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Speed Control of Induction Motor Using Dspic30f2023

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Abstract:- This paper presents design and analysis of a three phase induction motor drive using IGBT"s at the inverter power stage with variable frequency method in closed loop using dsPIC30F2023 as a controller. It is a 16 bit high-performance digital signal controller (DSC). DSC is a single chip embedded controller that integrates the controller attributes of a microcontroller with the computation and throughput capabilities of a DSP in a single core. A 1.5HP, 3-phase, 415V, 50Hz induction motor is used as load for the inverter. Digital Storage Oscilloscope Textronix TDS2024B is used to record and analyze the various waveforms. The experimental results for variable frequency control of 3-Phase induction motor using dsPIC30F2023 chip clearly shows by varying the frequency of voltage applied to the stator the speed of the motor can be controlled.

Keywords:- Induction motor, Variable frequency drive, dsPIC, Voltage source inverter, starter, Current source inverter.

I. INTRODUCTION

The electrical machine that converts electrical energy into mechanical energy, and vice versa, is the workhorse in a drive system. Drive systems are widely used in applications such as pumps, fans, paper and textile mills, home appliances, wind generation systems and robotics. Industrial drive applications are generally classified into constant speed and variable speed drives. Traditionally, ac machines with a constant frequency sinusoidal power supply have been used in constant speed applications, where as dc machines were preferred for variable speed drives. DC machines have the disadvantage of higher cost, higher rotor inertia, and maintenance problems with commutators and brushes. Commutators and brushes, in addition, limit the machine speed and peak current, cause EMI problems. AC machine do not have the disadvantages of dc machine, as mentioned above. In the last two or three decades, we have seen extensive research and development effort for variable frequency, variable speed ac machine drive technology.

There are different types of ac machines are available. They are classified as follows.

- Induction machines
- Synchronous machines
- Variable reluctance machines

Among all types of ac machines, the induction machine, particularly the cage type, is most commonly used in industry. These machines are very economical, rugged and reliable higher efficiency and are available in the ranges of fractional horse power to multi-mega watt capacity. Induction motor is a type of ac machine has been used in the past mainly in applications requiring a constant speed. Availability of thyristors, power transistors, IGBT and GTO has allowed the development of variable speed induction motor drives.

In this work IGBTs are used as switching devices, dsPIC as a controller, square wave modulation technique is used for controlling switching devices. Controller used is dsPIC30F2023. It is a 44 pin IC. As compared to the PIC Microcontroller and DSP, dsPIC is cheaper and most reliable. The dsPIC DSC has the "heart" of a 16-bit MCU with robust peripherals and fast interrupt handling capability and the "brain" of a DSP that manages high computation activities, creating the optimum single chip solution for embedded system designs. This work describes the speed of the motor is controlled by varying the frequency of the voltage applied to stator of the motor. There are three major units in this work, are as follows:

- **Rectifier:** A full wave three phase bridge rectifier converts three phase 50 Hz power supply to either fixed or adjustable dc voltage.
- **Inverter:** Electronic switches (IGBTs) switch the rectified dc on and off, and produce a current or voltage waveform at the desired new frequency.
- **Control Unit:** An electronic circuit receives the feedback information from the driven motor and adjust the output voltage or frequency to the selected valves.Controllers produces gate pulses for switching of the devices and also controllers may incorporate many complex control functions.

According to the requirement, a software program is written and is fed to the digital signal controller (dsPIC30F2023) for the necessary action.

II. VARIABLE FREQUENCY CONTROL OF THREE PHASE INDUCTION MOTOR

Figure 3.10 shows the torque-speed curve, if the stator supply frequency is increased with constant supply
voltage, where ω is the base angular speed. Note, however, that beyond the rated frequency ω , there is fall ineb maximum torque developed, while the speed rises. Synchronous speed and rated speed are two speed terms used in the electric machine. Synchronous speed is the speed at which a motor's magnetic field rotates. Synchronous speed is the motor's theoretical speed if there was no load on the shaft and friction in the bearings. The two factors affecting synchronous speed are the frequency of the electrical supply and the number of magnetic poles in the stator. The synchronous speed is given by;

$$N_S = 120\frac{f}{P}$$

Where;
f = Electrical frequency of the power supply in Hz *P* = Number of Poles

The rotor speed of an Induction machine is different from the speed of Rotating magnetic field. The percent difference of the speed is called slip as shown in equation

$$s = \frac{N_s - N_r}{N_s}$$

N_s = Synchronous speed N_r = Rotor speed

The induction motor speed is directly proportional to the supply frequency and the number of poles of the motor .Since the number of poles is fixed by design, the best way to vary the speed of the induction motor is by varying the supply frequency. Voltage induced in stator is proportional to the product of supply frequency fs and air-gap flux φm as shown in equation

$$E = 4.44N \square_m f_s$$

Where,
N= number of turns per phase

f stator drop is neglected, then *E* is equal to *V* as shown in equation (4). Then the supply voltage will become proportional to fs and φm

$$V=4.44\square_m f_s$$

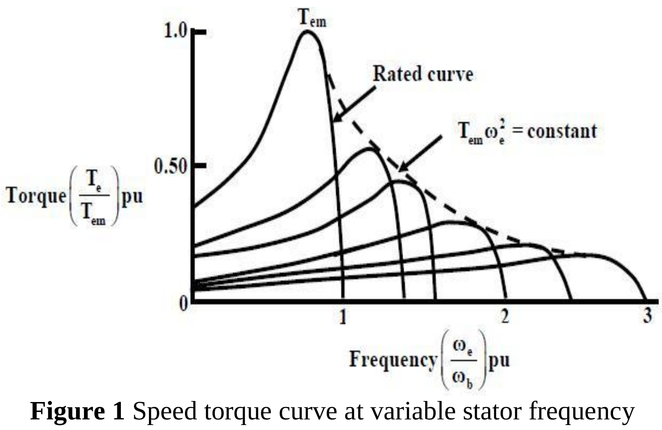

Figure 1 Speed torque curve at variable stator frequency

III. IMPLEMENTATION OF VARIABLE FREQUENCY DRIVE

A. System Overview

The basic block schematic of three-phase induction motor drive is shown in Fig.2. It has starter, three-phase full bridge rectifier, three-phase full bridge inverter, control circuit, speed sensing unit. The starting current of the induction motor will be five to six times that of the rated current. To limit this heavy current flow, starter unit is required. In this starter, two 56Ω wire wound resistors are connected in parallel in each phase of the input supply.

In the proposed work the three-phase bridge rectifier is designed using IN5408 power diodes. Three power diodes are connected in parallel to increase the current capability. The output of rectifier is filtered by 300μF, 900V capacitors. The three-phase inverter has FGA25N120ANTD IGBT switches; the output of the switches is given to the three phase induction motor.

B. Power circuit design

The power circuit is designed using 25A, 1200V IGBT. The 3-phase induction motor is connected to 3-phase bridge inverter as shown in Fig.3. If the upper and lower switches of the same leg are switched on at the same time then this will cause DC bus supply to short. To prevent the DC bus supply from being shorted, certain dead time must be given between switching off the upper switch and switching on the lower switch and vice versa. Freewheeling diodes are connected to provide a path for flow of current which is stored due to the inductive load when switches are OFF.

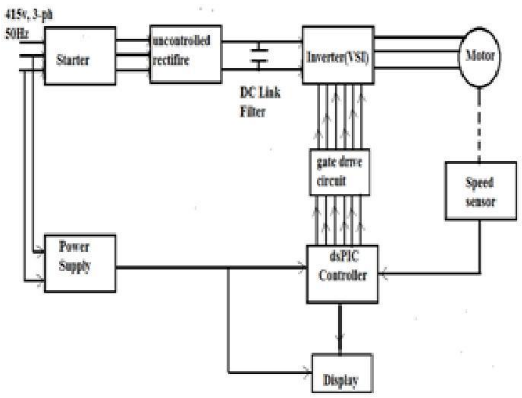

Figure 2. Block diagram of Complete System

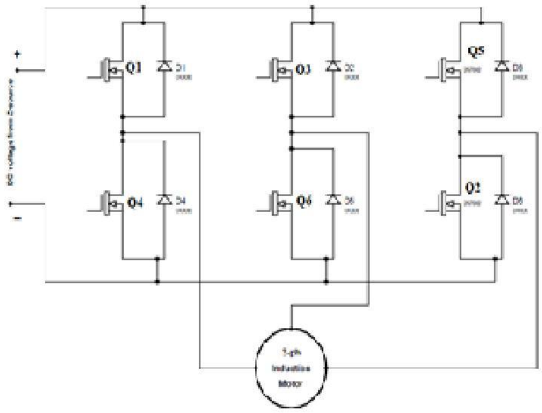

Figure 3. Three Phase Bridge Inverter

C. Control Circuit

In this work Microchip‟s dsPIC30F2010 digital signal controller is used. Microchip‟s dsPIC30F2010 digital signal controllers place unprecedented performance in the hands of 16-bit MCU designers. The dsPIC DSC has the "heart" of a 16- bit MCU with robust peripherals and fast interrupt handling capability and the "brain" of a DSP that manages high computation activities, creating the optimum single-chip solution for embedded control of three-phase induction motor [9]. It also consists of six opto coupler for isolating the control and power circuits. In this work an optocoupler TLP250 is used to isolate the gate drive circuit and the IGBT-based power circuit. Six IGBTs of the power circuit are controlled by square wave switching technique. These square wave signals are required to derive a varying AC voltage from the power circuit. A dead time of 2 micro second is given between switching off the upper switch and switching on the lower switch and vice versa, to avoid shorting the DC bus.

IV. EXPERIMENTAL RESULTS AND ANALYSIS OF SPEED CONTROL

The proposed control system was developed by a DSC (dsPIC30F2023) based voltage source inverter. C language is used to develop the program. The device is programmed using MPLAB Integrated Development Environment (IDE) tool. It is a free, integrated tool set for the development of embedded applications employing Microchips PIC and dsPIC controllers. For execution of C code, MPLAB compiler is used. In this work, 415V, 50Hz, 3-ph, 1.5HP induction motor is used.

The Variable Frequency drive for three phase induction motor is successfully developed and tested in our power electronics laboratory and the photographs of the complete project setup is as shown in figure 20. Closed loop is carried out for different speeds and loads. Storage oscilloscope is used to store gate pulses and voltage waveforms. Speed of the induction motor is varied from 1500 RPM to 1290 RPM and corresponding frequency range is from 50Hz to 44Hz. At a particular set RPM, load is varied from zero to 4 kg and corresponding frequencies are noted.

The developed Variable Frequency Drive is tested for a 3 Phase, 415 Volts, 1.5 H.P. (ABB) Induction Motor for different frequencies and load reading of Stator Voltage, Stator Current and Frequency are noted.

Table 1. Experimental Result for Variable Load At Speed 1500 Rpm

SI. NO	LOAD	ACTUAL RPM	Frequency (hz)
1	0.5Kg	1502	50.06
2	1	1502	50.06
3	1.5	1505	50.16
4	2	1510	50.33
5	2.5	1510	50.33
6	3	1512	50.4
7	3.5	1512	50.43
8	4	1513	50.4

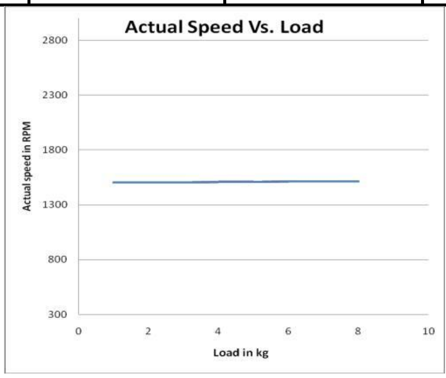

Figure 4. Characteristics of Actual RPM Vs. Load for the set speed 1500 rpm

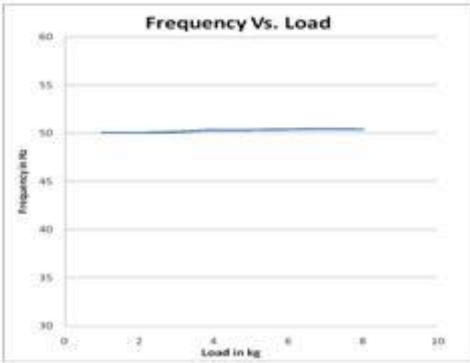

Figure.5 Characteristics of Frequency Vs. Load for the set speed 1500 rpm

Table 2. Experimental Result For Variable Load At Speed 1410 Rpm

SI. NO	LOAD	ACTUAL RPM	Frequency (hz)
1	0.5Kg	1405	46.83
2	1	1405	46.83
3	1.5	1407	46.9
4	2	1407	46.9

5	2.5	1407	46.9
6	3	1409	46.96
7	3.5	1411	47.03
8	4	1411	47.03

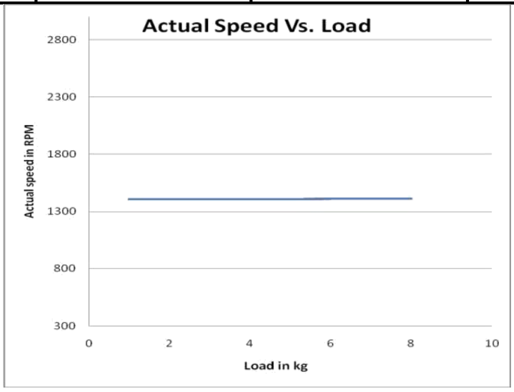

Figure 6. Characteristics of Actual Speed Vs. Load for the set speed 1410 rpm

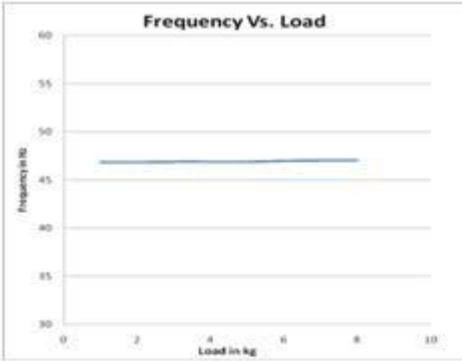

Figure 7. Characteristics of Frequency Vs. Load for the set speed 1410 rpm

Table 3. Characteristics of Frequency Vs. Load for the set speed 1320 rpm

SI. NO	LOAD	Actual RPM	Frequency (hz)
1	0.5Kg	1315	44
2	1	1315	44.24
3	1.5	1318	44.24
4	2	1318	44.30
5	2.5	1321	44.35
6	3	1321	44.80
7	3.5	1322	44.96
8	4	1322	45.05

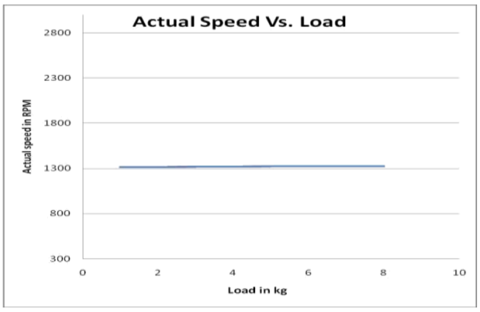

Figure 8. Characteristics of Actual RPM Vs. Load for the set speed 1320 rpm

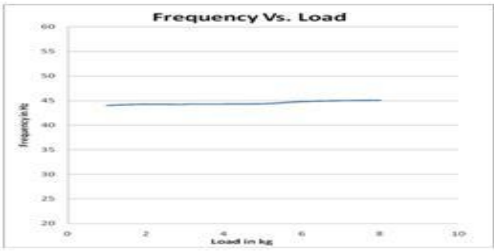

Figure 9. Characteristics of Frequency Vs. Load for the set speed 1320 rpm

THREE PHASE

Table 4. Tabulated Result At Different Rpm (200v)

SET RPM	**ACTUAL RPM**	**CURRENT (Amp)**	**FREQUENCY**	**Voltage (volts)**
1560	1545	1.71	51.5	199
1530	1529	1.77	50.96	199
1500	1510	1.80	50	200
1470	1450	2.10	48.32	200
1440	1430	2.25	47.66	201
1410	1400	2.40	46.66	201
1380	1375	2.55	45.82	202
1350	1340	2.85	44.66	201
1320	1320	3.00	44	201
1300	1310	3.15	43.66	201

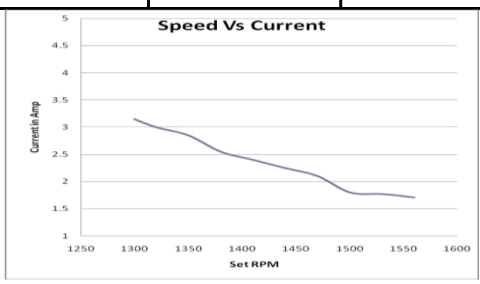

Figure 10. Characteristics of Speed Vs. Current

Table 5. Tabulated Result For Different Loads At 1560rpm(I/P Voltage 200v)

LOAD	**ACTUAL RPM**	**FREQUENCY (Hz)**	**VOLTAGE (VOLTS)**	**CURRENT (Amp)**
0.5	1540	51.33	250	0.99
1	1520	50.66	245	1.01
1.5	1400	46.66	245	1.02
2	1390	46.33	245	1.22
2.5	1380	46	244	1.30
3	1375	45.83	244	1.34
3.5	1370	45.66	244	1.38
4	1360	45.33	243	1.42

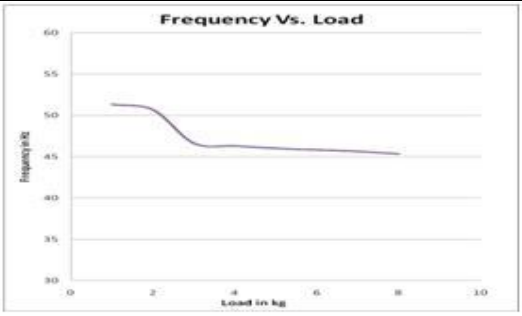

Figure 11. Characteristics of Load Vs. Frequency for the set speed 1560 rpm

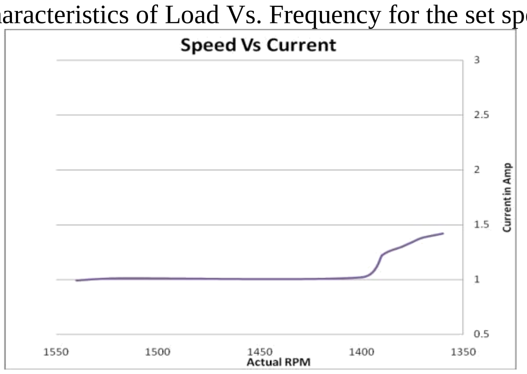

Figure 12. Characteristics of Speed Vs. Current for the set speed 1560 rpm

As it can be seen from tables for set rpm; 1500, 1410 & 1320, the rpm of motor remain in the range of set rpm with the error of +/- 10rpm. Hence the accuracy of approximately 98% is achieved.
Table1 shows the rpm and frequency recording at set speed of 1500 rpm and different loads. Their corresponding graphs are drawn as rpm versus load and frequency verses load and they are as shown in Fig4 and 5. The actual rpm verses load graphs is almost linear, thus shows that the closed loop control is good one. The frequency verses load graph is non-linear for set speed. This shows that to compensate for increase in load the frequency is increased by the controller to retain the set speed as 1500 rpm. The same explanation goes for set speeds as 1560 rpm, 1410 rpm, 1320 rpm.
The average frequency of the output voltage is;

- 50.33 for 1500 rpm
- 46.9for 1410 rpm
- 44.35 for 1320 rpm

The frequency is proportionally decreasing with decrease of rpm, thus follow the formula

$$(N_s = \frac{120f}{P}).$$

The waveforms of the gate pulses for the various rpm's and gate pulses of six IGBT's are as shown in fig. 13, 14, 15,16,17,18,19,20 and 21, there waveforms are directly acquired from the storage oscilloscope.

INVERTER OUTPUT VOLTAGE WAVEFORMS

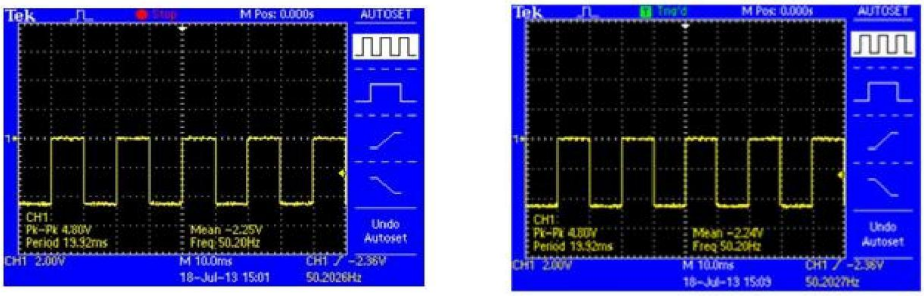

Figure 13. Waveforms of Gate Pulse of IGBT Q1 and Q2

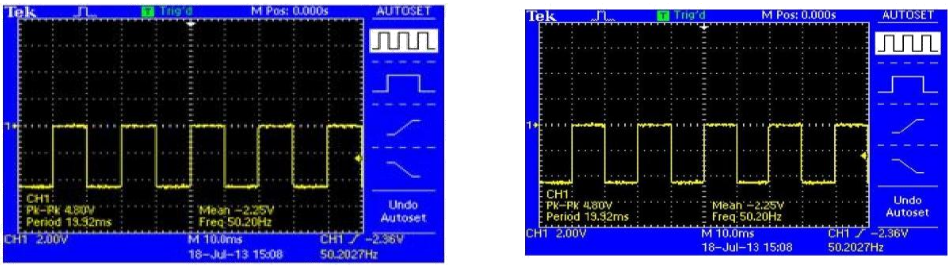

Figure 14. Waveforms of Gate Pulse of IGBT Q3 and Q4

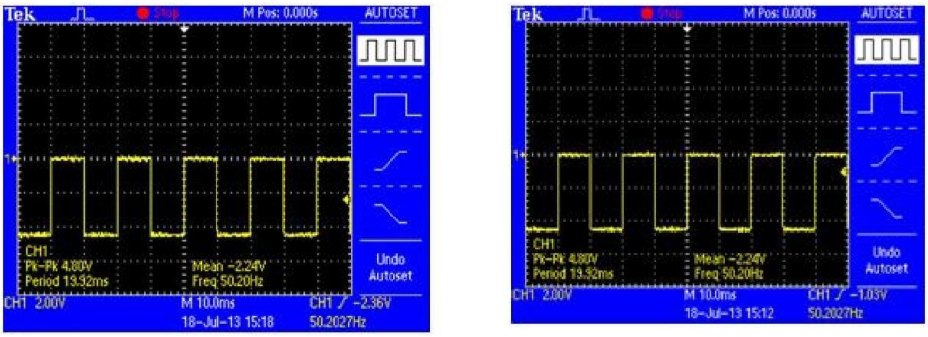

Figure 15. Waveforms of Gate Pulse of IGBT Q5 and Q6

WAVEFORMS FOR DIFFERENT RPM

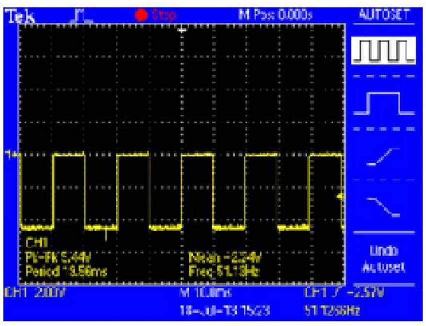

Figure 16. Waveforms for 1560 RPM

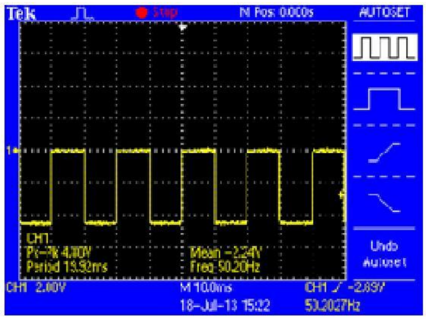

Figure 17. Waveforms for 1470 RPM

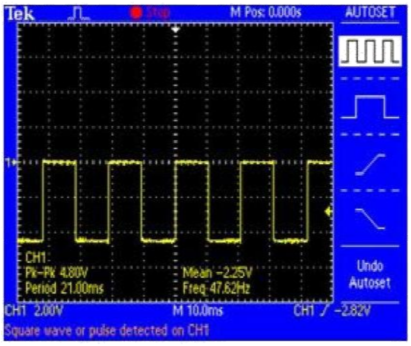

Figure 18. Waveforms for 1440 RPM

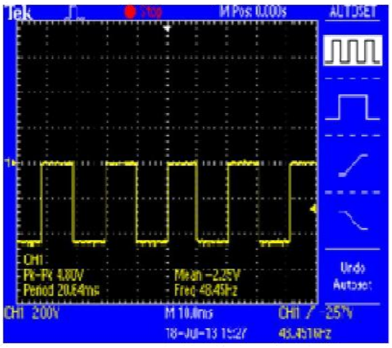

Figure 19. Waveforms for 1410 RPM

Figure. 20: Photograph of complete designed system

IV. APPLICATIONS

- A 3 phase induction motor has a simple design, inherently high starting torque, and high efficiency. Such motors are applied in industry for 3 phase pumps, fans, blowers, compressors, conveyor drives, and many other types of 3 phase motor-driven equipment.

Typical applications of pumps
- Chilled and hot water pumps
- Condenser water pumps
- Booster pumps Typical application of fans
- Supply and return fans
- Exhaust fans
- Boiler combustion fans
- Fume hood fans
- Large air conditioning equipment use 3 phase motors for reasons of economy and efficiency.

V. CONCLUSION

In the proposed system a new generation dsPIC approach for variable frequency control method of induction motor is applied and this complete system is developed and tested in power electronics laboratory. Speed control of motor is acquired with the accuracy of ±15 rpm. By varying the frequency of voltage applied to the stator the speed of the motor can be controlled. By meeting the required process demand, the system efficiency is improved. Hence we go for variable frequency drives.

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