

PERFORMANCE ANALYSIS OF PID CONTROLLER FOR THREE-PHASE INVERTER FED INDUCTION MOTOR

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ABSTRACT

This paper presents the study of proportional integral derivative controller (PID controller) for three-phase inverter fed induction motor. The PID controller is proposed due to its simplicity in term of the control structure and it is easy to design. The simulation result shows that the PID controller is able to control the switching signals to the three-phase inverter so that the induction motor can track the reference speed. Then the characteristics of the induction motor response are compared with a PI controller done by Madhavi L. Mhaisgawali, 2013. The proposed PID controller for three-phase inverter fed induction motor is able to track the reference speed and achieve the steady-state value faster than the one using PI controller. The speed control is essential to maintain the performance and efficiency of an induction motor and therefore avoid damage of the induction motor.

Keywords:

Three-phase Induction Motor, PID Controller, Three-phase Inverter, Pulse Width Modulation.

INTRODUCTION

Currently, the three-phase induction motor has a vital role and also widely used in industrial application. The development of high performance induction motor is very important in industrial as well as other purpose application. For example when the speed of the rotor shaft inside the generator is high and it has to be controlled within a certain period of time, so then the speed controller is able to control the switching signals to the three-phase inverter to control the speed of the rotor shaft. Two types of control methods used in motor control system such as the proportional integral (PI) controller and also the Proportional, integral and derivative (PID) controller. However, PI controller is unable to provide the desired control performance for more complex system such as induction motor where there exist of variable-frequency, harmonically optimum converter power supplies and the presence of harmonic. The disadvantage of adjusting the proportional and integral gains is very costly and it consumes a lot of time for a high speed control system. In addition it also cannot predict the error in future time. The error can only be solved by introducing the derivative gain.

This paper proposes the PID controller to control the velocity of the three-phase induction motor. PID controller consists of all the necessary dynamics such as the derivative, integral and proportional. The (P) Proportional gain eliminates oscillations which improve the rise time. The integral (I) gain increases the control signal which leads to zero error in the system or eliminates steady state error. The derivative (D) gain gives a fast reaction change of the controller input and also improves overshoot.

SYSTEM DESCRIPTION OF THE PROPOSED DESIGN

Overall Block Diagram of the Proposed Design

Figure 1 show the overall block diagram of the proposed design, where the DC voltage source is supplying a DC voltage of 400V to the three-phase inverter. Pulse-width modulation (PWM) technique is used to generate switching signal to the insulated gate bipolar transistors (IGBTs) of the three-phase inverter. The six number of IGBTs in the three-phase inverter are all of same rating and they are two complementary switch pairs in each phase in which only one of the switches in a pair will turn on each time while the other will be turned off. The PWM switching technique generates the inverter switching command to achieve desired torque at the motor shaft. Three-phase inverters are commonly used to supply three-phase loads; applications such as uninterruptible ac power supplies and ac motor drives. Each phase of the proposed three-phase inverter circuit consists of three legs, each for one phase. Basic one leg inverter is described with the similarity of each inverter leg. Therefore the output voltage from the inverter is independent from the direction of the load current. (Mohan, et al., 1989)

The three-phase stator current I_{s_a} , I_{s_b} and I_{s_c} is measured and feed to the direct current, I_d and quadrature current, I_q in stationary reference frame. The motor speed is compared with reference speed and the error produced is sent to the PID controller. (Pedro, N, 2010). The output of the PID controller is the electromagnetic torque. The quadrature stator current component and direct stator current component are converted into current references in stationary reference frame. The current references in stationary frame is converted to the phase current references and fed into the current regulator. The current regulator then processes the output and reference currents to produce the switching gate signals. The DC voltage source supplies voltage around 400V to the IGBTs and the pulse generator sends signal as pulse for the switching to take place and rotate the rotor.

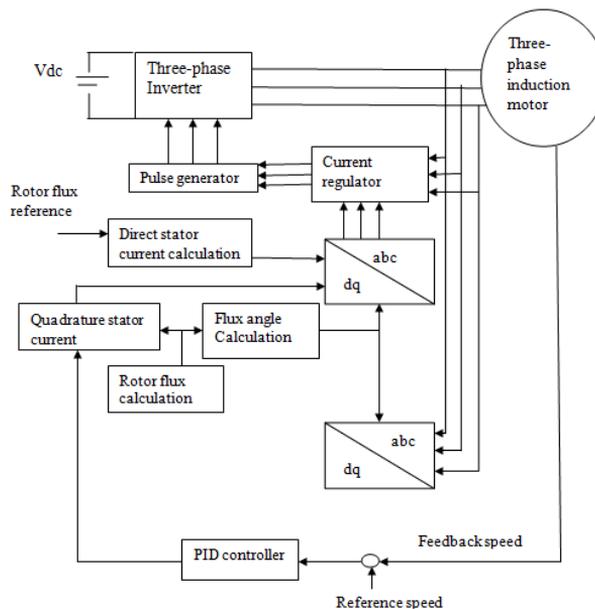


Figure 1: Overall Block Diagram of the Proposed Design

The proposed PID controller uses the same approach by Mhaisgawali, M, 2013 as shown in Figure 2. The mathematical equation for the control signal is as shown in equation 1,

$$u(t) = K_p e(t) + K_i \int e(t) dt + K_d \frac{de(t)}{dt} \quad (1)$$

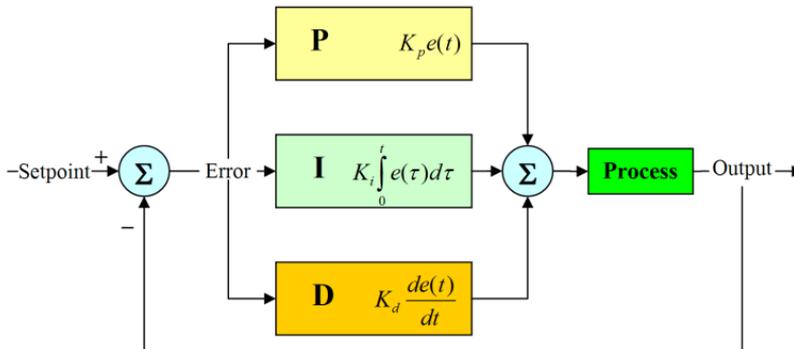


Figure 2: PID Overview (Mhaisgawali, M, 2013)

From equation 1 the error signal, e is a variable which tracks the error, and can be obtained by finding the difference between the reference value and the actual output. The error signal is then sent to the PID controller to compute integral and the derivative of the error signal. The control signal, u of the plant is the summation of the proportional gain, K_p multiplying with the magnitude of the error, the integral gain, K_i multiply with the integral of the error signal and the derivative gain, K_d multiply with the derivative of the error signal.

METHODOLOGY

SIMULINK Model of the PID controller for Three-Phase Inverter Fed Induction Motor

A complete SIMULINK diagram of the proposed PID controller for three-phase inverter fed induction motor is shown in Figure 3.

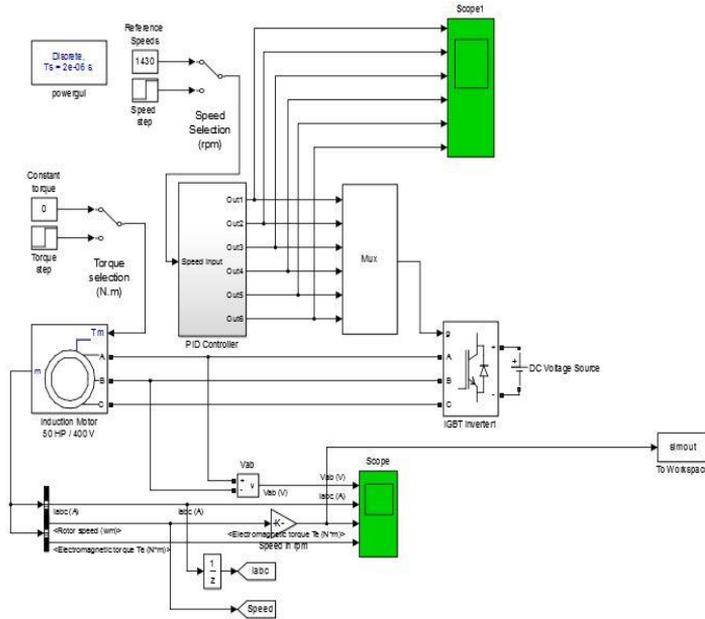


Figure 3: Developed SIMULINK model for the proposed PID controller of Three-Phase Induction Motor

The induction motor stator is fed by the current control of the three-phase IGBT inverter. Hysteris regulator regulates the stator currents and generates the inverter drive signals for the inverter switches to control the induction motor. Quadrature axis current component and the direct axis current component control the motor torque and the motor flux. The three-phase current is converted to into quadrature and direct current. Then, the stator currents were added into multiplexer by applying the mathematical operation using the functional block parameters provided in MATLAB SIMULINK to run the simulation.

The knowledge of the rotor flux magnitude and the rotor flux angle is the key information for the field oriented control of three-phase induction motor.

$$\psi_r = \frac{l_m i_d}{1 + \tau_r} \quad (2)$$

where

ψ_r = rotor flux

i_d = direct current

τ_r = rotor torque

l_m = magnetizing inductance

Equation (2) shows the rotor flux magnitude calculation. The induction motor stator is fed by the present control of the three-phase IGBT inverter. Hysteris controller manages the stator currents and creates the inverter drive signals for the inverter switches to control the induction motor. The stator currents were added into multiplexer by applying the mathematical operation using the functional block parameters provided in MATLAB SIMULINK to run the simulation.

SIMULATION RESULTS AND DISCUSSION

The proposed design is simulated using MATLAB SIMULINK. The velocity reaction of the three-phase induction motor is checked by utilizing the PID controller and compared with the response of the speed for three-phase induction motor utilizing the PI controller by Madhavi L. Mhaisgawali, 2013. Figure 4 shows the results obtained by Madhavi L. Mhaisgawali 2013 where PI controller is used as a speed controller for three-phase inverter fed induction motor.

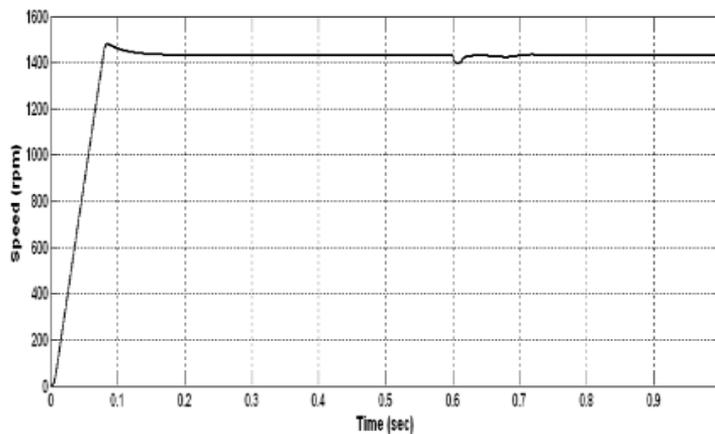


Figure 4: Speed Response of Three-Phase Induction Motor with PI Controller

As can be seen from Figure 4, the speed obtained from the simulation is 1430 rpm and the settling time is 0.269 s with the rise time 0.083 s. The PI controller disposes of the steady-state error and enhances the rise time however it requires longer time to settle to its consistent state value. In addition, the overshoot in the speed response can rapidly damage a motor system. The PID controller contains the derivative which is able to decrease the overshoot in the speed response of the rotor as can be seen in Figure 5.

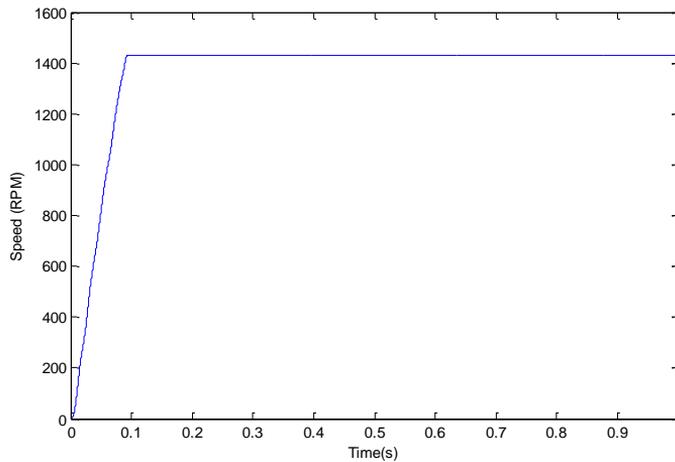


Figure 5: Speed Response of Three-Phase Induction Motor using the PID controller

The speed reaction of the three-phase induction motor utilizing the PID controller gives decrease in rise time, decrease in overshoot and the steady-state error is eliminated. The voltage given for the induction motor is 400V. The Table 1 below demonstrates the comparison of rise time and settling time of three-phase induction motor utilizing PID controller and PI controller.

Table 1: Comparison between PI Controller and PID Controller

Parameters	PI Controller	PID controller
Speed (RPM)	1430	1430
Rise Time(s)	0.083	0.0679
Settling time(s)	0.269	0.0897
Overshoot	Increase	Eliminate

It is observed from Table 1 that the proposed PID controller has better speed response as compared with the PI controller for the three-phase induction motor. The speed of the three-phase induction motor utilizing PID controller has lesser rise time, settling time and overshoot is eliminated.

The feedback of the rotor speed from the three-phase induction motor is given to the PID controller. The output from the PID controller is associated with the current regulator where the motor current tracks the reference current and the genuine motor current inside the hysteresis band. Therefore six pulses are produced to control the switches of three-phase inverter to give three-phase induction motor with its desired magnitude and frequency. In addition to the speed response, the three-phase output voltage from the three-phase inverter is also verified using MATLAB SIMULINK simulation. As can be seen from Figure 6, the three-phase output voltage, i.e., V_{ab} , V_{bc} and V_{ca} have the same magnitude of 400V and are displaced by 120° phase angle. The voltage can be controlled by changing the magnitude of the supply voltages to the stator. The magnitude of the three-phase output voltages are essential to guarantee the induction motor can work under desired condition.

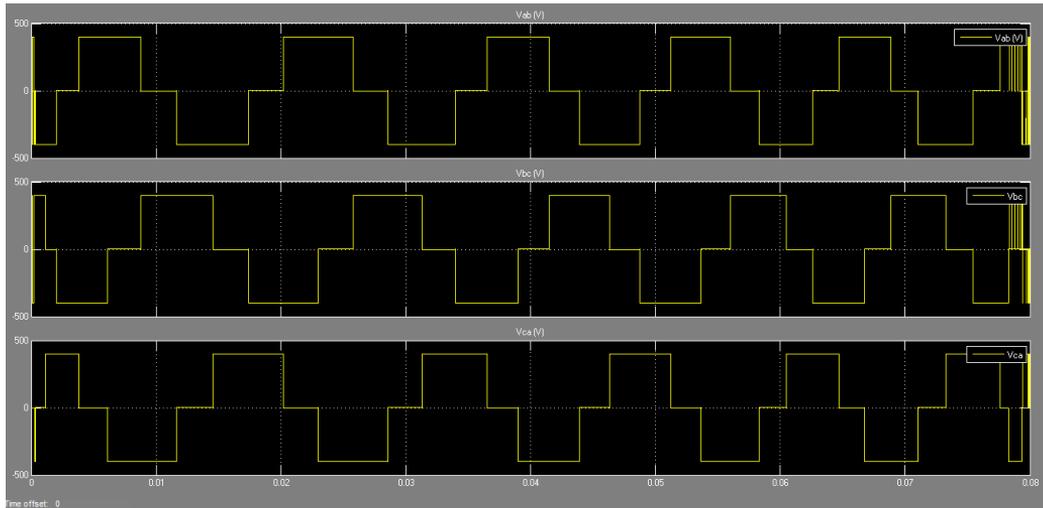


Figure 6: Simulation of voltage for three-phase induction motor

CONCLUSION

The paper proposes a PID controller for three-phase inverter fed induction motor by using MATLAB SIMULINK simulation. The simulation results reveal that the PID controller is able to control the switching signals to the IGBTs of inverter and track the reference speed of the induction motor. The PID controller has better effects compared to the PI controller as a speed controller for the three-phase inverter fed induction motor such that the PID controller has the ability to improve the transient response, eliminate the overshoot and decrease the settling time.

The proposed design is able to enhance the performance and efficiency of the three-phase induction motor. The motor can be damaged if the engine moves in a rapid over the rated speed by the engine itself.

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