International Journal of Electrical and Electronics Engineers
Vol. No.8 Issue 01, January-June 2016
www.arresearchpublication.com
IJEEE
ISSN 2321 - 2055

IMPROVEMENT IN PERFORMANCE OF INDUCTION MOTOR FED BY THREE PHASE PWM VSI USING VARIABLE MODULATION INDEX

Ankur Bhardwaj[1], Er.Abhishek Jain[2], Bhuvnesh Meena[3]

[1,3] M.Tech. Scholar, [2] Asst.Prof., Department of Electrical Engineering ,VCET, Bundi, (India)

ABSTRACT

Induction motors are most widely used motors for any industrial control and automation. It is often required to control the output voltage of inverter for the constant voltage/frequency (V/F) control of an induction motor.Three phasePulse Width Modulated Voltage Source Inverters (PWM-VSI) are widely utilized in motor drive and other three-phase power conversion applications as voltage/current sources with controllable output frequency and magnitude. This paper presents the results of an analysis regarding the behavior of three phase induction motor fed by PWM VSI in terms of total harmonic distortion in line and phasevoltage of inverter for modulation range 0<m<1. Simulink is utilized with MATLAB to get a reliable and flexible simulation. For the execution of the proposed drive the MATLAB/SIMULINK software has been used. The influence of the modulation index on the performance of the inverter has been done in terms of the waveforms for inverter phasevoltage and line voltage developed by the motor. The analysis of the inverter has been carried out by using the factor total harmonic distortion.

Keywords: Induction Motor Drive, Modulation Index, PWM, Switching, Simulink, THD

I. INTRODUCTION

Induction machines are commonly used in the industry, serving as one of the most important roles during the energy conversion between electrical power and mechanical power. Based on the functionality, they are given by two categories: induction motor and induction generator. Induction generators consume the mechanical energy and produce electrical power, which brief out the applications in the standing-alone electrical power generations and wind farms. Induction motors develop mechanical power while consuming the electrical power from the grid, which account for more than one half of the total electrical power consumed. Mainly the induction machines with squirrel cage rotors are the dominant types due to the simple structures, easy connections, lusty to severe operating conditions, low costs, and maintenance free features. They can be organizein the applications as the important driving sources where a certain motion is required either linear or rotating ones. They are utilize to drive, pumps, compressors, power tools, mills, elevators, cranes,fans, electrical vehicles, ships, etc.

DC-AC inverters are electronic devices used to generate AC power from low voltage DC energy (from a battery or solar panel). This makes them very appropriate for when required to use AC power tools or appliances but the usual AC mains power is not available. Following examples include operating appliances in caravans and mobile homes, and also running audio, video and computing equipment in remote areas. Most inverters do their job by performing two main functions: first they change the incoming DC into AC, and then they set up the resulting AC to mains voltage level using a transformer. And the aim of the designer is to have the inverter perform these functions as efficiently as possible. So that as much as possible of the energy wasted from the battery or solar panel is converted into mains voltage AC, and as little as possible is drawn as heat. Three-phase inverters areemploy for variable-frequency drive applications. A basic three-phase inverter contains three single-phase inverter switches each connected to one of the three load terminals.

II. THREE PHASE SPWM INDUCTION MOTOR DRIVE

The Voltage Source Inverter (VSI), is the most widely applied device with 3 power ratings ranging from fractions of a kilowatt to megawatt levelamong all the modern power electronics converters.The dc source has small or negligibleimpedance in the Voltage source inverter (VSI). The input terminal voltage is constant. Acurrent–source inverter (CSI) is fed with flexible currentfrom the dc source of high impedance that is from a constant dc source . The six power semiconductor switches with anti-parallel feedback diodes hold by VSI. It converts a fixed DC voltage to three phase AC voltages with governable frequency and magnitude. The VSI has discrete circuit modes for each set of switch states, developing an output voltage with correct frequency and magnitude need an averaging approach. In the widely employ Pulse Width Modulation (PWM) methods, the output voltage inverter approximates the reference value around high frequency switching. In AC motor drive applications, the AC three phase line voltages to DC voltage converted by rectifier device. Following the rectifier voltage passive filtering stage, the PWM-VSI interfaces the DC source with the AC motor to direct the shaft position/torque/speed. Some industrial applications of inverters are for induction heating, UPS for computers, standby aircraft power supplies, HVDC transmission lines, adjustable –speed drives etc.When employed in such applications, the device is often known as converter (opposite of inverter), hence PWM-VSC.

In all cases, to obtain high performance, improved efficiency, and reliable operation in a mannered way bythe power flow directed by the inverter switching device gate signals. Although its main circuit topology is quite simple, a modern PWM-VSI drive contains an overwhelming level of technology and intelligence. From the semiconductor power switching devices such as frequencies of Insulated Gate Bipolar Transistors (IGBTs) operated at as high as many tens of kilohertz to the microcontrollers and Digital Signal Processors (DSPs) processed the control signals at speeds beyond many tens of megahertz, PWM-VSI drive involved advanced technologies having most components of a state of the art. The people's increasing demand for multifunctionality, precision performance, efficiency, and reliability and user friendliness has encouraged engineers to make a significant amount of intelligence into the microcontrollers and DSPs of the PWM-VSI drives.The modern PWM-VSI drives made up into and generated Load parameter estimation, fault diagnostics, high performance vector control, observer based shaft encoder less speed control, optimization of energy efficiency etc. algorithms. ThePWM-VSI drives are modern technology devices with their global production rate above millions per year, the power ratings varies from fractions of a kilowatt to megawatts, and simple house application ranging appliances such as air-conditioning units to heavy industries such as steel mills, which have been experiencing a rapid progress over the last three decades.

International Journal of Electrical and Electronics Engineers
Vol. No.8 Issue 01, January-June 2016
www.arresearchpublication.com
IJEEE
ISSN 2321 - 2055

Stiff DC voltage source at its input terminals consists of VSI. In other words DC source has small and negligible impedance in Voltage source inverter.With adjustable current from a DC source of high impedance, i.e. from a stiff DC current source is fed by Current Source inverter. In a CSI fed with stiff current source, output current waves are not affected by the load.

It is the first requirement that theoutput of three phase inverter should be purelysinusoidal. The non-sinusoidal and contain certainharmonics consists of practical inverter waveform. These harmonics are developed by thesemiconductor devices employed in implementing threephase inverter is in the production of harmonics. The power electronics devicesutilize in practical circuitslike converter/controller circuits generate harmonics in the output voltage supply. The undesirable effects in power supply circuits likegeneration of humming noises, derating of the machinesand torque pulsations which make the operation of the machine pulsating are generatedby harmonics. The importantparameters which determine the quality of output voltage of inverter are

1. Harmonic Lowest Order
2. Total Harmonic Distortion
3. Distortion Factor
4. HarmonicFactor

In this paper, a technique is implemented to tolerate the fault in the inverter section of a three phase VSI fed induction motordrive. A standard power to three-phase voltage source inverter, fed from athree-phase mains supply, around a three-phase uncontrolled rectifier circuit, commonly supplies the induction motor used in this ACdrives category Fig. 1.

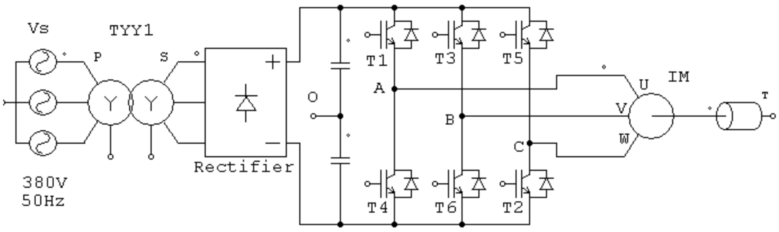

Fig. 1. Typical induction motor drive structure based on a voltage source inverter

III. TECHNIQUES USED TO IMPLEMENT INVERTER

Previously 180^0 conduction mode full bridge type inverter were used so as to generate three phase output voltage waveform. The availability ofoutput voltage is in the form of discrete pulses displaced from each other by an angle of 1200. However the harmonics contents are greater. Inverter gain is lesser in term and the output voltage regulation is poor .The difficulty in satisfaction of the constant voltage and frequency requirement.

So as to fulfill above mentioned requirements, Pulse Width Modulation Technique is the most efficient technique required to implement by the three phase inverter. The inverter so fabricated is called PWM Inverter. The width of each pulse is varied on per half cycle basis is done by this technique. The removal of the particular harmonic component from output voltage waveform and to control of output voltage in efficient manner together implemented by the variation ofthe pulse width in each half cycle. The below PWM techniques used for implementing three phase inverter are

1. Sinusoidal Pulse width modulation
2. Multiple Pulse Width Modulation
3. Single pulse Width Modulation

The harmonic contents can further be reducedby using the number of pulses and modulating the width of these pulses in each half cycle rather than using a single pulse. This methodology implemented by using Multiple Pulse Width Modulation and Sinusoidal pulse Width Modulation techniques [9, 10].

IV. ANALYSIS OF THREE PHASE SPWM VOLTAGE SOURCE INVERTER

The Fig. 2 shows the Simulink diagram of the developed model.Three phase induction motor fed by a PWM inverter constructed in Matlab/Simulink environmentits all done by Simulation. For the purpose of simulation, the tool box used is the Sim-power system tool box used in Matlab. The circuit of the proposed scheme contains the three phase induction motor as squirrel-cage rotor type having values as 5.4 HP, 400V, 50 Hz, 1430 RPM. The sinusoidal pulse width modulation technique helps the inverter for generating three phase balanced output.

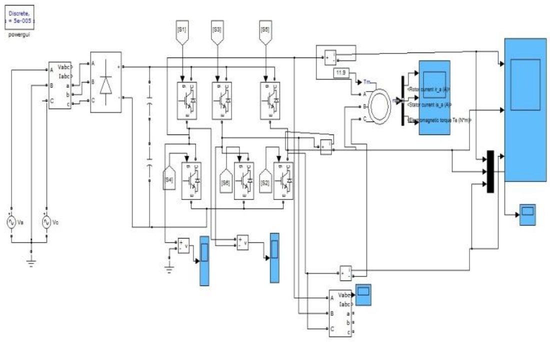

Fig. 2.Circuit diagram of PWM based VSI fed Induction motor

The six IGBTs switches in a bridge formis used to design theVoltage source pulse width modulated inverter. IGBT switches has been used because of the number of advantages offered them for switching purpose. Three phase output is taken from the of three arms of bridge circuit designated as a, b, c , which is connected to the three phases a, b, c, on the stator side of three phase induction motor. The output voltage and the load current has been measured in the presence of harmonics. The THD carries out the evolution of harmonics content and the FFT analysis used for extraction of harmonics spectrum.

V. PRODUCTION OF GATING PULSES

The gating pulses for the six IGBTs of three legs are produced. The production of these pulses is carriedout by one of the PWM technique that is Sinusoidal Pulse Width Modulation technique. Anumber of algorithms for PWM voltage generation are obtainable. Some well-known techniques are unipolarvoltage switching and bipolar voltage switching. In this work the unipolar switching scheme has been used.The simulation circuit of gate pulses given to the voltage source inverter is shown in Fig. 3.

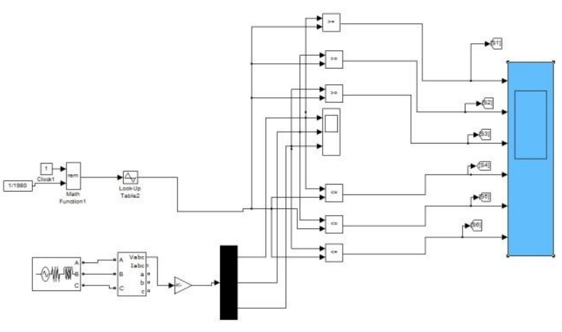

Fig. 3.Drive Circuit of IGBTs

VI. SIMULATION RESULTS

Results are obtained by simulating the circuit. Here we analyze the inverter and motor performance for modulation range between 0 and 1 i.e. 0 < m < 1. Amplitude Modulation index is defined as the ratio of control signal amplitude and carrier signal amplitude i.e. ma=Ar/Ac. The number of pulses per half cycle depends upon the value of the frequency modulation index mfdefined by the relation mf= fc/(2f), where fc= frequency of the carrier signal and f= frequency of the modulating signal.

A. For modulation index m_a=0.7

First of all the inverter is operated in the modulation index i.e. the value of ma =0.7 is maintained.The generated pulses are applied to the gate circuit of the six IGBTs which in turn produce the balanced pulse width modulated three phase output voltages.

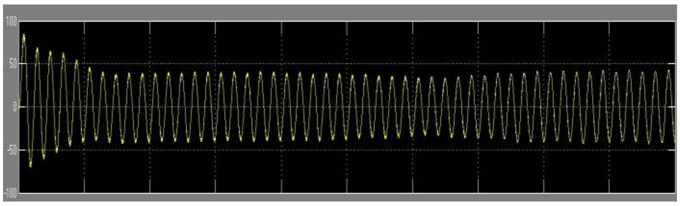

Fig. 4.Phase A current waveform for m_a= 0.7

Fig. 4 shows the waveform for the phase "a" current. From the waveform it is clear that the part of the wave form present before the time 0.33 sec is the transient part and after that it acquires it steady state value of x amperes.

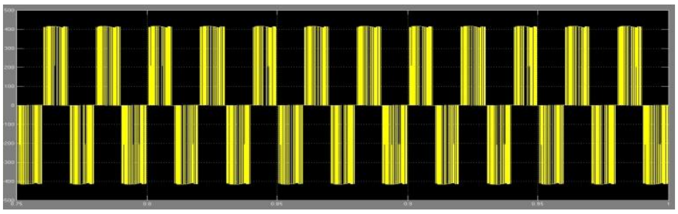

Fig. 5.Waveform of line voltage Vab for m_a = 0.7

Fig. 5 shows the waveform of line voltage Vab. Similar waveforms can be obtained for the other line voltages VbcandVca. From the waveform it is clear that the output waveform is PWM wave and the frequency of the output voltage wave is 50 Hz and its amplitude is 220V.

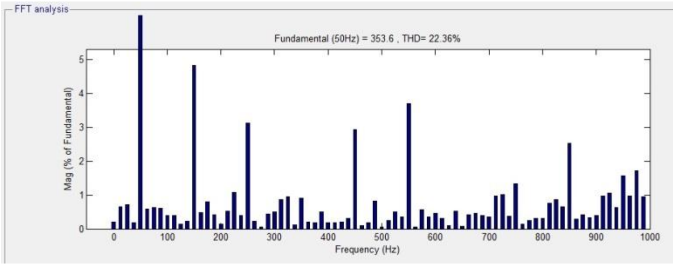

Fig. 6 FFT analysis in line voltage Vab for m_a = 0.7

Fig. 6 shows the frequency spectrum of the line voltage. The value of the THD is 22.36% for the value of M_a= 0.7. From the waveforms it is clear that the dominant harmonic is the third harmonic.

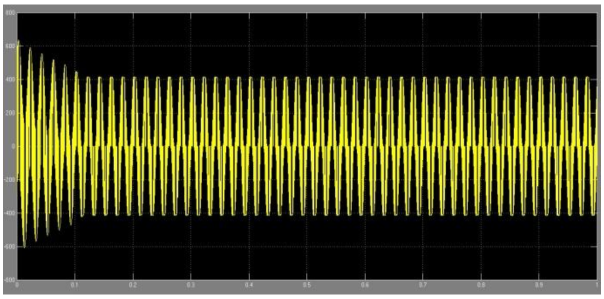

Fig. 7Phase 'a' voltage waveform for m_a= 0.7

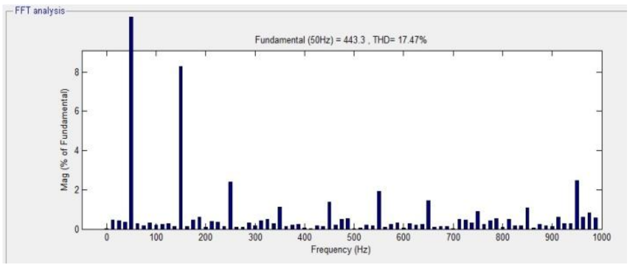

Fig. 8 FFT analysis in phase voltage 'a' for m_a = 0.7

Fig. 7 shows the waveform and Fig. 8 shows frequency spectrum of the phase voltage for m_a= 0.7. It shows THD of 17.47%

B. For modulation index m_a=0.8

For modulation index m_a= 0.8, the waveform of line voltage $V_{ab}$of inverter is shown in Fig. 9.Similar waveforms can be obtained for the other line voltages VbcandVca. From the waveform it is clear that the output waveform is PWM wave and the frequency of the output voltage wave is 50 Hz and its amplitude is 220V.

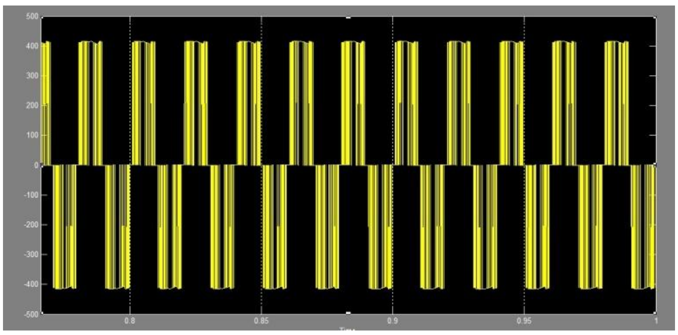

Fig. 9.Waveform of line voltage Vab for m_a = 0.8

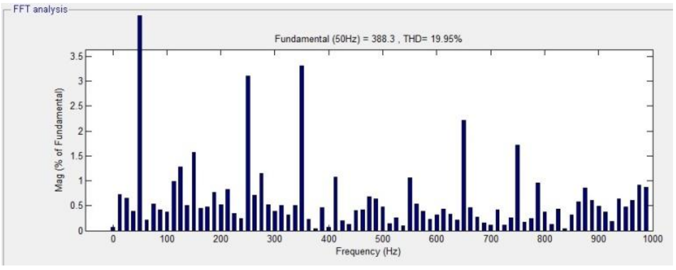

Fig. 10 FFT analysis in line voltage Vab for m_a = 0.8

Fig. 10 shows the frequency spectrum of the line voltage. The value of the THD is 19.95% for the value of M_a= 0.8. From the waveforms it is clear that the dominant harmonic is the third harmonic.

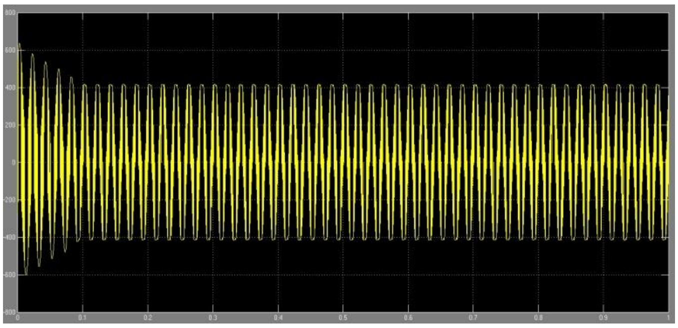

Fig. 11Phase 'a' voltage waveform for m_a= 0.8

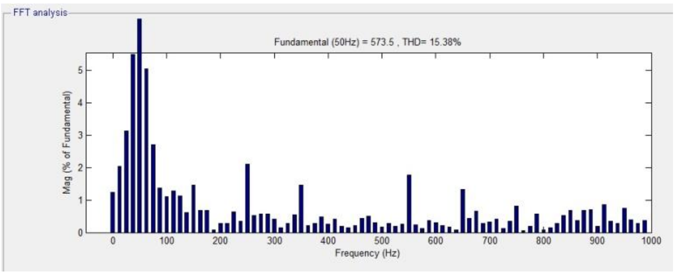

Fig. 12 FFT analysis in phase voltage 'a' for m_a = 0.8

Fig. 11 shows the waveform and Fig. 12 shows frequency spectrum of the phase voltage for m_a= 0.8. It shows THD of 15.38%.

C. For modulation index m_a=0.9

For modulation index m_a= 0.9, the waveform of line voltage $V_{ab}$of inverter is shown in Fig. 13.Similar waveforms can be obtained for the other line voltages VbcandVca. From the waveform it is clear that the output waveform is PWM wave and the frequency of the output voltage wave is 50 Hz and its amplitude is 220V.

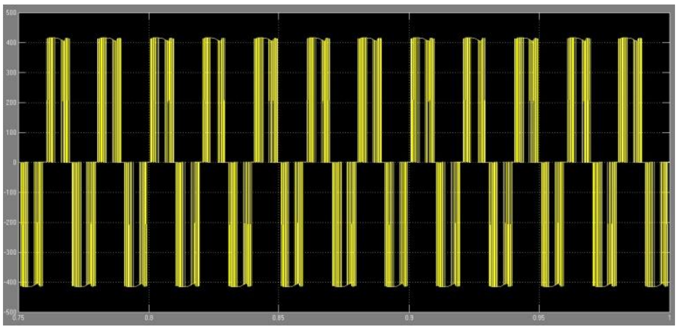

Fig. 13.Waveform of line voltage Vab for m_a = 0.9

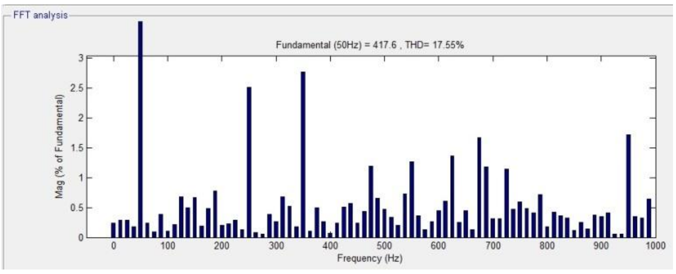

Fig. 14 FFT analysis in line voltage Vab for m_a = 0.9

Fig. 14 shows the frequency spectrum of the line voltage. The value of the THD is 17.55% for the value of M_a= 0.9. From the waveforms it is clear that the dominant harmonic is the third harmonic.

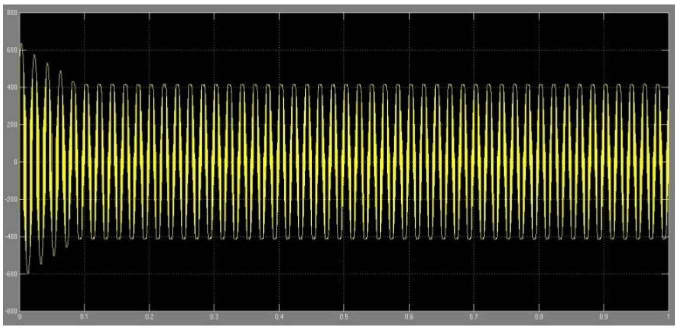

Fig. 15Phase 'a' voltage waveform for m_a= 0.8

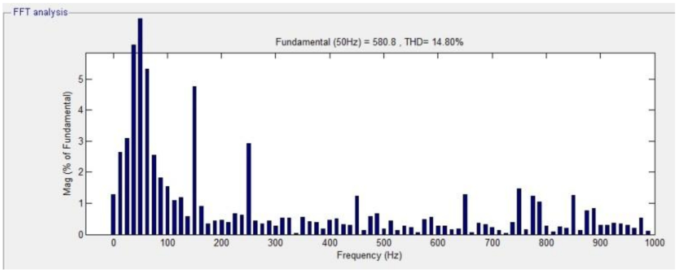

Fig. 16 FFT analysis in phase voltage 'a' for m_a = 0.8

Fig. 15 shows the waveform and Fig. 16 shows frequency spectrum of the phase voltage for m_a= 0.9. It shows THD of 14.80%.

VII. COMPARISON OF LINE AND PHASE VOLTAGE FOR VARIOUS MODULATION INDEX

S. No.	M_a	Line Voltage	Phase Voltage
1	0.7	22.36	17.74
2	0.8	19.95	15.38
3	0.9	17.55	14.80

VIII. CONCLUSION

The paper presents improvement in performance analysis of three phase induction motor fed by PWM voltage source inverter in under variable modulation range.The analysis has been carried in the modulation range 0 to 1.

The effect the modulation index on the motor performance in terms of the line voltage and phase voltage has been carried out. Its impact on the performance of the motor in terms of the transients and steady state response has been presented. The main positive point of this paper is that it reviles the performance or behavior of the three phase VSI as well asthe motor for the entire range of under modulation index. There is appreciable improvement in THD in inverter line and phase voltage as the modulation index is rises up and close to unity. Total harmonic distortion THD in line and phase voltage lowered as the value of modulation index rises its level.

REFERENCES

[1] M. Depenbrock, “Pulse width control of a threephaseinverter with non sinusoidal phase voltageof a three-phase PWM inverter”, Proc. IEEE Int.semiconductor Power Conversion Conf.,Orlando, Florida, USA, pp. 399-403, 1977.

[2] G. Dong, “Sensorless and efficiency optimizedinduction motor control with associated converterPWM schemes”, PhD Thesis, Faculty ofGraduate School, Tennessee TechnologicalUniversity, Dec. 2005.

[3] Muhammad H. Rashid, "Power Electronics; Circuit'sDevices andApplications”, Third Edition, PrenticeHall. 2004.

[4] B. Ismail, S.Taib MIEEE, A. R MohdSaad, M. Isa,C.M. Hadzer “Development of a Single Phase SPWMMicrocontroller-Based Inverter” First InternationalPower and Energy Coference PE Con 2006 November28 -29, 2006, Putrajaya, Malaysia.

[5] Mr. R.Senthilkumar,M.Singaaravelu “DesignOf Single Phase Inverter”, dsPIC30F4013International Journal ofEngineering Science andTechnology Vol. 2(11), 2010, 6500-6506.

[6] J. Kim, J. Hong, K. Nam “ A Current Distortion Compensation Scheme For Four-switch Inverters”,*IEEE Transactions on Power Electronics*, Vol. 24, No.4, April 2009, pp. 1032 – 1040.

[7] A. Iqbal, I. Lamine, Ashraf and Mohibullah,” Matlab/Simulink model for space vector modulation of three-phase VSI”, IEEE UPEC 2006, 6-8 Sept., New Castle, UK, Vol. 3, pp. 1096-1100. 2006.

[8] M.P. Kazmierkowski, R. Krishnan and F. Blaabjerg, “Control in power electronics- selected problems”, Academic Press, California, USA. 2002.

[9] R. J. Kerkman, B. J. Seibel, D. M. Brod, T. M. Rowan, and D. Branchgate, “A simplified inverter model for on-line control and simulation, IEEE Trans. Ind. Applicat., Vol. 27, No. 3, pp. 567–573. 1991.

[10]. Divyashree S, Sanjay Kumar N.V, Dr. Y. P. Gowramma. "A FAULT NODE RECOVERY ALGORITHM TO REINFORCES THE LIFETIME AND ROUTING IN WIRELESS SENSOR NETWORK." *International Journal of Advanced Technology in Engineering and Science* 3.Special Issue No. 01 (2015): 121-126.