International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 11, November - 2013

Electronics Simulation of Phase Shift Circuit for Three-Phase Pulse Width Modulated (PWM) Inverter

Ogunyemi Joel
Electrical Engineering Department,
Federal Polytechnic Ilaro

Abstract

This paper presents design of the firing circuit for a three phase inverter using the pulse-width modulation (PWM) technique. The PWM control of induction machines is now being increasingly applied to reduce harmonics inherent in other methods of control. The design adapts a phase shifting technique to obtain the three phase sinusoidal input for the PWM method. Electronic simulation was used to validate the design. The results of the simulation presented shows that the design procedure used was correct.

Introduction

Pulse width modulation (PWM) technique has been increasingly used in inverter designs. An inverter can convert a fixed dc voltage to a variable or fixed ac voltage and/or frequency. Various modulation techniques can be used to vary the output voltage. With appropriate choice of switching angles, specific harmonics can be eliminated. PWM technique also referred to as chopping control gives the most widely used techniques in power electronics as it is used in different DC/AC conversion processes. One of the advantages of PWM which makes it versatile is the easy control and implementation [4]. Many firing circuits therefore have evolved over the years using PWM techniques. The switching action in power semiconductor device is utilized to control the power delivered from DC source to AC operated load. The choice of firing circuit is very important in power inverter design. In PWM, the switching action is done in many points per cycle to generate many pulses per cycle each of which has varying width. The objective is to eliminate certain harmonics in the system as both voltage and frequency are controlled in one stage [3]. The principle is based on the comparison of analog sine wave known as reference or modulating wave with a triangular wave otherwise known as carrier wave [2]. The analog approach, though it limits the flexibility still find applications in some areas.

The components used are analog device which are locally available and relatively easy to implement when compared with tedious programming using micro processor or micro controller [5]. In order to obtain a balanced three-phase at 120^0 difference, phase shift oscillator circuit is employed. Thus three comparators are used for the three-phase with common carrier wave. The output of each comparator and its complementary signal obtained through a logic gate are the PWM waves used to trigger the six switches of the inverter for three-phase operation. The block diagram representation of the whole system is shown in fig. 1.

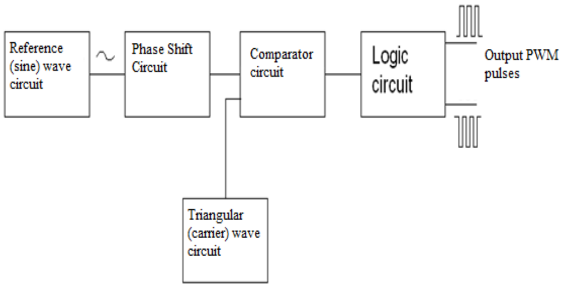

Fig 1: The Block Diagram of PWM stages

Phase Shift Circuit Design

This phase shift circuit uses an RC network in the feedback loop of op amp to generate the required phase shift at a particular frequency to sustain oscillations. They are usually moderately stable in frequency and amplitude, and very easy to design and construct [1].

The general design of the phase shift circuit is as shown figure 2a. The method employ here is using an ac signal of 50HZ the same with required output frequency. The voltage is stepped down to relatively low value of 12V. The reference sine wave is fed to the series of Phase Shift Circuits (PSC). The output of the PSCs has the same magnitude as the as the input sine wave, but the phase can be made difference. In order to obtain three set of sinusoidal wave which are 120^o apart (i.e. $0^{o,}$ 120^o &240^o); PSC1 is made to be in phase with the input. The output of PSC1 is then passed though the second phase shift circuit (PSC2) for 120^0 Phase difference. It is further phase-shifted by PSC3 to obtain 240^0. The phase between these two signals depends on the RC network. The resistor is made variable while the capacitor is fixed. Thus the signal can be controlled and varied continuously from 0 to $180^{o.}$ The detailed diagram of the Phase Shift is shown in figure 2b

Analysis of the Phase Shift Circuit

The transfer function of the phase shift circuit (fig 2a) is

$$H(s)=\frac{V_{out}}{V_{in}}=\frac{1-sCR}{1+sCR}---------1$$

$$H(j\omega)=\frac{1-j\omega CR}{1+j\omega CR}-----------2$$

The gain is

$$|H(j\omega)|=H(\omega)=\frac{\sqrt{1+(\omega CR)^2}}{\sqrt{1+(\omega CR)^2}}=1$$

That is a unity gain. The phase φ is

$$\varphi=-2\tan^{-1}(\omega CR)---------------3$$

The phase Shift is therefore a function of R&C

Note It can be observed that the gain is independent of RC.

A fixed value of 10uF is chosen for capacitor and value of resistor R to get 120^0 is obtained as follows;

From equation 3 above,

$$R=\frac{\tan\left(\varphi/2\right)}{2\pi fC}------------------4$$

$$R=\frac{\tan 60}{2\times\pi\times 50\times 10\times 10^{-6}}$$ Since $\omega=2\pi f$ Substituting the value, we have

$R=5500\Omega$ Or $5.5k\Omega$

Hence a fixed resistor of $5.6k\Omega$ is used since $5.5k\Omega$ is not available. Other alternative is to use $10k\Omega$ available and then select $5.5k\Omega$ for exact value as used in the simulation.

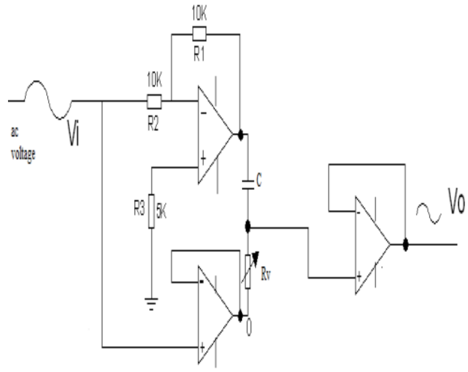

Fig2a: Phase Shift Circuit (PSC)

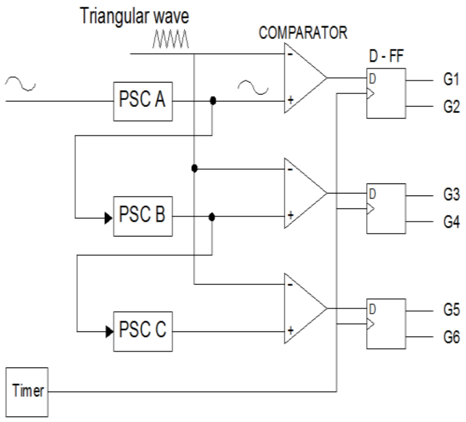

Fig2b: Phase Shift Circuit (PSC)

Simulation

The proposed circuit was first simulated using electronic simulator to validate the design. The circuit used in the simulation is shown below. The components used are ideal. The parameters used in simulations are the capacitor and the variable resistor. Different values of these components were selected. In the power section, MOSFET (N-channel) was used.

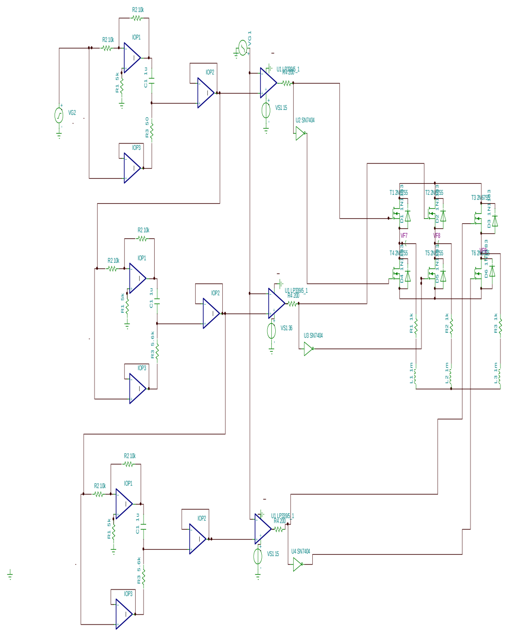

Fig3: Simulation Circuit

Results

The reference sine wave of 50Hz (single-phase) for the phase shifting is shown in fig4a and carrier wave PSC scheme for 3- phase circuit of 3 kHz used in the modulation process are shown in fig4a &b. The three-phase output of the phase shift circuit is shown in fig5. When the phase shift circuits above are fed to the three comparators for each phase with the common triangular wave, the waveforms are as shown in figures 6. It was observed that the variable resistor of 5.5k is needed to achieve120^o phase shift. During the simulation also, a 10k variable resistor was also used to show the phase shift at different stage. In order to obtain 0^0 phase, low value (fig6a) was needed while 120^0 phase shift was obtained with 50% settling the output is as shown (fig6c). The function generators on the simulator were used at different frequencies and amplitudes. The resulting chopping ratio (f_c / f_r) and the modulation index (A_r / A_c) have unique waveforms.

The design is then built and tested, and resistor or capacitor values are trimmed as necessary to provide the exact frequency of oscillation desired. Following are the output of the completed oscillator using the values calculated above:

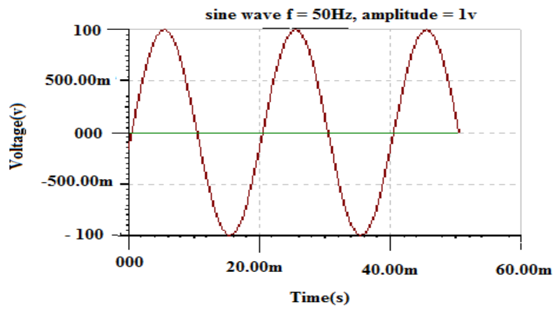

Fig4a Single-phase reference wave

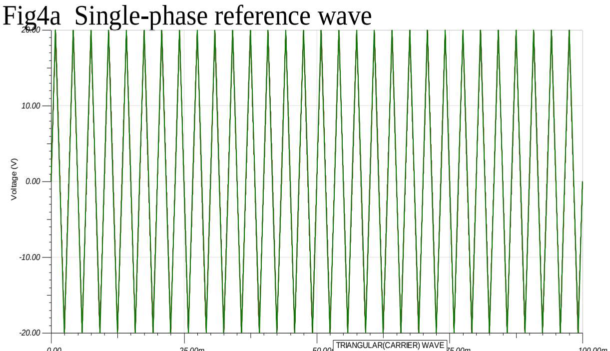

Fig4b Triangular waveform

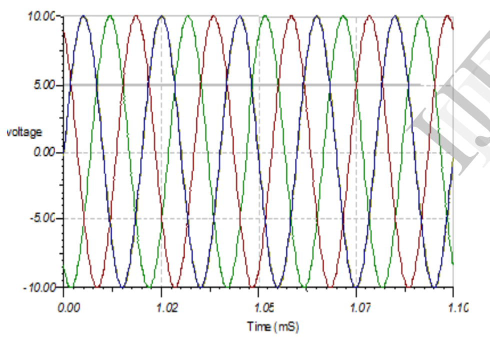

Fig5 Three- phase sine waveform output from phase shift oscillator

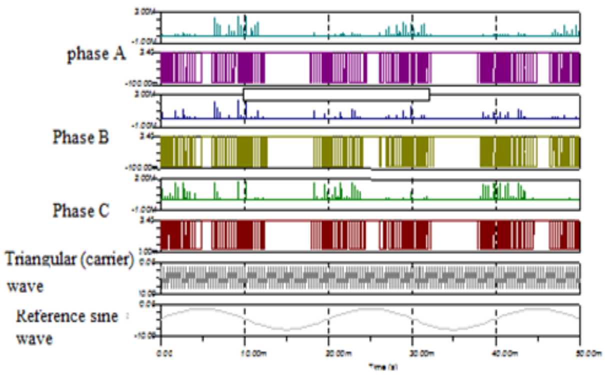

Fig:6a 0% Potentiometer (10K) setting showing no phase shift

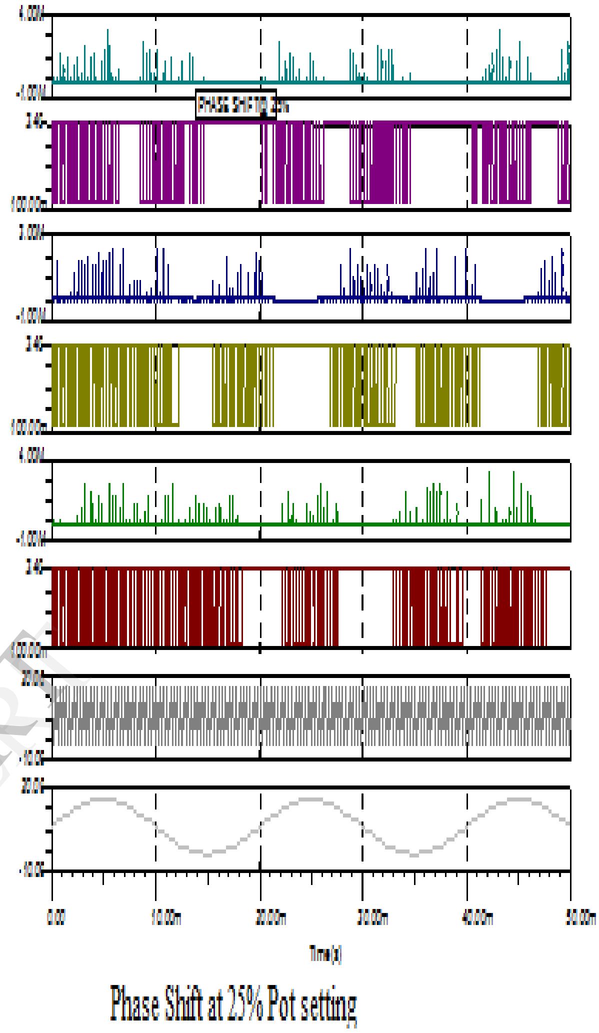

Fig: 6b

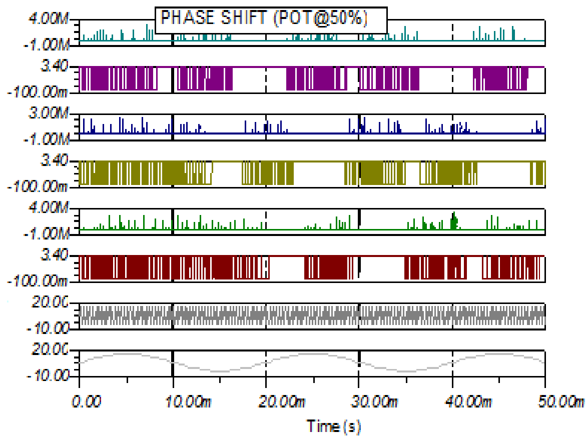

Fig: 6c Phase shift at 50% showing 120° phase shift

Conclusion

This paper has demonstrated the possibility of building a pulse width modulation generator circuit often use in application such as inverter circuit and UPS. The components used are analog devices which are locally available and relatively easy to implement when compared with tedious programming using microprocessor or micro controller. Though the latter is flexible in approach after the initial tedious programming the former can be implemented using pure hardware component only. However it presents the challenges of proper circuit design, and troubleshooting and modification in order to meet the required specification. The laboratory model has been built and under testing. The results of the simulation were presented.

References

[1] Aiken, R. (2001): Designing Phase Shift Oscillators for Tremolo Circuits (www.freepatentsonline.com, 2008).

[2] Bowes, S.R, (1992): New Sinusoidal pulse width modulation inverter. Proc Inst. Elect Engr., Vol. 122.

[3] Muhammad, H. R, (1993): Power electronics circuit, devices & application. Prentice Hall, Inc, 2nd edition.

[4] Patel, M. A. (2009); Use of PWM Techniques for Power Quality Improvement: International Journal of Recent Trends in Engineering, Vol. 1, No. 4, May 2009

[5] Younis, M. A.A, & Rahim, N.A. (2007): Three-Phase PWM Generation ASIC Design. Department of Electrical Engineering. Faculty of Engineering University of Malaya 50603 Kuala Lumpur, Malaysia.