A NON LINEAR MOTOR DRIVE CONTROL SYSTEM BY USING ARTIFICIAL INTELLIGENCE NETWORKS

B.MEGHYA NAYAK[1] DR. ANUPAMA A. DESHPANDE[2]
[1]Research Scholar JJTU, Jhunjhunu, Rajasthan, India
[2]JJTU, Jhunjhunu, Rajasthan, India
[1]meghya29@gmail.com [2]mangala.d.2000@gmail.com

ABSTRACT
Automatic Control of Electrical drives play an important role in rapidly growing industrial era. So the controlling of electrical drives is also important. Variable speed drives are the major part of power system, microelectronic, power plant and so on. Various applications like power plant, microelectronic, power require variable speed drives. Conventional controlling methods of electrical drives needed mathematical model of control process which was very tedious. Modern practice is to use Artificial Intelligence as it does not require mathematical modeling though contains both hard computation and soft computation. The problem is solved by artificial intelligence which contains both hard computation and soft computation. Hence, Artificial intelligence has found finds high application in most nonlinear systems such same as motor drive, which increases as no mathematical model is needed for artificial intelligent system so efficiency and reliability of drives increase as well as decrease volume, weight and cost of drives decrease. Soft starters are widely used with electronic motor as it provides improved operating characteristics and better control. Soft starter also reduces the wear and tear effects on motor and on the associated drive systems which in turn reduces maintenance cost, conserve energy and plays a significant role part in improving system performance. Escalators, pumps, elevators and conveyor belts can be operated more effectively with a soft starter.

Keywords: Artificial Intelligence, Induction Motor, Soft starting

1. Introduction

To improve the productivity of manufacturing industry, sophistication in factory automation is very much needed. In manufacturing process, variable speed drives play an important role and occupies a major part in terms of conveyor belts, robot arms, overhead cranes, steel process lines, paper mills and plastic and fiber processing units etc. Three phase Induction Motor have wide applications in electrical machines. About half of the electrical energy generated in a developed country is ultimately consumed by electric motors, of which over 90 % are induction motors. For a relatively long period, induction motors have mainly been deployed in constant-speed motor drives for general purpose applications. In about the same period, there were also advances in control methods and Artificial Intelligence (AI) techniques. Artificial Intelligent techniques mean use of expert system, fuzzy logic, neural networks and genetic algorithm.

Researchers soon realized that the performance of induction motor drives can be enhanced by adopting artificial-intelligence-based methods. The Artificial Intelligence (AI) techniques, such as Expert System (ES), Fuzzy Logic (FL), Artificial Neural Network (ANN or NNW), and Genetic Algorithm (GA) have recently been applied widely in control of induction motor drives. Among all the branches of AI, the NNW seems to have greater impact on power electronics & motor drives area that is evident by the publications in the literature. This paper tends to show Neuro controller has edge over fuzzy controller. Sugeno fuzzy controller is used to train the fuzzy system with two inputs and one output [10-13].The performance of fuzzy logic and artificial neural network based controllers is compared with that of the conventional proportional integral controller.

2. Artificial Intelligent Controller

Genetic algorithms, fuzzy logic, and neural networks are all techniques of digital computing in basis of artificial intelligence, which is popular in the area of informatics. But, increasingly, applications based on these new approaches to digital computing develop for practical applications in the fields of science and engineering.

The observers or the estimators based on the techniques of artificial intelligence lead a better dynamic and better accuracy and they are more robust. Their deliveries are very good even for large variations in the parameters of the machine. Nevertheless, the need for the perfect knowledge of the system to adjust or to estimate and the lack of expertise on system limits the current applications to a very specific range [6–8, 12–13].

Fuzzy Logic Controller. Fuzzy logic allows us to formulate mathematically imprecise concepts and to deduce precise actions from fuzzy rules coming from observations. The tool most commonly used in applications of fuzzy logics is the fuzzy rule base. A fuzzy rule has three stages: fuzzification, inference, and defuzzification.

The fuzzy controller consists of two input variables, the error (e) and error variation (de/dt), and an output variable. The error of the input variable is obtained from the difference between reference model with real speed of the rotor. The membership function of the determination of input and output variables is determined on the basis of experiments on the error of the system [13]. Resolved fuzzy rules are given in Table 1. Defuzzification method most used and that of the determination are the center of gravity of the resulting membership function witch converts linguistic variables into specific variables. The abscises of the center of gravity becomes the exit of the regulator and therefore the order of the system, the process depends on the output of the fuzzyset. In this study, seven triangular membership functions are used for the inference mechanism: NB (Negative Big), NM (Negative Medium), NS (Negative Small), EZ (approximately zero), PS (Positive

Small), PM (Positive Medium), and PB (Positive Big).

The base of rules for the membership functions is shown in Table 1.

The overall structure of a fuzzy controller is presented in Figure 1.

Artificial Neural Network. Neural modeling is chosen to bypass the parametric variations of the mathematical model of the motor. First, the neural network is driven offline; that is, the elements of the network are taken at the end of the application of all the data of the couples of training, for having a fixed network [11].

Then, the training of this one is done online for having an adaptation of the neural model in each moment. This type of training allows to conceive an adaptive order. The neural network can describe the behavior of a dynamic nonlinear system without need to know its parameters.

The neural network used for the command has a multi- layer structure with a hidden layer enabled by the sigmoid function, while the output layer is enabled by a linear function; its programming is carried by a backpropagation algorithm of the gradient with a learning rate adaptive [10]. The general principle of learning algorithms is based on the minimization of a cost function of quadratic of the differences between the outputs of the network and values desired [5– 10, 12– 14].

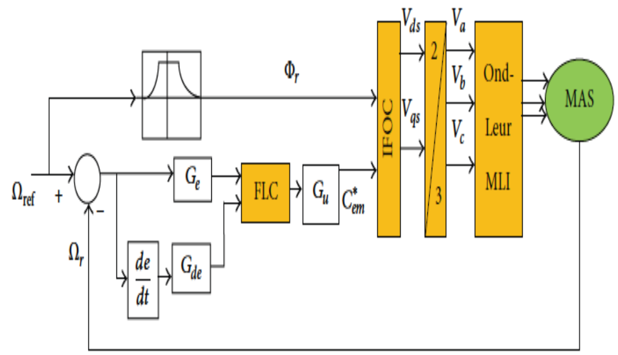


Fig 1: Structure of a fuzzy controller.

e \ de (u)	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NM	NM	NS	ZE	ZE	ZE
NM	NB	NM	NM	NS	ZE	ZE	ZE
NS	NB	NS	NS	ZE	ZE	ZE	PS
ZE	NM	NS	NS	ZE	PS	PS	PM
PS	NS	ZE	ZE	ZE	PS	PS	PB
PM	ZE	ZE	ZE	PS	PM	PM	PB
PB	ZE	ZE	ZE	PS	PM	PM	PB

Table 1: RULE DECISION

3. Control of induction motor drive

For several decades, researchers used classical methods to con- trol the speed of induction motor. Such controllers (like con- ventional PI controller) show simplicity in design and stability in performance.[17] Even though, the conventional controllers still require the mathematical model of induction motor. Besides, they may produce overshoot or long settling time in case of load disturbance or sudden change of reference speed.[18] To over- come these drawbacks, intelligent control systems, such as fuzzy logic, have been widely used for induction motor control. These control systems are based on artificial intelligence theory and conventional control theory.[4] Today, three-phase induction motor drives are employed in different industrial areas with a wide power range starting from few 100 W to several MW.[14] Drive industry is very thankful to the present generation of pow- erful microprocessors, microcontrollers, and digital processers such as DSP, field programmable gate arrays, and dSPACE, which are responsible for the realization of control functions within short cost margins.[16] However, cost of controller hardware is a limiting constraint, particularly at low-power and low-perfor- mance drives.[15] Main market share of about 80–90% are simple drives with low dynamic requirements like pumps and fans.[19] The v/f control drives are parameter independent, easy to imple- ment, and low cost, but they are classified as low-performance drives.[15] Therefore, the v/f control algorithm is widely adopted in general purpose inverters, such as adjustable-speed pumps, fans, or blowers where high-control quality would be superflu- ous.[20] In v/f control methods, the stator voltage is adjusted in proportion to the supply frequency, except for low and above base speeds. At low frequency operation, the voltage drop across stator resistance must be taken into account.[21] A pulse width modulated (PWM) inverter employing pure sinusoidal modula- tion cannot provide sufficient voltage to enable a standard motor to operate at rated values. Sufficient voltage can be obtained from the inverter by over modulating, however, producing distortion of the output waveform.[22] The space vector pulse width mod- ulation (SVPWM) method is an advanced, computation-inten- sive PWM method, and possibly the best among all the PWM techniques for variable frequency drive application.[5,6] Because of its superior performance characteristics, it has widespread application in recent years.[7] Figure 4 shows proposed control scheme for an induction motor in open loop and closed loop for static and dynamic analysis.[23] Figures 3(a) and (b) shows proposed control scheme for induction motor drive system in open loop and closed loop with artificial intelligent controller under implementation.

The PI controller gain is optimized using artificial intelligent controllers to get the optimized output of the controller in order to control the speed of the induction motor as shown in Figure 3.

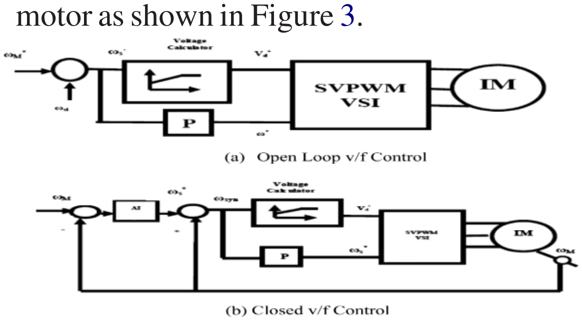


Fig 2: Basic v/f control of induction motor.

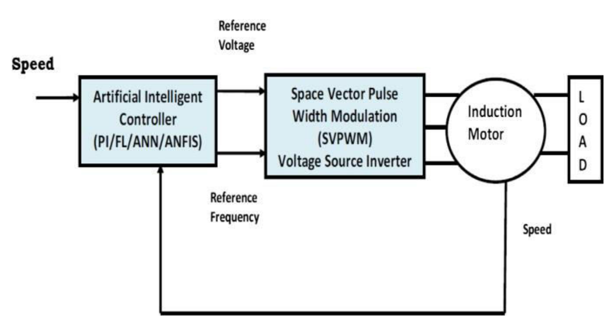


Figure:3. Proposed drive system

4 . Control Principle

AC motors, specially the squirrel-cage induction motor have some advantages like low cost, almost maintenance-free and reliable operation but for high dynamic performance industrial application, their control is still not so easy because of their non-linear characteristic and the variation of rotor resistance within the operating condition. Vector or field orientation control leads to independent control of torque and flux but motor parameter variations with a major disadvantage that they are very sensitive to motor parameter variations, such changes causing a major disadvantage in turn as the performance of conventional controllers like PID or PI deteriorates. So, nowadays the ultimate goal is to increase the robustness of the control system to make it, so that it will become more immune to uncertainty. Though conventional controls controllers have well established theoretical backgrounds on stability and allow achieving different design objectives such as steady state and transient characteristics of closed loop system, specifications of feedback control systems; they demand but for that correct mathematical model of the system. should be known. On the other hand, while using artificial control tools it is not necessary to know the mathematical model of the system and also the uncertainty or unknown variations in plant parameters and structure can be dealt with more effectively. Several works contributed to the design of hybrid control schemes also.

In this paper, both control methods conventional and artificial intelligence are introduced and applied to an indirect field-oriented induction motor. In first type of approach, a conventional PI controller is introduced in order to achieve speed control and starting situation is observed. The structure of PI controller used is shown in Figure 4 which is a regular parallel PI controller.

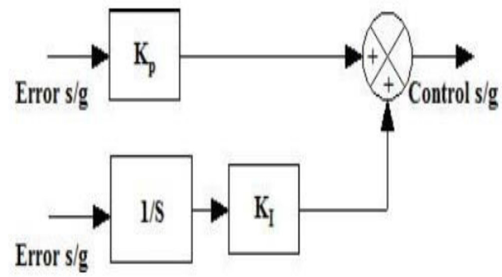


Fig 4: Conventional PI controller structure

In second approach of which is artificial intelligence based controller i.e. fuzzy logic controller, for which linguistic IF-THEN rules are used as a set of controller rule base. is introduced. The structure of fuzzy logic controller used is shown in Figure 5.

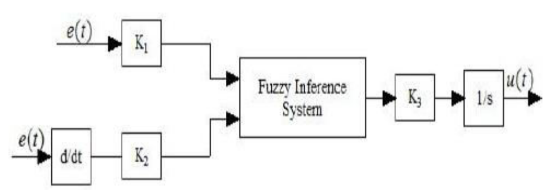


Fig 5: Fuzzy PI controller structure

Fuzzy logic controller based control strategy shows better result because fuzzy logic overcomes the difficulties of mathematical difficulties of modeling of highly non-linear systems, it responds in a more stable fashion to imprecise give precise readings of feedback control parameters, such as dc link current and voltage, its modification is very easy and it is very flexible.

5. Vector Controled Induction Motor Drive

Traditional control methods, such as v/f control methods control the frequency and amplitude of the motor drive voltage whereas vector control methods control the frequency, amplitude and phase of the motor drive voltage. The key principle of vector control is to generate 3-phase voltage as a phasor to control the 3-phase stator current as a phasor that controls the rotor flux vector and finally the rotor current phasor. Ultimately, the components of the rotor current need to be controlled. The rotor current cannot be measured because there is no direct electrical connection. So, they are indirectly computed using the parameters that can be measured. This technique is indirect vector control because there is no access to rotor currents. Indirect vector control is accomplished using the following data:-

1. Instantaneous stator phase currents.
2. Rotor mechanical velocity.
3. Rotor electrical time constant.

The motor must be equipped with sensors to monitor the 3-phase stator currents and rotor speed for feedback. Figure 6 shows the block diagram of vector controlled induction motor.

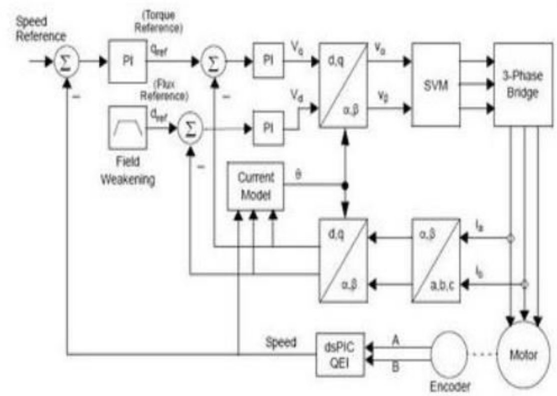


Fig 6: Block diagram of vector controlled IM

Following are the steps required for indirect vector control:-

1. 3-phase stator currents (Ia, Ib, Ic) and rotor speed are measured.
2. The 3-phase stator currents are transformed to a 2-axis time varying quadrature current values (I_α, I_β) as viewed from the stator perspective.
3. The 2-axis coordinate system is rotated to align with the rotor flux using transformation angle information calculated at the last iteration of the control loop. This conversion provides quadrature components of currents (I_d, I_q) transformed to the rotating co-ordinate system. I_d and I_q will be constant at steady-state.
4. I_d reference controls rotor magnetizing flux. I_q reference controls the torque output of the motor. The error signals computed after comparison are input to PI controllers. The output of the controllers provides V_d and V_q, which is a voltage vector.
5. A new coordinate transformation angle is calculated. The motor speed, rotor electrical time constant, I_d and I_q are the inputs to this

calculation. The new angle tells the algorithm where to place the next voltage vector to produce an amount of slip for the present operating conditions.

6. The V_d and V_q output values from the PI controllers are rotated back to the stationary reference frame using the new angle. This results in the quadrature voltage values V_α and V_β.

7. The V_α and V_β are transformed back to 3-phase values V_a, V_b and V_c. These 3-phase voltage values are used to calculate new PWM duty cycle values that generate the desired voltage vector.

6. Intelligent Speed Control

This model is achieved by improving the conventional and PI model simulation by adding ANN controller in open loop and closed loop. The *d–q* model of IM and Park's transformation and inverse Park's transformation are same as the conventional model, but AC source is replaced with SVPWM inverter which is controlled by neural controller.[16] So in the following sections, added models and their functionalities will be discussed. In this model, the SVPWM inverter produces the three-phase AC sources which are applied to Park's transformation, wherein three phases are converted to two signals and then the IM will act as conven- tional model. But the only difference which we observe in this model when compared with the conventional model is that, the induction motor rotor speed is applied to neural controller. The speed is normalized between zero and one and it is compared with one then error and change in error will be calculated. The produced crisp value is applied to neural network and the rated value will be produced. The speed controller block is shown in Figure 6. A feed forward carrier-based PWM technique, such as SVM, can also be looked upon as a nonlinear mapping phenomena, where the command phase voltages can be sampled at the input and the cor- responding pulse width patterns are generated at the output.

The sine wave is generated with amplitude, phase, and fre- quency which are supplied through a GUI. The clock signal which is the sampling time of simulation is divided by the crisp value which is obtained from ANN controller. By placing three sine waves with different phases one can compare them with triangu- lar waveform and generate necessary gating signals of SVPWM inverter. At the first sampling point, the speed is zero and error would be maximum. As the speed increases, the error will decrease, and the crisp value resulting from ANN will increase. So the frequency of sine wave will decrease which will cause IGBTs switched ON and OFF faster. These further increase the AC supply frequency and the motor will speed up. The controlling action of the induction motor drive is done with the help of ANNs. Before the signal is provided to controller, the generated speed signal is normalized and compared with reference signal. Thus, obtained error signal will be fed to controller which is designed with the neural network. This will produce the required gain to enhance the voltage signal which makes the induction motor to run at defined reference speed. Neural controller is a typical two-layer neural network model designed with the help of neural network toolbox. The parameters of the ANN controller are given in Table 2.

Generated signal is given to speed controller block where obtained sinusoidal signals will be compared with reference sig- nal to produce pulses. These pulses are used to excite the inverters in SVPWM block to generate three phase voltage signals.

Figure 6 shows the block diagram of fuzzy logic controller in which the steps involved in the fuzzy controller are shown.

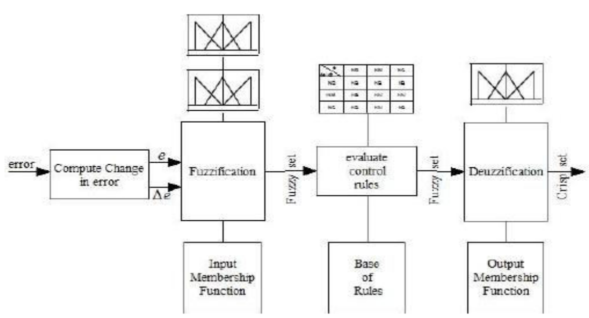
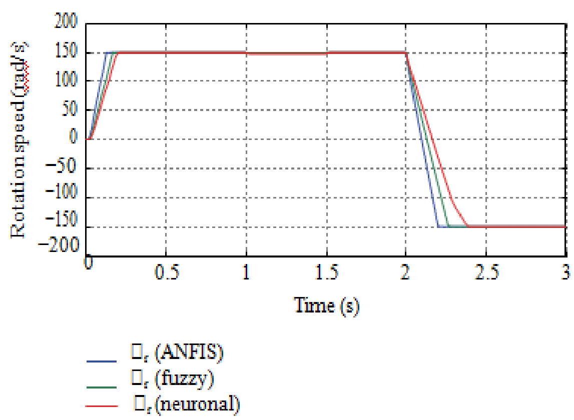


Fig 6: Fuzzy inference system for fuzzy controller



7. CONCLUSION

An induction motor consumes more energy than it actually needs to perform its work when operated at less than full load condition, that excess energy gets radiated in form of heat. By introducing the artificial intelligence in the system, one can control the amplitude of starting current and save the energy and also the new intelligent control structure is insensitive to disturbance generated outside or within the system. In addition, Fuzzy logic controller based control strategy shows better results because fuzzy logic overcomes the mathematical difficulties of modeling of highly non-linear systems, the cost and complexity of the controller is reduced and it responds in a more stable fashion to imprecise readings of feedback control parameters, such as dc link current and voltage, its modification is very easy and it is very flexible. In future some optimization technique can be used to optimize the number of rule base used in the Fuzzy logic controller, as time consumed in fuzzyfication and defuzzyfication is depends very much depends on the number of rules, which in turn effect affect the response of the controller.

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AUTHOR'S PROFILE:

B. MEGHYA NAYAK pursuing Ph.D. in JJTU, Rajasthan, received M.Tech in Power and Industrial Drives from JNTU, Hyderabad in 2013 and received B.Tech in Electrical and Electronics Engineering from JNTU Hyderabad in 2009. Currently working as an Assistant Professor and Head of the Electrical Engineering department in AGCE, Satara, Maharashtra. His research interest includes new converter topologies and control of power converters, Model Predictive Control, AI for Power converters and Electrical Drives. Area of interest Electrical Drives, Electrical Machines, Power Electronics, Power Quality.

Dr. Anupama A. Deshpande received here Ph.D. in Control Systems from IIT Bombay in 2006. She received M.E. from Shri Guru Gobindsingh (SGGS) College of Engineering in Nanded, in 1997 and also she received B.E. Electrical from Govt. College of Engineering, Aurangabad in 1967; she was the First Lady Engineer of Marathwada University. She worked in Maharashtra State Electricity Board at Aurangabad and Pune from 2007 to 2015. And also worked as a Principal of Atharva College of Engineering in Mumbai in 2017. At present teaching and guiding Ph.D. scholars of Shri Jagadish Prasad, Jhabarmal Tibrewala University, Jhunjhunu, Rajasthan.