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ANFIS Control Scheme for the Speed Control of the Induction Motor

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ABSTRACT
An adaptive neuro fuzzy inference strategy (ANFIS) provides a nonlinear modeling of motor drive system and motor's speed can accurately track the reference signal. ANFIS has the advantages of employing expert knowledge from fuzzy inference system and the learning capability of neural networks. An (ANFIS) for controlling speed of induction motor is presented in this paper. Induction motors are characterized by highly non-linear, time-varying dynamics, complex and inaccessibility of some of the states and outputs provide for measurements. A control signal develop depending on fuzzy based controllers which yields on the firing of rule base, this rule base written on previous experiences & also these rules are fired as random in nature. The proper rule base is selected depending upon the situation and it can be achieved using an ANFIS controller, this becomes an integrated method for the control purposes & produces excellent results, this is the highlight of this paper. The proposed (ANFIS) controller is compared with PI controller by computer simulation through the MATLAB/SIMULINK software. In ANFIS scheme, neural network techniques provide for a proper rule base, is achieved using the back propagation algorithm. This integrated approach improves the system performance, cost-effectiveness, efficiency, reliability of the designed controller.
Keywords – ANFIS Controller, Fuzzy Logic, Induction motor, Matlab, Membership functions, Simulink Model

I. Introduction

Induction motors play a vital role in the industrial sector especially in the field of electric drives & control. Speed imbalances shows that, it is virtually impossible to achieve the desired task for a specific application. AC motors, particularly the squirrel-cage induction motors (SCIM), make an inherent advantage like simplicity, reliability, low cost and virtually maintenance free electrical drives. Again for high dynamic performance industrial applications, their control remains a challenging problem because they exhibit significant nonlinearities and many of the parameters, mainly the rotor resistance, vary with the operating conditions. The Field Orientation Control (FOC) of an induction machine achieves decoupled torque and flux dynamics leading to independent control of the torque and flux as for a separately excited DC motor. The FOC methods are attractive, but suffer from one major disadvantage, viz., they are sensitive to motor parametric variations such as the rotor time constant and an incorrect flux measurement or estimation at low speeds.

Advanced variable speed drive applications require steeples control and suitable dynamic response and accuracy. These considerations made a large extent in the past due to thyristor controlled dc machines. However, the dc machine remains expensive in relation to the types of rotating machines. For the higher power drives in industries, the lighter, less expensive, reliable simple, more robust and commutator less induction motors [3] are desirable and these motors are being applied today to a wider range of applications requiring variable speed. Unfortunately, accurate speed control of such machines by a simple and economical means remains a difficult task. The development of the silicon controlled rectifier, triac and related members of the thyristor family, it has become most feasible to design variable speed induction motor drives for a wide variety of applications. The different techniques have been used, using SCR controllers. A back-to back connected SCR' are used in series with the rotor phases to control their effective impedance. A chopper controlled external resistance is used to control the speed by varying the duty cycle of the chopper. A controlled rectifier is used in the rotor circuit to feed the external resistance, also by varying the firing angle; due to this effective rotor impedance is controlled.

An induction motors are widely used in various industries as prime work to produce rotational motions and forces. In General, variable speed drives for induction motors require both wide operating range of speed and fast torque response, regardless of load variations. The classical control is always used in majority of the electrical motor drives in [7]. Conventional control makes use of the mathematical model for the controlling of the system. At the time when there are system parametric variations or environmental disturbance i.e. noise, behavior of system is not satisfactory & deviates from the desired performance. In addition, usual computation of system mathematical model is difficult or impossible. For exact mathematic model of the system, then one has to do some identification techniques such as the system identification & obtain the plant model. Moreover, the design and tuning of conventional controller increases the implementation cost and adds additional complexity in the control system & thus, may reduce the reliability of the control system. Hence, the fuzzy based techniques are used to overcome this kind of problems. The efficient torque control of induction motor drives in combination with resonant DC-link input filters can lead to a type of stability problem that is known as negative impedance instability. Fuzzy logic based flexible multi bus voltage control of power systems was developed by Ashok in [4]. From last few years, fuzzy logic has create growing interest in many motor control applications due to its non-linearities handling features and independence of the plant modeling. The fuzzy controller (FLC) operates in a knowledge based path, and its knowledge relies on a set of linguistic if-then rules, like a human operator. There are a number of significant control methods available for induction motors including scalar control, vector or field oriented control, direct torque and flux control, sliding mode control, and the adaptive control [9].

1.1 Mathematical Model for Induction Motor

In the control of any power electronics drive system i.e. a motor. It start with, a mathematical model of the plant is required. It means mathematical model play an important role in the speed control of Induction Motor. This mathematical model is required further to design any type of controller to control the process of the plant. The mathematical model can be obtained by various methods; these methods are from first principles, system identification methods, etc. This mathematical model may be a linear or non-linear differential equation or a transfer function (in s or z-domain) or in state space form. In this section, we present the mathematical model of the induction motor. The mathematical model of the SCIM system used in our work consists of space vector PWM voltage source inverter, induction motor, direct flux and the torque control. The drawback of the coupling effect in the control of SCIMs is that, it gives poor response and the system is easily prone to instability because of a high-order system effect. This problem can be solved by making use of either vector control or field-oriented control. When this type of control strategy is adopted, it can make an induction motor to be controlled like a separately excited DC motor. Of course, the control of AC drives can exhibit better performance. The power circuit of the 3- phase induction motor is shown in the Following Fig.1.

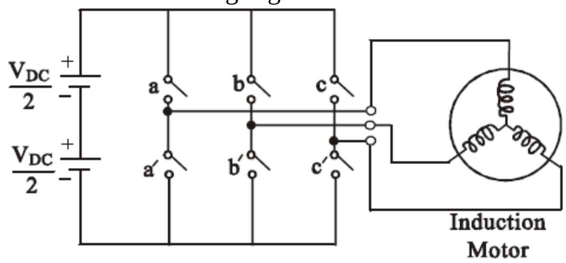

Fig.1: Power circuit connection diagram for the Induction Motor

1.2 Parameter Identification

The use of artificial neural networks (ANNs) for identification and control of nonlinear dynamic systems in power electronics and ac drives have been proposed. They are capable of approximating wide range of nonlinear functions to a high degree of accuracy. The capability of a neural network has been deployed to have online estimators to address the situation of similar disturbances in both stator and rotor resistances simultaneously. Multilayer feedforward neural networks are regarded as universal approximations and have the capability to acquire nonlinear input-output relationships of a system by learning through the backpropagation algorithm. It should be possible that a simple two layer feedforward neural network trained by the backpropagation technique can be employed in the rotor resistance identification. In this estimator, two models of the state variable estimations can be used, one is to provide the actual induction motor output states and the other is to give the neural model output states. The total error between the desired and actual state variables may then be back propagated as shown below in Fig. 2, to adjust the weights of the neural model, so that the output of this model tracks the actual output. At time of training and this training is completed, the weights of the neural network should correspond to the parameters in the actual motor.

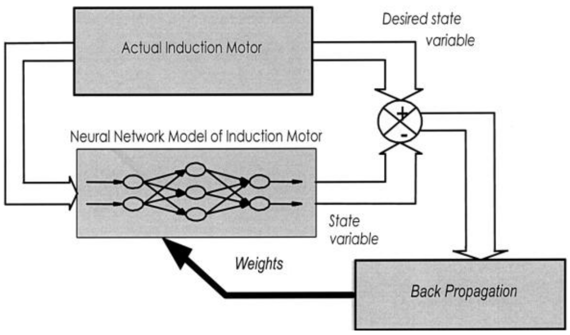

Fig.2: Parameter identification using neural networks

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II. Controller Design

A controller is a device which controls each & every operation in the system making decisions. As per the control system point, it is bringing stability to the system when there is a disturbance, thus safeguarding the equipment from further damages. It may be hardware based controller or a software based controller or a combination of both. In this section, the development of the control strategy for control of various parameters of the induction machine such as the speed, flux, torque, voltage and current is presented using the concepts of ANFIS control scheme, the block diagram of which is shown below in the Fig 3.

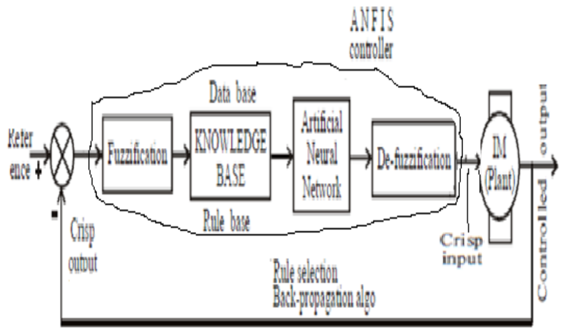

Fig.3: Block diagram of the ANFIS control scheme

Fuzzy logic is one of the successful applications of fuzzy set in which the variables are linguistic rather than the numeric variables. Linguistic variables, defined as variables whose values are sentences in a natural language (such as large or small) it may be represented by the fuzzy sets. Fuzzy set is an extension of a 'crisp' set where an element can only belong to a set (full membership) or not belong at all (no membership). Fuzzy sets allow partial membership, which means that an element may partially belong to more than one set. A fuzzy set A of a universe of discourse X is represented by a collection of ordered pairs of generic element and its membership function μ : X → {0 1}, which associates a number μ A(x) : X→ { 0 1}, to each element x of X. A fuzzy logic controller is based on a set of control rules called as the fuzzy rules among the linguistic variables. These rules are expressed in the form of conditional statements.

Our basic structure of the developed ANFIS coordination controller to control the speed of the Induction Motor consists of 4 important parts viz., fuzzification, knowledge base, neural network and the de-fuzzification blocks.

The inputs to the ANFIS controller, i.e., the error & the change in error is modeled by following equation-

$$e(k) = \omega_{ref} - \omega_r \qquad \text{--------- (1)}$$

$$\Delta e(k) = e(k) - e(k-1) \qquad \text{------ (2)}$$

Where, ω_{ref} is the reference speed, ω_r is the actual rotor speed, e (k) is the error and delta e (k) is the change in error.

The fuzzification unit converts the crisp data into linguistic variables, which is given as inputs to the rule based block. The set of 49 rules are written on the basis of previous knowledge and experiences in the rule based block. The rule base block is connected to the neural network block. Back propagation algorithm is used to train the neural network to select the proper set of rule base. The control signal developed due to the trainingand this training is a very important step in the selection of the proper rule base. Once the proper rules are selected & fired, the control signal required to obtain the optimal outputs is generated. The output of the Neural Network unit is given as input to the de-fuzzification unit and the linguistic variables are converted back into the numeric form of data in the crisp form. In the fuzzification process, i.e., in the first stage, the crisp variables, the speed error & the change in error are converted into fuzzy variables or the linguistics variables. The fuzzification maps the two input variables to linguistic labels of the fuzzy sets. The fuzzy coordinated controller uses the linguistic labels. Each fuzzy label has an associated membership function. The membership function of triangular type is used in our work .The inputs are fuzzified using the fuzzy sets & are given as input to ANFIS controller. The rule base for selection of proper rules using the back propagation algorithm is written as shown in the below table.

The developed fuzzy rules 7*7=49 included in the ANFIS controller. The control decisions are made based on the fuzzified variables in the below Table. The inference involves a set of rules for determining the output decisions. As there are 2 input variables & 7 fuzzified variables, the controller has a set of 49 rules for the ANFIS controller. Out of these 49 rules, the proper rules are selected by the training of the neural network with the help of back propagation algorithm & these selected rules are fired. Further, it has to be converted into numerical output, i.e., they have to be de-fuzzified. This process is called as defuzzification, which is the process of producing a quantifiable result in fuzzy logic.

Table: Rule base for controlling the speed

E / ΔE	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

The defuzzifcation transforms fuzzy set information into numeric data information. There are so many methods to perform the defuzzifcation, viz., centre of gravity method, centre of singleton method, maximum methods, the marginal properties of the centroid methods & so on. In our work, we use the centre of gravity method. The output of the defuzzification unit will generate the control commands which in turn is given as input called as the crisp input, to the plant through the inverter. If here is any deviation in the controlled output which is crisp output, this is fed back & compared with the set value & the error signal is generated which is given as input to the ANFIS controller which in turn brings back the output to the normal value, thus maintaining stability in the system.

III. Development of Simulink Model

Simulink model for the control of various parameters of the induction motor can be developed in Matlab 7. By using the command window of Matlab it creates the .fis file and it will be helpful in the simulink for controlling the speed of Induction Motor with an important role of ANFIS controller proposed in this paper. This simulink model with the ANFIS controller can be developed using the various toolboxes available in the simulink library such as the power system, power electronics, control system, signal processing toolboxes & from its basic functions. The entire system modeled in Simulink is a closed loop feedback control system consisting of the plants, controllers, samplers, comparators, feedback systems, constants, buses, the mux, de-mux, summers, adders, gain blocks, multipliers, constant blocks, CT & DT blocks, ANFIS editor blocks, clocks, sub-systems, integrators, state-space models, the output sinks (scopes), the input sources, work-space blocks, etc.

IV. Conclusion

The characteristic curves of speed, torque, current, flux, slip, load, etc. vs. time we will observed. The outputs can take less time to stabilize, which can be observed from the simulation results. Due to the incorporation of the ANFIS controller in loop with the plant, it will observe that the motor reaches the rated speed very quickly in a lesser time compared to the Mamdani method.

A systematic approach of achieving the speed control of an induction motor drive by means of adaptive neuro fuzzy inference control strategy has been proposed in this paper. Simulink model can developed in Matlab 7 with the ANFIS controller for the speed control of Induction Motor. The control strategy was also developed by writing a set of 49 fuzzy rules according to the ANFIS control strategy with the back propagation algorithm in the back end.

The main advantage of designing the ANFIS coordination scheme is to control the speed of the Induction Motor & to increase the dynamic performance & to provide good stabilization.

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References

[1] J. Zhao and B. K. Bose, “Evaluation of Membership Functions for Fuzzy Logic Controlled Induction Motor Drive,” IEEE 2002 28th annual Conference of the Industrial Electronics Society, Vol. 1, 2002.

[2] Kazuo Tanaka, Hua O. Wang, “Fuzzy Control Systems Design and Analysis: A Linear Matrix Inequality Approach” John Wiley & Sons, Inc., USA. 2002.

[3] R. P. Basu, “A Variable Speed Induction Motor Using Thyristors in the Secondary Circuit,” IEEE Transactions on Parer Apparatus and Systems, Vol. 90, 1971.

[4] Ashok Kusagur, S.F.Kodad, B.V. Sankar Ram, “Novel design of a Takagi-Sugeno fuzzy strategy for induction motor speed control”, Paper accepted for publicationin Journal of Electrical Systems, Vol. 6, issue 2, Jun. 2010.

[5] A. S. A. Farag, “State-Space Approach to the Analysis of DC Machines Controlled by SCRs,” IEEE Proceeding Publication-on the Control of Power Systems Conference, Oklahoma, March 10-12, 1976.

[6] M. G. Simoes and B. K. Bose, “Neural Network Based Estimation of Feedback Signals for Vector Controlled Induction

Motor Drive," IEEE Transactions on Industry Applications, Vol. 31, No. 3, 1995.

[7] Henrik Mosskull, Johann Gali´c, and Bo Wahlberg, "Stabilization of Induction Motor Drives With Poorly Damped Input Filters", IEEE Transactions on Industrial Electronics, Vol. 54, No. 5, Oct. 2007.

[8] Vas P., "Vector Control of AC Machines", Oxford University Press, London, UK, 1990.

[9] Mouloud Azzedine Denai, Sid Ahmed Attia, "Fuzzy and Neural Control of an Induction Motor", Proc. Int. J. Appl. Math. Computer. Sci., Vol.12, No. 2, 2002.

[10] Liu X., and S. Zhong, "T–S fuzzy model-based impulsive control of chaotic systems with exponential decay rate", Physics Letters A, Vol. 370, 2007.

Books:

[1] G.A. Vijayalakshmi Pai & S. Rajasekaran, *Neural Networks Fuzzy Logic and Genetic Algorithms analysis* (New Delhi: PHI Learning Private Limited, 2011).

[2] George J. Klir/Bo Yuan, *Fuzzy Sets and Fuzzy Logic* (New Delhi: Prentice-Hall of India Private Limited, 2005).

[3] S.N. Sivanandam, S.Sumathi and S.N. Deepa, *Introduction to Neural Networks using Matlab 6.0* (New Delhi: McGraw Hill Education (India) Private Limited, 2013).