# Neural fuzzy For Speed Control of Three Phase Induction Motor

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**Summary**
Despite their popularity in industries, three phase induction motors have been known to lack the ability to maintain a constant speed upon a load change. This is due mainly to their non-linear characteristic properties especially their on-rotor resistance whose value varies with operating condition. A controller is therefore needed to achieve the constant speed of the induction motor and to improve their performance upon load change. Neural fuzzy can be used as controller for non linier system where parameter variation and structure of plant have big uncertainty as does at induction motor. The aim of this paper is design neural fuzzy controller for induction motor speed control so can maintain speed according to reference speed although upon load change using MATLAB/SIMULINK. In particular, the simulation of neural fuzzy will be discussed to show how the constant speed can be achieved upon load changes.

***Key words:***
*Neural Fuzzy, induction motor, controller, load change*

## 1. Introduction

The three phase induction motor is mostly used as the prime mover in industries, it's due to the induction motor has simple construction, sturdy, easy maintenance and relatively low price, therefore that why the induction motor has start shifting the use of other prime mover in industries. The induction motor has some non linear parameters, especially rotor resistance, which has a wide variation in value for the difference of operation condition. The load change at the induction motor it will create change in motor speed, so that to keep motor speed constant it need some controller which could adapting the change of motors load. So that this controller should have the learning process to knows and identify the change of motor condition

The controller could use from some method for example; PI, PID, Fuzzy and *Artificial Neural network* (ANN). Controller Proportional Integral (PI) and Proportional Integral Derivative (PID) required accuracy parameter determination to produce better control performance. Since 1990 has a research the use of Fuzzy logic and neural network in controlling induction motor. Their's controlling performance has a good enough comparing to the conventional method. The fuzzy logic use the physical nature of the plant, but on fuzzy logic not have learning process other wise determination of membership function and rule were used at fuzzy logic are strongly affected the system performance. The constraint which faced in using fuzzy logic controller is a very difficult in determining shape and place of the membership function also determining the rule which matching with control system required [5]. While at neural network has developed to include learning process and plant identification, but for controlling which required quick processing by using this method it will require longer time [8]. So that ANN is suitable used for non linear system which it's as the result of load or parameter change therefore it's suitable for controlling induction motor [9].

Finally it's developed some method which an aliance between fuzzy logic and neural network which called Neuro-Fuzzy. Base on [6][9] research, the Neuro-Fuzzy method has revealed better system performance comparing to fuzzy logic control. In this research used Neuro-Fuzzy as the controller and reference model. Neural controller using Multilayer Perception (MLP) Back propagation type while fuzzy controller is used for improving the system performance.

## 2. Induction Motor Model

As the prime mover the induction motor has the advantage comparing with the DC motor, so that at the moment on many industries the using of induction motor has start shifting the AC motor. The induction motor has simple construction, sturdy, easy maintenance and relatively low cost, so that recently there is many industries has changed their prime mover from DC motor to induction motor. The torsion produced by AC motor is an interaction between current and fluctuation while at the induction motor where the power only supplied from the stator side, The current which produce torsion / speed and the current which produce fluction could not be seen as grossly as two separated signal. But as the mathematic with using method of field oriented control, the change of

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fluction and torsion could be separated as two signal which dependent each other [1]. In other side alternative current (AC) is a variable vector which change to time and can be more easy analized using complex number which have two coordinate axis, there are riil axis and imaginer axis. Hereinafter used axis equation d-q ( direct and quadrature axis). These variable for 3 phase ( voltage, current and fluction) in induction motor into variable with two coordinate axis ( axis d-q).

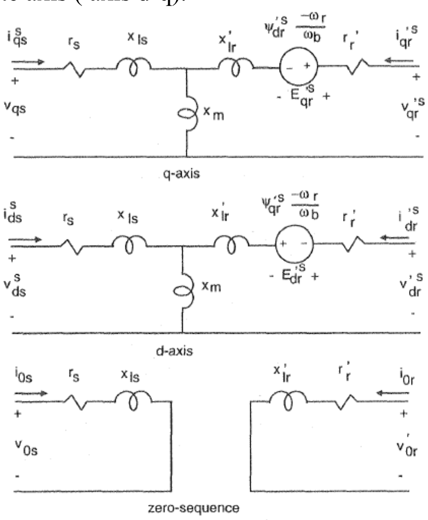



Figure. 1. Equivalent circuit d-q induction motor with *stationary reference frame*

Induction motor could be modeled by using equation d-q. According to [7] to perceiving transient response against to the speed and load change of the motor, usually will be more better if induction motor is modeled in the form of *stationary reference frame* . Equivalent circuit of induction motor in the form of *stationary reference frame* is referred to induction motor modeling which done by [7], the dynamic equivalent circuit shown on Fig. 1 Equation stator and rotor currents in the frame of d-q are stated on (1,4).

$$i_{qs} = \frac{1}{x_{ls}}\left(\psi_{qs} - \psi_{mq}\right) \quad (1)$$

$$i_{qr} = \frac{1}{x_{lr}}\left(\psi_{qr} - \psi_{mq}\right) \quad (2)$$

$$i_{ds} = \frac{1}{x_{ls}}\left(\psi_{ds} - \psi_{md}\right) \quad (3)$$

$$i_{dr} = \frac{1}{x_{lr}}\left(\psi_{dr} - \psi_{md}\right) \quad (4)$$

In this simulation the induction motor is squirrel cage $v_{qr}$ and $v_{dr}$ valued 0.The electrical torque which produced by induction motor is state as follows;

$$T_{em} = \frac{3}{2}\left(\frac{p}{2}\right)\frac{1}{\omega_b}\left(\psi_{ds} i_{qs} - \psi_{qs} i_{ds}\right) \quad (5)$$

So that the equation in system represent per-unit (pu) is as follows:

$$2H\frac{d(\omega_r/\omega_b)}{dt} = T_{em} + T_{mech} - T_{damp}(per-unit) \quad (6)$$

Where :

$\psi_{ij}$ : Flux Linkage (i=q or d and j=s or r)
$v_{qs}, v_{ds}$ : Stator voltage on q and d axis.
$v_{qr}, v_{dr}$ : Rotor voltage on q and d axis.
$r_s, r_r$ : Stator and rotor resistant
$x_{ls}, x_{lr}$ : Leakage reactance
$i_{qs}, i_{ds}$ : Stator current on q and d axis
$i_{qr}, i_{dr}$ : Rotor current on q and d axis
$p$ : Poles number.
$J$ : Inertia Moment.
$T_{em}$ : Electrical Torque
$T_{mech}$ : Mechanical Torque
$T_{damp}$ : Torque against rotation.
$\omega_e$ : Stator angel Frequency.
$\omega_b$ : Motor base angel frequency.
$\omega_r$ : Rotor angel speed

## 3. Design of Neural Fuzzy Controller

Since the last years fuzzy logic and neural network widely used in control applications. Both can result system performance better than conventional controllers [5,6,9]. Neural networks are very suitable for use in non-linear system. Neural networks cans be employed in control applications by making use learning processing, as well as fuzzy logic can overcome the high uncertainty in the system. Fuzzy logic have been designed base on linguistic variables that facilitate the design, although without knowing the mathematical model of the system. Neural Fuzzy is a combination of neural networks and fuzzy logic.

In this paper, neural Fuzzy controller will control the speed of induction motor according to reference speed.

Block diagram design controller on this research is shown on Fig. 2. Neural network controller is designed with two input there are reference speed and actual rotor speed (Y(K)) and has one output of control signal, while fuzzy controller have two input and one output. Fuzzy controller input are error and change of error. The output of reference model is the output of the reference of the controlled plant if this system has precise control. In determining reference model the degree of relatively reference model is same as the plant The dynamic input-output from reference model is given in model orde 2.

$$\omega r(k+1) = a1\omega r(k) + a2\omega r(k-1) + r(k) \qquad (7)$$

$$\omega r(k+1) = 0{,}78\omega r(k) + 0{,}25\omega r(k-1) + r(k) \qquad (8)$$

ωr(k) = Output signal reference model.
r(k) = Input signal reference model.

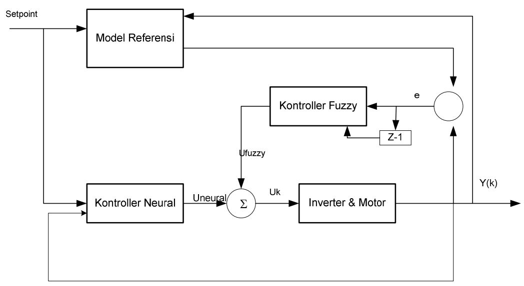



Figure 2. Block diagram controller

Neural network are arranged in layer of neurons :an input layer, one or more hidden layer and an output layer. Neural network controller which designed using neural network multilayer perception type Back error propagation. The structure of neural network which used is shown on Fig 3. The network has two input there are the output from reference speed and output from actual rotor speed, one output layer which as the control signal and one or more layers are hidden. The number of layers used are three layers and two layers with the number of neuron on each layers are 20 neuron. The activation function used for input layer and hidden are sigmoid logarithmic while for output neuron used linear activation function.

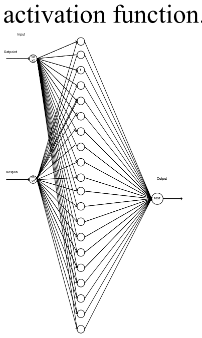
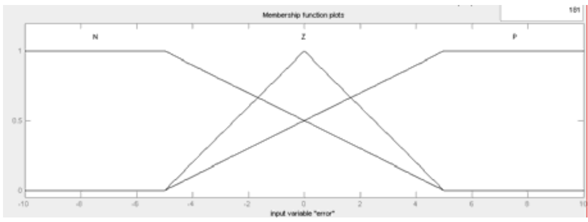


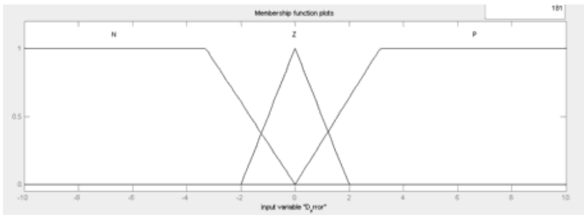
Figure 3. Structure neural network controller.

The Fuzzy controller has consist of two input variables and one output variable, input variable consist of error ( E ) and change of error ( CE ). Determination membership function of input and output variables are using the try and error system base on their experiences. Variable input error obtained from difference between reference model with actual rotor speed.

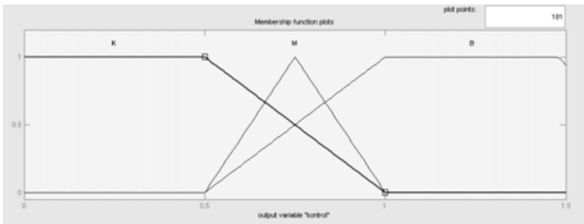
Input variable error and change of error has three membership function in the form of trapezium and triangular there are Negative (N), positive (P), and zero (Z), while output also has three member function there are; small (S), medium (M), and large (L) is shown on Fig.4. On this design the fuzzy rule base on area and heuristic for control signal as shown Table 1.




(a) Error membership function




(b) Change of error membership function




(c) Output membership function

Figure 4. Input and output membership function of fuzzy controller

Table 1. Fuzzy Rule

| e Δe | N | Z | P |
|---|---|---|---|
| N | S | S | S |
| Z | M | M | M |
| P | L | P | P |

## 4. Simulation Using Matlab

Simulation using simulink Matlab. The design of fuzzy using fuzzy tool boxes which available on simulink while neural network using m-file Matlab which carried into simulink. The simulink model used on this system is shown on Fig 5. In this paper, The control signal which used to drive the induction motor is a combination of control signal from fuzzy controller and neural network controller.

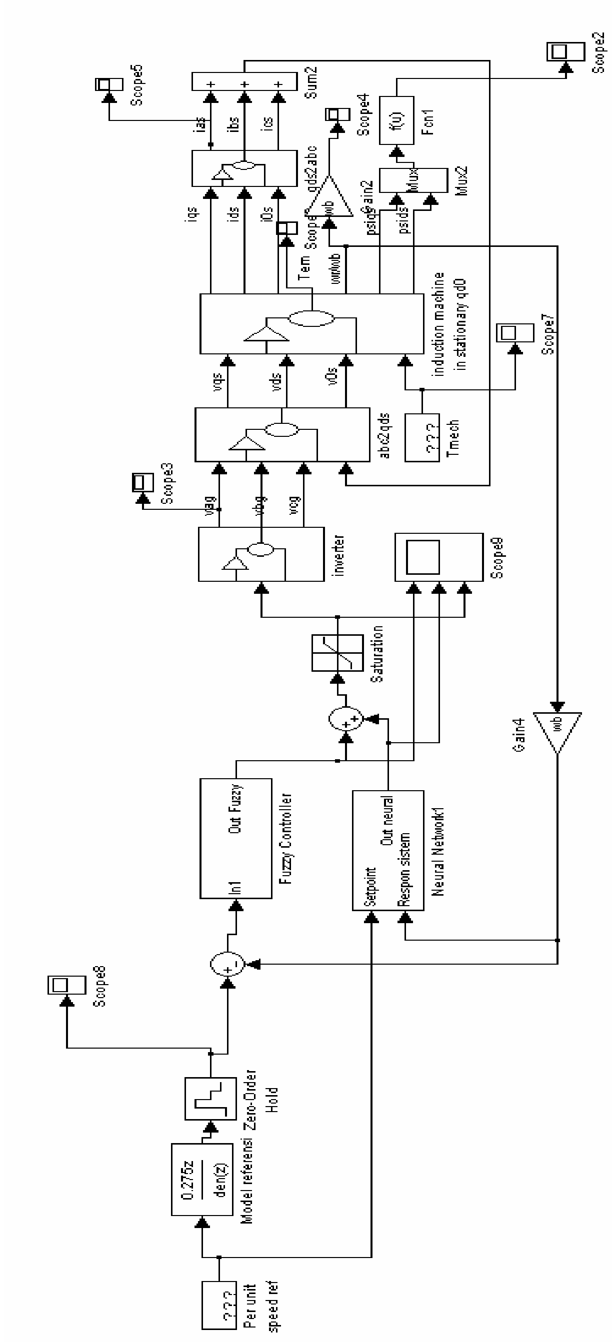
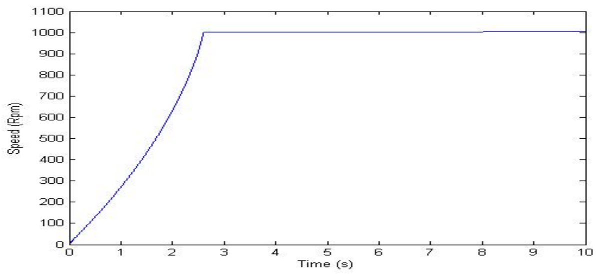



Figure 5 Design of simulink model.

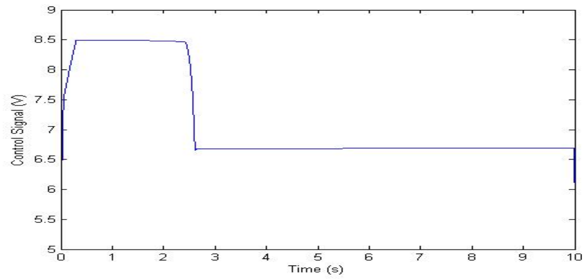
Induction motor is modeled by dq model. Parameters of induction motor used are inputed through m-file which it's connected into simulink, the parameters of induction motor used are stator resistant (Rs) =7.13 Ω, rotor resistant (Rr) = 8.18 Ω, stator reactant (Xls) = 9.45 Ω, rotor reactant (Xlr) = 9.45 Ω, Combination reactant (Xlm) = 189.65 Ω.

## 5. Simulation Result and Discussion

The simulation result are represented in Fig 6-9. The result of this simulation for two layers neural fuzzy controller comparing to neural fuzzy three layers. Fig 6 and Fig.8 present system response simulated with two layer neural fuzzy controller while Fig.7 and Fig.9 for three layer neural fuzzy controller. Rotor speed increases from 0 until 1000 rpm.

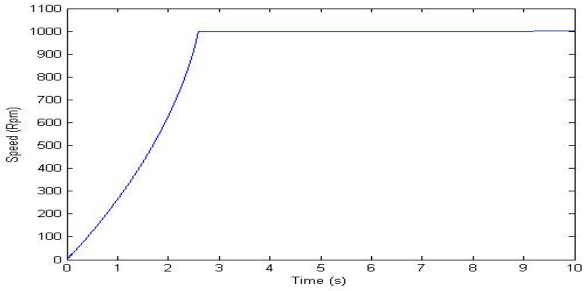



(a)

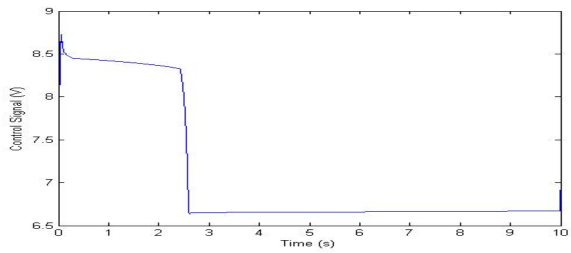



(b)

Figure 6 (a) System response two layer neural fuzzy without load; (b) Control signal of two layer neural fuzzy without load.




(a)

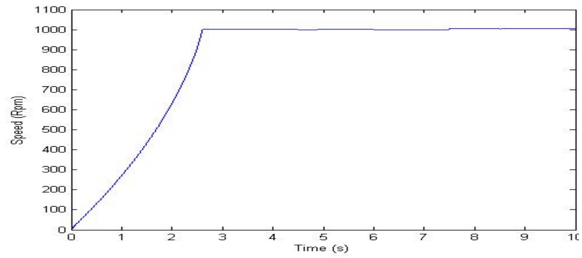



(b)

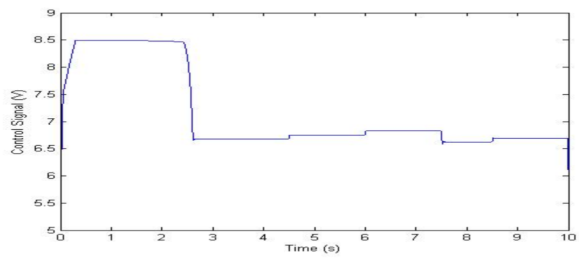
Figure 7 (a) Response system three layer neural fuzzy controller without load; (b) Control signal of three layer neural fuzzy controller without load

From Fig.6 and Fig.7, observed that neural fuzzy controller does not causing overshoot. Two layer neural fuzzy controller steady state value is achieved in 2.64 sec with error steady state 0.3%. Meanwhile three layer neural fuzzy can be achieved 2.61 sec and error steady state 0.1%. While response of neural fuzzy controller to load change can be analyzed in Fig 8 and 9.

Neural fuzzy controller can maintain speed of system as according to reference speed although happened load change. It's can follow load change with producing appropriate control signal so can maintain speed as according to reference. The controller can recognize load changes and because it has provided a learning process so controller can be detected load quickly. Differences of the number of layer in neural fuzzy controller will result in differences in recovery time and error steady state is generated by system. Recovery time is time needed by controller to recognize load change and return speed to reference. On two layer neural fuzzy controller has a steady state is 0.14% with recovery time 0.04s. Meanwhile three layer controller has a recovery time 0.04s with steady state 0.1%.

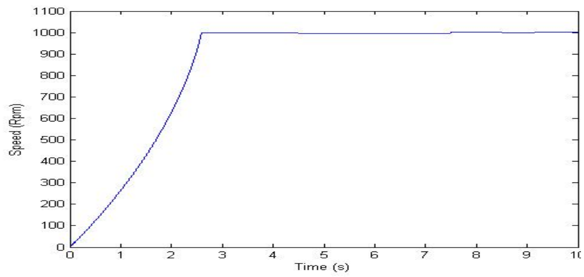



(a)

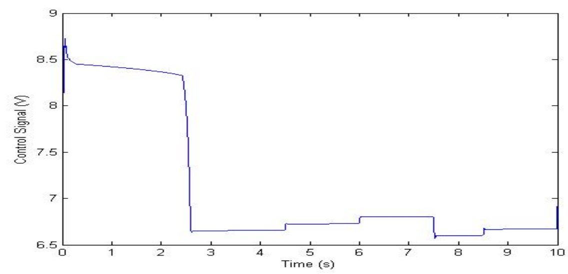



(b)

Figure 8 (a) System response two layer neural fuzzy with load change; (b) Control signal of two layer neural fuzzy with load change.




(a)




(b)

Figure 9 (a) System response three layer neural fuzzy with load change; (b) Control signal of three layer neural fuzzy with load change.

## 6. Conclusion

This paper has presented neural fuzzy for controlling speed of induction motor. Applications of neural fuzzy controller on induction motor control shown a good performance. Three layer Neural fuzzy controler is compared with two layer. The system was analyzed and designed, and performance was studied by simulation with simulink matlab. Performance of a three phase induction motor upon load changes can be improved and the constant speed can be achieved although happened load change.

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