltage, compensates dead-time effect which causes serious output voltage distortions and avoids the risk of damaging the inverter circuit. This condition cannot be obtained in the traditional inverters. A multilevel inverter is used in this circuit. These types of inverters are suitable in various high voltage and high power application due to their ability to synthesize waveforms with better harmonic spectrum and faithful output. The power quality improvement is achieved by reducing the harmonics present at the output voltage of the inverter. The pulse generation is same as that of traditional inverter. Here the null state is converted into shoot through state. The pulses for the multilevel inverter can be given by using phase shifted PWM technique. The whole system is modeled, integrated and simulated in a Matlab/Simulink environment***.

***Keywords*— Grid-connected, MPPT, photovoltaic, shoot-through, Z-source inverter.**

I.INTRODUCTION:

Grid-connected PV system feed electricity directly to the electrical network, operating parallel to the conventional electric source. System performance depends on local climate, the orientation and inclination of the PV array and inverter performance. The traditional grid-connected photovoltaic systems contain voltage source inverter and the current source inverter. They are either a boost or a buck converter but not a buck–boost converter. Their obtainable output voltage range is also limited. The common problem of this topology is that the two switches of any phase leg can never be turned on at the same time otherwise a short circuit (shoot through) will occur and it may damage the inverter.The proposed Z-source converter overcomes the theoretical barriers and limitations of the traditional converter and presents a novel power conversion concept. Fig 1 shows the basic circuit of a Z-source inverter. It is a two port network that consists of a split inductors L1 and L2,C1 and C2 connected in x shape to provide an impedance source.

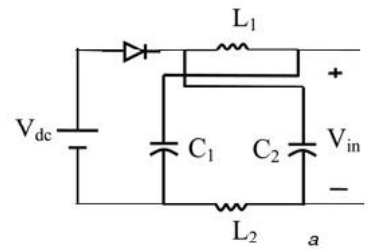

Fig .1 .Basic circuit of a z source inverter

The Z-source concept can be applied to all dc-ac, ac-dc, ac-ac and dc-dc power conversions. The boost control strategy is quite similar to the traditional carried-based pulse width modulation (PWM) control method . The basic idea of control is to turn null states into shoot through states and keep the active switching states unchanged . The reliability of the inverter is greatly improved because miss- gating can no longer destroy the circuit.

This paper develops A MATLAB/simulink model of an PV system with z-source inverter and starts with an introduction of the grid-connected photovoltaic system for the proposed one. After that, an analysis of the basic operating principle of Z-source inverter with its PWM strategy .Then, MPPT control technique is briefly analyzed. The main advantage of a Z-source converter is its shoot-through and voltage-buck or boost capabilities . In addition, power loss is reduced due to a lower number of switching devices.

II. MODEL OF A GRID CONNECTED PV SYSTEM WITH Z-SOURCE INVERTER

The grid-connected photovoltaic system is shown in fig .2 It contain PV array, Z-source bridge inverter, filter and control circuit. This system produces high quality sine wave output with the same phase and direction with the grid voltage. The whole control system consists of loops namely MPPT control loop, Z-source capacitor voltage control loop and voltage-current compensation loop.

The MPPT control circuit for PV array is realized by using incremental conductance (Inc-Con) technique , which keeps it working around the maximum power point

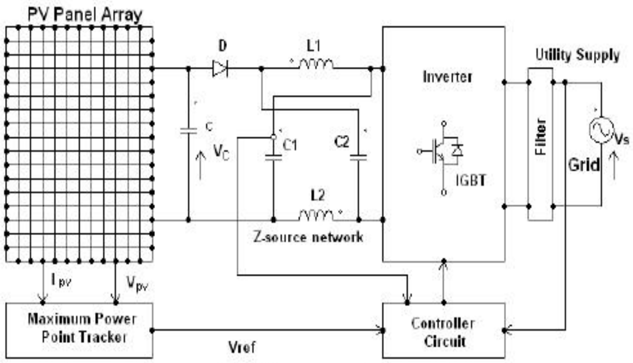

Fig .2. Schematic diagram of a grid-connected PV system

The Z-source capacitor voltage control compensation loop utilizes a shoot through technique. The shoot through duty ratio is used on the way to promise a relatively a stable voltage of z source capacitors. This loop is provide ride through capability under voltage sags to reduce line harmonics and to extend output voltage range .to improve performance with PWM generator. It modifies the control signal obtained from the comparison of MPPT and inverter output to generate PWMsignal.

III . OPERATING MODES OF A Z-SOURCE INVERTER:

The following Fig3 and fig .4. shows the equivalent circuit of the Z-source , the inverter bridge is equivalent to a short circuit when the inverter bridge is in the shoot-through zero state, as shown in Fig. 3, whereas the inverter bridge becomes an equivalent current source as shown in Fig. 4 when in one of the six active states. Note that the inverter bridge can be also represented by a current source with zero value (i.e., an open circuit) when it is in one of the two traditional zero states. Therefore, Fig. 4 shows the equivalent circuit of the Z-source inverter viewed from the dc link when the inverter bridge is in one of the eight non shoot-through switching states.

ZSI Working Strategy

For simplification purposes, Z-source network parametersare selected as L 1 = L 2 = L and C1 = C2 = C which make the Z-source network symmetrical. Accordingly, the capacitor and inductor voltages of the Z-source network become

$$V_{L1} = V_{L2} = V_L$$
$$V_{C1} = V_{C2} = V_C \qquad (1)$$

VC is the capacitor voltage and VL is the inductor voltage.

Consider the converter in the shoot-through state for an interval of To during a switching cycle T

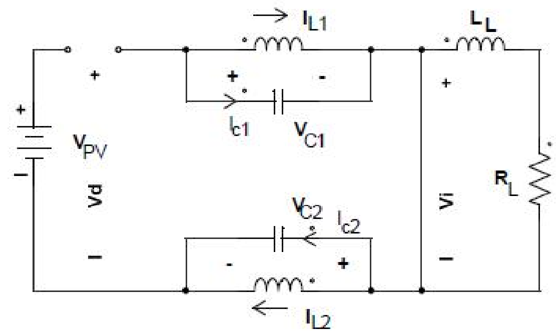

fig 3 Shoot-through zero state of a z-source inverter

Fig 3 shows the shoot-through state of simplified ZSI. In shoot-through states, the circuit can be described by the following equations

$$V_i = 0$$
$$V_L = V_C$$
$$V_d = 2V_C = V_{C1} + V_{C2} > V_{PV} \qquad (2)$$

where V_{pv} is the output voltage of PV array, V_i is Z – source network dc link voltage

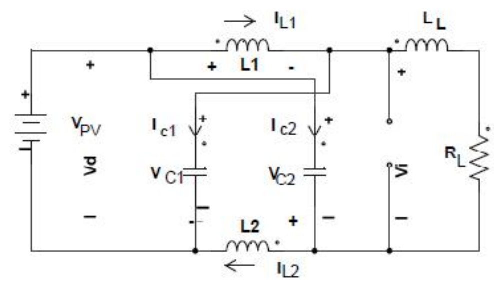

Fig 4: Non shoot- through switching state

shows active state of simplified ZSI. For the active states, the output side of the ZSI can be represented by an equivalent current source . So the following steady state equations can be obtained.

$$V_d = V_{PV} = V_L + V_C$$
$$V_i = V_C - V_L = 2V_C - V_{PV} \qquad (3)$$

The total duration of shoot through time and total active time are denoted by T_0 and T_1, the average voltage V_{L1} over a switching period T should be zero in steady state , which leads to the following equations

$$V_c\,To + (V_{PV} - Vc)T_1 = 0$$
$$T_o + T_1 = T \qquad (4)$$

From (4), the boost factor B can be derived as

$$B = V_1/V_{PV} = T/T_1 - T_O = 1/(1 - 2T_O/T_1) >= 1 \qquad (5)$$

For active states, the peak dc link voltage is

$V_1=TV_{PV}/(T_1-T_O)=BV_{PV}$ (6)

Then, from above, the ac output voltage of ZSI can be written as

$Voc=V_i m=mV_{Pv}\ 1/(1-2T_O/T_1)=BmV_{PV}$ (7)
$D_O=T_O/T$

Where m is modulation index and D_0 means shoot through duty ratio. As seen from (7), a desired ac output can be obtained by controlling the shoot through duty cycle D_0 and modulation index m.

All the traditional PWM schemes can be used to control the Z-source inverter and their theoretical relationships maintains true. In every switching cycle, the two non-shoot-through zero states are used along with two adjacent active states to synthesize the desired voltage. When the dc voltage is high enough to generate the desired ac voltage, the traditional PWM of is used. While the dc voltage is not enough to directly generate a desired output voltage, a modified PWM with shoot-through zero states will be used to boost voltage. It should be noted that each phase leg still switches on and off once per switching cycle.

IV. MATLAB MODEL FOR PWM:

In this paper for controlling the z-source inverter we used a phase shift SPWM. The following fig 5 shows the MATLAB Model for SPWM.

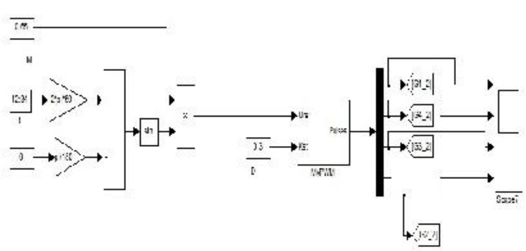

Fig 5 MATLAB model of a phase shift PWM controller

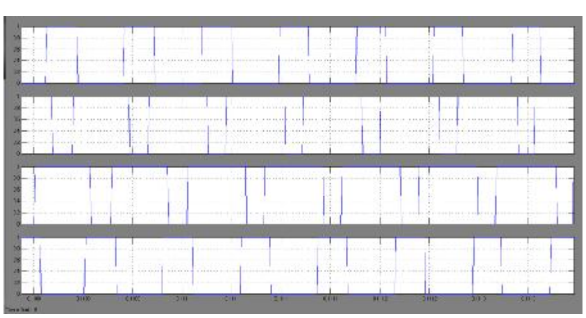

Fig 6 :pulses generated by a PWM generator

Similarly when Z-source inverter is simulated in the MATLAB /simulink the inductor current and voltage across capacitor is shown in fig and fig respectively. The purpose of the inductor is to limit the current ripple through the devices during boost mode with shoot-through state and inductor current increases linearly in this and voltage across inductor is equal to the capacitor voltage . during non-shoot-through mode ,the inductor the inductor decreases linearly, capacitor voltage is always equal to the input voltage. Therefore no voltage across inductor and only a pure dc current goes through it.

The purpose of capacitor is to absorb ripple and maintain a fairly constant voltage so as to keep output sinusoidal. During shoot-through ,the capacitor charges inductor and current through capacitor is equal to inductor current.

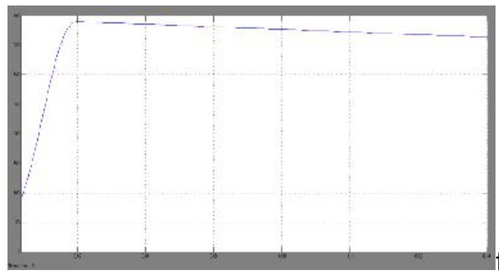

fig 7: MATLAB result showing voltage across capacitor

V. MATLABMODEL FOR GRID CONNECTED PV SYSTEM:

Two verify the proposed design strategies, a MATLAB/Simulink model of a single-phase root connected PV system based on z-source inverter is shown in figure 8. The designed system contains z-source inverter that transfers maximum power from the PV source to the grid side. Simulink model of PV array consisting of six PV modules that are connected in series. The Maximum Power Point Tracker (MPPT) tracks the maximum solar radiation from PV array. The technique incremental conductance method has relatively good tracking performance.

The parameter values of Z-source inverter used in simulation are taken as follows
L1=L2= 1mh
C1=C2=6300µf

The control circuit used in the proposed model is PID approach commonly used for converter applications. PID controller is a three term controller whose transfer function can be written as

$$G(s) = K_p + \frac{K_t}{S} + K_D S \quad (8)$$

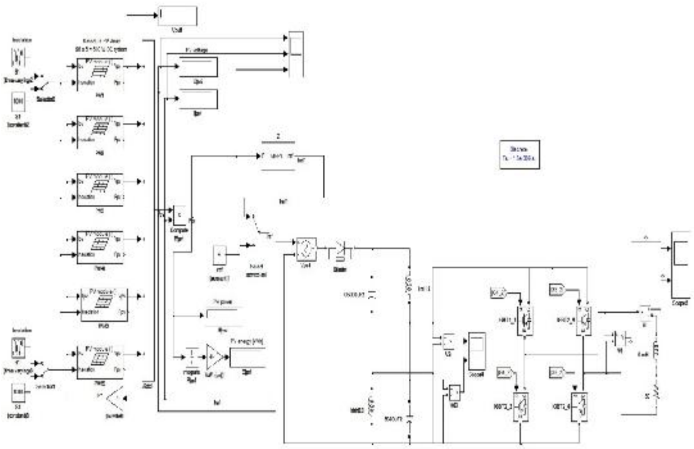

Fig 8: MATLAB simulink model of a single-phase grid connected PV system based on z-source inverter

The proportional term is providing an overall control action proportional to the error signal through the all pass gain factor. The integral term is reducing steady state errors through low frequency compensation by an integrator and derivative term is improving transient response through compensating by a differentiator. This PID is connected to PWM generator. The converter output voltage and PV array output voltage are compared by comparator, their resulting errors output signal which is fed to PID control circuit to obtain correction in output voltage. The PWM pulse generator circuit provides the PWM pulses to IGBT inverter.

VI. SIMULATION RESULTS:

The actual simulation results of the proposed system is shown below. The parameters of a PV module are

Short circuit current I_{sc}	= 5.45A
Open circuit voltage for 1PV module	= 22.2V
Output dc voltage	=7.5V
Output dc current	=4.5A
One module output power	=85.14Watts

The below figure shows the current characteristics of a PV cell

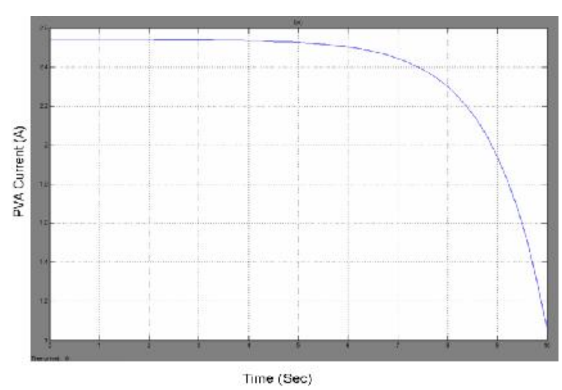

Fig 9: Current characteristics of a PV cell

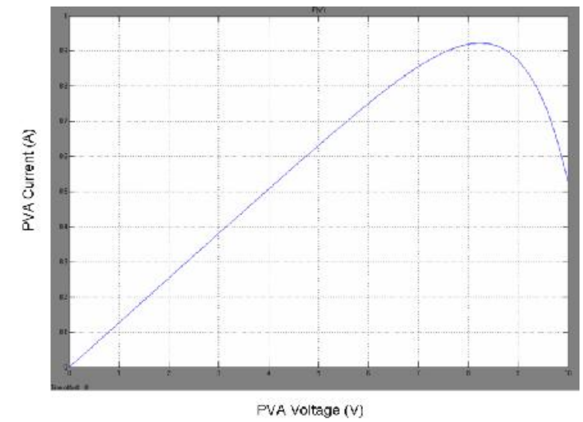

Fig 10: P/V characterstics of a PV cell

Fig 9 and fig 10 shows the performanc of a proposed PV system according to the temperature changes. From the fig 10 it is clear that the power generated from the PV cell is maximum at lowest temperatures and low at highest temperatures. This is achieved by using MPPT algorithm.

Clearly the proposed system is enable to maintain necessities of voltage or current regulation and maximization of generated power. In this model 6 PV modules are connected in series to increase output. The simulation results of PV array is as follows

PV array output voltage	v_{pv} = 114V
PV array output current	I_{pv} = 3098A
PV array output power	P_{pv} = 453.5W

This PV array output voltage is given input to the Z-source inverter.

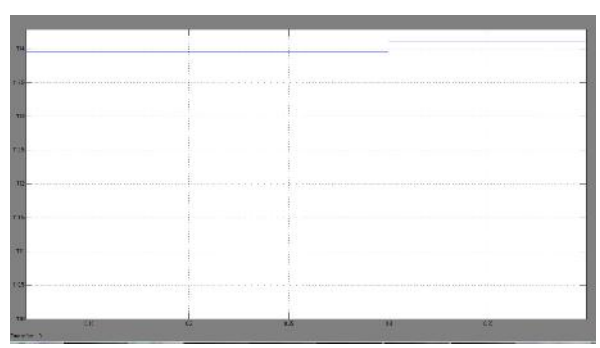

Fig 11: output of PV array and input to Z-source inverter

The Z-source inverter used in the proposed system boost up the output voltage of the PV array to 400V. This voltage is given as input to the IGBT inverter circuit. It converters dc output of PV array to ac output voltage. This inverter is not only capable to control the active power but also dynamically reconfigured to change the magnitude of reactive power injected into the grid.

The output of a proposed system or input to a grid is as shown below.
Proposed system output voltage $v_o = 600V$
Proposed system output current $I = 8A$
Proposed system output power $p = 4.8KW$

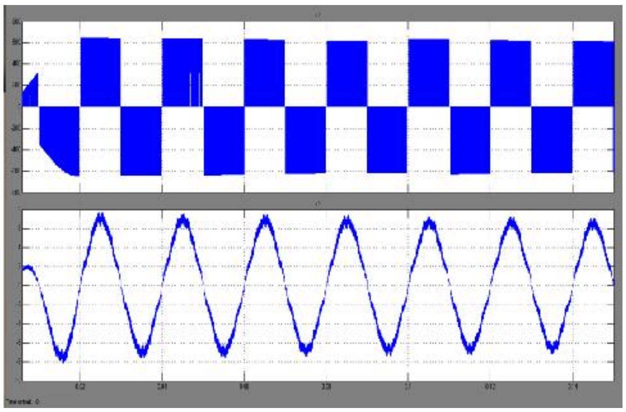

fig 12: MATLAB results showing inverter output voltage and output current

The below figure shows the FFT analysis of a output current of inverter. After testing the performance of the system the TOTAL HARMONIC DISTORTION(THD) is 7.14%

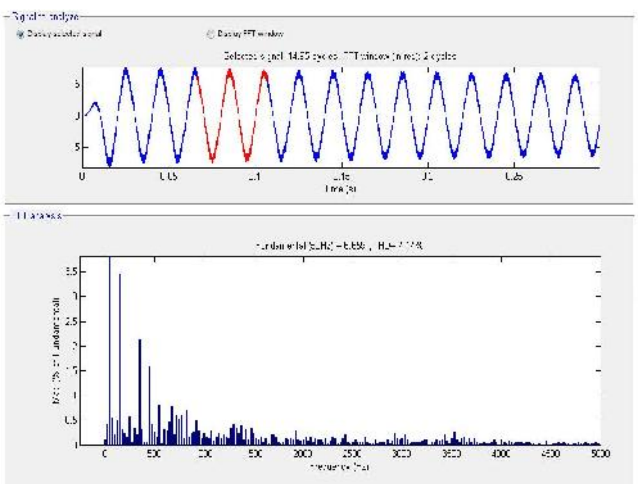

Fig 13: THD of output current of a inverter

The above simulation results clearly justify the needs of a utility grid and the inverter control strategy is not only capable to control the active power but also changes the magnitude reactive power injected into the grid.

VII. **CONCLUSION :**

In this paper single-phase grid connected pv system with Z-source inverter has been analysed using MATLAB /simulink. The proposed Z-source inverter has both voltage buck and boost capabilities due its unique impedance network . the basic idea of the proposed control is to obtain a low cost and simple controller.The MPPT control and split phase SPWM techinque makes the PVarray to work in a optimum manner.The proposed converter connects the main source and the grid effectively with its shoot–through switching states , it overcomes problems with traditional converters and provides a novel power conversions from the above simulink results it is clear that Z-source rectifier/inverter system can produce an output voltage greater than the ac input voltage by controlling the boost factor, which is impossible for the traditional systems.

REFERENCES :

[1]. K. Thorborg, *Power Electronics*, Prentice Hall International (U.K.) Ltd., London 1988.
[2]. Muhammad H. Rashid, *Power Electronics*, 2nd Edition, Prentice Hall, 1993.
[3]. N. Mohan, W. P. Robbin, and T. Undeland, *Power Electronics: Converters, Applications, and Design*, 2 nd Edition, John Wiley and Sons, 1995.
[4]. Andrzej M. Trzynadlowski, *Introduction to Modern Power Electronics*, John Wiley and Sons, 1998.
[5]. B. K. Bose, *Modern Power Electronics and AC Drives*, Prentice Hall PTR, 2002.
[6] F.Z. Peng, “Z-Source inverter”, IEEE Trans. Ind. Applicant. Volume 39, pp. 504-510, Mar/Apr. 2003.
[7] J.H. Oum,; Young-Cheol Lim. Young-Gook Jung. "Z-source active power filter with a fuel cells source", the 7th IEEE International Conference on Power Electronics 22-26 Oct. 2007 pp.467-471
[8] Yeyuan Xie Zhaoming Qian Xinping Ding Fangzheng Peng, “A Novel Buck-Boost Z-Source Rectifier”, Power Electronics Specialists Conference, pp 1-5, 2006. PESC '06. 37th IEEE Zhejiang Univ, Hangzhou.
[9] F. Z. Peng, M. Shen, A. Joseph, L. M. Tolbert, D. J. Adams, “Maximum Constant Boost Control of the Z- Source Inverter”, In proc. IEEE IAS’04, 2004.

G.Chakradhar was born in cementnagar, Andhra Pradesh, India in 1988. He received the B.Tech(Electrical and Electronics Engineering) degree from JNT University, Hyderabad affiliated college in 2011. He is pursuing M.Tech (Power Electronics) in RGMCET (Autonomous), Nandyal.
E-mail:chakri.212@gmail.com

B.M.Manjunatha was born in 1981 in India. He received the B.E from Vijaya Nagara Engg. College, Affiliated to Visweswara Technological University (VTU), Belgaum, India in 2004. Master of Technology from J.N.T.U, Hyderabad in 2008**.** Currently working as Assistant Professor in the Department of Electrical & Electronics Engineering, R.G.M. College of Engineering & Technology, Nandyal, Andhra Pradesh. His areas of interests are in Special Electrical Machines and Drives. E-mail: manjumtech003@gmail.com