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Unified MPPT Control Strategy for Z-Source Inverter

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Abstract*—This Paper proposes the PV array connected Z-source inverter is widely used because it boost up output voltage and reduces the harmonics and improves efficiency. Here single stage Photovoltaic power conversion system uses less number of switching devices and reduces the system cost. The Perturb and observation MPPT control algorithm provides shoot-through period which inserted into switching devices to produce maximum power to the Z-network. At this instant, the voltage across Z-source capacitor is equal to the output voltage of PV array at the MPP. The control of Z-source capacitor voltage beyond the MPP voltage of a PV array is not possible in Traditional Maximum Power Point Tracker algorithm. In this work Unified MPPT control algorithm is used to simultaneously achieve MPPT as well as Z-source capacitor voltage. The Operation and Performance of the Proposed Systems have been simulated using MATLAB/Simulink.

***Keywords*— Z-source inverter, Capacitor Voltage Control, Maximum Power Point Tracker, Photovoltaic array, Pulse width modulation.**

I. INTRODUCTION

Now a days Renewable energy sources plays an important role in domestic and industrial applications because this sources are inexhaustible and it does not pollute the environment. By using Renewable energy sources such as PV cell, wind energy, fuel cell we can regenerate electricity more and more. But, once non-renewable energy sources are used it cannot regenerate electricity and it produces waste disposal to environment. Photovoltaic systems have been the worldwide fast growing energy source because of the increase in energy demand and the fact that fossil energy sources are finite, and that they are expensive. So, PV array is used as an input source. A Photovoltaic system is directly converts sunlight into electricity[8]. The obtained energy depends on solar irradiation, temperature and the voltage produced in the photovoltaic module. The voltage and current available at the terminals of a PV device may directly feed small loads. Moreover, the solar cell V-I characteristic is nonlinear and varies with irradiation and temperature. In general, there is a unique point on the I-V or P-V characteristic called maximum power point (MPP), at which the entire PV system operates with only 30 % to 40 % efficiency and produces its maximum output power. The MPPT is used to track Maximum voltage and current in PV array and to improve the maximum efficiency of PV array. The Maximum power point tracker change DC input into high frequency ac and again it convert to a DC output voltage[3]. In this PV array connected Z-source inverter are used to overcome disadvantages of traditional Voltage source inverter and Current source inverter. The Maximum power point tracking algorithms are used to increases the system efficiency and it reduces Total Harmonic Distortion. The single stage power converter system uses less number of switching devices and it produces maximum desirable PV output voltage and it converts DC to AC for controlling the AC loads. In all of these methods, the output of the Maximum power point tracker controller is the reference signal for generating a shoot-through state to track the PV voltage at the maximum power point. This voltage is the reference voltage for the Z-source capacitor and the Z-source capacitor voltage is boosted to the PV voltage at the MPP. The voltage across the Z-source capacitor is equal to the photovoltaic array voltage at the MPP[4]. Since a MPPT algorithm generates a shoot-through period to extract the maximum power point voltage from the solar cell, this shoot-through period is unable to boost the capacitor voltage further than the desired level. Here Capacitor voltage control algorithm is employed to achieve MPPT as well as capacitor voltage control.

II. SINGLE STAGE PV CONVERSION SYSTEM FOR ZSI

The PV array connected Z-source inverter overcomes limitations of the traditional V-source inverter and current source inverter and provides a power conversion concept. In fig1 shows impedance network that contains a split-inductors L1& L2 and capacitors C1& C2 connected in X-shape[1]. Here PV array is used as an input source. The function of two inductors are used to regulates current

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ripples and reduces harmonics and Two capacitors are used to regulates voltage ripples and produces pure ac. This inverter is used to improve the efficiency and reduces THD. The Z-source network connected between power source and the main circuit[10]. The MPPT controller track maximum voltage and maximum current in PV array, it can produce shoot-through period and given reference signal to the modulator and generates pulses. These pulses are inserted into switching devices to produce to buck and boost up output voltage.

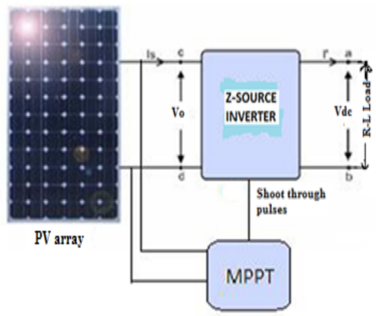

Fig.1 Equivalent circuit of PV cell connected Z-source inverter

A. *Operating Principle of Z-Source Inverter*

The circuit consisting three modes of operation according to the states of switches:

Mode1: (Active vector mode)

The inverter bridge is operating in one of the six active vectors thus acting as a DC link from the Z-source circuit as shown in fig. During this mode, the diode is conduct and energy stored in inductors and capacitors. Note that the both inductors have an identical current value due to the circuit symmetry. During this period harmonics are reduced.

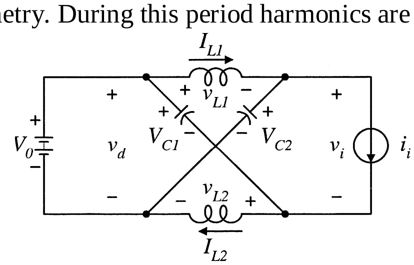

Fig.2 Equivalent circuit of Z-source inverter during Active Mode

During Active state, the inductor voltage is given by z-network is

$$V_L=V_0-V_C;\ V_{dc}=V_0 \qquad (1)$$

$$\hat{V}_{dc}=V_C-V_L=2V_C-V_0 \qquad (2)$$

Where V_{pv}=output voltage of PV array, V_{dc}= DC link voltage, $\hat{V}_{dc}$=Peak DC link voltage

The peak DC link voltage across the inverter bridge is given by

$$\hat{V}_{dc}=V_C-V_L=2V_C-V_0=B\ V_0 \qquad (3)$$

Mode2: (Shoot-through mode)

The Z-source inverter bridges working in one of the seven shoot-through states during this mode, diode is off, separating the DC link from the ac line, then line currents flows through the capacitor as shown in fig .During this mode, the capacitors charge the inductors.

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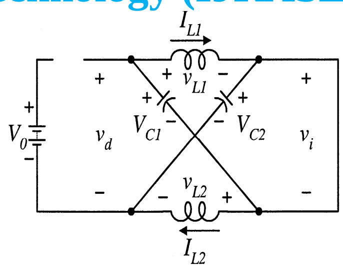

Fig.3 Equivalent circuit of Z-source inverter during Shoot-through Mode

Assume the inductors (L1&L2) and capacitors (C1&C2) have same inductance and capacitance values respectively.
From the above equivalent circuit, the capacitor voltage and inductor voltage is given by

$$V_{C1}=V_{C2}=V_C \quad (4)$$

$$V_{L1}=V_{L2}=V_L \quad (5)$$

$$V_L=V_C,\ V_d=2V_C,\ V_i=0 \quad (6)$$

Where V_C=capacitor voltage, V_L=inductor voltage

Mode3: (Zero-state Mode)

The inverter bridge is operating in one of the two traditional zero - state vectors and open circuit through either the upper or lower three devices, thus acting as a open circuit viewed from the z source circuit as shown in fig. in this mode, the diode conduct and carry current and reduces the harmonics.

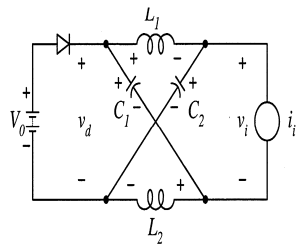

Fig.4 Equivalent circuit of Z-source inverter during Zero state Mode

III.UNIFIED MPPT CONTROL ALGORITHM

Flow chart of the proposed Unified Maximum Power Point Tracker Algorithm having two stages. The First stage is known as Perturb and Observation MPPT algorithm and Second stage is known as Capacitor Voltage Control algorithm. The first stage of the Unified MPPT algorithm is used to generate a shoot-through period and boosts the z-source capacitor voltage to the PV array voltage at the Maximum Power Point[2]. In this Power is measured and used feedback to Adjust the Shoot-through cycle to reach the Maximum Power Point. By using this First stage we can improves the capacitor voltage until it reaches MPP voltage of PV array and hence maximum power is extracted from the PV array[5]. But, here the control of z-source capacitor voltage beyond Maximum Power Point voltage of PV array is not possible. This Perturb and Observation MPPT algorithm is decreases efficiency and increases the Total Harmonic Distortion.

The Second stage of Capacitor Voltage Control algorithm track the reference capacitor voltage, the UMCA generates an additional Shoot-through factor (T_o')[6]. For a particular solar irradiation and temperature levels the Z-source capacitor voltage is first set to the MPP voltage of the PV array with MPPT algorithm. In first stage of MPPT algorithm, when actual capacitor voltage (V_c) is equal to the reference capacitor voltage (V_c*) , no additional shoot-through period generated. In Second stage of CVC algorithm two cases are possible to control the z-source capacitor[7]. In Case1(V_c*>V_c), the Reference capacitor voltage (V_c*) is greater than the Actual capacitor voltage (V_c) an additional shoot-through period (T_o') generated and added to the shoot-through period(T_o) generated in the MPPT algorithm. In case2, if the Reference voltage (V_c*) is less than the Actual voltage (V_c) at MPP voltage of the PV panel[9]. the net Shoot-through period (T_{sh}) is calculated by subtracting an additional shoot-through period(T_o')from the shoot-through time period(T_o)generated by the MPPT to provide a net shoot-through period(T_{sh})to update the Z-source capacitor voltage(V_c).The proposed control algorithm are used to control the Z-source capacitor voltage beyond the MPP and boost up the output voltage. This algorithm is used to increases the efficiency and reduces the THD[11].

The New shoot-through time period (T_{sh}) has simultaneous control of the MPPT and the Z-source capacitor voltage and is defined as follows.

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$$T_{sh}= T_o \pm T_o' \qquad (7)$$

$$D_{sh}= T_o/T \pm T_o'/T \qquad (8)$$

Where T_o is used to track V_{pv}*, T_o' is used to control capacitor voltage according to reference capacitor voltage (V_c*).
The new shoot-through time period can be written by as follows

$$T_{sh}/T \leq (1\text{-}M) \qquad (9)$$

The equation (7) and (9), the following is obtained

$$\pm T_o'/T \leq 1\text{-}(M+ T_o/T) \qquad (10)$$

The maximum value of the additional shoot-through duty ratio for both cases can be written as follows.

$$(T_o'/T)_{max} \leq \; 1\text{-}(M+ T_o/T) \text{ when } V_c^* > V_c \qquad (11)$$

$$(T_o'/T)_{max} \leq \; (1\text{-}(M+ T_o/T)) \text{ when } V_c^* < V_c) \qquad (12)$$

The reference straight lines to generate new shoot-through periods can be equal to:

$$V_P^* = (1\text{-}T_{sh}/T) = (1\text{-}D_{sh}) \qquad (13)$$

$$V_N^* = \text{-}\,(1\text{-}T_{sh}/T) = \text{-}V_P^* \qquad (14)$$

The Peak value of the AC output voltage of the ZSI is given by

$$V_{ac} = M\, V_{dc}/2 \qquad (15)$$

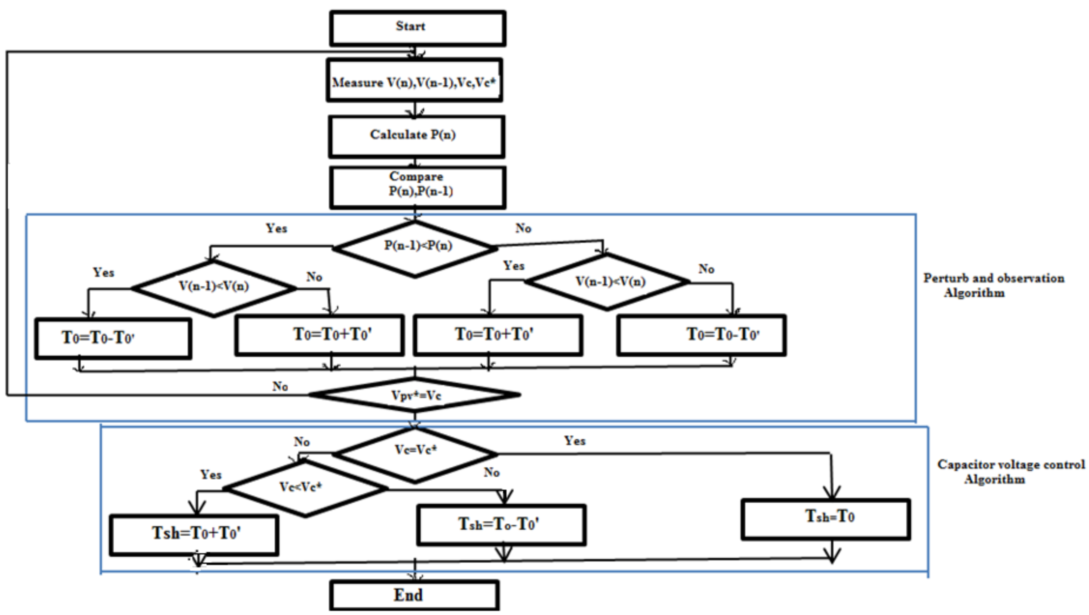

Fig.5 Flow chart of Unified MPPT control algorithm

IV. SIMULATION RESULTS

The simulation parameters are given as follows inductance and capacitors are L1=L2=1mH, C1=C2=1000uF and switching frequency is 5000 Hz.

Unified MPPT control of Z-source inverter was modeled in Simulink. The output voltage of PV array, Z-source Inverter output voltage and Z-source capacitor voltage at different cases are simulated as shown in below. FFT plot for the load voltage and load current at different cases are also shown in below.

CASE-1. ($V_c = V_{pv}$*)

In Case-1, The output voltage of PV array and Z-source inverter output voltage and Z-source capacitor voltage is 210V are obtained in simulation. In this Z-source capacitor voltage is boosted that is equal to the PV array voltage. Here, Z-source capacitor voltage is not controlled and it reduces the efficiency.

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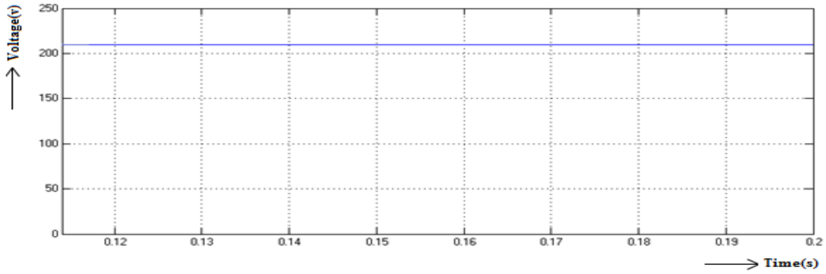

Fig.6 Output voltage of PV array

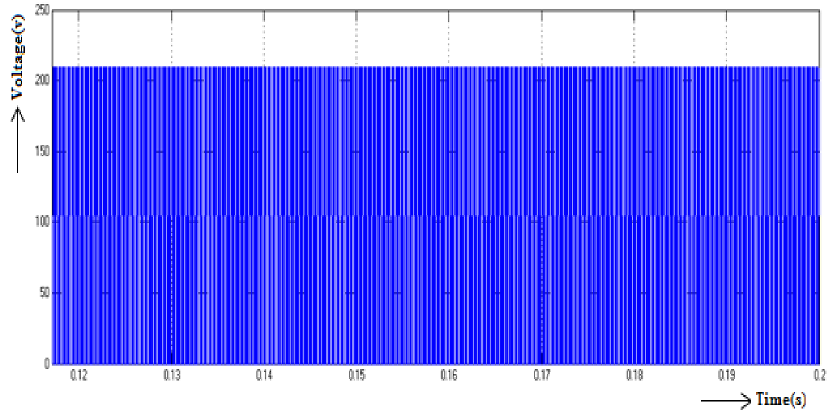

Fig.7 Z-source Inverter output voltage

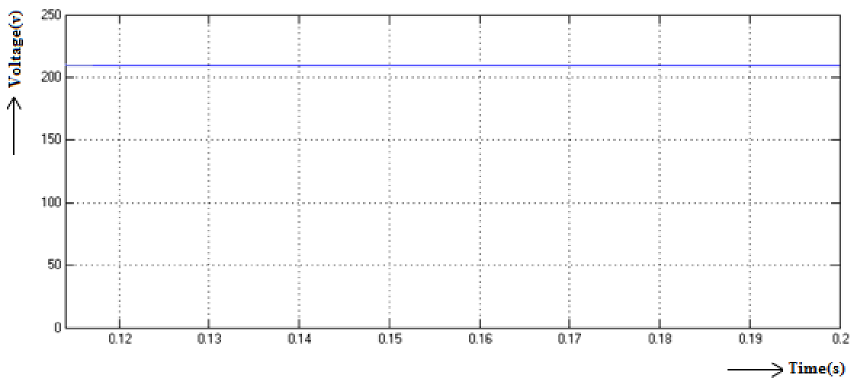

Fig.8 Z-source Capacitor Voltage

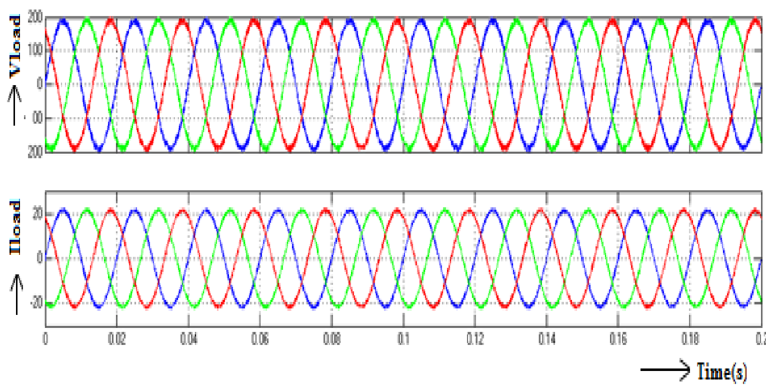

Fig.9 Simulation results for Load Voltage and Load Current waveforms

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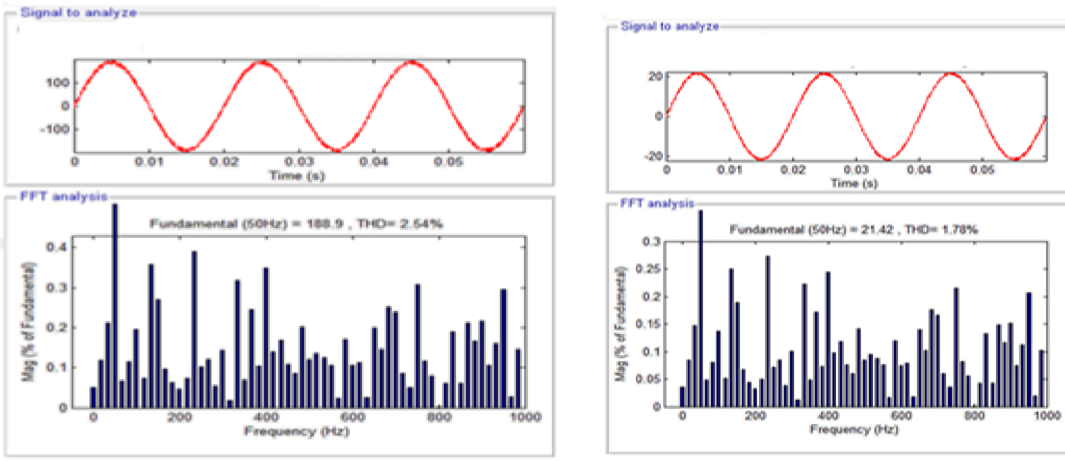

(a) (b)

Fig.10Results and FFT analysis of Two level Z-source inverter in simple boost pulse width modulation method (a) output voltage (b) output current

CASE-2. (V_c*<V_c)

In Case-2, The output voltage of PV array is 200V and the Z-source inverter output voltage is 350V and Z-source capacitor voltage is 257V are obtained in simulation. Here, Z-source capacitor voltage is controlled and reduces Total Harmonic Distortion.

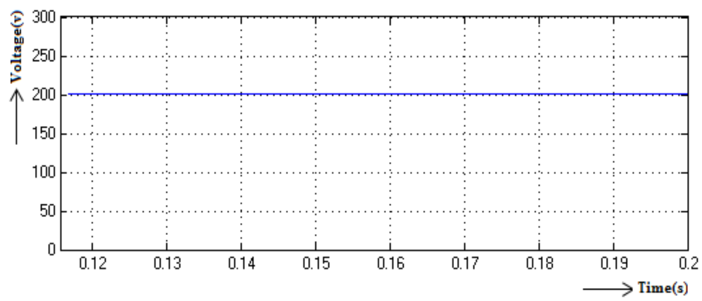

Fig.11 Output voltage of PV array

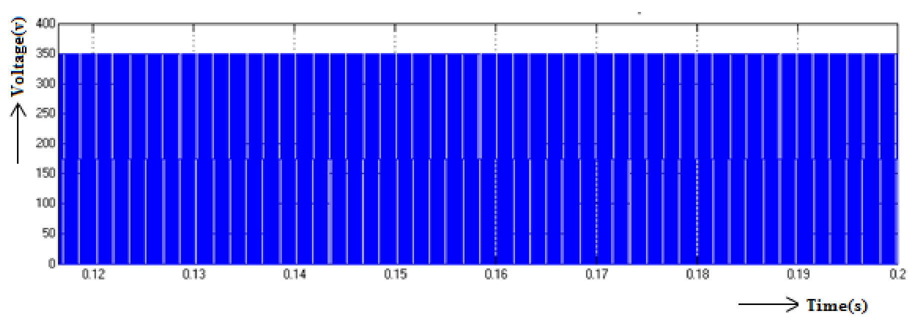

Fig.12 Z-source Inverter output voltage

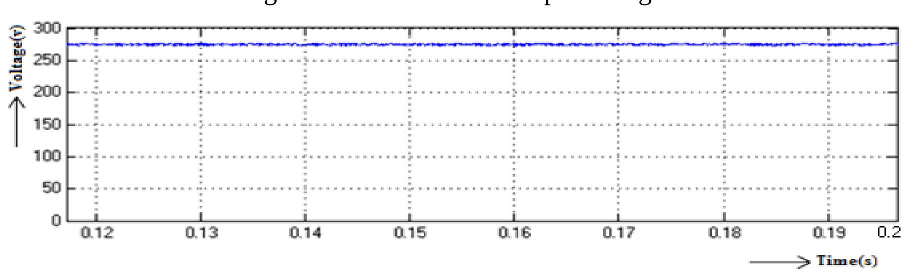

Fig.13 Z-source Capacitor Voltage

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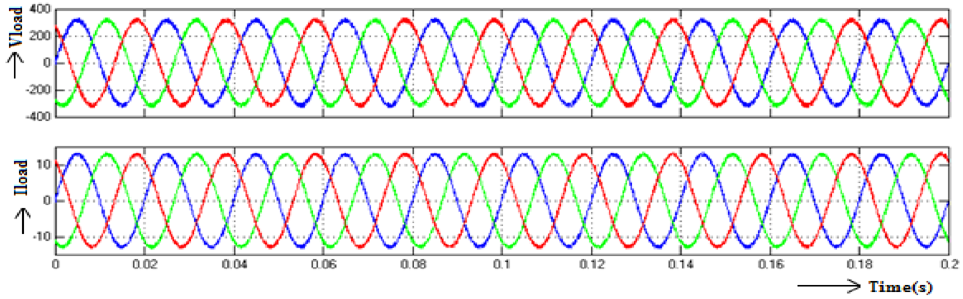

Fig.14Simulation results for Load Voltage and Load Current waveforms

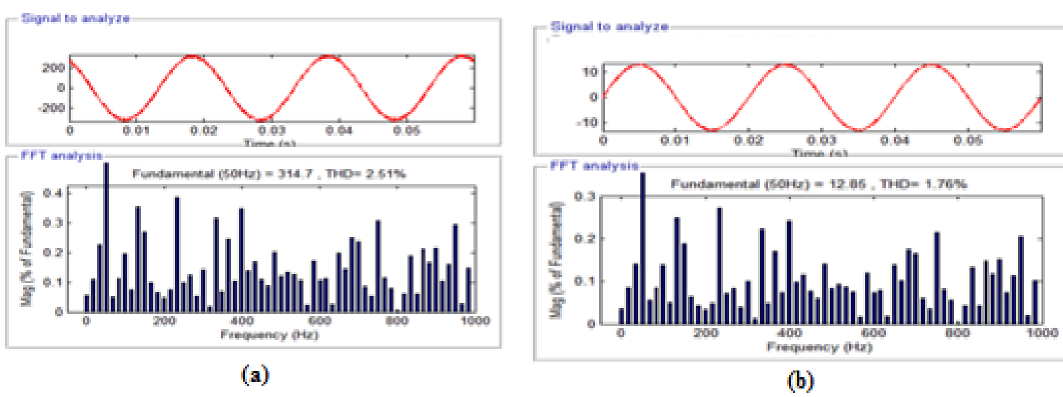

Fig.15 FFT analysis of Two level Z-source inverter in simple boost pulse width modulation method (a) output voltage (b) output current

CASE3. (V_c *>V_c)

In Case-3, The output voltage of PV array is 110V and the inverter output voltage is 420V and Z-source capacitor voltage is 327V are obtained in simulation. Here, Z-source capacitor voltage is controlled and reduces THD

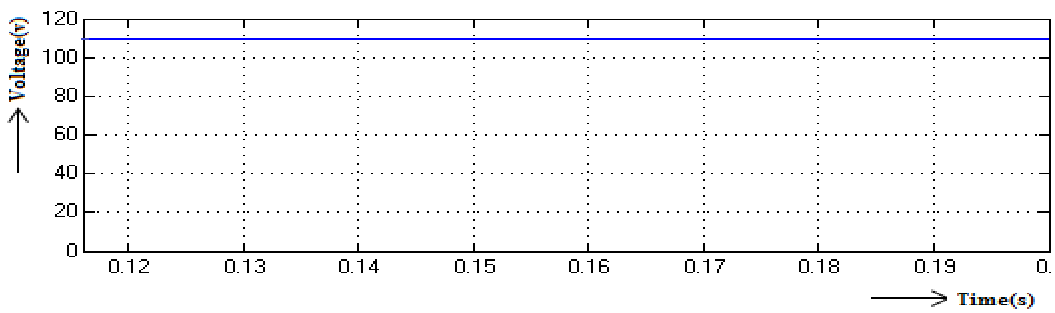

Fig.16 Output voltage of PV array

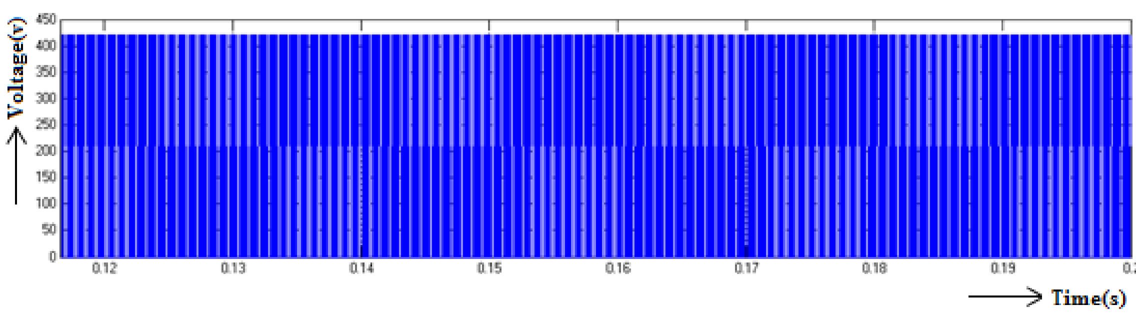

Fig. 17 Z-source Inverter output voltage

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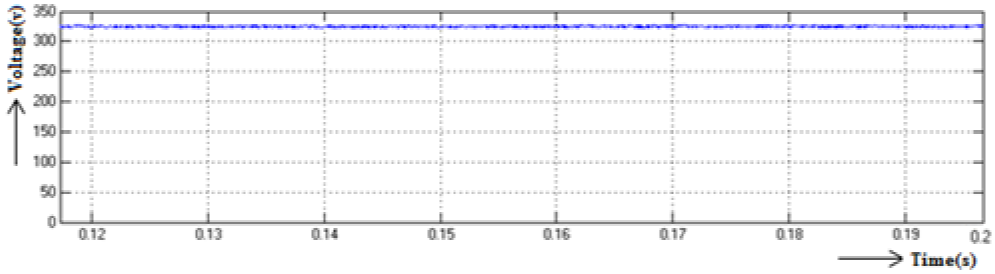


Fig.18 Z-source Capacitor Voltage

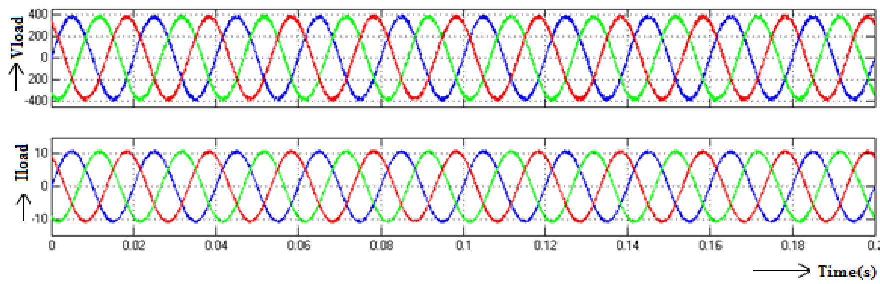
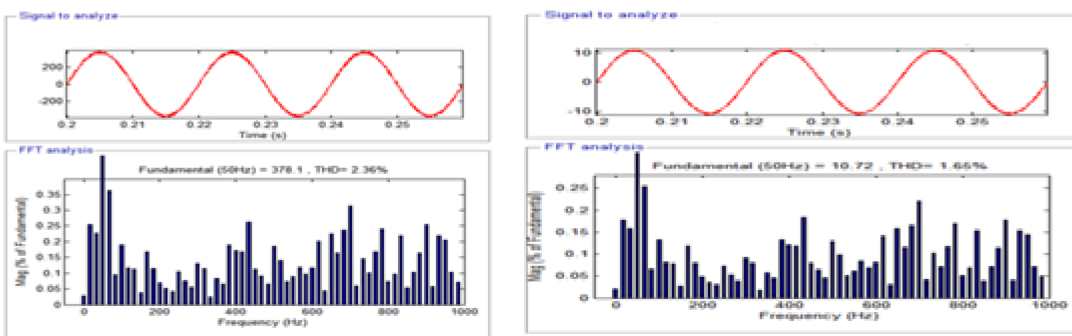


Fig.19 Simulation results for Load Voltage and Load Current waveforms



(a) (b)

Fig.20 FFT analysis of Two level Z-source inverter in simple boost pulse width modulation method (a) output voltage (b) output current.

V. COMPARISION OF SIMULATION RESULTS

Different Cases	THD of output voltage Without filter	THD of output voltage With filter	THD of inductor current
$V_{pv}^*=V_c^*$	63.33	2.54	1.78
$V_c^*<V_c$	63.13	2.51	1.76
$V_c^*>V_c$	63.8	2.36	1.65

VI.CONCLUSION

Unified MPPT control algorithm has been developed in this paper for the Z-source inverter supplied PV system. Three different cases are used to control Z-source capacitor voltage in inverter and it produces maximum desirable output voltages. Here, the single stage Photovoltaic power conversion system is reduces the system cost. The Proposed inverter is used to reduces the harmonics and improve the efficiency.

VII. ACKNOWLEDGMENT

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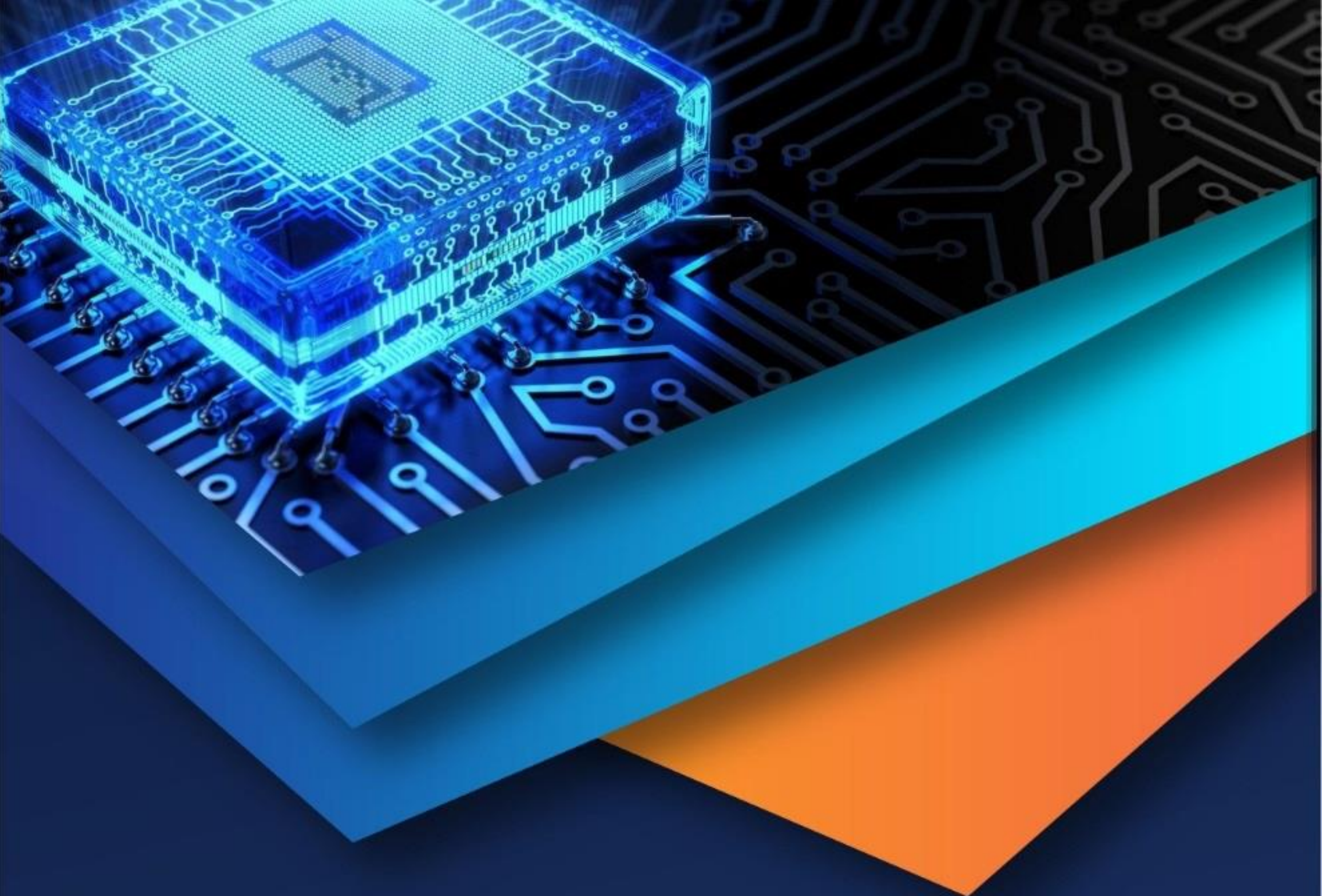

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