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Research Article

Photovoltaic System Based Trans Z Source inverter and Comparison of Various Carrier Disposition method for AC Load Applications

[1]R. Padmapriyadharishini, [1]N.KiruthikaIndumathi and [2]V.Ramakrishnan
[1]Department of EEE, St. Peter's University,
[2]Department of EEE, Madha Engineering College,Chennai, Tamil Nadu, India

Abstract: In this study presents the Trans Z source inverter with respect to the effective Photovoltaic (PV) power generation based system for different kind of AC loads Conditions. The most demand of solar array can be used for improve the operating life and high efficiency of power generation system. The Trans Z source consists of two voltage fed and current fed inverter for power conversion purpose. It gives the higher voltage gains while keeping voltage stress low and also reducing the Z-source network to one transformer and one capacitor. The single diode dynamic model of PV based proposed system can be used to extract the maximum power generation. In this study proposed the control strategy of various carrier dispositions used for R and RL Load condition. The comparison study of PD, APOD and POD PWM techniques have been carried out by Total Harmonic Distortion (THD). The proposed inverter has been used to produce the three level based output voltages by using controller unit. The proposed topology also can be applicable to induction motor for verifying the soft start capability. The simulation results have been analyzed and verified by MATLAB/SIMULINK software tool.

Keywords: AC load condition, Alternative Phase Opposition Disposition (APOD), induction motor, Photovoltaic Array (PV), PWM Pulse Generation, Phase Disposition (PD), Phase Opposition Disposition (POD), Total Harmonic Distortion (THD), Z source inverter

INTRODUCTION

Recently, the increase of energy demand can be motivated the research area of power converters. The various renewable energy resources such as wind, fuel cell, solar and tidal could be used with maximum efficiency by using the appropriate power converter. The Photovoltaic array based z source inverter produces the limited range of harmonic distortion on the output side. The performance of T Z source inverter can be analysis by using modified space vector pulse width modulation Techniques. The single stage of Z-source inverters with bulk inductors and capacitors are used in some topologies, but the harmonic content in the output is relatively high. Here, the new switching Strategy used to rectifying the above problem. The various PWM pulse generation of switching patterns depends upon the time independent and also produce the better results for single stage boost inverters. This method of control techniques can be applicable for both grid connected andstand alone applications (Mahendran*et al*., 2012; Jabavathi and Venkateswaran, 2014).

The development of Z Source technology has a set of connections of LC with revision and traditional pulse width modulated signal with modifications. The step up and down operation can be achieved by using the minimized count of components. It is major barrier in the traditional Voltage source and Current source inverter. The comparison of various Z source inverter study gives the details of operating condition. Here, the Γ-Z-source inverters have been proven to be the same as the trans-Z-source inverters to achieving the Operating gain and modulation ratio.

Hence, it gives higher than those of the traditional Z-source inverter. A new type of voltage fed Magnetically Coupled T-source Inverter can be produce a higher voltage gain in comparison with the traditional Z-Source Inverter (ZSI), Trans-Z-source inverter (trans-ZSI) and r-Source Inverters (rSI). Also, it gives the high boost capability by utilizing a three-winding coupled transformer and one capacitor formed in T -shape as an impedance network (Sreeprathab and Joseph, 2014; Loh*et al*., 2013; Tran and Low, 2014).

The multilevel based inverter can be used to generate the stepped AC signals for reducing the THD values. It has much number of switches and also generates staircase type output through controlled switching of various switches. The Sinusoidal Pulse

Corresponding Author: R. Padmapriyadharishini, Department of EEE, St. Peter's University, Chennai, Tamil Nadu, India

Width Modulation (SPWM) is used generating gate pulses for multilevel inverter. Because of this method has advantages like low switching losses, the output has fewer harmonic and method is easy to implement. The novel topology was developed with reduced number of switches and DC sources for multilevel inverter applications. In order to reduce the THD further Level shifting SPWM techniques such as PD, POD and APOD are used and also compared with above SPWM techniques (Vadhiraj*et al*., 2013; Thombre*et al*., 2014).

An improved Z Source inverter topology based system can be used to reduce the Z-source capacitor voltage stress significantly to perform the same voltage boost and also has inherent limitation to inrush current at startup. This soft-start strategy has to suppress the inrush surge and the resonance of Z-source capacitors and inductors. Also, the advantages of the Z-source capacitor voltage stress could be reduced greatly to perform the same boost ability. The low-voltage capacitors can be utilized to reduce the system cost and volume.

A new type of SPWM modulation method is introduced in the inverter and the appropriate strategy of soft-start is carried out to reduce the surge current in starting. The corresponding results are given by such as low voltage stress of component, low startup surge current, stable of the output voltage and the device works reliable for achieving the satisfactory effect. The two independent control variables such as the shoot-through duty ratio and the modulation index are used to control the Z source based PV system in order to provide the required voltage and power. The new networks demonstrate some unique advantages such as the increased voltage gain and reduced voltage stress in the voltage-fed trans-ZSI (Ali, 2013; Tang *et al*., 2009; Zhenyu, 2012; Vidhyarubini and Rohini, 2011; Mehdipour*et al*., 2012).

The advantages of PV system based Trans Z source inverter consider such as increased voltage gain, reduced voltage stress and reduced components of impedance network. By using proper control method for improving the performance of standalone mode and grid connected mode applications. An improved Trans Z source inverter has a transformer to obtain the high voltage. This topology gives the shoot through state and turns ratio can be regulated by using the control of voltage gain compared with conventional Z source inverter (Bajestan*et al*., 2013; Divya and Prabhu, 2014). The T Z source inverter uses a lower transformer turn ratio, reduces the transformer's size and weight when producing the same output voltage gain.

The current fed trans-Z-source-inverter can be used to protract the motoring operation range to more than that can be achieved in the original Z-source/quasi Z-source inverters. A new current-type magnetically coupled T-source inverter can be used to produce a high current gain by utilizing a three-winding coupled transformer and a capacitor organized in T-shape as an impedance network (Nguyen *et al*., 2013; Qian*et al*., 2011; Tran *et al*., 2014).

In this Study proposes the photovoltaic system based Trans Z source inverter for various AC Load applications. The dynamic modeling of single diode PV system has been designed for power generation purposes. The T shaped Z source inverter can be applicable for step up and step down of voltage gain configuration. The various type of carrier disposition PWM pulse generation method has been analyzed for R and RL Load condition. The simulation results are verified by using Total Harmonic Distortion (THD). The soft start capability of induction motor has been analysis with control techniques of Phase Disposition (PD) PWM pulse generation.

MATERIALS AND METHODS

Single diode PV modeling: The Photovoltaic array can be used mainly for grid-connected electricity to operate such as residential appliances, commercial equipment, lighting and air conditioning for all types of buildings. The stand-alone systems and use of batteries can be well suited for remote regions when need not requirement of electricity source. The Solar PV panelscan be ground mounted, installed on constructing rooftops and also designed into building materials at the point of manufacturing.

It may be use a solar tracking system to improve the system's overall performance and also include an integrated battery solution as prices for storage devices are expected to refuse. The most common model of single diode PV model can be used to predict the energy production in cell modeling (Jung and Ahmed, 2010; Walker, 2001) shown in Fig. 1a and the practical model of PV array represent the series and parallel resistance respectively shown in Fig. 1b.

The idealistic photovoltaic cell consists of a single diode connected in parallel with a light generated current source (I_{SC}) as shown in above Fig. 1. The equation of the PV output current is expressed by:

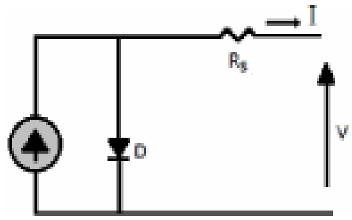
$$I = I_{SourceCurrent} - I_{Diode} \quad (1)$$

$$I_{Diode} = I_{SourceCurrentref}\left[\exp\left(\frac{qV_{oc}}{kAT}\right) - 1\right] \quad (2)$$

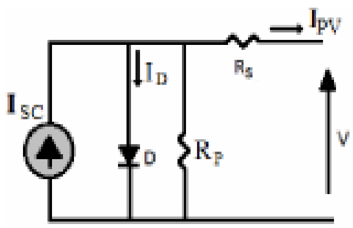
The equation that describes the I-V characteristic of the circuit in Fig. 1b is expressed by:

$$I_{SourceCurrent} - I_{Diode} - \frac{V_D}{R_P} - I_{PV} = 0 \quad (3)$$

$$I_{PV} = I_{SourceCurrent} - I_{Diode} - \frac{V_D}{R_P} \quad (4)$$



(a)



(b)

Fig. 1: Photovoltaic cell model using single diode

$$I_{SourceCurrent} = \left[I_{SourceCurrentref} + K_i\left(T_k - T_{ref}\right)\right] * \frac{\sigma}{1000} \quad (5)$$

where,

V_{oc} : The open circuit voltage

K_i : The short-circuit current/temperature coefficient

T_k, T_{ref} : Denoted as the actual and reference temperature in K

σ : The irradiation on the device surface

The simulink model of PV cell is shown in Fig. 2. Also, I_{Diode} depends mainly on the operating temperature, a series resistance (R_S) and a shunt resistance (R_O) used to take account of the resistive losses. The reverse saturation current and output current of PV module are given in below equations by:

$$I_{RS} = I_{SourceCurrentref}\left[\exp\left(\frac{qV_{oc}}{N_s kAT}\right) - 1\right] \quad (6)$$

$$I_{PV} = N_P I_{SourceCurrent} - N_S I_{Diode} \left\{\exp\left(\frac{q(V_{PV} + I_{PV} R_S)}{N_S kAT}\right) - 1\right\} - V_{PV} + \left(\frac{I_{PV} R_S}{R_p}\right) \quad (7)$$

The simplified dynamic circuit model of PV array makes to the suitable for power electronics designers and effective model for the simulation of photovoltaic devices with power converters. The rating of these PV model parameters at real condition of irradiance and temperature of the target PV modules has determined by according to their initial values. It is rendered the PV output current varies gradually with insulation conditions and the optimum operating point such that PV system delivers its maximum possible power to the load.

The optimum operating points changes with respect to the solar insulation, temperature and load conditions. The advantages of PV system such as peak power point changes continuously due to environmentalvariations, sometime significant drop in power especially during partial shading conditions.

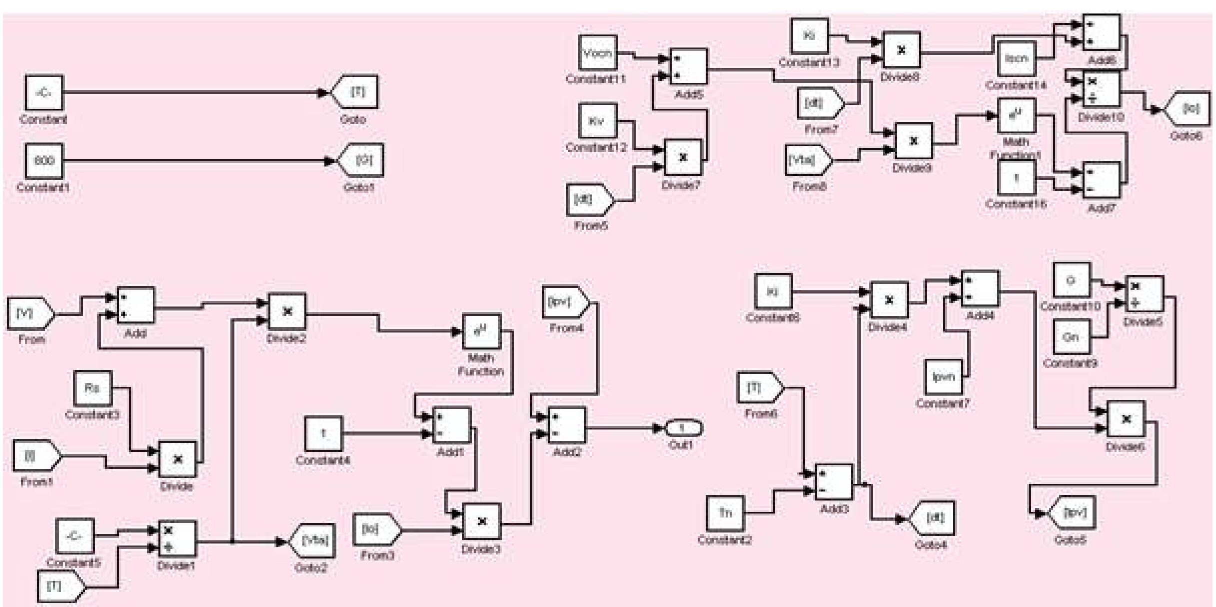


Fig. 2: Simulink model of PV cell

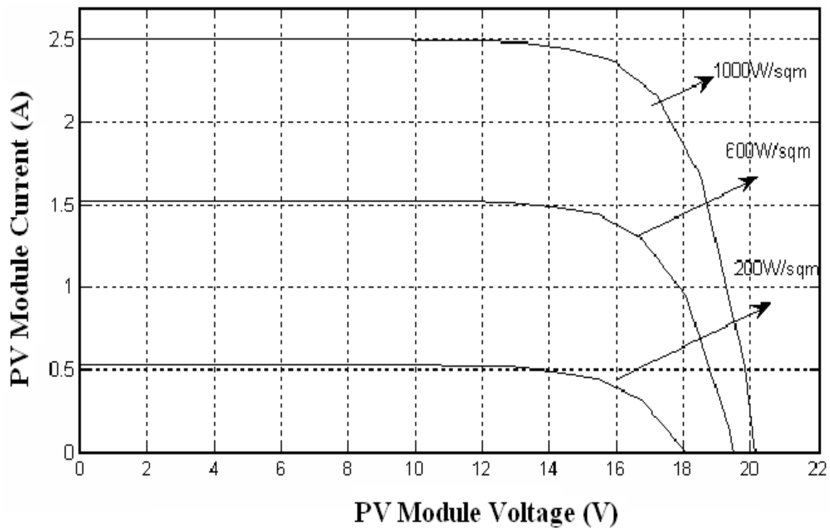


Fig. 3: I-V characteristic curve with varying irradiation

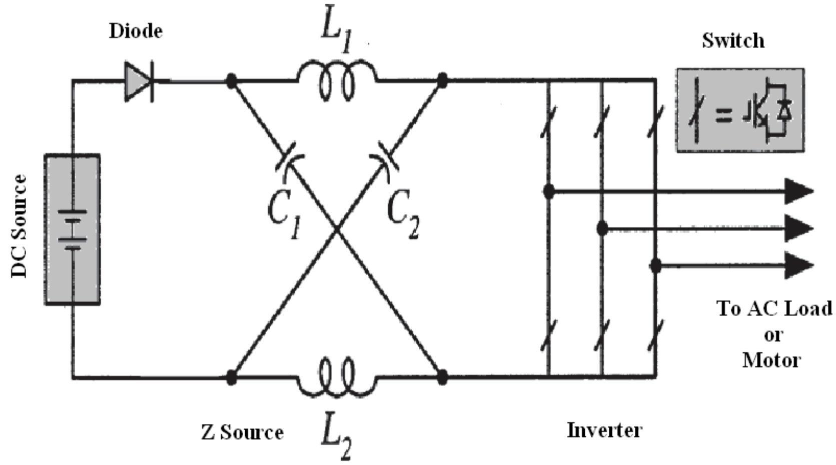


Fig. 4: Basic configuration of Z source inverter

The output I-V characteristic of various irradiation curves is shown above in Fig. 3. The operating temperature of this model increases for the current output increases marginally but the voltage output decreases gradually. The result is gives the net reduction in power output with a rise in temperature.

Trans Z source inverter topology: The impedance source inverter is also called as Z source inverter with a new inverter technology. It can be used boost the dc input voltage without requirement of step up transformer and boost converter. The basic structure of Z Source inverter has an X shape impedance network inserted between the DC source and the inverter can be shaped by using the two inductors and capacitors. In order to achieve the boost or buck of input voltage, various types of Z source inverter have been used for get the required level of output voltage. There are many topologies in Z source inverter has the capacity to deal with even two input DC sources. The basic configuration of Z source inverter is shown below in Fig. 4.

Generally, the Bidirectional operation is done in voltage fed Z source or quasi-Z-source inverters. Here, if the diode gets replaced by bidirectional conducting and uni-directional blocking switch. The improved Trans Z Source inverter has continuous flow of input current and boost inversion capability. Also, it has facilitates of resonant current suppression and high boost factor with the inclusion of capacitor and one inductor in Trans Z source inverter. It has been produce the Lower current stress in transformer windings and also the DC link diode has reduced voltage stress with higher modulation index. An Improved Trans Z Source inverter topology is shown below in Fig. 5.

The Capacitor across the voltage of an improved Trans Z Source Inverter can be obtained by using volt-second balance principle given by:

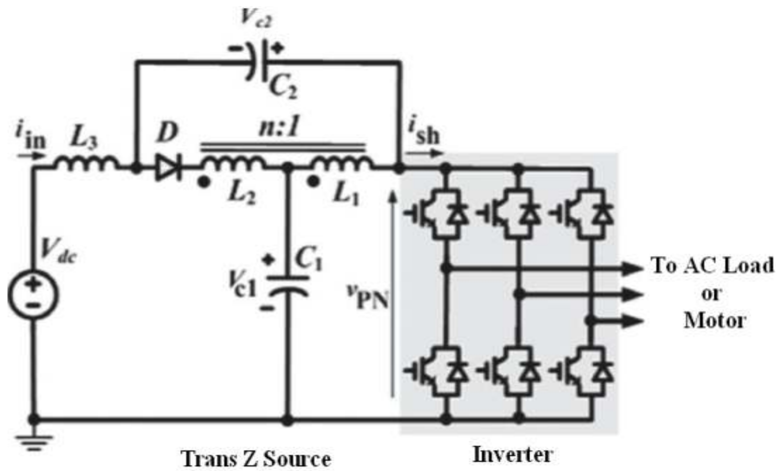


Fig. 5: Trans Z source inverter topology

$$V_{C1} = \frac{1-D}{1-2+nD}.V_{dc} \tag{8}$$

$$V_{C2} = \frac{1+nD}{1-2+nD}.V_{dc} \tag{9}$$

$$V_{PN} = \left(\frac{1}{1-2+nD}\right).V_{dc} = BV_{dc} \tag{10}$$

where, V_{PN} represent the peak dc-link voltage across the inverter main circuit for identifying the purpose of operating states. The boost ability of improved Trans *Z* source inverter range$n\geq1$ is higher and also can be increased by increasing the turn's ratio of transformer. Moreover, the voltage stress on the diode and current stress on the main power circuit during the shoot through state of this inverter is higher. So, it has stronger power capability at the highest modulation index. The performance of an improved Trans *Z* Source inverter source inverter has been analyzed with conventional type of *Z* Source inverter. It has higher boost output voltage, reduced voltage stress on dc link, lower input current ripple and lower current stress flow to the transformer windings.

Various PWM pulse generation's methodology: The performance of Trans Z source inverter depends on the control strategy of various PWM pulse generation topology. Generally, the two type of PWM techniques used for this control purpose such as Carrier based Modulation (CB-PWM) and Space Vector based Modulation (SV-PWM). The multi carrier based PWM methods used for n-1 triangular carrier signals and only one modulating sinusoidal signal as reference.

The reference zero signal is placed in the middle of the carrier set. At the every instant time of each carrier signal is compared with the modulating sinusoidal signal. The most of common multilevel inverter has been verified by using multicarrier phase shifted method. There are two type of PWM pulse generation consider as phase shifted PWM method and Carrier disposition method.

The output voltage of Multi-level inverter is the sum of all of the individual inverter outputs. Here, each of the H-bridges active devices switches used only at the fundamental frequency and also the each of H-bridge unit generate a quasi-square waveform by phase shifting techniques. The carrier disposition method represent the reference signal is sampled through a number of carrier signals displaced by continuous increments of the reference signal amplitude. Most of the carrier based PWM techniques have been deduced from the classical carrier disposition strategies. The phases of carrier signals are rearranged to produce three main disposition techniques known as PD, POD and APOD.

Phase disposition techniques (PD): In this phase disposition method of all the carriers have the same frequency and amplitude. However, the entire N-1 carriers signals are in phase with each other. But differ only in DC offset. So, it has an equal number of carrier signals above and below the zero reference and also in phase with the same amplitude and frequency. The PD method of Pulse generation is shown in Fig. 6.

Generally, this method gives rise to the lowest harmonic distortion in higher modulation indicators while compared to other disposition methods. It can be applicable for cascaded type of inverters.

Alternative Phase Opposition Disposition Techniques (APOD): This method consists of all carrier waveforms are phase-displaced by 180° alternatively. Here, all the carriers have the same amplitude, frequency and different DC offset. The APOD method of Pulse generation is shown in Fig. 7.

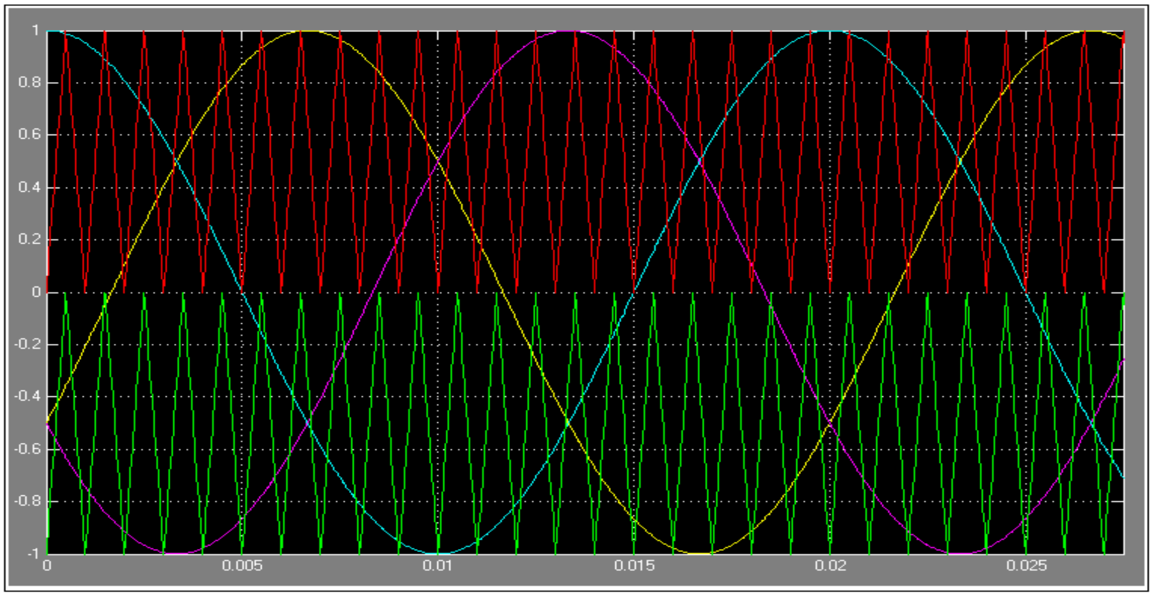


Fig. 6: PD PWM pulse generation

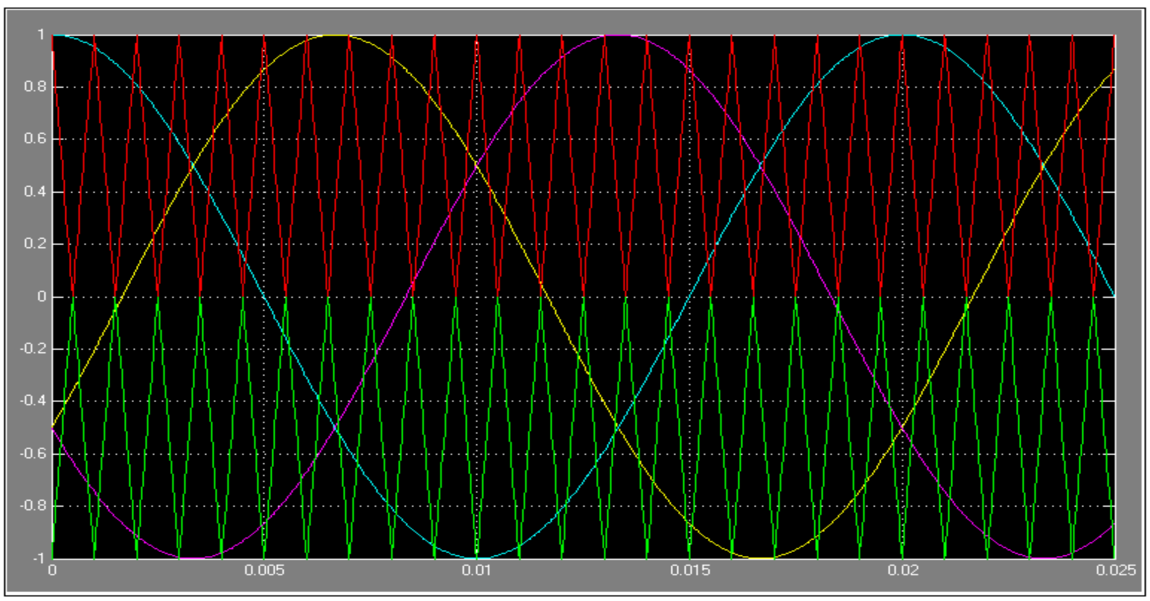


Fig. 7: APOD PWM pulse generation

The Larger amount of third order harmonics is not important issues for cancellation of line voltages. Thus, this method gives the better results of Total Harmonic Distortion (THD) for line voltages while comparing to the POD method. So, it should be noted that the POD and APOD methods are exactly same of three-level inverter.

Phase Opposition Disposition Techniques (POD): The POD method has the carriers above zero line of reference voltage and out of phase by 180 degree. Here, all carrier signals above the zero reference are in the same phase but the carrier signals below the zero reference are phase shifted by 180 degrees. The POD method of Pulse generation is shown in Fig. 8.

It has no harmonics at the carrier frequency, multiples and distribution of harmonic occurs around configuration. Because of the Frequency and amplitude of carrier waves are same but it can be differing in DC offset.

RESULTS AND DISCUSSION

The proposed system considered of simulation is a Photovoltaic cell based Trans Z source inverter for various AC load conditions. The dynamic model of

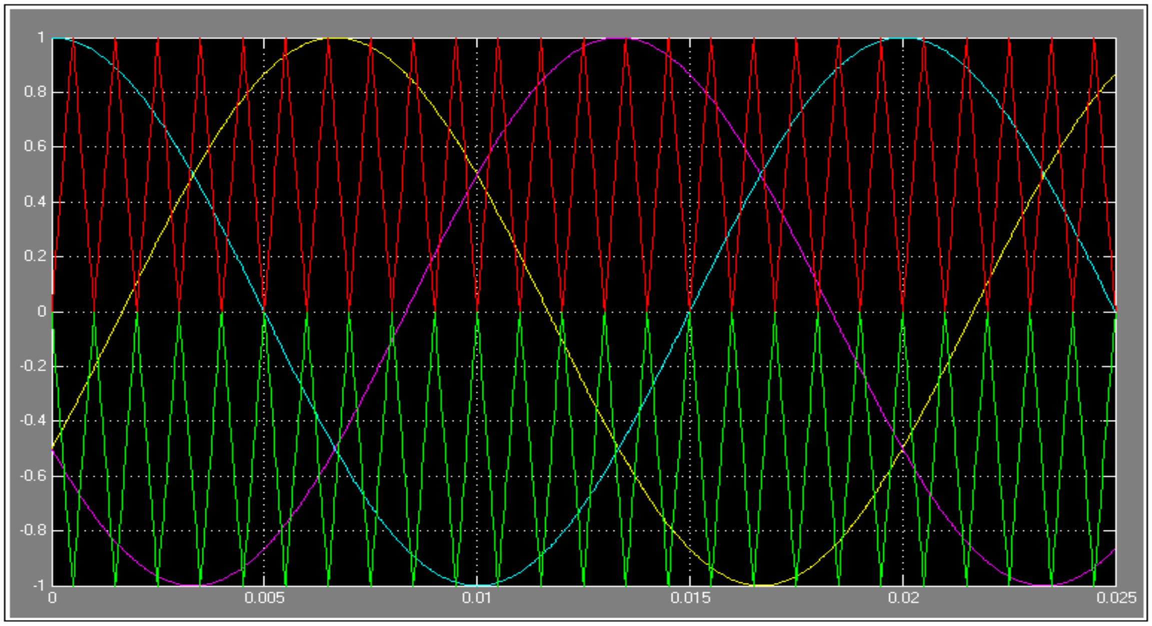


Fig. 8: POD PWM pulse generation

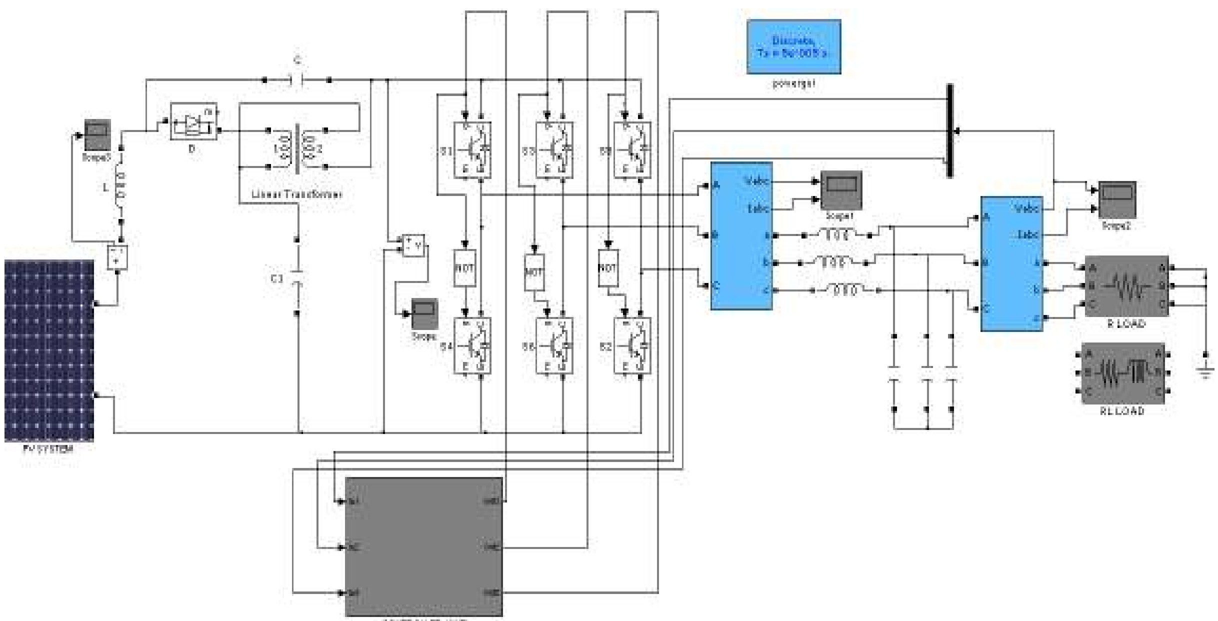


Fig. 9: Simulink model of proposed topology

solar photovoltaic array has been designed for power generating purposes. The three level based inverter output voltages can be obtained by using various carrier disposition PWM methods. The comparison of simulation results have been verified with reduction of Total Harmonic Distortion (THD) for PD, APOD and POD methods. The proposed topology have been analyzed with R and RL load Condition. Also, the soft start capabilities of induction motor and overall corresponding results have been verified by using simulated inMATLAB/SIMULINK environment. The simulink proposed scheme of model with R and RL Load condition is shown in Fig. 9.

The Solar PV cell presents the relationship between module parameters and circuit performance. This involves the step-by-step method for the PV modeling. The corresponding simulation results waveform of the proposed topology are given in Fig. 11 to 14. To extract maximum power from PV in two conditions is considered varying solar radiation in constant temperature and varying temperature in constant radiation. The simulation result of photovoltaic voltage and current of the system is shown in Fig. 10.

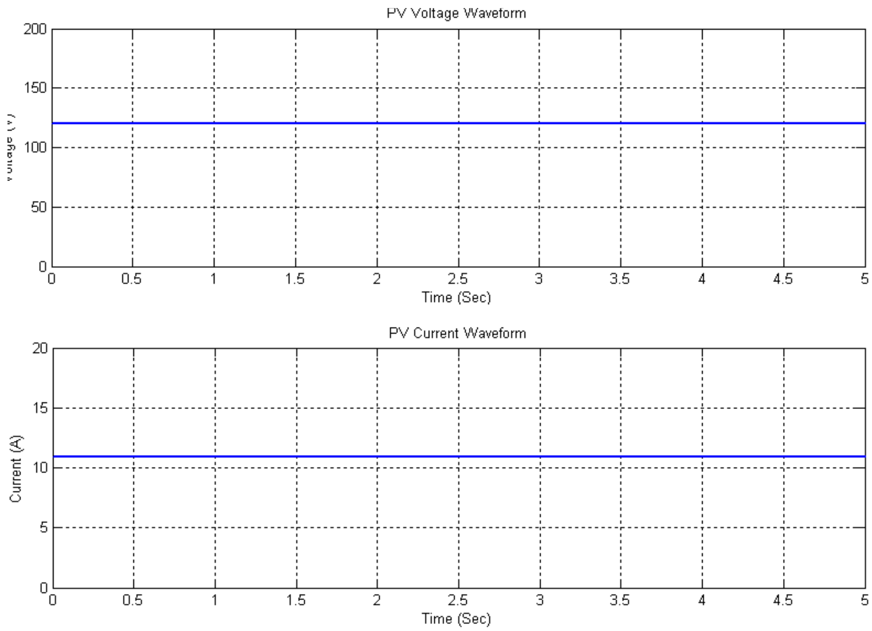
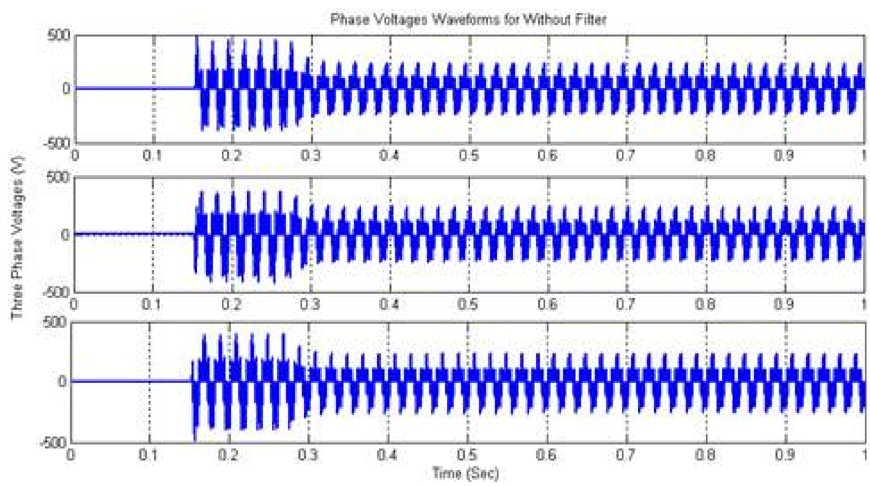
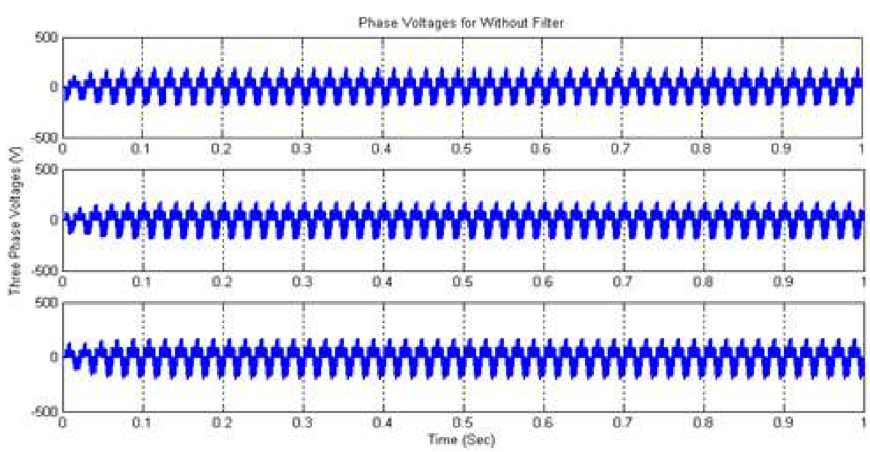


Fig. 10: Photovoltaic cell voltage and current waveform



(a)



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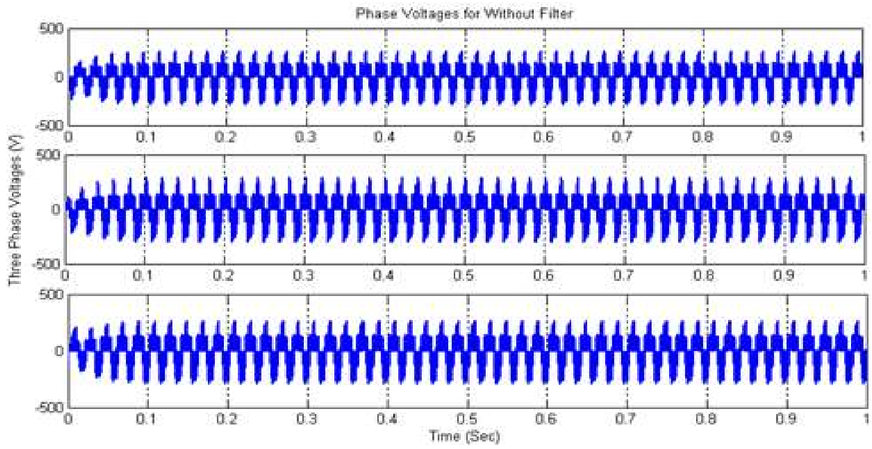
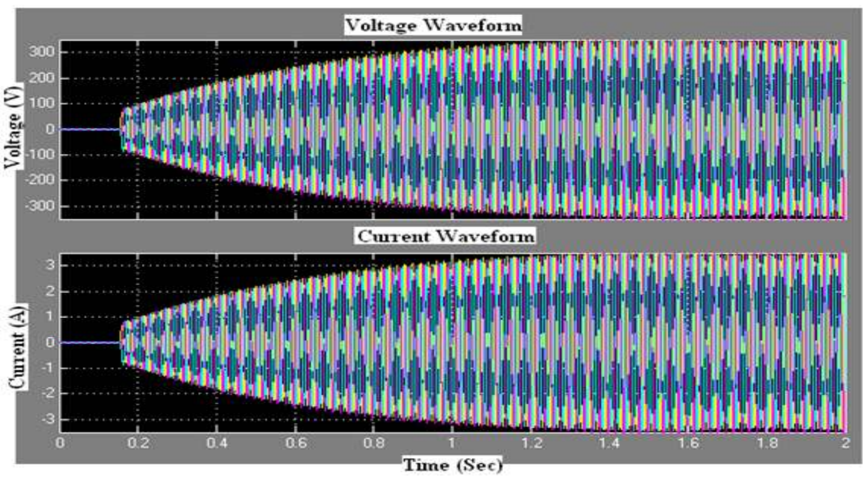
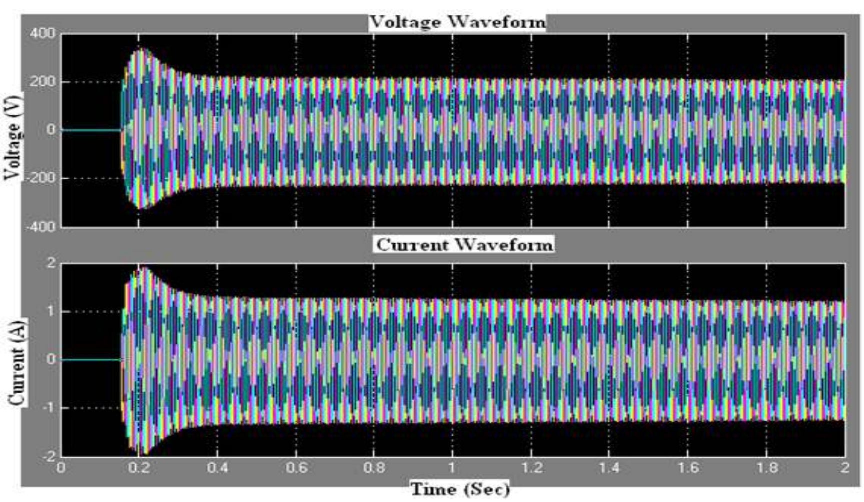


(c)

Fig. 11: Output phase voltage waveforms without filter for PD, APOD and POD method

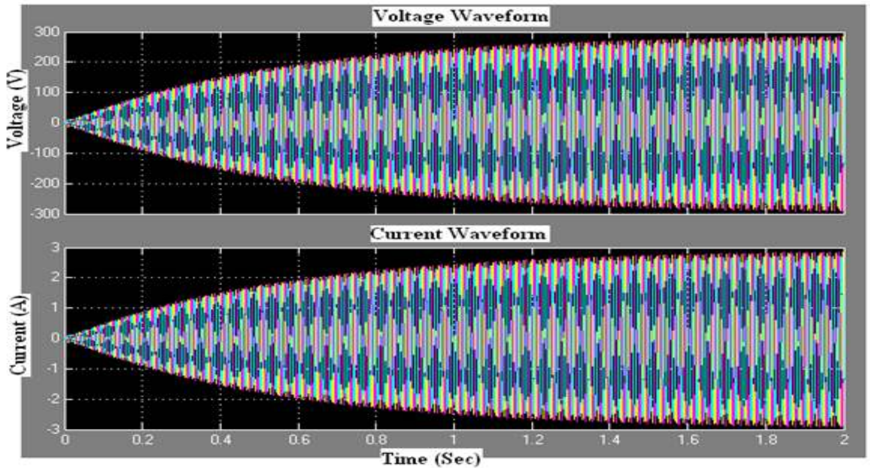


(a)

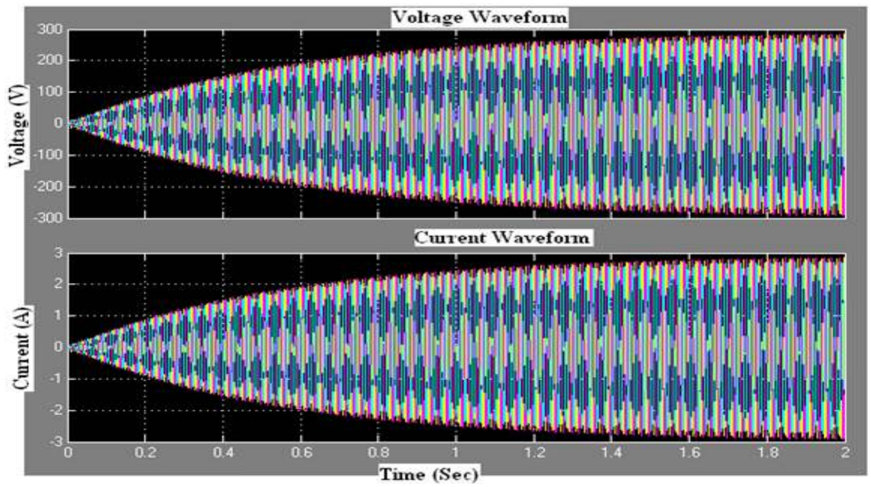


(b)

Fig. 12: Output voltage and current waveforms with filter for PD method; (a): R load condition; (b): RL load condition

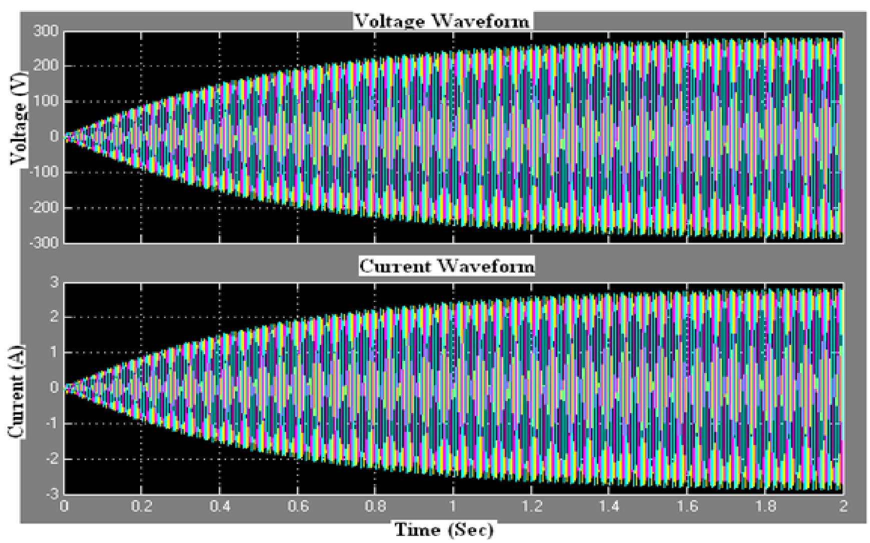


(a)

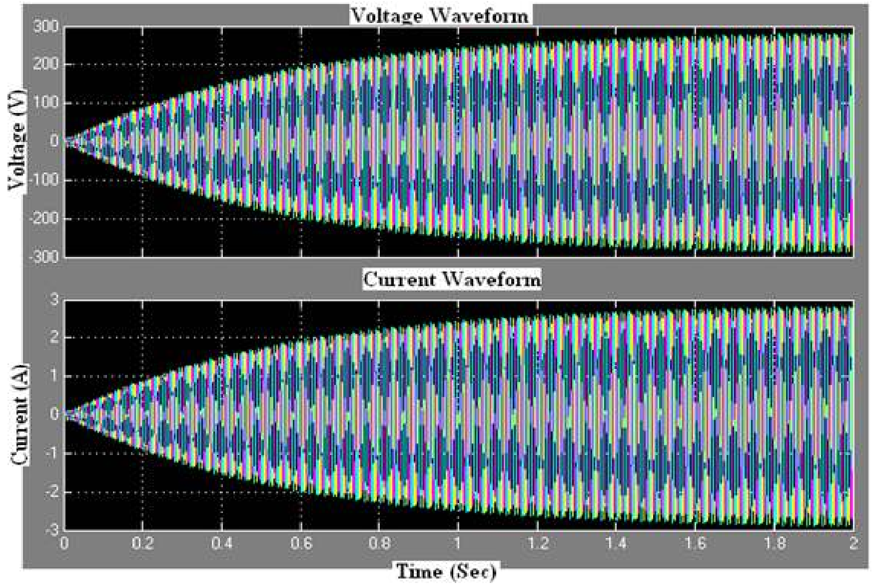


(b)

Fig. 13: Output voltage and current waveforms with filter for APOD method; (a): R load condition; (b): RL load condition



(a)



(b)

Fig. 14: Output voltage and current waveforms with filter for POD method; (a): R load condition; (b): RL load condition

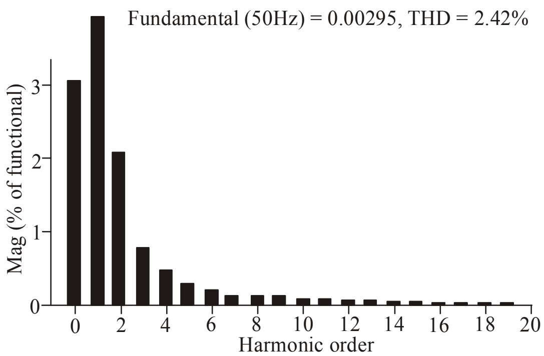


Fig. 15: THD waveform for PD method

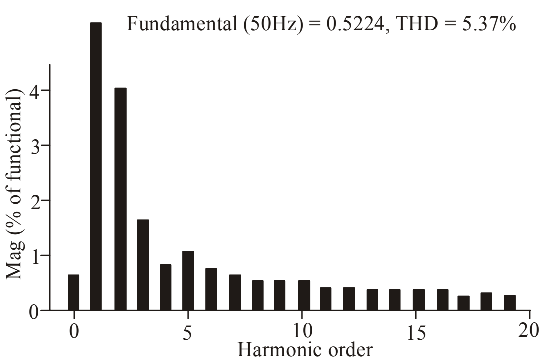


Fig. 16: THD waveform for APOD method

The comparison of simulation results can be shown in figure by using the Wave form for Total Harmonic Distortion (THD). The FFT analysis can be used for calculating the total harmonic distortion and provided in Simulink model in the form of powergui. The comparison resultsand PD method of THD analysis is most better than other type of APOD and POD method. It gives the better reduction of harmonics, voltage stress and current ripple. These corresponding waveforms are shown in Fig. 15 to 17.

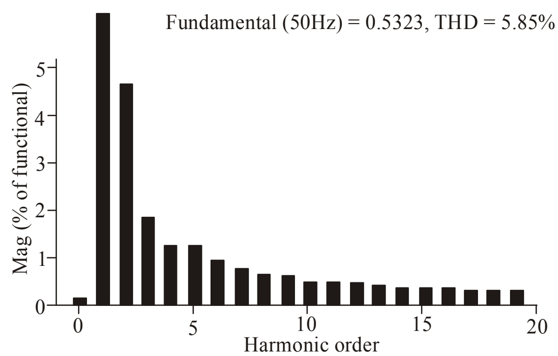


Fig. 17: THD waveform for POD method

The above given THD analysis is better to give a comparison among the various carrier disposition based PWM pulse generation namely such as Phase Disposition (PD), Alternative Phase Opposition Disposition (APOD) and Phase Opposition Disposition (POD) for the same operating R and RL Load conditions. Here, the better result can be obtained from by using PD method of pulse generation. So this method of control strategy could be used for soft start capability of induction motor. The performance of induction motorhas been verified with PD method of simulink diagram and corresponding simulation results are shown in Fig. 18 and 19 (Table 1).

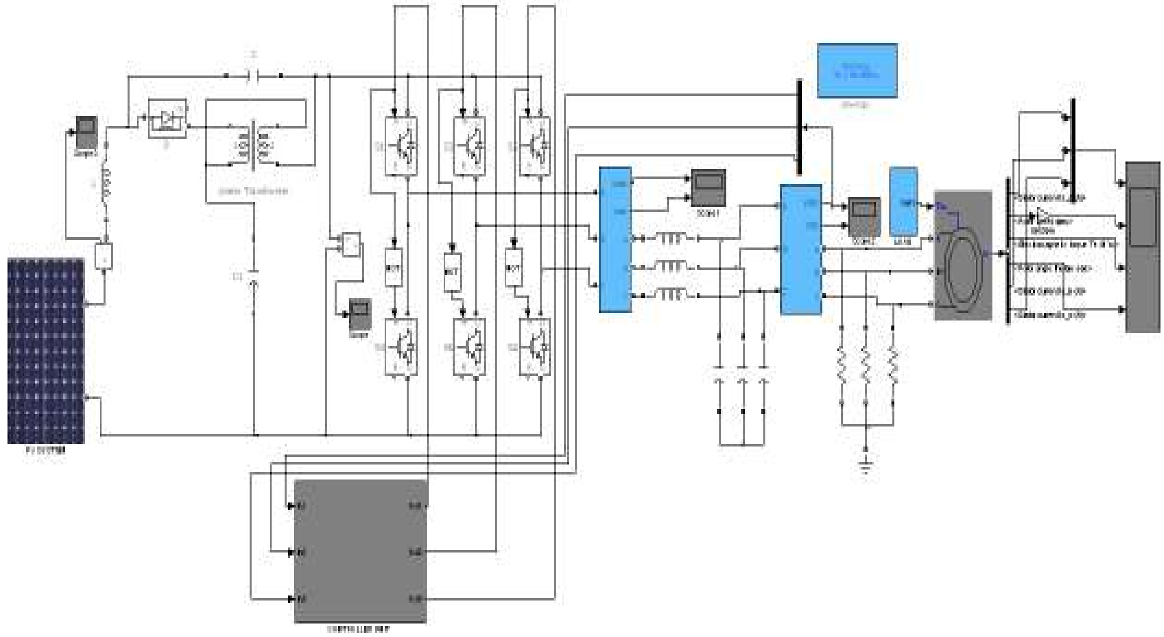


Fig. 18: Simulink model for soft start capability of induction motor

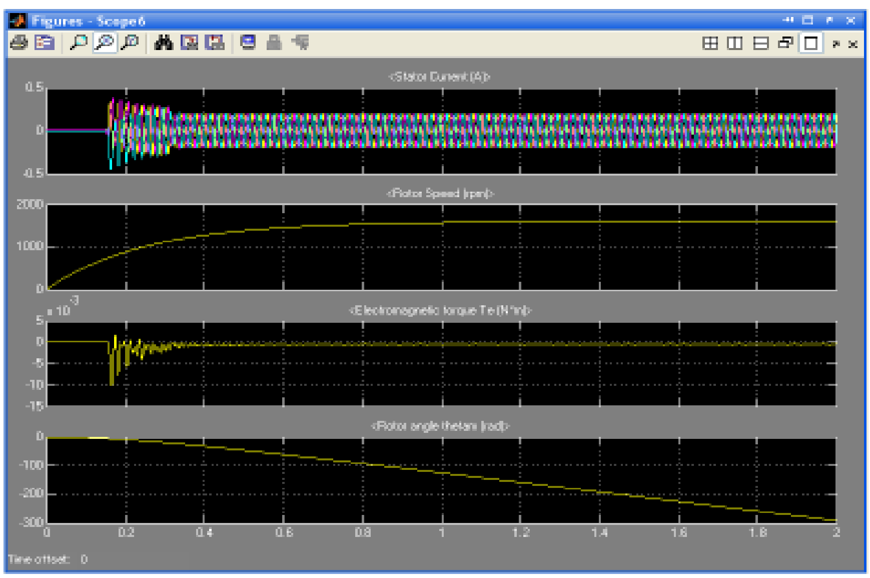


Fig. 19: Simulation results of induction motor performance

Table 1: Specification of simulation parameter

Parameters	Values
PV Voltage (V)	120V
PV Current (A)	10A
Switching frequency(f_{sw})	1kHZ
DC voltage (V_{dc})	250V
Filter of L (L_f)	$20e^{-3}H$
Filter of (C_f)	$50e^{-5}F$

CONCLUSION

In this study proposes the photovoltaic array based an improved Trans Z source inverter for AC loadapplications. This proposed inverter has a higher voltage gain compared to traditional Z-source/quasi Z-source inverters suitable for PV generation. The advantages of improved Trans Z Source inverter following such as high boost voltage, continuous input current and possible of buck boost operation by varying the shoot through interval and also by varying the transformer turns ratio. The current-fed Trans-Z source-inverter can be extending the motoring operation range to more than that achieved in the original Z-source and quasi Z-source inverters.

The control strategy of proposed system has been verified with R and RL load condition. The various carrier disposition based PWM method namely such as

PD, APOD and POD can be applicable for AC Load condition. The comparison of simulation results are carried out by using the FFT based tool. Here, it is found the PDPWM techniques give least Total Harmonic Distortion (THD) to compare with other two techniques. The proper soft start strategy could be used for reducing the inrush current and resonance of Z source inverter. The soft start capability of induction motor has been analyzed and verified with best control of PD PWM method using MATLAB/SIMULINK software.

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