Single Phase Induction Motor Solid State Drive using PWM Technique

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***Abstract*- This paper presents torque speed in single phase AC induction motor using PWM inverter. Nowadays AC induction motors are widely used in home appliances and other multipurpose instruments. An ATmega328 microcontroller (arduino uno) is used to generate the desire pulse width modulation (PWM) to optocouplers. Optocouplers function is like a driver to isolate the triggering pulse for buffering and sending to inverter where it will control the H-bridge inverter. Four IRF740 (power MOSFET) used to perform H-bridge inverter [1] and 240 Volt DC voltage supply to this inverter then due this inverter circuit it converted to AC voltage to fed induction motor. The final output will be observed by measuring the rotor speed (rad/s) and the electromagnetic torque (Nm). The simulation is done using matlab/simulink and Psim.**

Keyword: pulse width modulation, inverter and microcontroller.

I. INTRODUCTION

The inverters are widely used in electrical applications; start with small switching power in computer to large electric utility such as solar, air conditioner and motor [6]. Inverter is the devices that converts direct current (DC) into alternating current which is (AC) opposite to the function of rectifier [6]. The main problem in inverter is harmonic distortion due to several causes among them are the modulation algorithm, nonlinearities in the output filter, dead times, voltage drops across the switches and modulation of DC bus voltage [2].

The total harmonics distortion must be less than 5% according to IEEE 519 standard [8].

Due to this problem, by adjusting the switching frequency and passive filters, the lower order harmonics can be reduced [1]. The factor that contributes to the harmonics distortion and the way to reduce the distortion is studied the most popular method controls the gate of the inverter in the circuit is using PWM control [1]. Thus, a good controller circuit such as Atmega328 microcontroller is used to generate the PWM.

As for the motor, there are probably more single phase AC motors induction motors are used today than other types because of less expensive and lowest maintenance [1]. The induction motor can run only at its rate speed when it is connected to the main supply but they are constant motor. The single phase type of motor used for this circuit is main and auxiliary winding for stating torque motor [3]

II. PWM INVERTER SINGLE PHASE INDUCTION MOTOR METHOD

PWM inverter is commonly used nowadays in many applications to control motor. Figure 2.1, illustrates the block diagram adopted in this project. The rectifier converts AC to DC signal and the MOSFET will turn back DC to AC signal to start the motor, while the PWM acts as passive filter to drive the gate of MOSFET.

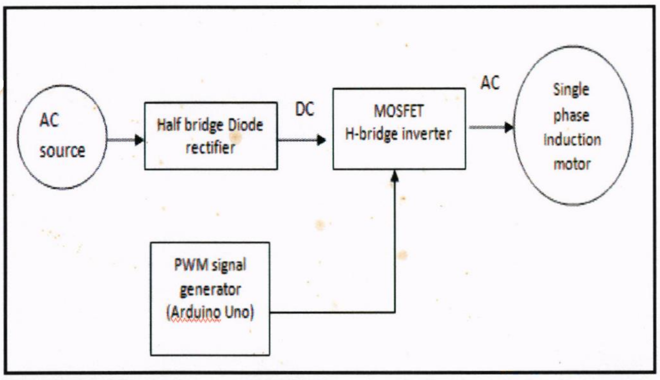

FIGURE 2.1: Block diagram of PWM inverter single phase induction motor

III. PROPOSED DESIGN FOR SINGLE PHASE AC MOTOR

A. Pulse width modulation (PWM)

PWM is a powerful technique for controlling analog circuit and is employed in a wide variety of application ranging from measurement and communications to power control conversion. In AC motor drivers, PWM inverters make it possible to control both frequency and magnitude of the voltage and current applied to a motor [4]. As a result PWM inverter powered motor drivers are more variable and offered in wide range better efficiency and higher performance compared to fixed frequency motor drivers.

The supply of PWM inverter to the ac motor is controlled by PWM signals applied to the gates of the power switches at different times for varying duration to produce the desired output waveform.

As shown in Figure 3.1, PWM is generated when sinewave is compared with high then reference voltage.

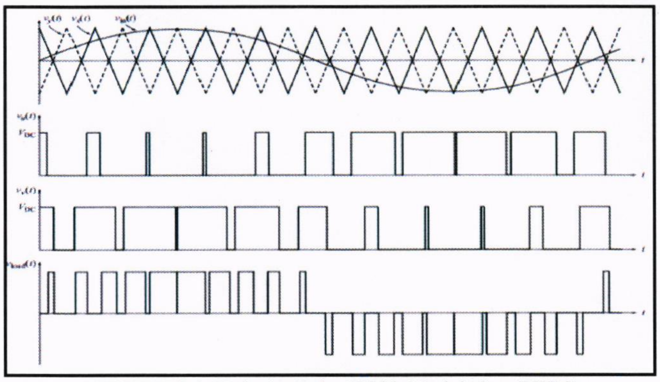

FIGURE 3.1: Unipolar Pulse Width Modulation (PWM)

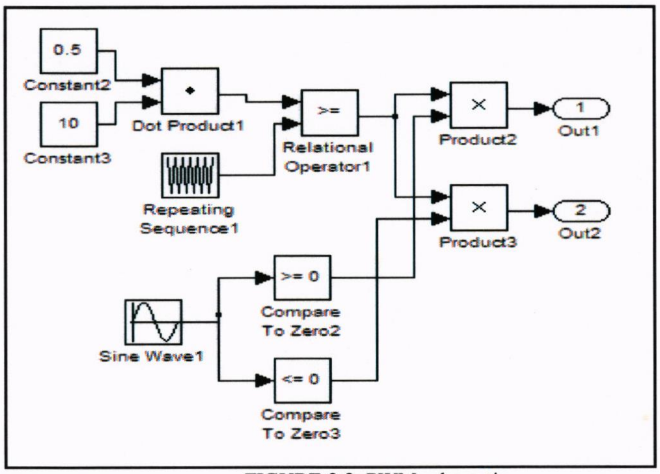

FIGURE 3.2: PWM schematic.

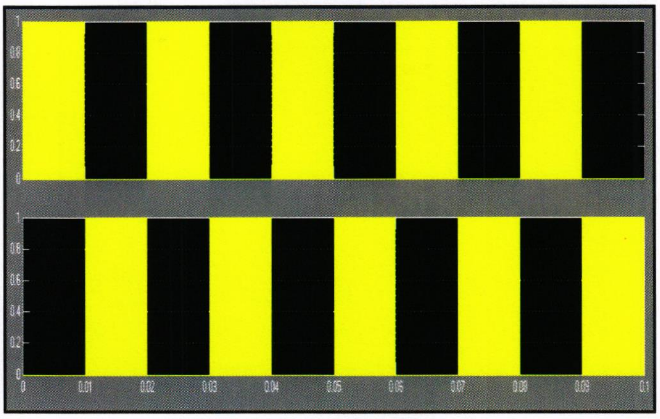

FIGURE 3.3: pulse width Modulation

Figure 3.2 and 3.3 shows the simulation and the result in simulink respectively. Where the modulation index are controlled by constant in the schematic and then compared to sinewave to get the output.

For this project circuit the PWM is generated using ATmega328 microcontroller (Arduino). By using this microcontroller it gives easier way to produce PWM to control MOSFET gate.

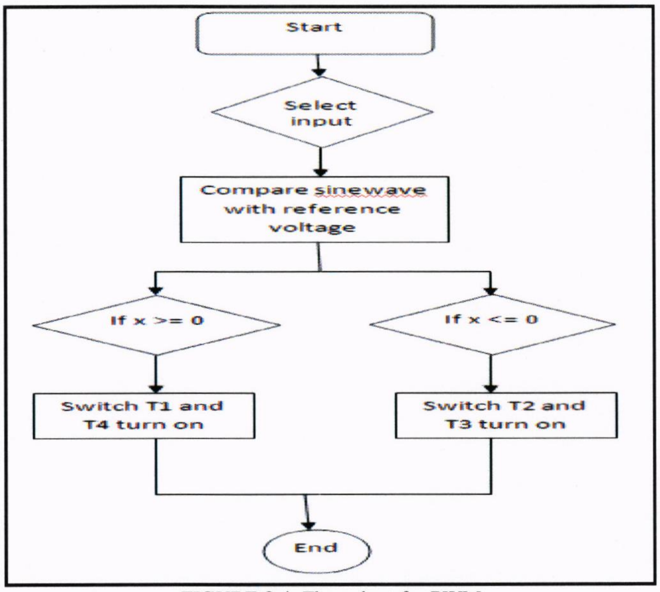

FIGURE 3.4: Flow chart for PWM

B. H-Bridge inverter using power MOSFET

Figure 3.5 shown the H-Bridge inverter design by [1] which is used IRF740 as switching device.

The operations of the inverter are;

1. T1 and T2 ON: both create short circuit across DC source and invalid
2. T3 and T4 ON: both create short circuit across Dc source and invalid
3. T1 and T4 ON: applies positive voltage (VS) to the load.
4. T3 and T2 ON: applies negative voltage (-VS) across the load.

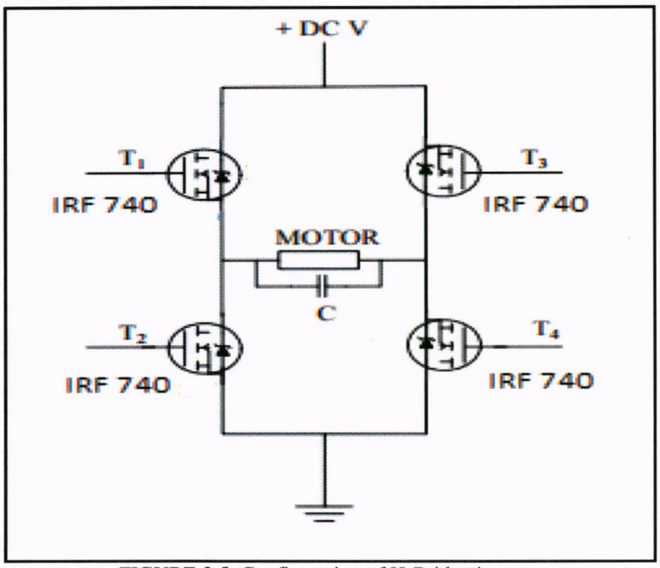

FIGURE 3.5: Configuration of H-Bridge inverter

The IRF 740 will act as switch where the PWM control the gate to allow voltage to flow and produce alternating current supply to the motor.

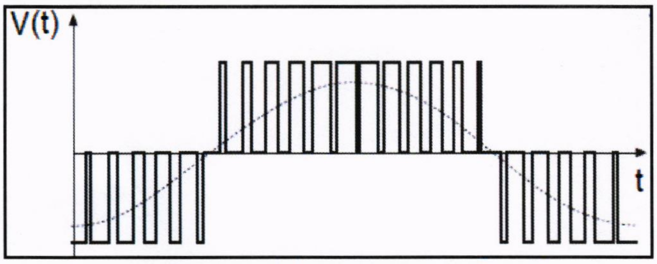

FIGURE 3.2: PWM convert to alternating current.

IV. Total Harmonics Distortion (THD)

Harmonics are related to the fundamental frequency and defined as whole number multiples by the fundamental frequency. It creates the distortion of the normal sine wave by non-linear loads [7].

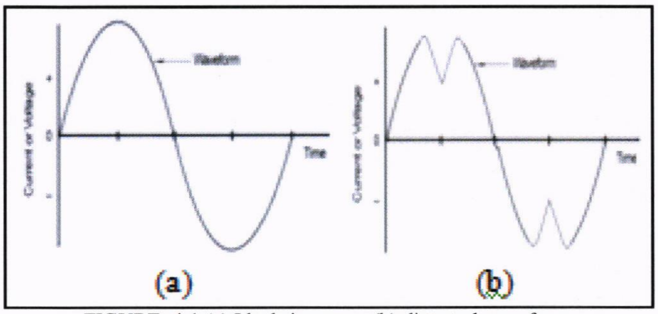

FIGURE: 4.1 (a) Ideal sine wave (b) distorted waveform.

Total harmonics distortion THD is the summation of all harmonics components of the voltage or current waveform compared against the fundamental component of the voltage or current wave. THD may be calculated by one of the following expressions by [5]:

$$THD_1 = \frac{\sqrt{\sum_{h=2}^{N/2} v_h^2}}{v1} \qquad (1)$$

$$THD_2 = \frac{\sqrt{\sum_{h=2}^{N/2} v_h^2}}{\sqrt{\sum_{k=1}^{N/2} v_h^2}} \qquad (2)$$

Where, h is the harmonics order, N is the amount of samples per period and Vh is the harmonics order h amplitude. N/2 is the maximum harmonics order. Equation (1) calculates the THD related to the fundamental (first order) power, while (2) calculate it related to the total signal power. In both case it is possible to define the distortion amplitude, by (3).

$$V_d = \sqrt{\sum_{k=2}^{N/2} v_h^2} \qquad (3)$$

Due to (3), (1) and (2) becomes (4) and (5).

$$THD_1 = \frac{vd}{vt} \qquad (4)$$

$$THD_2 = \frac{vd}{\sqrt{v1^2+vd^2}} \qquad (5)$$

V. Result And Discussion

From the simulation using Matlab/simulink, the value of THD between direct AC supply single phases motor with PWM inverter single phase induction motor can be determined by their constant simulation time. The rotor speed (rpm) and electromagnetic torque are also measured.

A. Direct AC supply single phase motor

1. The schematic shown in figure 5.1 illustrates the direct supply single phase motor using simulink where the motor main and auxiliary source connected to the AC supply.

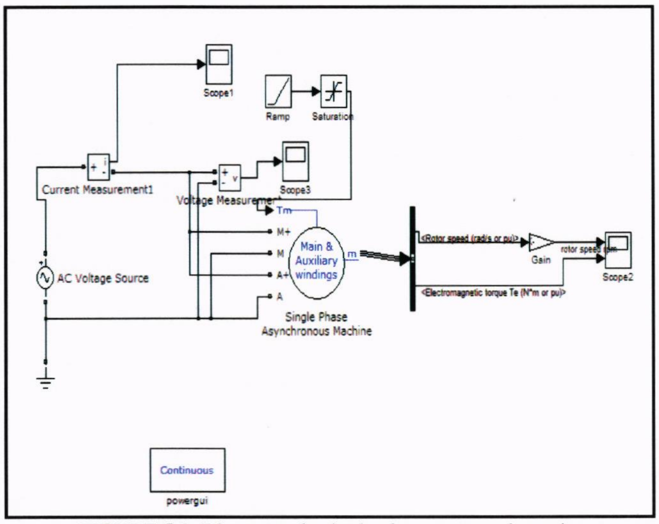

FIGURE 5.1: Direct supply single phase motor schematic.

2. Figure 5.2 shown the input current supplied by AC voltage source. The amplitude of its current is 15 and the time set to 0.1 second. The frequency set to 50Hz and one cycle is equal to 0.02 second. Where T (period) = 1 / F (frequency).

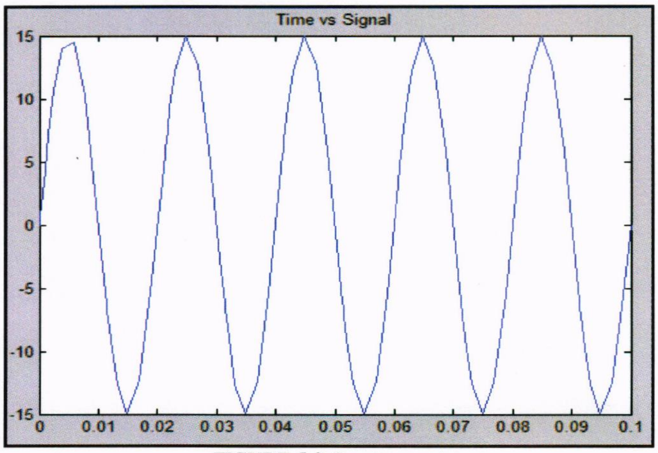

FIGURE 5.2: Input current

3. The figure 5.3 shown the result of THD from input current which is measured in 4 cycles and the THD value is 3.28%. The 1st harmonics order is the fundamental where it must higher than other harmonics order (2nd, 3rd, and ... n). Then from this figure it shown that 1st harmonics order is 10.16.

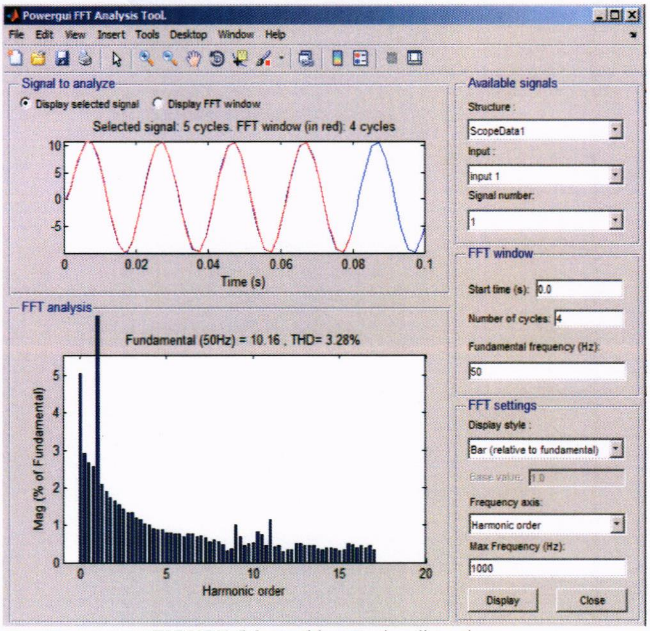

FIGURE 5.3: total harmonics distortion

4. The Figure 5.4 shown that rotor speed constant at 1.5 second with 1100 rpm and electromagnetic torque constant after 0.5 second.

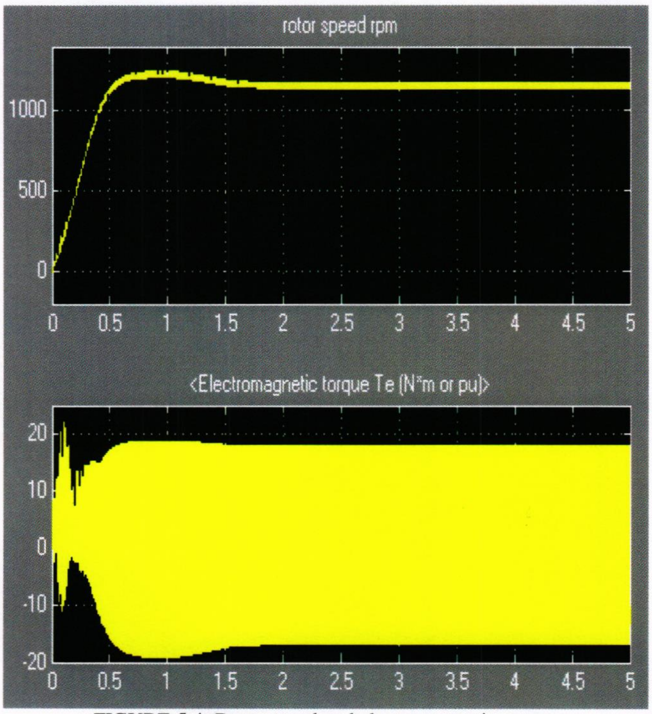

FIGURE 5.4: Rotor speed and electromagnetic torque

B. PWM inverter single phase motor

1. Figure 5.5 illustrate the schematic diagram using PWM inverter simulate using simulink where the AC source connected to the main terminal while auxiliary connected to the output of the switch. The value of LC filter set to 0.2H and 0.25mF.

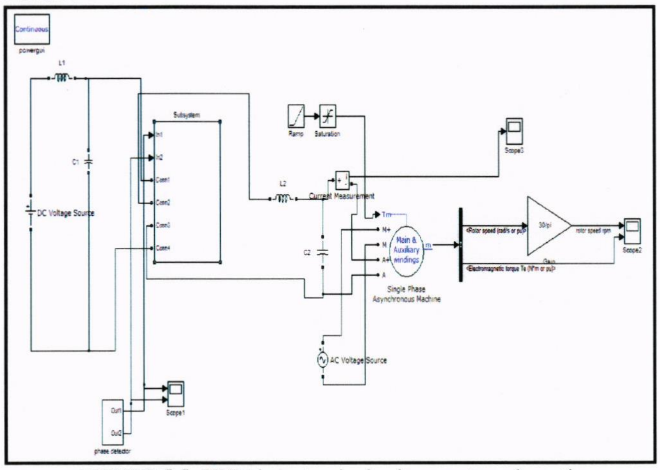

FIGURE 5.5: PWM inverter single phase motor schematic

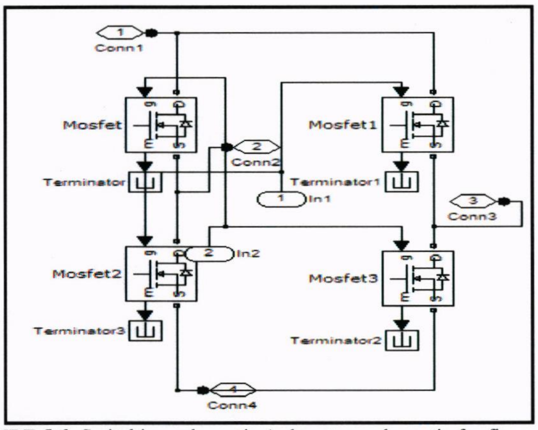

FIGURE 5.6: Switching schematic (subsystem schematic for figure 5.5)

2. Input current

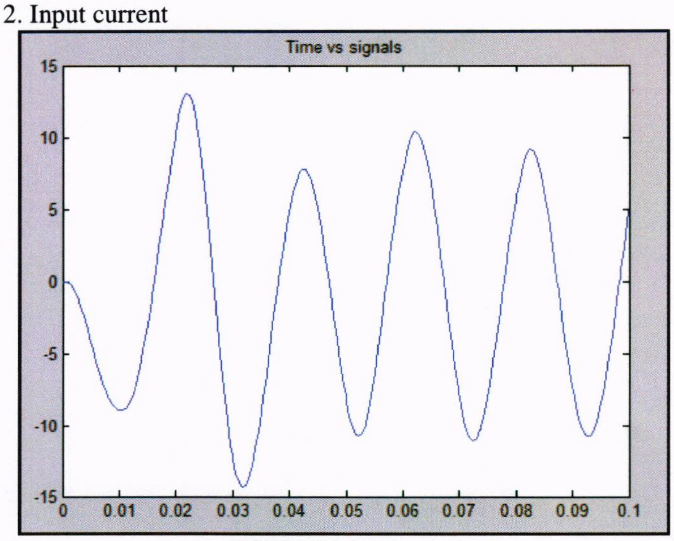

FIGURE 5.6: input current

Figure 5.6 shown the sinusoidal wave is not stable at the beginning and become smoother after 0.06 second. It is because of passive filter where the rate of discharging is higher at the start.

3. The figure 5.3 shown the result of THD from input current which is measured in 4 cycles and the THD value is 3.34%. The 1^{st} harmonics order (fundamental at 50Hz) is equal to 9.328 and also still higher than onward harmonics order.

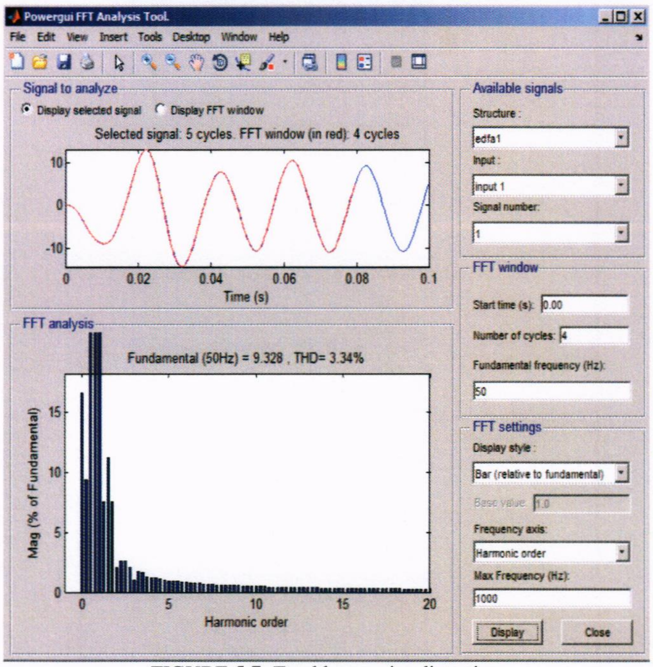

FIGURE 5.7: Total harmonics distortion

4. Figure 5.8 shown the result of simulation using simulink where rotor speed constant at 1.5 second with 1210 rpm and electromagnetic torque constant after 1.5 second.

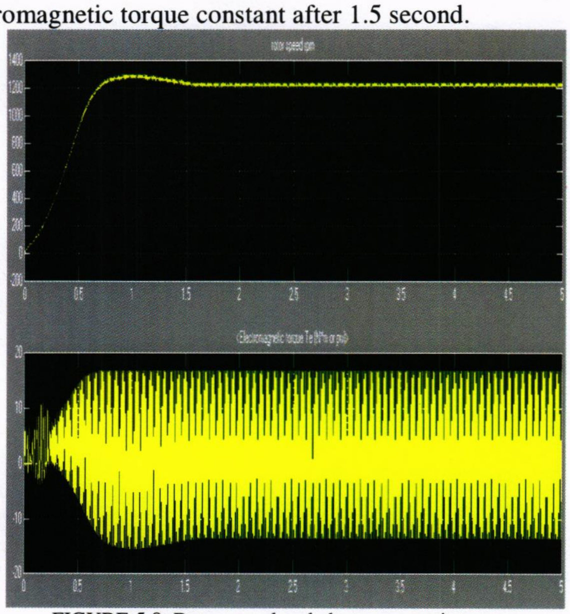

FIGURE 5.8: Rotor speed and electromagnetic torque

Discussion

From the result shown in Figure 5.3, it shows that the THD for the PWM inverter single phase motor follows the standard of IEEE 519 standard which is below then 5%. In order to improved the THD passive filter must be adjusted until get the smooth signal of input current. As comparison, direct AC supply to the induction motor show the lowest value of THD and stable input current to the motor because the circuit does not contain many electronic devices where the harmonics are created or produced.

For the PWM technique circuit it contains many electronic devices such as inverter as switch and passive filter. Because of that, the sinusoidal wave generated to fed the motor become less stable compare to direct AC supply. The value of THD also higher than direct AC supply but it still follows the IEEE 519 standard which is less than 5%.

The rotor speeds for both cases are different in terms of speed and the ripple produced. When the AC voltage is supplied to the induction motor, the waveform of the rotor ripple is compared to output waveform produce using PWM inverter. The rotor increases gradually from zero to 1200 rpm in 0.5 second and constant at 1100 rpm for direct AC while for PWM inverter increases gradually from zero to 1300 rpm in 0.7 second and constant speed at 1200 rpm. This comparison shows that the rotor speed increases slowly then AC direct but much stable. This is much better because when the rotor speed rises rapidly the spike may exceed and cause damage to the induction motor.

For the electromagnetic torque the PWM inverter method shows that it produces a smooth torque and reduces torque ripple and torque pulsation.

VII. CONCLUSION

This project has achieved its objective which is to provide better torque speed characteristic of induction motor and obtain less than 5% total harmonic distortion (THD). From the result, it can observed that by using PWM inverter it produces much better torque speed of the AC motor. The THD harmonics also can be reduced by using PWM passive filter or PWM control technique. The THD for input current is below then 5%.

Direct AC supply gives better current and low THD to the motor but this kind of connection will limit the application of the motor. The implement of PWM technique as switch controller give more option in motor application furthermore the comparison between this two connections tell that by using this PWM technique it can achieve same output with direct AC supply.

VIII. RECOMMENDATION

Replace the passive filter with active filter where it can control the non linear load in term of charging and discharging state. For this simulation, the passive filter just used to control phase detector for produce 50Hz waveform at the output.

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