Double Stage Drive System for Induction Motor Based on Direct Axis Current Control

Satyam Prakash[*1], Vivek Mishra[2] and Arvind Singh[3]

ABSTRACT

This paper deals with double stage drive system of 3-phase induction motor. As 3-phase induction motor consider as load thus its speed and torque at output shaft counts as performance parameter. One of these two stages is to control over DC voltage use to fed in inverter set provide controlling over output shaft torque. A feedback signal of torque generate error signal of PID controller which control output voltage level of phase control rectifier. This controlled voltage is fed to inverter where another stage comes into existence. Conversion of 3 to 2 phase of load current use as feedback signal for this stage of controlling. Another PID controller is use to control direct axis current of output supply of inverter. This 3-phase controlled output of inverter is fed to the armature winding of 3-phase induction motor by which controlling over speed will achieve. Simulation result will show the effect of this two stage controlling technique in the performance of 3-phase induction motor.

Keywords: T_d *(develop torque),* E_1 *(stator voltage),* N_s *(Synchronous speed),* N_r *(rotor speed),* f_s *(stator supply frequency),* I_d *(direct axis current),* I_q *(Indirect axis current).*

1. INTRODUCTION

The poly-phase induction motor categorized as singly excited alternating machine. When balanced poly phase supply is given to poly-phase stator winding, constant amplitude rotating m.m.f. wave is produced in air-gap. This m.m.f. causes the production of m.m.f. wave in rotor circuit. The interaction of stator m.m.f. and rotor m.m.f. develops a steady electromagnetic torque. Since poly-phase induction motor have simple construction and have better operational characteristic therefore its most popularly used in modern industries, in various traction applications. As a motor poly-phase induction motor always faces variation in load condition and also requires various operating speed to fulfill the load requirement. In case when induction machine works as induction generator in wind turbines it also requires various speed range. In such a manner we can say that speed control of Poly-phase induction generator always a matter of concern of an electrical engineer.

The speed control is a either manual or automatic process based on power switches by which speed of the drive intentionally can be varied up to desired level quickly. The fundamental methods which are used to control speed of three phase induction motors are: pole changing methods, stator voltage control, supply frequency control, rotor resistance control, and slip energy recovery methods. In paper we are going to discuss a about how, speed of three phase induction motor can be controlled by using the stator voltage control method. This method states that the speed of three phase induction motor can be varied by varying the supply voltage; from torque equation we see that the torque is directly proportional to the square of supply voltage and the slip at the maximum torque is

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independent of supply voltage. The variation of supply voltage does not alter the synchronous speed. This method of speed control is used to control speed below the normal rated speed. In this paper control scheme is employed with the help of PID controller. PID control is often combined with logic, sequential functions, selectors, and simple function blocks to build the complicated automation systems used for energy production, transportation, and manufacturing.

2. CONTROLLING METHOD AND TECHNIQUES

The overall controlling technique can be divided into two stages : (i) Rectifier stage control and (ii) Inverter stage control. In the first stage of controlling the single phase AC supply can be rectified by a phase controlled rectifier. As by controlling the phase control rectification of this wave provide require DC voltage. The single phase voltage has value of 215V 50Hz.By observe above technique we can conclude that output voltage of rectifier will control torque produce in the 3-phase induction motor. Thus, this technique which control torque in 3-phase induction motor can also consider as torque controlling stage of induction motor.

2.1 Torque controlling of 3-phase induction motor

As we know the relation between torque develop and voltage level of 3-phase AC provide to the induction motor is given as equation as

$$\tau_d \,\alpha\, E_1^{\,2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where τd is develop torque in the induction motor
E_1 is voltage magnitude of stator of induction motor

This condition can be develop by considering all other variables of the motor consider constant. That means speed of the motor and frequency of the supply should maintain constant. Thus, over all torque developed in induction motor directly depends upon the square of the voltage level of the power supply to the motor. In this paper the voltage level maintained by the controlled switching of power switches connected to the system. The gate signals for these power switches are provided by pulse width modulation technique. This generation of gate signals for power switches is the outcome of PID controller which is fed by a feedback signal of torque at shaft. Thus, the voltage level provided for inverter action is primarily controlled by a phase control rectifier. The torque of output shaft is fed as feedback and generate error signal for PID controller attached to the pulse generator. Thus the pulse generate by generator is depends upon the controlled signal provided by the controller.

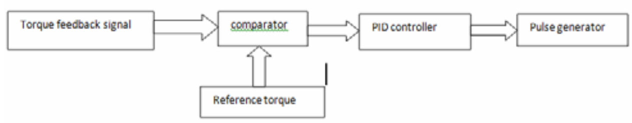

Fig.1. Block Diagram for Torque Control

These signals of pulse are used to trigger the power switches connected to the circuit. This particular circuit is used to convert single phase AC into controlled DC voltage by full wave controlled rectification. A capacitor of desire value is connected at the output of the system to maintain voltage level constant at a particular require level. This output of rectifier is fed as an input of inverter. As the level of voltage is maintained by error signal of torque. Thus, this voltage maintains torque constant throughout the operation of the machine as discussed above.

This DC voltage is fed to the inverter to generate 3-phase AC voltage for input of the induction motor. The frequency of 3-phase AC supply can be controlled by inverter action of the system. This inverter action depends upon speed requirement of the induction motor. As the second stage is inverter action and control the speed of the induction motor thus this stage also consider as speed controlling stage of the induction motor.

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2.2 Speed control of 3-phase induction motor

The relation between input frequency and output rotational speed is given as :

N_r *á* sf ……………………..(2)

Where s is slip of the 3-phase induction motor

f is supply frequency

N_r is rotor speed

Thus, by considering the slip constant the speed of motor depend upon input frequency. By controlling the input frequency of supply for induction motor rotating speed of 3-phase resultant flux can control. Thus, due to changing mechanism of rotor, speed of the rotor can be control by controlling the rotating speed of the resultant flux. For controlling the synchronous speed model provide a feedback signal to the comparator to this the comparator. The output of the comparator generate error signal this error signal fed into the PID controller to generate control signal for the system. 3-phase current is also takes as feedback this signal is convert into the direct axis and indirect axis current by the use of Planks transformation. These values of two axes current compare with reference value of direct axis and indirect axis current. Thus an error signal will generate. These two error signal of direct and indirect current will fed to the controller.

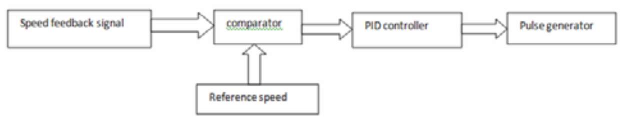

Fig.2. Block Diagram for Speed Control

This model is used as PID controller for proper controlling of the system. The output of this controller is again convert into 3-phase current controlling signal and fed to a 3-phase controlled inverter circuit. These gate signals are used to controll sequence trigger the power switches connected with inverter. Thus, output of the inverter is controlled and provides controlled speed application at the induction motor end.

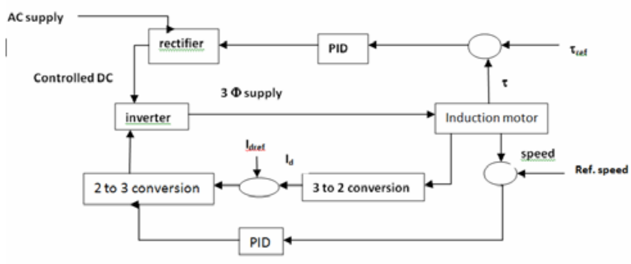

Fig.3 Block Diagram Representation of Controlling Technique

By above block diagram represent overall controlling technique of 3-phase induction motor. Thus, an induction motor can be controlled on the basis of torque produced at the output as well as speed of the rotor separately or together. This controlling technique is based on the fast acting power switches at both the stages of controlling these are rectifier and inverter stages. Using this power switches makes this controlling technique more quick responsive, reliable, and durable.

3. MATHEMATICAL MODELING

The mathematical modeling of this SIMULINK model can be divided into two parts : one is magnitude of voltage controlling part and the other is frequency of voltage controlling part. The second part depends upon the planks transformation.

Relation between output torque and magnitude of voltage of 3-phases AC is given as :

$$T_d = \frac{3T_{s_2}{}^2 E_1^2 s R_2}{6.28 n_s T_{s_1}{}^2 (R_2^2 + s^2 X_{20}{}^2)}$$

Thus, by this equation we can conclude that torque develop in 3-phase induction motor will directly depend upon magnitude of supply voltage. Any increment in supply voltage will cause to increase the value of output torque in square of the voltage magnitude. That means the overall torque production in induction motor can be control by controlling the magnitude of AC voltage apply to the motor.

To control the magnitude of AC voltage a phase control rectifier is in use. Relation between output voltage of rectifier and firing angle is given as

$$V_{0\ avg} = \frac{2vm\cos\alpha}{\prod}$$

That means any change in firing angle will directly shows its effect on average value of output voltage which count as DC voltage. Thus, output of controller will generate firing pulse for power switches and output voltage can be control. By controlling the output voltage by control switching sequence of power switches of rectifier output voltage can be controlled. So torque of the induction motor can be control. This controlling of voltage will be done in the first stage of controlling. Thus, this controlled voltage is fed as input of the inverter to generate 3-phase AC supply for induction motor.

The second stage controlling of 3-phase induction motor is based on Parks transformation and used to control speed of the induction motor. 3-phases to two phase conversion is the first step for this controlling technique. Method for this is given in following by which three phase current in induction motor will convert in direct axis and indirect axis current. By obtaining these values of direct and indirect axis current comparison will takes place and thus error signal will generate for direct axis current. This direct axis component of 3-phase current is responsible for generation and controlling of active power flow in induction motor.

$$\begin{matrix} I_d \\ I_q \end{matrix} = \begin{matrix} \sin\theta - 2\prod/3 & \sin\theta + 2\prod/3 \\ \cos\theta - 2\prod/3 & \cos\theta + 2\prod/3 \end{matrix} \quad \begin{matrix} I_a \\ I_b \\ I_c \end{matrix}$$

By controlling the magnitude of voltage in first stage of controlling torque can be considered constant. Thus, any change in the active power will directly affect the speed of the induction motor.

The real value of direct axis current will compare with reference value and error signal will generate. This error signal is fed into the controller and output of controller is fed to generate require value of direct axis current. This value of direct axis current will combine with indirect axis current and generate switching sequence for power switches connected to convert controlled DC voltage into the 3-phase AC voltage. By this controlling technique active power in the induction motor will control with constant value of torque; thus overall change in active power will appear at the speed of rotor.

4. SIMULATION RESULTS

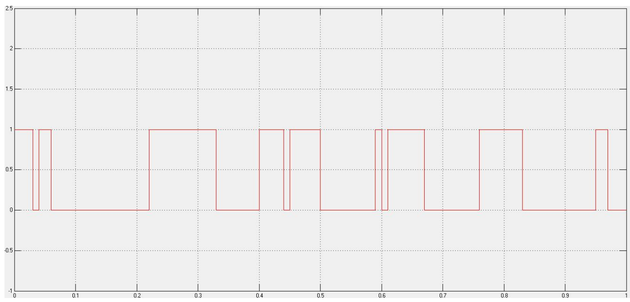

Fig.4. Pulse Signals for Phase Controlled Rectifier

Fig. 4 shows the triggering signals generate by pulse generator to trigger power switches connected to perform controlled rectification action and provide output as controlled DC.

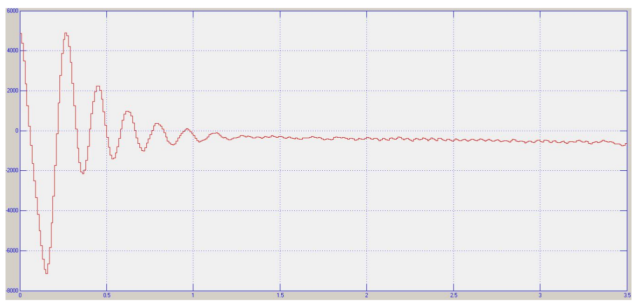

Fig.5. PID Controller Output

Fig. 5 shows the output signal of PID controller which shows its presence during transient time and decrease its value as the time passes.

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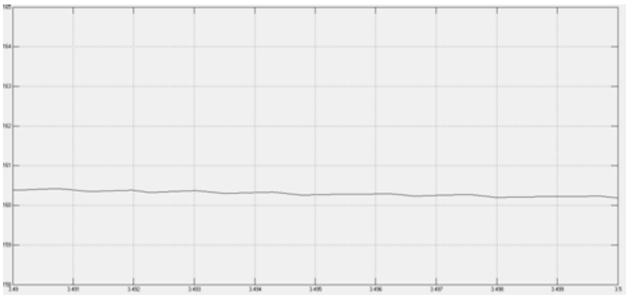

Fig.6 Output DC Voltage of Phase Controlled Rectifier

Fig. 6 shows controlled output DC voltage of phase controlled rectifier. The output limits its value at value of 160.40V DC. This DC voltage fed to the inverter for controlled inverter action.

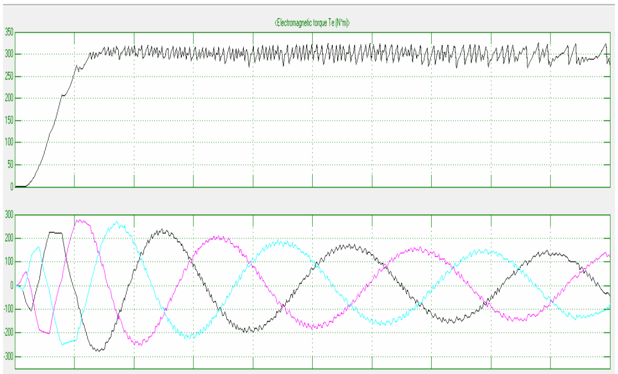

Fig.7 Output Torque and 3-phase Current of Induction Motor

By switching signals provide to the power switches of inverter action gives three phase controlled output. Thus Fig.7 shows the output current of 3-phase supply which injected into the induction motor. After transient of 0.008 sec the 3-phase waveform of the current will become 3-phase supply of constant value.

During this transient duration the value of torque will raise form 1 to 400 N-m. and become constant at this particular value. Some small ripples are present in the torque of the induction motor which will also overcome by a long time period of operation.

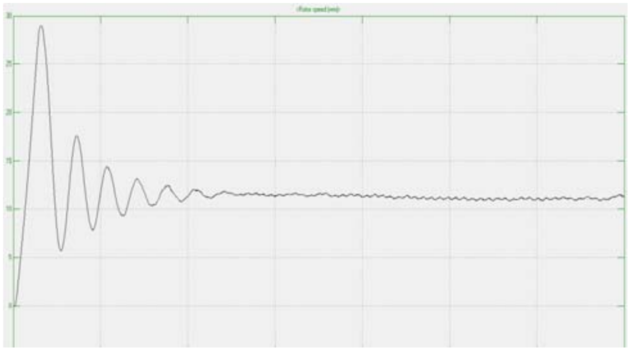

Fig.8. Output Speed of Induction Motor

As the above two figure shows the variation in torque and current. Thus, during this transient time the current will oscillate this oscillation of speed will damped out after second stage controlling technique will comes into action. Selecting speed control as second stage controlling makes transient appearance in speed for some long time as compare to 3-phase current and torque.

5. CONCLUSION

This result shows that by two stages controlling of 3-phase induction motor user can control either speed or torque of the output. These controlling can be together which mean by controlling any one require stage user can control either speed or torque without change in active power flow into the induction motor. Similarly by adopting controlling over both the stages user can control speed and torque together by change in active power flow into the induction motor.

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