International Journal of Electrical and Electronic Science
2018; 5(3): 71-76
http://www.aascit.org/journal/ijees
ISSN: 2375-2998

American Association for Science and Technology

Design and Simulation of an AC Drive Using SPWM Technique

Abdullah Koorvandi

Department of Electrical Engineering, Tuyserkan Branch, Islamic Azad University, Tuyserkan, Iran

Email address

k.iau@mail.com

Citation

Abdullah Koorvandi. Design and Simulation of an AC Drive Using SPWM Technique. *International Journal of Electrical and Electronic Science.* Vol. 5, No. 3, 2018, pp. 71-76.

Received: March 9, 2018; **Accepted**: April 2, 2018; **Published**: June 13, 2018

Abstract: In this paper presents a new method to extend the linearity of the sinusoidal pulse width modulation (SPWM) to full range of the pulse dropping region presented. Adjustable speed drive is an equipment that adjusts speed by external controller. Here, by comparing sine wave and carrier wave SPWM is generated. SPWM inverter produced ac, drives the single-phase induction motor. The control signal is PI controlled and speed is adjusted by changing the load as per requirement. To remove the harmonics produced by SPWM inverter filter is designed.

Keywords: PWM, SPWM Inverter, AC Drive

1. Introduction

Electrical Energy already constitutes more than 30% of all energy usage on Earth. And this is set to rise in the coming years. Its massive popularity has been caused by its efficiency of use, ease of transportation, ease of generation, and environment-friendliness. Part of the total electrical energy production is sued to produce heat, light, in electrolysis, arc-furnaces, domestic heating etc. Another large part of the electrical energy production is used to be converted into mechanical energy via different kinds of electric motors- DC Motors, Synchronous Motors and Induction Motors As fuel is getting diminished so energy savings have been a big factor nowadays. So, for saving energy with increased motor longevity adjustable speed drive is largely used nowadays.

In proper speed control we need to vary both the motor voltage and frequency to control slip. For single phase induction motors with just one phase we get a pulsating voltage only. So single phase motors artificially create a second phase to create the rotation. This second phase can be created in many ways using auxiliary windings and phase shift capacitors. So, this idea of proper speed control does not really work. The work in this paper is divided in two stages. 1) SPWM inverter design 2) PI control. An inverter is a circuit which converts a DC power into an AC power at desired output voltage and frequency. The AC output voltage could be fixed or variable voltage and frequency. This conversion can be achieved either by controlled turn on and turnoff devices (e.g. BJT, MOSFET, IGBT, and MCT etc.) or by forced commutated thyristors, depending on application [4, 6]. Pulse width modulated (PWM) voltage source inverters (VSI) are widely utilized in ac motor drive applications and at a smaller quantity in controlled rectifier applications as a means of dc to ac power conversion devices SPWM inverter design is done by using IGBT. Here, sine wave is compared to triangular wave and gate pulse is generated. During positive half cycle if IGBT2 is always OFF and if IGBT1 is ON, then IGBT4 is getting pulse and IGBT3 is getting pulse through a NOT Gate. Similarly, for the negative half cycle, if IGBT1 is always OFF and IGBT2 is ON, then IGBT3 is getting pulse and IGBT4 is getting pulse through a NOT Gate. IGBT has greater turn off time, high input impedance, high power gain. [2, 5]

paper is organized as follows, section 2 describes method. In Section 3 proposed result, in section 4 discussion and in Section 5 presents conclusion.

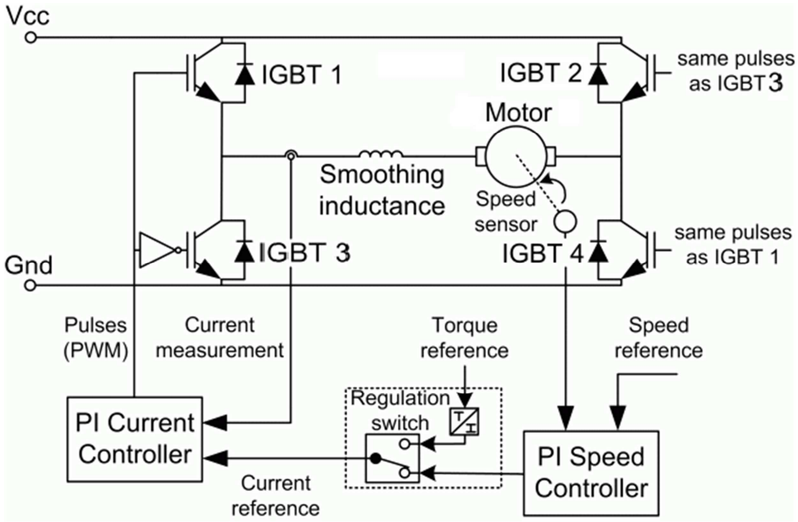

Figure 1. *Pulse width-modulated (PWM) voltage-source inverters (VSI).*

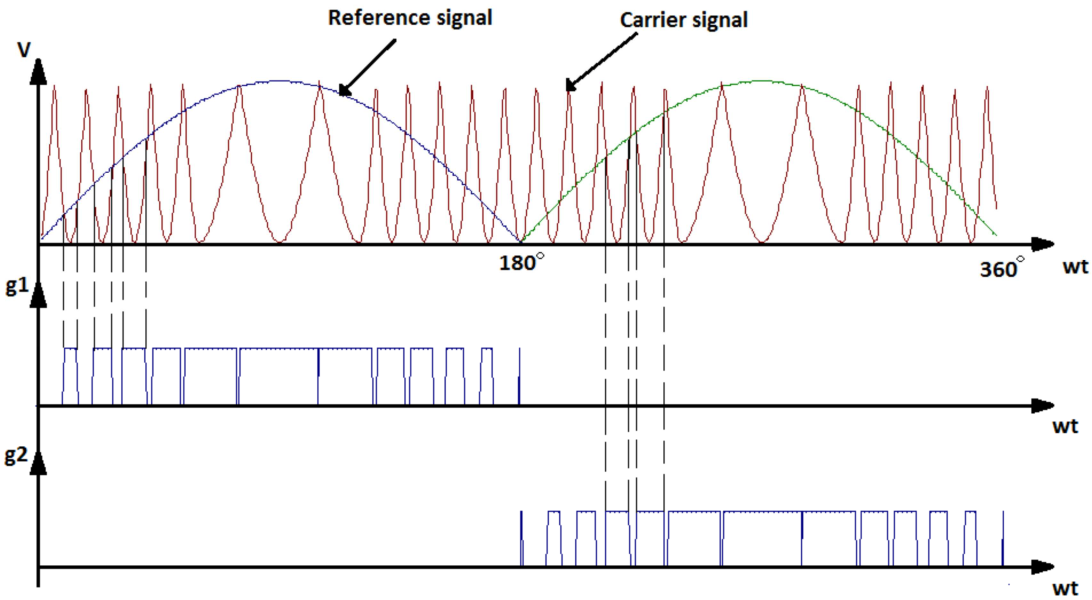

Figure 2. *Pulse width-modulated (PWM) voltage-source inverters waveform.*

2. Method

2.1. Block Diagram

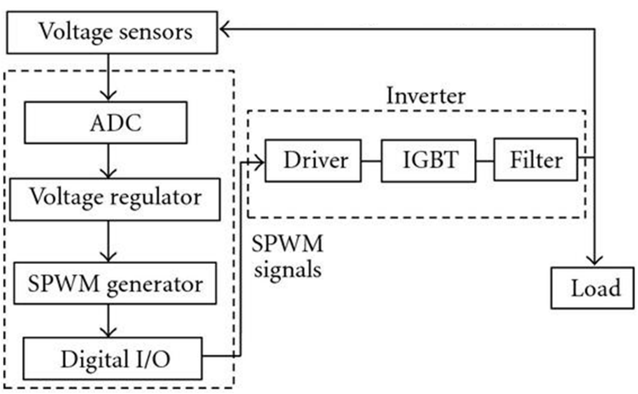

Figure 3. *Block diagram of SPWM Inverter.*

The total work done is based on a planning. The planning is one sine wave and one triangular wave (carrier wave) is compared and thus the pulse width is generated. Here by comparing two sine waves pulses are generated.

We got the Unipolar SPWM output. SPWM inverter is chosen because power loss is low and no voltage drop across the switch [2, 3, 5] Now, this voltage is filtered to reduce harmonics.

In presence of nonlinearity and parameter variation PI control gives best results. But it gives overshoot during tracking mode and load disturbance rejection. This is mainly due to the fact that the complexity of the system does not allow the gain of the PI controller to exceed a certain low value and at the starting mode the high value of the error is amplified across a PI controller causing annoyance high variations in command torque. Whenever the gains of the controlled exceed a certain value, the variation in the command torque become very high and will destabilize the system. In order to overcome this problem, it must to use a limiter ahead PI controller. Now the speed error has come within saturation limits. An Inverter is a circuit which converts a DC power input into an AC power output at a desired output voltage and frequency. This conversion is achieved by controlled turn-on and turn-off devices like IGBT"s. Ideally, the output voltage of an Inverter should be strictly sinusoidal. However, the outputs are usually rich in harmonics and are almost always non-sinusoidal. Square-wave and quasi-square-wave voltages are acceptable. The DC power input to the inverter may be a battery, a fuel cell, solar cell or any other DC source. Most industrial applications use a rectifier which takes AC supply from the mains and converts it into DC to feed it to the inverter. [4, 6, 10] Modelling a single-phase Inverter consists of the following steps:

i. Designing a Power Circuit.

ii. Designing a Control Circuit.

2.2. Related Work

There are various kinds of modulation that are used for the communication of information. When the amplitude of a high frequency signal is varied according to a low frequency signal it is called AM, or Amplitude Modulation. When the frequency of a signal is modified according to the modulating signal, it is called FM, or Frequency Modulation. These are the two schemes most commonly used in radio transmissions. Since communication via pulses has been introduced, the amplitude, frequency and width of pulses started being modulated by the message signal. The latter gave rise to PWM, or Pulse-Width Modulation. The various kinds of PWM are:

i. Linear PWM: This is the simplest scheme where the average ON time of the pulses is varied proportionally with the modulating signal.

ii. Sawtooth PWM: In this scheme, the comparison of the signal is made with a sawtooth wave. The output signal goes high when the signal is higher than the sawtooth and goes low when it is lower. This is done with the help of a comparator. This helps in the generation of a fixed frequency PWM wave.

iii. Regular Sampled PWM: Here, the width of the pulse is made proportional to the value of the modulating signal at the beginning of the carrier period [8, 9].

2.3. Proposed Method

This project is to design a SPWM inverter with reduced harmonics and drive a single-phase induction motor and adjusting the speed by a closed loop control of PI controller. SPWM are of two types (i) Bipolar, (ii) Unipolar.

Bipolar technique is a 4-quadrant technique. So, its generating mode's back emf is greater than motoring mode.

Motor current is always flowing through the single shunt resistor, regardless of which state the PWM signal is in, with bipolar PWMs, if the pulse width for one of the PWM states is too short, it can simply flip to the other PWM state, where the shunt signal will be correspondingly longer. So, we expect to have at least one interval within each PWM cycle (regardless of the duty-cycle value) where the shunt signal width is wide enough to easily facilitate an accurate reading of the motor current [5]. But, it contains more harmonics than unipolar. For unipolar SPWM, THD performance is better, Filter requirement is less but due to the presence of zero state it opens a leakage current path. Here, unipolar SPWM inverter is designed.

Filter design is the process to eliminate harmonics, which are produced from SPWM inverter. Here, the LC filter can be calculated as bellow:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

1. LC filter is loss less.
2. Ripple is less.

This voltage is applied to single phase induction motor, then the speed output is compared to a reference speed and then it is PI controlled. To avoid the problem of high command torque and destabilization a limiter is given. Finally, the speed is adjusted and as the name suggests adjustable speed drive is done.

3. Result

3.1. Simulation

Simulation is a process of creating and analyzing a physical model to predict its performance. Here, simulation blocks are used from simulation library and connection is done. The data is given and finally implementation is done.

The idea of the project is implemented and the main circuit diagram is given.

Here, a SPWM Inverter is designed and DC voltage is given to it, DC is converted to ac and a single-phase induction motor is driven by this ac o/p and speed of this motor is adjusted by closed loop speed control method. The output of the inverter is fed to motor and then speed is controlled by PI controller is shown.

Here, sine wave is compared to triangular wave (carrier wave) and gate pulse is generated.

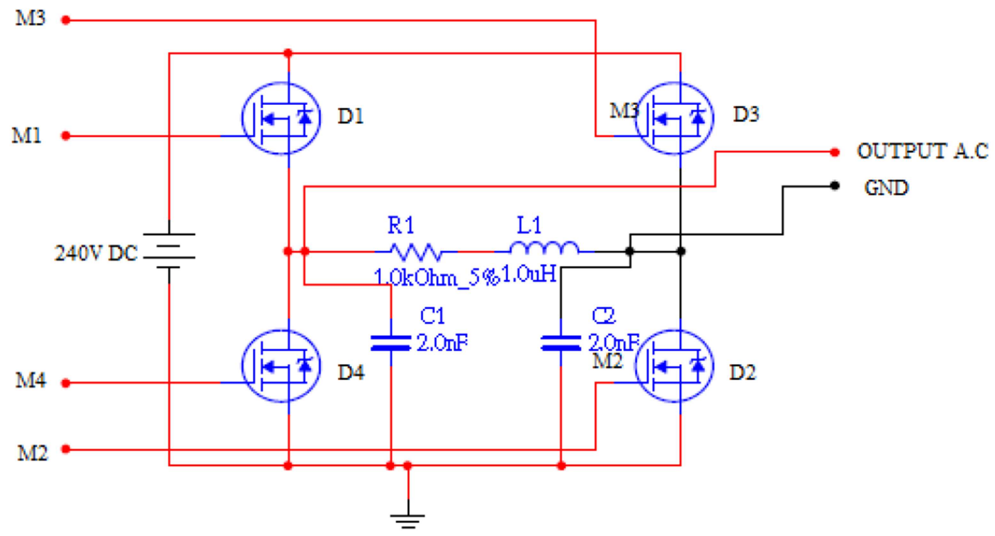

Figure 4. *Speed control through the AC SPWM.*

3.2. Experimental Results

Induction Motors account for more than 85% of all motors used in industry and domestic applications. In the past they have been used as constant-speed motors as traditional speed control methods have been less efficient than speed control methods for DC motors. However, DC Motors require commutators and brushes which are hazardous and require maintenance. Thus, Induction Motors are preferred. The experiment shows the results (i) SPWM inverter output without using filter, (ii) SPWM inverter output with using filter, (iii) motor output. The turn on-off switching pulse is obtained from MATLAB simulation.

The peak output voltage is 200v. The MATLAB Simulink simulation is used to design the SPWM generator and constructed the single-phase inverter. The simulation result is used as an indicator to design the hardware part. But the output is square waves which is full of harmonics, which is not desired. The modulation index is determined by formula m=(f_d/f_m). Max. frequency deviation of carrier (f_d) and Max. modulating frequency is (f_m) and m= modulation index.

The harmonics present in SPWM output is eliminated by LC filter. After filtering the simulation result is as given. The peak voltage is near 200v. This output is given to single phase induction motor for getting better response. For better approach harmonic trap filters can be used.

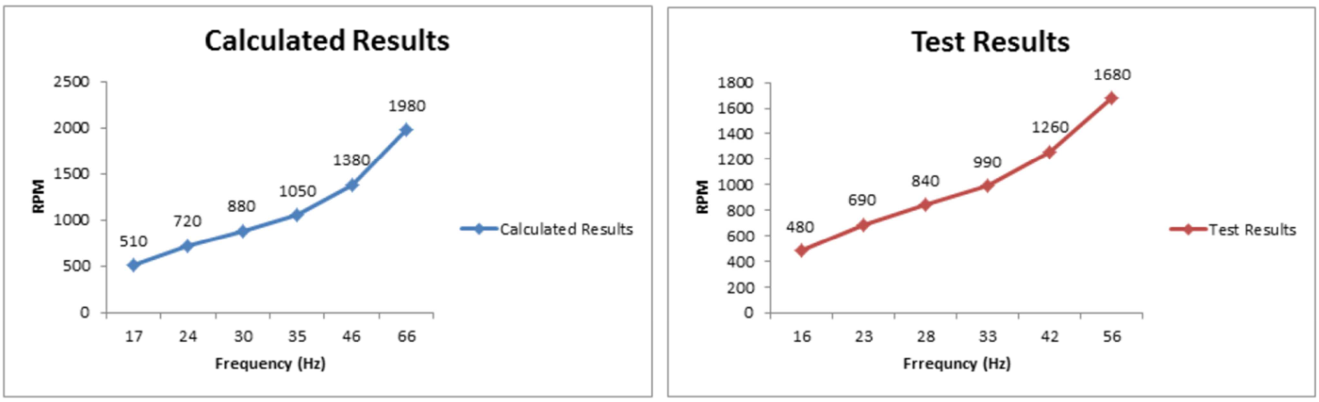

Figure 5. *Motor output and measurement results.*

Here, it can be seen here after changing the load speed is remaining constant. As, torque is proportional to voltage square so when T_m is changed voltage is also changed, and after PI control frequency is changed, so voltage and frequency ratio is remaining constant, so speed is constant. Thus, we have got the speed and electromagnetic torque as shown.

The Total Harmonic Distortion is defined as the measure of closeness in shape between a waveform and its fundamental components:

$$THD = \frac{1}{V_1}\sqrt{\sum_{n=2}^{\infty} V_i^2}$$

Where V_i is the rms value of i'th harmonic component, and V_1 is the rms value of fundamental harmonic component.

Fundamental frequency	50Hz
Carrier frequency	Fc= 5000Hz
Modulation Index	0.2,0.6,0.8
Motor Ratings	Permanent magnet stepper motor Step angle=1.8 degree , Detent Torque =0.12 NM , Flux linkage =0.005vs , R=0.7ohm, L= 4.6mH

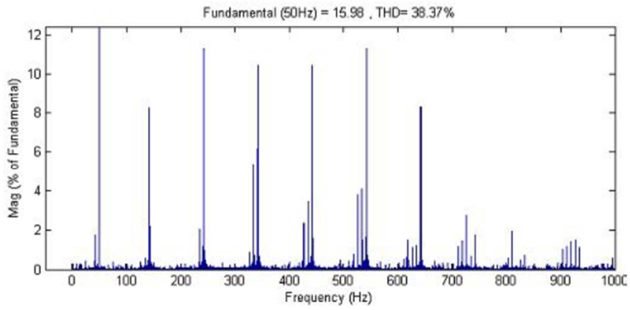

Figure 6. *Experimental Parameters and THD contents.*

4. Discussion

This project could be further researched upon and extended by considering various other advanced simulation tools, both in the hardware and in the software.

The developed control strategy is not only simple but also reliable and may be easy to implement in real-time applications using dSPACE, Data acquisition cards, TMSDSP cards, NI cardsetc. For control of various parameters and can also be combined with fuzzy, ANNs and rough sets for other applications. [6, 7]

5. Conclusion

In this paper, the development of the speed control system using frequency control has been designed by combinations of PWM control circuit, driver circuit and H-Bridge inverter. The most important parts in this research is to make a simple, robust and compact open-loop PWM controller circuit to control the SPIM. The experimental results show that the SPIM can be successfully driven to a variable frequency and speed. The frequency range of the designed variable drive circuit is 16 Hz up to 56 Hz at a constant voltage to control the SPIM speed. While the speed is limited to 480 rpm up to 1680 rpm if 50 Hz single phase AC motors are used. This report introduced adjustable speed drive system of a single-phase induction motor. We presented SPWM inverter and control its speed. When the load is changing, the voltage and frequency are changed, but voltage upon frequency ratio is constant so speed is remaining constant. Thus, the speed can be adjusted bye a system incorporating SPWM technique.

Loss of voltage is 16.5%. Actual voltage is 220V and Practical value is 180V, IEEE says harmonic content as "a measure of the presence of harmonics in a voltage or current waveform expressed as a percentage of the amplitude of the fundamental frequency at each harmonic frequency. The total harmonic content is expressed as the square root of the sum of the squares of each of the harmonic amplitudes." [5] For harmonic reduction tuned banks will be needed to eliminate all harmonics away from the system. For better approach PLC, fuzzy logic can be used. VFDs are now widely used in industry, and even in residential applications. VFDs can be used to save energy by controlling the speed of motors in several applications, use of VFDs can also be used for savings from better machinery, lower costs, better process control, and so higher productivity, quality etc. is obtained.

Demand for VFDs is highest in the Asia Pacific region, owing to presence of a large number of oil and gas companies. The Middle East, especially GCC, produces the bulk of oil and gas, employing hundreds of thousands of motors. The regional VFD manufacturing industry is quite strong, and western corporations are targeting the region, owing to its immense potential. [7]

References

[1] C S Kailash, Melvin George, Sreekanth M, Gomathy S, "The Speed Control of a 3-phase Induction Motor Using PI Control Method and Fuzzy Logic Control Method" international journal on emerging technology and advanced engineering, ISSN 2250-2459, ISO 9001:2008 certified journal, volume 5, issue 3, pp: 601-602, 2015.

[2] B. J. Baliga, Power Semiconductor Devices. Boston: PWS Publishing, 1995.

[3] A. Aminian and M. K. Kazimierczuk, Electronic Devices, A Design Approach. Upper Saddle River, NJ: Prentice Hall, 2004.

[4] A. E. Fitzgerald, Charles Kingsley, Jr. And Stephan D. Umans, "Electrical Machinery", McGraw-Hills Publications, Year 2002.

[5] Scott Wade, Matthew W. Dunnigan, and Barry W. Williams, "Modelling and Simulation of Induction Machine Vector Control with Rotor Resistance Identification", IEEE transactions on power electronics, vol. 12, no. 3, may 1997.

[6] "IEEE Standard Test Procedure for Polyphase Induction Motors and Generators", volume 112, issue 1996 of IEEE, by IEEE Power Engineering Society.

[7] H. Stemmler and T. Eilinger, "Spectral analysis of the sinusoidal PWM with variable switching frequency for noise reduction in inverter-fed induction motors, "in Proc. PESC'94, pp. 269-277.

[8] Frede Blaabjerg, M. M. Pecht, "Robust Design and Reliability of Power Electronics", IEEE Trans. on Power Electron., vol. 30, no. 5, pp. 2373-2374, 2015.

[9] S. Chowdhury, Patrick Wheeler, Chris Gerada, S. Lopez Arevalo, "A dual inverter for an open end winding induction motor drive without an isolation transformer", Conf. Proc. IEEE Applied Power Electronics Conference and Exposition, IEEE-APEC'15, Charlotte, NC, USA, pp. 283-289, 15-19 March 2015.

[10] Mohammad H. Rashid, Power Electronics Circuits, Devices & Applications. 2nd Edition Prentice Hall of India Pvt. Ltd., 1996.