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Research Article / Araştırma Makalesi

FUZZY LOGIC BASED INDIRECT VECTOR CONTROL OF SQUIRREL CAGE INDUCTION MOTOR

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ABSTRACT

Squirrel cage induction motors are widely used in industry. These induction motors need smart control applications for high performance. In this paper an indirect vector control of squirrel cage induction motor is modelled mathematically. The mathematical model is moved to simulation using Matlab/Simulink software. For improvement, the indirect vector control simulation is based on fuzzy logic. Eventually, the simulation results for fuzzy logic speed control of induction motor are obtained for different reference speeds. The results showed effectiveness of fuzzy control system for indirect vector control of squirrel cage induction motor simulation model.
Keywords: Squirrel cage, induction motor, indirect vector control, fuzzy logic.

1. INTRODUCTION

Induction motors are used in many areas of industry. For example industrial tapes, paper mills, water pumps, fixed speed construction machines, washing machines and three-phase turning machines. Induction motors are located in constant speed motors because of having small difference between operating at load speed and no load speed. So, we can say that with load, induction motor's speed varies very little. And this little speed is negligible. Induction motors are classified according to the rotor structure, operating modes and number of phases. Mostly used induction motor type manufactured from a few watts up to 300 MW is squirrel cage induction motor [1].

Squirrel cage motors are the easiest to manufacture, most durable, high operating reliability, low maintenance and the most commonly used types of electrical motors. In these motors, silicon sheets are cut and packed in mold presses. Then molten aluminum is poured into the channel. Thus, the rotor is obtained. There are three-phase alternating current windings on the stator. These

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windings are arranged accordingly. We can produce an induction motor having a number of poles we want.

In recent years, induction motors are being produced by all major manufacturers and we see that high-efficiency induction motors are ever-increasing at share of the motors market.

There are some techniques are used to improve the efficiency of induction motors. These techniques are [2]:

- To reduce copper losses, more copper is used in the stator windings.
- To reduce the magnetic flux density on the air gap the rotor, stator core length is increased.
- To a greater amount of heat transfer out of the motor and to reduce operating temperature more steel is used in the stator.
- For lower hysteresis losses the steel used in the stator which is special high-grade electrical steel.
- To reduce the eddy current losses in the induction motor that the steel has a very high internal resistivity and steel is made of an especially thin gauge.
- To reduce the stray load losses the rotor is carefully machined for a uniform air gap.

2. INDIRECT VECTOR CONTROL

Variable-speed drive systems for the control of induction motors are methods based on the change of the stator voltage and frequency. These can be divided into three main parts;

• Scalar Control
• Vector control
• Direct Torque Control

Vector control methods are two types. These are direct and indirect vector control. In general indirect vector control is preferred over direct vector control. For low speed applications direct vector control is difficult to implement practically and indirect vector control is more accuracy over all speed range. In indirect vector control for instantaneous speed information, the rotor flux is estimated using field oriented control equations. To generate torque and flux components from speed and flux errors, a fixed gain PI controller is used [3], [4], [5], [6].

In synchronous motors, vector control is easier than induction motors .Because the field in the rotor circuit is fed separately and independently adjustable. Rotor flux is constant and does not change with the appropriate field speed.

When compared with the scalar control, the vector control has some advantages. These advantages are; having better torque response, precising speed control and proximity to DC driving. The disadvantage of vector control method is more expensive than scalar control, because of the feedback elements.

Induction motor's dynamic model is derived by transforming the three phase quantities into two phase direct and quadrature axes quantities. The three-phase and two-phase equivalence model is derived from the concept of power invariance. In figure 1, uniform air gap of induction motor with sinusoidal distribution mmf is taking into account. It is neglected the saturation effect and parameter changes [7].

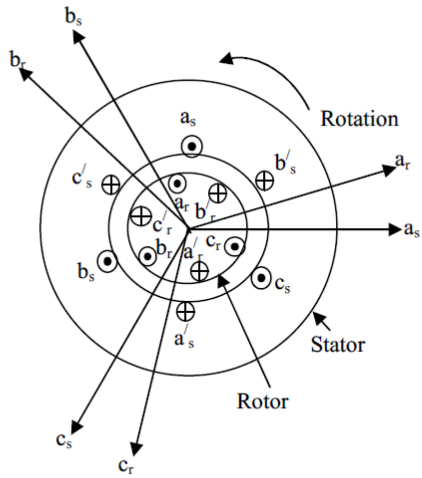


Figure 1. Mmf distribution in induction motor [4].

Vector control, such as free-excited DC motors, allows controlling induction motors in high-performance. Synchronously rotating reference on the roof, the induction motor has been likened DC motor. By using synchronous reference frame, the induction motor can be control as DC motor. Here, i_{ds} and i_{qs} are two induction motor control components. The i_{qs} generates torque, the i_{ds} generates field. Figure 2 gives a phase diagram of the indirect vector control [8].

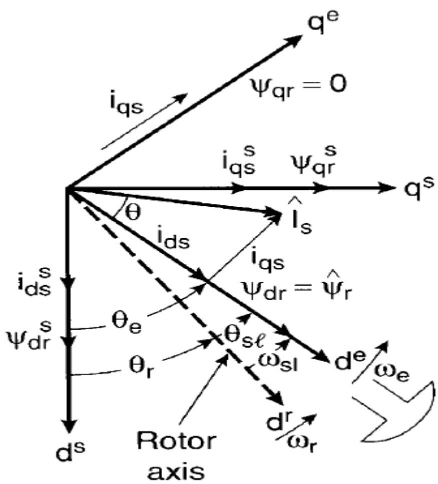


Figure 2. Phase diagram of indirect vector control[4].

3. FUZZY LOGIC CONTROLLER

Fuzzy logic or fuzzy set theory was put forward in 1965 by Lotfi A. Zadeh. Today, the fuzzy logic controllers are applied successfully in many areas [9]. A fuzzy logic controller structure consists of four main units. As shown in figure 3, the units are; fuzzification, fuzzy rule base, fuzzy inference and defuzzification unit [10].

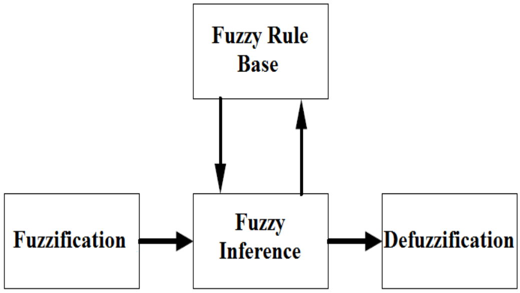


Figure 3. The basic structure of fuzzy logic controller

The rule base is defined by experts. The rule base contains the rules that determine the fuzzy logic control system behavior. In this study, total of 49 rules are defined, shown in Table 1.

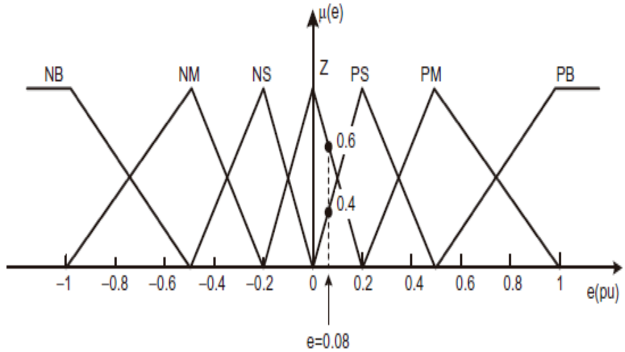
Table 1. Rule base matrix for fuzzy logic speed control [8].

du(pu)

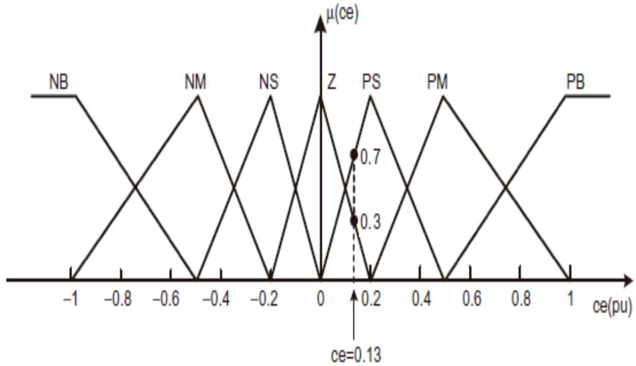
ce(pu) \ e(pu)	NB	NM	NS	Z	PS	PM	PB
NB	NVB	NVB	NVB	NB	NM	NS	Z
NM	NVB	NVB	NB	NM	NS	Z	PS
NS	NVB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PVB
PM	NS	Z	PS	PM	PB	PVB	PVB
PB	Z	PS	PM	PB	PVB	PVB	PVB

Fuzzification is the process of converting input information from the system to the symbolic value of linguistic variables. In this study, for error membership function, for change in error membership function and for change in output membership function nine linguistic variables are used. These are NB, NM, NS, Z, PS, PM PB, NVB and PVB. In order to make the system works efficiently, different fuzzy set shapes (triangles, trapezoids, bell curve etc.) can be selected. Triangle sets are selected in our membership functions which are shown in figure 4.

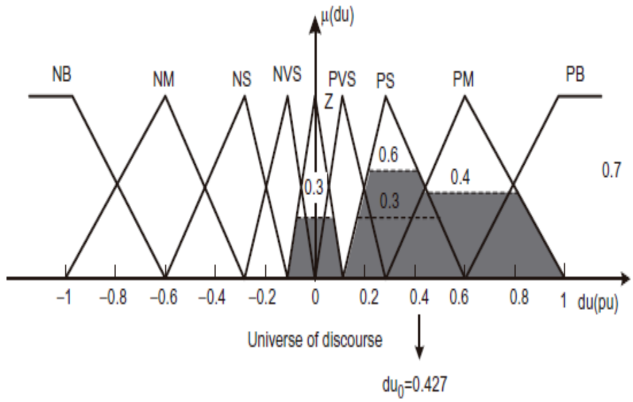
For improvement in the motor's performance, using of the fuzzy controller provides advantages such as no oscillations and overshooot. It regulates speed at the reference value and regulates the flux. Speed response is smoother and faster. For simulation and application of this controller, it does not demand the mathematical modeling of the system. In case of changes in the motor load and parameters, the controller provides a strong performance [11].



a) Error membership function



b) Change in error membership function



c) Change in output membership function

Figure 4. Membership functions for fuzzy logic speed control [8].

4. SIMULATIONS AND APPLICATIONS

In this section, we will compare the results obtained from experimental application and simulation. For experimental application, the used three-phase squirrel cage induction motor is shown in figure 5. The motor brand is Gamak, the motor has 4 pole and star connected. The motor power is 0,37 kW and the motor rotation speed is 1390 r/min.

Baumer Thalhem brand incremental encoder is used for the motor's position information. When the motor shaft produces a circular tour this encoder produces 4096 pulses. Selected operating voltage is 70 volts. For switching frequency 10 kHz is taken [6].

Figure 5. Used three-phase squirrel cage induction motor

Prepared Matlab software for the induction motor control application is directly transferred to the processor with fiber optic connection. Used DS1103 Ace kit is produced by DSPACE firm in figure 6. DS1103 Ace kit can establish a direct connection with Matlab software. The setpoint speed of motor is adjusted is made by Matlab software with using DSP control units.

Figure 6. Used DS1103 expansion box

Fuzzy logic controller is designed in Matlab/Simulink, the obtained results from the simulations and experimental applications of the study are shown in the following figures.

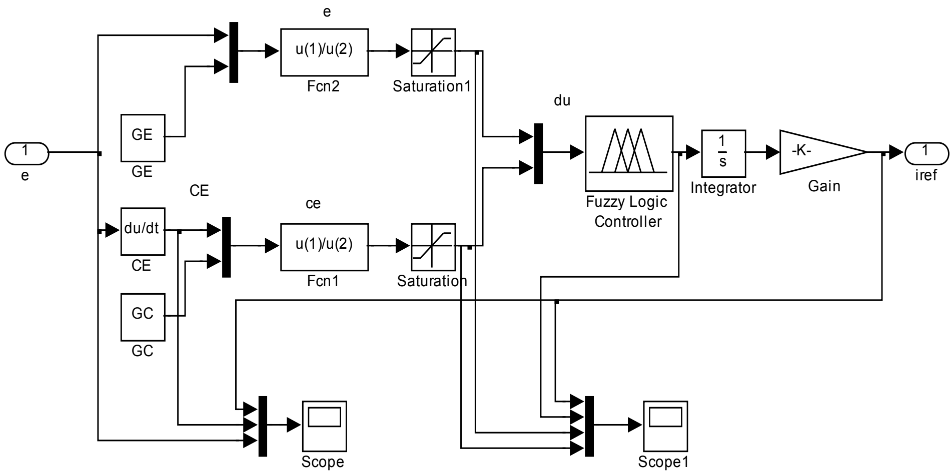


Figure 7. Fuzzy controller in Matlab/Simulink simulation scheme

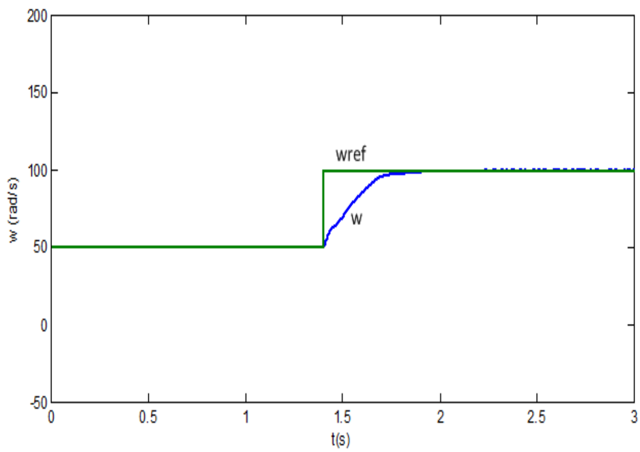


Figure 8. Matlab/Simulink result for w=50 to 100 rad/s

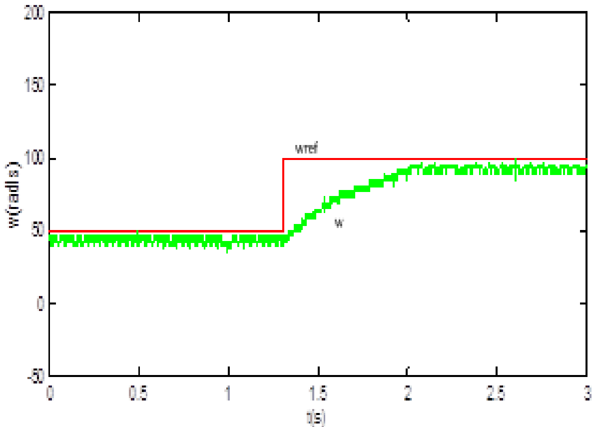


Figure 9. Experimental application result for w=50 to 100 rad/s

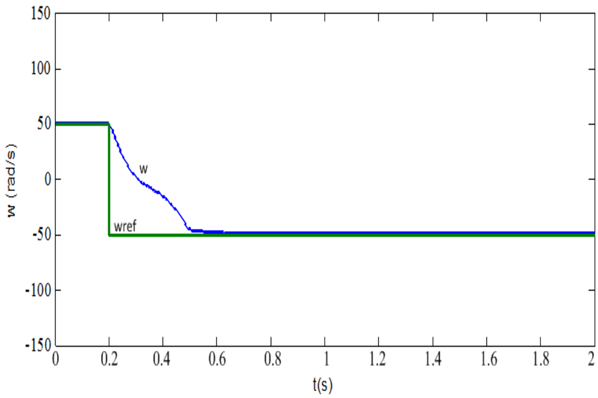


Figure 10. Matlab/Simulink result for w=50 to -50 rad/s

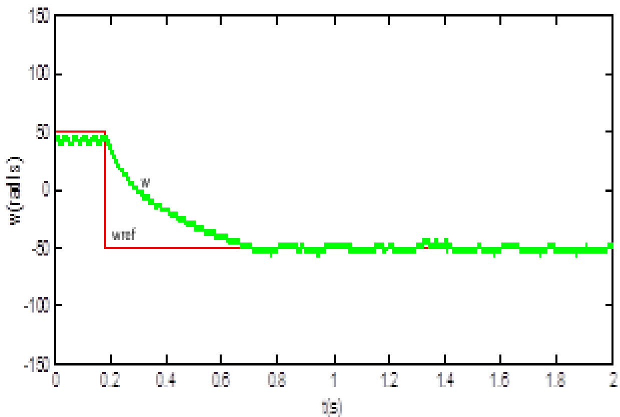


Figure 11. Experimental application result for w=50 to -50 rad/s

5. CONCLUSION

In this study, a three-phase squirrel cage induction motor speed control performed with fuzzy logic. Indirect vector control of induction motor's mathematical model formed using Matlab/Simulink software. For different values of reference speed, the simulation results were obtained. The validation of the fuzzy logic speed controller is provided with results obtained from the simulation and experimental results.

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