Design of Torque Hysteresis DTC Controller for Squirrel Cage Induction Motor

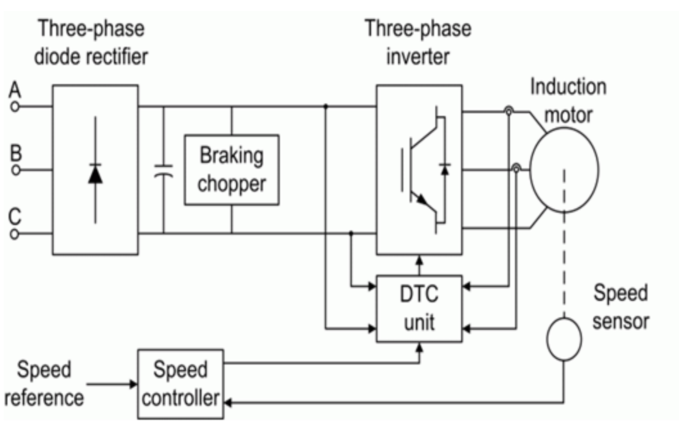
Rahul Modanwal, S.K.Singh, Pushpender singh, Raj Kumar Sagar, Sanjay singh

Abstract— Direct Torque Control or DTC as it is called is the very latest AC drive technology developed by ABB and is set to replace traditional PWM drives of the open- and closed-loop type in the near future. Direct Torque Control describes the way in which the control of torque and speed are directly based on the electromagnetic state of the motor. DTC is the first technology to control the "real" motor control variables of torque and flux. Because torque and flux are motor parameters that are being directly controlled, there is no need for a modulator, as used in PWM drives, to control the frequency and voltage. This, in effect, cuts out the middle man and dramatically speeds up the response of the drive to changes in required torque. DTC also provides precise torque control without the need for a feedback device.

Index Terms— Induction motor, MATLAB, Braking chopper, Inverter, Rectifier, DTC controller, Hysteresis, Voltage Vector.

1 Introduction

THIS The objective of the research work is to design the Speed Control of Three-Phase Induction Motor using Direct Torque Control (DTC). The control action should provide good accuracy. For this proposed system is shown below To implement speed control scheme MATLAB simulation has been used. In MATLAB simulation designing of DTC is done, Induction Machine Model, Three Phase Inverter, Three Phase Diode Rectifier model, Braking Chopper and Speed Controller MATLAB simulink models. Some of the modules of the block diagram has been discussed below.



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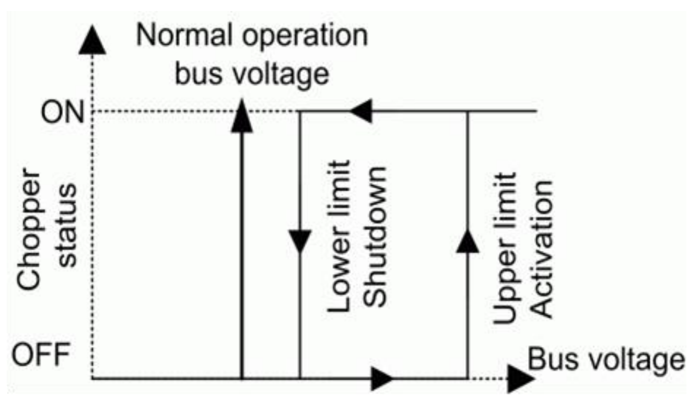
2 Procedure for Torque and Speed Hysteresis Concepts

2.1 BRAKING CHOPPER

The braking chopper block contains DC bus capacitor and the dynamic braking chopper (consist of braking resistance series with chopper), which is used to absorb the energy produce by motor deceleration. Baking resistance is used to avoid bus over-voltage during motor deceleration or when the load torque tends to accelerate the motor.
Braking chopper activation and shutdown voltage;-



Hysteresis diagram

The dynamic baking is activated when the bus voltage reaches the upper limit of hysteresis band. Figure will illustrates the baking chopper hysteresis logic. The dynamic baking is shutdown when the bus voltage reaches the lower limit of hysteresis band. Figure will illustrates the baking chopper hysteresis logic. The output of baking chopper is applied to three-phase inverter [1].

2.2 THREE-PHASE INVERTER

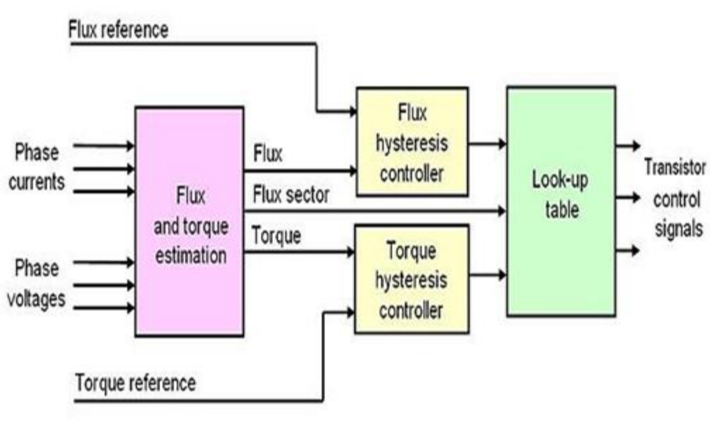
It converts DC signal to AC signal and applied to three-phase induction motor. Here we are using Voltage Source Inverter which is used to regulate the speed of three-phase squirrel cage motors by changing the frequency and voltage and consist of input rectifier, DC link, output converter . They are available for low voltage range and medium voltage range [4].

2.3 SPEED CONTROLLER

The speed controller is based on PI regulator. PI controller is an algorithm that can be implemented without resorting to any heavy control theory. The aim of such an algorithm is to determine the plant input (in our case the stator volt-age frequency) that will make the measured output (in our case the speed of the rotor) reach the reference (the speed the user wishes to have). PI stands for Proportional and Integral, two terms which describe two distinct elements of the controller [5] [6].

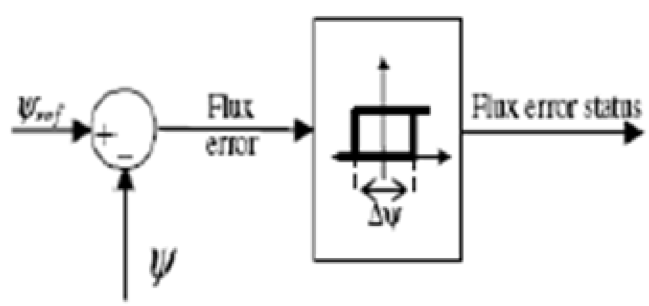
2.4 DIRECT TORQUE CONTROL

Direct Torque Control (DTC) is one of the most excellent control strategies of torque control/ speed control in induction machine.



Block diagram of the DTC technology

The stator voltage vector is selected according to the differences between the reference and actual torque and stator flux linkage. Here only the stator current and voltages is needed to calculate the actual torque and the flux linkages. The status of the torque and flux linkages is applied the optimal switching logic. This optimal switching logic is used for the switching of the three-phase inverter [2] [3].



Block diagram of the stator flux hysteresis comparator

2.5 Direct Torque Control

The instantaneous torque in terms of stator and rotor flux linkages is given by :

$$T_e = \frac{3}{2}\frac{L_m}{\sigma L_s L_r}\overline{\psi_s}\times\overline{\psi_r} = \frac{3}{2}\frac{L_m}{\sigma L_s L_r}\psi_s\psi_r \sin\theta_{sr}$$

In order to obtain instantaneous torque control, it is necessary to vary θ_{sr} quickly. Variation of θ_{sr} and electromagnetic torque with the application of different voltage vectors are given in Table. Two assumptions are motor rotates in counterclockwise rotation, and load torque remains constant. It can be summarized that, the stator flux which lies in sector k, plays an important role in controlling θ_{sr} by applying an appropriate voltage vector as tabulated in Table.

VARIATION OF θ_{sr} AND T_E WITH DIFFERENT VOLTAGE VECTORS

Voltage vector	Effect on stator flux	θ_{sr} and T_e
Active forword ($\bar{V}_{s,k+1}$ and $\bar{V}_{s,k+2}$)	Stator flux advances forward	Increases
Zero ($\bar{V}_{s,0}$ and $\bar{V}_{s,7}$)	Stator flux weakens only due to stator resistance drop	Decrease
Radial ($\bar{V}_{s,k}$ and $\bar{V}_{s,k+3}$)	Stator flux magnitude increases or redudes rapidly	Decrease
Reverse active ($\bar{V}_{s,k-1}$ and $\bar{V}_{s,k-2}$)	Stator flux rotates in reverse direction	Decrease rapidly

Relation of Voltage vector and their effect on stator flux

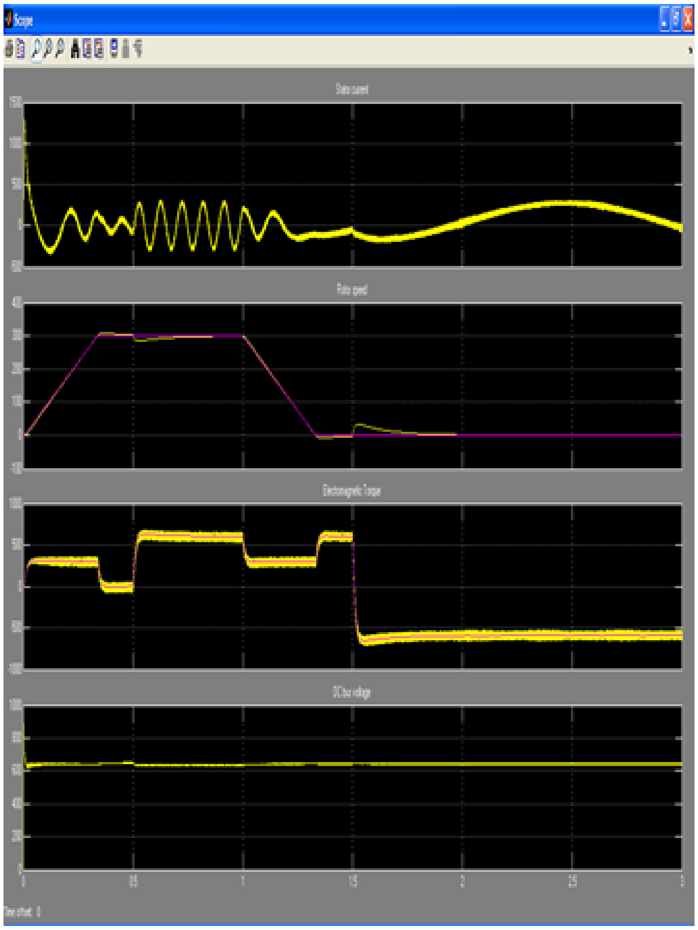
3 SIMULATION RESULTS AND DISCUSSIONS

The induction motor is fed by a voltage source inverter which is built using a Universal Bridge Block. The speed control loop uses a proportional-integral controller to produce the flux and torque references for the DTC block. The DTC block computes the motor torque and flux estimates and compares them to their respective reference. The comparators outputs are then used by an optimal switching table which generates the inverter switching pulses. The result of simulation of the speed control with different reference speed and load torque is shown below:-

Simulation Test Run

Speed, at time(s): [0 1], amplitude is [300 0]
Torque, at time(s): [0 0.5 1], amplitude [0 692 -692]
Start the simulation. You can observe the motor stator current, the rotor speed, the electromagnetic torque and the DC bus voltage on the scope. The speed set point and the torque set point are also shown.
At time t = 0 s, the speed set point is 300 rpm. Observe that the speed follows precisely the acceleration ramp.
At time t= 0.3s, speed is ramping to final value. The electromagnetic torque decrease to 400 Nm and then stabilize at 600 Nm.
At t = 0.5 s, the full load torque is applied to the motor shaft while the motor speed is still ramping to its final value. This forces the electromagnetic torque increase and stabilize at 600 Nm once the speed ramping is completed and the motor has reached 300 rpm.
At t = 1 s, the speed set point is changed to 0 rpm. The speed decreases down to 0 rpm by following precisely the deceleration ramp even though the mechanical load is

inverted abruptly, passing from 592 Nm to - 592 Nm, at t = 1.5 s. Shortly after, the motor speed stabilizes at 0 rpm.



Result of torque Hysteresis DTC Controller of Three Phase induction Motor

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REFERENCES

[1] Takahashi. I and Noguchi. T (1986); “A new quick response and high efficiency control strategy of an induction motor” IEEE Transactions on Industrial Application, Vol. 22, No. 5, pp. 820-827, Japan.

[2] Depenbrock. M (1988); “Direct self control (DSC) of inverter-fed induction Machines”, IEEE Transactions on Power Electronics, Vol. 3, No. 4, pp. 420-429, West Germany.

[3] Takahashi. I and Ohmori. Y (1989); “High-performance direct torque control of induction motor”, IEEE Transactions on Industrial Application, Vol. 25, No. 2, pp. 257-264, Japan.

[4] Badder. U and Depenbrock. M (1992); “Direct self control (DSC) of inverter-fed induction machines: A basic for speed control without speed measurement”, IEEE Transactions on Industrial Application, Vol. 28, No. 3, pp. 581-588, West Germany.

[5] Lascu. C , Boldea. I and Blaabjerg. F (2000); “A modified direct torque control for induction motor Sensorless drive Applications”, IEEE Transactions on Industry Applications, Vol. 36, No. 1, pp. 122-130,

[6] 6. Domenico Casadei, Francesco Profumo, Giovanni Serra and Angelo Tani (2002); “FOC and DTC: Two Viable Schemes for Induction Motors Torque Control”, IEEE Transactions on Power Electronics, Vol. 17, No. 5, pp. 779-787, Itlay.