Analysis and Simulation of Discrete Modelling on Induction Motor

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Abstract— This paper design to implement the accurate behavioural modelling of induction motor helps in designing controller for the machine and is also useful in detection of faults in machines. The rotor subsystem is expressed in qd coordinates and the stator subsystem is expressed in abc phase coordinates. Computer studies of an induction motor for Voltage-behind reactance model demonstrate the improvement in computational efficiency as compared with the qd or PD model. In this paper Voltage-behind-reactance model is developed in stationary reference frame using MATLAB-SIMULINK platform.

Key words: MATLAB; Modelling; Simulation; SIMULINK; Three-Phase Induction Motor

I. Introduction

Motion control is required everywhere, be it domestic application or industry. The systems that are engaged for this purpose are called drives. Such a system, if uses electric motors for control is known as an electrical drive. In electrical drives, various sensors and control algorithms are employed to control the speed of the motor using suitable speed control methods. The basic block diagram of an electrical drive is shown below Although construction of induction motor is simple, its speed control is considered to be far more complex than that of DC motors. The reason is nonlinear and highly interacting multivariable state space model of the motor. The rapid and revolutionary progress in microelectronics and variable frequency static inverters with application of modern control theory has made it possible to build sophisticated controllers for AC motor drives. The design and development of such drive system require proper mathematical modelling of the motor . The induction motor (IM) is largely used in many industrial applications due to low cost, good torque density and robustness. Analytical model are commonly used and are appreciated for their speed. The modelling approach for this machine may be roughly divided into three categories finite element method; equivalent magnetic circuit approach; and coupled electric approach [8].The most popular representation for ac machines for transient simulation is the so-called qd model based on a series of mathematical transformations. The direct and quadrature axis model based on the space phasor theory is widely used to study the dynamic behaviour of three phase inductor motor. Rotating reference frame, e.g. stationary, rotor or synchronous are used to transform physical (abc) variables of the machine into fictitious (qd) variable [1][5] . By having the voltage and current quantities in qd frame, it is possible to control the speed of the machine by controlling the flux and torque independently. It is also a method of sensor less measurement. to optimize the controller structure, the inputs needed and the gain parameters. [13]

II. Induction Motor Modeling

A proper model for the three phase induction motor is essential to simulate and study the complete drive system. The model of induction motor in arbitrary reference frame is derived in [6-7]. Following are the assumptions made for the model: 1. each stator winding is distributed so as to produce a sinusoidal mmf along the air gap, i.e. space harmonics are negligible. 2. The slotting in stator and rotor produces negligible variation in respective inductances. 3. Mutual inductances are equal. 4. The harmonics in voltages and currents are neglected. 5. Saturation of the magnetic circuit is neglected. 6. Hysteresis and eddy current losses and skin effects are neglected. The voltage equations of the three phase induction motor in synchronous reference frame are:

III. Linear Motion

For linear motion, the forces acting on a body may usually be simplified to a driving force, *Fe*, acting on the mass, and an opposing force (or load), *Fl*, as shown on Figure 1.

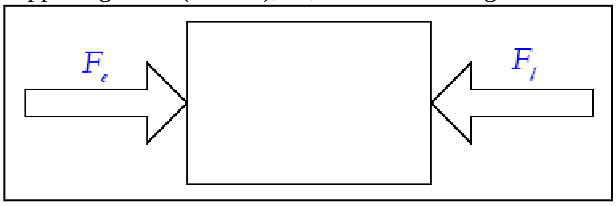

Fig. 1: A body acted on by two forces.

For translational motion the following may be written:

$$\frac{dv}{dt} = \frac{F_e - F_L}{M}$$

In any speed and position control of linear motion, force is the fundamental variable which needs to be controlled.[7][15]

A. Rotary Motion

If the motion is rotary about an axis instead of translational, a situation as shown in Figure 2 arises.[11][2]

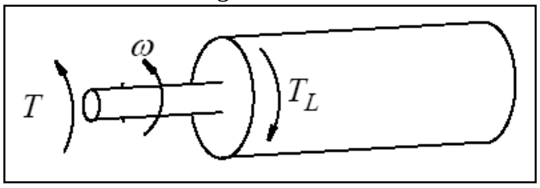

Fig. 2: A body acted on by two torques.

For rotary motion the following may be written:

$$\frac{dw}{dt} = \frac{T - T_L}{J}$$

In any speed and position control of rotary motion, torque is the fundamental variable which needs to be controlled.[14]

IV. Torque in an Electric Drive

Electromagnetic torque produced by a motor is opposed by load torque. The difference, $T_{em} - T_L$, will accelerate the system.

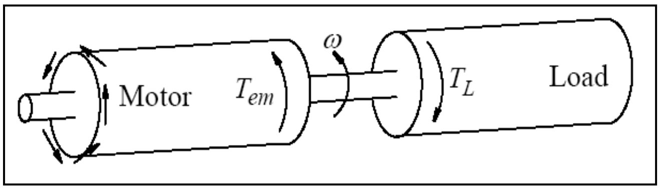

Fig. 3: A load acted on by a motor

For motor-load motion the following may be written:

$$\frac{dw}{dt} = \frac{T_{em} - T_L}{J}$$

Torque is the fundamental variable which needs to be controlled. Note that under steady state conditions angular speed is constant and $T_{em} = T_L$.

V. DC-MOTOR DRIVE PERFORMANCE

One of the most essential qualities of a motor is the ability to generate torque. The total torque may be described by

$$T_{em} = k_a \Phi_f I_a$$

Where I_a is the current flowing in the armature and k_a becomes a factor describing the physical shape of the winding. DC machine equivalent circuit is shown in Figure 4.[10]

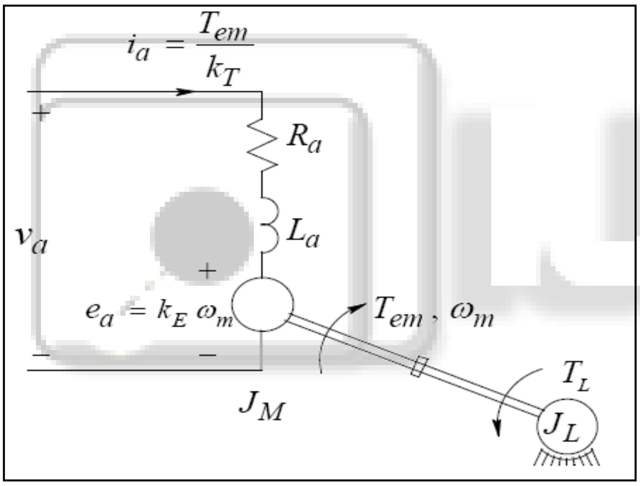

Figure 4: DC machine equivalent circuit

To change T_{em} as a step, the armature current i_a is changed as a step by the power-processing unit as shown in Figure 5.

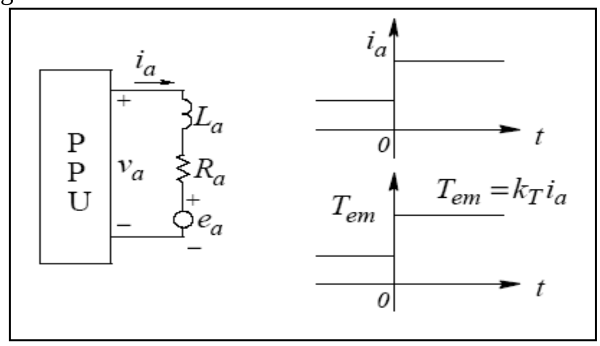

Fig. 5: DC-motor drive performance

Emulation of DC-motor drive performance In vector control of induction-motor drives, the stator phase currents $i_a(t)$, $i_b(t)$ and $i_c(t)$ are controlled in such a manner that $i_{sq}(t)$ delivers the desired electromagnetic torque while $i_{sd}(t)$ maintains the peak rotor-flux density at its rated value. The references values $i_{sq}^*(t)$ and $i_{sd}^*(t)$ are generated by the torque, speed, and position control loops. The total torque may be described by

$$T_{em} = k_T B_r i_{sq}$$

Simulation of induction machine using Matlab and SimulinkTraditionally in analysis and design of 3-phase induction motors, the "per-phase equivalent circuit" is shown in Figure 6 has been widely used. In the circuit, R_s (R_r) is the stator (rotor) resistance and L_m is called the magnetizing inductance of the motor. Note that stator (rotor) inductance L_s (L_r) is defined by

$$L_s = L_{ls} + L_m,\ L_r = L_{lr} + L_m \quad (1.1)$$

where L_{ls} (L_{rs}) is the stator (rotor) leakage inductance. Also note that in this equivalent circuit, all rotor parameters and variables are not actual quantities but are quantities referred to the stator

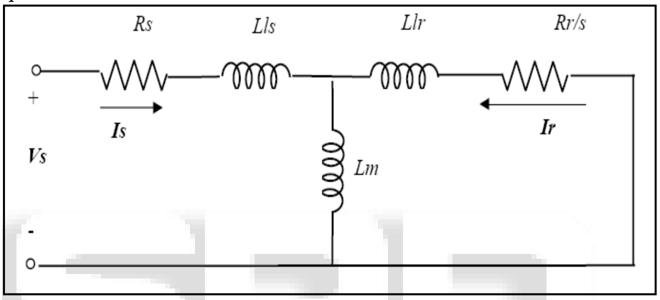

Fig. 6: Conventional Per-phase Equivalent Circuit

It is also known that induction motors do not rotate synchronously to the excitation frequency. At rated load, the speed of induction motors are slightly (about 2 - 7% slip in many cases) less than the synchronous speed. If the excitation frequency injected into the stator is w_{syn} and the actual speed converted into electrical frequency unit is w_m, slip s is defined by

$$s = (w_{syn} - w_m) / w_{syn} = w_{slip} / w_{syn}, \quad (1.2)$$

and w_{slip} is called the slip frequency which is the frequency of the actual rotor current. Although the per-phase equivalent circuit is useful in analyzing and predicting steady-state performance, it is not appropriate to explain dynamic performance of the induction motor. Output a sine wave:

O(t) = Amp*Sin(Freq*t+Phase) + Bias

Sine type determines the computational technique used. The parameters in the two types are related through

Samples per period = 2*pi / (Frequency * Sample time)

Number of offset samples = Phase * Samples per period / (2*pi)

Use the sample-based sine type if numerical problems due to running for large times (e.g. overflow in absolute time) occur.

Element-wise gain (y = K.*u) or matrix gain (y = K*u or y = u*K).

VI. PROPOSED MODEL

The model has been formulated by means of the space-phasor notation in which all the three-phase quantities (Voltages, Currents, flux and inductances) are converted to the two-axis d-q notation. The dynamic equations of the induction machine are elegantly implemented The model is then tested in a direct-on-line startup by applying a three-phase ac voltage signal to the machine. Simulation results are presented for a load torque of 10N.m and 40N.m at t=1s to validate the effectiveness of the proposed model.

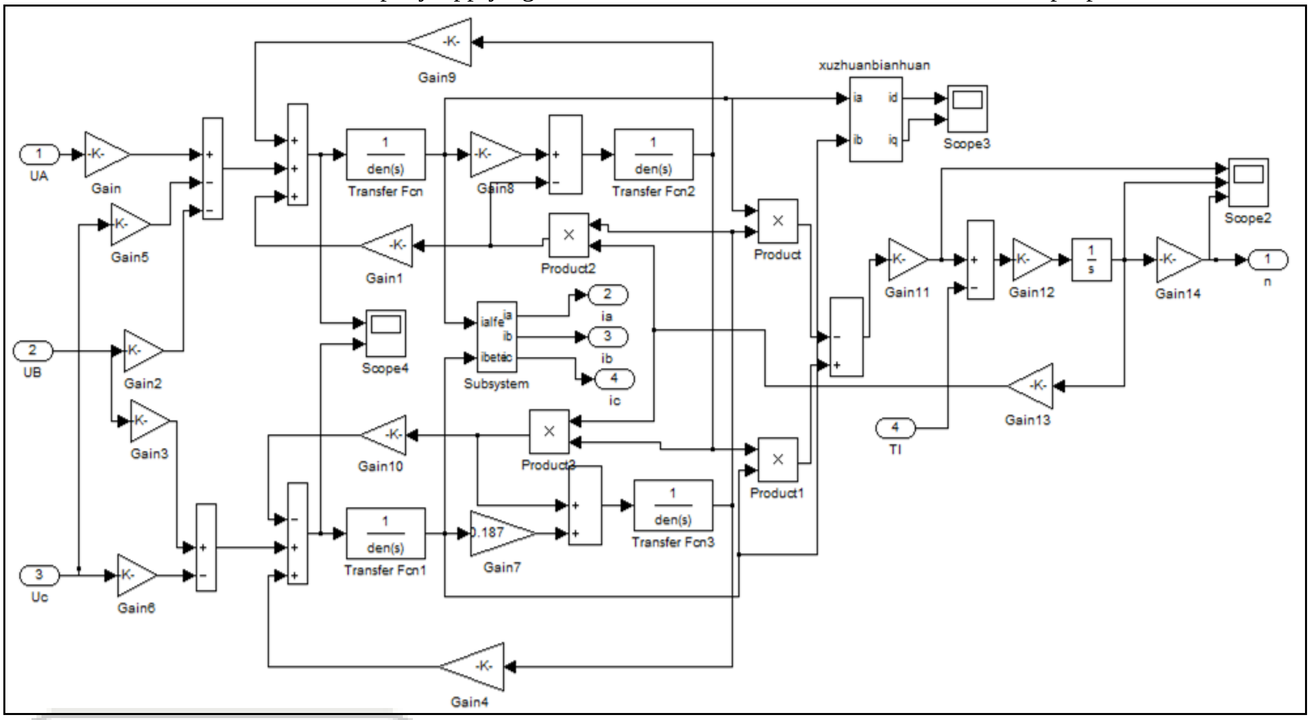

Fig. 7: Induction machine dynamic model implementation in Simulink.

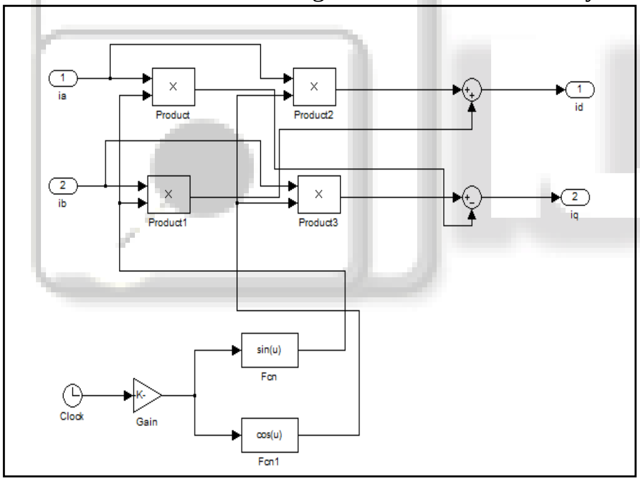

Fig. 8: IM- SUB 1

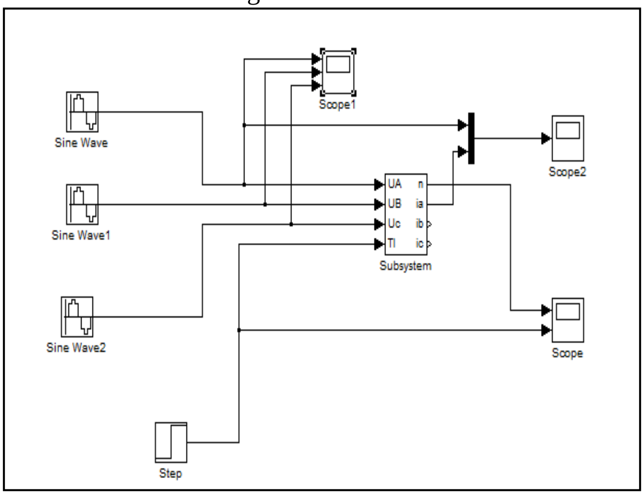

Fig. 9: IM-SUB -2

VII. SIMULATION & RESULT

The stator voltage for all the phases is given as sinusoidal input with different phase shift values and the load torque as timer input. The result which discusses about the stator current, rotor currents, torque and speed variations is shown below.

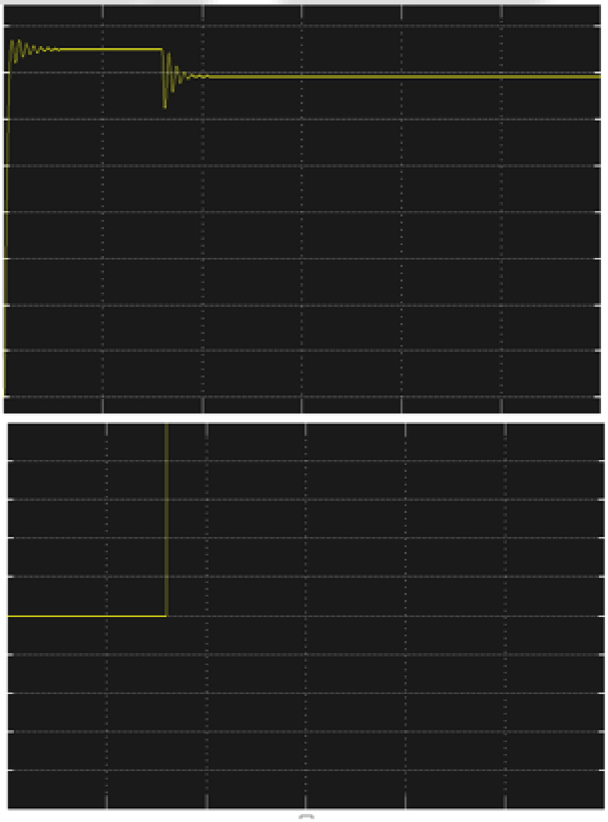

Fig. 10: Rotor current variations

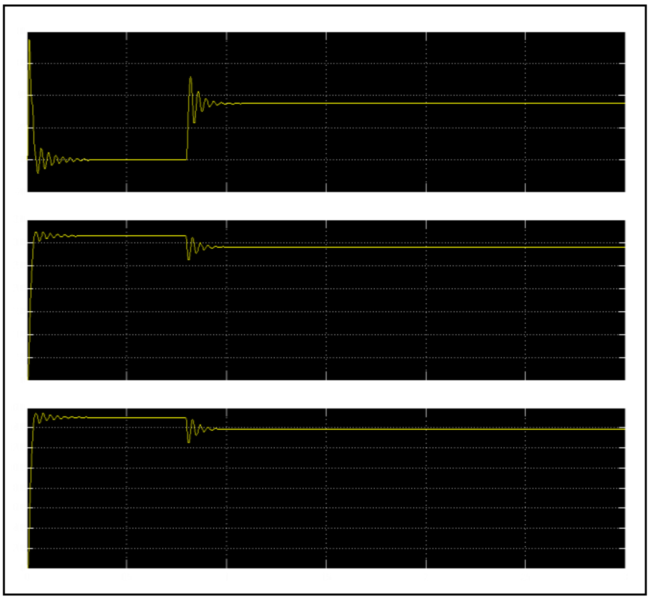

Fig. 11: Speed Variation

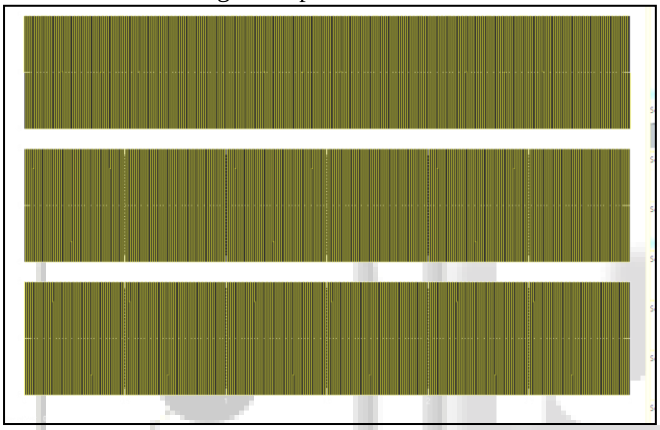

Fig. 12: Induction Motor Start

VIII. CONCLUSION

The contributions of this paper can be stated as follows. The combination of sliding mode and block control results in a control law that achieves an excellent performance in the worst case scenario. With the flux observer it was demonstrated that its dynamics are stable. The load torque observer performs well. RE

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