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V/F Speed Control Technique of Three Phase Induction Motor

Omkar Gawade[1], Onkar Utekar[1], Swapnil Ranjane[1], Ashish Raut[1], Rekha Sonune[2]

B.E. Student, Department of Electrical Engineering, Lokmanya Tilak College Of Engineering, Navi Mumbai, India[1]

Assistant Professor, Department of Electrical Engineering, Lokmanya Tilak College Of Engineering, Navi Mumbai, India[2]

Abstract: When we connect an induction motor directly to the main supply it can run only at its rated speed. However, many operations need variable speed applications. Also we felt that in many applications input power is directly proportional to the cube of motor speed. Today about 90% of all industrial motor applications use three phase induction motor because they are simple in design, easy to maintain and are less costly than other design. There are many induction motor control techniques in practice today, but the most popular control technique is by generating variable frequency supply, which has constant voltage to frequency ratio. This technique is popularly known as V/F speed control technique. The torque developed by the induction motor is directly proportional to the ratio of the applied voltage and the frequency of supply. By varying the voltage and the frequency, but keeping their ratio constant, the torque developed can be kept constant throughout the speed range. This is exactly what VF control tries to achieve.

Keywords: Speed control, variable frequency, three phase induction motor, PWM, IGBT, simulations.

I. INTRODUCTION

Many methods are used for the speed control of the induction motor. In the speed control of induction motor the main issue is to achieve maximum torque & efficiency. Smooth speed control of an induction motor had been a major problem in the early industry, difficulty in control has led the industry to go for other options like DC motors. However, with development of microcontroller and power electronic devices there is a scope of better speed control of induction motor. Constant volts per hertz control is the most popular scalar control scheme that varies terminal voltage in proportion to the supply frequency to maintain the air gap flux at approximately the rated V/F ratio especially when the machine operates below its rated frequency[6].

There are two methods to achieve the V/F speed control scalar and space vector PWM M.Reddy [3] and

Zhe Zhang [7] and Pallavi Alagur [4] had discussed several recent design topologies of V/F speed control techniques as well as their applications they have also introduced various techniques related in changes in open loop system. The design improvements in V/F speed control techniques have been described after research and developments in power electronics and PWM because of its quick operation, time high speed performance and lesser overall power requirements.
Researchers have long been trying to optimize and enhance the constant V/F control by compensating the stator voltage drop the simple compensation method of boosting the stator voltage by the magnitude of the current resistance (I.R) drop was proposed in [8]. A voltage auto boost method proposed in [9] provides with optimal V/F pattern based on knowledge of the induction machine equivalent circuit parameters and given load characteristics we have done research on V/F speed control technique and have performed simulations of PWM generation and six pulse inverter output and also analyzed the circuit parameters.

II. DESCRIPTION OF V/F SPEED CONTROL

There are two methods to achieve V/F speed control of induction motor.

2.1 Scalar method: In this method constant V/F is achieved using six pulse inverter with PWM firing. The controller circuit essentially takes the reference speed and actual speed of the motor in account. Depending upon difference between the reference speed and actual speed and decides the frequency of gate pulse of IGBT. The conventional approach of motor control is to first convert the line voltage into DC. DC is again converted to single/three phase AC as per load requirements. The output voltage, frequency or both of inverter can be controlled by the application of power electronics and microcontroller.

2.2 Space Vector method: Space Vector Modulation (SVM) Technique was originally developed as a vector approach to Pulse Width Modulation (PWM) for three- phase inverters. It is a more sophisticated technique for generating sine wave that provides a higher voltage to the motor with lower total harmonic distortion [10]. It gives a higher output Voltage for the same dc-bus voltage, lower switching losses, and better harmonic performance. Generally open-loop systems use V/F control which is used to a large number of applications where the basic need is to vary the motor speed and control the motor efficiently. It is also simple to implement and cost effective. The advantage of using V/F for speed control of three phase induction motor is as follows [2]:

- The current required at the starting is reduced.
- The motor runs more in stable region. Instead of simply running at its base rated speed the motor can be run typically from 5% of the synchronous speed up to the base speed. The torque generated by the motor can be kept constant throughout this region.
- We can drive the motor beyond the base speed by increasing the frequency further. However, the applied voltage cannot be increased beyond the rated voltage. Therefore, only the frequency can be increased, which results in the reduction of torque. Above the base speed, the factors governing torque become complex.
- By changing the supply frequency to the motor with respect to time we can control the acceleration and deceleration of the motor.

III. OPERATION

Fig.1 shows the overall block diagram of the V/f speed control Induction Motor module. The main three phase supply is rectified by using a diode bridge rectifier. The ripple on the DC voltage is filtered by appropriate filter arrangement. The filtered DC voltage is connected to the IGBT based 3 phase inverter. The inverter output is controlled by PWM gating signal obtained by microcontroller. By varying PWM signal we get required speed control as we obtain Variable frequency but constant V/f ratio at inverter output.
A potentiometer connected to analog input of microcontroller is used to vary the PWM signal and thus speed of motor. The PWM outputs are generated by on-chip hardware modules on the microcontroller. These are used to drive the IGBT drivers through optoisolators. IGBT driver receives gating signal from microcontroller through optoisolators, which in turn drives IGBT by appropriate signal amplification.
Overvoltage and overcurrent protection can be provided by using controller logic which compares stepped down voltage of DC bus with reference standard voltage; In case of fault microcontroller stops the operation.
Direction of rotation of Motor can also be changed by microcontroller. On giving reverse signal to microcontroller it will just interchange PWM output for any two phases after some delay.

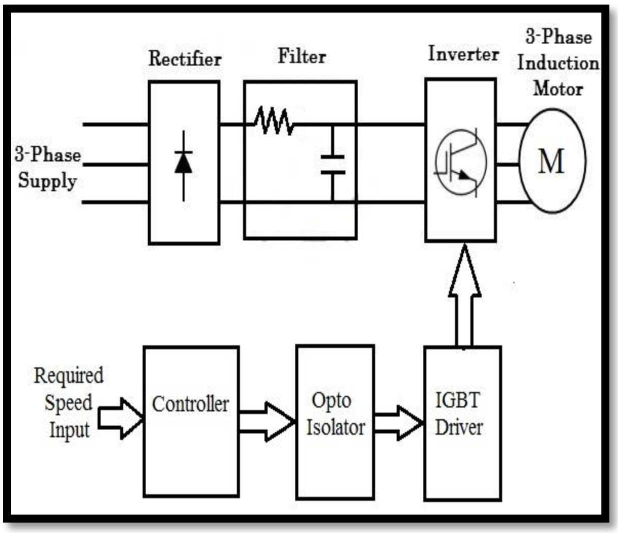

Fig.1: Block diagram of V/F speed control

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IV. SIMULATION MODEL

Simulation model of Inverter model is shown in Fig.2. Six IGBTs are used to form a six pulse Inverter circuit. 180° mode of operation is used where each switch conduct for 180° of cycle. IGBT pair in each arm i.e. S1, S4; S3, S6 and S5, S2 are turned on with a time interval of 180°. It means that S1 conduct for 180° and S4 for the next 180° of a cycle. Switch in the upper group i.e. S1, S3, S5 conduct at an interval of 120°. It implies that if S1 is fired at ωt=0°, then S3 must be fired at ωt=120° and S5 at ωt=240°.Similarly lower group of switches are fired. For our application we require variable voltage as well as variable frequency at output of inverter. This is achieved by using PWM firing scheme. RL equivalent load of Induction motor is connected at output. Antiparallel diodes are connected across each IGBT to provide path for inductor current to flow and protect IGBT. Simulation model of Sinusoidal PWM for Inverter firing is shown in FIg.3 Three sinusoidal signals of 50 Hz frequency with 120° phase difference between them are used as modulating signals. Saw tooth waveform of 1 KHz frequency is used as carrier signal for PWM. This produces three PWM outputs to be used as firing pulses for upper group of inverter switches. NOT operation is done on this three PWM outputs to get firing pulses for lower group of inverter switches. For RL equivalent load of Induction motor simulation is performed and voltage and current output across load phase is observed.

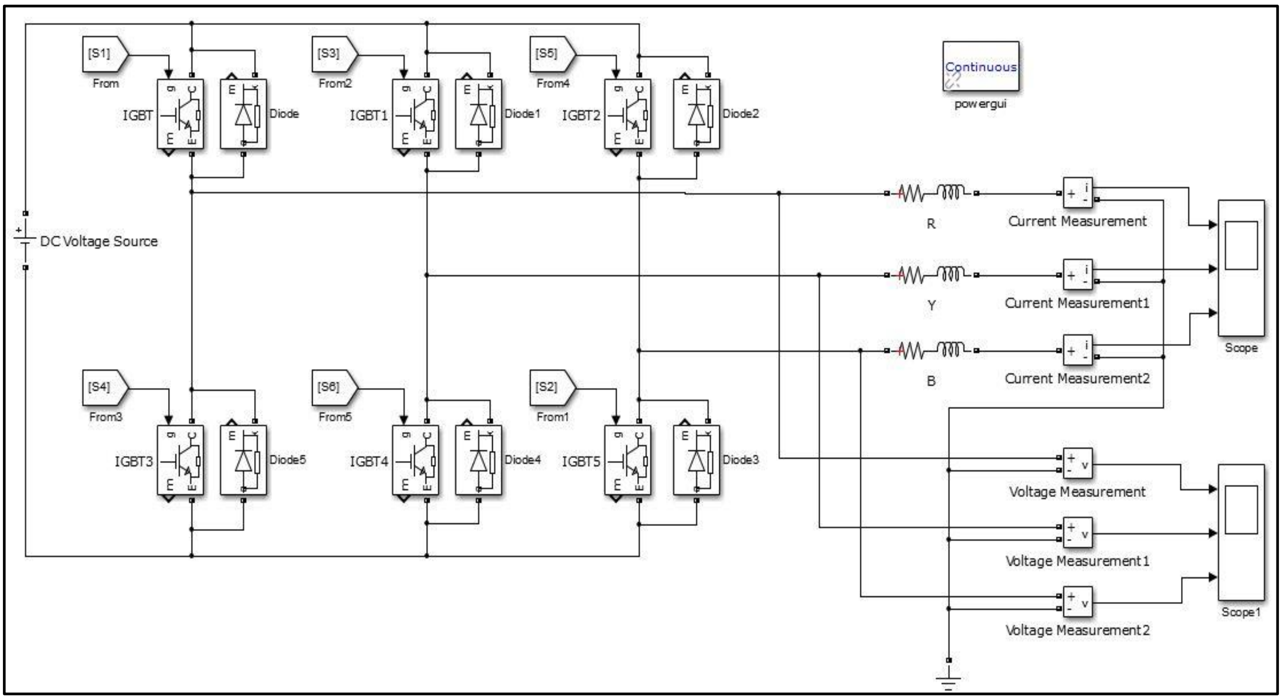

Fig.2: Simulation model of Inverter model with equivalent motor load

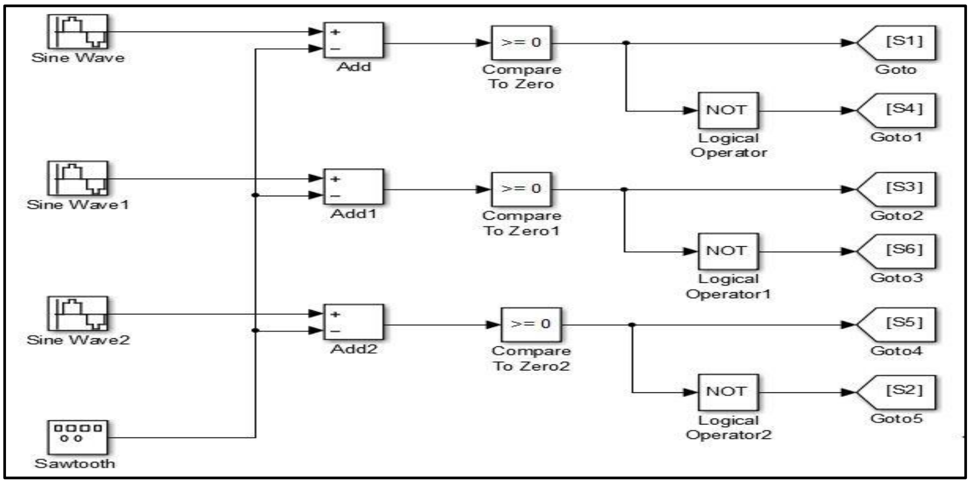

Fig.3: Simulation model of Sinusoidal PWM for Inverter firing

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Sinusoidal signals are compared with saw tooth signal, when they are equal output is toggled. This gives corresponding PWM output. Since three sinusoidal signals are used with 120° phase difference as modulating signals, we get three PWM outputs phase shifted by 120° from each other. This three PWM outputs are given to upper group of inverter switches which is shown in fig.4. NOT operation on this PWM outputs gives firing logic for lower group inverter switches. First sinusoidal signal compared with saw tooth gives first PWM which is given to S1 switch. This PWM after performing NOT operation is used to fire corresponding lower group inverter switch i.e.S4. Similarly firing for other inverter switches is obtained. By varying amplitude of saw tooth signal duty cycle of PWM output can be controlled.

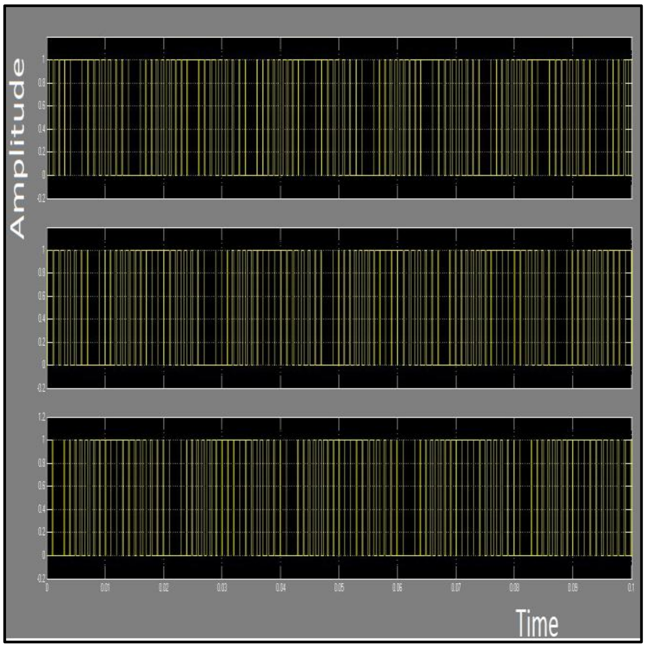

Fig.4: PWM output waveform for upper group inverter switches

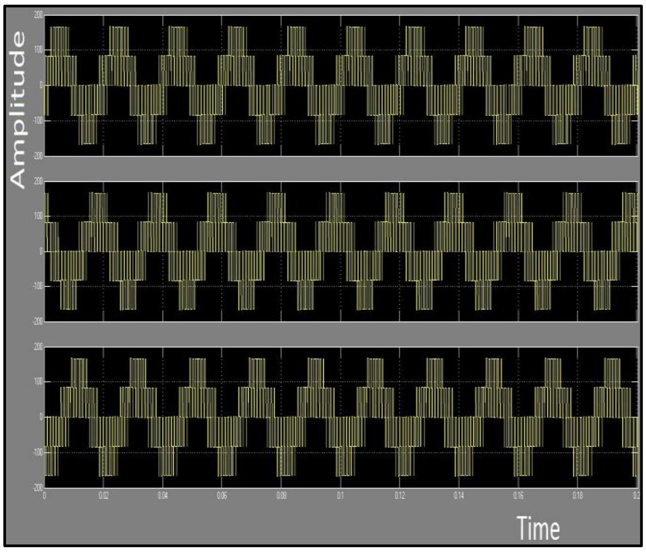

Fig.5: Voltage output waveform across inverter with RL load

Voltage output across each phase of load connected to inverter output is shown in fig.5 Frequency of output voltage is same as frequency of modulating sinusoidal signal i.e. 50 Hz. Average voltage can be controlled by varying duty cycle of PWM signal and thus by saw tooth signal amplitude. Filters are used in practical application to smooth the voltage waveform and to remove harmonics.

Fig.5 Voltage output waveform across inverter with RL load Current output across each phase of load connected to inverter output is shown in Fig.6 Due to inductance of load, current waveform is smooth sinusoidal. Induction motor consists of coils thus has inductance. Inductance with its property to oppose change in current acts as filter.

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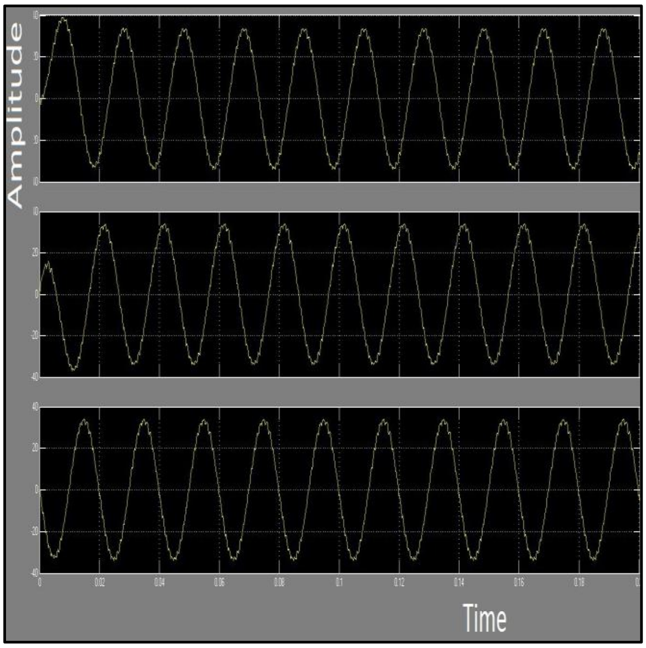

Fig.6: Current output waveform of inverter with RL load

V. CONCLUSION

The V/f speed control of Induction motor by using Inverter with PWM firing is successfully simulated. Equivalent RL load of induction motor is supplied by the inverter output voltage and output voltage and current waveforms are observed. Antiparallel diodes are connected across IGBTs to provide path for inductance load of motor to discharge. A variable frequency 3 phase voltage with Voltage to frequency ratio constant is achieved by using SPWM firing of Inverter. Requirement and advantages of V/f speed control of Induction motor are studied and discussed.

Microcontroller or 555 timer can be used to generate PWM signal for firing inverter circuit. Filter circuit is required at inverter output to smooth the voltage waveform and to remove harmonics. Microcontroller can also be used for additional application such as reversing motor direction by inter-changing PWM outputs for any two phases, also to start and stop motor. Protection can be provided by using comparator to detect overvoltage or overcurrent in DC bus and control action can be provided using microcontroller.

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