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Expert System Based Maximum Torque Control for Single Phase Induction Motor

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Abstract: *The Capacitor start run single phase induction motors are widely used for heavy-duty applications requiring high starting torque. In modern control theory, the induction motor is described by different mathematical models, according to the employed control method. The most commonly used controller for the speed and torque control of induction motor is Proportional plus Integral (PI) controller. However, the PI controller has some disadvantages Such as: the high starting overshoot, sensitivity to controller gains and sluggish response due to sudden disturbance. A new intelligent controller based on Fuzzy logic control is proposed to overcome the above said disadvantages. The performance of the intelligent controller has been investigated through MATlab/Simulink environment, for different operating conditions. Finally, the results are compared with PI controller and intelligent Fuzzy controller. It is observed that Fuzzy logic based controllers give better responses than the traditional PI controller.*

Kew Words: *Fuzzy logic Control, Torque control, Induction Motor, PID, control methods.*

I. INTRODUCTION:

For any machine we expect less error, maximum output for that we need to control the torque. In single phase induction motor the maximum torque control can be achieved in different methods. The controlling of maximum torque can be done in conventional controllers such as proportional controller, proportional plus integral controller but these are very much useful in steady state and for linear system. However, the P, PI controller has main disadvantage is tuning of parameters $(k_{p,}k_d, k_i, t_i, t_d)$ and also other problems like the high starting overshoot, sensitivity to controller gains and sluggish response due to sudden disturbance. So to overcome the above said problems we are introducing heruistatic methods in that we have artificial neural networks, fuzzy logic controller, adaptive [8].

Exact meaning of fuzzy is confusion. Numbers of linguistic variables are more so that accuracy is achieved. Here we are using a control capacitor with a value where the induction motor achieves its maximum torque for any rotor speed. We can control the capacitor for any step size so that we are able control the torque of motor. For larger step size convergence rate is more for smaller step size convergence rate is more. The complete control system have been developed and validated by simulation results.

The single phase induction motors are widely used then three phase induction motor. Here we are specifically controlling the torque for capacitor start run motor because it is economic and other way it is easy to control. In modern control theory, the induction motor is described in by different mathematical models, according to employed control method. In this we are using fussy logic control type associated with vector control strategy. Through this control method, the induction motor operation can be analyzed and maximum torque control can be done. For controlling purpose we are concentrating on capacitor because by controlling the capacitor we are controlling voltage so that we are controlling voltage. The fuzzy controller now used camcorders, flight control system, antilock braking systems.

A) Mathematical equations:

$$\Psi_{qs}^{s} = \frac{\omega_b}{p}\left[v_{qs}^{s} + \frac{R_q}{X_{lq}}\left(\Psi_{Mq}^{s} - \Psi_{qs}^{s}\right)\right] \text{--------} (1)$$

$$\Psi_{ds}^{s} = \frac{\omega_b}{p}\left[v_{ds}^{s} + \frac{R_d}{X_{ld}}\left(\Psi_{Md}^{s} - \Psi_{ds}^{s}\right)\right] \text{------} (2)$$

$$\Psi_{qr}^{'s} = \frac{\omega_b}{p}\left[\frac{R_{rq}^{'}}{X_{lrq}^{'}}\left(\Psi_{Mq}^{s} - \Psi_{qr}^{'s}\right) + \frac{N_q}{N_d}\frac{\omega_r}{\omega_b}\psi_{dr}^{'s}\right] \text{---} (3)$$

$$\Psi_{ds}^{'s} = \frac{\omega_b}{p}\left[\frac{R_{rd}^{'}}{X_{lrd}^{'}}\left(\Psi_{Md}^{s} - \Psi_{dr}^{'s}\right) + \frac{N_d}{N_q}\frac{\omega_r}{\omega_b}\psi_{qr}^{'s}\right] \text{----} (4)$$

$$\Psi_{Mq}^{s} = X_m\left(\frac{\Psi_{qs}^{s}}{X_{lq}} + \frac{\Psi_{qr}^{'s}}{X_{lrq}^{'}}\right) \text{-------} (5)$$

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$$\Psi_{Md}^{s} = X_a\left(\frac{\Psi_{ds}^{s}}{X_{ld}} + \frac{\Psi_{dr}^{\prime s}}{X_{lrd}^{\prime}}\right) \text{----- (6)}$$

$$X_m = \frac{1}{\frac{1}{X_{mq}}+\frac{1}{X_{lq}}+\frac{1}{X_{lrq}^{\prime}}} \text{ -------- (7)}$$

$$X_m = \frac{1}{\frac{1}{X_{md}}+\frac{1}{X_{ld}}+\frac{1}{X_{lrd}^{\prime}}} \text{ -------- (8)}$$

$$i_{qs}^{s} = \frac{1}{X_{lq}}(\psi_{qs}^{s} - \psi_{Mq}^{s}) \text{ ---------- (9)}$$

$$i_{ds}^{s} = \frac{1}{X_{ld}}(\psi_{ds}^{s} - \psi_{Md}^{s}) \text{ ----------- (10)}$$

$$i_{qr}^{\prime s} = \frac{1}{X_{lrq}^{\prime}}(\psi_{qr}^{\prime s} - \psi_{Mq}^{s}) \text{ --------- (11)}$$

$$i_{dr}^{\prime s} = \frac{1}{X_{lrd}^{\prime}}(\psi_{dr}^{\prime s} - \psi_{Md}^{s}) \text{ --------- (12)}$$

$$T_e = \frac{P}{2}\frac{1}{\omega_e}\left(\frac{N_d}{N_q}\psi_{qr}^{\prime s}\, i_{dr}^{\prime s} - \frac{N_q}{N_d}\psi_{dr}^{s}\, i_{qr}^{\prime s}\right) \text{-------(13)}$$

$$p\left(\frac{2}{p}\right) w_m - \frac{1}{j}(T_e - T_i) = 0 \text{ -------- (14)}$$

$$v_{qs}^{s} = v_s \text{ ------------ (15)}$$

$$v_{ds}^{s} = v_s - \frac{1}{p}\omega_b X_c i_{ds}^{s} \text{ --------- (16)}$$

$$v_s = z_{qs}+$$

$$z_f + z_b)i_{qs} - j\frac{n_d}{n_q}(z_f - z_b)i_{ds} \text{ ------ (17)}$$

$$v_s = j\frac{n_d}{n_q}(z_f - z_b)i_{qs} + \left[z_c + z_{ds} + \left(\frac{{n_d}^2}{n_q}\right)(z_f - z_b)\right]i_{ds} \text{--- (18)}$$

$$z_{qs} = r_q + jx_{1q} \text{ -------- (19)}$$

$$z_{ds} = r_d + jx_{1d} \text{ ----------- (20)}$$

$$z_c = -jx_c \text{ ----------- (21)}$$

$$z_f = r_f + jx_f = \frac{\left(-x_{mq}x_{1rq}^{\prime} + j\frac{x_{mq}r_{rq}^{\prime}}{s}\right)}{2\left(\frac{r_{rq}^{\prime}}{s} + j\left(x_{mq} - x_{1rq}^{\prime}\right)\right)} \text{ ------- (22)}$$

$$z_b = r_b + jx_b = \frac{\left(-x_{mq}x_{1rq}^{\prime} + j\frac{x_{mq}r_{rq}^{\prime}}{2-s}\right)}{2\left(\frac{r_{rq}^{\prime}}{2-s} + j\left(x_{mq} - x_{1rq}^{\prime}\right)\right)} \text{ --------- (23)}$$

$$T_e = \frac{|I_{qs}|^2 \left|\frac{N_d}{N_q}I_{ds}\right|^2 (R_f - R_b) + 2\frac{N_d}{N_q}|I_{qs}|\,|I_{ds}|(R_f - R_b)\sin(\theta_d - \theta_q)}{\omega_e} \text{ ----- (24)}$$

II. PRINCIPLE OF FUZZY MAXIMUM TORQUE CONTROL

The Fuzzy Logic system involves three steps fuzzification, application of Fuzzy rules and decision making and defuzzification [5]. Fuzzification involves mapping input crisp values to Fuzzy variables. Fuzzy inference consists of Fuzzy rules and decision is made based on these Fuzzy rules [9]. These Fuzzy rules are applied to the fuzzified input values and Fuzzy outputs are calculated. In the last step, a defuzzifier converts the Fuzzy outputs back to the crisp values. The Fuzzy controller in this paper is designed to have three Fuzzy input Variables and one output variable for applying the Fuzzy control to direct torque Control of Induction Motor[4], there are three variable input Fuzzy Logic variables - the stator flux error, electromagnetic torque error, and angle of flux stator.[6] The membership functions of these Fuzzy sets are triangular with two membership function N, P for the flux-error, three membership functions N, Z, P for the torque-error, six membership variables for the stator flux position sector and eight membership functions for the output commanding the inverter[7]. The inference system contains thirty six Fuzzy rules which are framed in order to reduce the torque and flux ripples. Each rule takes three inputs, and produces one output, which is a voltage vector. Each voltage vector corresponds to a switching state of the inverter. The switching state decides the pulse to be applied to the inverter. The Fuzzy inference u e Mamdani’ procedure for applying Fuzzy rules which is based on min-max decision. Depending on the values of flux error, torque error and stator flux position the output voltage vector is chosen based on the Fuzzy rules [7]. Using Fuzzy Logic controller the voltage vector is selected such that the amplitude and flux linkage angle is controlled. Since the torque depends on the flux linkage angle the torque can be controlled and hence the torque error is very much reduced.

Fig.1. Fuzzy Logic controller

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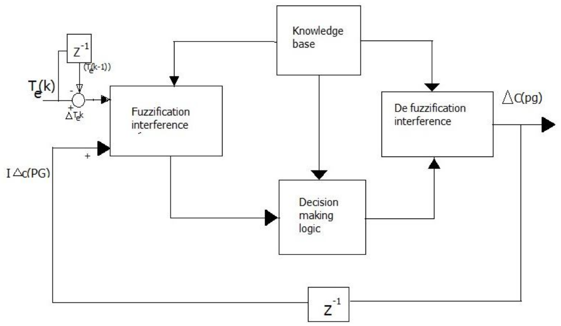

Fig2.Fuzzy logic optimization scheme block diagram

Table 1:Fuzzy Rule base system

T / ΔT	**NL**	**NM**	**NS**	**ZE**	**PS**	**PM**	**PL**
NL	NL	NL	NLM	NM	NMS	NS	ZE
NM	NL	NLM	NM	NMS	NS	ZE	PS
NS	NLM	NM	NMS	NS	ZE	PS	PMS
ZE	NM	NMS	NS	ZE	PS	PMS	PM
PS	NMS	NS	ZE	PS	PMS	PM	PLM
PM	NS	ZE	PS	PMS	PM	PLM	PL
PL	ZE	PS	PMS	PM	PLM	PL	PL

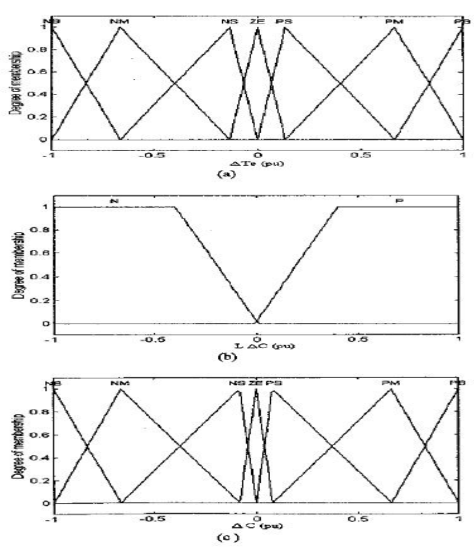

Fig.3. membership functions for the Fuzzy logic controller(a)Change of T_e (b) Change in error (c) change in output

III. PI CONTROLLER

The proportional plus integral (PI) controller is one of the famous controllers used in a wide range in the industrial applications. The output of the PI controller in time domain is defined by the following equation:

$v_c(t)= k_p(t)+ k_i \int e(t)dt$

where v_c (t) is the output of the PI controller, k_p is the proportional gain, k_I is the integral gain, and e(t) is the instantaneous error signasl. The main advantage of adding the integral part to the proportional controller is to eliminate the steady state error in the controller variable. However, the integral controller has the serious drawback of getting saturated after a while if the error does not change its direction. This phenomenon can be avoided by introducing a limited to the integral part of the controller before adding its output to the output of the proportional controller [10]. The input to the PI controller is the speed error (e), while the output of the PI controller is used as the input of reference current block.

IV. SIMULATION RESULTS:

In this section, the software Matlab/Simulink is used to simulate the whole MTC system to examine the performance of induction motor. The simulation conditions is given as: the speed is 200r/min and the reference flux is 0.9 Wb the initial load torque is 30N.m, when at 0.2 second, the load torque set at 30 Nm; simulation time is 0.25 second. The figure shows the comparative study of MTC with PI controller and that with fuzzy controller. Figure 5, Figure 6 shows the block diagram of the single phase Induction motor with the PI controllers and proposed controllers. Figure 7A & 7B shows the speed response in which the speed reaches steady state at 200 rev/min at 0.13, but with that using fuzzy controller speed reaches steady state much faster shown in. Figure 8 A & B shows the torque response which reaches 30 Nm much faster with fuzzy controller. Figure (9) shows the capacitor voltage which it will compensate the Induction motor speed error and faster response with fuzzy controller.

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V.SIMULATION RESULTS

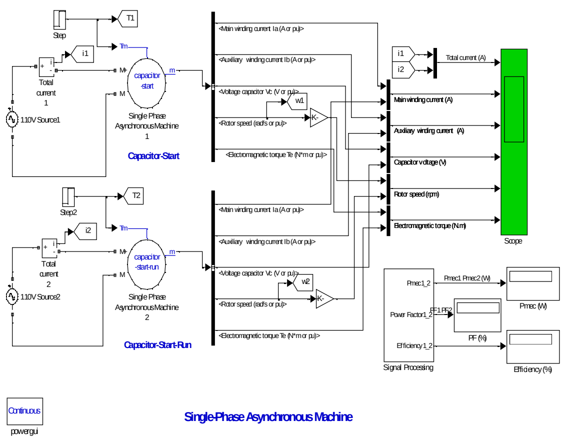

Fig.5. Simulink diagram of the Single Phase Induction motor with the PI Controllers

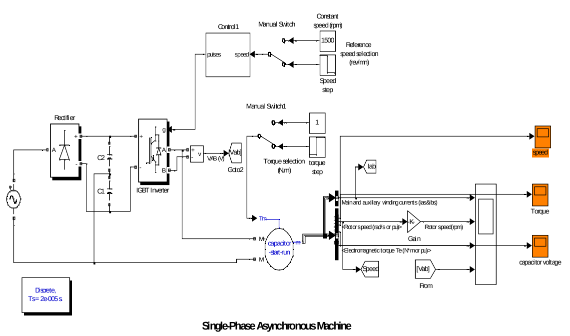

Fig.6. Simulink diagram of the Single Phase Induction motor with the Fuzzy Controllers

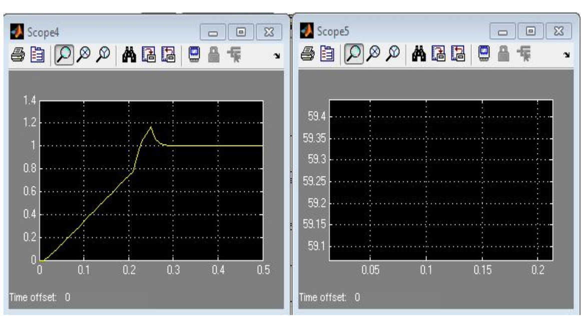

Figure 7(A)

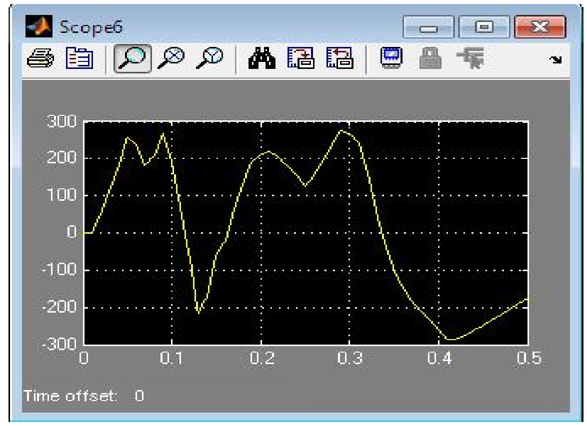

Figure7 (B).

Figure 7(A & B) Speed, Torque And Capacitor Voltage

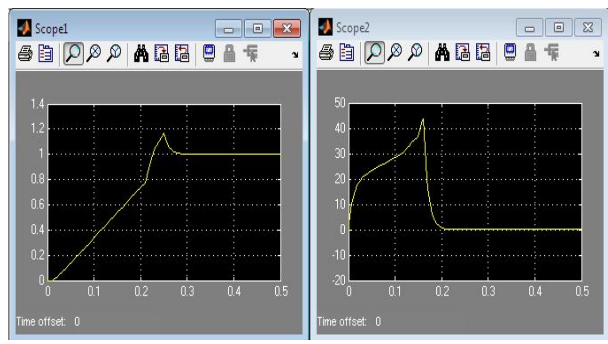

Figure 8(A)

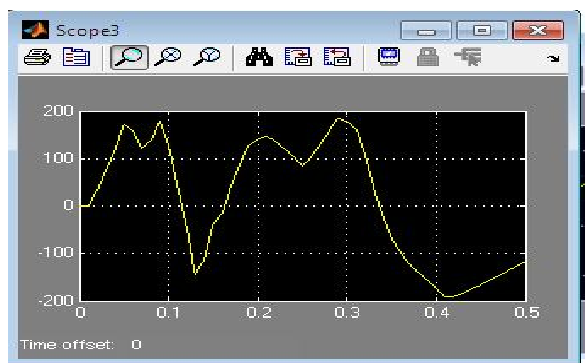

Figure 8(B)

Figure 8(A&B): Speed, Torque and Capacitor Voltage

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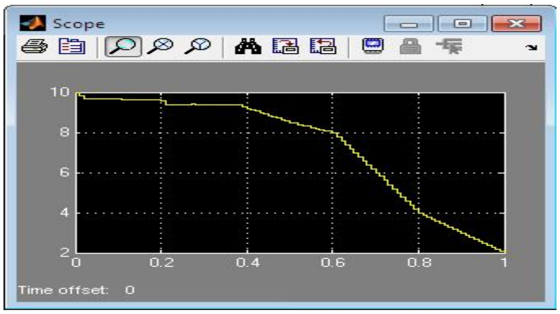

Figure 9.Capacitor Vs Speed

V.CONCLUSIONS:

The maximum torque control of single phase induction motor is achieved by using fuzzy logic based controller. And the responses are compared with PI controller it has been observed that the ripple content and rugged response to sudden changes in an Induction Motor are reduced. The speed also increased compared to conventional controller. From the simulation results from this proposed method it is observed that the drive performance is improved for shorter acceleration time and maximum torque is achieved.

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