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Research Article

Speed Control of Three Phase Induction Motor using Variable Frequency Derive Control System

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Abstract

Three-phase AC induction motors play a very important role in industry due to its low price and simplicity. The induction motor is used to convert three-phase AC power into mechanical power. When the load on an induction motor increases the percentage of slip is increase, which leads to decrease the speed of induction motor while constant speed in industry is very important. This paper presents a simple converter for driving three-phase Induction motor from three-phase AC supply by using the variable frequency drive in feedback. So the speed of induction motor is controlled by variable frequency device automatically through controller. It is simple and efficient method to control the speed because speed depends upon voltage, pole and frequency. Poles are fix inbuilt in the motor so we cannot change it and speed control through VFD is simple and energy efficient method. This technique implemented on hardware. So this technique is robust and simpler to implement.

Keywords: *Three-phase induction motor, VFD, Speed control*

Introduction

When the load on an induction motor increases the percentage of slip is increase, which leads to decrease the speed of induction motor. The aim of this research to control speed of three phase induction motor and maintain it to its rated speed by using feedback control system. Induction motor is used in place of DC motors because of high initial and maintenance cost, it cannot be used for explosive and hazard condition and un-availability of DC supply. The use of induction motor is very large from domestic level to industry level.

In early the cost of variable frequency derive is very high so cannot use at that time. Technology improve the VFD and nowadays VFD is available at very low price.

Three phase induction motor speed control by using TRIAC in line rather than SCR in series and TRIAC are used in phase control mode. The firing angle from 0^0 to 180^0 is controlled by using TRIAC so the voltage phase angle is controlled which control the speed of motor (Kenly *et al*, 1976).This method is not efficient due to $\frac{dv}{dt}$ commutation.

Speed of induction motor is controlled through digital phase locked loop in feedback system. The speed of motor is compared with the reference frequency. Transducer is an encoder which is used to find the stator frequency as well as speed. If the output frequency is decreases due to load then speed of motor is also decrease, so transducer compare it with reference frequency and increase the output frequency so speed of motor is increased (Moffat *et al*, 1979).

Variable speed of the induction motor closed loop have a dynamic behavior and motor control derive system consist of SCR was connected the motor in three phase star configuration at the open side of star circuit (Romamoorty *et al*, 1979).

To observe the motor performance under load by changing the frequency through VFD and check the total loss of energy by using VFD and without use of VFD(Burt Charles *et al*, 2008).

Power cable control application was also used to control the speed of induction motor. The power cable use as feedback loop in inverter fed electric drive. Communication channel was made from power cable which verify and model in laboratory. Communication through PLC takes time delay in communication and having limitations to use at home but communication through power cable have no time delay constant and fast response(Konate *et al*, 2009).

The simple method to control single phase induction motor by controlling the frequency. The frequency control device consist of AC to DC and DC to

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AC conversion, H-bridge, IC and MOSFET (Latt Aung Zaw *et al*, 2009).

The voltage and frequency ratio is adjusted in such a way that the voltage and frequency ratio kept constant by keeping the v/f constant so the speed of motor is constant. When the speed of motor is decreased it mean frequency or voltage is also decreased to kept the voltage and frequency ratio constant to achieve the required speed. By using this technique different speed and torque can be achieved (Arulmozhiyal *et al*, 2009).

Multi-cell inverter includes an array of the single phase inverters have the ability to control the higher rating voltage device from lower rating device. A Real Time Digital Feedback Controller (RTDFBC) combined with the Repetitive Controller which is proposed to control the Variable Frequency Drive (VFD) fed by the multi-cellular inverter. This digital control characterized by very fast transient response and low switching losses, and the proper compensation for cyclical fluctuations and load disturbances(Ben-Brahim *et al*, 2010).

Direct Torque Control method provides the decoupled control of flux and torque of induction motor. This method has a simple control structure and provides good and fast dynamic torque response. It also provides the indirect control stator currents and the voltages (Sobha *et al*, 2011)(Verma Vimlesh *et al* 2013).

The fault tolerant of speed control of five-phase induction motor drives with ability to run the system after and before an open-phase fault situation using an FCS-MPC plan. The Experimental results which are provided the rated currents, fast and ripple-free torque response(Guzman Hugo er al, 2013).

Stator is a primary part and rotor of the motor act as a secondary part of the transformer flux produce in secondary winding due to the flow of current in primary winding through mutual induction. Observe the different parameter of the motor behavior of motor changes when load increase flux frequency and flow of current in primary and secondary winding is also change. Observe all these parameter and then verify these parameters by the modeled circuit on Simulink (Batool Munira *et al*, 2013).

When the motor operate at low frequency flux in air gap is also decreased due to impedance decreased in stator so the stator voltage maintain in such a way to get the flux constant at the same time the input frequency is also varied according to the output speed to get the voltage and frequency ratio constant (Petal jay *et al*, 2014) .

The speed and torque of motor control and improve through direct torque control (DTC) from zero to maximum rated speed and torque (Alsofyani *et al*, 2015).

The variable voltage and variable frequency derive is very efficient through variable frequency derive(Park *et al* 2016). The torque produced by the motor has direct relation to the magnetic field which produced by stator and stator magnetic flux directly proportional to the stator voltage so torque is controlled by voltage as well as speed. The starting current of motor is very high because at starting it requires high torque. So reduced the starting current by varying the voltage and frequency and achieve the rated speed and torque through changing the voltage and frequency(AL-Naib *et al* 2017).

In this paper variable frequency derive is used in feedback control system. Motor speed has directly relation to the frequency and inverse relation to the poles.

Constant speed achieved by variable frequency drive and this is very efficient low cost and power saving method.

Methodology

In VFD three phase AC voltages are converted into pulsating DC voltages where ripples are minimized by using low pass filters. Converted DC is applied to the IGBT's to invert it into three phase square waves AC. Phase sequence of three phase AC is adjusted by using gate driver. Inverted AC is applied to three phase induction motor. An encoder is adjusted with the shaft of motor to measures motors RPM, which is then sent to controller where it compares reference to update the required speed.

In three phase full wave un-controlled rectifiers 6-diodes are used to obtain six numbers of pulses known as six-pulse Bridge. Each diode having current rating of 10A and voltage rating of 1200V are used. A 3-phase AC-DC rectifier is shown in Fig 1.

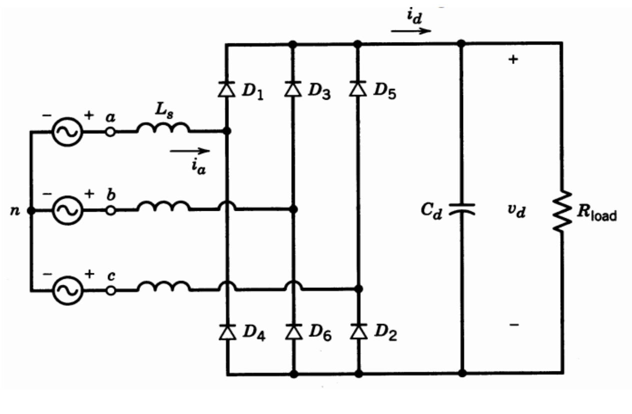


Fig. 1. Three-Phase AC to DC Rectifiers

Opto-coupler or optical isolator uses light while transferring electrical signal between two circuits. Opto-isolator consists of a phototransistor and LED in parallel opaque fashion. The 6N137 is an Opto-coupler consists of a 850nm AlGaAS LED, coupled to a very high speed photodetector logic gate storable output. Temperature ranges for coupled parameters is-40°C to +85°C. The symbol an Opto-coupler and an IC is also shown in Fig 2.

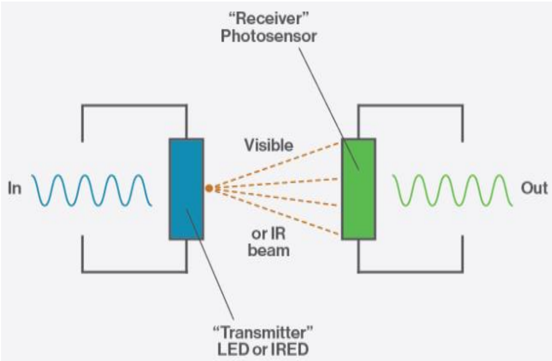


Fig. 2. Working Principle of Opto-coupler

Variable frequency derive have different types v/f, vector and flux. The most commonly used method is v/f other two method is also used but v/f most efficient method. Speed of motor controlled from zero to maximum speed through VFD. VFD operation circuit is shown in fig 3.

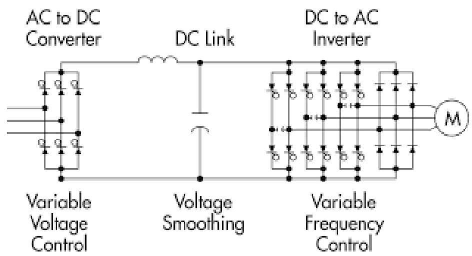


Fig. 3. VFD Operation

Following equivalent circuit shows the complete circuitry of three phase induction motor speed control by using frequency control scheme in Fig 4.

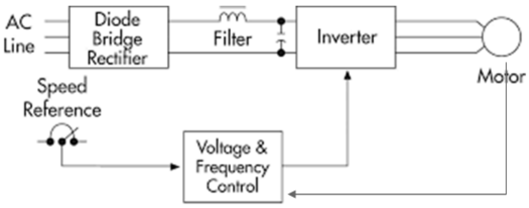


Fig. 4. Equivalent Circuit Diagram with VFD system

Complete Hardware

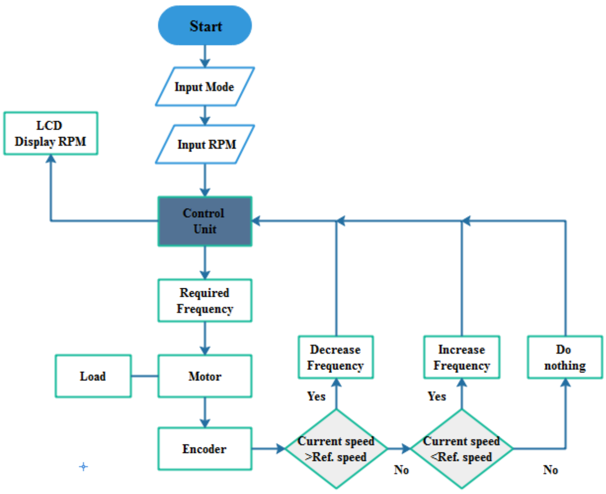
Speed of induction motor depends upon stator frequency, stator voltage, number of poles, constant of V/F, and rotor resistance in case of wound type rotor etc. Applied voltage of an induction motor has direct relation with torque.

Applied frequency has directly proportional to rotor speed and inversely proportional to the number of stator pole.

Electric load is connected with generator to vary the torque of motor, a variation in electric load on generator results in change in the speed of induction motors. Electric load would be resistive or inductive. Electric load is connected in parallel. Complete hardware is shown in Fig 5.

Fig. 5. Complete Hardware

Flow chart



1-

2- Power on to run the hardware. The 3-Φ supply is applied to hardware to turn on the controller and other electrical components.

3- First of all system needs mode selection from user: with feedback or without feedback. Press the desired button to proceed further. Secondly speed in rpm as input from user and press "*". If user don't enter speed then system will runs at default speed.

4- Motor will run only at given input set from the keypad.

5- Motor speed limit is adjusted from 800 to 1300 RPM. Motor will operate if we enter values range between 800 to 1300 RPM. If YES, then it will move forward and update frequency value. Otherwise NO, then motor will run on 800 RPM when entered RPM is less than 800 otherwise run on 1300 RPM.

6- Controller receives RPM from encoder and compare it with reference RPM. When both RPM's are equal then controller do nothing, if current speed is greater than reference speed controller reduce frequency to decrease the speed of motor otherwise increase the motor speed.

Result and Discussion

Results are compared with feedback and without feedback system. The motor is three phase 0.5-hp, 4-pole, and 2-pole, 1-hp, 500 watts and 220 volts of generator is coupled with motor. Loads of 15watts, 30watts and 45watts are applied on both of technique as shown in Tables.

Table I. Speed without Feedback at different loads and 1200 RPM

Sr.	Reference Speed	Current Speed without load	Load	Current Speed With Load
1	1200	1180	15	1145
2	1200	1181	30	1115
3	1200	1179	45	1096

TABLE II. Speed with Feedback at different loads and 1200 RPM

Sr.	Reference Speed	Current Speed without load	Load	Current Speed With Load
1	1200	1198	15	1203
2	1200	1203	30	1201
3	1200	1201	45	1195

Case 1

In first case 15 watts resistive load is connected with generator and speed of three phase induction motor is decreased.

Without feedback

When motor is initially started at 1200 rpm without feedback, it approaches 1180 instead of 1200 rpm. When a load of 15 watts is applied its speed is decreased to 1135 rpm, which will never approach steady state values (1180 or 1200 rpm). The graph at 15 watt load and 1200 rpm (reference) is shown in Fig 6.

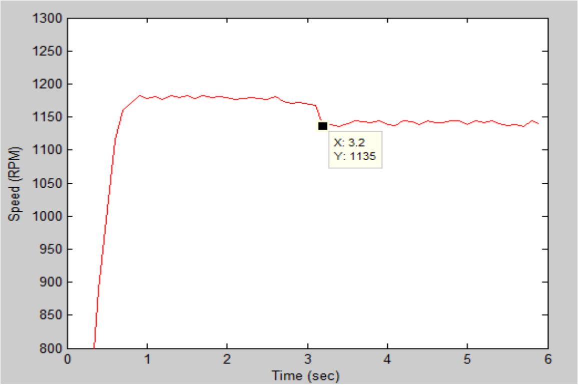


Fig. 6. Time vs Speed

With feedback

When motor is initially started at 1200 rpm with feedback, it approaches 1198 rpm after an overshoot which is the motor behavior. When 15 watts load is applied its speed is decreased to 1165 rpm, which will approach steady state values (1203 rpm) in 200 msec. The graph at 15 watt load and 1200 rpm (reference) is shown in Fig 7.

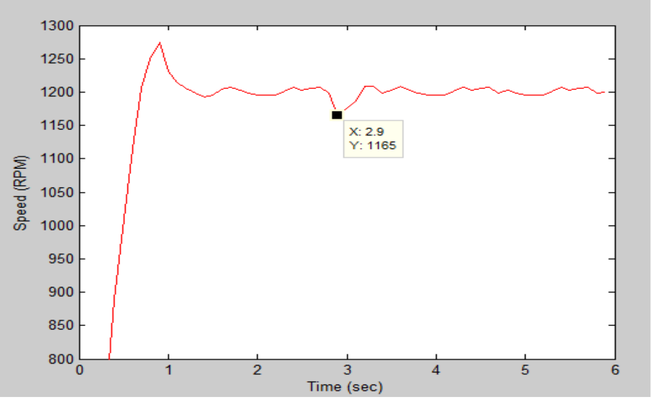


Fig. 7. Time vs Speed

Case 2

In second case load of 30 watts is applied on motor and set speed of the motor is 1200 rpm.

Without feedback

When motor is initially started at 1200 rpm without feedback, it approaches 1181 instead of 1200 rpm. When a load of 30 watts is applied its speed is decreased to 1115 rpm, which will never approach steady state values (1170 or 1200 rpm). The graph at 30watt load and 1200 rpm (reference) is shown in Fig 8.

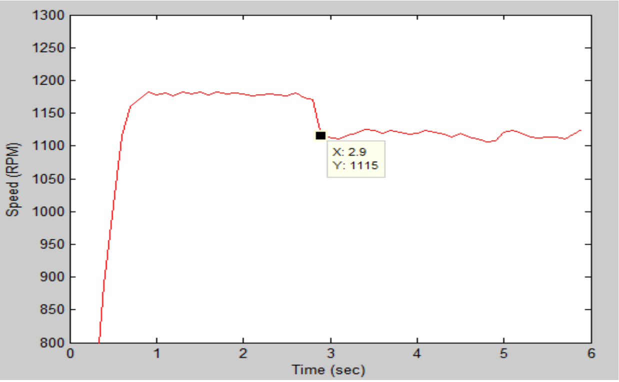


Fig. 8. Time vs Speed

With feedback

When motor is initially started at 1200 rpm with feedback, it approaches 1203 rpm after an overshoot which is the motor behavior. When 30 watts load is applied its speed is decreased to 1135 rpm, which will approach steady state values (1201 rpm) in 250 msec. The graph at 30 watt load and 1200 rpm (reference) is shown in Fig 9.

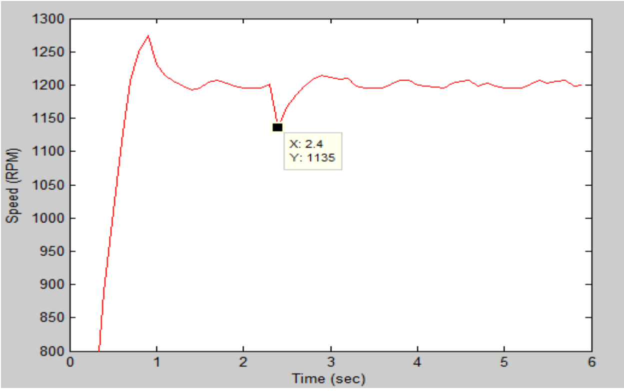


Fig. 9. Time vs Speed

Case 3

In 3rd case load of 45 watts is applied and results are compared below.

Without feedback

When motor is initially started at 1200 rpm without feedback, it approaches 1179 instead of 1200 rpm. When a load of 45 watts is applied its speed is decreased to 1096 rpm, which will never approach steady state values (1170 or 1200 rpm). The graph at 45watt load and 1200 rpm (reference) is shown in Fig 10.

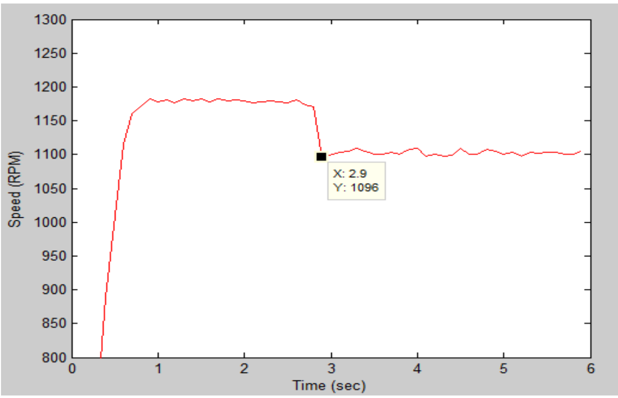


Fig. 10. Time vs Speed

With feedback

When motor is initially started at 1200 rpm with feedback, it approaches 1201 rpm after an overshoot which is the motor behavior. When 45 watts load is applied its speed is decreased to 1115 rpm, which will approach steady state values (1195 rpm) in 300 msec. The graph at 45 watt load and 1200 rpm (reference) is shown in Fig #11.

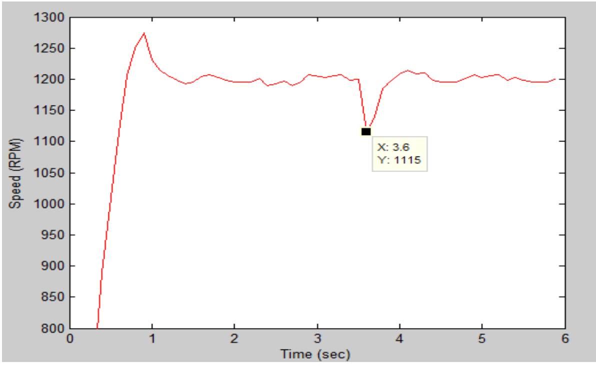


Fig.11. Time vs Speed

Conclusion

This paper addresses the VFD technique to regulated the speed of 3-ϕ induction motor. The hardware of VFD based speed control of induction motor was implemented to balance the speed at nominal value and to reduce the starting current. VFD controller is tested under different load conditions. It give satisfactory performance. It is possible to implement speed control system to control the multiple motors with the same device. The controller used in this paper is also use to monitor the other parameters of the motor.

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