Torque Control of Three Phase Induction Motor Using Intelligent Controller

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***Abstract*- Induction motors are extremely used in a variety of industrial applications. Direct Torque Control of induction motor is one of the efficient control methods. But the motor is unable to perform under non linear conditions. In this project, direct torque control of three phase induction motor using intelligent controller (genetic algorithm and fuzzy logic) has been proposed. The proposed fuzzy logic controller fuzzifies the torque error and flux linkage of the three phase induction motor and it is optimized by genetic algorithm to improve the dynamic characteristics. The simulation model has been developed and tested using MATLAB software.**

Index terms-Three phase Induction Motor, Direct Torque Control (DTC), Fuzzy Logic Control (FLC), Genetic Algorithm (GA).

I.INTRODUCTION

INDUCTION motors have been employed in high performance industrial applications because of their high speed operation, low cost, minimum maintenance and robustness. Induction motors can be controlled using both open loop and closed loop techniques. The control of IM under high performance is a challenging problem. To improve the performance many control methods have been invented.

DTC is one method that provides an effective control of the flux and torque. The advantages of this DTC is fast, dynamic response, better dynamic performance, does not require rotor position sensors, low losses.

In fuzzy logic controller, the parameters are controlled using rule based system. Fuzzy logic is the simplest which does not require a detailed mathematical model and so it can be applied for non linearity problem. The FLC has multiple rules and membership function that lead to high computational burden. To overcome this disadvantage genetic algorithm based fuzzy logic controller has been proposed.

II.DTC

DTC was introduced by Takahashi and by Depenbrock. The torque and stator flux is to be estimated so that can be directly controlled by DTC. To achieve this condition, the appropriate sector is to be selected in space vector modulation. It is known that the torque depends on the stator flux, rotor flux and the angle between the vectors. The torque produced by machine is calculated by

$$T = \frac{3}{2}\frac{p}{2}\frac{L_m}{L_s L_r}\ |\Phi r|\,|\Phi s|\ \sin\theta_{rs} \qquad (1)$$

Where

L_m is the mutual inductance, L_s is the stator inductance, L_r is the rotor inductance, θ_{rs} is the angle between the vectors, Φ_r is the rotor flux, Φ_s is the stator flux and p - poles of the machine.

The stator flux vector, $\vec{\phi}_s$ with respect to stator voltage space vector, $\overline{v_s}$ is given for a stator fixed co-ordinate system as

$$\overline{v_s} = R_s\vec{i_s} + d\vec{\phi}_s/dt \qquad (2)$$

A. Flux controller

The stator flux $\Delta\vec{\phi}_s$ is approximated during the time interval Δt, as

$$\Delta\vec{\phi}_s = \overline{v_s}\ \Delta t \qquad (3)$$

Where $\overline{v_s}$- stator voltage vector, Δt- time interval.

The stator flux is controlled by choosing the voltage vector. It is done by dividing the stator flux plane into six sectors which has their corresponding voltage vectors. The estimated stator flux is adjusted to match the reference stator flux.

B. Torque controller

The electromagnetic torque is the sinusoidal function of stator flux $\vec{\phi}_s$ and rotor flux $\vec{\phi}_r$. The angle between these two flux vectors are denoted by θ_{rs} will be greatly varied which in turn causes high variation in the output torque. So the voltage vectors of the inverter must be chosen properly to reach a faster speed for achieving better dynamic performance. Similarly the torque is controlled.

III. VOLTAGE SOURCE INVERTER

The desired stator flux is obtained by using space vector modulation technique. The space vector modulation is described using voltage source inverter which feeds a three phase induction motor. The inverter converts the dc signal into ac signal through power electronic devices such as MOSFET (Metal Oxide Semiconductor Field Effect Transistor) switches. The block diagram of voltage source inverter is shown below

By neglecting the stator resistances, the flux equation is expressed as

$$d\vec{\phi}_s/dt = \overline{v_s} \qquad (4)$$

Where $\overline{v_s}$ and $\vec{\phi}_s$ are the stator voltages and flux respectively.

From eqn,

$$\Delta\vec{\phi}_s = \overline{v_s}\ \Delta t \qquad (5)$$

Hence the stator flux is proportional to the stator voltage.

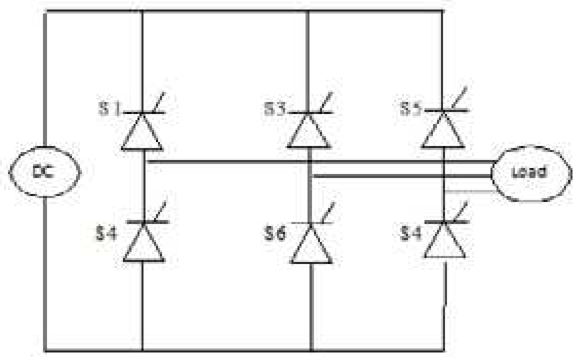

Fig.1 voltage source inverter

The voltage source inverter depends on the ON-OFF switching state of each MOSFET. These are eight switching states. The ON state is indicated by the number 1 and OFF state is indicated by the number 0. In that, two of the switching states have null voltage and so zero flux states. The outputs of the voltage source inverter are fed to the three phase induction motor.

IV. SPACE VECTOR PWM

SVPWM directly transform the stator voltage vectors into PWM signals. This technique gives the switching scheme of six power switches of three phase inverter. It uses eight switching modes of inverter to control the stator flux to approach the reference flux circle and attains higher control performance. The eight switching modes corresponds to eight space voltage vectors that contains six non- zero vectors and two zero vectors. The applied phase voltage corresponds to eight combination s on to the d-q plane by performing d-q transformation. The eight vectors are called basic space vectors. They are denoted by V_1 (100), V_2 (110), V_3 (010), V_4 (011), V_5 (001), V_6 (101), V_7 (111) and V_0 (000). The six non-zero vectors divide equally the d-q plane into six sectors. The angle between two adjacent vectors is 60 degrees.

SVPWM has several types of implementations. The carrier based SVPWM is used here which allows fast and efficient implementation of SVPWM without sector determination. This technique is based on the duty ratio profiles that SVPWM exhibits. By comparing the duty ratios with higher frequency triangular carrier, the pulses are generated.

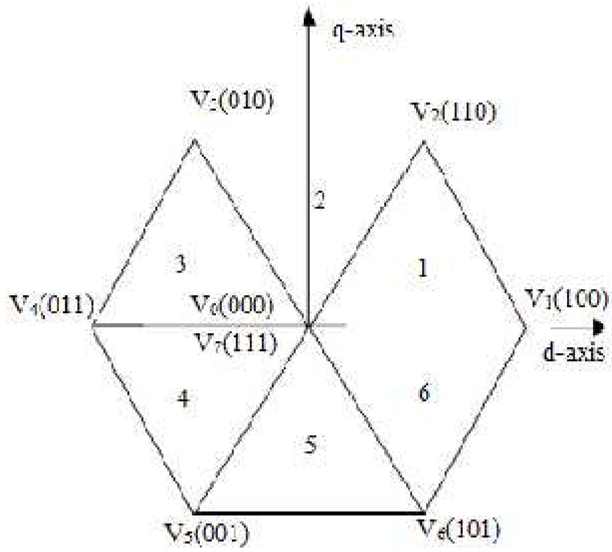

Fig. 2. Basic switching sectors and vectors

V. FUZZY LOGIC CONTROLLER

Fuzzy logic controller has proven effective for complex and non linear processes. It converts a linguistic control strategy into automatic control strategy. FLC consists of three components namely fuzzification, inference (knowledge base and decision making) and defuzzification. In general a fuzzy set is used to express a fuzzy variable which is defined by a membership function. The values of membership function vary between 0 and 1.

Fuzzification involves the process of converting the input data into suitable linguistic values. The knowledge base includes database and rule base. Database are used to define the necessary linguistic control rules using the syntax

IF<fuzzy proposition> THEN<fuzzy proposition>

The IF part is called as antecedent and THEN part is called as consequent. Decision making logic is the most important part of FLC. It has the capability of simulating human decision making based on fuzzy concepts and rules through ‘AND’, ‘OR’ fuzzy operators which in turn generates a single truth value that determines the outcome of rules. The outcome of decision making logic is the inferred fuzzy control action. The third component is the defuzzification, which yields a non- fuzzy control action from an inferred control action.

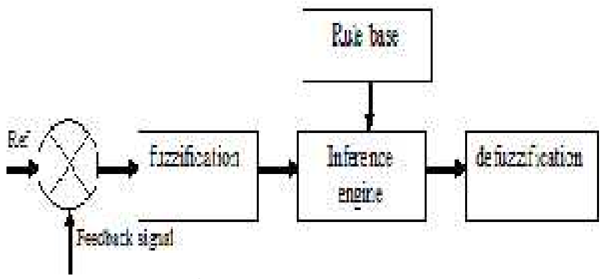

Fig. 3. Block diagram of Fuzzy Logic Controller

Here penta triangular fuzzy sets have been used to partition the input and output spaces. They are Negative Big (NB), Negative Small (NS), Zero (ZE), Positive Small (PS) and Positive Big (PB).

TABLE I
RULE BASE FOR DTC SCHEME

ce \ e	NB	NS	ZE	PS	PB
NB	ZE	PS	PS	PB	PB
NS	NS	ZE	PS	PS	PB
ZE	NS	NS	ZE	PS	PS
PS	NB	NS	NS	ZE	PS
PB	NB	NB	NS	NS	ZE

The efficient conditional statement between fuzzy input variable and fuzzy output variable is given by

IF x is A_i and y is B_i THEN z is C_i.

Where x, y and z are the linguistic input variables and output variable. A_i, B_i and C_i are the fuzzy sets of the variables.

The method used here is Mamdani model of FLC. This model nexuses the inference results of rules using superimposition that has the mechanism of words on linguistic or rule based control strategy. Mamdani's fuzzy inference method is the most commonly used fuzzy methodology. Mamdani's method was among the first control systems built using fuzzy set theory. It was launched in 1975 by Ebrahim Mamdani who applied a set of linguistic control rules obtained from experienced human operators. Mamdani-type inference, as 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.

The elegant Mamdani-style fuzzy inference process is performed in four steps: (1) fuzzification of the input variables, (2) rule evaluation, (3) aggregation of the rule outputs, and finally (4) defuzzification.

Step 1: Fuzzification(so it implies first transformed to fuzzify and it is easy to process in fuzzified logic then defuzzify it). To take the crisp inputs and determine the degree to which these inputs belong to each of the appropriate fuzzy sets.

Step 2: Rule Evaluation. To take the fuzzified inputs and apply them to the antecedents of the fuzzy rules. If a given fuzzy rule has multiple antecedents, the fuzzy operator (AND or OR) is used to obtain a single number that represents the result of the antecedent evaluation. This number (the truth value) is then applied to the consequent membership function.

Step 3: Aggregation. It is the process of unification of the outputs of all rules. To correlate the rule consequent with the truth value of the rule antecedent, clipping or scaling method is used. This method is easier to defuzzify the output surface and losses less information which is very useful in fuzzy expert systems. The membership functions of all rule consequents previously clipped or scaled is taken and are combined into a single fuzzy set. The input of the aggregation process is the list of clipped or scaled consequent membership functions, and the output is one fuzzy set for each output variable.

Step 4: The fuzzy inference process here is defuzzification. Fuzziness helps us to evaluate the rules, but the final output of a fuzzy system has to be a crisp number. The input for the defuzzification process is the aggregate output fuzzy set and the output is a single number. There are several defuzzification methods, but the most popular one is the centroid method. It pragmatically finds the point where a vertical line would slice the aggregate set into two equal masses.

Mathematically the centre of gravity (COG) can be expressed as

$$COG = \frac{\int_a^b \mu_A(x)\,x\,dx}{\int_a^b \mu_A(x)\,dx} \qquad (6)$$

Where μ_A – aggregated output membership function.

Centroid defuzzification method finds a point representing the centre of gravity of the fuzzy set, *A*, on the interval, *ab*. The advantages of the Mamdani method are, it is intuitive, has widespread acceptance and is well suited to human input.

VI. PROPOSED SCHEME

The proposed block diagram is shown in fig.4. The measured voltage and current from the inverter is given to the torque and flux calculator and the abc variables are transformed to dq variables. The calculated torque and flux are given to the intelligent controller (fuzzy logic and genetic algorithm). The torque and flux are fuzzzified and optimized. After optimization the outputs are defuzzified and again dq variables are transformed into abc variables and are given to the switching circuit.

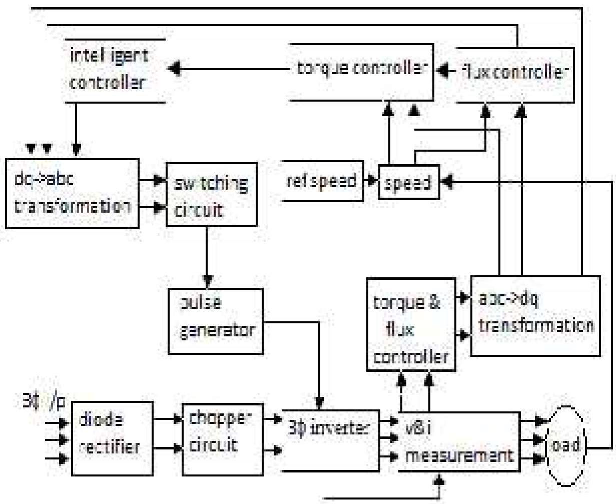

Fig. 4. Block Diagram of proposed system

VII. SIMULATION RESULTS

The proposed direct torque control of three phase IM has been verified with simulated results are shown below. Using DTC and FLC technique, the speed response is smooth and the ripples are almost neglected. The speed and the torque response drive are shown in fig.5 and 6. The torque is controlled using Direct Torque Control and Fuzzy Logic Control technique. The performance of the Induction Motor is improved.

The performance of the proposed model has been tested using 4kw motor. The motor parameters are R_s = 1.405Ω, R_r = 1.405Ω, L_s = 0.005839H, L_r = 0.005839H, L_m = 0.1722H, frequency = 50Hz, applied voltage = 400V (line to line).

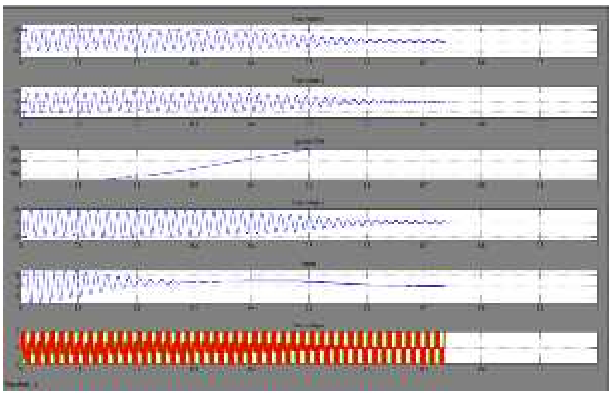

Fig. 5. Torque response using DTC

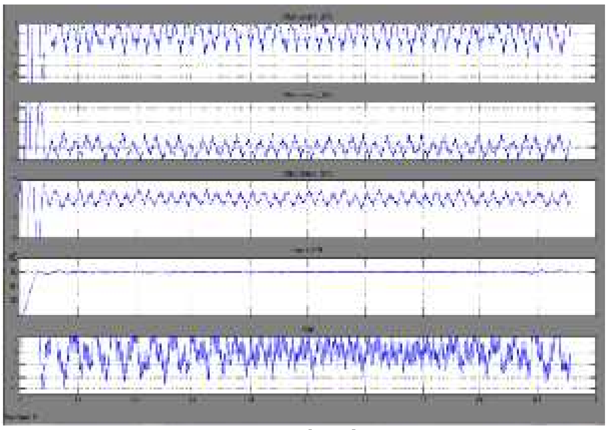

Fig. 6. Torque response using DTC based FLC

VIII.CONCLUSION

In this paper, the torque control of three phase Induction Motor using intelligent controller has been proposed. In the proposed system, direct torque control of three phase Induction Motor using fuzzy logic controller has been implemented. The simulation results show that the torque ripple is minimized and the torque control performance has been improved. The intelligent controller (GA based FLC) is under development and the results will be provided later for the torque control of induction motor using genetic algorithm based fuzzy logic control. The extension of the work used to frame a innovative methodology using neuro fuzzy and GA for the expedite future.

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