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Adaptive Neuro Fuzzy Inference System with Self Turning for Permanent Magnet Synchronus Motor

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Abstract – The PMSM (Permanent Magnet Synchronous Motor) drive systems are often used in electrical drives because of their simple structures, ease of maintenance and efficiency. However, the nonlinear behaviour which arises mainly from motor dynamics and load characteristics and the presence of uncertainties make their control an extremely difficult task. So, the speed control strategy should be adaptive and robust for successful industrial applications. To handle the control issue more effectively, By using the self-tuning Adaptive neuro fuzzy inference system with modified rule base is reduce the complexity of the controller without losing system performance and stability. The best topology is modelled in MATLAB/Simulink platform and the results are analyzed.

Index Terms – Permanent Magnet Synchronous Motor (PMSM), Scaling Factor (SF), Adaptive speed control,ANFIS,Self–Tuning PI-link Adaptive Neuro Fuzzy Inference System.

1. INTRODUCTION

The PMSM is a type of synchronous machine PMSM is electro-magnetic and electro-dynamic equipment which convert electrical energy into mechanical energy. It provides high reliability, wide-speed range at constant power, low manufacturing cost, fast dynamic response, ruggedness and fault tolerance. It is used in variable applications like pumps, fans, compressor, conveyors applications, it is used in small industrial drives applications etc.

In high performance variable speed drive (HPVSD) systems the motor speed should closely follow a specified reference trajectory regardless of load disturbances, parameter variations and model uncertainties. In order to achieve high performance, field oriented control is the most popular choice. Traditionally, these control issues are handled by the conventional proportional-integral (PI) controller and other controllers such as model reference adaptive controller, sliding mode controller, variable structure controllers.

However, the difficulties of obtaining the exact d-q axis reactance parameters of the PMSM lead to cumbersome design approach for these controllers.Moreover, the conventional fixed gain PI controller is very sensitive to step change of control speed, parameter variations and load disturbances.Moreover, the precise speed control of a PMSM drive becomes a complex issue due to nonlinear coupling among its winding currents and the rotor speed as well as the nonlinearity present in the electromagnetic developed torque due to magnetic saturation of the rotor core.

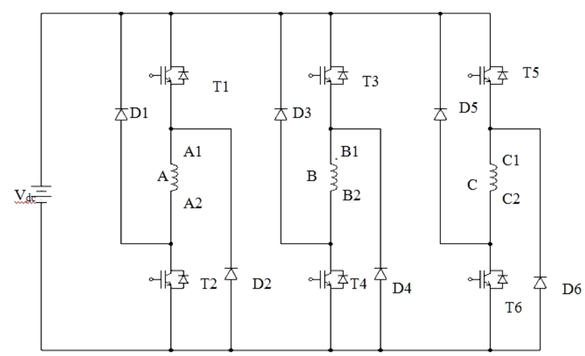
Thus, the intelligent controllers are expected to play an increasing role for high performance PMSM drive system. The draw-backs of Fuzzy Logic Control (FLC) and Artificial Neural Network (NN) can be overcomeby the use of Adaptive Neuro-Fuzzy Inference System (ANFIS). ANFIS is one of the besttradeoff between neural and fuzzy systems, providing: smooth control, due to the FLC interpolationand adaptability, due to the NN back propagation. Some of advantages of ANFIS are modelcompactness, require smaller size training set and faster convergence than typical feed forward NN.Since both fuzzy and neural systems are universal function approximators, their combination, the hybrid neuro-fuzzy system is also a universal function approximator.

The non-linear mapping in aneuro-fuzzy network is obtained by using a fuzzy membership function basedneural network. Using the developed model of the BLDC motor, a detailed simulation and analysis of a BLDC motor speed servo drive is obtained. Closed loop control of PMBLDC motor drive consisting of PI speed controller and hysteresis current controller is simulated and later compared with the ANFIS controller.

2. PER PHASE CONVERTER

The phase converter was used for controlling the Permanent magnet motor. It contains two power semiconductor switching devices and two diodes which shown in fig. For high speed operation it is required to see that the stored energy can be fed back to the mains within the available period.

The advantage of these converter are the other phases are independently controlled by each phase, the energy from the off going phase is feedback to the source, which results in utilization of the energy and the converter is able to free wheel the energy during the chopping period at low speeds which helps to reduce the switching frequency and thus the switching losses of the converter.



The phase winding A is connected to the dc supply through power semiconductor devices T1 and T2. Depending upon the rotor position, when the phase winding A is to be energized the devices T1 and T2 are turned ON. When the phase winding A is to be disconnected from the in the phase winding A tends to maintain the current in the same direction. This current passes from the winding through D1 and D2 to the supply. Thus the stored energy is fed back to main.

Similarly phase winding B & C are also switched on to the supply and switched off from the supply in a cyclic manner. Usually the upper devices T1, T3 and T5 are turned on and off from the signals obtained from the rotor position sensor. The duration of conduction or angle of conduction can θ be controlled by using suitable control circuit. The lower devices T2, T3 and T5 are turned on and off from the signal. The current in the phase winding is the result of logically adding ofthe rotor position sensor and chopping frequency. As aresult it is possible to vary the effective phase current from a very low value to a high value. For varying the current the following methods are available.

3. SPEED CONTROL

3.1. PI Control

PI controller is widely used in industry due to its ease in design and simple structure. The rotor speed is compared with the reference speed and the resulting error is estimated at the nth sampling instant as:

$$\omega e(n) = \omega r(n)\ \omega - \omega r(n)$$

The new value of torque reference is given by:

$$T(n) = T(n-1) + Kp\{\omega e(n) - \omega e\ (n-1)\} + K1\{\omega e(n)\}$$

Where,ωe (n − 1) is the speed error of previous interval, and ωe(n) is the speed error of the working interval. Kp and K1 are the gains of PI speed controller. By using Ziegler Nichols method the Kp and KI values are determined.

3.2. ANFIS Controller

In this section basics of ANFIS and development of ANFIS controller are given. ANFIS uses the neural network's ability to classify data and find patterns. It then develops a fuzzy expert system that is more transparent to the user and also less likely to produce memorization error than a neural network. ANFIS keeps the advantages of a fuzzy expert system, while removing (or at least reducing) the need for an expert.

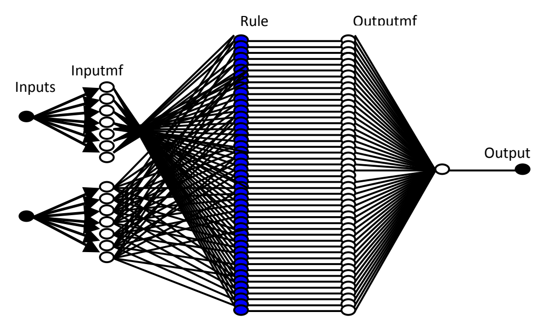
The problem with ANFIS design is that large amounts of training data require developing an accurate system. The ANFIS, first introduced by Jang in 1993, is a universal approximator and, as such, is capable of approximating any real continuous function on a compact set to any degree of accuracy. ANFIS is a method for tuning an existing rule base with a learning algorithm based on a collection of training data.

This allows the rule base to adapt. As a simple example, a fuzzy inference system with two inputs x and y and one output z is assumed. The first-order Sugeno fuzzy model, a typical rule set with two fuzzy If–Then rules can be expressed as

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

The resulting Sugeno fuzzy reasoning system is shown here, the output *z* is the weighted average of the individual rules outputs and is itself a crisp value. The corresponding ANFIS architecture is shown in.



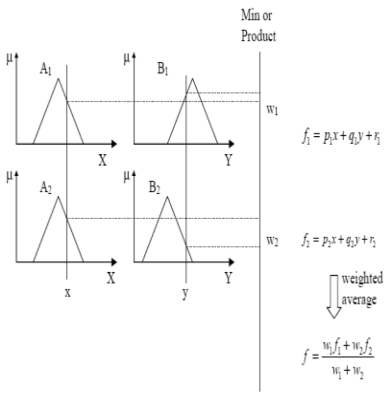
ANFIS architecture

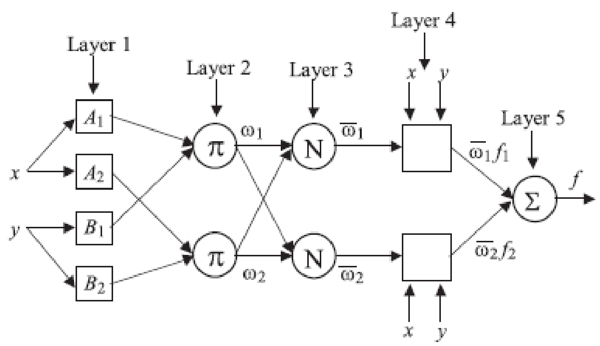
If the firing strengths of the rules are *w1 and w2* , respectively, for the particular values of the inputs Ai and integral of Bi, then the output computed as weighted average,

Layer 2: .Every node in layer 2 is a fixed node, whose output is the product of all incoming signals.

$$Wi = \mu Ai(x)\ \mu Bi(y),\ i=1,2$$

Layer 3: This layer normalizes each input with respect to the others (The *I* th node output is the *I* thinput divided the sum of all the other inputs).



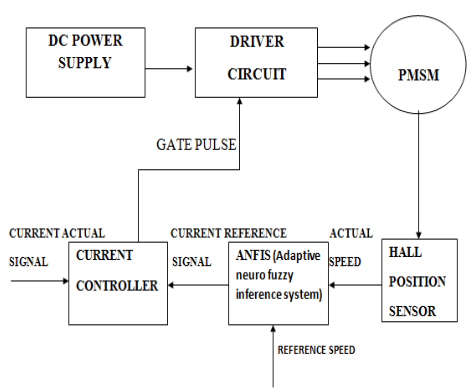


Layer 4: This layer's *I th* node output is a linear function of the third layer's *I th* node output and the

ANFIS input signals.

Layer 5: This layer sums all the incoming signals.

4. BLOCK DIAGRAM OF PROPOSED SYSTEM



Block Diagram Description

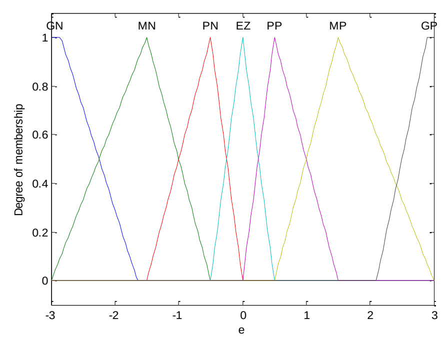
The separately excited dc machines andsynchronous machines have two sources ofexcitation, one for its field and the other to the armature. In these, the torque is proportional to the product of the armature and field currents. The system is made linear by keeping the magnetization (field) current constant, thus making the torque-producing part of the (armature) current a variable to provide a variable air gap torque as in the case of dc and ac machines.

The suggestion of the excitation source being single is that the machine's torque is proportional to the square of the excitation current, among the other, resulting in a nonlinear system.

The coupling of the air gap torque to the load through the mechanical system. The inability to separate the excitation current into a magnetizing or flux-producing part and a torque producing part makes it difficult to obtain a high-performance control in the PMSM drives.

The block diagram of speed control in switched reluctance motor by PI controller. The set speed and reference speed are compared and error signal is applied to PI Speed Controller. The PI controller output current is fed to current controller. It compares the motor current and reference current and feeds the gate triggering pulse to the converter. The converter output controls the motor speed.

Design of Membership Function (MF)

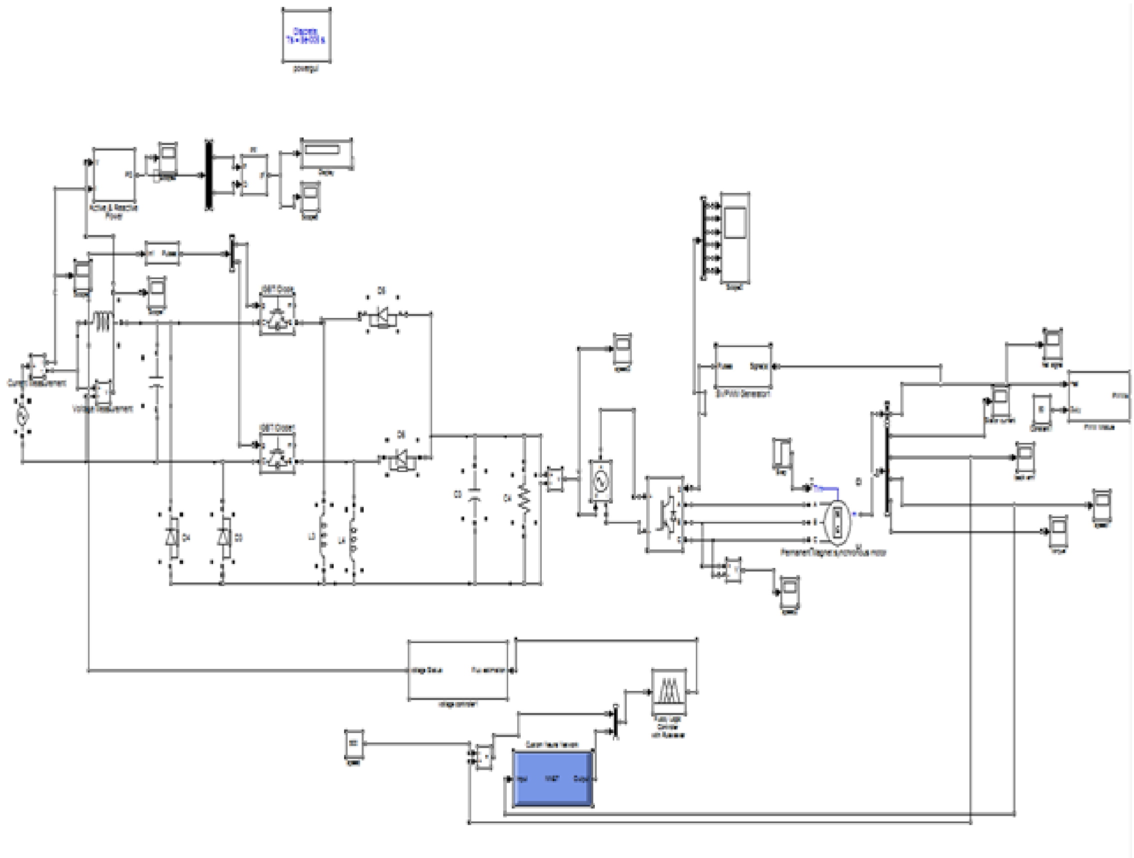


The design of membership function

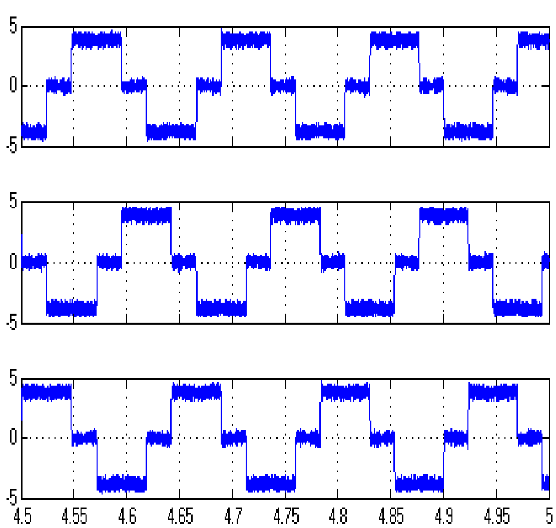
A membership function is a curve that defines how each point in the input space is mapped to a membership value (degree of membership) between 0 and 1.The simplest membership functions are formed using straight lines of these, the simplest is the triangular membership function, and it has the function name „trimf‟. It's nothing more than a collection of three points forming a triangle.

We can see that the overall efficiency is improved under PAM control compared with that under PWM control at high speed, as the increased waveform quality reduces the motor loss and the harmonic content. The overall system loss consists of the motor loss (including the active motor loss and the passive generator loss), $L1$ the inverter loss, $L2$ the rectifier loss, $L3$, and the control system loss, $L4$.

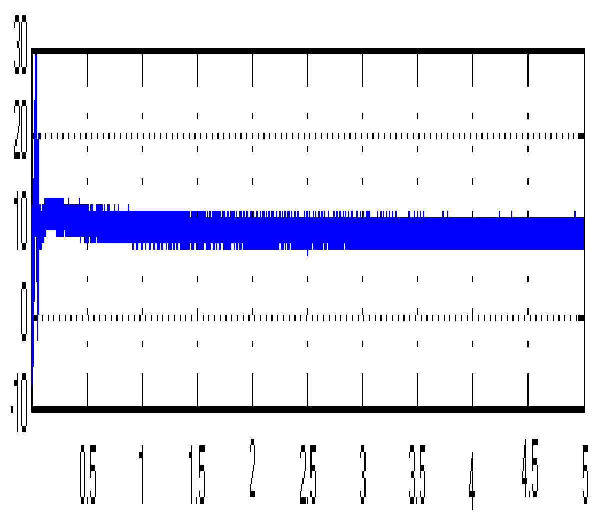
5. SIMULATIONDIAGRAM



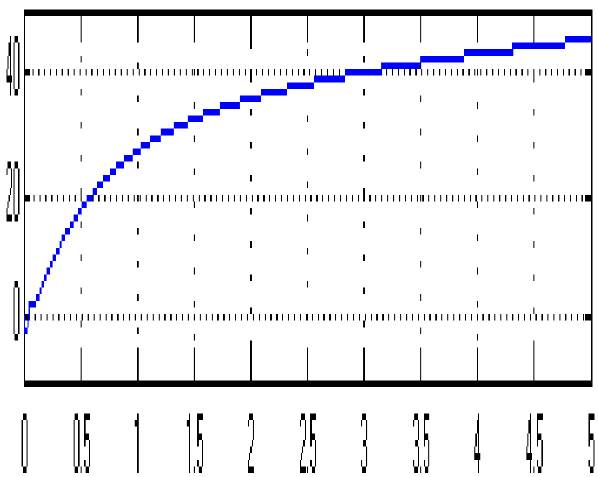
5.1. Simulation Output



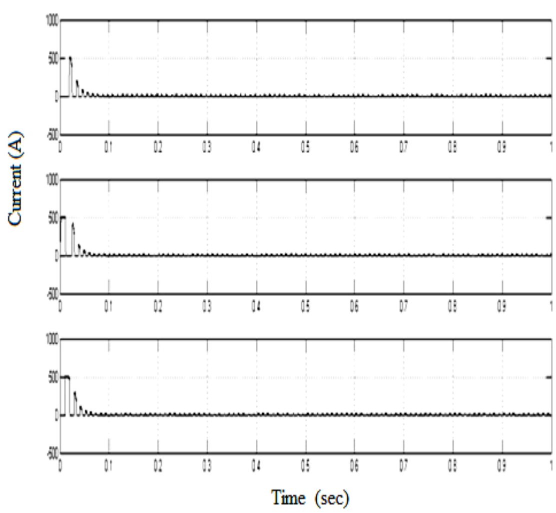
Stator Current ANFIS controller.



Torque Response -ANFIS Controller



Speed Response – ANFIS Controller



ANFIS Three Phase Current Output Waveform

5.2. Comparative Study Of Set Speed And Settling Time

The below table is representing the conventional PI controller and fuzzy self-tuning controller according to the tuning and settling time of the controller the desired speed is obtained. The self–tuning fuzzy logic controller performance is better than conventional PI controller.

The various set speed and settling time in conventional PI controller and fuzzy logic speed controller. Compared to conventional PI controller the Adaptive neuro fuzzy inference system (ANFIS) settling time is very low.

Controller	**Speed (rpm)**	**% Over shoot (%)**	**settling Time (sec)**	**Starting Torque (nm)**
PI	1500	0.266	0.27	1.7
FUZZY	1500	0	0.0.18	6
Hybrid fuzzy – PI	1500	0	0.16	6.8
GA-Based PI	1500	0	0.12	6.9
ANFIS	1500	0	0.1	7

6. CONCLUSION

The conventional PI controller parameters need to be constantly adjusted in order to achieve better control performance. Adaptive neuro fuzzy inference system can automatically adjust control parameters in accordance with the speed error and change in speed error, so it has better self-adaptive capacity.

Adaptive neuro fuzzy inference system has smaller overshoot and less rising and settling time than conventional PI controller and has better dynamic response properties and steady state properties.

The project presents a new Adaptive neuro fuzzy inference system to ensure excellent reference tracking of switched reluctance motor drives. The speed of PMSM motor has been found to be proportional to the DC link voltage.

The proposed method is analyzed using MATLAB/SIMULINK software. From the simulation results it is clearly understand that the smooth speed control is obtained during acceleration and deceleration by controlling the voltage at DC link.

Simulated results are presented to demonstrate an improved power quality of the PMSM motor system in a wide range of speed. In conventional method power factor range is 0.88 and the proposed method gives the improved power factor range is 0.99.

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