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Torque Control of Induction Motor Using Simulink/Matlab

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Abstract-A novel technique of controlling induction motor, called direct torque control which controls both electromagnetic torques, flux, directly and independently, is the topic of this work. The evolution of direct torque control from other prevalent control strategies has been outlined. A dynamic model of direct torque control scheme for an induction motor has been developed using SIMULINK / MATLAB.

1. INTRODUCTION

The induction motor is the workhorse of the Industry. According to an estimate, seventy percent of electrical motors are induction motors. This is due to the fact that it is simple, rugged, reliable, less costly, compact and economical. The induction machine with squirrel cage rotor is most widely used at fixed speed at lower power levels. In the past, DC motors were extensively used in areas where variable speed operation was required, since heir flux and torque could be controlled easily by the field and armature current. However DC motors have certain disadvantage especially due to the presence of commutator and brushes that require periodic maintenance.. The study of dynamic performance in terms of analysis and simulation helps in understanding the starting phenomenon, machine stability problem and dynamic behavior of the motor under various operating conditions. Accurate analysis and simulation is very important to minimize costly replication of designs [2]. These simulation results can also be comprehensive documentation to assess the change in motor performance due to parameter variations. Direct Torque control is a revolutionary control method of ac drives which allows direct, accurate and independent control of both torque and speed without pulse encoder feedback from the motor shaft down to zero speed. This technique works using flux and torque as primary variables. This control scheme allows very fast torque responses and flexible control of an induction machine. Hence, this type of control can be used in high performance drives like industrial machine tools, spindle drives, cutters, rollers, etc. as it can instantly react to dynamic changes. This project work is an attempt to model direct torque Control of induction motor on MATLAB/SIMULINK (application software) platform, which is an equation solver program. In order to achieve this, the general dynamic model of three-phase induction machine (in stationary reference frame) is created in this application software platform. This model is represented by a sixth order state space equation. The behavior of the machine model is studied by simulating various dynamic operating conditions of the machine and analyzing its performance parameters as a motor. The objectives of the project are to understand the concept of Direct Torque Control (DTC) as applied to the induction motor, To Create a 'SIMULINK' model for DTC of a three

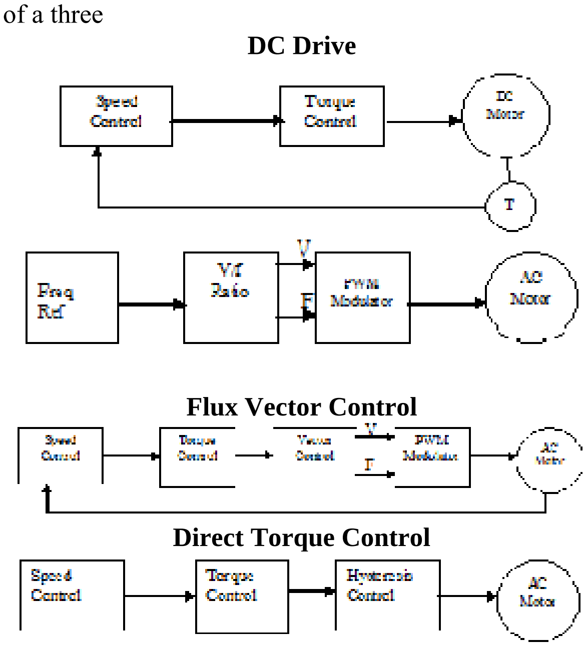

Fig.1 Evolution of Drive Control Techniques

-phase induction motor and to study the dynamic response of the model in motoring mode during the various operating conditions like starting, reversal and change of reference speed setting.

2. DIRECT TORQUE CONTROL CONCEPT

Direct torque control has its roots in field-oriented control and direct self control. Field-oriented control uses spatial vector theory to optimally control magnetic field orientation. It has been successfully applied to the design of flux vector controls and is well documented. Direct self-control theory is less well known. The fundamental premise of direct self control is as follows. Given a specific dc-link voltage (Edc) and a specific stator flux level (ψref), a unique frequency of inverter operation is established. This is true because the time (T) required by the time integral of the voltage (Edc) to integrate up to the field flux level (ψref) is unique and represents the half-period time of the frequency of operation. Since the operational frequency is established without a frequency reference, this operational mode is referred to as direct self control [10]. Output frequency is, thus, not requested, but rather, is self-controlled via the actual frequencies present. Once sensed, whether the frequency increases or decreases depends on what the torque reference from the speed regulator requests. Differential changes to operational frequency are determined by the torque request. Direct torque control combines field-oriented control theory, direct self-control theory, and recent advances in digital signal processor (DSP) and application specific Integrated Circuit (ASIC) Technology to achieve a practical sensor less variable frequency drive.

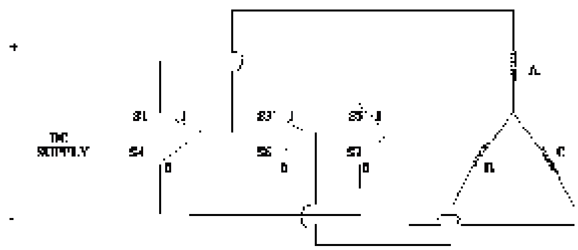

Fig.2 : Direct torque-control scheme

Fig.2 shows the basic functional blocks used to implement the core of the direct torque-control scheme. The relationship of this core to the complete control will be described in a subsequent section. Three key blocks interact to provide the primary control required:1)torque/flux comparators; 2) optimal switching logic; and 3) adaptive motor model. The torque comparator and the flux comparator are both contained in the hysteresis control block. These function to compare the torque reference with actual torque and the flux reference with actual flux. Actual levels are calculated by the adaptive motor model. When actual torque drops below its differential hysteresis limit the torque status output goes low. Similarly, when actual flux drops below its differential hysteresis limit, the flux status output goes high and when actual flux rises above its differential hysteresis limit, the flux status output goes low.

3. MODELING OF INDUCTION MOTOR

Induction motor can be represented by the following equations in “dq0” format, in arbitrary reference frame, which is rotating at an angular speed in the direction of rotation of the rotor:

$Vqs = RsIqs + \omega\psi ds + p\psi qs$ (1)
$Vds = RsIds - \omega\psi qs + p\psi ds$ (2)
$Vos = RsIos + p\psi os$ (3)
$Vqr = RrIqr + (\omega - \omega r)\,\psi dr + p\psi qr$ (4)
$Vdr = RrIdr - (\omega - \omega r)\,\psi qr + p\psi dr$ (5)
$Vor = RrIor + p\psi or$ (6)

Also,

$\psi qs = (Lls + Lm)Iqs + LmIqr$ (7)
$\psi ds = (Lls + Lm)Ids + LmIdr$ (8)
$\psi os = LlsIos$ (9)
$\psi qr = Lm\, Iqs + (Llr + Lm)Iqr$ (10)
$\psi dr = Lm\, Ids + (Llr + Lm)Idr$ (11)
$\psi or = LlrIor$ (12)
$\psi ds = \int (vds - RsIds)dt$ (13)
$\psi qs = \int (vqs - RsIqs)dt$ (14)

For a balanced three phase system, the zero sequence components are zero and for a squirrel cage induction motor, Vqr = Vdr = 0. Also, as the motor is modeled in stationary frame of reference ω = 0. With above considerations and further simplification, we have following set of equations:

□qr = Iqs(LmRr / (Lr s +Rr))+ □dr (Lrωr /(Lr.s + Rr)) (15)

□dr = Ids (LmRr / (Lr.s +Rr)) - □qr (Lrωr /(Lr s + Rr)) (16)

Ids = Vds(1/ Lsm s + Rs)) – (□dr / Lr) (Lm s / (Lsm s + Rs)) (17)

Iqs = Vqs (1/ (Lsm s + Rs)) – (□qr / Lr) (Lm s / (Lsm s + Rs)) (18)

Where, Ls = Lls + Lm, Lr =Llr + Lm and Lsm =Lm + Lls – (Lm 2 / Lr)

With the help of equations (13) to (18), motor is modeled. For electromagnetic torque calculation following equations is used:

Tem = (3/2)(p/2)(Lm / Lr) (□drIqs – □qr Ids) (19)

Tem – Tload = J (dωr / dt) (20)

For motoring operation load torque is positive and for generating mode of operation load torque is negative.

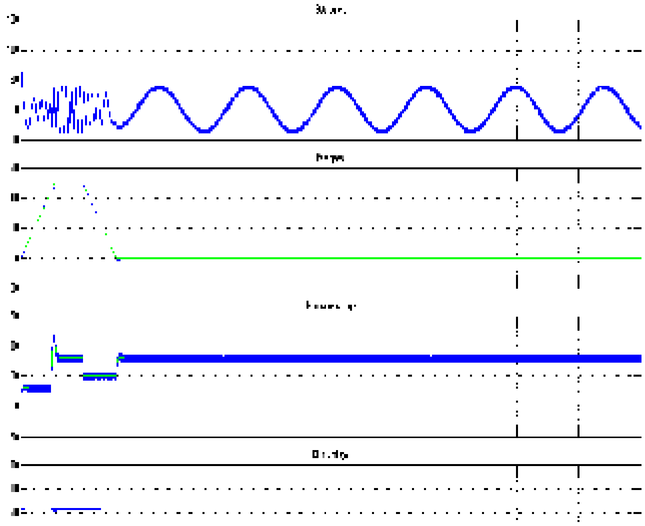

Fig. 3

4. SIMULATION RESULTS

The model which is developed was simulated for an induction motor of rating 1.1 KW (machine parameters are given in appendix A) Simulation results in form of computer traces of electromagnetic torque developed, estimated torque , estimated and actual speed, stator flux and stator current have been depicted in this chapter. Simulation is done for following two cases:

Case A

The motor was started at no load with a set speed of 150 rad/sec and at t=0.5 sec a load torque of 5 Nm.(65 % of rated torque) was applied. API controller is employed in the speed loop to make the steady state error in speed zero. The values of Kp and Ki are changed to obtain plots showing the dependence of the Simulation result of Stator current , Rotor speed ,Electromagnetic torque,and DC bus voltage performance on Kp and Ki Following observations were made:Case A has been analyzed for the following two conditions:

i) With Kp = 4.0 and Ki=0.4, the starting time of the motor is 0.12 sec. Amplitude of steady state oscillations (peak to peak) in the electromagnetic torque plot is 1.3 Nm and peak overshoot is 9.3 Nm.

ii) With Kp = 20 and Ki =0.4, the starting time of the motor is 0.13 sec. Amplitude of steady state oscillations (peak to peak) in electromagnetic torque plot is 2.2 Nm and peak overshoot is 9.4 Nm.

Similarly,

Case B

Ithas also been simulated for the following two conditions:

i) With Kp =4.0 and Ki =0.4 the starting time of the motor is 0.13 sec. Amplitude of steady state oscillations (peak to peak) in electromagnetic torque plot is 1.7 Nm and peak overshoot is 9.2 Nm. Speed reversal time is 0.13 sec.

ii) With Kp = 20 and Ki = 0.04, the starting time of motor is 0.14 sec. Amplitude of steady state oscillations (peak to peak) in electromagnetic torque plot is 2.1 Nm and peak overshoot is 9.4 Nm. Speed reversal time is 0.13sec.

Estimated Flux remains the same in all the cases a shown in Fig. From then plots it is seen that estimated torque and electromagnetic torque are close to each other. Also actual and estimated speed plots are close to each other. By increasing the value of Kp, the pulsations in the electromagnetic torque increase. The response of the model for Kp=4.0 and Ki = 0.4 is the best in terms of staring time and peak overshoot and undershoot.The suitable values of Kp and Ki have been arrived at by trail In the present chapter motoring operation under different conditions of operation and the effect of Kp and Ki on parameter estimation has been studied.

5. CONCLUSION

Direct torque control combines the benefit of direct flux and torque control into sensor less variable frequency drive that does not require a PWM modulator. Recent advances in digital signal processor and application specific integrated circuit and the theoretical concepts eveloped so far for direct self control make this possible. The objective of the present work was to make a model of direct torque control of three phase induction motor .Various speed control schemes were studied and extensive literature survey was carried out for understanding the direct torque control technique. MATLAB/SIMULINK was chosen as modeling and simulation tool because of its versatility. Model for direct torque controlled induction motor was developed using MATLAB/SIMULINK and performance of the system for different operating condition like starting, load changes, speed reversal, effect of changing the values of Kp and Ki on the performance characteristics, was studied. The model was validated by comparing the plots of various performance parameters with those available with literature. It was also observed that for motoring operation, the performance was best in terms of starting time, overshoot and undershoot when the value of Kp is 4 and that of Ki is 0.4.

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