“ANALYSIS AND INVESTIGATION OF DIFFERENT TWO HIGH PERFORMANCE CONTROLLED STRATEGIES, FOC AND DTC FOR AN I.M. DRIVE”

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Abstract: Mechanical energy is needed in the daily life use as well as in the industry.Drives are required in large number of industrial and domestic applications like transportation systems, rolling mills, paper machines, textiles mills, machine tools etc. Induction motor drives may be classified into two main control strategies. Scalar control, of the voltage magnitude and frequency is one. A second is controlling both the voltage vector and the frequency, which can be FOC or Direct Torque Control (DTC).

INTRODUCTIO N

Mechanical energy is needed in the daily life use as well as in the industry. Induction motors play a very important role in both worlds, because of low cost, reliable operation, robust operation and low maintenance. There are two main types of induction motors which are the wounded rotor and squirrel-cage design and both of them are in widespread use. Squirrel-cage rotor winding design is considered of the two more reliable and cheaper to make In this thesis a comparison of two of the most commonly used electric drive methods of induction motors (IM) has been carried out. These methods, which have been used for three decades are Field Orientation Control (FOC) and Direct Torque Control (DTC). Theoretical background for both methods is explained. Due to its simplicity of use, MATLAB/ SIMULINK is used to simulate the dynamic model of (IM) and applying both techniques on it. The comparative study of speed, torque, and flux is performed in detail. The proposed control method is been employed with MATLAB simulation to a 1 HP, 415Volts, 50 Hz , 4 pole, 1.8 amp, 0.8 pf squirrel cage Induction Motor .

In 1971, Blaschke [10] encompassed the advantages of dc motor into ac motor and named his invention as “field-oriented control”. In due course, the vector control or so called field-oriented,

M. Depenbrock [15]and I. Takahashi et al [16] proposed simplified version of vector control method called Direct Torque Control (DTC). In this method the torque & flux values and stator flux position are estimated under stator co-ordinate system.

1 Motivation for Thesis One motivation for doing this thesis as a comparative study between FOC and DTC, is that few research papers were published on this topic as a comparative study and a detailed study to explore future control approaches is required. As many papers, on the other hand, were written about DTC and FOC individually and using many types of controllers trying to improve the performance of those methods of motor control. The other motivation is that all those papers and studies were done based on the performance comparison only assuming that everything is in normal operation which is not always the case. Therefore, two power quality issues are included in these comparison studies which are the voltage sag and short interruption.

In this thesis a comparison of two of the most commonly used electric drive methods of induction motors (IM) has been carried out. These methods, which have been used for three decades are Field Orientation Control (FOC) and Direct Torque Control (DTC). MATLAB/ SIMULINK is used to simulate the dynamic model of (IM) and applying both techniques on it.

2. Induction Motors

An induction or asynchronous motor is an AC electric motor in which the electric current in the rotor needed to produce torque is induced by electromagnetic induction from the magnetic field of the stator winding. An induction motor does not require mechanical commutation, separate-excitation or self-excitation for all or part of the energy transferred from stator part to rotor part, as in universal, DC and synchronous motors. An induction motor's rotor can be either wound type or squirrel-cage type .

2.1 Introduction To Modeling Of Induction Machine

The per-phase equivalent circuit of a machine is valid in steady-state condition only. Where studying the steady-state performance of a electrical machine, the electrical transients are ignored during load changes and stator frequency variations. In an adjustable-speed drive.

2.2 Three – Phase Model of Symmetrical Induction Machine A Symmetrical three-phase, two-pole IM (as shown in Fig. 2.1) is considered here. The following assumptions are made to simply the

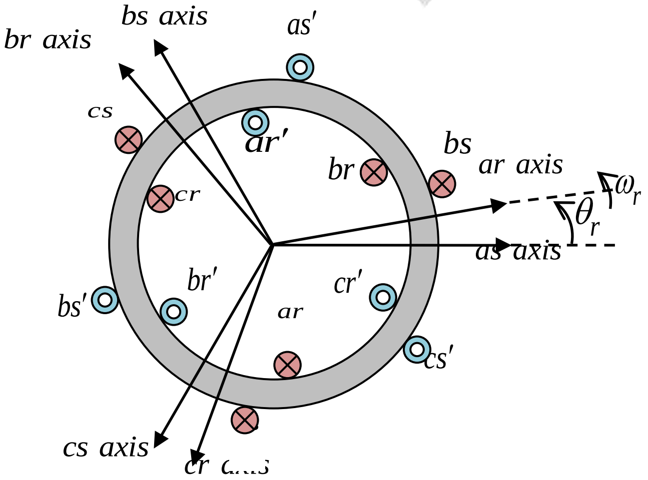


Fig. 2.1 Cross – section of symmetrical three-phase induction machine

2.3 Torque in separately excited dc motor

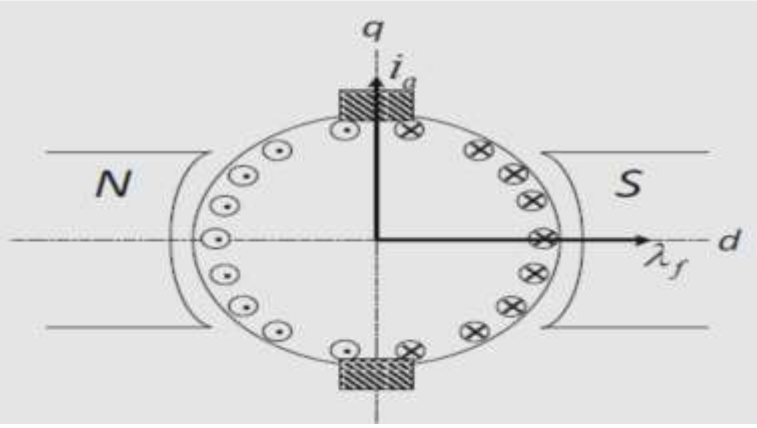


Figure 2.2 Simple representation of separately excited DC motor.

By looking to the Fig 2.2 which represents a simple model of separately excited dc motor, the field circuit is shown as two poles pointed as N and S. The armature circuit represented as two brushes which connect the current to the coils in the armature. The field space vector λf is produced by the stator pole which is on the same line with the direct axis By looking which represents a simple model of separately excited dc motor, the field circuit is shown as two poles pointed as N and S. The armature circuit represented as two brushes which connect the current to the coils in the armature. The field space vector λf is produced by the stator pole which is on the same line with the direct axis

3.TORQUE EQUATIONS FOR VECTOR CONTROL

All vector control strategies agree that the machine torque and the flux linkage can be controlled using the stator current vector alone . That is the flux linkage component on the q-axis of synchronous frame, and equal to zero because the rotor flux is aligned with the d-axis as shown in Fig 3.2.

$\lambda qr' e=Lmiqse+Lr'iqr' e=0$ $Wb. Turn$ (3.2)

$iqr' e=-LmLr'iqseA$ (3.3)

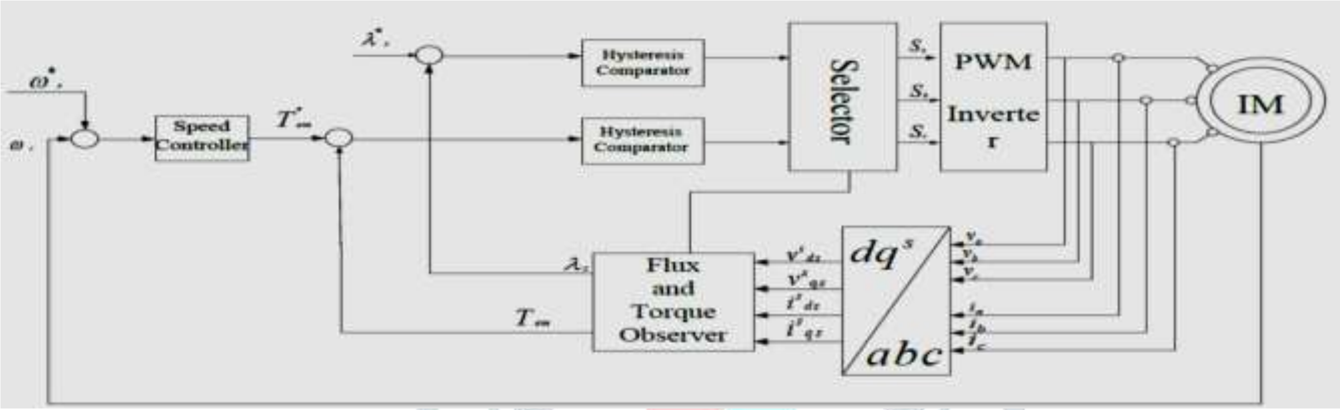
3.1 METHODS VECTOR CONTROL The way of determining the angle (position) of the rotor flux vector, rotating at the synchronous speed, depends on the type of the field orientation: either direct field orientation or indirect field orientation

3.2 Direct Field Orientation Method (DFO)

When the identification of the flux vector is done by direct Hall sensor measurement or even indirectly by estimation of other motor electrical variables, it is called direct field orientation

3.3 Schematic of Stator Flux Based DTC

The schematic of stator flux based DTC is given in Fig. 3.3. The torque and stator flux reference values are produced by PI controller and field-weakening controller respectively. As shown, the DTC contains two different loops corresponding to the magnitudes of the stator flux and torque. The reference values of the stator-flux modulus and torque are compared with the actual values,



4. VECTOR CONTROL BLOCK

It is the main block which performs vector control operation for induction motor

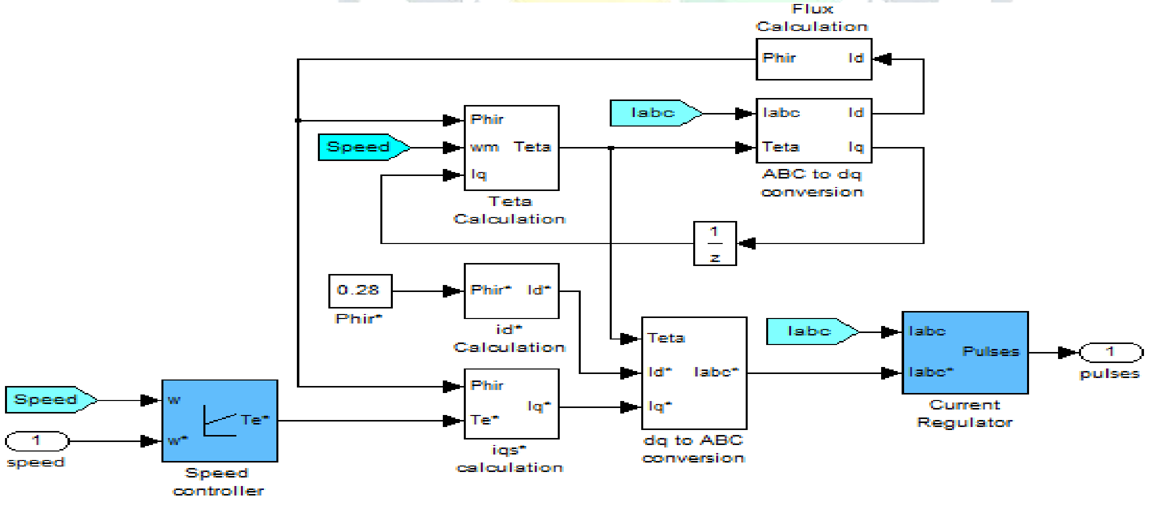


Fig. 2.3 vector control block

4.1 DEVELOPMENT OF SIMULATION MODEL OF DTC

The Simulink model of Direct Torque Control Induction Motor has been discussed in detail in this section. It contains six main blocks consisting of current and voltage transformation block, torque and flux estimation blocks, block for estimation of flux magnitude and for estimation of reference torque. These blocks using Simulink/Matlab are shown below one by one along with their equations.

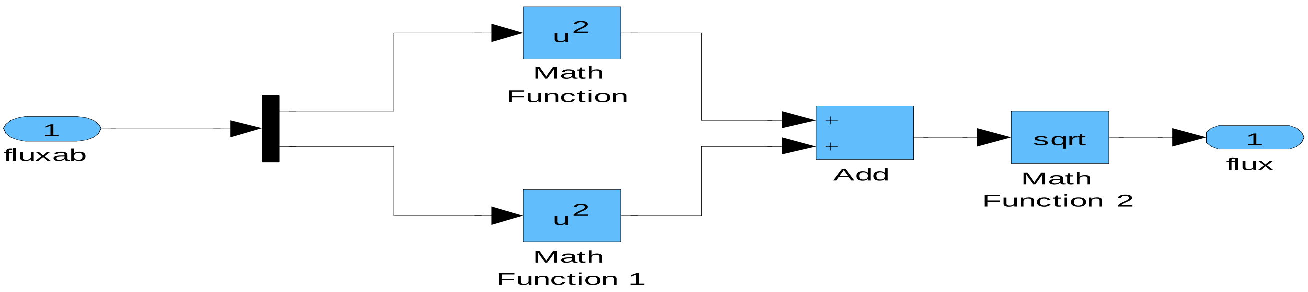


Fig 2.4 Simulink Model for Estimation of Flux Magnitude

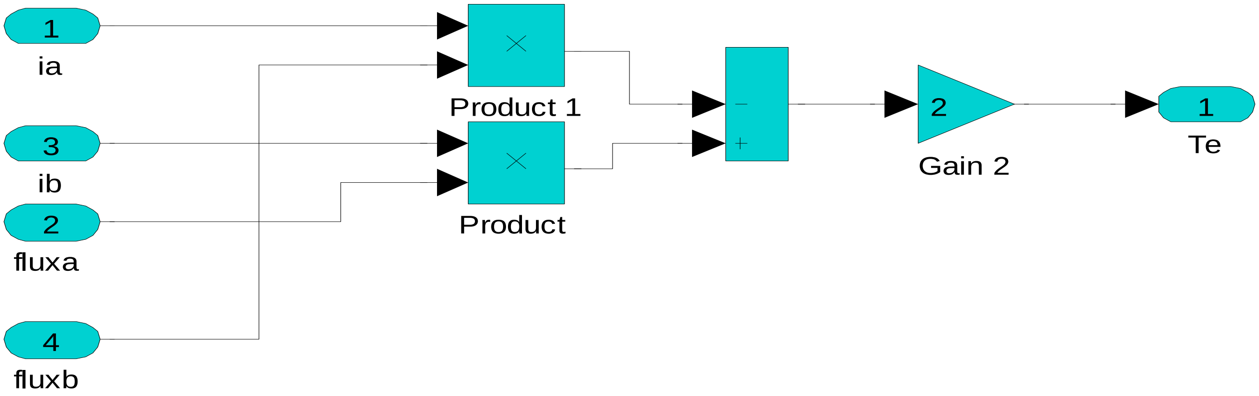


Fig 2.5 Simulink Model for Estimation of Torque

4.2 Implementation of Proposed Scheme

The speed control algorithm implemented for the proposed drive is shown in Fig.5.14. It is a conventional PI control based scheme.

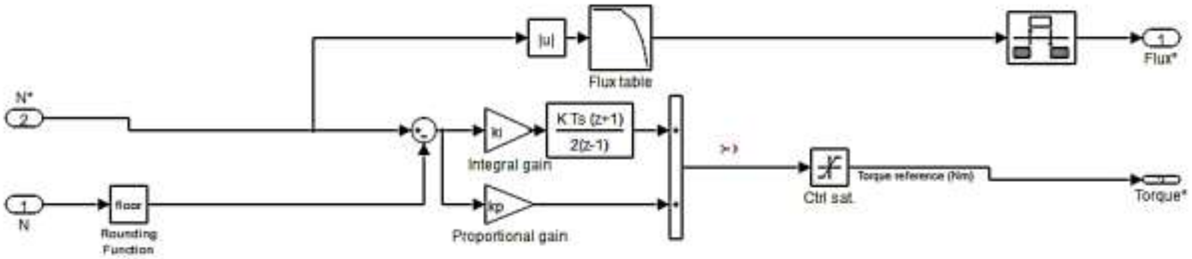


Fig 2.6 Simulink Model for Speed Control

5. Results for DTC Algorithm

A series of simulations are conducted on proposed DTC drive to evaluate its performance of proposed algorithms. This section discusses the simulation results for different operating condition of the drive. This section deals with the simulation results for stator currents; torque response and speed response of direct torque controlled Induction Motor, varying speed and Constant flux.

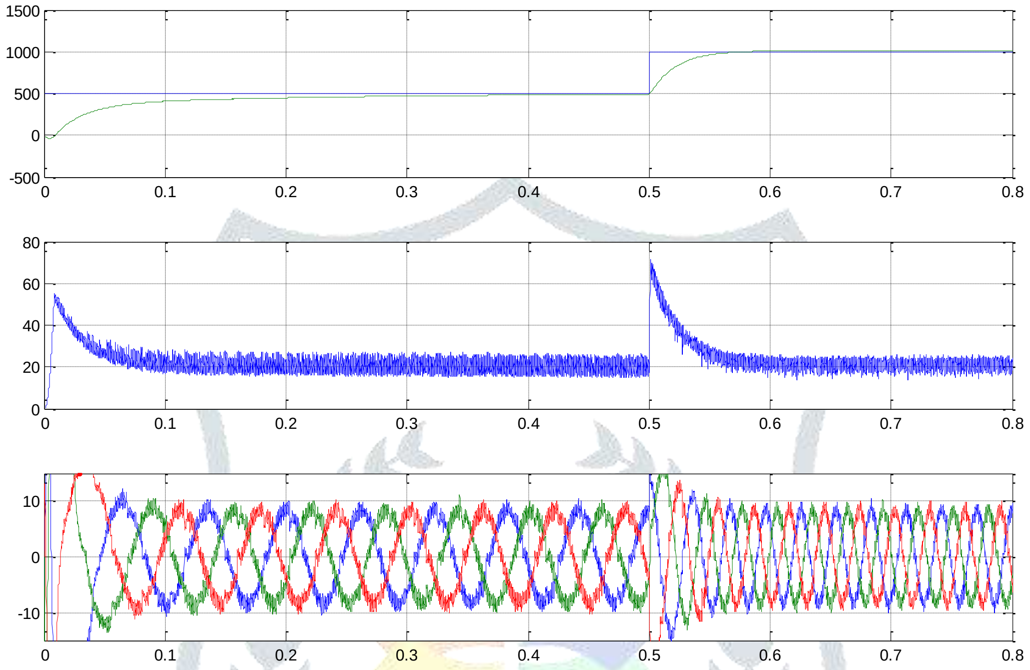


Fig.2.7 Simulation results for (a) speed response(b)Torque response(c)Stator currents for proposed DTC

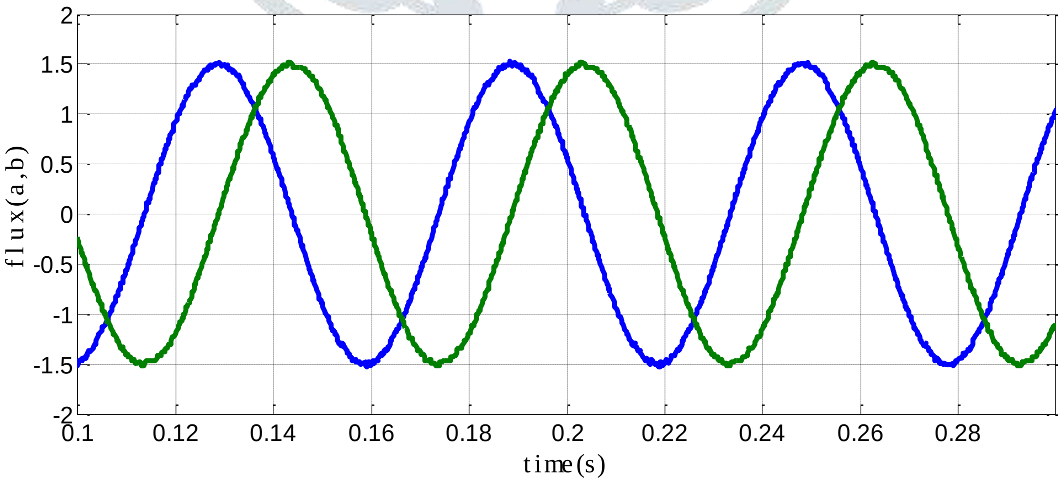


Fig.2.8 Simulation results of flux for proposed DTC

5.1 Simulation Results for Varying Speeds

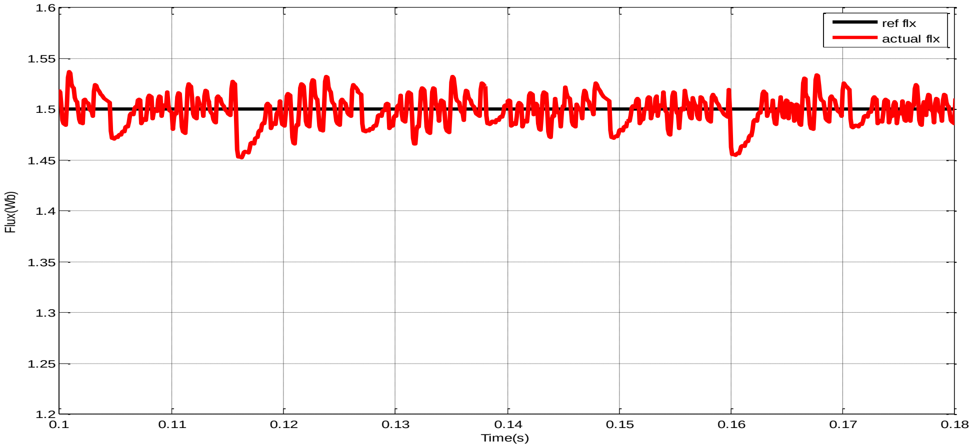
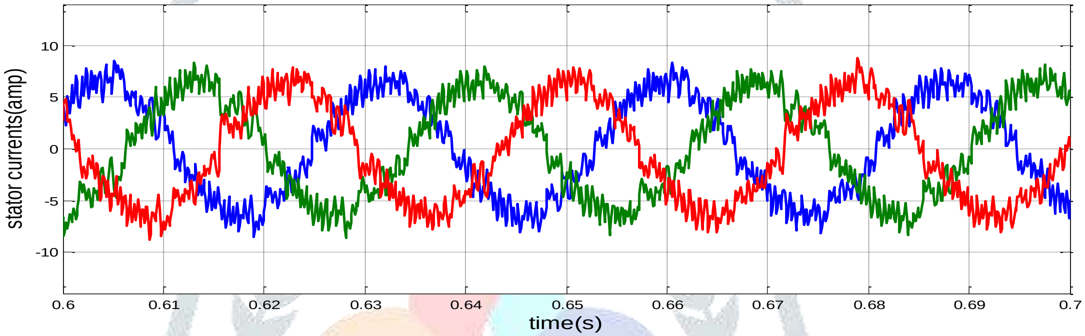


Fig.2.9 Simulation result of proposed DTC for Constant Flux with 20N-m load for varying speeds



Simulation results for Stator currents of induction motor for proposed DTC at varying speed (0-500) and 20N-m load

5.2 Simulation Results For Varying Torques

Further shown simulation results for varying torques of the proposed conventional Direct Torque Control shows in fig the steady state stator currents for a step load of 5 N-m – 20N-m. The reference speed is set at 1500rpm with a constant flux of 1.5 Wb.

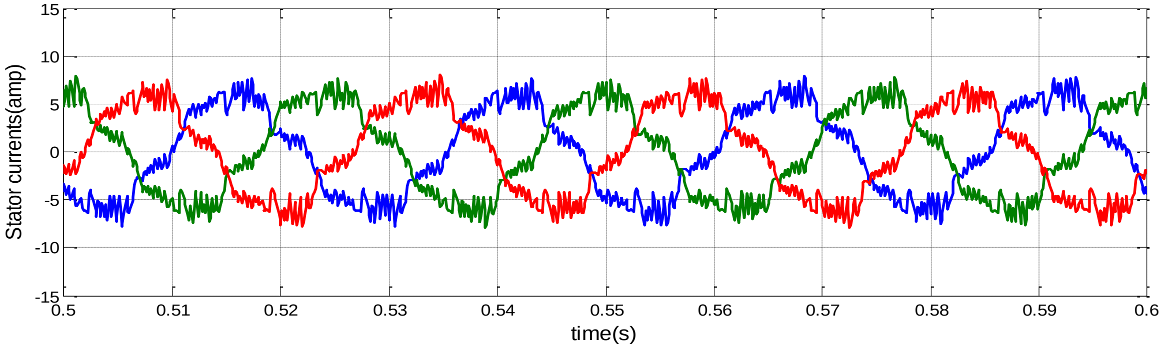
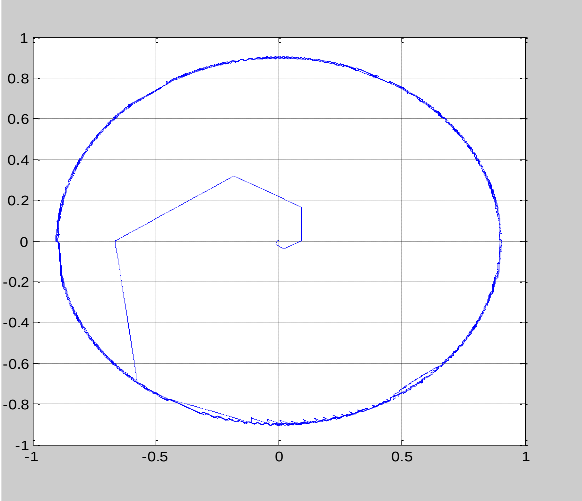
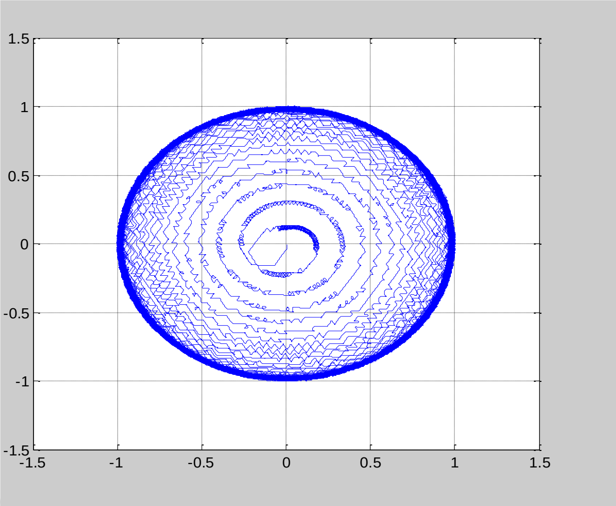


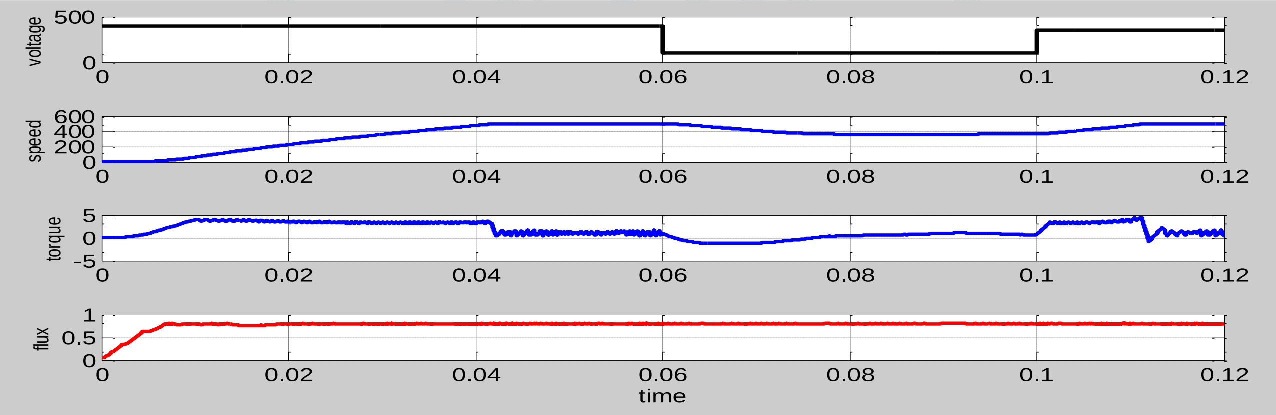
Fig 2.10 simulation results for steady State stator currents

6 . PERFOMANCE COMPARISON

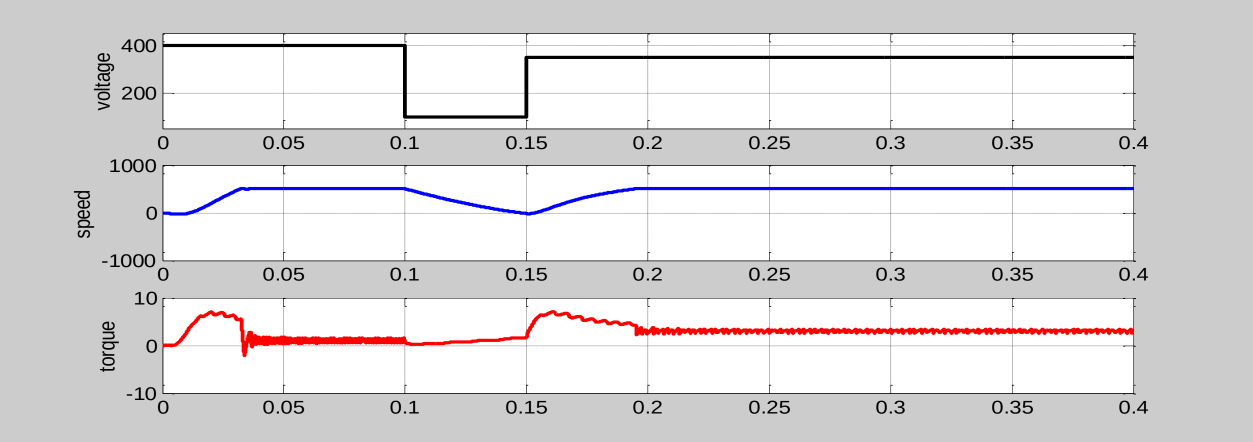




Flux trajectory (DTC) Flux trajectory (FOC)



Response for voltage sag (DTC)



Response for voltage sag (FOC)

CONCLUSIONS

The final conclusions that can be drawn from the proposed study based on simulation results can be summarised as under. In this thesis project, two induction motor drive techniques (FOC and DTC) are first studied theoretically by using MATLAB/SIMULINK. We also explained the basic principles of those two differing methods and the mathematical representations and the needed operation to achieve the high performance control. Those methods are compared are tested using MATLAB/SIMULINK for the following cases Thus it can be finally concluded that DTC and FOC are two advanced control algorithm which can emulate the performance of a DC drive in a AC drive. Both the techniques can have a decoupled control of torque and flux,

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