Speed Control of Three Phase Induction Motor using Digital Signal Controller

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Abstract— A.C induction motor is the workhorse of industrial and residential motor applications due to its robustness, durability and reliability. Normally induction motors are constant speed motors but various application needs variable speed so speed control of induction motor is a big concern now a days. This paper presents the design and analysis of speed control of three phase induction motor using IGBT as switches in the three phase voltage source inverter with constant V/F method control in closed loop using dsPIC30F4011 controller.dsPIC30F4011 is a 16 bit high performance digital signal controller (DSC). DSC is a single chip embedded controller which has both the features of microcontroller and DSP.A 1HP, 3 Phase, 415 volt, 50Hz, 1405 RPM induction motor is used as load for the inverter. Digital storage oscilloscope is used to record and analyze the waveforms.

Key words: Induction Motor, PWM Inverter, DSC, Constant V/F Method

I. Introduction

Three-phase induction motors are the most common motors used in industrial control systems and commercial applications. Induction motor has many advantages they are simple, rugged design, low-cost, low maintenance and direct connection to an AC power source etc. In the past, induction motors were preferred only for constant speed applications. Adjustment of speed of induction motor was very difficult and also needs high cost. So, DC motors were the optimum option for the variable speed applications. But over the years, this situation has changed depending on developments in power electronics and semiconductor technology. As a result many kinds of induction motor variable speed drives have been developed and now the induction motors are very good alternative for variable speed applications.

Induction motor is practically a constant speed motor that means, for under loading condition, change in speed of the motor is quite small. The speed of 3 phase induction motor depends on various factors like supplied voltage, frequency, number of poles. Speed of 3 phase induction motor needs to vary according to requirement. Induction motors speed reduction is accompanied by a corresponding loss of efficiency and poor power factor. As induction motors are widely being used, their speed control may be required in many applications.

The synchronous speed of the induction motor is given by

$$Ns = \frac{120f}{P} \quad (1)$$

Where ‘f’ is frequency and ‘p’ is number of poles.

The running speed of the induction motor is given by the equation

$$Nr = Ns\,(1 - s) \quad (2)$$

Where‘s’ is slip of the induction motor expressed in terms of percentage.

As the number of poles is not variable, varying the supply frequency would result in the variation in speed of the induction motor. Variation of the voltage should be in proportion to frequency**,** so that the torque developed is constant over the speed range.

When the induction motor is connected to the supply directly it runs at rated speed at no load. If the motor is loaded then speed of the motor starts to drop. So it is necessary to run the motor below the rated speed constantly with load and without load.

The various methods of speed control of induction motors are pole changing, frequency variation, variable rotor resistance, variable stator voltage, constant V/F control, slip recovery etc. the most generally used method is constant V/F method. Voltage/ frequency (V/F) controlled motors fall under the category of Variable Voltage Variable Frequency (VVVF) drives For Variable Voltage Variable Frequency (VVVF) drives; there is a need to control the fundamental voltage of the inverter if its frequency needs to be varied. In constant V/F control method, by use of PWM inverter, we can vary the supply voltage as well as the supply frequency such that the V/F ratio remains constant so that the flux remains constant too.

This work describes the closed loop speed control of three phase, 415V, 50HZ, 1H.P. induction motor using Digital Signal Controller (DSC), dsPIC30F4011. DSC is a single chip embedded controller that integrates the controller attributes of a microcontroller (MCU) with the computation and throughput capabilities of a Digital Signal Processor (DSP). The microchip dsPIC DSC offers all the facilities that are produced by a 16- bit microcontroller and DSP processor. The use of this 16 bit DSC yields enhanced operations, fewer system components, lower system cost and increased efficiency.

According to the requirement, a software program is written and is fed to the dsPIC30F4011 controller for the necessary action. The controller circuit compares the set speed with the actual speed. Depending on the difference between the set speed and actual speed, the microcontroller decides the frequency of gate pulses of IGBTs.

II. Proposed V/F Motor Drive Block Diagram and Design

The figure1 shows the block diagram of 3 phase induction motor speed control using digital signal controller. The block diagram consists of single phase bridge rectifier, three phase voltage source inverter, control circuit and speed sensing unit.

In the proposed work BR1010,10 amps full bridge rectifier is used. The output of rectifier is filtered by three capacitors of each value 330 micro farad are connected in

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parallel. The three phase voltage source inverter has KGT25N120NDA IGBT switches with the RC snubber circuit. The digital control of motor is achieved by applying gate pulses from the control circuit to each of IGBTs switch through optocoupler.

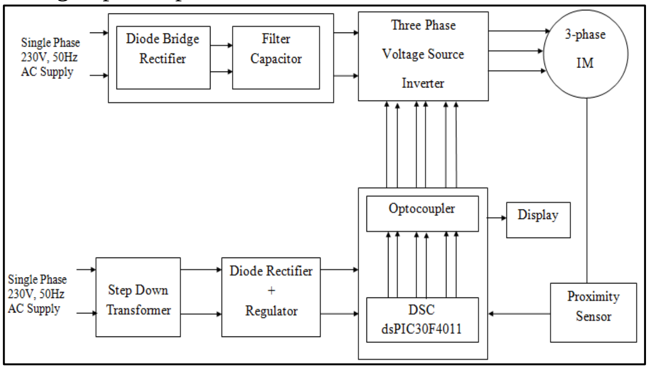

Fig. 1: Block diagram of three phase induction motor using Digital signal controller.

The diode bridge wave rectifier is used to convert input AC supply into DC and capacitor is used to remove the ripples from the output of the rectifier. A PWM based voltage source inverter is used to convert the DC link voltage to the required AC voltages and frequency. The PWM inverter has six IGBT switches that are controlled in order to generate an AC output from the DC input. dsPIC controller is programmed to generate a sinusoidal PWM pulses. Totally six number of pulses are generated. Three-phase inverter is used to get the three-phase output. In this inverter three legs are available. Each legs belongs to each phase. Each leg has two IGBT. The output of three-phase inverter having variable voltage and variable frequency.

A. *Power Circuit Design*

The selection of IGBT is done on the basis of voltage, current and power ratings of the induction motor. Also the maximum reverse voltage available across its collector and emitter terminal taken into consideration. The power circuit consists of 25 A, 1200V IGBT. Each IGBTs are provided by RC snubber circuit for providing dv/dt protection. The value of resistance and capacitances in the RC snubber circuit are respectively 500 ohm and 1nanofarad.

In time, a maximum of three switches will be on, either one upper and two lower switches, or two upper and one lower switch. Upper and lower switches of the same limb should not be switched on at the same time. This will prevent the DC bus supply from being shorted. A dead time is given between switching off the upper switch and switching on the lower switch and vice versa. Normally the dead time of 2 micro second is given.

B. *Control Circuit Design*

In this work dsPIC30F4011 digital signal controller is used. DSC is a single chip embedded controller that integrates the controller attributes of a microcontroller (MCU) with the computation and throughput capabilities of a Digital Signal Processor (DSP). The microchip dsPIC DSC offers all the facilities that are produced by a 16- bit microcontroller and DSP processor. The use of this 16 bit DSC yields enhanced operations, fewer system components, lower system cost and increased efficiency.

In order to protect the controller it is essential to provide isolation circuit between power circuit and control circuit otherwise the high power components may damage the low power PWM circuit components. In this work an optocoupler TLP 250 IC is used as optocoupler and driver circuit for the IGBT. Optocoupler is used for isolating the control circuit from power circuit. Six IGBTs of the power circuit are controlled by pulse width modulation signal generated by the controller. These generated PWM signals are applied to inverter in turn controls the speed based on variable voltage and variable frequency method.

III. EXPERIMENTAL RESULTS

The proposed scheme is implemented and tested in the laboratory. And photograph of the complete project work is shown in the figure 9.The readings of speed of the motor with change in duty cycle are taken and it shows in table 1and the graph of speed in rpm v/s duty cycle in % shown in the figure 2. Digital storage oscilloscope (DSO) is used to store gate pulses and inverter output voltage waveforms.

Duty cycle	Speed (RPM)
9 %	300
20 %	450
30 %	600
60%	8300
30 %	600
70 %	1050
89 %	1380

Table 1: Speed of I.M. with respective duty cycle

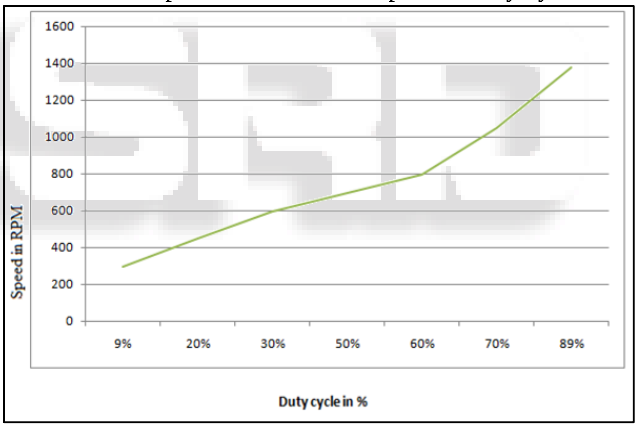

Fig. 2: Speed in RPM V/S Duty cycle in % graph

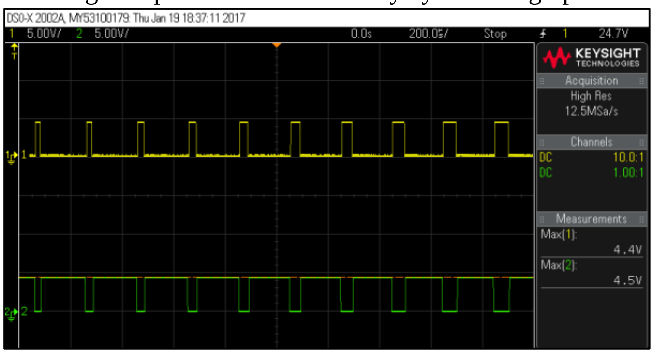

Fig. 3: Gate pulses for IGBTs

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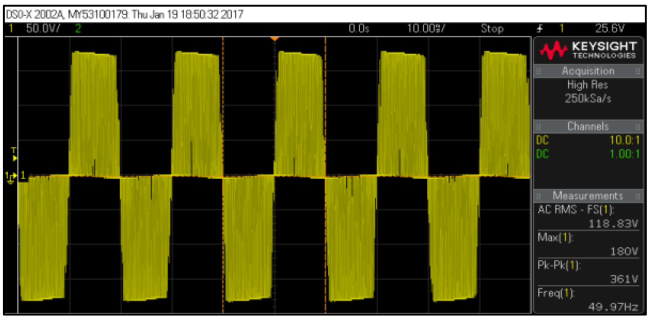

Fig. 4: Phase voltage at 1380 RPM

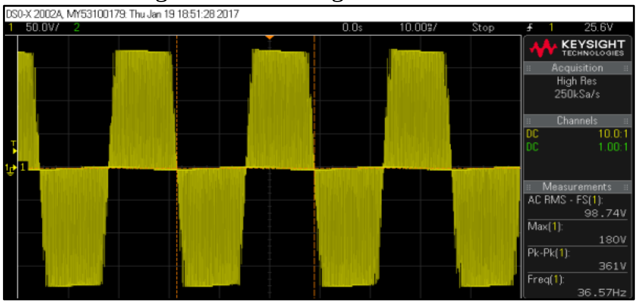

Fig. 5: Phase voltage at 1020 RPM

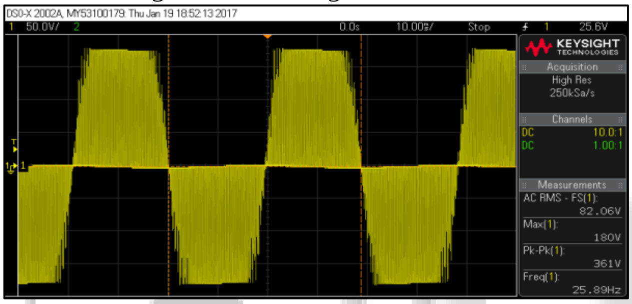

Fig. 6: Phase voltage at 700 RPM

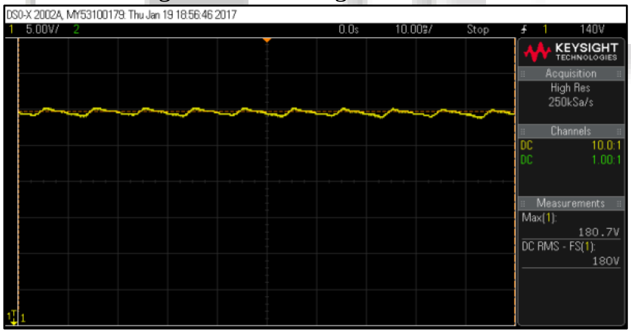

Fig. 7: DC link voltage with ripple

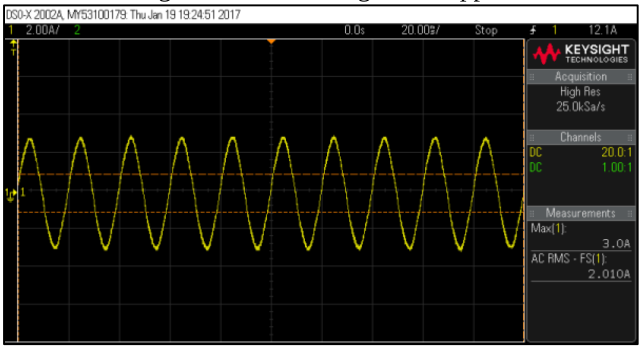

Fig. 8: Load current

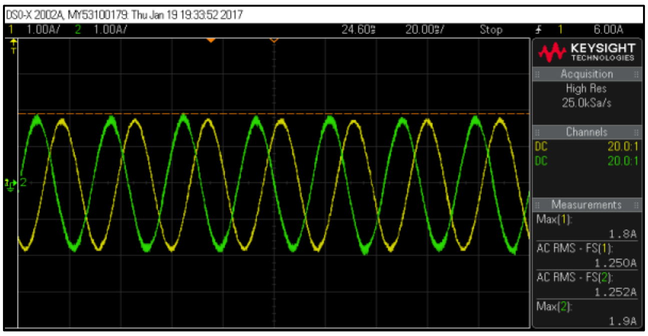

Fig. 9: Phase current

The figure 2 shows the gate pulses for the IGBTs. The figure 3, 4 and 5 shows the phase voltage between 2 phases at 1380, 1020 and 800 RPM respectively. The figure 6 shows the output of the rectifier and the figure 7 and 8 shows the load and phase current respectively.

Fig. 10: Photograph of complete designed system

IV. CONCLUSION

A new generation of dsPIC approach for the V/F control of three phase induction motor is presented. This completed system is developed and tested in the laboratory. Speed control of motor is acquired with the accuracy of +/- 10 RPM. Digital controller based systems can be efficiently used for speed control of induction motor along PWM technique. By using PWM technique speed of the induction motor can be control according to requirement. By maintaining the constant V/F ratio motor runs at various speed according to the requirement. Hence this three phase induction motor V/F control with PWM technique by DSC is more efficient and stable.

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