A Model Reference Adaptive PI Controller for the Speed Control of Three Phase Induction Motor

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***Abstract*—Induction motors are highly nonlinear in nature. Speed control of induction motor is not a simple task. Induction motors are commonly used in industries due to their low maintenance cost and robustness. Vectorial analysis with rotor flux orientation is used to create mathematical model of the motor for speed control. A model reference adaptive PI controller is used for speed conrol.MIT rule is used here to implement the adaptation mechanism. Simulation results show that MRAC can eliminate peak overshoot and it can improves the settling time when it compares with conventional PI controller.**

Keywords—MRAC ,.MIT rule

I. INTRODUCTION

Among all types of machines three phase squirrel cage induction motors are used in industries. These machines are rugged and reliable. Induction motors are available in the ranges of fractional horse power to multi megawatt capacity. Fundamental principal of three phase induction motors is the creation of rotating and sinusoidally distributing magnetic field in the air gap. Sinusoidal three phase power supply in the three stator windings creates a synchronously rotating magnetic field. Induction motor cannot produce torque at synchronous speed. At other speed it produces slip speed induces rotor current. So torque is produced[1].The speed of rotating magnetic field is called synchronous speed. Synchronous speed depends on frequency and number of poles of the machine. Rotor speed is always less than synchronous speed. Induction motor can runs at its rated speed .But many applications need variable speed operation. Conventional controllers like PI, PID can be used to control the speed of three phase induction motor. But these conventional controllers shows overshoot in the output wave form, ie the speed overshoot the set point value. Commonly an inverter fed speed control system of induction motor uses a conventional PI controller. But external load changes interferes the stable operation.

This paper deals with the speed control of three phase induction motor through model reference adaptive control approach .Adaptive control is a control method used by a controller the parameters of the controller are updated with respect to changes in the output. Model reference adaptive control gives adaptation to the plant through a reference model and adjustment mechanism. Adjustment mechanism is the core of model reference adaptive control (MRAC).Lyapnov method and MIT rule are usually used to implement adjustment mechanism.

II. MATHEMATICAL MODEL OF THE MOTOR

Vector controlled induction motor operates like a separately excited DC motor .If we consider the control of induction motor in a synchronously rotating reference frame DC machine like performance can also be extended to the motor. In vector control direct axis stator current is analogous to field current in a dc motor and quadrature axis stator current is analogous to armature current in a DC motor[1]. Electromagnetic torque produced by the motor can be expressed as

$$T_e(t) = k_d \psi_{rd}(t) i_{sq}(t) \quad (1)$$

k_d is a positive constant, ψ_{rd} is the direct axis rotor flux linkage. Induction motor dynamics can be expressed by equation(2).DC machine like performance is possible if direct axis stator current is aligned in the direction of flux and quadrature axis stator current is maintained perpendicular to it.

$$\frac{Jd\omega(t)}{dt} = T_e(t) - B\omega(t) - T_l(t) \quad (2)$$

Dynamics of three phase induction motor is given by equation (2). Here J is the moment of inertia of the rotational speed, $T_e(t)$ is the electromagnetic torque developed by the motor. B is the damping constant. $T_l(t)$ is the load torque ω is the rotor angular mechanical speed [2].

$$JS\omega(S) = \frac{k_d \psi_{rd} i_{sq}(s)}{J} - \frac{B}{J}\omega(S) \quad (3)$$

$$S\omega(S) = \frac{k_d \psi_{rd}}{J} i_{sq}(s) - \frac{B}{J}\omega(S) \quad (4)$$

$$\omega(s) = \frac{k_p}{s + a_p} \quad (5)$$

$$\frac{k_d \psi_{rd}}{J} = k_p \quad (6)$$

$$\frac{B}{J} = a_p \tag{7}$$

III.MODEL REFERENCE ADAPTIVE PI CONTROLLER

Model reference adaptive control comes under adaptive control[3]. Adaptive control is differ from robust control that it does not need a prior information about the uncertainties .In 1950 adaptive control was designed to implement an autopilot in an aircraft operation at wide range of altitude and speed .So a control law is necessary to adapt itself to such changing condition. Reference model, plant, adjustment mechanism etc are the inevitable parts in a model reference adaptive control system [4]. Reference model produces a perfect output. Our plant should track this reference model. Adjustment parameter adjusts the controller parameter with respect to the changes in output. Lyapnov stability theory was established in 1960 for providing convergence in adaptive control system. In 1960 Park found another way of redesigning the laws for adaptive control system and MRAC.

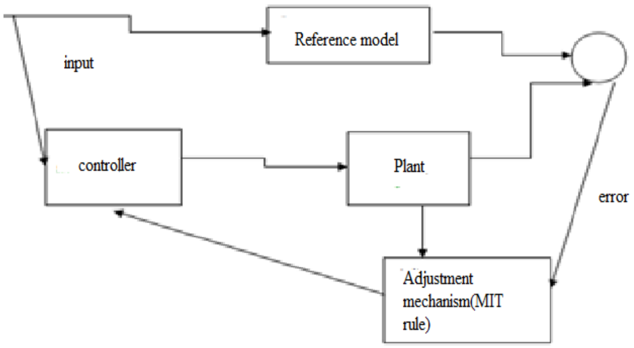

Fig 1: Model reference adaptive control system

A reference model describes the desired system performance. Plant response should match the response of the reference model. Adaptation mechanism or adjustment mechanism searches for a parameter to adjust the plant response as a perfect one like the reference model. MRAC basically belongs to direct adaptive system. Lyapnov method,MIT rule etc are used for adaptation mechanism.

IV. MIT RULE

MIT (Massachusetts Institute of Technology) rule was developed by researchers in Massachusetts institute of technology in 1960s for adaptation mechanism in MRAC. According to MIT rule [5] cost function or loss function can be expressed as

$$J(\theta) = e^2/2 \tag{8}$$

Here 'e' is the error. Error the difference between the output of the actual plant and the model. Here θ is taken as the adjustable parameter. Here θ is adjusted in such a way that the loss function is minimized .For this is reason adjustment parameter is kept in the direction of negative gradient of J.

$$\frac{d\theta}{dt} = -\gamma \frac{\partial J}{\partial \theta} \tag{9}$$

$$\frac{d\theta}{dt} = -\gamma e \frac{\partial e}{\partial \theta} \tag{10}$$

$\frac{\partial e}{\partial \theta}$ is called partial derivative of the system. This term shows that how error signal is changing with the adjustment parameter. γ is the adaptation gain of the controller and it also a positive quantity. Consider a linear transfer function KG(s).Here G(s) is the transfer function and K is an unknown parameter. Our aim is to design a controller that should track the reference model. Transfer function of the reference model can be chosen as k_0 G(s).The error signal is

$$e(t) = y(t) - y_m(t) \tag{11}$$

$$E(S) = KG(S)U(S) - K_0 G(S) U_C(S) \tag{12}$$

By defining control law we can write

$$U(t) = \theta^* u(t) \tag{13}$$

$$\frac{\partial E(s)}{\partial \theta} = KG(S)U_C(S) = \frac{K}{K_0} y_m(S) \tag{14}$$

$$\frac{d\theta}{dt} = -\gamma e \frac{K_0}{K_m} y_m \tag{15}$$

Equation (15) gives the MIT rule for adjustment mechanism. θ is the adjustment parameter. Adjustment mechanism automatically adjusts the controller parameter with respect to the changes in the output of the system.

V.MODEL REFERENCE ADAPTIVE PI CONTROLLER

PI controllers are widely used in industries .PI controllers are commonly used for first order systems. These are applicable to first order systems. Controller tries to minimize the error between the set point value and measured output.

$$u(t) = k_p e(t) + k_i \int_0^t e(t).dt \tag{16}$$

The proportional term k_p produces an output proportional to error signal. The proportional gain can be adjusted by multiplying proportional gain with a constant, called proportional gain constant. Large value of proportional gain makes the system unstable. Here the integral term is proportional to the integral of error signal. Integral term accelerates the process towards set point value and it reduces the steady state error. The main disadvantage of PI controller is that it overshoots the set point value. In model reference adaptive PI controller the adjustment mechanism automatically update the parameter of the controller.

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$$U = U_c \theta \tag{17}$$

$$U = [k_p e(t) + k_d \frac{de(t)}{dt} + k_i \int_0^t e(t).dt]\theta \tag{18}$$

VII.SIMULATION PARAMETERS

$k_d = 21.8$, $\psi_{rd} = 87.5 \times 10^{-5}$ Weber, $B = 5.65 \times 10^{-3} kgm^2 / s$, $J = 5 \times 10^{-4}$, $kp = 3797.56$, $a_p = 11$ for a .25 HP motor. The reference model chosen here is $\frac{21}{s+21}$.

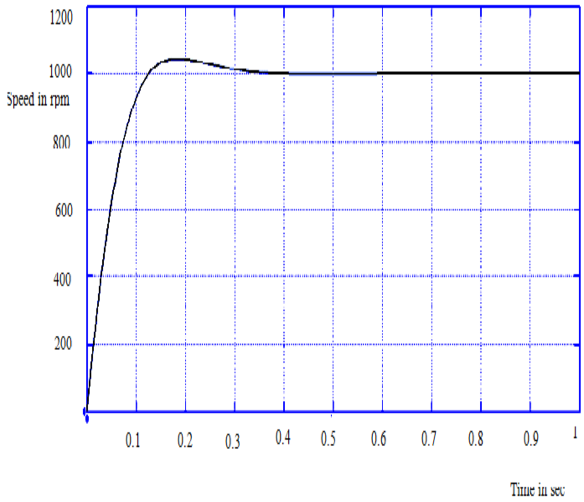

Fig 2 : Motor speed with conventional PI controller

TABLE 1 COMPARISON BETWEEN MRAC AND CONVENTIONAL CONTROLLERS

Controller	Settling time(in sec)	Peak overshoot
PI	0.4	1050
Model reference adaptive PI controller	0.25	0

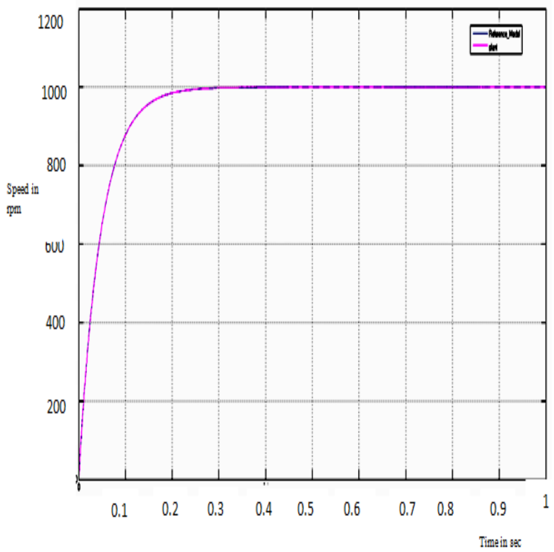

Fig 3: Motor speed with Model reference adaptive PI Controller

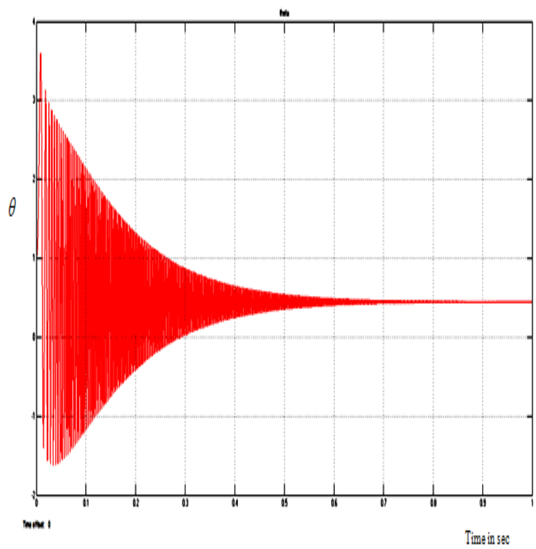

Fig 3: Variation of adjustment parameter

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VI.CONCLUSION

This paper presents the speed control of three phase induction motor using model reference adaptive PI controller approach. MIT rule is used to implement adaptation mechanism. Simulation results shows that Model reference adaptive PI controller shows better control performance than conventional PI controller. MRAC eliminate peak overshoot from the speed curve and it reduces the settling time of the process.

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