Direct torque control scheme

A schematic of Direct Torque Control is shown. As it can be seen, there are two different loops corresponding to the magnitudes of the stator flux and torque. The reference values for the flux stator modulus and the torque are compared with the actual values, and the resulting error values are supplied into the two level and three-level hysteresis blocks respectively.

The outputs of the stator flux error and torque error hysteresis blocks, together with the position of the stator flux are used as inputs of the look up table. The inputs to the look up table are given in terms of 1, 0,-1 depend on whether torque and flux errors within or beyond hysteresis bands and the sector number in which the flux sector presents at that particular moment. In accordance with the figure 1. 2, the stator flux modulus and torque errors tend to be restricted within its respective hysteresis bands.

From the schematic of DTC it is cleared that, for the proper selection of voltage sector from lookup table, the DTC scheme require the flux and torque estimations.

Techniques for Quantifications of Stator Flux in DTC:

Accurate flux quantifications in Direct Torque controlled induction motor drives is necessary to ensure proper drive operation and stability. Most of the flux estimation methods proposed was based on voltage model, current model, or the combination of both. The estimation based on current model normally applied at low frequency, and stator current and rotor mechanical speed or position.

In some industrial applications, the use of incremental encoder to get the speed or position of the rotor is undesirable since it reduces the robustness and reliability of the drive. It has been generally known that even though the current model has managed to remove the sensitivity to the stator resistance variation. The use of rotor parameters in the estimation introduced error at high rotor speed due to the rotor parameter variations. So in this present DTC control scheme the flux and torque are quantified by using voltage model which does not need a position sensor and the only motor parameter used is the stator resistance. (Oghanna, 2011)

Introduction of FLC

Fuzzy logic has become one of the most successful of today'stechnologyfor developing sophisticated control system. With it aid, complex requirement may be implemented in simply, easily and inexpensive controlling method. The application ranges from consumer products such as cameras, camcorder, washing machines and microwave ovens to industrial process control, medical instrumentation and decision support system . many decision-making and problem solving tasks are too complex to be understand quantitatively however, people succeed by using knowledge that is imprecise rather than precise.

Fuzzy logic is all about the relative importance of precision. It has two different meanings. In a narrow sense, fuzzy logic is a logical system which is an extension of multi valued logic, but in wider sense fuzzy logic is synonymous with the theory of fuzzy sets. Fuzzy set theory is originally introduced by LotfiZadeh in the 1960s, resembles approximate reasoning in it use of approximate information and uncertainty to generate decisions.

Several studies shows, both in simulations and experimental results, that Fuzzy Logic control yields superior results withrespectto those obtained by conventional control algorithms thus, in industrial electronics the FLC control has become an attractive solution in controlling the electrical motor drives with large parameter variations like machine tools and robots.

However, the FL Controllers design and tuning process was often complex because several quantities, such as membership functions, control rules, input and output gains, etc. must be adjusted. The design process of a FLC can be simplified if some of the mentioned quantities are obtained from the parameters of a given Proportional-Integral controller (PIC)for the same application. (Lotfizabeh, 2011).

Why fuzzy logic controller (FLC)

- Fuzzy logic controller was used to design nonlinear systems in control applications. The design of conventional control system is normally based on the mathematical model. If an accurate mathematical model is available with known parameters it can be analyzed and controller can be designed for specific performances, such procedure is time consuming.
- Fuzzy logic controller has adaptive characteristics. The adaptive characteristics can achieve robust performance to system with uncertainty parameters variation and load disturbances.

The Main Principles of Fuzzy Logic Controller

The fuzzy logic system involves three steps fuzzification application of fuzzy rules and decision making and defuzzification. Fuzzification involves mapping input crisp values and decision is made based on these fuzzy rules. These fuzzy rules are applied to the fuzzified input values and fuzzy outputs are calculated in the last step, a defuzzifier coverts the fuzzy output back to the crisp values.

The fuzzy controller in this thesis is designed to have three fuzzy input variables and one output variable for applying the fuzzy control to direct torque control of induction motor. There are three variable input fuzzy logic variables. The stator flux error, electromagnetic torque error, and angle of the flux in the stator.

Block Diagram of Fuzzy Logic Controller

The membership functions of these Fuzzy sets are triangular with two membership function N and P for the flux-error, three membership functions N, Z, P for the torque-error, six membership variables for the stator flux position sector and eight membership functions for the output commanding the inverter. The inference system contains thirty six Fuzzy rules which is framed in order to reduce the torque and flux ripples.

Each rule takes three inputs, and produces one output, which is a voltage vector. Each voltage vector corresponds to a switching state of the inverter. The switching state decides the pulse to be applied to the inverter. The Fuzzy inference uses MAMDANI's procedure for applying Fuzzy rules which is based on minimum to maximum decision.

Depending on the values of flux error, torque error and stator flux position, the output voltage vector is chosen based on the Fuzzy rules. Using Fuzzy Logic controller the voltage vector is selected such that the amplitude and flux linkage angle is controlled. Since the torque depends on the flux linkage angle the torque can be controlled and hence the torque error is very much reduced.

Fuzzy logic controller (FLC)

Fuzzy logic expressed operational laws in linguistics terms instead of mathematical equations. Many systems are too complex to model accurately, even with complex mathematical equations, therefore traditional methods become impracticable in these systems.

However fuzzy logics linguistic terms provide a possible method for defining the operational characteristics of such system.

Fuzzy logic controller can be considered as a special class of symbolic controller. The configuration of fuzzy logic controller block diagram is shown in Fig. 2. 6

Block diagram for Mamdani type Fuzzy Logic Controller

The fuzzy logic controller has three main components

1. Fuzzification.
2. Fuzzy inference.
3. Defuzzification.
4. Fuzzification

The following functions:

1. Multiple measured crisp inputs first must be mapped into fuzzy membership function this process is called fuzzification.
2. Performs a scale mapping that transfers the range of values of input variables into corresponding universes of discourse.

3. Performs the function of fuzzification that converts input data into suitable linguistic values which may be viewed as labels of fuzzy sets.

Fuzzy logic's linguistic terms are often expressed in the form of logical implication, such as IF-THENrules. These rules define a range of values known as fuzzy membership functions.

Fuzzy membership function may be in the form of a triangle, a trapezoidal, and a bell as shown in Fig. 2. 7

Triangle Trapezoid

Bell

Figure 2. 7. (a) Triangle, (b) Trapezoid, and (c) BELL membership functions.

The inputs of the fuzzy controller are expressed in several linguist levels. As shown in Fig. 2. 8 these levels can be described as positive big (PB), positive medium (PM), positive small (PS), negative small (NS), negative medium (NM), and negative big (NB). Each level is described by fuzzy set below.

Figure. 2. 8. Seven levels of fuzzy membership function

Fuzzy inference

Fuzzy inference is the process of draw up the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made. There are two types of fuzzy inference systems that can be implemented in the Fuzzy Logic Toolbox: Mamdani-type and Sugeno-type. These two types of inference systems vary to some extent in the way outputs are determined.

Fuzzy inference systems have been successfully applied in fields such as automatic control, data classification, decision analysis, expert systems, and computer vision. Because of its multi-disciplinary nature, fuzzy inference systems are associated with a number of names, such as fuzzy-rule-based systems, fuzzy expert systems, fuzzy modeling, fuzzy associative memory, fuzzy logic controllers, and simply, fuzzy Mamdani's fuzzy inference method is the most commonly seen fuzzy methodology.

Mamdani's method was among the first control systems built using fuzzy set theory. It was proposed in 1975 by Ebrahim Mamdani as an attempt to control a steam engine and boiler combination by arranging a set of linguistic control rules obtained from experienced human operators. Mamdani's effort was based on LotfiZadeh's 2011on fuzzy algorithms for complex systems and decision processes.

The second phase of the fuzzy logic controller is its fuzzy inference where the knowledge base and decision making logic reside . The rule base and data base from the knowledge base. The data base contains the description of the input and output variables. The decision making logic evaluates the control rules . the control-rule base can be developed to tolerate the output action of the controller to the inputs.

Defuzzification

The output of the inference mechanism is fuzzy output variables. The fuzzy logic controller must convert its internal fuzzy output variables into crisp values so that the actual system can use these variables. This conversion is called defuzzification.

Fuzzy Direct Torque Controller

The fuzzy direct torque control technique consists of inverter, induction motor, torque controller, flux controller, flux estimator, torque estimator and clarke's transform. The fuzzy logic technique which is based on the language rules, is used to solve this nonlinear issue. In a three phase voltage source inverter, the switching commands of each inverter leg are matched. For each leg a logic state Ci (I = a, b, c) is defined, thatCi is 1 IF the upper switch turned ON and zero IF the lower switch turned OFF. IFCi is 0 THEN it means that the lower switch is ON and upper switch is turned OFF. Since three are independent there will be eight different states, so eight different voltages.

To study the performance of the developed DTC model, a closed loop torque control of the drive is simulated using MATLAB/Simulink simulation package. The torque error and flux errors were compared in their respective hysteresis band to generate their respective logic state as (ST) and (S?). The sector logic state (S?) is used as the third controlling signal for referring the DTC switching table. These three controlling signals are used to determine the instantaneous inverter switching voltage vector from three dimensional DTC switching lookup table. The simulation results are implemented for conventional DTC scheme and proposed fuzzy based DTC scheme. There are three non-zero voltage vectors and two voltage vectors.

Block Diagram of fuzzy logic DTC

The DTFC on induction motor drives is designed to have three fuzzy input variables and one output control variable to achieve fuzzy logic based DTC of the induction machine. Its functional block diagram is as shown in fig. 2. 9 the three input variables are the stator flux error, electromagnetic torque error and angle of stator flux. The output was the voltage space vector. The DTF Cconsist of fuzzification, rule base, data base, decision making and defuzzification.

The input variable (? T) and (?) are fuzzified using fuzzy functions over the respective domains. The output of DTFC was also fuzzified, the all possible fuzzy rules are stored in fuzzy rule base.

DTFC takes the decision for the given input crisp variables by firing this rule base.

DTC functional Block Diagram

SUMMARY

With the principle of direct torque control (DTC)of induction motor, the high ripple torque in the motor have being reduced to above 65% in the reviewed work.

These controls have being one of the best controls for driving induction motor because of its principles. Though DTC strategy is popular and simpler to implement than the flux vector control method because voltage modulators and coordination transformations are not required.

Although, it introduces some drawbacks as follows:

1. High magnitude of torque ripple
2. Torque and small errors in flux and torque are not distinguished. In other word, the same vectors are used during start up and step changes and during steady state.

3. Sluggish response in both start up and step changes in either flux or torque.

In other to overcome the mentioned drawbacks, there are difference solution like fuzzy logic duty ratio control method. In this work fuzzy logic with duty ratio control is proposed to use with direct torque control to reduce this high ripple torque and realized the best DTC improvement.