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# Analysis and Simulation of Multi Level Inverter Fed Induction Motor Drive

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## Abstract

This paper presents the simulation of cascaded multilevel inverter fed induction motor drive. The poor quality of voltage and current of a conventional inverter fed induction machine is due to the presence of harmonics and hence there is significant level of energy losses. To obtain high quality sinusoidal output voltage with reduced harmonics, multi carrier based Sinusoidal pulse width modulation(MSPWM) control scheme is proposed for cascaded H bridgemultilevel inverter. The field orientation control techniqueis used to control the speed of induction motor by controlling the quadrature axis current using PI speed regulator. The proposed system is an effective replacement for the conventional method which produces high switching losses results in poor drive performance. The simulation results reveal that the proposed circuit effectively controls the motor speed and enhances the drive performance through reduction in total harmonic distortion (THD). The effectiveness of the system is verified through simulation using PSIM Simulink software.

**Keywords**: Cascaded multilevel inverter(CMLI), field orientation control (FOC), PSIM simulink, Total harmonic distortion(THD), Voltage source multi levelinverter(VSI), etc.

## Introduction

Majority of industrial drives use ac induction motor because these motors are rugged, reliable, and relatively inexpensive. Induction motors are mainly used for constant speed applications because of unavailability of the variable frequency supply voltage but many applications need variable speed operations. Historically, mechanical gear systems were used to obtain variable speed. Recently, power electronics and control systems have matured to allow these components to be used for motor control in place of mechanical gears. Present day drive types are the Induction motor drives with voltage source inverters. Also the voltage waveforms of traditional two level inverter fed Induction motor shows that the voltage across the motor contains not only the required “fundamental” sinusoidal components, but also pulses of voltage i.e. “ripple “voltage. Adjustablespeed drives usually employ a front-end rectifier to convertutility ac voltage to dc voltage and an inverter to convert the dcvoltage to variable frequency and variable voltage for motorcontrol. Motor damage and failure has been reported byindustry as a result of adjustable speed drive inverters’ highfrequency PWM switching. The main problems reported havebeen “motor bearing failure” and “motor winding insulationbreakdown” because of internally induced circulating currents. The cause of these currents are related to the capacitiveelements between the winding conductor and motor shaft and also the insulation between different winding layers being subjected to high voltage transients.

The problems associated with conventionaladjustable speed drive inverters are as follows:

1. High-frequency switching requires significant de rating of switching devices and generates large switching losses.
2. High dV/dt because of switching causes motor bearing failure and stator winding insulation breakdown.
3. High-frequency switching generates broadband (10 kHz to 30 Mhz) electromagnetic interference (EMI) to nearbycommunication or other electronic equipment.

The recent advancement in power electronics has initiated to improve the level of inverter instead increasing the size of filter. The total

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harmonic distortion of the classical inverter is very high. The performance of the multilevel inverter is better than classical inverter. In other words the total harmonic distortion for multilevel inverter is low. The total harmonic distortion is analyzed between multilevel inverter and other classical inverter.

Multilevel inverters also solve problems with present high-frequency PWM adjustable speed drives (ASD). A multilevel converter has several advantages over a conventional two-level converter that uses high switching frequency pulse width modulation (PWM) like Staircase waveform quality which can generate the output voltages with very low distortion but also can reduce the dv/dt stresses therefore electromagnetic compatibility (EMC) problems can be reduced also Multilevel converters produce smaller CM voltage therefore the stress in the bearings of a motor connected to a multilevel motor drive can be reduced. Multilevel converters can draw input current with low distortion and operates at low the switching frequency. It should be noted that lower switching frequency usually means lower switching loss and higher efficiency.

Multilevel converters do have some disadvantages. One particular disadvantage is the greater number of power semiconductor switches needed. Although lower voltage rated switches can be utilized in a multilevel converter, each switch requires a related gate drive circuit. This may cause the overall system to be more expensive and complex.

## Cascaded Multi Level Inverter

Cascaded H-Bridge (CHB) configuration has recently become very popular in high-power AC supplies and adjustable-speed drive applications. A cascade multilevel inverter consists of a series of H-bridge (single-phase full bridge) inverter units in each of its three phases. Each H-bridge unit has its own dc source, which for an induction motor would be a battery unit, fuel cell or solar cell. Each SDC (separate D.C. source) is associated with a single-phase full-bridge inverter. The ac terminal voltages of different level inverters are connected in series. Through different combinations of the four switches, S1-S4, each converter level can generate three different voltage outputs, $+V_{dc}$, $-V_{dc}$and zero. The AC outputs of different full-bridge converters in the same phase are connected in series such that the synthesized voltage waveform is the sum of the individual converter outputs.In this topology, the number of output-phase voltage levels is defined by $m= 2N+1$, where $N$ is the number of DC sources.

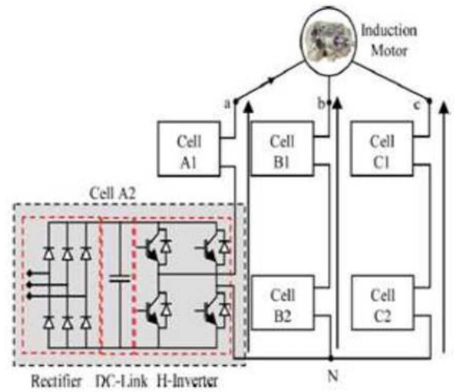


**Fig1:Structure of two cells cascaded multi-level inverter**

A five-level cascaded converterfor example consists of two DC sources and two full bridge converters. Minimum harmonic distortion can be obtained by controlling the conducting angles at different converter levels. Each H- bridge unit generates a quasi-square waveform by phase shifting its positive and negativephase legs‟ switching timings. Each switching device always conducts for 180° (or half cycle) regardless of the pulse width of the quasi-square wave. This switching method makes all of the switching devices current stress equal. In the motoring mode, power flows from the batteriesthrough the cascade inverters to the motor. In the charging mode, the cascade converters act asrectifiers and power flows from the charger (ac source) to the batteries. The cascade converters can also act as rectifiers to help recover the kinetic energy of the vehicle if regenerative braking is used. The cascade inverter can also be used in parallel HEV configurations. This newconverter can avoid extra clamping diodes or voltage balancing capacitors.

The combination of the 180° conducting method and the pattern-swapping scheme makethe cascade inverters voltage and current stresses the same and battery voltage balanced.Identical H-bridge inverter units can be utilized, thus improving modularity and manufacturability and greatly reducing production costs. Battery-fed cascade inverter prototype driving an induction motor at 50%and 80% rated speed both the voltage and current are almost sinusoidal.

The main advantages of using the cascade inverter in an induction motor thatit makes induction motor more accessible/safer and open wiring possible for most of an induction motor power system. Traditional 230 V or 460 V motors can be used, thus higher efficiency is expected as compared to low voltage motors.No EMI problem or common-mode voltage/current problem exists. Low voltage

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switching devices can be used.No charge unbalance problem exists in both charge mode and drive mode.

## Control Techniques

Many applications, such as robotics and factory automation, require precise control of speed and position. Speed Control Systems allow one to easily set and adjust the speed of a motor. The control system consists of a speed feedback system, a motor, an inverter, a controller and a speed setting device. A properly designed feedback controller makes the system insensible to disturbance and changes of the parameters. The purpose of a motor speed controller is to take a signal representing the demanded speed, and to drive a motor at that speed. Closed Loop speed control systems have fastresponse, but become expensive due to the need of feedback components such as speed sensors.

## Implementation of the Speed Control Loop

For a PM motor drive system with a full speed range the system will consist of a motor, an inverter, a controller (constant torque and flux weakening operation, generation of reference currents and PI controller) as shown in figure.

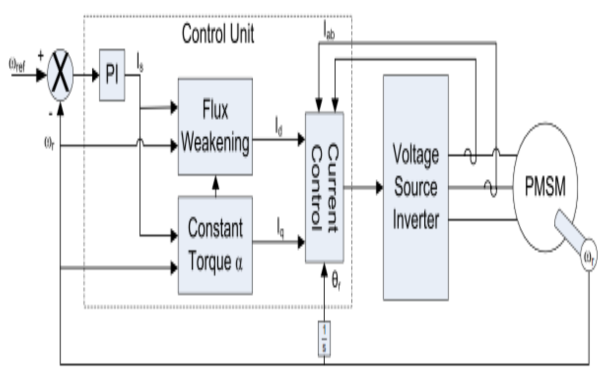


**Fig2.Block Diagram**

The operation of the controller must be according to the speed range. For operation up to rated speed it will operate in constant torque region and for speeds above rated speed it will operate in flux-weakening region. In this region the d-axis flux and the developed torque are reduced.Speed controller calculates the difference between the reference speed and the actual speed producing an error, which is fed to the PI controller. PI controllers are used widely formotion control systems. They consist of a proportional gain that produces an outputproportional to the input error and an integration to make the steady state error zero for a step change in the input.

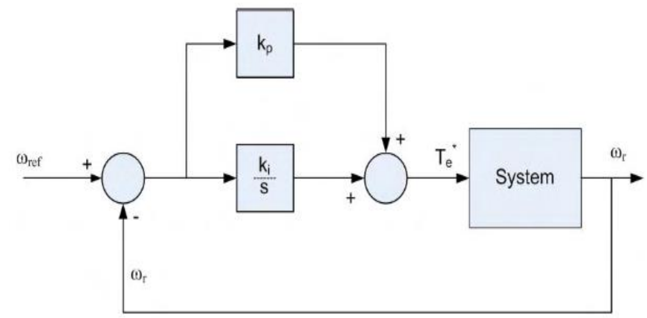


**Fig3. PI Controller**

Speed control of motors mainly consist of two loops the inner loop for current and the outer loop for speed. The order of the loops is due to their response, how fast they can be changed. This requires a current loop at least 10 times faster than the speed loop.

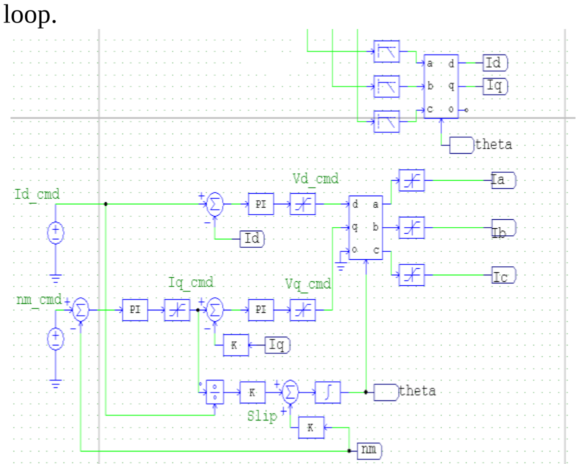


**Fig4. Control Circuit**

## Modulation Topologies For Multilevel Inverters

Mainly the power electronic converters are operated in the "switched mode". Which means the switches within theconverter are always in either one of the two states - turned off when no current flows or turned on. To control the flow of power in the converter, the switches alternate between these two states. This happens rapidly enough that the inductors and capacitors at the input and output nodes of the converter average or filter the switched signal. The switched component is attenuated and the desired DC or low frequencyAC component is retained. This process is called Pulse Width Modulation (PWM), since the desired average value iscontrolled by modulating the width of the pulses. To achieve the greatest possible attenuation of the switching component,it is generally desirable that the switch frequency f is high — many times the frequency of the desired fundamental ACcomponent f1c seen at the input or output terminals. No frequency

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components below the fundamental frequency will exist. This is important since an undesired harmonic component near zero frequency, even if small in amplitude, can cause largecurrents to flow in inductive loads. Beyond these basic requirements, there are many different ways of generating PWMswitching edges. Any technique can probably be placed into one of the following three categories: 1)Off-line or pre-calculated PWM technique, 2) Hysteresis control PWM, 3) Carrier based PWM.

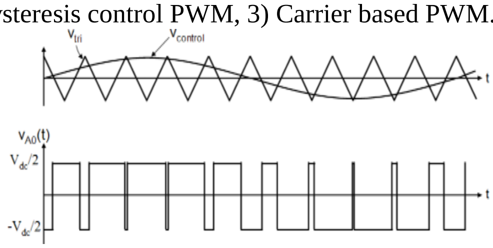


**Fig5. Pulse width modulation**

## Simulation and Simulation Results

The computer software package PSIM Simulink is used to implement all of theModulation Techniques.Fig. shows the simulation model of 5-level symmetrical multi-level inverter fed induction motor drive model.

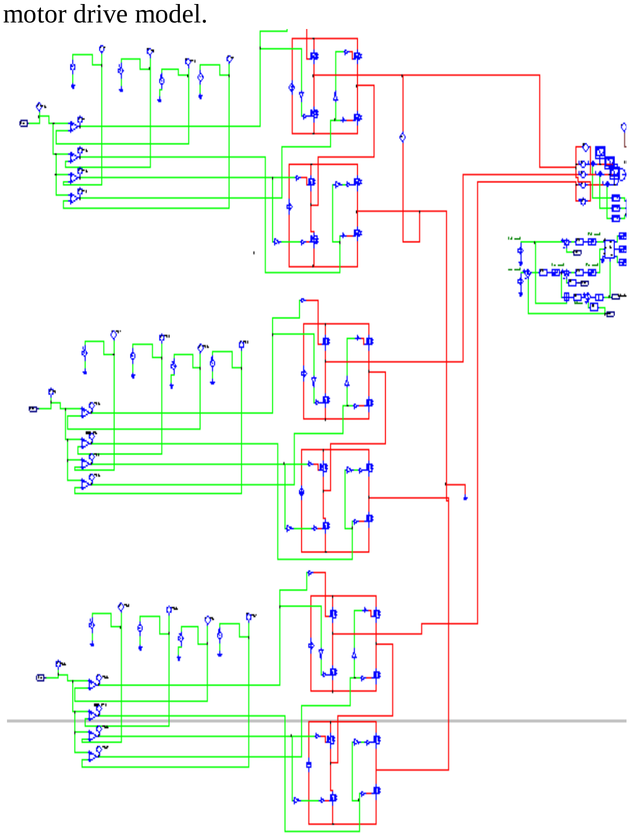

**Fig6.Simulation model of 5-level PWM inverter fed IM**

In above simulation circuit, 5 level inverter used to supply the induction motor controlled voltage as per set reference by user. Multi carrier PWM technique is used to produce the various getting signal for multilevel inverter. First three feedback current are taken using current transformer and then that current is converter in to three phase to two phase current using Clark's transformation ($i_\alpha$, $i_\beta$) and then this current is converted in to two phase stationary reference frame current using park's transformation ($i_d$, $i_q$). This id and iq current is nothing but flux controlling and torque controlling components. This current is compare and error signal is generated using PI regulator and that is according to set reference signal feed by user. Error signal is converted in to again three phase controlled current using inverse park and Clark transformation. This three controlled current compare with triangular signal using comparator circuit and that generate gating signal for multilevel inverter and according to that gating signal inverter produced controlled output voltage that supplied to the three phase induction motor.

## Hardware Results

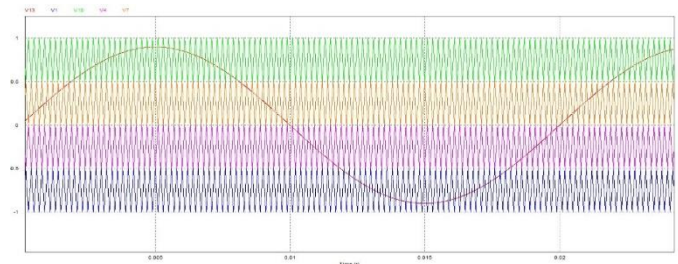

**Fig7. Multicarrier sinusoidal PWM waveform**

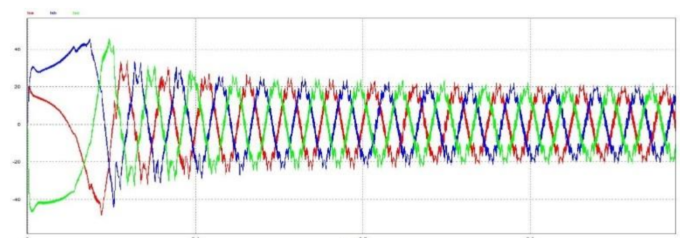

**Fig8. Three phase load current waveforms**

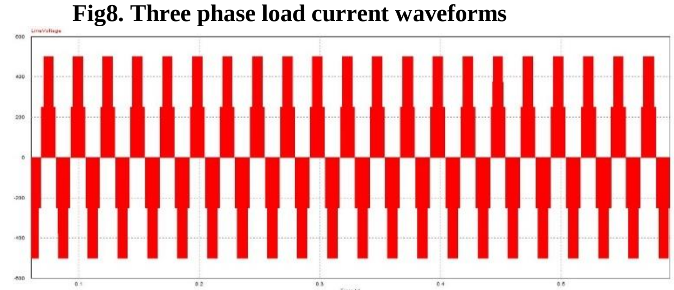

**Fig9. Three phase line voltage**

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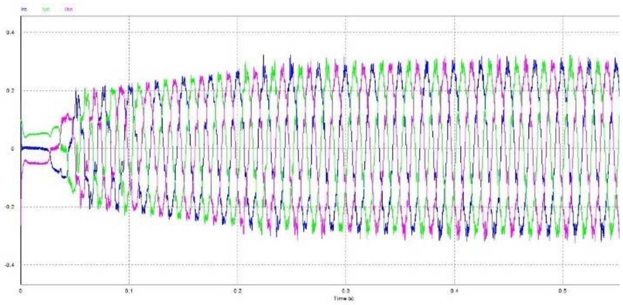

**Fig10.Three phase controlled current using FOC**

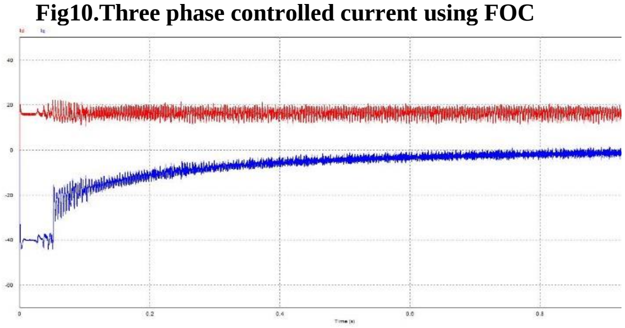

**Fig.11. $I_d$ and $I_q$ current**

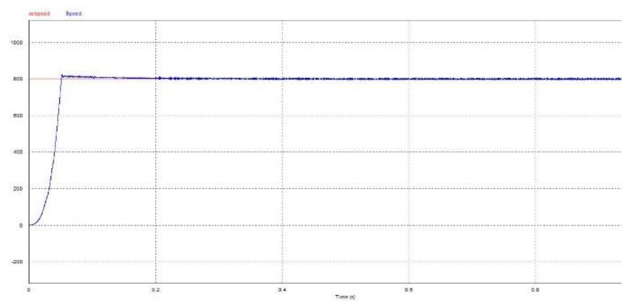

**Fig12. Reference speed and motor actual speed**

## Conclusion

The proposed multicarrier based multilevel inverter fed induction motor drive using field orientation control technique is give high quality output signal with lower total harmonics distortion which is less than 5% as compare with normal inverter topology and also it provide better speed and torque regulation.

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