

## Performance Investigation of AC Servomotor Position Control using Fuzzy Logic and Observer Based Controllers

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**Key words:** AC servomotor, induction motor, fuzzy logic, observer based controllers

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**Abstract:** An AC servomotor which is mostly a two-phase induction motor with two stator field coils placed 90 electrical degrees apart used for controlling position, speed and acceleration in manufacturing industries. In this study, a two-phase induction motor has been designed with a fuzzy logic and observer based controllers to improve the performance of the system. Comparison of the AC servomotor with the proposed controllers for tracking a step and a square desired position signal input has been done using MATLAB/Simulink toolbox and a promising result obtained.

### INTRODUCTION

AC servomotor is a rotary actuator or linear actuator that lets in for specific manage of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for role feedback. It also requires a fairly sophisticated controller, often a devoted module designed mainly to be used with servomotors. AC servomotors aren't a specific elegance of motor, despite the fact that the term servomotor is often used to consult a motor suitable for use in a closed-loop control system<sup>[1]</sup>. AC servomotor is a closed-loop servomechanism that makes use of position feedback to control its movement and very last role. The input to its manipulate is a signal (either analogue or digital) representing the position commanded for the output shaft.

### MATERIALS AND METHODS

**Mathematical model of the AC servomotor:** An AC servomotor is basically a two-phase induction motor that has two stator field coils placed 90 electrical degrees apart as shown in Fig. 1.

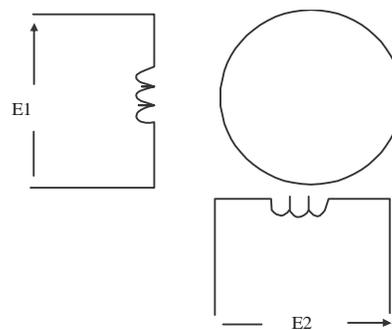


Fig. 1: AC servomotor

In a two-phase motor the ac voltage  $E1$  and  $E2$  are equal in magnitude and separated by a phase angle of 90 degrees. A two-phase induction motor runs at a speed slightly below the synchronous speed and is essentially a constant-speed motor. The synchronous speed  $n_s$  is determined by the number of poles  $P$  produced by the stator windings and the frequency  $f$  of the voltage applied to the stator windings<sup>[2, 3]</sup>.

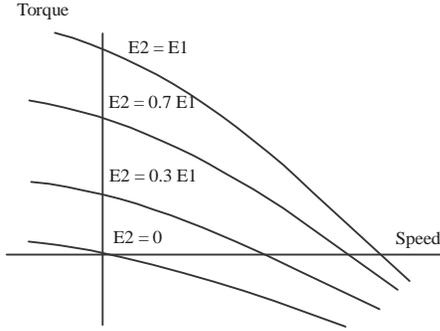


Fig. 2: Torque-speed curves for various control voltages

When the unit is used as a servomotor, the speed must be proportional to an input voltage. The two-phase motor can be used as a servomotor by applying an ac voltage  $E_1$  of fixed amplitude to one of the motor windings. When the other voltage  $E_2$  is varied, the torque and speed are a function of this voltage. Figure 2 shows a set of torque-speed curves for various control voltages.

The torque generated is a function of both the speed  $\omega$  and the control-field voltage  $E_2$ . In terms of partial derivatives, the torque equation is approximated by effecting a double Taylor series expansion of  $T(E_2, \omega)$  about the origin and keeping only the linear terms:

$$\left. \frac{\partial T}{\partial E_2} \right|_{\text{Origin}} E_2 + \left. \frac{\partial T}{\partial \omega} \right|_{\text{Origin}} \omega = T(E_2, \omega) \quad (1)$$

If the torque-speed motor curves are approximated by parallel straight lines, the partial derivative coefficients of (Eq. 1) are constants that can be evaluated from the graph. Let:

$$\begin{aligned} \frac{\partial T}{\partial E_2} &= K_1 \\ \frac{\partial T}{\partial \omega} &= K_2 \end{aligned} \quad (2)$$

For a load consisting of a moment of inertia and damping, the load torque required is:

$$T_L = J \frac{d\omega}{dt} + B\omega \quad (3)$$

Since, the generated and load torques must be equal, Eq. 1 and 3 are equated:

$$K_1 E_2 + K_2 \omega = J \frac{d\omega}{dt} + B\omega \quad (4)$$

Table 1: System parameters

Parameters	Symbols	Values
Torque voltage constant	$K_1$	54
Torque speed constant	$K_2$	-28
Load moment of inertia	$J$	18 Nm sec/rev
Load viscous friction	$B$	8 Nm sec/rev

Rearranging and writing (Eq. 4) in terms of position  $\theta$  becomes:

$$J \frac{d^2\theta}{dt^2} + (B - K_2) \frac{d\theta}{dt} = K_1 E_2 \quad (5)$$

In order for the system to be stable the coefficient  $(B - K_2)$  must be positive. Observation of the motor characteristics shows that  $\partial T / \partial \omega = K_2$  is negative; therefore, the stability requirement is satisfied. The transfer function of the AC servo motor becomes:

$$G(s) = \frac{\Theta(s)}{E_2(s)} = \frac{K_1}{Js^2 + (B - K_2)s}$$

Table 1 shows the parameters of the AC servo motor. Finally, the transfer function of the AC servo motor becomes:

$$G(s) = \frac{\Theta(s)}{E_2(s)} = \frac{3}{s^2 + 2s} = \left( \frac{1}{s} \right) \left( \frac{3}{s+2} \right)$$

**Proposed controllers design:** In this study, the design of the proposed controllers will be discussed.

**Fuzzy logic control:** Fuzzy Logic Control (FLC) or Fuzzy Linguistic Control is a knowledge primarily based control strategy that can be used:

- While both a sufficient correct and but no longer unreasonably complicated model of the plant is unavailable
- When a (single) specific degree of overall performance isn't significant or realistic

FLC Model design is based totally on empirically received knowledge concerning the operation of the process. This expertise, cast into linguistic or rule-based form is the main of the FLC system<sup>[4, 5]</sup>. The rule base (know-how base) gives nonlinear transformations with none built-in dynamics. The block diagram of the AC servomotor with fuzzy logic controller is shown in Fig. 3.

**Input and output of fuzzy controller:** The error and change of error input and the output of the fuzzy logic controller is shown in Fig. 4-6, respectively.

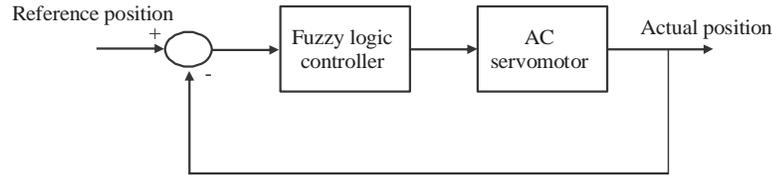


Fig. 3: Block diagram of the AC servomotor with fuzzy logic controller

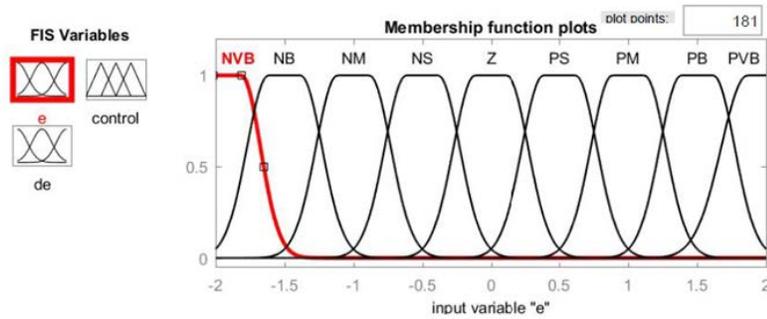


Fig. 4: Error input

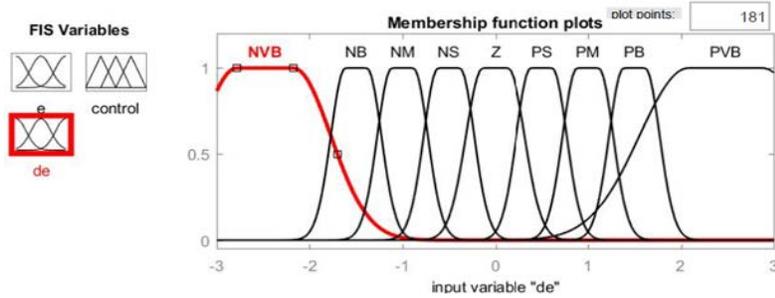


Fig. 5: Change in error input

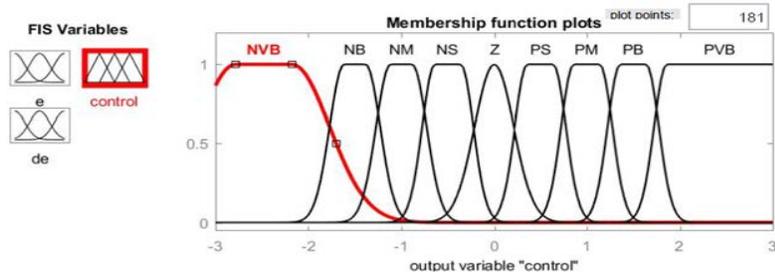


Fig. 6: Output

**Observer-based controller design:** The deal with the general case where only a subset of the states or linear combinations of them are obtained from measurements and are available to our controller. Such a guideline is referred to as the output feedback problem<sup>[6,7]</sup>. The output is of the form:

$$y = Cx + Du \quad (6)$$

We shall examine a class of output feedback controllers constructed in two stages:

- Contracting an observer a system dynamic that is driven by the inputs and the outputs of the system and yield a deliberation of its state variables
- Using the estimated state instead of the actual state in a estate response scheme

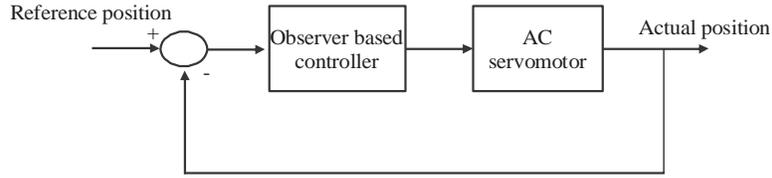


Fig. 7: Block diagram of the AC servomotor with the observer-based controller

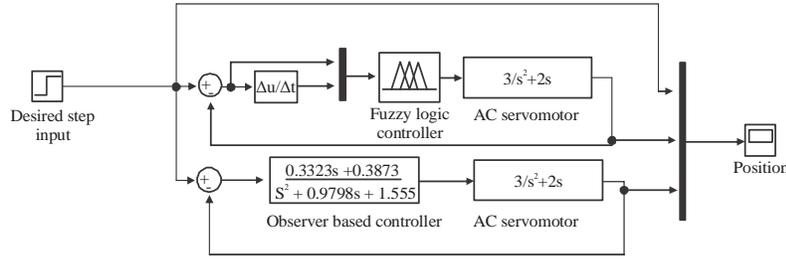


Fig. 8: Simulink Model of the AC servomotor with fuzzy logic and observer based controllers for tracking desired step position input signal

The block diagram of the AC servomotor with the observer-based controller is shown in Fig. 7 and 8. The controller  $G_c(s)$  can be further derived in the following form:

$$G_c(s) = I - K(sI - A + BK + HC)^{-1} B \quad (7)$$

With its state space realization:

$$G_c(s) = \begin{bmatrix} A - BK - HC & B \\ -K & I \end{bmatrix} \quad (8)$$

The controller  $G_c(s)$  in Eq. 8 is called the observer-based controller, since, the structural idiot of the observer is implicitly reflected within the controller.

Where the state space model of the plant,  $G$ , the state feedback gains vector  $K$  and the observer gain vector  $H$  are then returned, respectively. We select the weighting matrix  $Q$  and  $R$  as:

$$Q = \begin{pmatrix} 3 & 0 \\ 0 & 3 \end{pmatrix} \text{ and } R = 5$$

And we select the observer gain vector as:

$$H = \begin{pmatrix} 1.5 \\ -0.5 \end{pmatrix}$$

And we obtain the state feedback gain vector  $K$  as:

$$K = [0.4798 \quad 0.7746]$$

The observer-based controller transfer function become:

$$G_c(s) = \frac{0.3323s + 0.3873}{s^2 + 0.9798s + 1.555}$$

## RESULTS AND DISCUSSION

**Comparison of the ac servomotor with fuzzy logic and observer based controllers for tracking step position signal:** The Simulink Model of the AC servomotor with fuzzy logic and observer based controllers for tracking desired step position input signal is shown in Fig. 8. The comparison simulation result is shown in Fig. 9. The data of the rise time, percentage overshoot, settling time and peak value is shown in Table 2.

As Table 2 shows that the AC servomotor with fuzzy logic controller improves the settling time and the percentage overshoot better than the AC servomotor with observer based controller<sup>[8]</sup>.

**Comparison of the ac servomotor with fuzzy logic and observer based controllers for tracking square position signal:** The Simulink Model of the AC servomotor with fuzzy logic and observer based controllers for tracking desired square position input signal is shown in Fig. 10. The comparison simulation result is shown in Fig. 11.

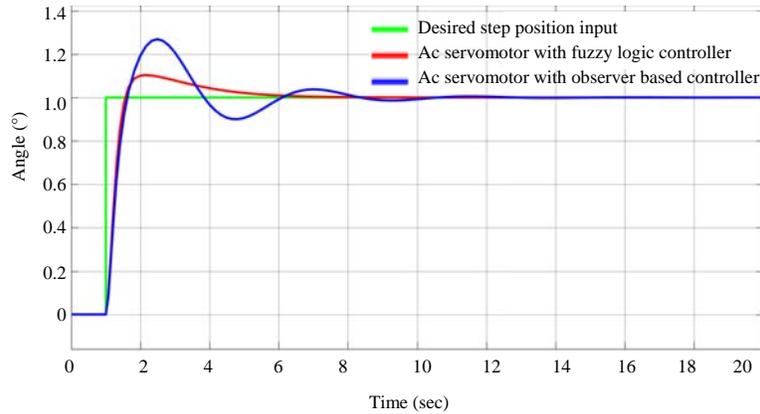


Fig. 9: Step response simulation result; Output position response to step desired position input

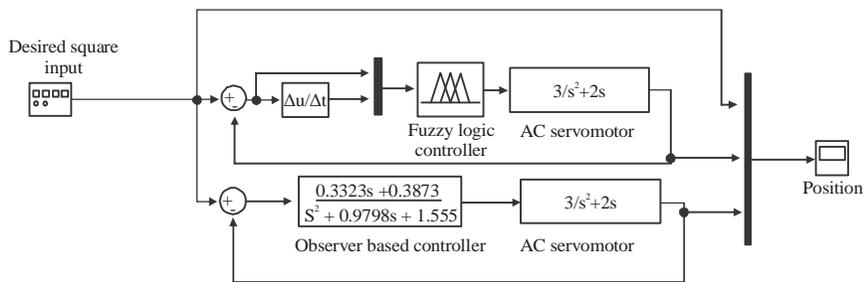


Fig. 10: Simulink Model of the AC servomotor with fuzzy logic and observer based controllers for tracking desired square position input signal

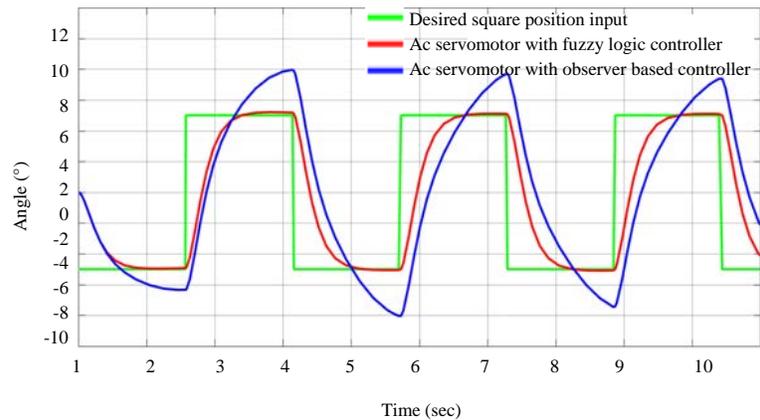


Fig. 11: Square wave response simulation result; Output position response to step desired position input

Table 2: Step response data

Performance data	Fuzzy logic	Observer based
Rise time	1.4 sec	1.4 sec
Per. overshoot	12%	29%
Settling time	6 sec	13 sec
Peak value	1.12°	1.29°

The simulation result Fig. 11 shows that the AC servomotor with fuzzy logic controller improves the settling time with 0.7 sec and with 0% overshoot.

## CONCLUSION

In this study, modeling, designing and simulating of an AC servomotor with fuzzy logic and observer based controllers have been done with the help of Matlab/Simulink Toolbox successfully. A two-phase induction motor that has two stator field coils placed 90 electrical degrees apart is used as a servomotor by applying an ac voltage E1 of fixed amplitude to one of the

motor windings and the other voltage E2 is varied. Comparison of the AC servomotor with the proposed controllers for tracking a step and a square desired position signal input has been done. The simulation result for tracking the desired step input position signal proves that the AC servomotor with fuzzy logic controller improves the settling time and the percentage overshoot while the simulation result for tracking the desired step input position signal proves that the AC servomotor with fuzzy logic controller improves the settling time with 0.7 sec and with 0% overshoot.

#### **REFERENCES**

01. Balasaheb, B.S., C.G. Ajaysingh, M.S. Dattu, R.J. Ramdas and G.S. Ramesh, 2019. Voltage regulation using AC servomotor. *Int. Res. J. Eng. Technol.*, 6: 4043-4045.
02. Oh, H.W., 2019. A study on servo motor control in multi pallet system. *IEMEK J. Embedded Syst. Appl.*, 14: 339-346.
03. Rahmat and Wiyono, 2020. Fuzzy-PI algorithm application to controlling servo motor position using microcontroller AVR. *J. Phys. Conf. Ser.*, Vol. 1517.
04. Isik, M.F., E. Cetin, H. Aykul and H. Bayram, 2015. AC servo motor speed and position control using Particle Swarm Optimization (PSO). *Hittite J. Sci. Eng.*, Vol. 2, No. 2. 10.17350/HJSE19030000020.
05. Sheng-Liang, C., H.N. Dinh and N. Van-Thanh, 2017. Synchronized injection molding machine with servomotors. *Adv. Technol. Innovation*, 2: 34-39.
06. El-Hamid, A.S.A. and A.H. Eissa, 2015. Position control of AC servomotor using internal model control strategy. *Int. J. Eng. Innovation Res.*, 4: 277-281.
07. Wang, C. and J. Luo, 2019. Effects of delays on current loop bandwidth in servo motor control system. *AIP Conf. Proc.* Vol. 2154, No. 1.
08. Yu, S., T. Zhang, H. Zhang, P. Zeng and X. Chen, 2018. Research on model based design method of permanent magnet synchronous motor servo system based on FPGA. *JPhCS*, Vol. 1074, No. 1.