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Indirect Vector Control of Induction motor using Fuzzy Logic Controller

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ABSTRACT: *AC motors are widely used in industries for motion control systems. The advantages of using induction motor over dc motor are rugged construction, high efficiency and maintenance free operation. For electrical drives good dynamic performance is mandatory so as to respond to the changes in command speed and torque. These requirements of AC drives can be fulfilled by the vector control system. With the advent of the vector control method, an induction motor has been controlled like a separately excited DC motor for high performance applications. This method enables the control of field and torque of induction motor independently (decoupling) by manipulating corresponding field oriented quantities. Conventional PI controller regulates the speed and flux value depending upon the given reference. In the outer speed loop of the indirect vector control, the PI controller is used to generate the torque command so as to regulate the actual speed same as the reference speed. This is a simple controller and gives stable operation of motor when tuned properly. But unexpected load changes and environmental conditions cause overshoot, oscillations in motor speed, oscillations of torque, long settling time and thus the deterioration of motor performance. These off line tuned controllers are difficult in dealing because of the continuous motor parameter variation and non-linearity present in the entire system. This problem can be overcome using on line gain adaptive controllers. The fuzzy based intelligent controller can be implemented in place of PI controller. There is some advantage of fuzzy logic controller as compared to conventional PI, PID and adaptive controller such as it does not require any mathematical model, it is based on linguistic rule which is the basis of the human logic. When fuzzy logic based intelligent controller is used instead of PI controller, excellent control performance is achieved even in the presence of parameter variation and drive non-linearity.*

Keywords -*Vector control, Induction motor, Fuzzy logic controller, speed control and space vector PWM.*

I. INTRODUCTION

The induction motor is the most widely used rotating machine in industries with very wide power ranges from fractional HP to a few megawatts. V/f control method can control the speed in wide range with full load torque capability even at the lower speed. This causes high energy savings [1].But it is disadvantageous when the transient response is considered. During the speed transition or change in loading there is change in flux which is responsible for poor transient response. The change in flux is recovered in sluggish manner. This leads to over-current and over-heating during transient period. It means motor has to be oversized which is not cost effective [2]. The cause of deviation of the flux from the reference value is inherent coupling between flux and torque. They can be decoupled and controlled independently to obtain high transient response. This method of decoupling and controlling the flux and torque components is known as the vector control method. The basic working principle of vector control method is to split stator current into flux and torque producing component by transforming it into synchronously rotating frame of reference. The change in frame of reference causes the current to appear stationary which simplifies the control circuitry [3].

There are two types of vector control methods; direct and indirect field oriented control. In direct vector control method the rotor flux is estimated either by using flux sensor in the air gap or estimating it by sensing stator voltages. In indirect vector control the rotor flux is estimated using field oriented control equations which need instantaneous speed information. The direct vector control is very difficult to implement practically for low speed application. The indirect field oriented control is preferred over direct vector control because of more accuracy over a whole speed range. Generally, the fixed gain PI controllers are used for generating torque and flux components from speed and flux errors. It is simple and gives stable operation in wide speed range. However, unexpected change in load conditions or environmental factors would produce overshoot, oscillation of motor speed, oscillation of the torque, long settling time and thus causes deterioration of the drive performance. Also the accurate tuning of PI controllers demand the accurate mathematical model of system, otherwise it takes time. The fuzzy logic controller can replace the PI controller. It involves some advantages like improvement in transient response, more stability and simplicity in design. Mathematical modeling of the induction motor is complex, difficult and requires provision for continuously varying induction motor parameters [4]. The Fuzzy logic controller does not demand any mathematical model and it embodies human like thinking [5]. In the given paper, working of the IFOC with fuzzy controller has been explained and the superiority of the Fuzzy controller is validated over PI controller using MATLAB simulink[2].

II. INDIRECT VECTOR CONTROL OF INDUCTION MOTOR

2.1Fuzzy logic

Fuzzy logic is a way of reasoning with uncertainty to obtain the control signal. Fuzzy logic is based on the Fuzzy logic set theory which contains variables having degree of membership from 0 to 1. It is a different approach from the conventional way as in classical (conventional) set theory variable has value either 0 or 1 (IEC). Human logic thinking does not confine to crisp “yes/no” but it is vague, imprecise and fuzzy [3]. This vagueness and impreciseness can be added in the controller through fuzzy logic. Such controller is known as an intelligent controller [6][3].

Fuzzy system consists of the following five steps [6][7]:

2.1.1 Fuzzification of input variables

In this step actual physical variables are converted into degree of membership of membership functions of fuzzy variables.

2.1.2 Application of Fuzzy operator in the antecedent part of the rule

If there are multiple input variables then multiple antecedents have to be resolved into one value using fuzzy operator. When AND or minimum operator is used, the antecedent with minimum value is selected. On the other hand if OR or maximum operation is used then antecedent with maximum value is selected. The selected value is known as degree of fulfillment.

2.1.3 Implication from antecedent to consequent

If and then rules are formed between antecedent and consequent based on the knowledge and experience of the operator. The consequent part is calculated based on the antecedent and rules. This consequent part is further modified depending on the degree of fulfillment. In mamdani method membership function of the consequent is truncated at the height of value corresponding to degree of fulfillment.

2.1.4 Aggregation of the consequent

All the consequents are combined together in the accumulative manner to get the final fuzzy output.

2.1.5 Defuzzification

The resultant fuzzy output is defuzzified to get output in actual physical form. There are various methods for defuzzification but generally centre of gravity method is utilized.

2.2Fuzzy logic in Vector Control

The block diagram of Vector control using fuzzy logic controller is shown below in Fig. 2 The fuzzy controller observes the pattern of the speed error and the flux error and correspondingly updates the outputΔi_{qs}^{*} and Δi_{ds}^{*}.This regulates the flux and speed at the reference value. The advantage of using fuzzy controller is the improvement in the performance of the motor. This regulates the flux and speed at the reference value. The advantage of using fuzzy controller is the improvement in the performance of the motor. No overshoot and oscillations occurs in torque and flux value. The response of speed is faster and smoother. The design and implementation of this controller does not demand the mathematical modeling of the system.It gives robust performance even in the presence of unexpected load changes and motor parameter variation [4][3].

The fuzzy logic controller in the vector control has two inputs. The first is error and the other is rate of change of speed or flux error. Triangular and trapezoidal membership functions are used.

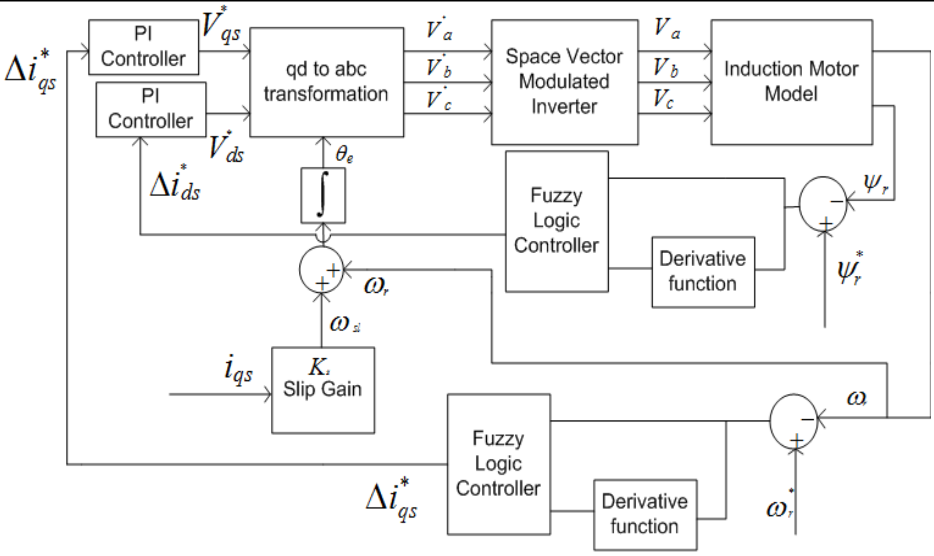

Fig. 1 Block diagram of indirect vector control with Fuzzy logic controllers

There are 6 fuzzy variables that are NB, NM, NS, Z, PS, PM and PB in the error and rate of change of error membership function plot. There are additional two membership functions which are NVB and PVB in the output membership function plot [4].

These all are the linguistic variables which have general meaning.

NVB=Negative very big, NB= Negative big, NM= Negative medium, NS= Negative small, Z= zero, PB= positive big, PS= Positive small, PM= Positive medium, PVB= Positive very big.

As there are fuzzy sets of 7 fuzzy variables in each error and rate of change of error membership function, 49 possible combinations are possible. For each combination there is a rule which decides the output fuzzy variable for that particular combination. These rules are based on the experience of the operator.

III. MATLAB SIMULATION OF INDIRECT VECTOR CONTROLLED DRIVE

The simulation was performed on 5.4 HP, 415 V, 50 Hz delta connected Induction Motor. The three phase AC supply is rectified and used as an input DC voltage for the three phase inverter. The speed controller generates the torque producing current component and flux controller produces the flux producing current component with the help of either PI or Fuzzy based controller.

These components are passed through the PI controllers to produce the reference voltage command. The rated speed command is applied at the starting with acceleration rate of 900 rpm/sec with the motor fully loaded. The response of motor torque, speed and flux is observed. Fig 3 shows the speed response with PI and Fuzzy controller respectively. The speed is tracking reference speed in both the cases. Fig 4 and Fig 5 shows the response of the torque and flux with PI and Fuzzy controller respectively. It can be seen that with Fuzzy controller there is no overshoot in the torque and peak to peak ripple is less. The flux is regulated tightly around the reference value and no overshoot occurs when fuzzy logic controller is used. The response with PI controllers has inherent overshoots and oscillation when transients occur. The simulation results validate the superiority of Fuzzy Controller over PI controller in Vector Control operation.

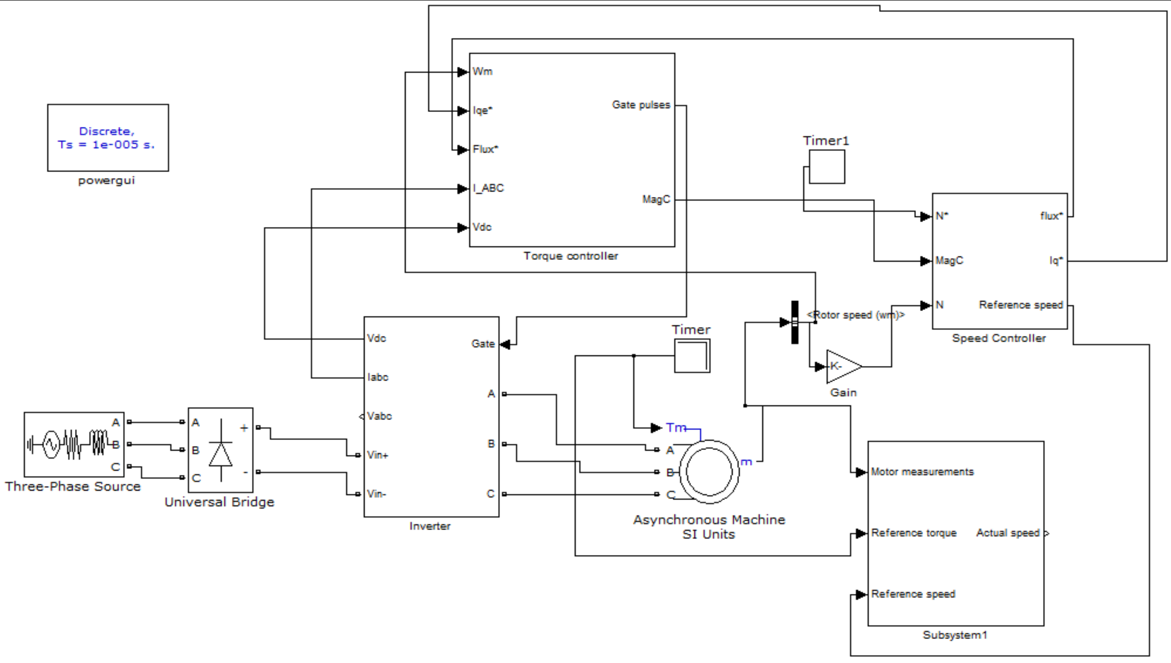

Fig. 2Matlab simulation diagram of Indirect Vector control drive

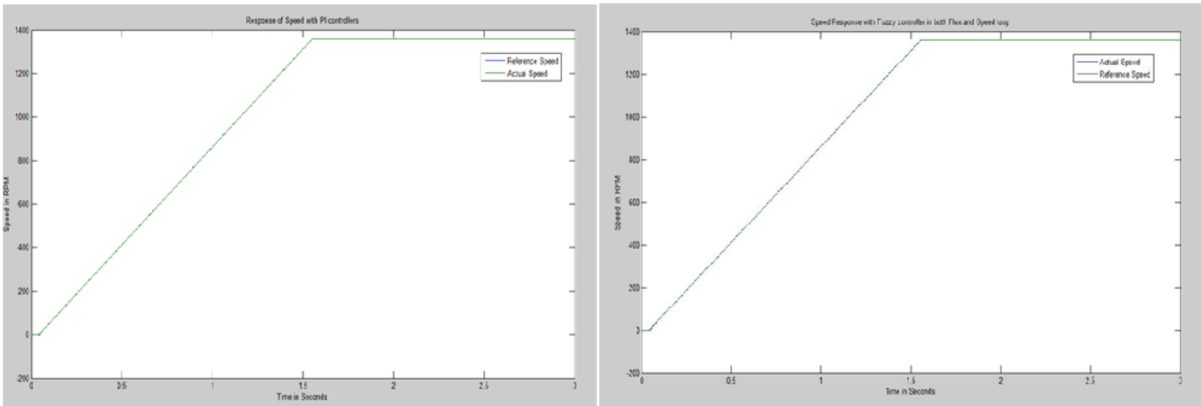

Fig. 3 Speed with PI and Fuzzy logic controller

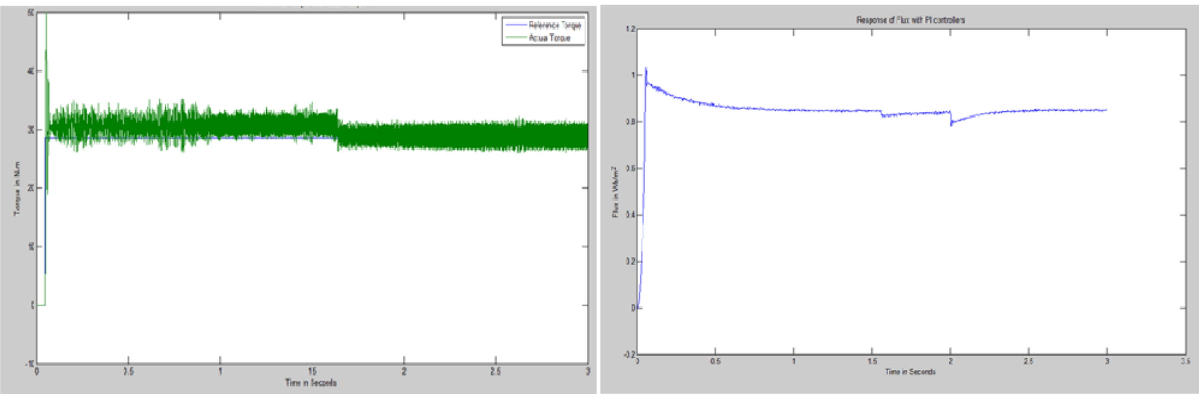

Fig. 4 Torque and flux with PI controller

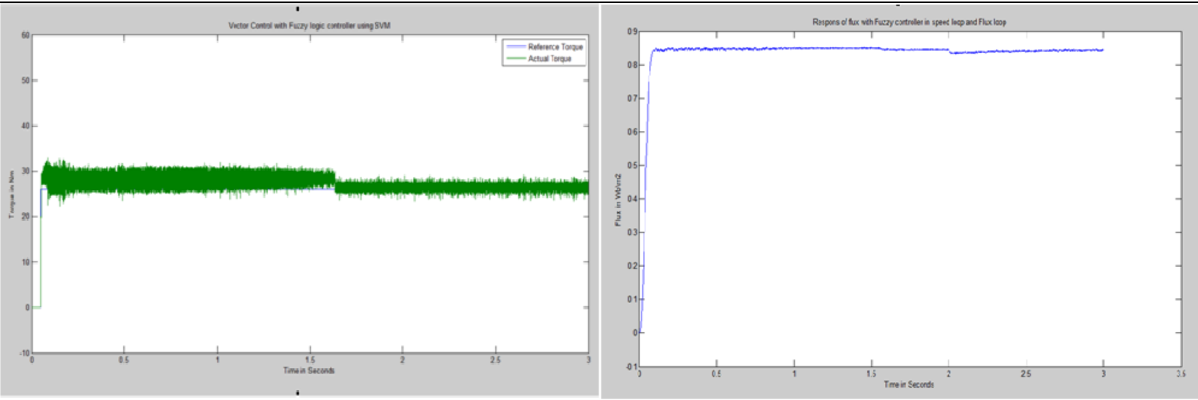

Fig. 5 Torque and flux with Fuzzy logic controller

IV. CONCLUSION

The Induction motor performance is analyzed with Indirect Vector Control method using PI and Fuzzy Controllers in MATLAB simulink. The simulated result shows the better dynamic performance with Fuzzy Controller as compared to PI controllers. The overshoot and large pulsations in the torque are observed with PI controller which results in oscillations in speed and long settling time. Fuzzy logic controller based drive has no overshoot in torque and it shows reduction in torque ripple. It gives robust performance in the presence of induction motor parameter variation and sudden load changes, but PI controller based drive causes coupling between torque and flux when parameter variations are occurred. The fuzzy logic controller can respond similar to the expertise operator, hence it is known intelligent controller. It is simple to implement and once designed it can be easily placed and modified in different applications.

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