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Design and Implementation of Speed Adjustment for Single Phase Induction Motor

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Abstract: *In this paper, the design and implementation of Speed adjustment of single-phase induction motor using microcontroller and MOSFETs is considered. The conventional Complex circuit has been replaced with the PIC microcontroller for the generation of sinusoidal pulse width modulation signals. The microcontroller produces SPWM signals that switch MOSFETs of the H-Bridge resulting in near sinusoidal waveform at the output. It acts as the controller circuit that produces carrier signal and modulating signal for the inverter. PIC16F887 is the microcontroller and IR2110 are the MOSFETs used in the work. This work offers energy efficiency, low cost and ease of operation, which makes it better than already existing works.*

Key Word*: H-bridge, microcontroller, MOSFET driver, speed adjustment, Single phase induction motor, pulse width modulation and spwm signals.*

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I. Introduction

Speed Adjustment Drives (SADs) are among the most useful devices in home and industrial world. They allow the speed of an electric motor to be altered whenever the behavior of the motor load changes. By changing its output frequency and voltage, the SAD allows the motor to modify its RPMs to adjust to those demands of improved process control. Benefits include energy savings, higher reliability and reduced wear and tear [1]. Alternating Current induction motors are common in manufacturing and processing plants. If motors were delivering products at a constant speed and not taking into consideration new changing conditions, scrap would pile up and energy would be wasted. The pulse width modulation (PWM) SAD is the most common design because of its ability to work with ranges of motor sizes, from fractional to hundreds of horsepower. An induction motor saves significant energy at lower speed compared to when it is run at full speed. When using a SAD, motor speed can be changed almost instantaneously to address load and process changes. A SAD provide a “soft start” capability for a motor decreasing the mechanical stresses associated with full-voltage start-ups. The result is lower maintenance costs. In the past, various techniques for controlling the speed of ac machines were available; commonly among them was the use of auxiliary rotating machines. These auxiliary machines have now been supplanted by static ac drive systems using various types of power semiconductor, operating as electrically controlled switches. High efficiency is attained because of the low "ON-state" conduction losses, when the power semiconductor is conducting the load current and the low “OFF-state” leak-age losses, when the power semiconductor is blocking the source, or load voltage. [2].

Recent works in speed adjustment control of ac motors adopt various approaches as outlined:

Trupti *et al* [3], adjusted the speed of a single-phase induction motor using android application that communicate with Bluetooth device interfacing AVR microcontroller of 8051 family. Data is sent through android application as per code and is executed by AVR to deliver signal to triac. Though the work was a success, it was operated within a short range of Bluetooth application.

While Hamad *et al* [4], adjusted the speed of single-phase induction motor using close-loop adjustable drive as voltage amplitude is controlled. Microcontroller was used for this technique. The speed’s feedback was sensed, and the appropriate pulse width generation was done by the microcontroller. The generated pulse width signal operates gate voltage of the chopper yielding desired speed. The controlled input voltage to single phase isolated Gate Bipolar Transistor (lGBT) bridge inverter and PWM technique has been employed at inverter, hence the motor supplied with ac voltage.

Jiangmin Yao [5] implemented the microcontroller (PIC17C756) in a single-phase induction motor adjustable speed drive using hardware and software program. The microcontroller yielded pulse width modulation for control of single-phase motor. The chip with re-programmable ROM replaces the conventional complex circuit solution. It was concluded that, there is low cost, and flexibility to change the control algorithm without the volts per hertz (v/f). Induction motor drives with inverters are widely used in a number of industrial applications promising not only energy saving, but also improvement in productivity and quality. The low-cost applications usually adopt v/f scalar control when no particular performance is required. Variable speed pumps, fans and appliances are the examples.

Sangita *et al* [6] reviewed speed control techniques of single-phase induction motor using different types of methods (PWM, Direct Flux, and V/F techniques) and showed that PWM technique has very low switching losses and high efficiency with low power consumption.

The work by Neha *et al* [7], simulated single-phase induction motor fed by AC Chopper, using asymmetrical PMW technique to reduce the harmonics present in the motor current. The flow of power to the motor was controlled by a switch action of the power switch that controlled the motor speed.

Suneeth *et al* [8], described several PMW strategies with an AC Chopper to control speed of single-phase induction motor. Power electronic switches were operated using asymmetrical PMW technique. The work was able to maintain speed of single-phase induction motor constant at different load conditions using asymmetrical PMW technique.

Niraj *et al* [9] designed six-step inverter that controls voltage level for three phase induction motor.

The performance evaluation of the motor was conducted with different semiconductor switches. The work was able to reduce losses in the three-phase inverter by replacing MOSFET with IGBT power switches in the three phase six step inverter.

Deshmukh *et al* [10] presented a new energy efficient technique of a three phase AC - AC voltage control using medium frequency pulse width modulation and extinction angle control. This technique independently control the speed and power factor of the three phase induction motor using four semiconductor controllable switches.

Kasthuri [11] presented a model that controls both frequency and voltage using PWM technique. The speed of the motor was compared with the speed of the reference voltage. The feedback determines generation of pulses corresponding to the desired speed.

Chaitanya *et al* [12], investigated speed control performance of single-phase induction motor with microcontroller 18F2520. Sinusoidal PWM was employed in H-bridge inverter to supply the motor with AC voltage.

II. Design Methodology

System Description

The power supply of this circuit was fed via a transformer, rectified, filtered, and regulated 5 V dc for microcontroller, opto-coupler and both 5 Vdc and 12 Vdc for MOSFET drivers respectively. The dc link supplies 300 Vdc to inverter circuit while, PIC microcontroller is programmed for sinusoidal pulse width modulation (SPWM) creation at 16 MHz. The last component of this set up is the inverter which receives the amplified dc signal from MOSFET driver switching systematically and converting dc link voltage to AC power to feed the motor under control. The block diagram of system used in this work is shown in Figure 1.

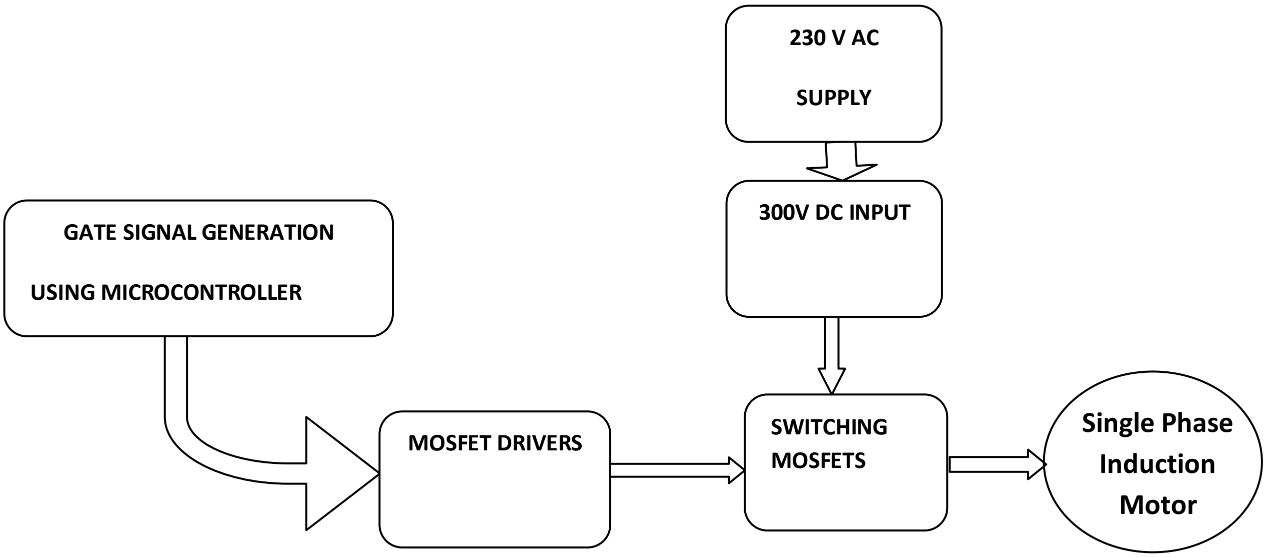

Figure 1: Systems Block diagram

PIC microcontroller

PIC16F887 is used as the microcontroller for sinusoidal pulse width modulation, (SPWM) creation. It has 40 pins input and output. The advantage of this microcontroller is the built-in 8 MHz oscillator and analog to digital converter. In addition, it can drive up to 98 LCD segments, and has PWM modules, flash program memory and operating voltage of range 2 V dc to 5 V dc. On the PIC16F887, the program memory is 14 bits wide by 8192 words [13].

H-Bridge Inverter

The inverter is made up of four MOSFETs, each with a free-wheeling diode as shown in the Figure 2. The MOSFETs used in the inverter formation are IRF450. The inverter switching frequency is equal to 16 KHz. The inverter produces a voltage waveform, with a fundamental frequency component of 50 Hz, which powers the single-phase induction motor.

When selecting MOSFET, drain to source information is required. This is the total amount of resistance present within the MOSFET between drain and source of the device when it is operating in the active region or when the gate of the MOSFET is fully charged. This is to avoid high dissipation of heat. In case of high-power inverter, the dc rail voltage is set at 170 volts and the intended upper threshold of supply power will be 1000 watts. Therefore, the upper current threshold will be I = 1000W/170V = 5.88A. This is the highest current that can be pulled through the inverter at a time. Referencing the IRF450 datasheet (www.semelab-tt.com), the series resistance is 0.4 ohms. Using this value, the maximum power dissipation in the inverter would be (0.4 ohms*5.88 amps) 5.88amps =13.8 watts which agree with MOSFET maximum power dissipation of 150 watts [14]. This shows that IRF450 can successfully operate within the calculated current specification.

The next factor to consider for selecting IRF450 for H-bridge is the gate to source threshold voltage which is 4 volts when current of 250 microamperes is flowing at the drain [14]. This is the total required voltage needed to turn the MOSFET from “off” state to “on” state.

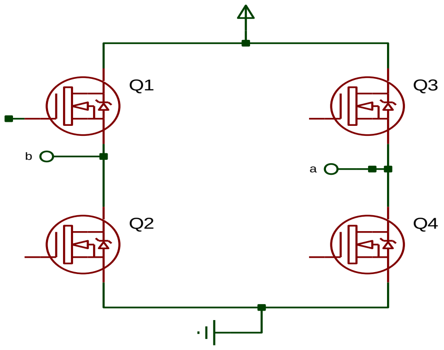

Figure 2: H-Bridge Inverter

The single-phase inverter is complementary pairs, in which the switching semiconductors of the same leg can never be in the conduction state simultaneously. Hence, one semiconductor must be off before turning-on the other semiconductor. Therefore, the turn off and turn on of the complementary switches are not carried out at the same time. Since power switches take more time to turn-off than to turn-on, a dead time must be introduced between turn-off of the switching semiconductors and turn-on semiconductor necessarily.

Table 2: H-Bridge Switching Truth Table

Q_1	Q_2	Q_3	Q_4	V_{OUT}
1	0	0	1	1
0	1	1	0	1
1	0	1	0	0
0	1	0	1	0
1	1	0	0	0
0	0	1	1	0

Opto-coupler:

The single channel opto-coupler consists of an 850 nm AIGasAS LED optically, coupled to very high-speed integrated photo detector logic gate with a strobe output. This output features an open collector, thereby permitting wired OR output. In this project, the 6N137 opto-coupler is used to isolate between high voltage of the inverter and low voltage of the PIC, for isolating between the H bridge inverter gates and the SPWM output from the PIC [15]. It is the opto-coupler that is used to transfer electrical signal with the help of light between two separated circuits. It consists of one chip photo IC and high emitting diode. It is an eight-pin device which comes in DIP package as shown in Figure 3.

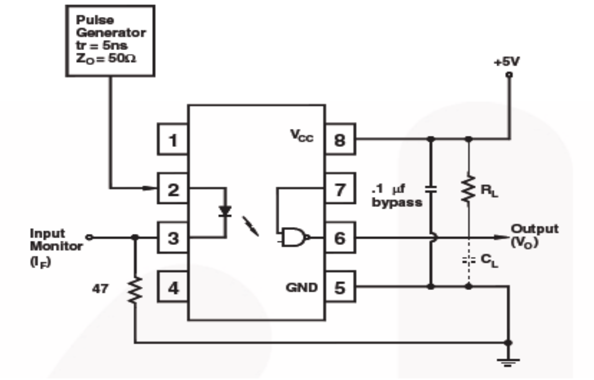

Figure 3: Typical Circuit diagram of opto-coupler [15].

MOSFET Drivers and H Bridge

Microcontroller outputs are used to control the MOSFET H-Bridge through MOSFET drivers U3 and U4, whose pins are connected as shown in IR2110 datasheet. The outputs of the MOSFET drivers are fed to the MOSFET gates through resistors R8, R10, R12, and R14, which control the MOSFET switching speed as shown in Figure 4. Their values were obtained from the IR2110 datasheet. R9, R11, R13 and R15 are to discharge MOSFETS' gate capacitance. Capacitors C3, C4, C6 and C7 are bootstrap capacitors, which are charge through D5, D2 diodes whenever High side MOSFET circuit is off. The Q1, Q2, Q3 and Q4 MOSFETS H-Bridge is powered by 300 Vdc from the dc link and the output is obtained on pin 6 of the IR2110 MOSFET driver.

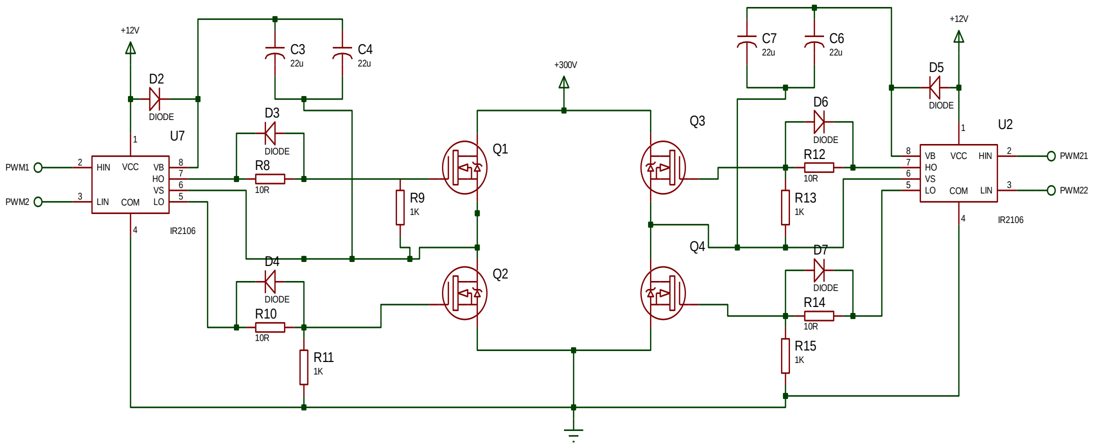

Figure 4: MOSFET driver and bridge

III. Result

The speed adjustment of single-phase induction motor circuit was designed using PIC16F887. The project was simulated using MATLAB just the way it should be in hardware. Figure 5, 6 and 7 show output speeds, currents, and voltages waveforms from H-bridge at 800 rpm, 1200rpm and 1500rpm using the modelling parameters in Table 3.

Table 3: Single Phase Induction motor Simulation Parameters

Parameters	**Value**
Dc Link Voltage	300 Vdc
Switching Frequency of triangular wave carrier	16 KHz
Frequency of sinewave modulating signal	50 Hz

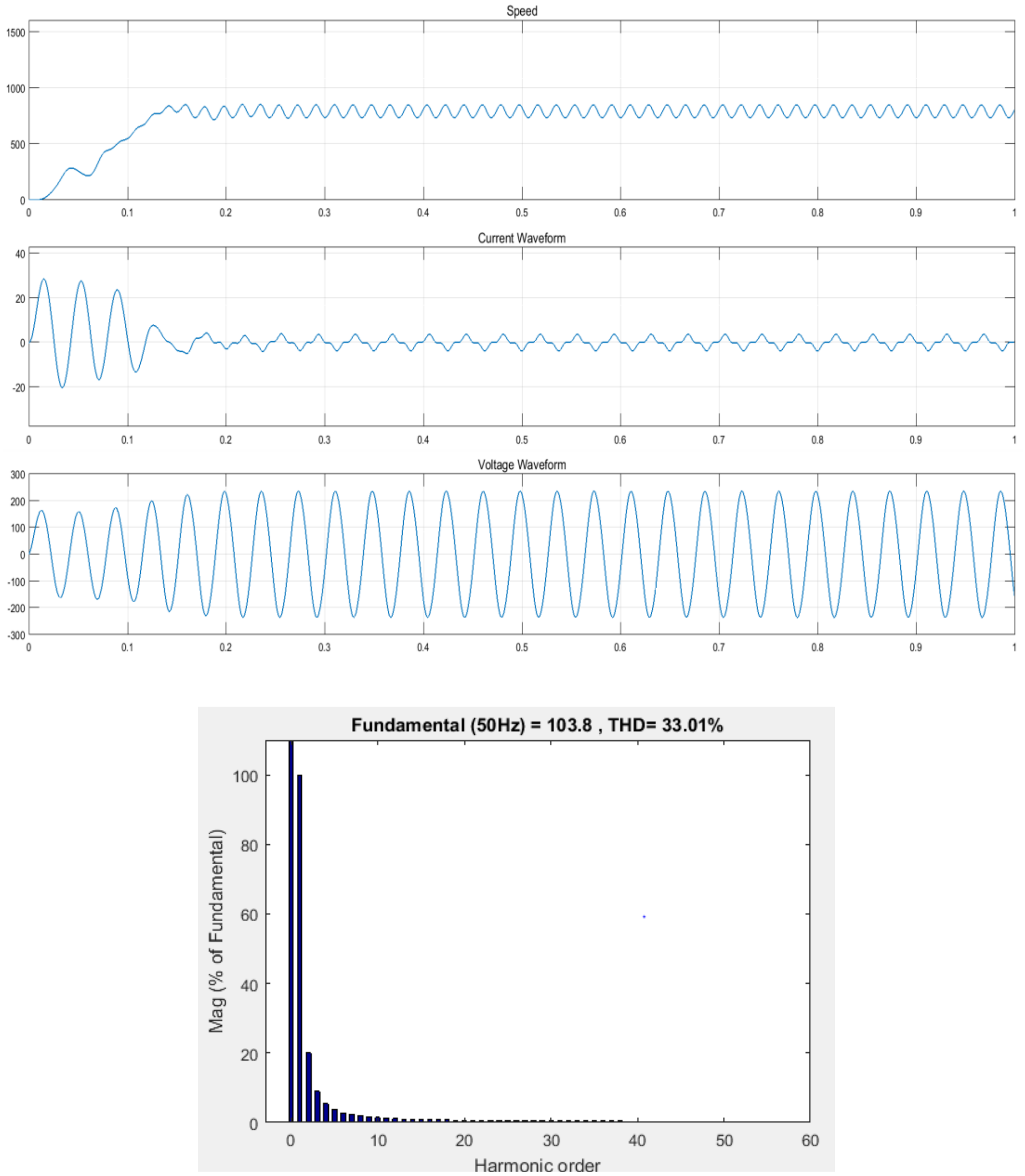

Figure 5: H-bridge outputted waveforms from MATLAB simulation at 800rpm

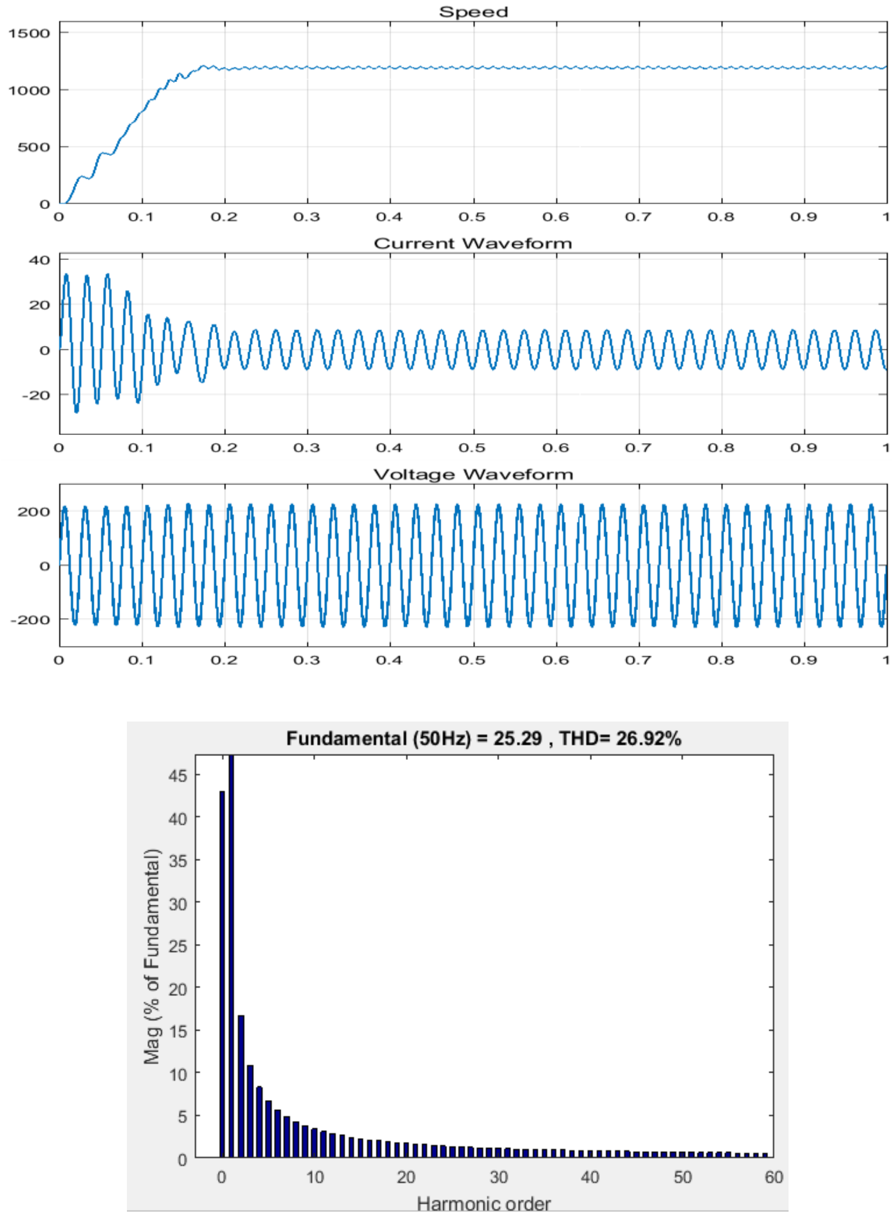

Figure 6: H-bridge outputted waveforms from MATLAB simulation at 1200rpm

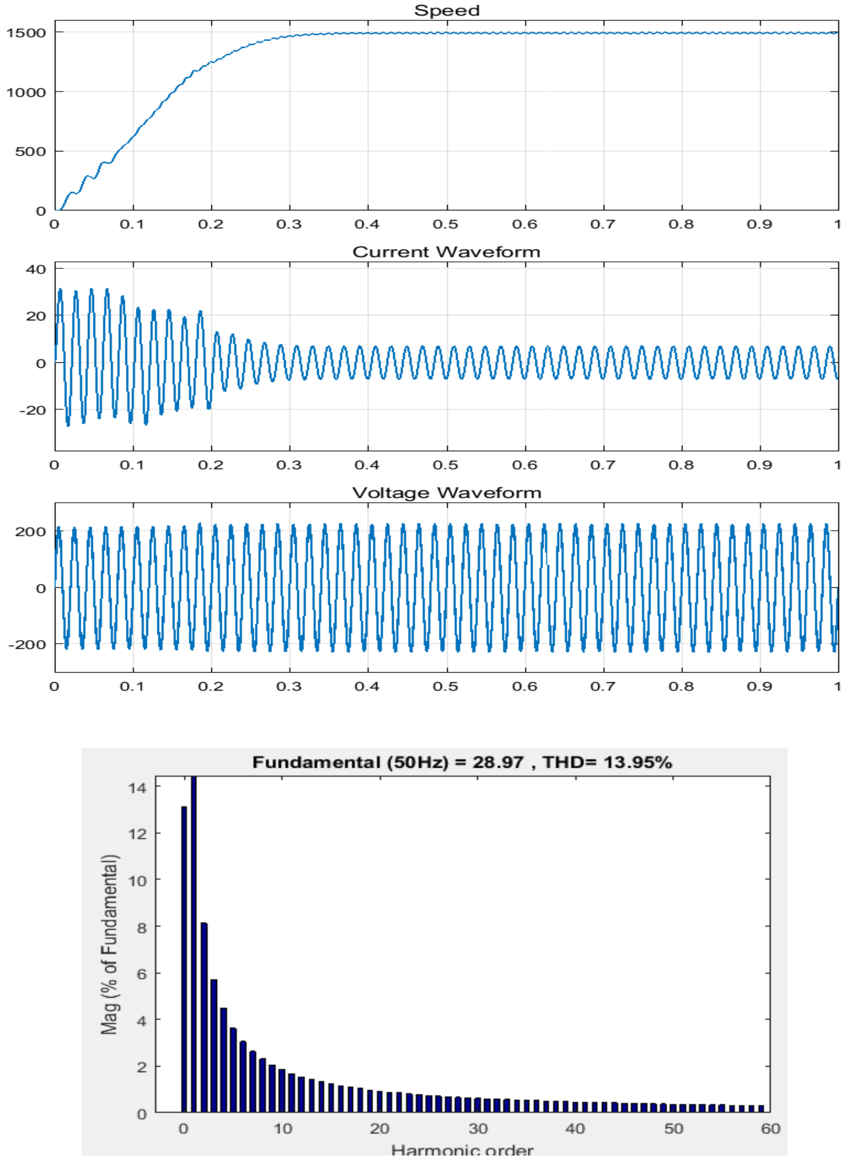

Figure 7: H-bridge outputted waveforms from MATLAB simulation at 1500rpm

Signal Generating circuit simulation Result.

The signal generating unit was simulated in Proteus environment after the hex file was uploaded in the microcontroller resulting to the following signals as shown in figure 8.

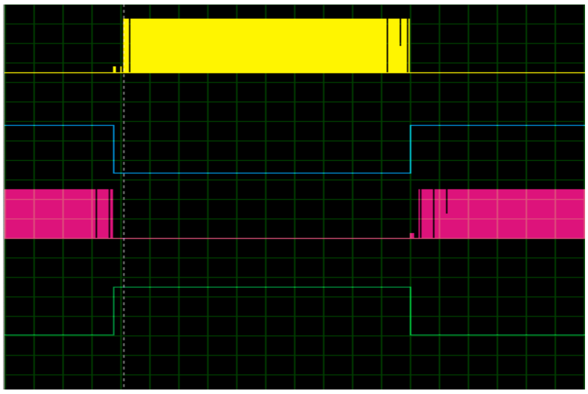

Figure 8: Microcontroller Signals from Proteus simulation

Actual Signal Generation Circuit SPWM signals

A 5 Vdc was fed to the microcontroller through a 5 Vdc constant regulator with ac filter capacitor at the input and output side. The capacitor value was obtained from IC 7805 regulator datasheet.

The microcontroller was clocked with an external clock of 16MHz which was grounded using capacitors whose values were obtained from PIC16F887 datasheet.

Sine tables of 32 values has been developed to corresponding to a half cycle of 50HZ sine wave. Each of the 32-value table corresponds to a particular duty cycle. By adjusting the amplitude of the sine wave, the duty cycle of PWM is automatically controlled.

By setting microcontroller in enhance mode, SPWM signals are generated at pin 17, 30, 28 and 29.

Pulses were generated at the following speeds and captured using UNI-T UTD2062CE oscilloscope: 800, 1200, 1500 rpm and that of 800 rpm shown in figure 9:

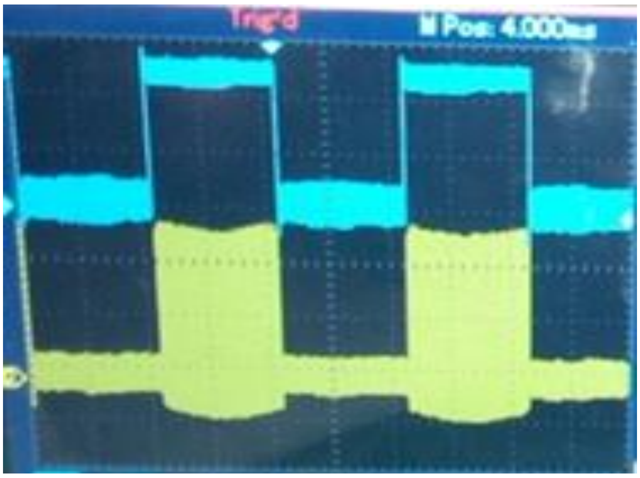

Figure 9: Oscilloscope Gate pulse from microcontroller at 800rpm

Actual Project Final Result

This final stage of the project also presents the following readings of the voltage and current waveforms at 1500, 1400, 1200, 1000 and 800 rpm using capacitor start single phase induction motor with the following details: 230 Vac, 70W.

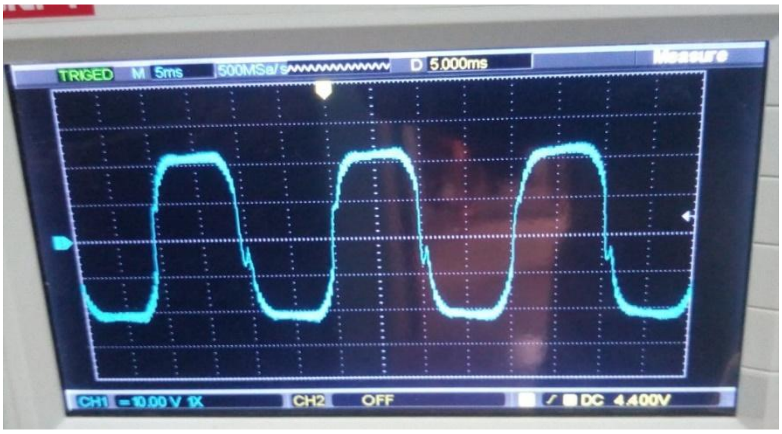

Figure 10: Oscilloscope voltage waveform of the circuit output at 800 rpm

The speed ranges and output voltages measured during the experiment are shown in Table 4:

Table 4: Speed ranges with measured voltages

SPEED RANGE (%)	MEASURED VOLTAGE (V)	MEASURED SPEED (RPM)
10	195.6	815
20	199.8	900
30	199.8	1001

70	209.7	1200
80	213.6	1311
90	215.8	1420
100	219.5	1510

IV. Conclusion

The design and implementation of speed adjustment drive (SAD) for single phase induction motor has been presented. PIC16F887 micro-controller was used to generate SPWM signals, the H-bridge that handled the sinusoidal pattern switching was developed and the voltage sine wave was realized. The speed of single-phase induction motor was controlled with the developed SAD within the range of 800rpm – 1500rpm. This system could be applicable in process control of feed rate process and low speed fans.

References

[1]. Niraj,k. Rajeev, S. (2017)"Performance Evaluation of Three Phase Induction Motor using MOSFET and IGBT based Voltage Source Inverter" International Research Journal of Engineering and Technology. Vol.4, iss.6, 2017.

[2]. Lewis, M.L. (1980). Electrical Installation Technology, Nelson Thornes Ltd.

[3]. Trupti, S.B. Anushri,S.S. Anushri, S.G. Kaware,U.W. Dehankar ,R.K. (2015). "Induction motor speed controlusing android application", International Journal of Engineering Research and General Science. vol.3, Iss.2, 2015, pp.140-142.

[4]. Hamad, S.H. Bashi, S.M. Aris, I. and Mailah, N.F.(2004). "Speed drive of single phase induction motor" IEEE, proceedings of national power & Energy conference, Kualalumpur, Malaysia2004,pp.121-126.

[5]. Jiangmin, Y. (2000). Single phase induction motor adjustable speed control using DSP and microcontroller. Course Project for ECE734 Fall Semester at UW-Madison

[6]. Sangita,G. Bhavsar, P. Gandhi , D. (2015) "A Review on Special Control Techniques of Single Phase Induction Motor" International Journal of Science and Research. Vol.6, iss.10, 2015.

[7]. Neha J. Fauda, N.H. Meshram, N. Sudha, S.(2016) "Speed Control of Single Phase Induction Motor using AC Chopper by Asymmetrical PMW Technique" GRD Journals vol.1, iss4, 2016

[8]. Suneeth, R. Usha, P.(2014) " Speed Control of Single Phase Induction Motor using AC Chopper by Asymmetrical pwm Method" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering. Vol.3, iss.10, 2014.

[9]. Niraj,k. Rajeev, S. (2017)"Performance Evaluation of Three Phase Induction Motor using MOSFET and IGBT based Voltage Source Inverter" International Research Journal of Engineering and Technology. Vol.4, iss.6, 2017.

[10]. Deshmukh, S.H. Medha, R. Afsana, S. and Tutakhe, D. (2016)"Energy Efficient Variable Speed High Power Factor Three Phase Induction Motor Drive Using Combined pwm and Extinction Angle Control" Journal for Research vol.2,iss.6,2016.

[11]. Kasthuri,S. (2018)"Certain Investigation on Induction Motor Performance With Variable Frequency Drive" International Research Journal of Engineering and Technology vol.5, issue 8,2018

[12]. Chaitanya, N. Vijaya, H. (2014) "Speed Control of Single-Phase Induction Motor Using Microcontroller" International journal of Engineering Research and Application 2014.

[13]. http://www.microchip.com Visited on 11th February 2019.

[14]. http://www.semelab.com Visited on 11th February 2019.

[15]. http://www.onsemi.com Visited on 9th February 2019.

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