Simulation of Fuzzy Inductance Motor using PI Control Application

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Abstract
Fuzzy control has been widely used in industrial controls, particularly in situations where conventional control design techniques have been difficult to apply. Number of fuzzy rules is very important for real time fuzzy control applications. This study is motivated by the increasing need in the industry to design highly reliable, efficiency and low complexity controllers. The proposed fuzzy controller is constructed by several fuzzy controllers with less fuzzy rules to carry out control tasks. Performances of the proposed fuzzy controller are investigated and compared to those obtained from the conventional fuzzy controller. Fuzzy logic control method has the ability to handle errors in control operation with system nonlinearity and its performance is less affected by system parameter variations.

Key Words: FLC, PI Control, Induction Motor, Torque, Genetic Algorithms

Introduction

An induction motor is a motor that provides power. It owes its name to the way it operates. Alternating current (AC) voltages are induced by the magnetic and rotating field of the stator in the rotor circuit. An induction motor is constructed with elements of copper, steel, and aluminum. While this makes them more expensive than universal motors, it also increases their quality and durability. The construction of an induction motor is almost identical to the construction of a three-phase synchronous motor. An induction motor consists of a rotor that is manufactured from a laminate cylinder with a slotted surface. The windings in these slots can be one of three types: a squirrel-cage winding, a slip ring rotor, or a solid core rotor. A squirrel-cage winding is made of copper bars that span the length of the rotor. They are connected at each end through a ring. The rotor bars are skewed and not straight in order to reduce noise. Slip-ring rotors do not contain the bars found in squirrel-cage rotors. Instead, they contain windings that are connected to slip rings. If the slip rings are shortened, it causes the rotor to behave much in the same way as squirrel-cage rotors. Solid-core rotors induce the current needed to rotate and are made from solid steel. In induction or asynchronous motor is an AC motor in which all electromagnetic energy is transferred by inductive coupling from a primary winding to a secondary winding, the two windings being separated by an air gap. In three-phase induction motors, that are inherently self-starting, energy transfer is usually from the stator to either a wound rotor or a short-circuited squirrel cage rotor. Three-phase cage rotor induction motors are widely used in industrial drives because they are rugged, reliable and economical. Single-phase induction motors are also used extensively for smaller loads. Although most AC motors have long been used in fixed-speed load drive service, they are increasingly being used in variable-frequency drive (VFD) service, variable-torque centrifugal fan, pump and compressor loads being by far the most important energy saving applications for VFD service. Squirrel cage induction motors are most commonly used in both fixed-speed and VFD applications.

Equivalent Circuit

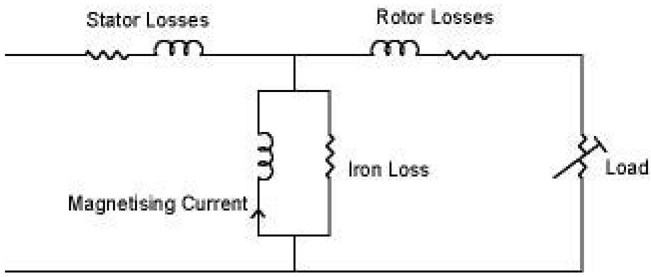

Fig.1 Circuit for Induction Motor

The induction motor can be treated essentially as a transformer for analysis. The induction motor has stator leakage reactance, stator copper loss elements as series components, and iron loss and magnetising inductance as shunt elements. The rotor circuit likewise has rotor leakage reactance, rotor copper loss and shaft power as series elements. The transformer in the centre of the equivalent circuit can be eliminated by adjusting the values of the rotor components in accordance with the effective turn's ratio of the transformer. From the equivalent circuit and a basic knowledge of the operation of the induction motor, it can be seen that the magnetising current component and the iron loss of the motor are voltage dependant, and not load dependant. Additionally, the full voltage starting current of a particular motor is voltage and speed dependant, but not load dependant. The magnetising current varies depending on the design of the motor. For small motors, the magnetising current may be as high as 60%, but for large two pole motors, the magnetising current is more typically 20 - 25%. At the design voltage, the iron is typically near saturation, so the iron loss and magnetising current do not vary linearly with voltage with small increases in voltage resulting in a high increase in magnetising current and iron loss.

Genetic Algorithms

Genetic Algorithms provide an adaptive searching mechanism inspired on Darwin's principle of reproduction and survival of the fittest. The individuals in a population are represented by chromosomes; each of them is associated to a fitness value. The chromosomes are subjected to an evolutionary process which takes several cycles. Basic operations are selection, reproduction, crossover and mutation. Parent selection gives more reproductive chances to the fittest individuals. During crossover some reproduced individuals cross and exchange their genetic characteristics. Mutations may occur in a small percentage and cause a random change in the genetic material, thus contributing to introduce variety in the population. The evolution process guides the genetic algorithm through more promising regions in the search space. Some of the advantages of using genetic algorithms are: it is a global search technique, can be applied to the optimization of ill-structured problems and do not require a precise mathematical formulation for the problem. Besides, genetic algorithms are robust, applicable to a number of problems and efficient, in the sense that either a suboptimal or optimal solution may be found within reasonable time.

Fuzzy Logic Control

Fuzzy Logic Control system blocks are shown in Fig.2 .Fuzzy Logic Controller is a technique is similar to human-like thinking into a control system. A fuzzy controller can be designed to follow human deductive thinking, that is, the process people use to suppose conclusions from what they know. Fuzzy logic has met a growing interest in many motor control applications due to its non-linearity's handling features and independence of the plant modelling. The Fuzzy Logic Controller (FLC) operates in a knowledge-based way, and its knowledge relies on a set of linguistic if-then rules, like a human operator. With Fuzzy Logic the first step is to understand and characterize the system behaviour by using our knowledge and experience. The second step is to directly design the control algorithm using fuzzy rules, which describe the principles of the controller's regulation in terms of the relationship between its inputs and outputs. The last step is to simulate and debug the design. If the performance is not satisfactory we only need to modify some fuzzy rules and re-try. Fuzzy Logic control mainly applied to the control of processes through fuzzy linguistic.

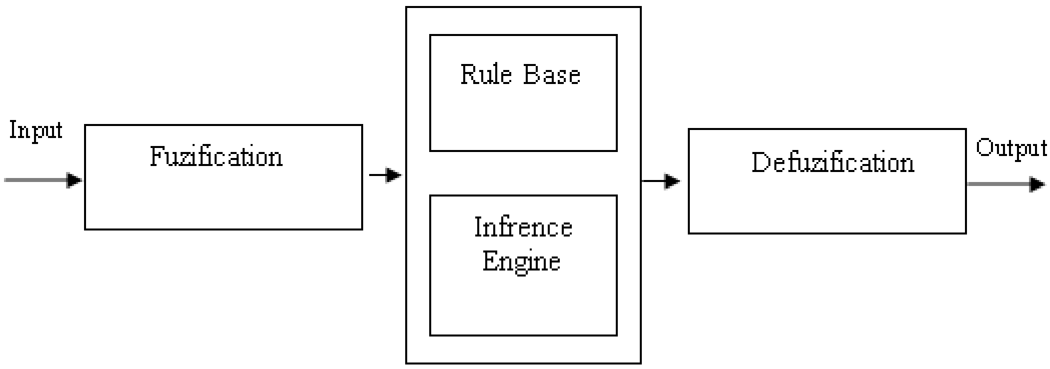

Fig.2: Fuzzy Logic Control system

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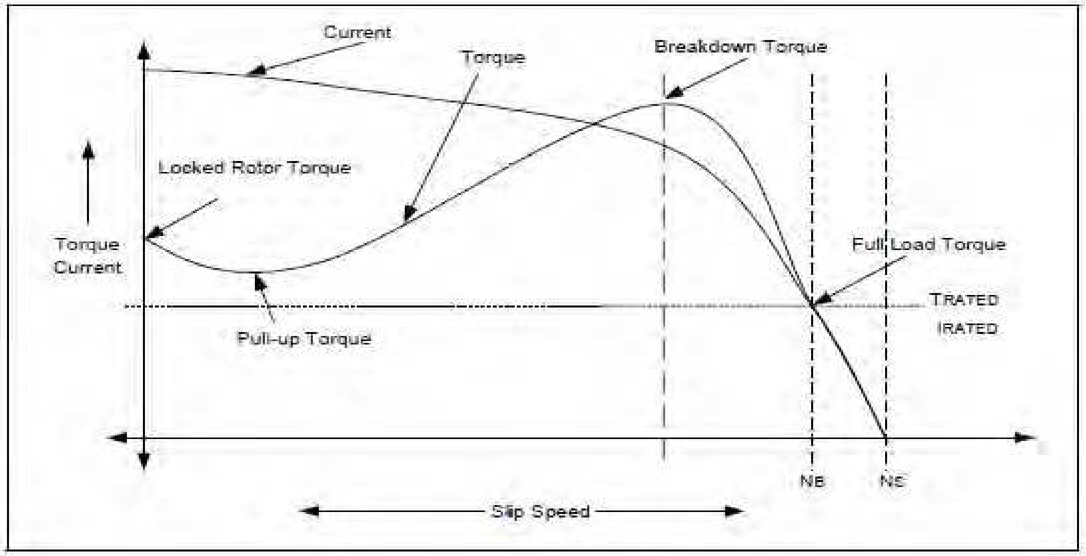

Fig 3. Speed vs Torque

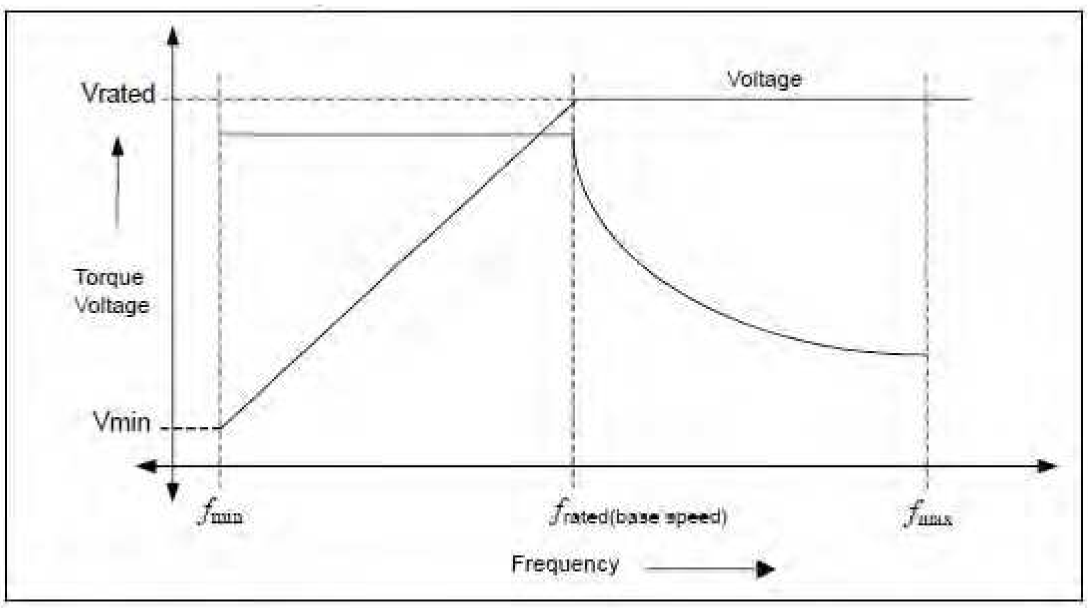

Fig 4. Frequency VS Torque Voltage

Fig 3. Shows the typical speed-torque characteristics of an induction motor. The induction motor's speed- toque characteristic states that the induction motor draws rated current and delivers the rated torque at the base speed. The relation of Induction motor is given below. Stator Voltage (V) $\propto$ Stator Flux (φ) x Angular Velocity (ω)

$$\mathbf{V \propto \varphi \times 2\pi f}$$
$$\mathbf{\Phi \propto V/f}$$

This makes constant V/f the most common speed control of an induction motor. Fig.3. shows the relation between the voltage and torque versus frequency. As shown in fig.4. at low frequencies and at low voltages the drop across the stator impedance prevents sufficient voltage availability. Therefore, to maintain sufficient torque at low frequencies, a voltage more than proportional needs to be given at low speeds.

Fuzzy PI Control

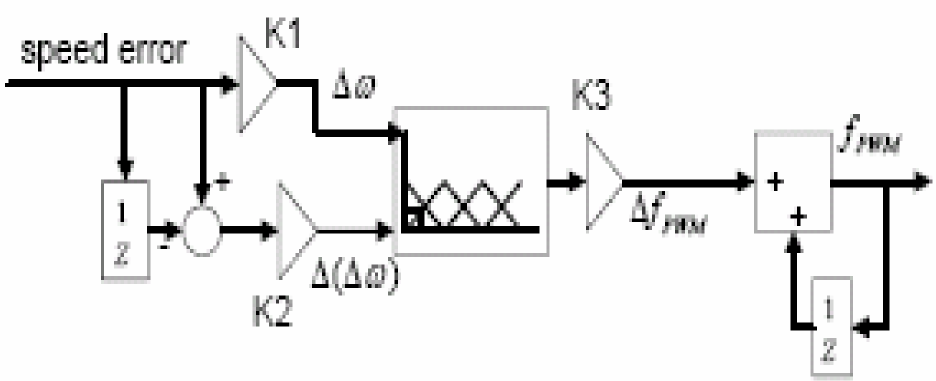

Fig.5 PI Fuzzy Control

Every training data set produces a corresponding fuzzy rule that is stored in the fuzzy rule base. Therefore, as each input output data pair is processed, rules are generated. A fuzzy rule or knowledge base is in the form of two dimensional table, which can be looked up by the fuzzy reasoning mechanism. Speed error is calculated with comparison between reference speed and speed signal feedback. Speed error and speed error changing are fuzzy controller inputs. Input variables are normalized with a range of membership functions specified and the normalization factors are named as K1 and K2. Suitable normalization has direct influence in algorithm optimality and faster response in Fig. 5.

Rule Base for Controlling Speed

		Speed Error						
		NL	NM	NS	ZZ	PS	PM	PL
Speed Error Vari Ation	NL	NL	NL	NL	NM	NM	NS	ZZ
	NM	NL	NM	NM	NS	NS	ZZ	PS
	NS	NM	NM	NS	NS	ZZ	PS	PS
	ZZ	NM	NS	NS	ZZ	PS	PS	PM
	PS	NS	NS	ZZ	PS	PS	PM	PM
	PM	NS	ZZ	PS	PS	PM	PM	PL
	PL	ZZ	PS	PM	PM	PL	PL	PL

Table.1 Speed Error Variation Vs Speed Error

The array implementation improves execution speed, as the run-time inference is reduced to a table look-up which is a lot faster, at least when the correct entry can be found without too much searching. A typical application area for the table based controller is where the inputs to the controller are the error and the change in error. The controller can be embedded in a larger system, a car for instance, where the table is downloaded to a table look-up mechanism. The fuzzy logic controller operation is based on the control operation shown in Table I. Total 49 rules are generated as shown in fuzzy control system data base. It should be noted that result reflect a similar performance. Therefore, in order to evaluate with precise numbers, mean relative error and standard deviation (STD) with respect to reference speed were calculated, as illustrated in Table V with the ramp reference, the fuzzy controller shows less error than the PID controller.

Result and Conclusion:

Fuzzy logic is a technique to embody human like thinking into a control system A fuzzy controller can be designed to emulate human detective thinking that is the process people use to infer conclusions from what they know. Fuzzy control has been primarily applied to the control process through fuzzy linguistic descriptions. The proposed speed controller gives maximum torque over the entire speed range. In the steady state the efficiency of the induction motor is increased. According to this the PID and PI gains were adjusted to the best performance in step-up and step-down reference. The PI controller gain parameters were adjusted and they produce good performance in both PI and PID controllers is shown fig.6. The load torque is applied to the induction motor rotor shaft varies from approximately 2.2NM when the speed is 800rpm to 3.9NM at 1800rpm.

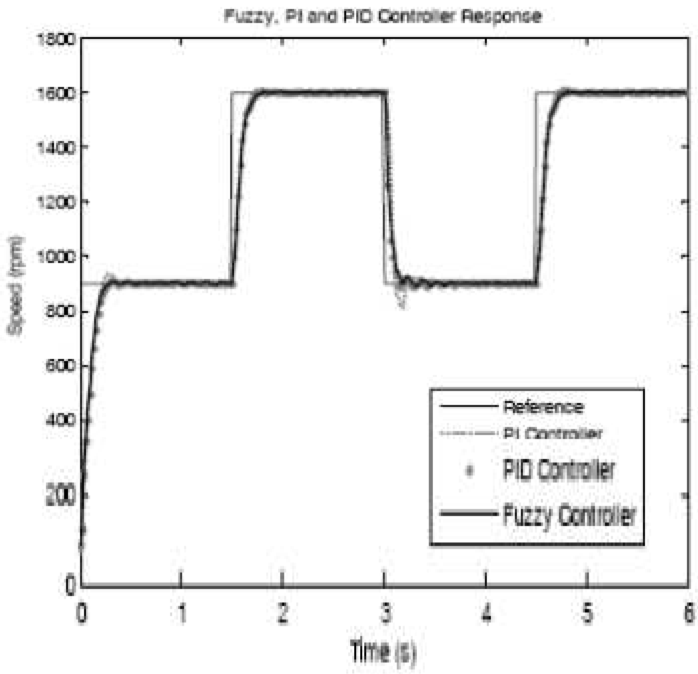

Fig.6 .Fuzzt PI and PID controller Process

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