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Perfect Speed Tracking of Direct Torque Controlled-Induction Motor Drive Using Fuzzy Logic

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ABSTRACT

The paper entitled "Perfect Speed Tracking of Direct Torque Controlled-Induction Motor Drive Using fuzzy logic" by T.S. Radwan will be validated. In this project, a simple perfect speed tracking of direct torque controlled induction motor drive using fuzzy logic is proposed. The fuzzy logic controller (FLC) solves the problem of non linearities and parameter variation of induction motor. Unlike the conventional standard fuzzy logic controllers, the proposed controller has much less computationally demanding. Direct torque control scheme of induction motor is first introduced. Then, the specified rule and their membership functions of proposed fuzzy system will be represented. The performance of proposed controller will be evaluated under various operating conditions. A simplified FLC with relatively fewer rules will be implemented for perfect speed tracking.

Keywords: **Direct torque control (DTC), Induction motor drive(IMD), Fuzzy logic control (FLC)**

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I. INTRODUCTION

The most commonly encountered electric motors in industry are induction motors. In recent years the control of high-performance induction motor drives has received widespread research interests. It has been valued more not only because it is the most used motor in industries but also due to their varied modes of operation. It has good self-starting capability, simple, rugged structure, low cost and reliability etc. Induction motors have been used in past mainly in applications requiring a constant speed. It has attracted the attention because such machine are made and used in largest numbers and also due to their varied mode of operation both under steady state and dynamic states. Induction motor finds its place amongst more than 85% of industrial motor drives and as well as single phase form in various domestic usages. Direct Torque Control is the first control method that controls IGBT inverter and motor as a complete system. An ordinary PWM drive simulates power network by adjusting motors static operation point and flux vector drive more or less emulates DC drive. In DTC both inverter and motor are controlled together. All delay making parts have been removed, as modulator. The core of the system is the Direct Torque Comparator and Flux Comparator block with the optimal switching logic. The accurate adaptive motor model is also a very essential part of the DTC. Motor model estimates the actual torque, stator flux and shaft speed by means of measurements obtain two motor phase currents and intermediate circuit dc voltage. Also different models can be used Torque and flux references are compared with the actual values and control signals are produced by using a two-level hysteresis control method in recent years the control of high-performance induction motor drives has received widespread research interests. It has been valued more not only because it is the most used motor in industries but also due to their varied modes of operation. Also it has good self-starting capability, simple, rugged structure, low cost and reliability etc.

Main property that makes it more useful for industries is its low sensibility to disturbance and maintenance free operation. Despite of many advantages of induction motor there are some disadvantages also. Like it is not true constant speed motor, slip varies from less than 1% to more than 5%. Also it is not capable of providing variable speed operation. But as it is so useful for industries we have to find some solution to solve these limitations and the solution is speed controller that can take necessary control action to provide the required speed. Not only speed, it can control various parameters of The induction machine such as flux, torque, voltage, stator current. Out of the several methods of speed control of an induction such as changing no of pole, rotor resistance control, stator voltage control, slip power recovery scheme and constant V/f control, the closed loop constant V/f speed control method is most popular method used for controlling speed. In this method, the V/f ratio is kept constant which in turn maintains the magnetizing flux constant that eliminates harmonic problem and also the maximum torque also does not change. So, it’s a kind of complete utilization of the motor. And the controller used are conventional P-I controller, and fuzzy logic controller.

II. PREVIOUS WORK

This thesis paper portrays the way of implementing fuzzy logic in improving the performance of induction motor drive. Here a rule-based fuzzy logic based controller is designed and simulated with the help of MATLAB. A PI controller is also designed in SIMULINK. Then performances of both the controller are simulated and compared. For controlling speed here scalar control method is employed, where magnitude of the stator voltage and frequency is changed proportionately. For this V/F control, a reference speed is chosen and controller is designed as such, it can provide that desired (reference) speed in case of frequent load changes. The major merit of Fuzzy controller over PI controller is use of linguistic variable and user defined rule base that makes it possible to incorporate human intelligence in the controller. Fuzzy logic based controller also has the capability to control both linear and nonlinear system. Inputs given to the fuzzy logic based controller are speed error (e) and change in speed error (Δe). And output is the change of control (ω), which is the frequency correction. So the inputs error and change in error are processed according to the rule base, which is user defined and output correction is provided to the inverter. The membership functions and the rules are defined in FIS editor window. Based on rules, control surface is also generated. The system or model for speed controlling of induction drive is simulated both with PI and Fuzzy controller and results are analysed and compared and Fuzzy controller is found to perform better than the conventional PI controller.

III. ALGORITHM USED

The general algorithm for a fuzzy system designer can be synthesized as follows:

A) Fuzzificatin

(a) Normalize of the universes of discourses for the fuzzy input and output vector.

(b) Convert crisp data into fuzzy data or membership function.

(c) Calculate the membership function for every crisp value of the fuzzy input.

B)Fuzzy Inference

d) Combine membership function with the rule to drive the fuzzy output.

(e) Calcution of the membership function for every crisp value of the fuzzy input.

C) Defuzzificatin

(f) Calculate the fuzzy output, using suitable defuzzification method.

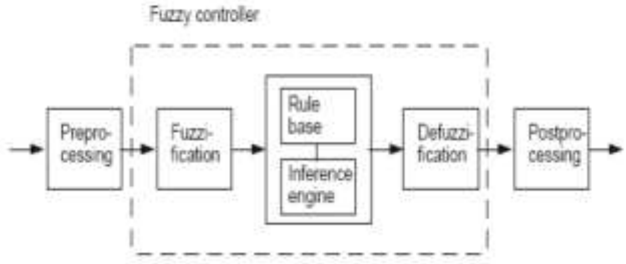

Figure 1. . Process blocks of a fuzzy controller

(A) Fuzzy membership function A membership function for a fuzzy set A on the universe of discourse X is defined as μA: X → [0,1], where each element of X is mapped to a value between 0 and 1.This value, called membership value or degree of membership, quantifies the grade of membership of the element in X to the fuzzy set A.

(B) Types of inference system **Mamdani-Type Fuzzy Inference-** is defined for the toolbox, expects the output membership functions to be fuzzy sets.

After the aggregation process, there is a fuzzy set for each output variable that needs defuzzification. **Sugeno-Type Fuzzy Inference-** This topic discusses the so-called Sugeno, or Takagi-Sugeno-Kang, method of fuzzy inference. Introduced in 1985, it is similar to the Mamdani method in manyrespects. The first two parts of the fuzzy inference process, fuzzifying the inputs and applying the fuzzy operator, are exactly the same. The main difference between Mamdani and Sugeno is that the Sugeno output membership functions are either linear or constant.

(C) Fuzzy rules for developing fis Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made, or patterns discerned. The process of fuzzy inference involves all of the pieces that are described in the previous sections: Membership Functions, Logical Operations, and If- Then Rules.

2. System design with FLC: The membership functions should be chosen such that they cover the whole universe of discourse.Now the algorithm is implemented in matlab with a seven Member fuzzy inference system used for the input parameters, that is, error and change in error and also for the output. A Mamdani-type fuzzy inference approach is utilized. The set up is as shown in fig.2 Table 1 is of Fuzzy Sets and mfs for Input Variable Speed Error (e). Table 2 is of Fuzzy Sets and mfs for Input Variable Change in Error (Δe) The membership function is displayed in fig. 3.

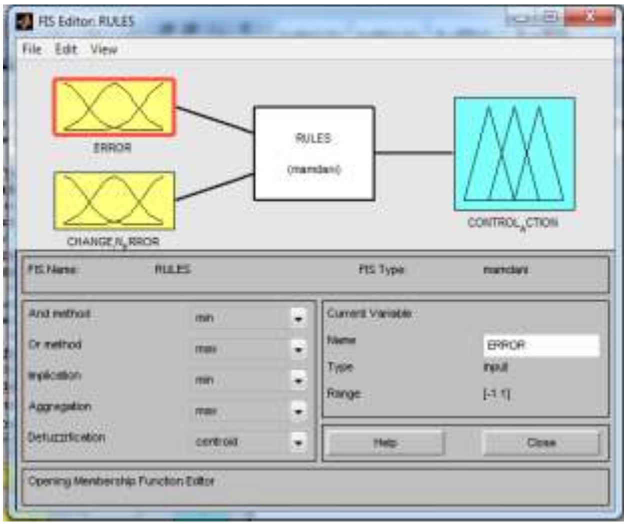

Figure2.Selection of number of I/O for designing FIS for FLC

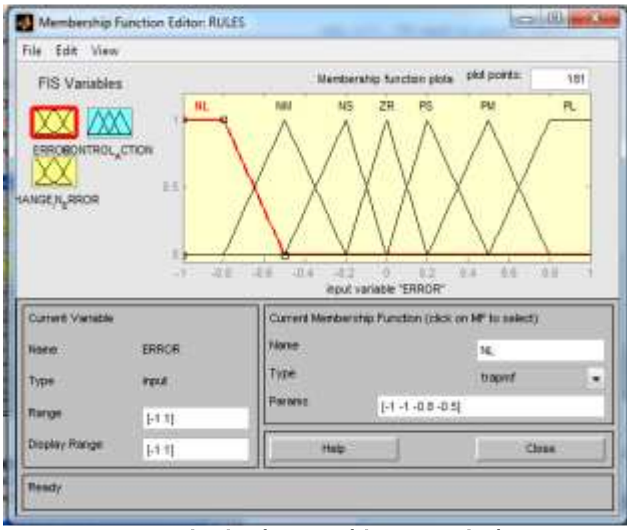

Fig.3: Membership function of the input to the fuzzy logic controller

Fuzzy set or label	Set Description	Range	Membersihp Function
NL (Negative Large)	Speed error is high in the negative direction.	-1.0 to -1.0 -1.0 to -0.8 -0.8 to -0.5	Trapezoidal
NM (Negative Medium)	Speed error is medium in the negative direction.	-0.8 to -0.5 -0.5 to -0.2	Triangular
NS (Negative Small)	Speed error is small in the negative direction.	-0.5 to -0.2 -0.2 to 0	Triangular
ZE (Zero)	Speed error is around zero.	-0.2 to 0 0 to 0.2	Triangular
PS (Positive Small)	Speed error is small in the positive direction.	0 to 0.2 0.2 to 0.5	Triangular
PM (Positive Medium)	Speed error is medium in the positive direction.	0.2 to 0.5 0.5 to 0.8	Triangular
PL (Positive Large)	Speed error is high in the positive direction.	0.5 to 0.8 0.8 to 1.0 1.0 to 1.0	Trapezoidal

Table 1. Fuzzy sets and the respective membership functions for speed error (e)

Fuzzy set or label	Set Description	Range	Membersihp Function
NL (Negative Large)	Speed error is high in the negative direction.	-1.0 to -1.0 -1.0 to -0.8 -0.8 to -0.5	Trapezoidal
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NS (Negative Small)	Speed error is small in the negative direction.	-0.5 to -0.2 -0.2 to 0	Triangular
ZE (Zero)	Speed error is around zero.	-0.2 to 0 0 to 0.2	Triangular
PS (Positive Small)	Speed error is small in the positive direction.	0 to 0.2 0.2 to 0.5	Triangular
PM (Positive Medium)	Speed error is medium in the positive direction.	0.2 to 0.5 0.5 to 0.8	Triangular
PL (Positive Large)	Speed error is high in the positive direction.	0.5 to 0.8 0.8 to 1.0 1.0 to 1.0	Trapezoidal

Table 2. Fuzzy sets and the respective membership functions for Change in Error (Δe)

IV. PROPOSED DESIGN

The system block diagram is shown in Figure 1. It consists of Hall Effect speed sensor to sense motor speed in rpm,a microcontroller for controlling systems activities, a LCD for local real-time display of the speed of motor.

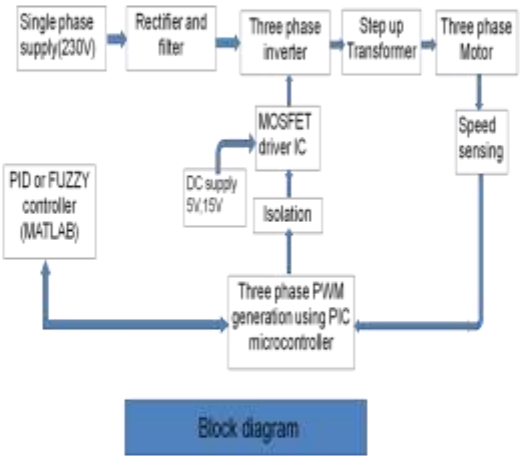

Figure4. System block diagram

The design of various hardware components to implement the three phase induction motor control drive using PIC 16f877a microcontroller is explained as follows. It includes inverter design, gate drive circuit, isolation and microcontroller for the proposed work. Figure 1 show the block diagram of the proposed drive, which consists of various blocks which are as follows

- Microcontroller.
- Isolator.
- MOSFET Driver.
- Rectifier.
- Voltage Source Inverter.
- Speed sensing.
- Step-up transformer.
- Serial communication to matlab.
- For FUZZY implementation

the operation of the inverter, variable frequencies are generated by the microcontroller and applied to voltage source inverter through gate drive circuit. The frequency for operation is read by Serial UART terminal form matlab. The gate drive circuit is consists of opto-isolator to provide isolation for microcontroller and the other gate drive circuitry, which is work on low voltage from the high power circuit side.The basic three phase voltage source inverter consists of six power MOSFETs with built in anti parallel diodes. The IRFP–460 N-CHANNEL MOSFET is semiconductor device which works as a switch. It operates at highest possible turn-ON and turn-OFF speeds,extremely high dv/dt capability and maintaining the most accurate operation of the inverter.

AC voltage from the power grid is rectified using the power bridge and capacitor is used as a filter, the output of filter gives pure DC to the three phase inverter as DC source. Depending upon the frequency generated by microcontroller, the power supplied to the motor is varied. Hall effect sensor used to measure the speed of motor using external interrupt and in build timer feature of a PIC microcontroller this measured speed send to matlab through UART feature of microcontroller also 16*2 LCD is interfaced to show actual speed of motor which is sensed by hall effect sensor

V. OBJECTIVE OF PROPOSED

The main objective of the project is to design and develop a Fuzzy Logic based Controller which can take necessary control action to provide the desired speed. The control method used here is scalar control method where magnitude of the stator voltage and frequency is changed proportionally to keep the main flux constant.

VI. CONCLUSION

This project investigates experimentally and matches in simulation the occurrence of the fuzzy controller controlled drive is providing better results in improving the performance of the induction motor than PI controller. Whenever the machine is loaded, the speed of the machine fell to some extent but this fall in speed is very less in case of fuzzy controlled drive. So we can say that overshoot is more in case of PI controller. And overall we can say that Fuzzy controller is proving better result than PI controller

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