Three Phase Voltage Source Inverter for Harmonic Improvement using Microcontroller and Simulation in MATLAB

D. O. Sakle[1], G. A. Kulkarni[2], D. R. Khadse[3]

[1,2,3]*Electronics and Telecommunication Engineering, Shri Sant Gadge Baba College of Engineering and Technology, Bhusawal, India*

***Abstract*— This paper presents a three phase inverter with Sinusoidal Pulse Width Modultion switching scheme. The Sinusoidal pulse width modulation scheme is used as a switching pulse for turning on and off thyristors to generate alternating current waveform at the output of an inverter circuit. Prototype hardware is developed using PIC 16F877A microcontroller and Simulation is carried out using SIMULINK/MATLAB. PIC 16F877A microcontroller is used for generation of PWM signal with variable switching frequency.The proposed IGBT inverter is working on high switching frequency PWM signal which is applied from PIC16F877A microcontroller.Improvement in harmonics was observed.**

***Keywords- Harmonic, PWM, Inverter, MATLAB, Microcontroller*.**

I.INTRODUCTION

The fundamental voltage distortion in distribution systems (harmonic distortion) became one of the most investigated areas since the late 1970s or early 1980s, when power electronics was initiated within industrial plants. Since then, power electronics has been used to satisfy commercial, industrial and residential requirements in one form or the other [1].

Harmonics are one of the major concerns in aninverter. It causesdistortion in current and voltage waveforms resulting into distortion. Harmonics present in power system also has non-integer multiples of the fundamental frequency and have periodic waveform. The harmonics are generated in a power system from two distinct types of loads such as linear load and non linear load.IEEE 519, 1992 defines a harmonic as, "A sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency" [2].

With advances in solid-state power electronic devices and microprocessors, various inverter control techniques employing pulse-width-modulation (PWM) techniques are becoming increasingly popular in AC motor drive applications. These PWM-based drives are used to control both the frequency and the magnitude of the voltages applied to motors [3].

A) Pulse Width Modulation:

Because of advances in solid state power devices and microprocessors, switching power converters are used in more and more modern motor drivers to convert and deliver the required energy to the motor [4-5]. Task of inverter is to convert DC input voltage to AC voltage with desired magnitude and frequency.

Output voltage regulation is made as constant or variable frequency. Variable output voltage can be obtained keeping constant inverter gain and adjusting DC input voltage. Another method, if DC input voltage is constant and not adjustable, variable output voltage can be obtained by adjusting the inverter gain, this is provided by PWM control of inverter [6].

The basic PWM techniques are:

1. Single Pulse Width Modulation
2. Multi Pulse Width Modulation
3. Sinusoidal Pulse Width Modulation (SPWM)

Sinusoidal pulse width modulation (SPWM) is widely used in power electronics to digitize the power so that a sequence of voltage pulses can be generated by the on and off of the power switches. The PWM inverter has been the main choice in power electronic for decades, because of its circuit simplicity and rugged control scheme. Sinusoidal Pulse Width Modulation switching technique is commonly used in industrial applications or solar electric vehicle applications.SPWM techniques are characterized by constant amplitude pulses with different duty cycles for each period. The width of these pulses are modulated to obtain inverter output voltage control and to reduce its harmonic content. Sinusoidal pulse width modulation is the mostly used method in motor control and inverter application [7].

B)Hardware Implementation

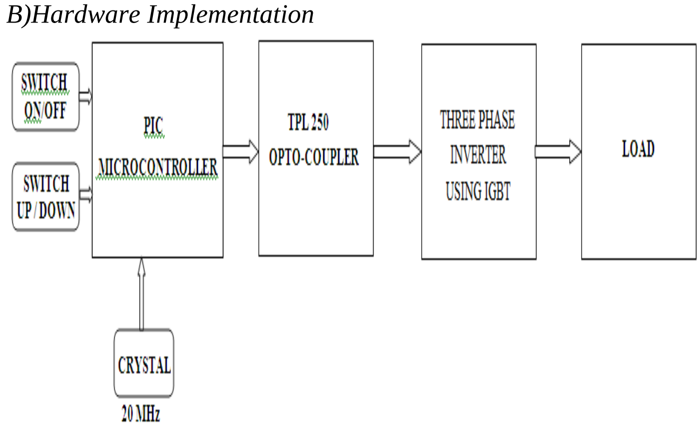

Fig. 1 Block diagram of the hardware design.

The block diagram of PIC based PWM inverter is shown in figure (1). As shown in order to design this PWM inverter, the entire design process is divided into various small modules. The functionality of each section is tested separately.

*1) PWM Generation using PIC microcontroller:*The PIC microcontroller is used to generate the SPWM signal. In case of single phase inverter we require four different PWM pulses while for three phase inverter we need six pulses. These pulses will drive the IGBT, when the pulse is high the IGBT will turn ON and when the pulse is low the IGBT will turn OFF. By varying the turn ON and turn OFF time it is possible to control the output voltage of inverter. In this project author used PIC 16F877A microcontroller for generation of SPWM pulses as shown in following fig (2).

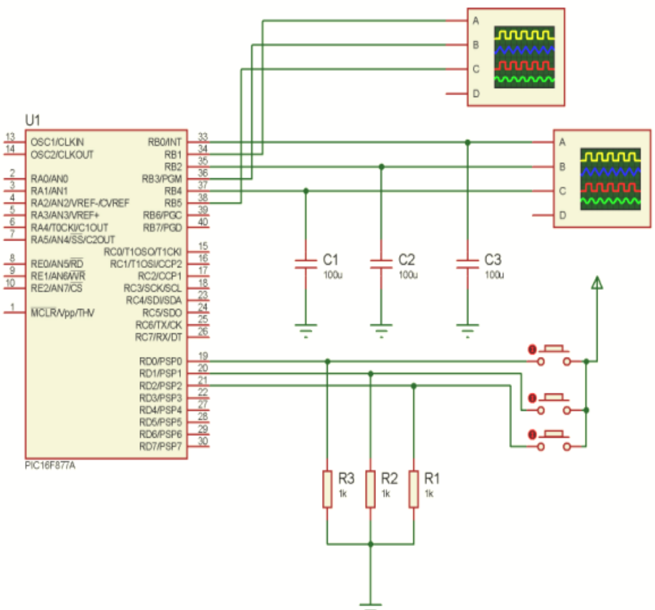

Fig. 2SPWM generation by PIC microcontroller.

The generated SPWM pulses are shown in figure (3),these pulses will be used for switching function of three phase inverter.

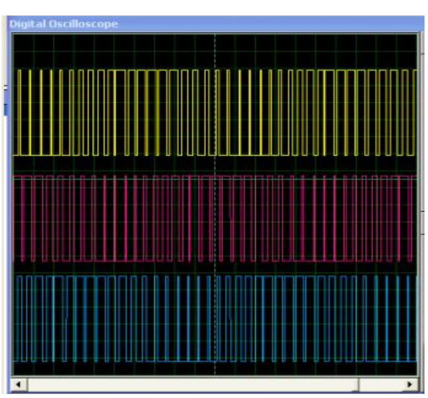

Fig. 3 Generated SPWM pulses

*2) IGBT Gate Drive:*Gate drive circuit for MOSFETs and IGBTs usually contains input opto-isolation, input buffer amplifier and totem pole arrangement of gate driving transistor with high current sink and source capability. There are number of gate driver ICs available in the market that are designed to drive power transistors such as MOSFETs, IGBT [8].

The gate driver IC used in this project is Toshiba TLP250, which is an 8-pin photocoupler designed exclusively for use with IGBT. The Toshiba TLP 250 has the ability to drive the IGBTs and power MOSFETs directly, making system design easier, allows simpler circuit configurations and improves system reliability [9]. The details of the Toshiba TLP250 are given in below fig (4),

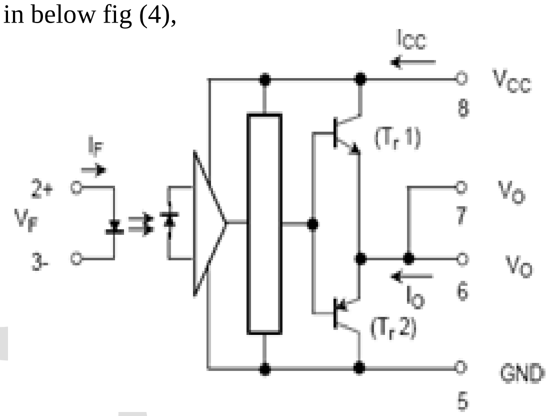

Fig. 4: Schematic of Toshiba TLP 250.

3) Three Phase Voltage Source Inverter:

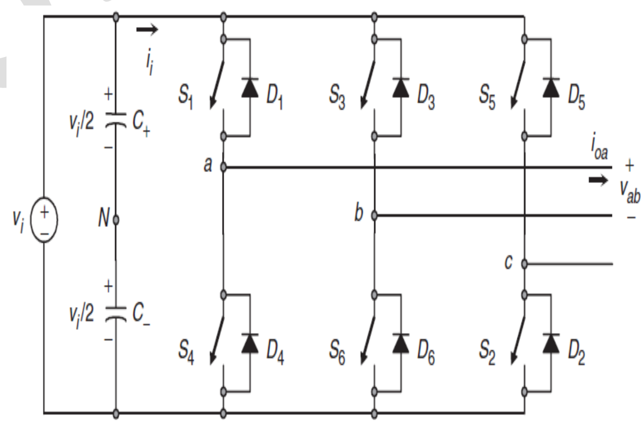

Fig. 5:Three phase Voltage Source Inverter topology.

A three phase voltage source inverter is shown in fig. (5). If the two switches of any leg are ON then the dc supply voltage v_i is shorted, e.g. for if switch S1 and S4 are ON then the leg a becomes short result in dc supply voltage vi becomes get shorted and the output voltage becomes zero.The six valid switch states that produce non-zero ac output voltage of three phase inverter is shown in table 1.The remaining two states (7 and 8 in Table 15.3) produce zero ac line voltages.

TABLE I

Valid switch states for a three phase VSI [10].

State	State #	v_{ab}	v_{bc}	v_{ca}
S_1, S_2 and S_6 are on and S_4, S_5 and S_3 are off	1	v_i	0	$-v_i$
S_2, S_3 and S_1 are on and S_5, S_6 and S_4 are off	2	0	v_i	$-v_i$
S_3, S_4 and S_2 are on and S_6, S_1 and S_5 are off	3	$-v_i$	v_i	0
S_4, S_5 and S_3 are on and S_1, S_2 and S_6 are off	4	$-v_i$	0	v_i
S_5, S_6 and S_4 are on and S_2, S_3 and S_1 are off	5	0	$-v_i$	v_i
S_6, S_1 and S_5 are on and S_3, S_4 and S_2 are off	6	v_i	$-v_i$	0
S_1, S_3 and S_5 are on and S_4, S_6 and S_2 are off	7	0	0	0
S_4, S_6 and S_2 are on and S_1, S_3 and S_5 are off	8	0	0	0

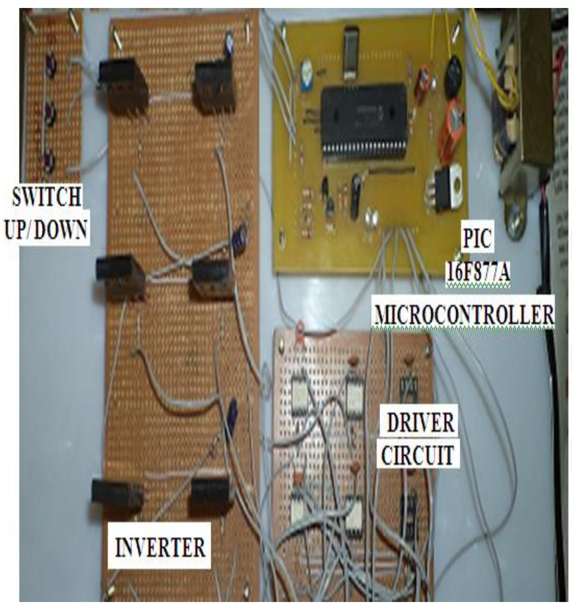

Fig. 6Hardware prototype of three phase Voltage Source Inverter.

C) MATLAB Based Simulation

The three phase voltage source PWM inverter model simulated in MATLAB is shown in figure (7).

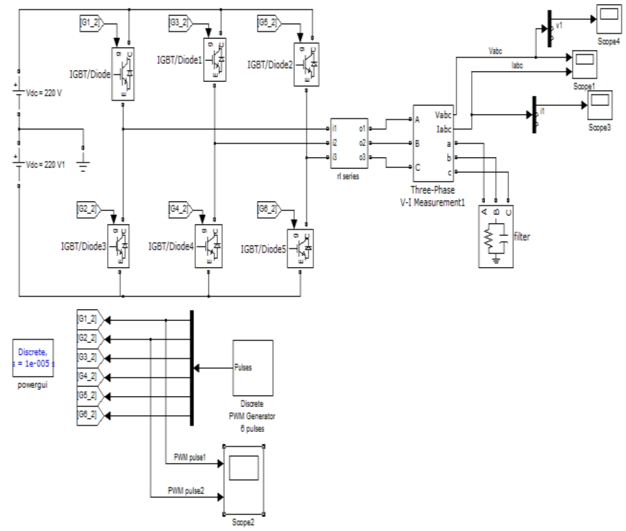

Fig.7 Simulink model for Three Phase Voltage Source inverter.

D) Hardware and Simulation Results.

*1) Hardware Results:*The hardware results were tested on Digital Oscilloscope at various test points. The snapshots of these results were shown in fig (8-10),

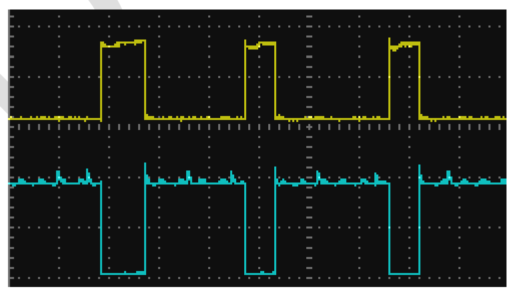

Fig.8 PWM Signal generated by PIC 16F877A microcontroller.

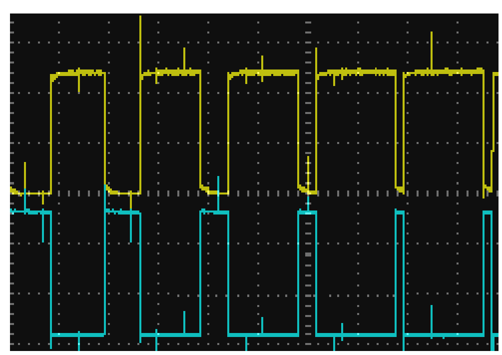

Fig. 9Gate driver Toshiba TLP250 output.

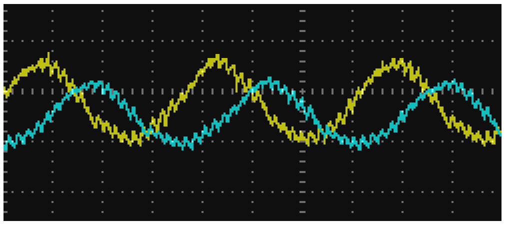

Fig. 10 Output of two phases of the three phase inverter.

*2) Simulation Results:*The results obtained by simulating the circuit are shown in figures (11-17). Here we have analyzed the inverter performance for various modulation index which ranges from m = 0.3 to 0.9 (less than m=1). At each modulation index the total harmonic distortion is shown using FFT analysis.

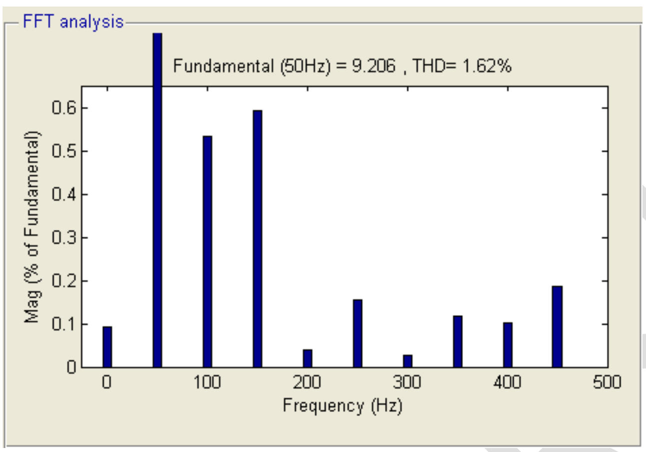

Fig. 11: FFT analysis of Three phase Voltage Source Inverter for m=0.9

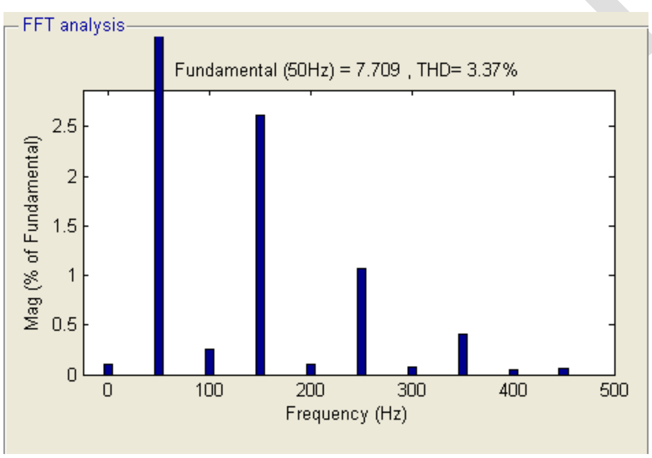

Fig. 12: FFT analysis of Three phase Voltage Source Inverter for m=0.8

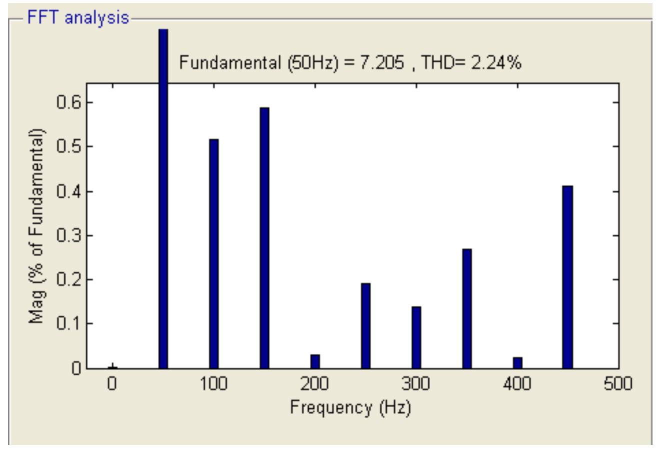

Fig. 13: FFT analysis of Three phase Voltage Source Inverter for m=0.7

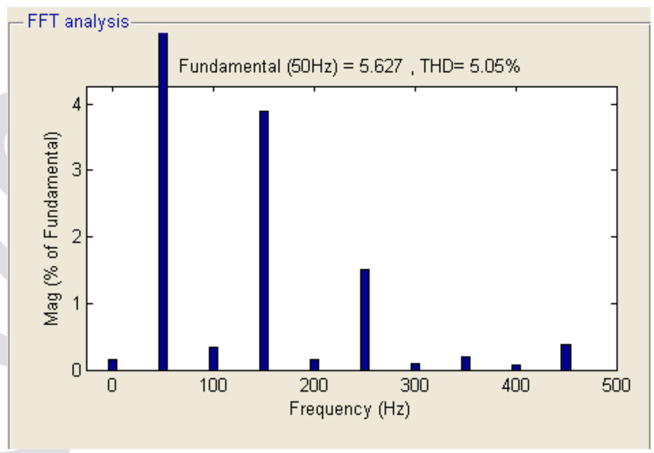

Fig. 14: FFT analysis of Three phase Voltage Source Inverter for m=0.6

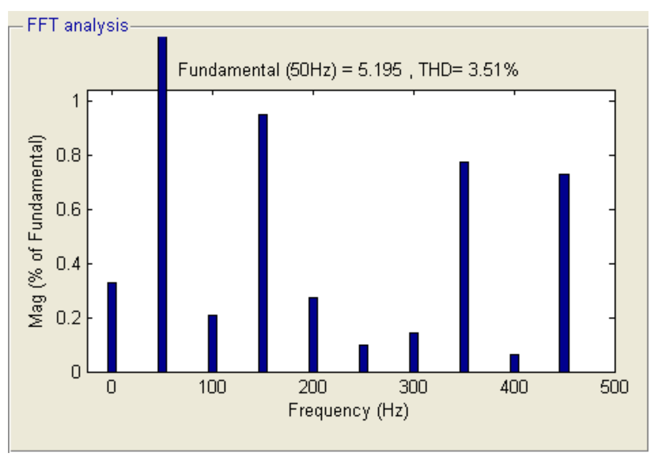

Fig. 15: FFT analysis of Three phase Voltage Source Inverter for m=0.5

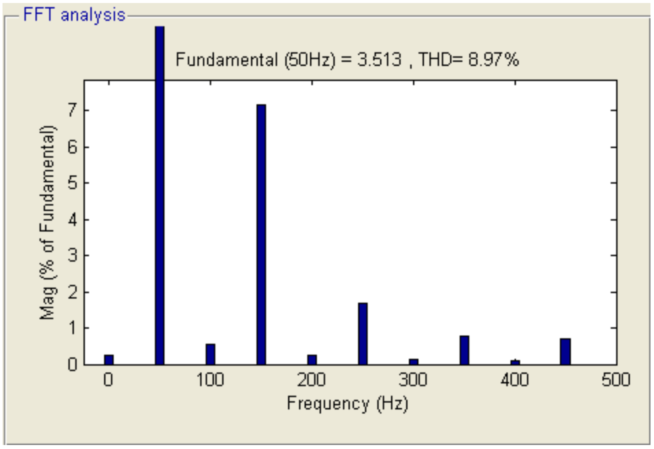

Fig. 16: FFTanalysis of Three phase Voltage Source Inverter for m=0.4

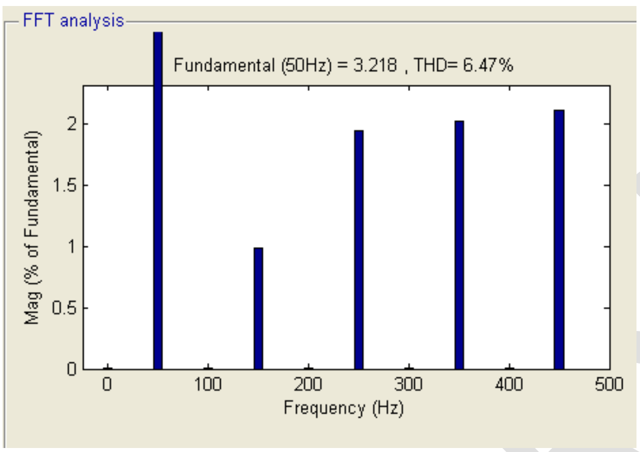

Fig. 17: FFT analysis of Three phase Voltage Source Inverter for m=0.3

TABLE 2

Total harmonics with modulation index

Duty Cycle	Fundamental at 50 Hz	THD%
0.9	9.206	1.62%
0.8	7.709	3.37%
0.7	7.205	2.24%
0.6	5.627	5.05%
0.5	5.195	3.51%
0.4	3.513	8.97%
0.3	3.218	6.47%

From above table it is observed that the maximum harmonic distortion and the minimum harmonic distortion on the variation of modulation index between the range of 0.3 to 0.9 and it's clear that the modulation index at 0.9 having minimum harmonic distortion of 1.62% and the modulation index at 0.4 having minimum harmonic distortion 8.97%.

CONCLUSIONS

From above result it is seen that when the switching frequency is low, the inverter circuitprovides high harmonics. As the frequency goes on increasing harmonics are reducing according to increasing of variable frequency with their duty cycle. Low switching frequency shows high harmonics signal, while high switching frequency produce low harmonics. The study shows improvement in harmonics. The variation of modulation index is varied from 0.3 to 0.9 for total harmonic distortion measurement. Thus it is clear that PWM inverters are efficient and also improves quality.

REFERENCES

[1] Ahmed AhsanLatheef, "Harmonic Impact of Photovoltaic Inverter Systems on Low and medium voltage distribution systems", School of Electrical, Computer and Telecommunications Engineering, University of Wollongong, 2006.

[2] IEEE Std 519-1992 (Revision of IEEE Std 519-1981), IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.

[3] H. Salehfar, "DSP-Based Implementation of Vector Control of Induction Motor Drives," Taylor & Francis Group, LLC, 2005.

[4] Mehmet Yumurtaci, SeydiVakkasUstun, SecilVarbakNese and HasanCimen, "Comparison of Output Current Harmonics of Voltage Source Inverter used Different PWM Control Techniques", WSEAS Transactions on Power Systems, Issue 11, Vol. 3, Nov. 2013, pp. 695-704.

[5] Yu, Z., Mohammed, A., Panahi, I., A Review of Three PWM Techniques, Proceedings of American Control Conference, Vol.1, 4-6 June, 1997, pp.257-261.

[6] Đncekara, B., Implementation of PWM Inverters, M. Sc. Thesis, Yıldız Technical University, Science and Technology Institute, Đstanbul, 2000.

[7] Nazmul Islam Raju, Md. Shahinur Islam, Ahmed AhsanUddin, "Sinusoidal PWM Signal Generation Technique for Three Phase Voltage Source Inverter with Analog Circuit & Simulation of PWM Inverter for Standalone Load & Micro-grid System", International Journal of Renewable Energy Research, Vol.3, No.3, pp. 647-658.

[8] AmolSutar, SatyawanJagtap, "Advanced Three Phase PWM Inverter Control Using Microcontroller", IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), Volume 5, Issue 2, Mar. - Apr. 2013, PP 21-28.

[9] "IGBT/Power MOSFET Gate Drive Photo-IC Couplers TLP250 (Inv)/TLP250F (Inv)", TOSHIBA Corporation, Japan, 1999.

[10] M. A. Latif, M. J. Alam, M. A. Rashid, A. Karim, N. H. Ramly, I. Daut, "Microcontroller based PWM Inverter for Speed Control of a Three Phase Induction Motor", Engg Journals Publications, 2013, pp. 624-630.