Induction Motor Control Using Artificial Intelligence

Govinda S Kedar
Assistant Professor,
ARMIET, Shahapur

Saeed Ahmed Nayeem Mulla
Energy Engineering Department
Technical University Berlin (Germany)

Abdul Hakim Khan
PG Scholar at University
Mumbai

Abstract- This paper presents the vector control of induction motor by using artificial intelligence. In scalar control or V/f control of induction motor, flux is maintained constant by keeping voltage to frequency ratio constant. This control method gives the wide range of speed control with full load torque capability even at lower speed. This cause high energy savings but it is disadvantageous when the transient response is consider. Speed transition or change in loading there is change in the flux which is responsible for poor transient response. The change in flux is recovered in sluggish manner. This lead to over current, over heating during transient period which necessitates a drive to be oversize and no longer cost effective. The causes 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 component is known as the vector control method. For precise control used artificial intelligence(fuzzy logic control). The theoretical basis of each algorithm is explained in detail and its performance is tested with simulations implemented in MATLAB/SIMULINK and performance of induction motor control verified with MATLAB simulation result at dynamic load condition.

Keywords: scalar control, vector control, induction motor, fuzzy logic controller.

I. INTRODUCTION

Electric motors used in industrial and commercial premises consume high electricity. early days DC motors were used in applications for industrial robots and numerically controlled machinery where speed, torque and position control is required. it is easy to control flux and torque. But the main drawback of DC motor is low power density and , commutator. its increase the motor size and maintenance cost and motor life is reduced. The induction motor control has become a cost-effective solution due to the improvements in power electronics and digital technology and high power density, small size compare to Dc motor for same rating of motor. Thus, induction motors replaced the DC motors in various industrial plants.

There are scalar control techniques that operate variable speed of three phase electric motors but for decoupling and precise control, field oriented vector control are used. Field oriented control helps in providing smooth motion at low speeds and active operation at high speeds [1]. But the performance of the field orientation is largely dependent on exact knowledge of the machine parameters Over the past two decades a great deal of work has been done into techniques such as Field Oriented Control, Direct Torque Control and Space Vector Pulse Width Modulation. Fuzzy logic controller used to provide the dynamic smooth performance of induction motor[2]. Fuzzy controller alongs with the PWM controlled inverter gives accurate controlled speed through controlling voltage level and it simplifies complex task into manageable subtasks.

The induction motor is fed by the voltage source inverter with predictive current controller using fuzzy logic controller. The technique helps induction motor in achieving similar torque and speed control performance of dc machine hence replacing the dc machine with induction machine in many high-performance applications.

II. INDIRECT VECTOR CONTROL OF INDUCTION MOTOR DRIVE

Induction motor transformed to a dc motor with field oriented control or vector control. In induction motor the armature winding is on the rotor and currents generate field in the stator winding as in dc machine. The rotor conduction motion with respect to stator field and armature current induces the EMF in the winding, this derives the rotor current. the source for the magnetic field and the armature current is stator current. In the squirrel cage motor which is the most commonly used, only the stator current can be controlled as the rotor winding cannot be accessed. There is no rigid physical disposition between stator and rotor fields and non linear torque equation results in non inherent optimal torque production condition. Therefore the field and torque control is not as easy as in dc motor. The block diagram of an indirect vector control of induction motor drive is shown in Fig.1. The following dynamic equations are taken into consideration to implement indirect vector control strategy [3].vector rotation operating theta θe are obtained from adding actual speed and slip speed of motor and integrate it.

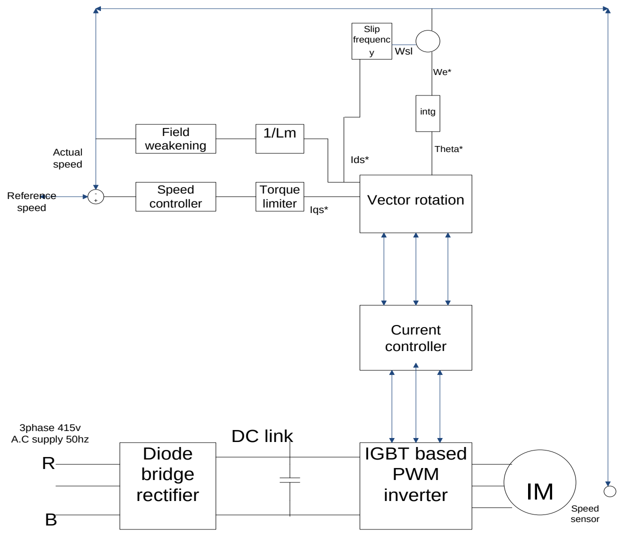

Figure 1: Indirect vector controlled Induction Motor Dive

$$\theta_e = \int \omega_e dt = \int(\omega_r + \omega_{sl}) = \theta_r + \theta_{sl} \qquad (1)$$

The rotor circuit equation

$$\frac{d\Psi_{dr}}{dt} + \frac{R_r}{L_r}\Psi_{dr} - \frac{L_m}{L_r}R_r i_{ds} - \omega_{sl}\Psi_{qr} = 0 \qquad (2)$$

$$\frac{d\Psi_{qr}}{dt} + \frac{R_r}{L_r}\Psi_{qr} - \frac{L_m}{L_r}R_r i_{qs} + \omega_{sl}\Psi_{dr} = 0 \qquad (3)$$

For decoupling control $\Psi_{qr} = 0$, the total flux $\widehat{\Psi_r}$ directs on the d^e axis.

Now from equations (1) and (2) we get

$$\frac{L_r}{R_r}\frac{d\widehat{\Psi_r}}{dt} + \widehat{\Psi_r} = L_m i_{ds} \qquad (4)$$

Slip frequency can be calculated as

$$\omega_{sl} = \frac{L_m R_r}{\Psi L_r} i_{qs} \qquad (5)$$

For constant rotor flux Ψ_r and $d\Psi_r/dt$=0, substituting in equation (4) yields the rotor flux set as

$$\widehat{\Psi_r} = L_m i_{ds} \qquad (6)$$

The electromechanical torque developed is given by

$$T_e = \frac{3}{2}\frac{P}{2}\frac{L_m}{L_r}\widehat{\Psi_r} i_{qs} \qquad (7)$$

III. FUZZY LOGIC CONTROL

The Fuzzy logic controller perform task based on IF and THEN condition. The functional block diagram of fuzzy logic controller shown in Fig.4. there is two input variable of fuzzy controller, first input is the speed error 'e' and second is the change in speed error 'ce' at sampling time 'ts'. The two input variables e(ts) and ce(ts) are calculated at every sampling time as

$$e(t_s) = \omega_r^*(t_s) - \omega_r(t_s)$$
$$ce(t_s) = e(t_s) - e(t_s - 1) \qquad (8)$$

Fig4:Functional block diagram of Fuzzy Logic Control, where 'ce' denotes the change of error, $\omega_r^*(t_s)$ is the reference rotor speed, $\omega_r(t_s)$ is the actual speed, $e(t_s - 1)$ is the value of error at previous sampling time. The output variable is the change in torque ΔT which is integrated to get the reference torque as shown in the equation

$$T^*(t_s) = T^*(t_s - 1) + \Delta T \qquad (9)$$

the fuzzy logic controller consists of four blocks, Fuzzification, inference mechanism, knowledge base/data base and Defuzzification.

A. Fuzzification**:**

The variables of input error $e(t_s)$ and change in error $ce(t_s)$ are modified intro fuzzy variables in this stage. It maps the e and ce to competence labels of fuzzy sets. Each label is associated with membership function consisting two inputs(e and ce) and output.as the sets of variables of input error $e(t_s)$ and change in error $ce(t_s)$ increases then its gives more precise descriptions of fuzzy variables. All the inputs and output have membership function with the following linguistic labels: NVB,NB,NM, NS, ZE, PS, PM, PB,PVB.

B. Knowledge base and Inference mechanism:

Knowledge base defines the rules termed as IF-THEN rules which govern the input and output relationship in terms of membership function. The input variables e(ts)and ce(ts) executes 9*9 rules and are processed by inference mechanism using Mamdani's algorithm. For example if we consider the first rule, IF speed error and change in speed error is NVB, THEN the output is NVB, if we consider, IF speed error is NVB and change in speed error is PS, THEN the output is NB.

C. Defuzzification:

Defuzzification uses various methods in producing fuzzy set value of fuzzy variable ΔT. Here the centre of gravity or centroids method is used in calculating the final fuzzy value $\Delta T(t_s)$. COA method used in defuzzification generates $\Delta T^*(t_s)$ output with the help of centre of gravity in which ΔT(ts) is considered as geometric centre of $\mu_{out}(\Delta T)$ area, the $\mu_{out}(\Delta T)$ is formed by uniting all the contributions of rules satisfying the condition to be greater than zero. The COA expression can be written as

$$\Delta T = \frac{\sum_{i=1}^{n} \Delta T_{i.}\mu_{out}(T_i)}{\sum_{i=1}^{n} \mu_{out}(\Delta T_i)} \qquad (10)$$

The Te* obtained by integration is used to calculate i*qs.

$e(pu$ / $e(pu$	NVB	NB	NM	NS	ZE	PS	PM	PB	PVB
NVB	NVB	NVB	NVB	NVB	NVB	NB	NM	NS	ZE
NB	NVB	NB	NB	NB	NB	NM	NS	ZE	PS
NM	NVB	NB	NB	NB	NM	NS	ZE	PS	PM
NS	NVB	NB	NB	NM	NS	ZE	PS	PM	PB
ZE	NVB	NB	NM	NS	ZE	PS	PM	PB	PVB
PS	NB	NM	NS	ZE	PS	PM	PB	PB	PVB
PM	NM	NS	ZE	PS	PM	PB	PB	PB	PVB
PB	NS	ZE	PS	PM	PB	PB	PB	PB	PVB
PVB	ZE	PS	PM	PB	PVB	PVB	PVB	PVB	PVB

TABLE1: FUZZY CONTROLLER RULE

IV. SIMULATION RESULTS AND DISCUSSION

The machine will be at stand still initially without any load. The reference speed increases linearly from zero and its rated value is 314 rpm with fuzzy logic control. The simulink block diagram of indirect vector controlled induction motor drive with fuzzy controller is demonstrated in Fig.2. Motor specification: 7.5hp, 415volt, 1440rpm, rated full load current16A. Fig.3 shows the stator current of induction motor at different load condition and Fig.4 shows the load torque and actual electromagnetic torque of induction motor at different loading conditions. Fig.5 shows the actual and reference speed result at different load conditions. FLC-based drive system is faster and superior system in all respect rise time, settling time and overshoot.

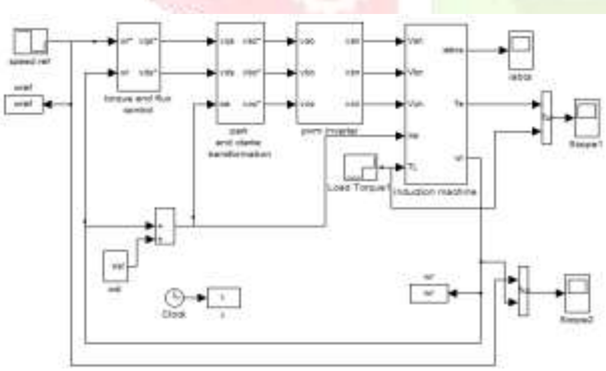

Fig.2.Simulink block diagram of indirect vector controlled induction motor drive

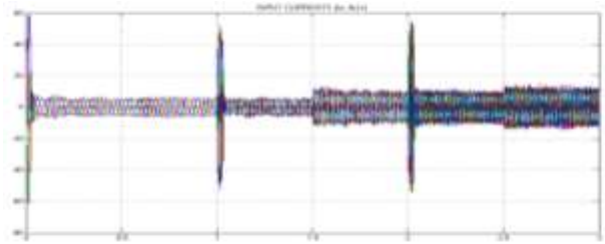

Fig.3 Stator currents of induction motor at different load condition

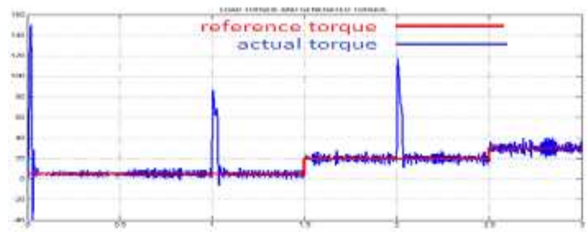

Fig.4 Load torque and electromagnetic torque at rated condition

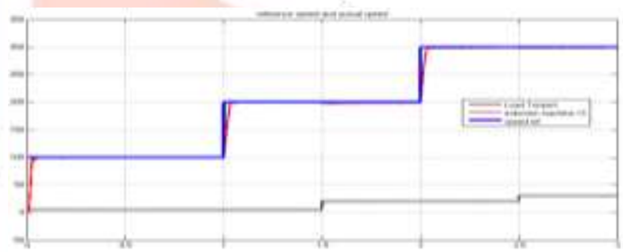

Fig.5 Reference speed and actual speed at rated rotor resistance

V. CONCLUSION

In this paper fuzzy logic controller based speed control of induction proposed. The performance of the FLC based indirect vector controlled induction motor drive was with MATLAB simulation results at dynamic load conditions or dynamic operating conditions such as sudden change in reference speed, step change in load, etc. Successfully proper field orientation is achieved, Hence total flux is completely oriented along d-axis, and q-axis current will respond to the change in load torque but not d-axis current and having smooth control.

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