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SENSORLESS VECTOR CONTROL OF THREE PHASE INDUCTION MOTOR

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Abstract: - This paper presents the management of Associate in nursing induction motor through sensorless vector management. The theoretical basis of every algorithmic program is explained thoroughly and its performance is tested on Matlab. Vector management of induction motor is predicated upon the field-oriented co-ordinates aligned within the direction of the rotor m.m.f. However, there's no direct means that of measurement the rotor flux linkage position ρ and thus Associate in Nursing observer is required to estimate ρ for the implementation of sensor less vector management.

Keywords: Induction motor drive, sensorless vector control, indirect vector control, MRAS, DSP controller

1.1 INTRODUCTION

Induction motors are comparatively rugged and cheap machines. thus a lot of attention is given to their management for varied applications with completely different management needs. Associate in Nursing induction machine, particularly coop induction machine, has several benefits in comparison with DC machine. 1st of all, its rock bottom. Next, it's terribly compact structure and insensitive to surroundings. moreover, it doesn't need periodic maintenance like DC motors. However, as a result of its extremely non-linear and matched dynamic structure, Associate in Nursing induction machine needs additional complicated management schemes than DC motors. Ancient open-loop management of the induction machine with variable frequency might give a satisfactory answer underneath restricted conditions. With the arrival of power physical science, new impulse was given to variable speed applications of each DC and AC machines. The previous generally use thyristor controlled rectifiers to supply high performance force, speed and flux management. Variable speed IM drives use primarily PWM techniques to come up with a poly part offer of a given frequency. Most of those induction motor drives are supported keeping a relentless voltage/frequency (V/f) quantitative relation so as to take care of a relentless flux within the machine. though the management of V/f drives is comparatively easy, the force and flux dynamic performance is extraordinarily poor. As a consequence, nice quantities of business applications that need smart force, speed or position management still use DC machines. the benefits of induction machines are clear in terms of strength and price; but it absolutely was not till the event and implementation of field oriented management that induction machines were able to vie with DC machines in high performance applications.

Conventionally, a PI controller has been used for the speed regulation to come up with a command current for last 20 years, and accepted by trade as a result of its simplicity. albeit, a well-tuned PI controller performs satisfactorily for a field-oriented induction machine throughout steady state. The speed response of the machine at transient, particularly for the variable speed following, might generally be problematic. In last 20 years, different management algorithms for the speed regulation were investigated. the varied speed estimation ways are:

1. Model Reference adaptive Systems (MRAS) a pair of. Kalman filter techniques

3. adaptive observers supported each voltage and current model four. Neural network flux and speed estimators five. Sliding mode flux and speed estimators.

In MRAS, in general, a comparison is formed between the outputs of 2 estimators [8, 10]. The figure that doesn't contain the number to be calculable is thought-about as a reference model of the induction machine. The opposite one that contains the calculable amount is taken into account as Associate in nursing adjustable model. The error between these 2 estimators is employed as Associate in nursing input to Associate in nursing adaptation mechanism. For sensorless management algorithms most of the days the number that differentiate reference model from the adjustable model are that the rotor speeds. The calculable rotor speed within the adjustable model is modified in such some way that the distinction between 2 estimators converges to zero asymptotically, and therefore the calculable rotor speed are going to be adequate to actual rotor speed. Kalman filter (KF) is Associate in nursing other methodology utilized to spot the speed and rotor-flux of an induction machine supported the measured quantities like stator coil current and voltage [11]. Kalman filter approach relies on the system model and a mathematical model describing the induction motor dynamics for the utilization of Kalman filter application. Parameter deviations and measuring disturbance are taken into thought in KF. For this purpose variance matrices of the KF should be properly initialized. KF itself works for linear systems, thus for non-linear induction motor model extended Kalman filter (EKF) is employed [12]. However, KF approach is computationally intensive and depends on the accuracy of the model of the motor. Over the past 20 years an excellent deal of labor has been done into techniques like Field minded management, direct force management and house Vector Pulse dimension Modulation. Another rising space of analysis involves the applying of sensorless management. This differs from typical ways as a result of it doesn't need mechanical speed or position sensors. Removing these sensors provides variety of benefits like lower production prices, reduced size, accumulated reliable ness and elimination of excess cabling. Sensorless drives also are additional appropriate for harsh inaccessible environments as they need less maintenance. This work is principally centered on the sensorless vector management of induction motor. For this purpose, model reference adaptive system (MRAS) is employed to estimate the rotor speed. Victimization this system, one will acquire terribly precise flux and speed data as shown within the simulation and tested results. Here planned 1st the Dynamic model of induction machine was developed within the capricious organization. With the assistance of synchronous organization model the indirect field minded vector management that is incredibly widespread and convenient methodology in real time implementation was developed. Third, Model Reference adaptive System is studied as a state figurer. Rotor flux estimation theme is applied to MRAS formula to estimate rotor speed. Lastly 2 modules (Current & voltage sensing module and MRAS observer module) of sensorless vector management are tested on DSP controller TMS320C240.

2.1 INDUCTION MACHINE CONTROL

The controllers required for induction motor drives can be divided into two major types: conventional low cost volts per hertz v/f controller and torque controller [1, 2]. In v/f control, the magnitudes of the voltage and frequency are kept in proportion. The performance of the v/f control is not satisfactory, because the rate of change of voltage and frequency has to below. A sudden acceleration or deceleration of the voltage and frequency can cause a transient change in the current, which can result in drastic problems. Some efforts were made to improve v/f control performance, but none of these improvements could yield a v/f

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torque controlled drive systems and this made DC motors a prominent choice for variable speed applications.

2.1.1. VECTOR CONTROL

To emulate the magnetic operational conditions of a DC motor, i.e. to perform the sphere orientation method, the flux-vector drive has to understand the special spatial relation of the rotor flux within the AC induction motor. With flux vector PWM drives, field orientation is achieved by electronic means that instead of the mechanical commutator/ brush assembly of the DC motor.

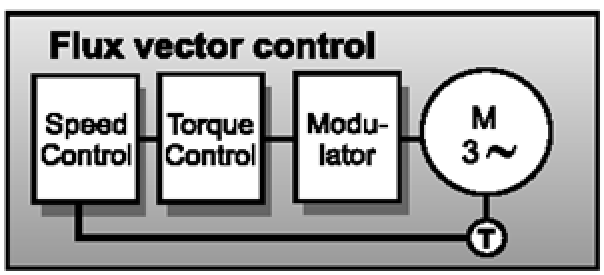

Fig.1. Flux vector control

Firstly, data regarding the rotor standing is obtained by feeding back rotor speed and spatial relation relative to the mechanical device field by means that of a pulse encoder. A drive that uses speed encoders is spoken as a "closed-loop drive".

2.1.2 FIELD ORIENTATION CONTROL OF INDUCTION MACHINE

The concept of field orientation control is used to accomplish a decoupled control of flux and torque. This concept is copied from dc machine direct torque control that has two requirements [2]: An independent control of armature current to overcome the effects of armature winding resistance, leakage inductance and induced voltage; An independent control of constant value of flux;

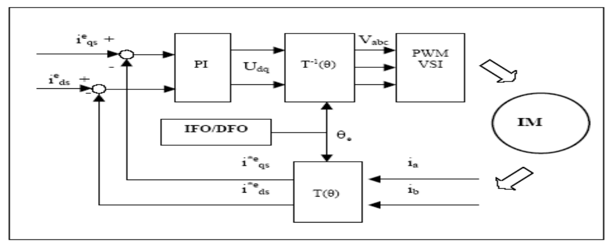

Fig.2. Field Oriented induction Motor Drive System

The control algorithm for calculation of the rotor flux angle using IFO control is shown in the Fig 3. This algorithm is based on the assumption that, the flux along the q-axis is zero, which forces the command slip velocity to be $w_{sl} = i^*_{qs}/(T_r i^*_{ds})$ as a necessary and sufficient condition to guarantee that all the flux is aligned with d-axis and the flux along q-axis is zero.

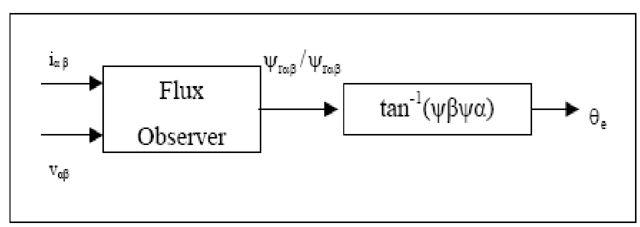

Fig.3 Direct Field Oriented Drive System

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2.1.3 SENSORLESS VECTOR CONTROL

Sensorless vector control of an induction motor drive essentially means vector control without any speed sensor. An incremental shaft – mounted speed encoder is required for closed loop speed control. A speed signal is also required in indirect vector control in the whole speed range, and in direct vector control in low speed range including zero speed at start - up operation. A speed encoder is undesirable because it adds cost and reliability problems, besides the need for the shaft extension and mounting arrangements. It is possible to estimate speed signal from machine terminal voltages and currents with the help of a DSP.

3. SIMULINK IMPLEMENTATION AND THEIR RESULTS

The inputs of a squirrel cage induction machine are the three-phase voltages, their fundamental frequency, and the load torque. The outputs, on the other hand, are the three phase currents, the electrical torque, and the rotor speed. The d-q model requires that all the three-phase variables have to be transformed to the two-phase arbitrary rotating frame. Consequently, the induction machine model will have blocks transforming the three-phase voltages to the d-q frame and the d-q currents back to three-phase. There are four important blocks present in D-Q model implementation of simulink.

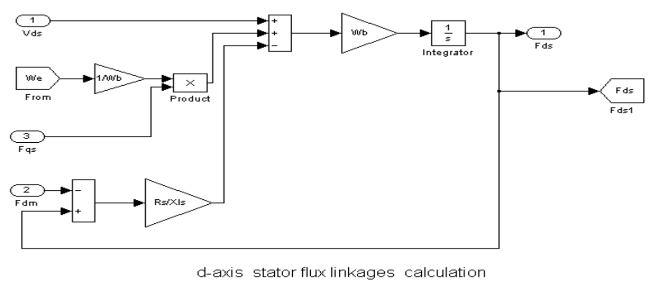

Fig.5 Simulation model of induction motor

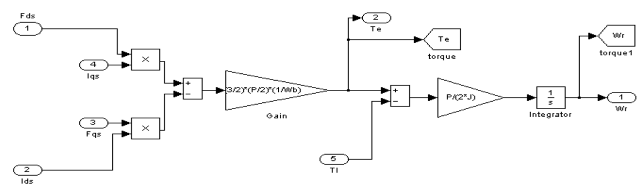

Fig. 6 Simulation model for speed control of induction motor

3.6.1 SIMULATION RESULTS

Free acceleration characteristics of induction motor are given with load torque zero. Simulation is done in various reference frames like arbitrary (W_a=100), synchronous (N=synchronous speed), Rotor (W_a=W_r) and stationary reference frames (W_a=0). From graphs we can conclude that the shape of speed torque characteristics of machine does not depend on reference frame we have chosen. But the corresponding d-q axis currents and fluxes are changing with change in reference frame. The step response of load torque is also shown in the graph. From this graph it can be observed that

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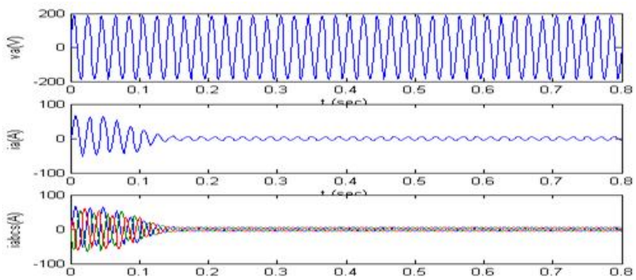
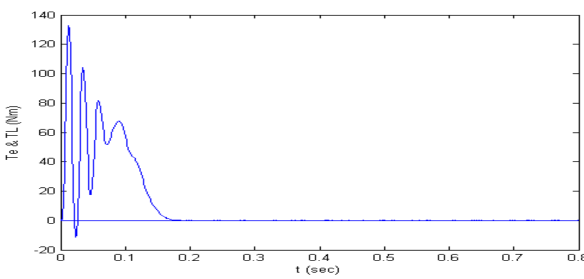
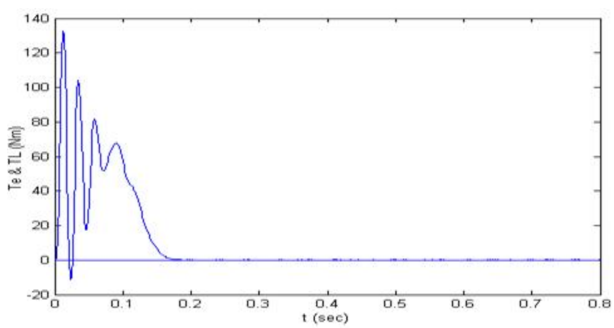
the response of an induction motor due to load torque is very sluggish and takes too many oscillations to reach steady state. Therefore by employing vector control we can avoid this sluggish response by perfect decoupling Torque and Flux.



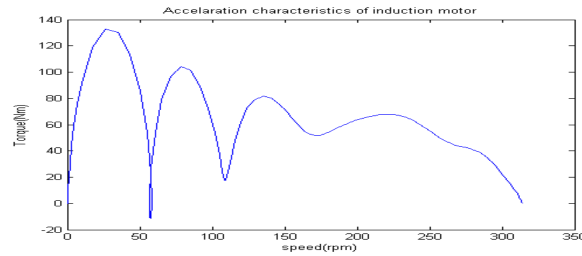
Graph: 3.1. No-Load response of stationary Frame induction motor model



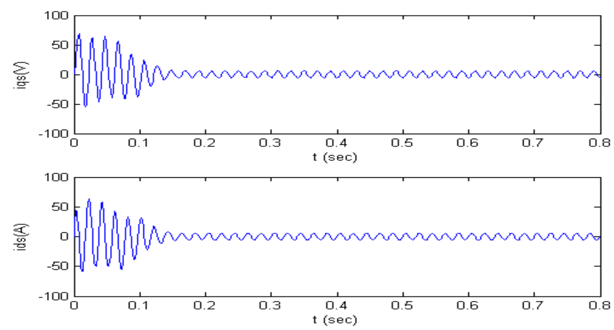
Graph: 3.2.Torque response in direct AC startup with T_L=0



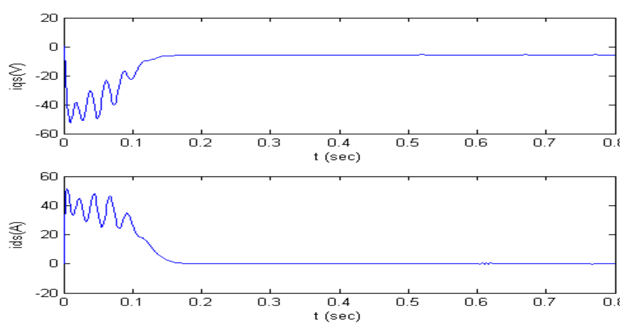
Graph:3.3. Speed response in direct AC startup with T_L=0



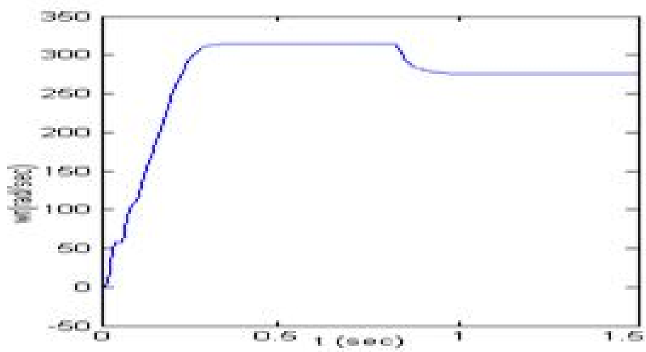
Graph: 3.4. Acceleration characteristics of induction motor



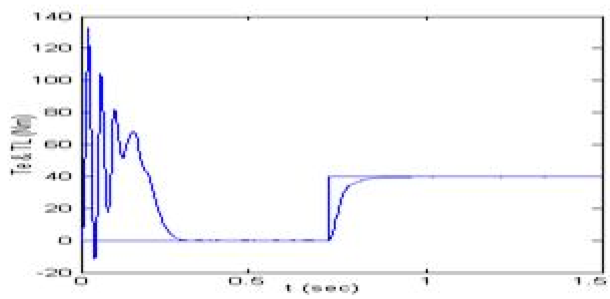
Graph: 3.5. I_{ds} and I_{qs} of induction motor in stationary reference Frame



Graph: 3.6. I_{ds} and I_{qs} of induction motor in synchronous reference Frame



Graph: 3.7 Response of stationary frame induction motor model to step change in T_L



Graph: 3.8 Torque Response of stationary frame induction motor model to step change in T_L=40 Nm

8.1 CONCLUSIONS

Generalized dynamic mathematical model of the induction motor is simulated in different reference frames. The speed and Torque waveforms are independent of the type of reference frame used but the d and q axes flux and current components depend on type of reference frame used. An adaptive state observer, MRAS is tested to observe rotor speed. The high performance of this scheme is shown in simulation results. This is a flux observer with voltage model and current model combination. The outputs of this observer were fed to an open-loop speed estimator. Using this observer, Sensorless vector control is simulated and dq-axis rotor-stator fluxes, rotor speed were estimated and found satisfactory as shown in the simulations Graphs. In Sensorless vector control also proper field orientation is achieved because the value of q axis flux is zero and there is no change in d axis current due to the application of load torque.

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