FRONTIER ENERGY SYSTEM AND POWER ENGINEERING
ISSN: 2720-9598

Hybrid Method for Optimization of Permanent Magnet Synchronous Machine (PMSM) Rotation using FA-ANFIS

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Abstract

PMSM uses the principle of Faraday's experiment by rotating a magnet in a coil by utilizing another energy source. When the magnet moves in the coil or vice versa. The rotation of the machine will change the flux of magnetic force on the coil and penetrate perpendicularly to the coil so that a potential difference arises between the ends of the coil. It is caused by a change in magnetic flux. The Firefly Algorithm (FA) method has been proven successful in overcoming system optimization problems. Modifying the FA is expected to improve its performance of the FA. To get the best control method, it is necessary to vary the speed control model. This study compares the PMSM speed control without a controller, PID Control, PID-FA, and PID-FA-ANFIS. The simulation results show that the best model on the PID-FA-ANFIS controller which is closest to the Speed Reff (2980 rpm) is that PID-FA-ANFIS obtains a rotation profile with the smallest undershot, the fastest steady state, the best output current profile, the best torque profile, and the best stress profile. The results of this study will be followed by other uses of artificial intelligence.

Keywords

Ant Colony Optimization, ANFIS, Dual axis solar tracking system, Hybrid System

INTRODUCTION

The Regional Public Drinking Water Company (PERUMDAM) carries out a service function in the form of meeting the needs for clean water for the people of Jombang. PERUMDAM Tirta Kencana is expected to provide services for clean water that are evenly distributed to all levels of society, assisting the development of the business world and setting tariff structures that are adjusted to the level of community capacity. However Synchronous reluctance Machines have low torque, they can be used in several specific applications[1], where precise speed control is required to spin fibers with constant thickness. PMSMs are typically three-phase machines, although many newer designs have other phase numbers[2]. Operation is essentially similar to large-field-wound synchronous machines with one important exception, PMSMs are typically operated from variable speed power electronics and do not operate at a single fixed speed. PID Controller[3], Fuzzy Logic Controller (FLC), and Adaptive Neuro-Fuzzy Inference System (ANFIS) [4]are often used to solve system optimization problems. FA has been widely used to solve control optimization problems[5][3], wind turbine optimization[6], wind-diesel optimization[7], micro hydro optimization[8], photo voltaic optimization[3][9], vehicle steer optimization[10], power grid reconfiguration[11], and other optimizations.

SYNCHRONOUS RELUCTANCE MACHINES

Synchronous Reluctance Machines utilize a reluctance rotor design but use standard 3-phase ac winding. The induction cage on the rotor provides starting torque, but once the engine approaches synchronous speed, the reluctance torque will synchronize the engine with the supply. An electric machine that can be operated either as a generator or as a motor. A generator is an electrical machine that works based on mechanical energy which then converts it into electrical energy that can be used in everyday life. The magnetic flux can be changed by moving the magnet in the coil or vice versa by utilizing other sources of energy, such as wind and water to rotate the turbine blades so that they drive the magnet. If a conductor moves to cut the magnetic field there will be a voltage difference at the ends of the conductor[12].

ISSN: 2720-9598

PID CONTROLLER

A proportional Integral Derivative Controller is a controller of an instrumentation system with the characteristic of having feedback on the system[13]. The PID component consists of 3 types of constants, namely Proportional, Integrative, and Derivative. The three constants can be used together or separately, depending on the response we want to a plant.

PID is a control that uses proportional, integrative, and derivative components. PID control is a combined control system between proportional, integral, and derivative controls. In this method, the tuning is done in a closed loop where the reference input used is a step function. The controllers in this method include proportional (Kp), integral (Ki), and derivative (Kd) controllers[9].

FUZZY LOGIC CONTROLLER (FLC)

In this study, the fuzzy logic method is used to process and adjust the input speed reference value that has been entered. The fuzzy logic controller uses linguistic variables instead of numeric variables[14]. In a control system, the error between the reference signal and the output signal error signal can be explained for example:

NB: Negative Big
NS : Negative Small
Z : Zero
PS : Positive Small
PB : Positive Big

The rule base to be used is shown in the error table which consists of 5 members and has an output of 25 members.

TABLE I
Rule Base Function

e/de	NB	NS	N	PS	PB
NB	NB	NB	NB	NM	Z
NS	NB	NM	NS	Z	PM
Z	NB	NS	Z	PS	PB
PS	NM	Z	PS	PM	PB
PB	Z	PM	PB	PB	PB

In the MATLAB Simulink software, Fuzzy Logic Toolbox is available which has 5 types of Graphic User Interface (GUI) for designing fuzzy inference system (FIS). Here are 5 types of Graphic User Interface (GUI), as detailed in Figure 1:

1. Fis Editor
2. Membership function
3. Rules editor
4. Rule viewer
5. Surface viewer

This figure shows the process which is collaborated 5 role druing the fuzzy interference where the partial processes are included in own parts for defining results.

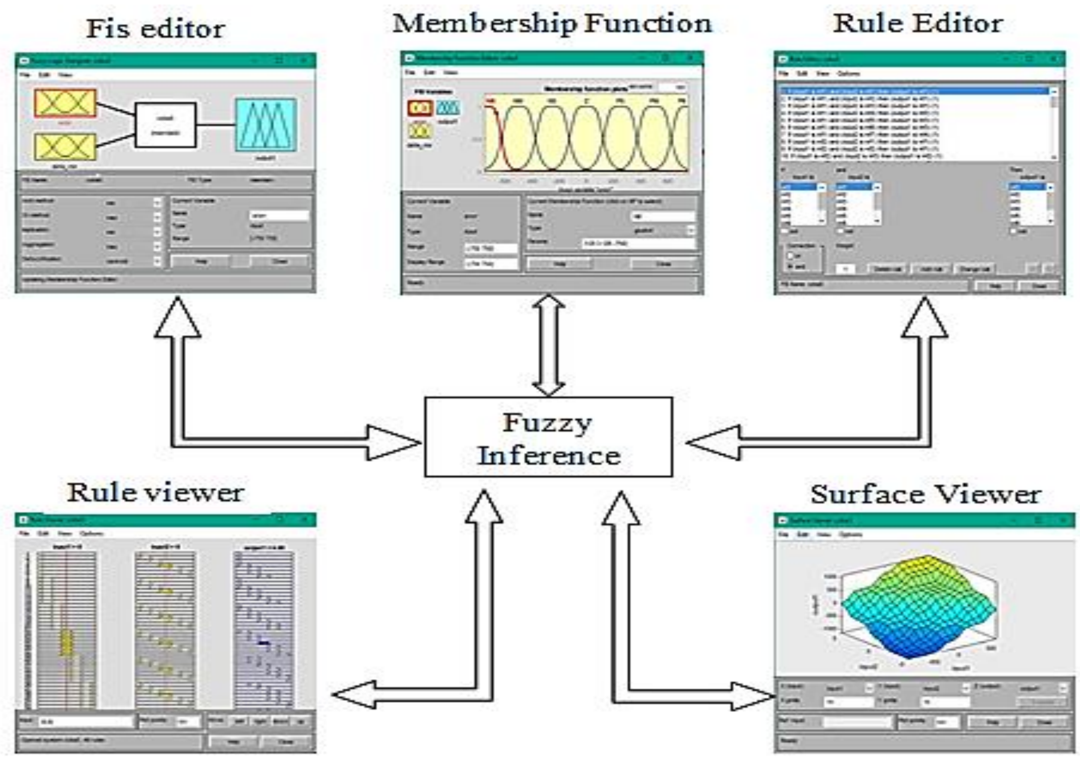

Figure 1. Fuzzy Inference System in Matlab

The rule editor on FLC can be seen in Figure 2.

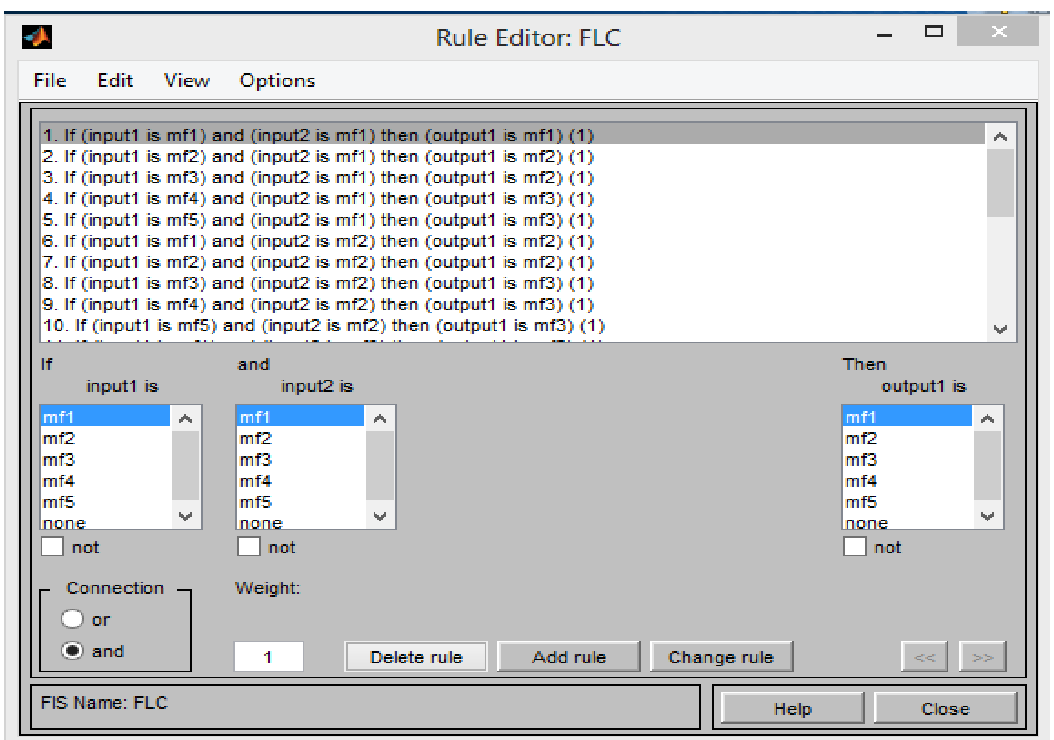

Figure 2. FLC Rule Editor

The FLC Rule Viewer can be seen in Figure 3.

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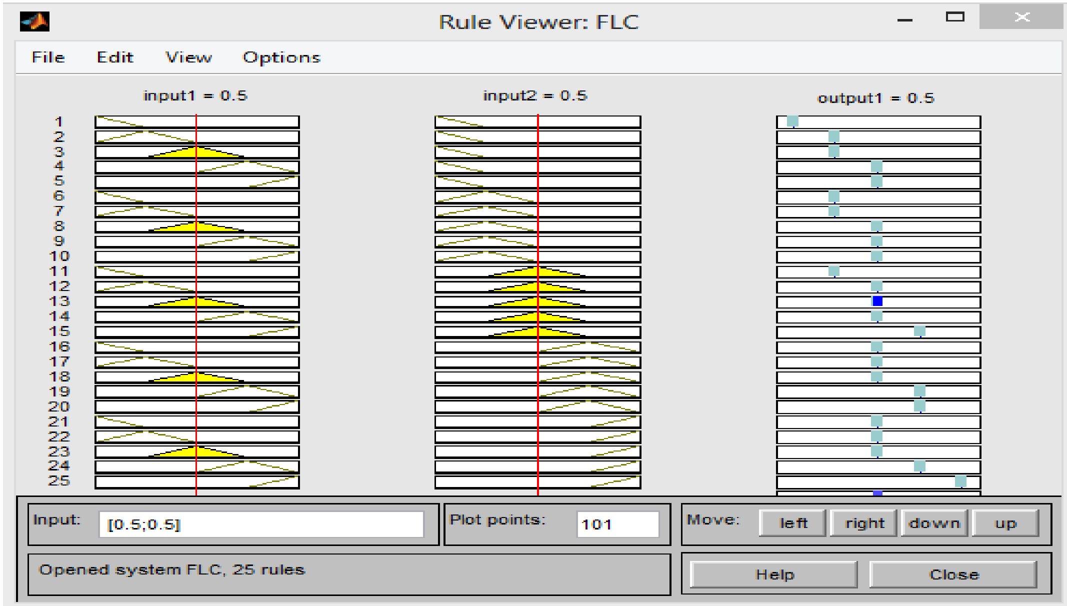

Figure 3. Rule Viewer FLC

Surface Viewer FLC can be seen in Figure 4.

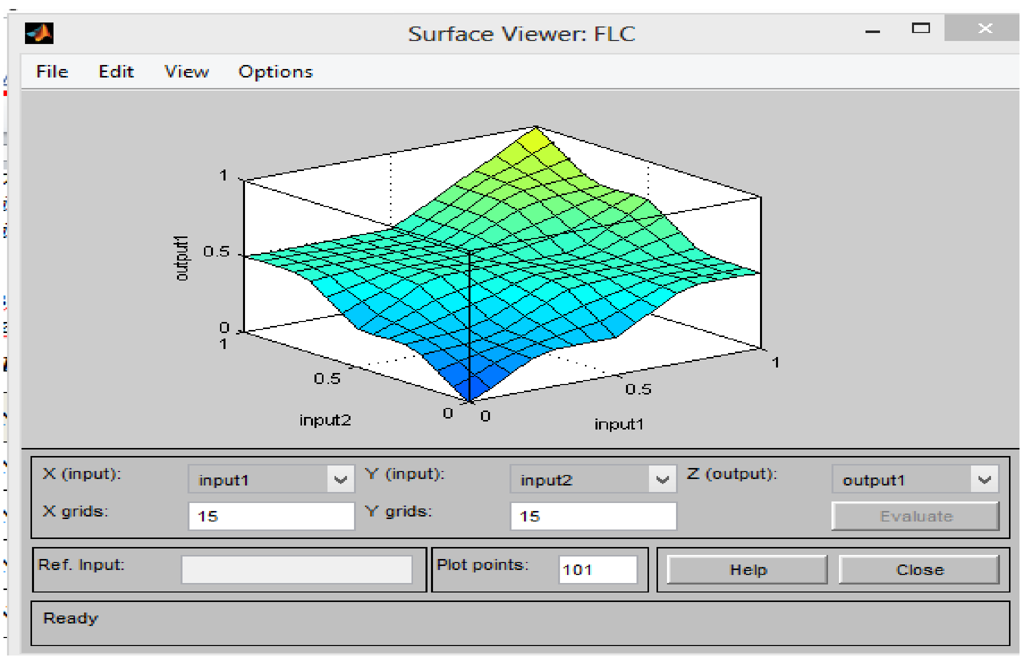

Figure 4. Surface Viewer FLC

ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM

The Adaptive Neuro-Fuzzy Inference System (ANFIS) is an amalgamation of the Fuzzy Inference System (FIS) mechanism described in the Neural Network (NN) architecture. In the simulation, the ANFIS architecture is used to model nonlinear functions and identify nonlinear components online in the control system. A new methodology based on ANFIS for estimating vehicle viewing angles[15]. The measure was validated by comparing the proposed CARSIM model, which is an experimentally validated software[5]. The FIS used is a first-level fuzzy model from the Tagaki-Sugeno-Kang (TSK) model with considerations of simplicity and computational ease. First order TSK

ISSN: 2720-9598

fuzzy inference mechanism with two inputs x and y (Fig. 5). Rule base with two fuzzy if-then rules, as below:

Rule 1: if x is A1 and y is B1 then f1 = p1x + q1y + r1

Rule 2: if x is A2 and y is B2 then f2 = p2x + q2y + r2

Inputs: x and y. consequent if f.

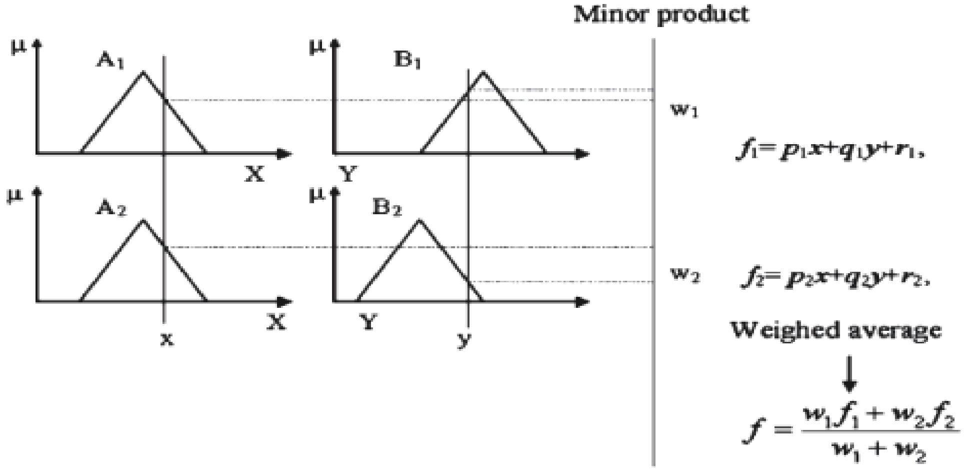

Figure 5. Fuzzy Inference System

The structure of ANFIS can be seen in Figure 6.

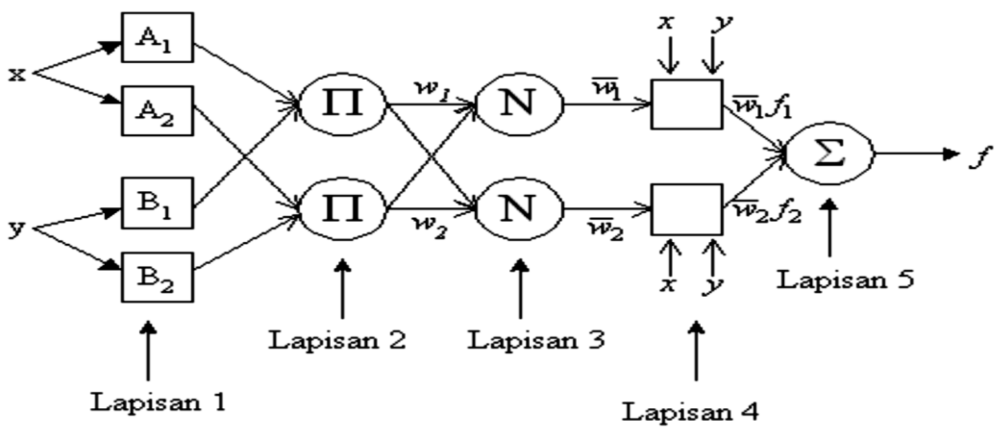

Figure 6. ANFI Structure

The results of the ANFIS training data taken from the PID data can be seen in Figure 7.

ISSN: 2720-9598

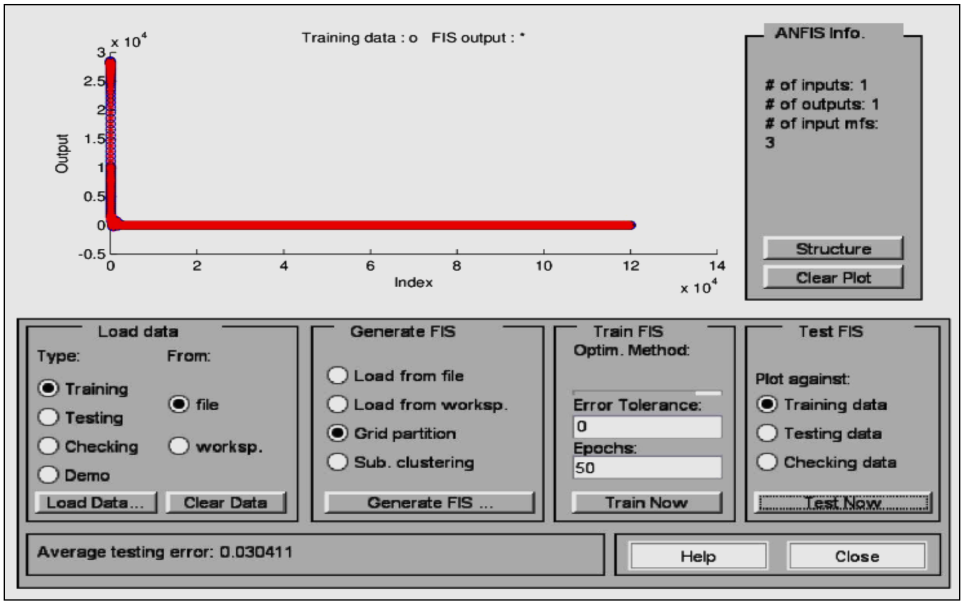

Figure 7. The results of the ANFIS training test data

Permanent Magnet Synchronous Machine

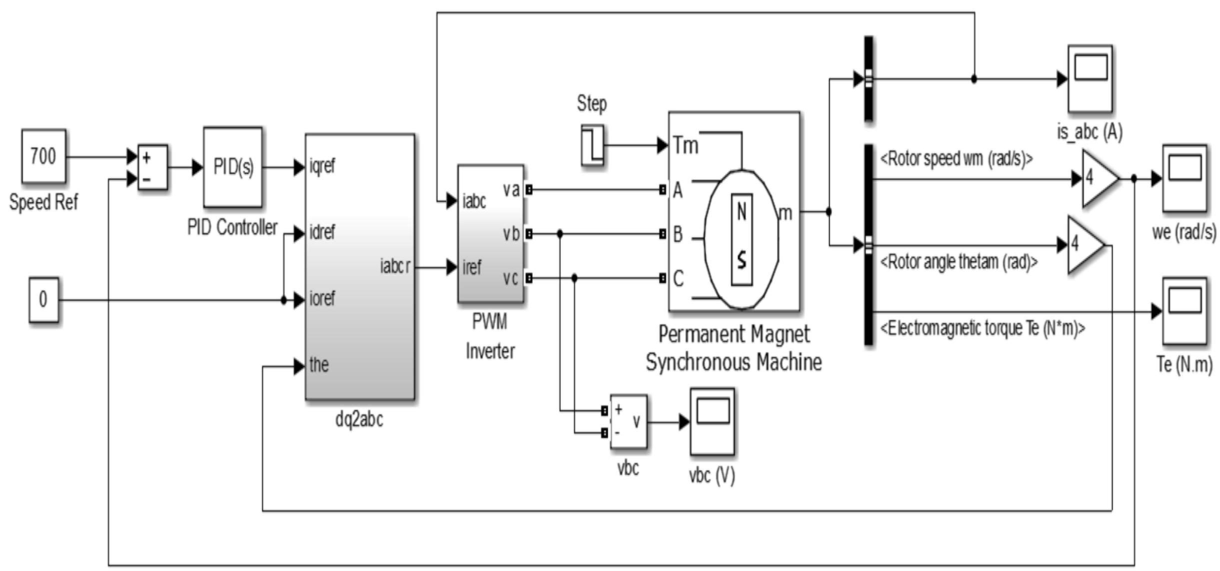

Figure 5. Simulink PMSM[2]

Simulink conversion dq to abc can be seen in Figure 6.

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ISSN: 2720-9598

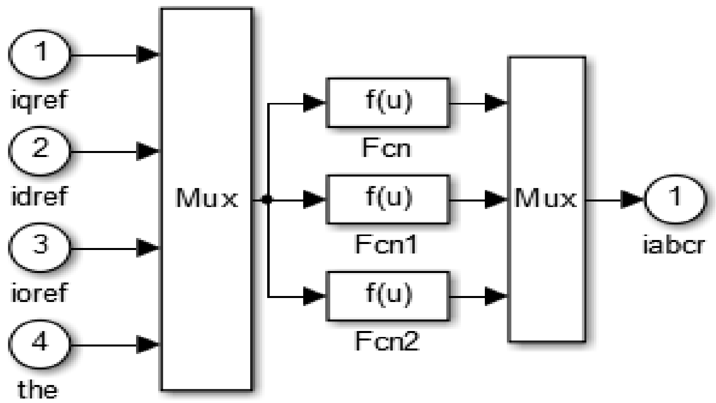


Figure 6. Convert dq to abc . axis

The PWM inverter image can be seen in Figure 7.

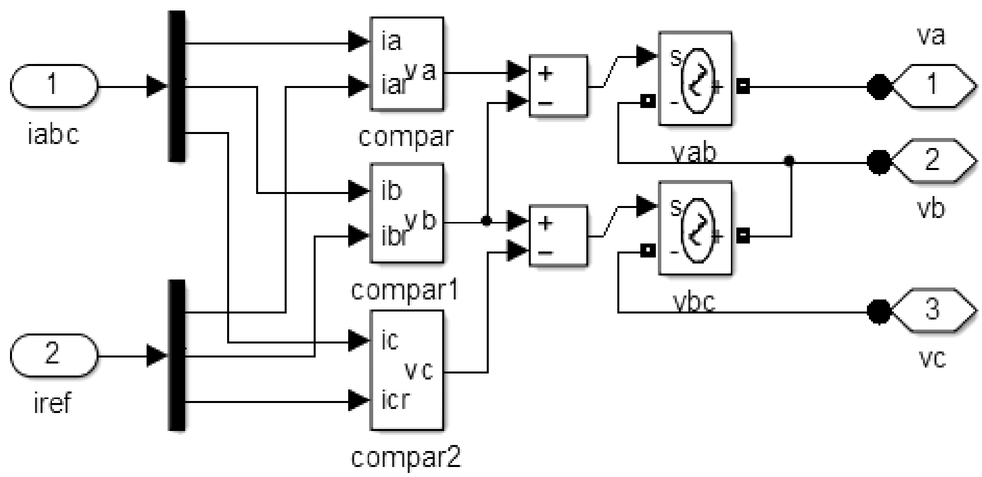


Figure 7. PWM inverter

MACHINE PARAMETERS

A three-phase engine rated at 132 kW, 220/380 V and 2980 rpm is fed by a PWM inverter. The PWM inverter is built entirely with standard Simulink blocks. The output passes through the Controlled Voltage Source block before being applied to the stator winding of the PMSM block. The load torque applied to the engine shaft is initially set to its nominal value (3 Nm) and drops to 1 Nm at t = 0.04 s. Two control loops are used. Loop in regulating motor stator current. The outer ring controls the motor speed. The stator current is quite "split" which is to be expected when using a PWM inverter. Also, the amplitude of this current decreases at t = 0.04 s, as the load decreases. Rippel introduced by the PWM inverter is also observed in the form of a torsion electromagnetic wave Te. However, the inertia of the motor prevents this noise from appearing in the motor speed waveform.

SYSTEM MODEL

Transient stability problems can be calculated through the initial conditions before the disturbance, during the disturbance, and after the disturbance. The initial condition before the disturbance is defined as x_pre when the

ISSN: 2720-9598

disturbance occurs at time t=0. Then the system is governed by the dynamic equation when the disturbance is as follows [5],

$x = fF(x), 0 \le t \le \tau, x(0) = x\_pre$ (1)

Where $x \in R^N, t \in R, fF: R^N \to R^N$

The curve of the calculation result of the above equation is in the form of a fault on a trajectory, equation 1 can be written

$x(t) = X\_F(t; x\_pre), 0 \le t \le \tau$ (2)

Where $X\_F(t; x\_pre): R \to R^N$

The disturbance is eliminated when t=τ and the system is governed by a dynamic equation as follows,

$x = f(x), \tau \le t \le \infty; f: R^N \to R^N$ (3)

The result of the above equation is the path after the disturbance occurs. Equation 3 can be written

$x(t) = X(t; x^0), \tau \le t \le \infty; X(t: x^0: R^N \to R^N)$ (4)

Given that the initial condition x^0 is a point on the critical path of the fault at the time, the fault time is lost

$x^0 = X\_F(\tau, x\_pre)$ (5)

SIMULATION AND DATA ANALYSIS

PMSM design can be seen in Figure 9.

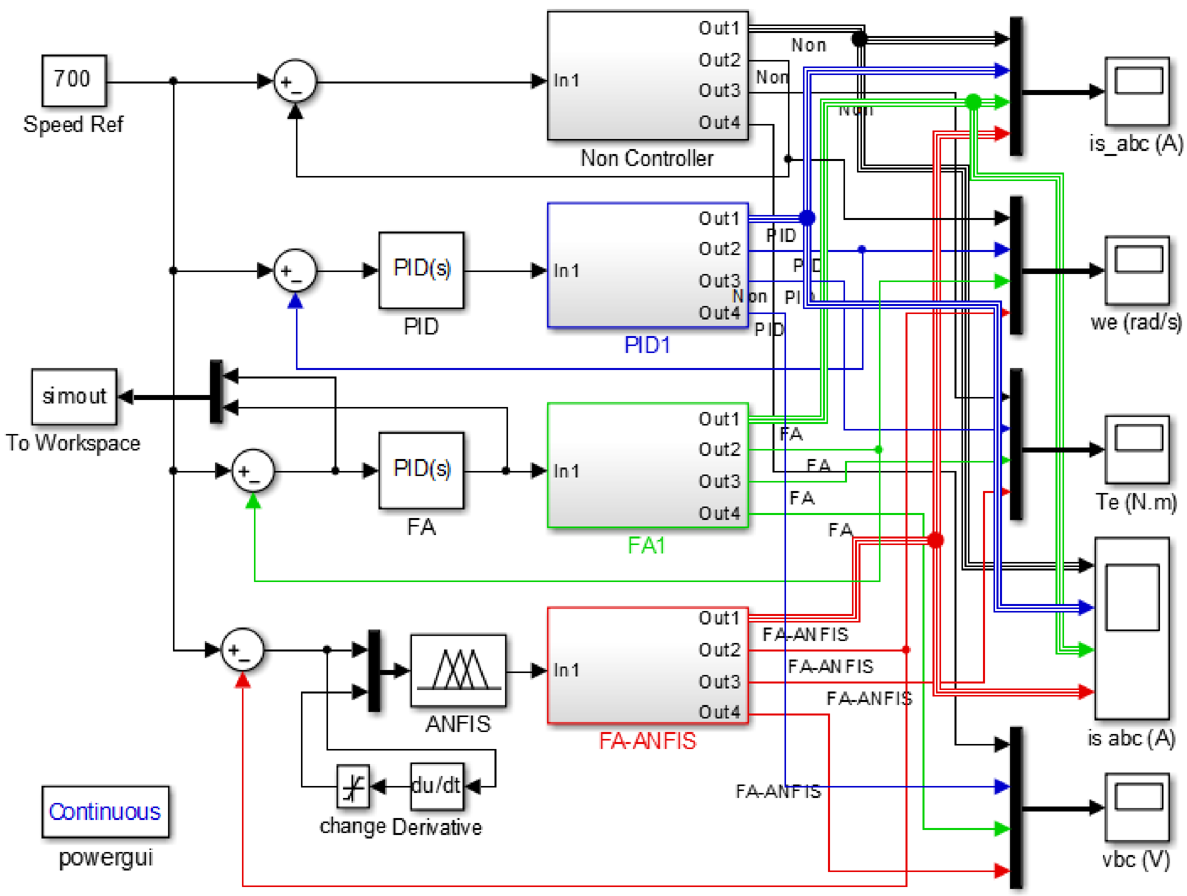
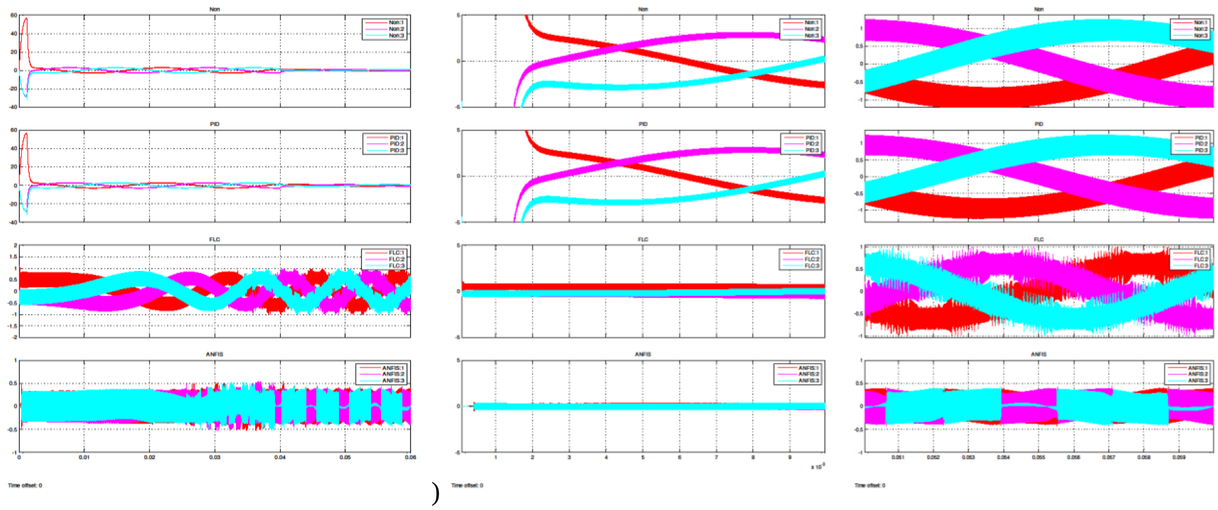


Figure 9. Controller model design

The output current profile (is) in amperes can be seen in Figures 10(a), 10(b), and 10(c).

http://dx.doi.org/10.17977/um048v4i2p09-19

ISSN: 2720-9598



)

Figure 10. Design (a) 3-phase output current, (b) Transient current, (c) steady-state current

Figure 9. (a), 9. (b), and 9(c) shows that the output current profile is the best on the FA controller. At the time of transient overshot produced at Without Control = 56.79 A, at PID = 56.78 A, at FA = 15.26 A, and FA-ANFIS = 16.85 A. At steady state without control = 0.98 A, at PID = 0.99 A, at FA = 3.39 A, and at FA-ANFIS = 2.45 A.

The Torque Profile obtained can be seen in Figures 11(a) and 11(b)

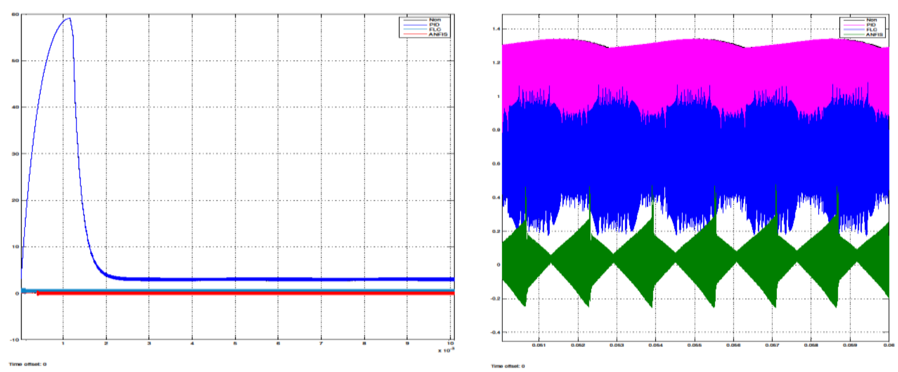


Figure 11. (a) PMSM torque profile at transient and 10(b) PMSM torque profile at steady state.

Figure 11. (a) and 11. (b) show that the best torque profile (smallest overshot) is on the FA-ANFIS controller. At the time of transient overshot produced at No Control = 59.19 pu, at PID = 59.19 pu, at FA = 1.32 pu, and FA-ANFIS = 0.28 pu.

The voltage profile obtained can be seen in Figures 12(a) and 12(b).

ISSN: 2720-9598

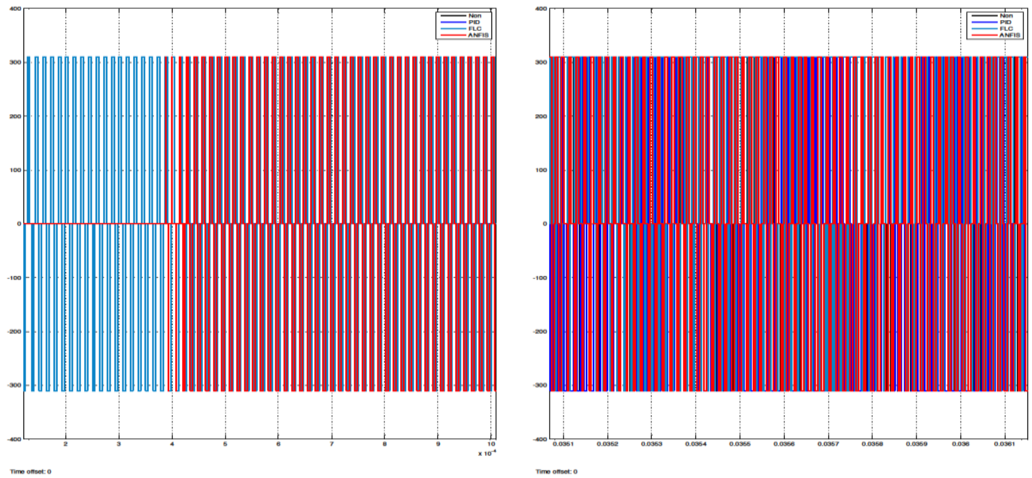


Figure 12. (a) Transient current, (b) current steady state profile voltage PMSM

Figure 12. (a) and 12. (b) show that the best (most continuous) voltage profile is on the FA-ANFIS controller. During transients, the voltage frequency is 296.8 Volts without control with an output frequency of 6.666 Hz, at PID is 298.4 Volts with an output frequency of 8.33 kHz, on FA is 300.2 Volts with an output frequency of 8.75 kHz, and FA-ANFIS is 300.03 Volts with an output frequency. 8.84 kHz.

Images of engine speed (rad) can be seen in Figures 13. and 13. b.

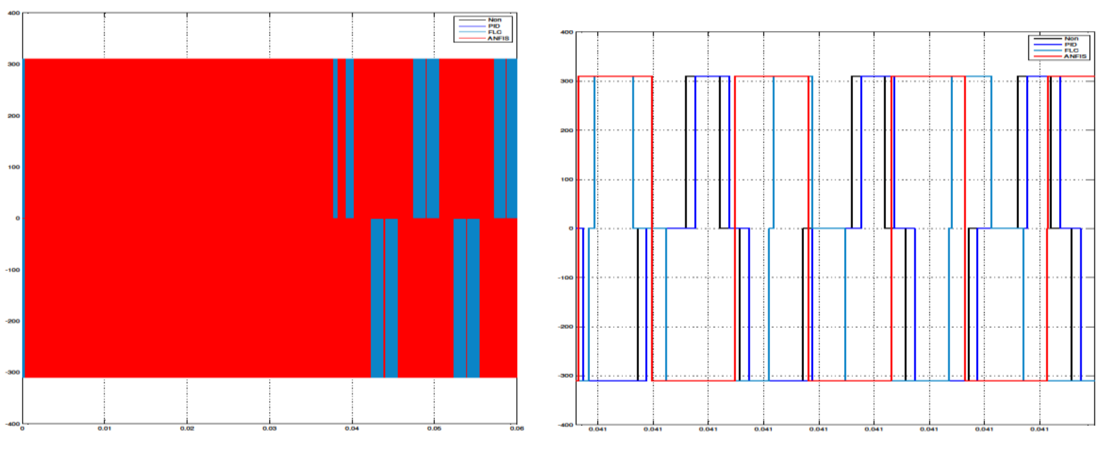


Figure 13. (a). engine speed in radians (rad) and (b). when zoomed in (zoom)

Figures 13. (a) and 13. (b) it shows that the model closest to the speed reff (300 rpm) is FA-ANFIS with the smallest undershot of 300,015 rpm at t = 0.006 seconds and steady state at 300.0224 rpm at 0.0042 seconds. . Without control there was an undershot of 297 rpm at t=0.006 seconds and steady state at 299 rpm at 0.004 seconds. PID control occurs undershot at 298.322 rpm at t=0.006 seconds and steady state at 300.323 rpm at 0.0421 seconds. FA has an undershot of 0.002 pu at t=0.006 seconds and a steady state at 300.332 rpm at 0.004 seconds.

CONCLUSION

The simulation results show that the model that is closest to the speed reff (300 rpm) is FA-ANFIS, the rotation profile with the smallest undershot is 300,015 rpm at t = 0.006 seconds and steady state at 300.0224 rpm at 0.004 seconds, the best output current profile is obtained at FA = 3.39 A, the best torque profile (smallest overshot) on the FA-ANFIS controller is 0.281 pu, the best (most continuous) voltage profile is 300.0323 Volts with an output frequency of 8.84 kHz. Overall it can be stated that the best control design is on the FA-ANFIS controller.

http://dx.doi.org/10.17977/um048v4i2p09-19

ISSN: 2720-9598

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