Modelling and Simulation of New PV-Battery Based Hybrid Energy System for Z source Inverter using SVPWM fed Industrial Applications

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Abstract- Three level inverters with single quasi z-source neutral point clamped inverter using the space vector modulation technique is proposed in this paper. The proposed inverter has the main features in that the output voltage can be bucked or boosted and in-phase with the input voltage. The quasi z-source concept can be applied to all DC-AC, ACDC and DC-DC power conversion whether two-level or multi-level. Previous publications have shown the control of a Z-source neutral point clamped inverter using the space vector modulation technique. Three level inverters with single quasi Z-source are proposed in this concept. Space Vector Modulation (SVM) Technique has become the most popular and important PWM techniques for three phase Voltage Source Inverters. Z-Source Inverters have the ability to boost the dc link voltage, thus increasing the output ac voltage beyond the values reached by conventional inverters. The Conventional sources of energy are rapidly depleting. Moreover the cost of energy is rising and therefore photovoltaic system is a promising alternative. They are abundant, pollution free, distributed throughout the earth and recyclable. The hindrance factor is its high installation cost and low conversion efficiency. Therefore our aim is to increase the efficiency and power output of the system. It is also required that constant voltage is supplied to the load irrespective of the variation in solar irradiance and temperature.the proposed concept is implemented to new PV-Battery based hybrid energy system for Z-Source Inverter for industrial Applications by using Mat lab/Simulink software.

Index Terms— Impedance source inverter, modified Z-source inverter, space vector pwm

I. INTRODUCTION

Speed and motion control is required in large number of industrial and domestic applications. Ex: Robot, fans, washing m/c, mills etc. Markets for adjustable-speed drives continue to expand steadily in response to the well-recognized opportunities for major efficiency and cost improvements made possible by upgrading fixed-speed industrial process equipment to adjustable speed. Earlier DC motors have been used in industries for variable speed control applications. In 20th century induction motors had been the most popular electrical motors in domestic and industrial application due its simple construction, less maintenance, commutator less or slip rings, low cost and reliability. The drawback of induction motor are small air gap, less power density , the possibility of cracking the rotor bars due to hot spot at plugging and reversal , and lower efficiency and low power factor than synchronous machine.

Due to this permanent magnet brushless motor has become more attractive option than induction motors. Other reasons are dropping cost of rare earth magnets and development in power electronics. The advancement in power electronics technology has made it possible to vary the frequency of the voltage. Thus, it made more extensive use in variable speed drive applications and the control of PM motor has become easier and cost effective, with the possibility of operating the motor over a wide range of speeds and still retains a good efficiency. In normal PM motor drive, the motor is usually fed with pulse width-modulated (PWM) voltages which cause sharp voltage wave fronts (dv/dt) which appear across the motor terminals. This may cause the breakdown of motor insulation. In addition, motor damages are reported due to the high-voltage change rates (dv/dt) which produces common-mode voltages across the motor windings [4]. High- frequency switching increases the severity of this problem due to the increased number of times this common-mode voltage is applied in each cycle [I]-[4].

This is a matter of big concern for variable-speed medium-voltage drives where the voltage levels are very high. The above problem can be resolute by applying changeable voltage with low dv/dt, i.e., by using of multilevel inverter topology. Moreover, the multilevel inverters can effectively work at lower switching frequencies as compared to conventional PWM inverters [5], [6]. A multilevel converter can operate at both fundamental switching frequency and high switching frequency PWM. It means that lower switching frequency usually means lower switching loss and higher efficiency. Multilevel inverters include an array of power semiconductors and capacitor voltage sources, the output of which generate voltages with stepped waveforms. A two-level inverter generates an output voltage with two values (levels) with respect to the negative terminal of the capacitor, while the three level inverter generates three voltages, and so on. The term multilevel starts with the three-level inverter introduced by Nabae. By increasing the number of levels in the inverter, the output voltages have more steps generating a staircase waveform, which has a reduced harmonic distortion [7], [8].

However, a high number of levels increases the control complexity and introduces voltage imbalance problems. [n multilevel inverter three different topologies have been proposed they are diode clamped or neutral point clamped, flying capacitors clamped and cascaded multi inverter. Cascaded multi cell inverter is the best because it uses less number of components considering there are no extra clamping diodes or voltage balancing capacitors, switching redundancy for inner voltage levels is possible because the phase voltage output is the sum of each bridge's output and possible of electrical shock is reduced due to the separate dc sources. The series structure allows a scalable, modularized sized circuit layout and packaging since each bridge has the same structure. In high power applications efficiency can also be increased by reducing harmonic content of the output waveform. This can be achieved by using propped switching technique. [n this paper Sinusoidal and third harmonic injected carrier based PWM technique i.e. phase shifted carrier PWM (PSCPWM) and level shifted carrier PWM (LSCPWM) are implemented. Better modulating technique is applied to drive the five level cascade H bridge fed Permanent Magnet Synchronous Motor drive

II. FIVE LEVEL CASCADED H-BRIDGE CONVERTER

Figure 1 Shows the five level cascade H bridge multilevel inverter. The advantage of this type structure makes easier maintenance and provides a very convenient way to add laying-off into the system. The cascaded bridge multilevel inverter uses separate DC input source for the synthesize of a desired voltage from several independent dc voltages sources, which may be obtained from batteries, fuel cells, or solar cells. This Topology recently becomes very popular in adjustable speed drives and in ac power supply systems. This topology avoids use of extra clamping diodes or voltage balancing capacitors makes cost effective. Table 1 shows the comparison between components required in different types of multilevel inverter configurations.

TABLE 1 COMPARISON OF COMPONENTS REQUIRED IN MULTILEVEL INVERTER CONFIGURATION

Inverter topology	Diode clamped MLI	Flying capacitor	Cascaded h bridge MLI
Main switching devices	2(p-1)	2(p-1)	2(p-1)
Main diodes	2(p-1)	2(p-1)	2(p-1)
Clamping diodes	(p-1)(p-2)	0	0
DC bus capacitor	(p-1)	(p-1)	(p-1)/2
Balancing capacitor	0	(p-1)(p-2)/2	0

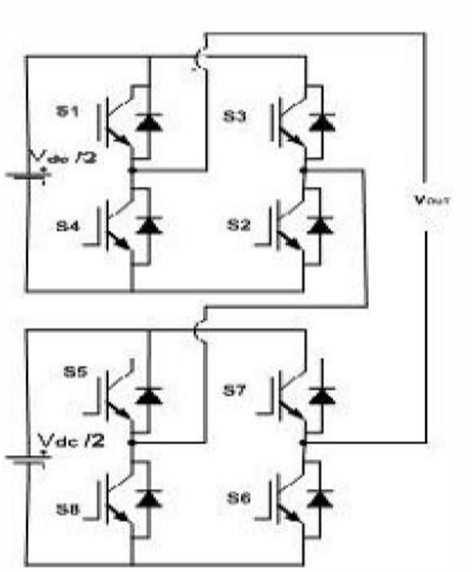
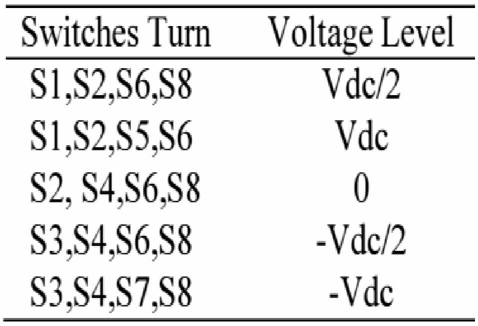


Fig l Five level CHB inverter

Table 2. shows the switching states of the five level inverter. Here even though we have eight switches at any switching state only two switches are on/off at a voltage level of $V_{dc}/2$, so switching losses are reduced. [n three level inverter dv/dt is V_{dc}, but in five level inverter dv/dt is Vdc/2. As dv/dt reduces the stress on switches reduces and EMI reduces.

TABLE 2 SWITCHING TABLE FOR FULL H-BRIDGE OF FIVE LEVEL INVERTER



Switches Turn	Voltage Level
S1,S2,S6,S8	Vdc/2
S1,S2,S5,S6	Vdc
S2, S4,S6,S8	0
S3,S4,S6,S8	-Vdc/2
S3,S4,S7,S8	-Vdc

III. PWM TECHNIQUES FOR MULTILEVEL INVERTER

The multilevel topology involves several modulation techniques. Each technique involves different modulation methods. The well-known modulation topologies for multi level inverters are (a) Sinusoidal or Natural Pulse Width Modulation (SPWM), (b) Selective Harmonic Eliminated Pulse Width Modulation (SHE PWM) or Programmed Waveform Pulse Width Modulation (PWPWM) and (c) Optimized Harmonic Stepped-Waveform Technique (OHSW).The advantage of PWM technique are , control of output voltage can be obtained without any additional components and With this type of control, lower order harmonics can be eliminated or minimized along with its output voltage control.

The filtering requirements are minimized as higher order harmonics can be filtered easily. The most popular PWM techniques used for CHB inverter are Phase Shifted Carrier PWM (PSCPWM) and Level Shifted Carrier PWM (LSCPWM). In level shifted carrier PWM three types are there these are in phase disposition (lPO), alternative phase opposite disposition (APOD) and phase opposite disposition (POD).

a) Phase Shifted Carrier PWM (PSCPWM):

Figure 2 shows the PSCPWM. In general, a multilevel inverter with m voltage levels requires (m-l) triangular carriers. In the PSCPWM, all the triangular carriers have the same frequency and the same peak-to-peak amplitude, but there is a phase shift between any two adjacent carrier waves, given by <pcr=3600/ (m-l).

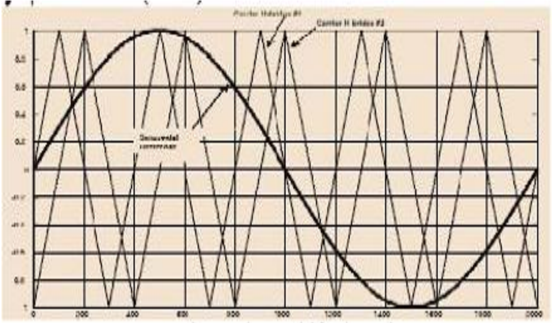


Fig 2 phase shifted carrier PWM

The modulating signal is usually a three phase sinusoidal wave with adjustable amplitude and frequency. The gate signals are generated by comparing the modulating wave with the carrier waves. It means for five-level inverter, four triangular carriers are needed with a 90° phase displacement between any two adjacent carriers. In this case the phase displacement of $V_{crI} = 0°$, $Vcr2 = 90°$, $V_{crl}- = 1\ 80°$ and $Vcr2- = 270°$.

3.3.2. Level Shifted Carrier PWM (LSCPWM):

Figure 3 shows the LSCPWM. The frequency modulation index is given by

$$mf = fcr / fm, \tag{1}$$

where fm i s modulating frequency and fcr are carrier waves frequency. The amplitude modulation index 'rna' is defined by

$$ma = Vm / Vcr(m\text{-}1) \quad \text{for } 0 \leq ma \leq 1 \tag{2}$$

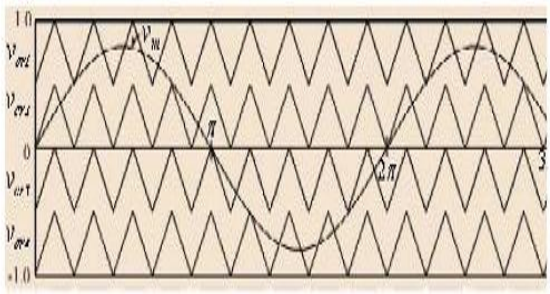


Fig 3 Level shifted carrier PWM (IPD)

Where Vm is the peak value of the modulating wave and Vcr is the peak value of the each carrier wave. The amplitude modulation index, rna is 1 and the frequency modulation index, mf is 6. The triggering circuit is designed based on the three phase sinusoidal modulation waves V_a, V_b, and V_c. The sources have been obtained with same amplitude and frequency but displaced 1 20° out of the phase with each others. For carriers signals, the time values of each carrier waves are set to [0 1 1600 1 1300] while the outputs values are set according to the disposition of carrier waves. After comparing, the output signals of comparator are transmitted to the IGBTs. Figures 3.3, 3.4 and 3.5 show the waveforms based on three schemes of LSCPWM: (a) in phase disposition (lPO) fig. 3.3, where all carriers are in phase; (b) alternative phase opposite disposition (APOO) fig. 3.4, where all carriers are alternatively in opposite disposition; and (c) phase opposite disposition (POD) fig. 3.5, where all carriers above zero reference are in phase but in opposition with those below the zero reference. Out of IPD, APOD and POD, it is observed that the IPD give better harmonic performance.

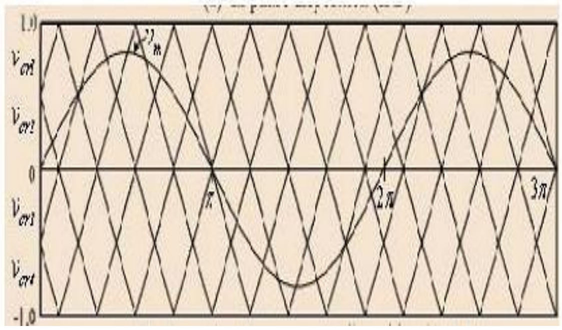


Fig 4 Alternative phase opposite deposition (MOD)

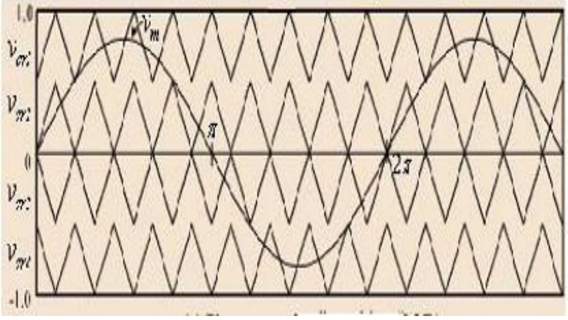


Fig 5 Phase opposite disposition (POD)

IV. MODELLING OF PMSM DRIVE

The d-q axis model has been developed on rotor reference frame as shown in Fig. 3.6. At any time t, the rotating rotor d-axis makes an angle θr with the fixed stator phase axis and rotating stator miff makes an angle a with the rotor d-axis. Stator mmf and the rotor rotate at the same speed.

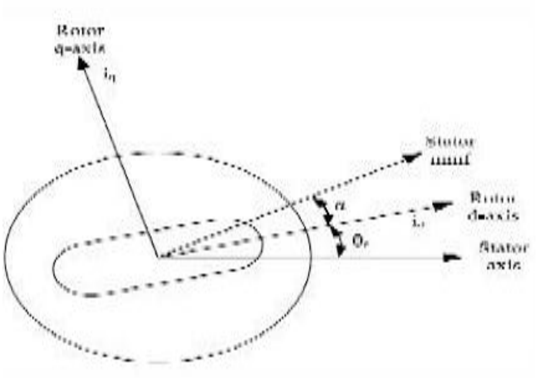


Fig 6 Motor Axis

$$V = R_s i_d - \omega_r \Psi_q + p\Psi \tag{3}$$

$$v_q = R_s i_q + \omega_r \Psi + p\Psi \tag{4}$$

Flux linkages equations are

$$\Psi_q = L_q i_q \tag{5}$$

$$\Psi_d = L_d i_d + \Psi_f \tag{6}$$

Solving above four equations

$$V_d = R_s i_d - \omega_r L_q i_q + p(L_d i + \Psi_f) \tag{7}$$

$$V_q = R_s i_q + \omega_r L_d i_d + \omega_r \Psi_f + p L_q i_q \tag{8}$$

Above two equations (7) and (8) can be written in matrix form

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \begin{bmatrix} R_s + p L_d & -\omega_r L_q \\ \omega_r L_d i_d & R_s + p L_q \end{bmatrix} \begin{bmatrix} i_d \\ i_q \end{bmatrix} + \begin{bmatrix} p\Psi_f \\ 0 \end{bmatrix} \tag{9}$$

Electromagnetic torque developed by the motor is

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)(\Psi_d i_q - \Psi_q i_q) \tag{10}$$

IV. PV-BATTERY SYSTEM

a) PV system:

A photovoltaic system, converts the light received from the sun into electric energy. In this system, semi conductive materials are used in the construction of solar cells, which transform the self contained energy of photons into electricity, when they are exposed to sun light. The cells are placed in an array that is either fixed or moving to keep tracking the sun in order to generate the maximum power [9]. These systems are environmental friendly without any kind of emission, easy to use, with simple designs and it does not require any other fuel than solar light. On the other hand, they need large spaces and the initial cost is high.

PV array are formed by combine no of solar cell in series and in parallel. A simple solar cell equivalent circuit model is shown in figure. To enhance the performance or rating no of cell are combine. Solar cell are connected in series to provide greater output voltage and combined in parallel to increase the current. Hence a particular PV array is the combination of several PV module connected in series and parallel. A module is the combination of no of solar cells connected in series and parallel.

The photovoltaic system converts sunlight directly to electricity without having any disastrous effect on our environment. The basic segment of PV array is PV cell, which is just a simple p-n junction device. The fig.1.4 manifests the equivalent circuit of PV cell. Equivalent circuit has a current source (photocurrent), a diode parallel to it, a resistor in series describing an internal resistance to the flow of current and a shunt resistance which expresses a leakage current. The current supplied to the load can be given as.

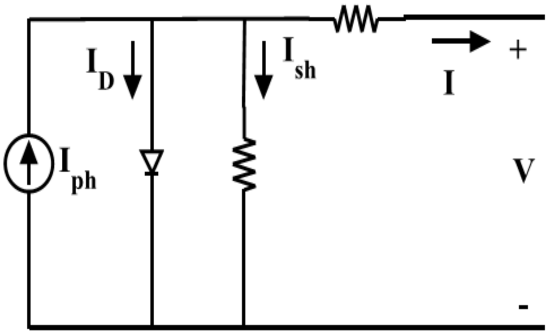


Fig 7 Equivalent circuit of Single diode modal of a solar cell

$$I = I_{PV} - I_0\left[\exp\left(\frac{V + IR_S}{aV_T}\right) - 1\right] - \left(\frac{V + IR_S}{R_p}\right) \tag{11}$$

Where

IPV–Photocurrent current,

IO–diode's Reverse saturation current,

V–Voltage across the diode,

a– Ideality factor

VT –Thermal voltage

Rs – Series resistance Rp –Shunt resistance

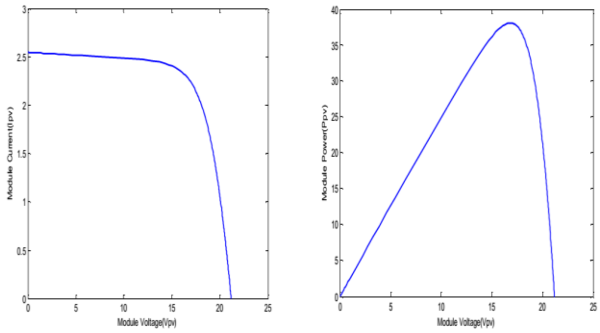


Fig 8 V-I & P-V Characteristics of a 36w PV module

The Voltage vs Power characteristics and Voltage vs Current characteristics of a solar cell are mainly dependents upon the solar irradiation. If there is change in the environmental condition then the solar irradiation level change which results different maximum power. So maximum power point tracking algorithm are used to maintain the maximum power constant if there is any change in the solar irradiation level. If the solar irradiation level is higher, then the input to the solar sell is more which results more magnitude of the power with the same voltage value. Also when there is increase in the solar irradiation the open circuit voltage increases. Because, when there is more solar light fall on the solar cell, with higher excitation energy the electrons are supplied, they increase the mobility level of electron and more power is generated.

V. MATLAB AND SIMULATION RESULTS

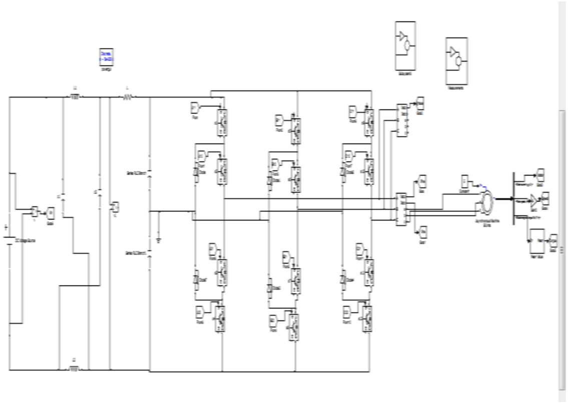


Fig 9 Simulation model of impedance source inverter

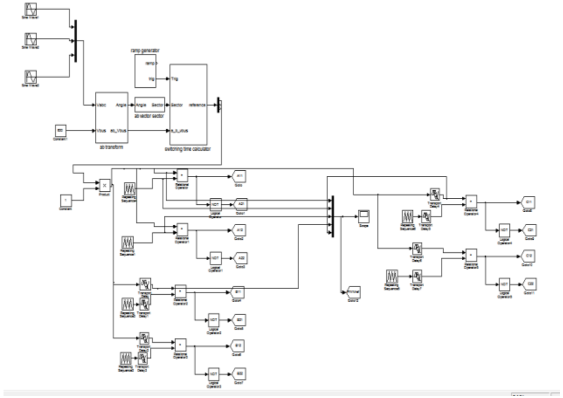


Fig 10 Simulation model of SVPWM control technique

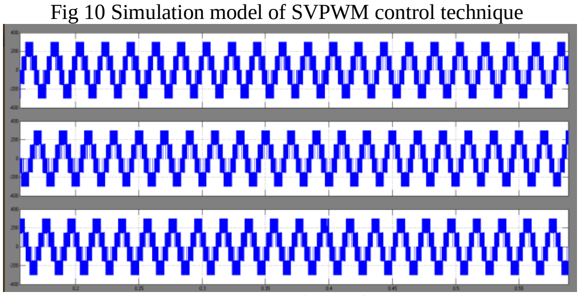


Fig 11 Simulation waveform of Line voltage

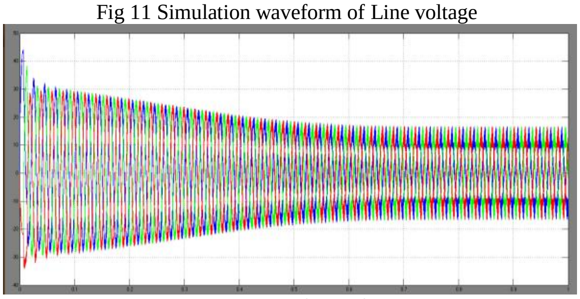


Fig 12 Simulation waveform of Line current

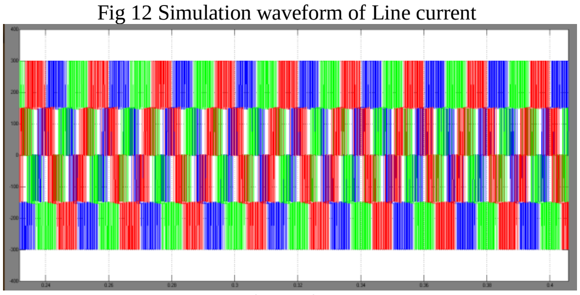


Fig 13 Simulation waveform of Three phase line current

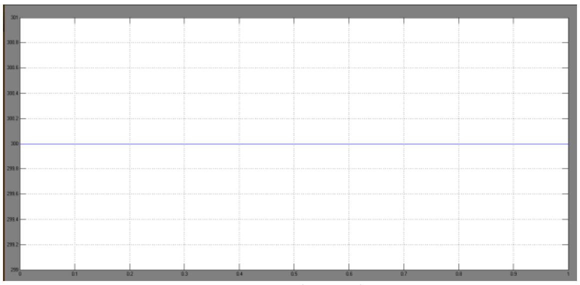


Fig 14 Simulation waveform of Input voltage

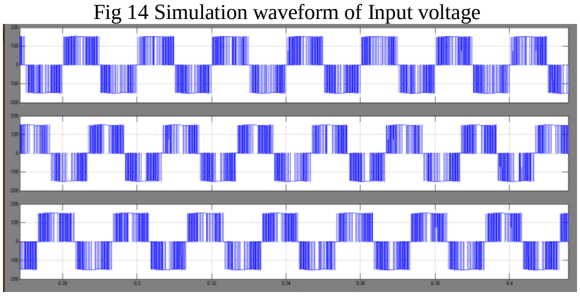


Fig 15 Simulation waveform of Phase voltage

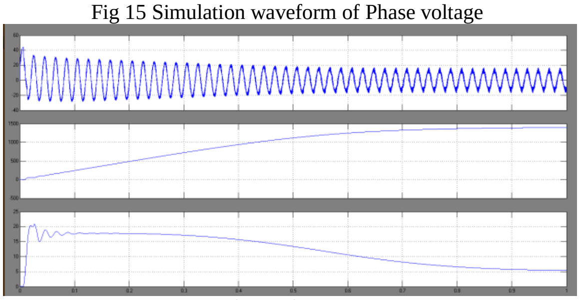


Fig 16 Simulation waveform of Three phase induction motor characteristics

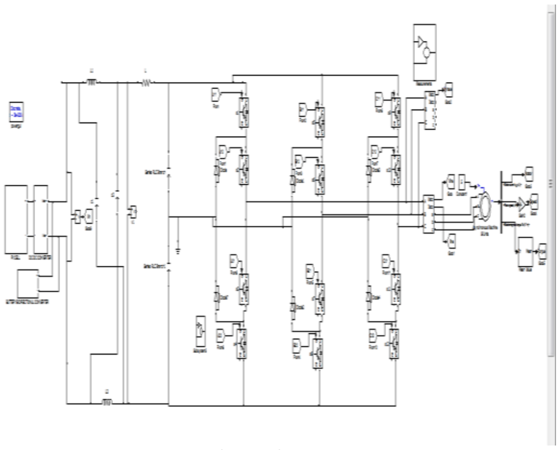


Fig 17 Simulation waveform of PV-battery based impedance source inverter

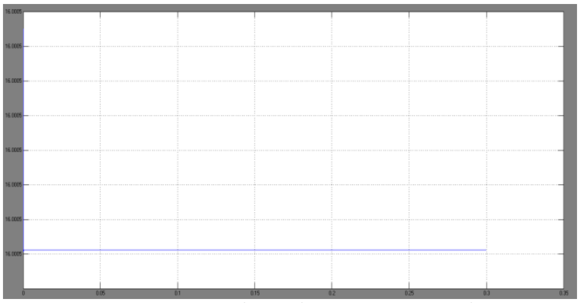


Fig 18 Simulation waveform of Voltage extracted from PV

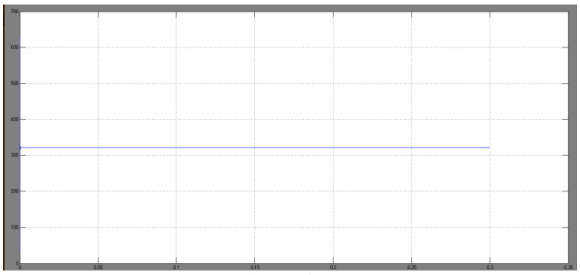


Fig 19 Simulation waveform of PV-Battery input voltage

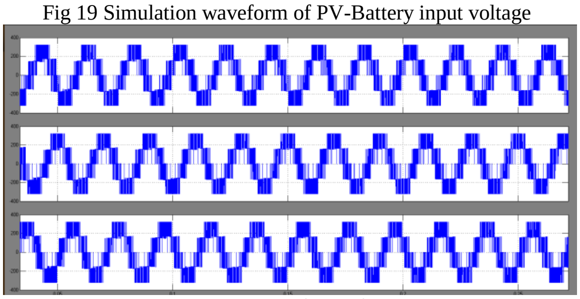


Fig 20 Simulation waveform of Line voltage

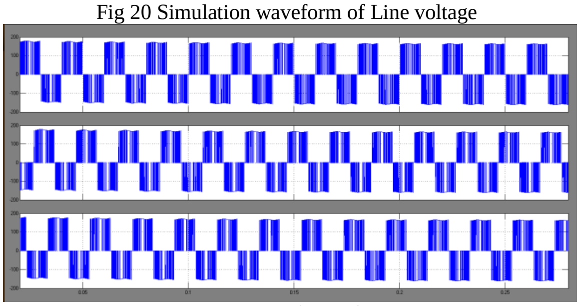


Fig 21 Simulation waveform of Phase voltage

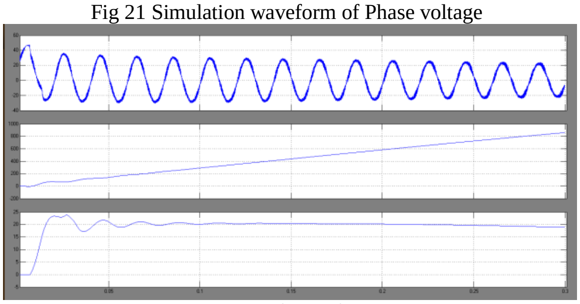


Fig 22 Simulation waveform of IM characteristics

VI. CONCLUSION

Due to the advancement in power electronics technology had made it possible to vary the frequency and magnitude of the voltage. Thus, it made more extensive use in variable speed drive applications. By using of hybrid system improves the system stability and improves the reliability of the system. The renewable sources give improvement of power quality. A multilevel converter can operate at both fundamental switching frequency and high switching frequency PWM. It means that lower switching frequency usually means lower switching loss and higher efficiency. In high power applications efficiency can also be increased by reducing harmonic content of the output waveform. This can be achieved by using propped switching technique. In this paper Sinusoidal and third harmonic injected carrier based PWM technique In level shifted carrier PWM (a) in phase disposition (IPD), (b) alternative phase opposite disposition (APOD) and (c) phase opposite disposition (POD) modulating technique is applied. Better modulating technique is applied to drive the five level cascades H Bridge fed Permanent Magnet Synchronous Motor drive

REFERENCES

[1] F. Wang, "Motor shaft voltages and bearing currents and their reduc- tion in multilevel medium-voltage PWM voltage source-inverter drive applications," IEEE Trans. Ind. Appl., vol. 36, no.5 , pp. 1336-1341, Sep.lOct. 2000.

[2] S. Chen and T. A. Lipo, "Bearing currents and shaft voltages of an induction motor under hard- and soft-switching inverter excitation," IEEE Trans. Ind. Appl., vol. 34, no. 5 , pp. 1042- 1048, Sep.lOct.1998.

[3] L. M. Tolbert, F. Z. Peng, and T. G. Habetler, "Multilevel converters for large electric drives," IEEE Trans. Ind. Appl., vol. 35 , no. I, pp. 36-44, Jan./Feb. 1999.

[4] A. Muetze and A. Binder, "Calcu1ation of circulating bearing currents in machines of inverter-based drive systems," IEEE Trans. Ind. Elec1rrn., vol54, no. 2,pp. 932-938,Apr.2007.

[5] J. Rodriguez, J. S. Lai, and F. Z. Peng, "Multilevel inverters: A survey of topologies, control and applications,"IEEE Trans. Power EIec1rrn., vol.49,no. 4, pp. 724-738,Aug,2002.

[6] P.W. Hammond, "A new approochto enhanced power quality for medium voltage drives," IEEE Trans. Ind Appl., vol.33, no. I, pp. 202-208, JanlFeb. 1997.

[7] Y.S.Lai and F.S.Shyu. 'Topology for hybrid multi level inverter", lEE Proc-Electr.Power Appl.Vol 149,No 6 nov 2002

[8] M.D. Manjrekar, P.\(. Steimer, and T.A. Lipo. "Hybrid multilevel power conversion system: A competitive solution for high power applications". IEEE Translations on Industry Applications,36(3) :834-841, May /June 2000.