



Mathematical MATLAB Model and Performance Analysis of Asynchronous Machine

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ABSTRACT: In this paper the modelling of 3 phase induction motor is implemented with the help of dq axis transformation. 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 theory of axis transformation is widely used to create such model because it reduces the complexities of time-varying variables. Here a step by step Simulink model of an induction machine using dq axis transformations of the stator and rotor variables in the arbitrary reference frame has been implemented. This paper demonstrates the simulation of steady-state performance of induction motor by MATLAB Program.

KEYWORDS: Squirrel cage induction motor, Induction machine model, S-Function, Simulink,

I. INTRODUCTION

Induction motor is basically an electric transformer whose magnetic circuit is separated by an air gap into two relatively movable portions, one carrying the primary and the other the secondary winding. Alternating current supplied to the primary winding from an electric power system induces an opposing current in the secondary winding, when the latter is short-circuited or closed through external impedance. Relative motion between the primary and secondary structure is produced by the electromagnetic forces corresponding to the power thus transferred across the air gap by induction. The essential features which distinguish the induction machine from other type of electric motors is that the secondary currents are created solely by induction, as in a transformer instead of being supplied by a dc exciter or other external power sources, as in synchronous and dc machines.

In the electric drive systems the machine is a part of the control system elements. To control the dynamics of the drive system, dynamic behavior of the machine need to be considered. The dynamic behavior of IM can be described by using dynamic model of IM. The dynamic model considers the instantaneous effects of varying voltages/currents, stator frequency and torque disturbance. In this paper the dynamic model of IM is derived by using d and q variables in a synchronously rotating reference frame.

II. THE INDUCTION MACHINE MODEL

The dynamic behaviour of an induction machine is complex due to the coupling effect between the stator and rotor phases. The space-phasor voltage equations of the stator and rotor can be expressed in d-q components as

$$\begin{bmatrix} v_{ds} \\ v_{qs} \\ v_{dr} \\ v_{qr} \end{bmatrix} = \begin{bmatrix} R_s + sL_s & 0 & sL_m & 0 \\ 0 & R_s + sL_s & 0 & sL_m \\ L_m & \omega_r L_m & R_r + sL_r & \omega_r L_r \\ -\omega_r L_m & sL_m & -\omega_r L_r & R_s + sL_r \end{bmatrix} \begin{bmatrix} i_{ds} \\ i_{qs} \\ i_{dr} \\ i_{qr} \end{bmatrix}$$



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Where, R_s and R_r are the stator and rotor resistances, L_s and L_r are the stator and rotor self-inductance respectively, and are the stator and rotor speed respectively and is the mutual inductance.

Flux linkage equations of induction machine is

$$\begin{bmatrix} \psi_{ds} \\ \psi_{qs} \\ \psi_{dr} \\ \psi_{qr} \end{bmatrix} = \begin{bmatrix} L_s & 0 & L_m & 0 \\ 0 & L_s & 0 & L_m \\ L_m & 0 & L_r & 0 \\ 0 & L_m & 0 & L_r \end{bmatrix} \begin{bmatrix} i_{ds} \\ i_{qs} \\ i_{dr} \\ i_{qr} \end{bmatrix}$$

Where L_s and L_r are the stator and rotor flux linkages respectively.

The mechanical speed of the induction machine is related to the torque is given by $T_e = T_L + \frac{2J}{p} \cdot \frac{d\omega_r}{dt}$

Where T_e is the electrical Torque, T_L is the load torque, J is the combined rotor and load inertia, p is the number of poles and ω_r is the rotor speed.

Implementation of S-Function

S-functions (system-functions) mechanism is useful for extending the capabilities of Simulink. It is a computer language description of a Simulink block and can be written in MATLAB, C, C++, FORTRAN etc. By using S-Function we can represent a dynamic system as a mathematical set of equations. To implement an S-function into a Simulink model, the name of the M-file is specified in the user-defined Simulink S-function block from the Simulink library blocks. The parameters specified in the S-Function Parameters field are passed to the corresponding S-Function. An M-file S-function consists of a MATLAB function of the form as $[\text{sys}, \text{xo}, \text{str}, \text{ts}] = \text{f}(\text{t}, \text{x}, \text{u}, \text{flag}, \text{p1}, \text{p2}, \dots)$. Where f is the S-function name, t is the current time, x is the state vector of the corresponding S-function block, u is the block's inputs, flag indicates a task to be performed, and $\text{p1}, \text{p2}, \dots$ are the block's parameters. The standard format for the flags in an S-Function is given by

Flag	Simulation stage
Flag = 0	Initialization
Flag = 1	Calculations of derivatives
Flag = 2	Update of discrete states
Flag = 3	Calculations of outputs
Flag = 4	Calculation of next sampling hits
Flag = 9	End of simulation tasks

Table 1. Standard format for the flags in an S-Function

III. SIMULINK IMPLEMENTATION

The S-Function induction machine model in Simulink is shown in Fig. 1. The three-phase ac voltages are converted to two-phase voltages and vice-versa using the two matrix gain blocks 'ABC2ab' and 'ab2ABC' respectively.

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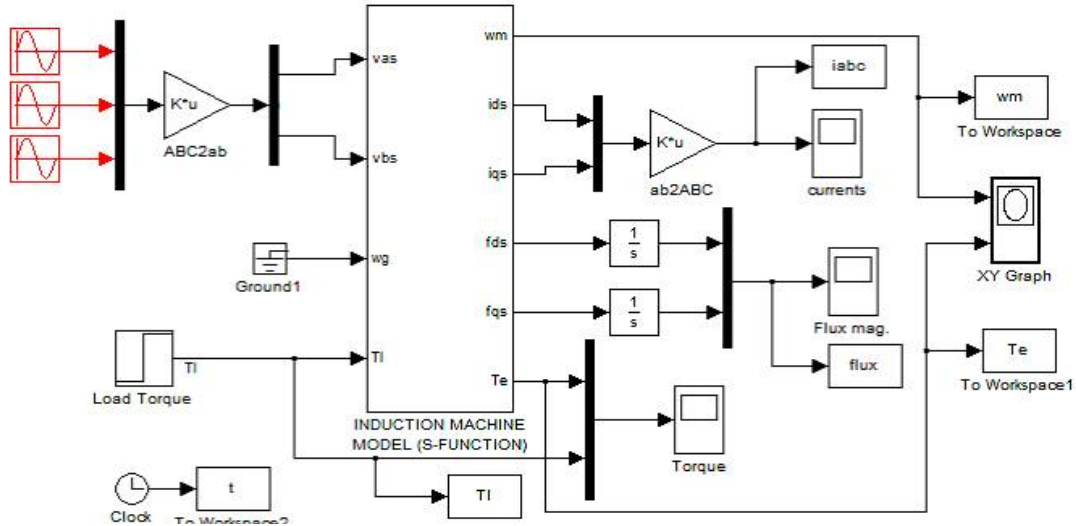


Fig. 1. Induction Machine test model

The three-phase to two-axis transformation is achieved using the equations

$$\begin{bmatrix} v_{as} \\ v_{bs} \end{bmatrix} = \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}$$

IV. SIMULATION RESULTS

Here we take a three phase induction motor with the following parameters such as $R_s = 0.585\Omega$, $R_r = 0.41\Omega$, $L_{sl} = .0027H$, $L_{rl} = .0027H$, $L_m = 0.081H$, $f_0 = 50Hz$, $J = 0.1Kg/m^2$, $p = 4$.

To illustrate the transient operation of the induction motor, a simulation study of direct-on-line, auto transformer starting is demonstrated. At $t=0$, the motor, previously de-energized and at standstill, is connected to a 440 V, 50 Hz three-phase supply through a cable. The load torque, T_L , is constant at 40 N.m. Figs. 2 and 3 show the characteristics of electromagnetic torque and speed of the induction motor after simulation using the SIMULINK model.

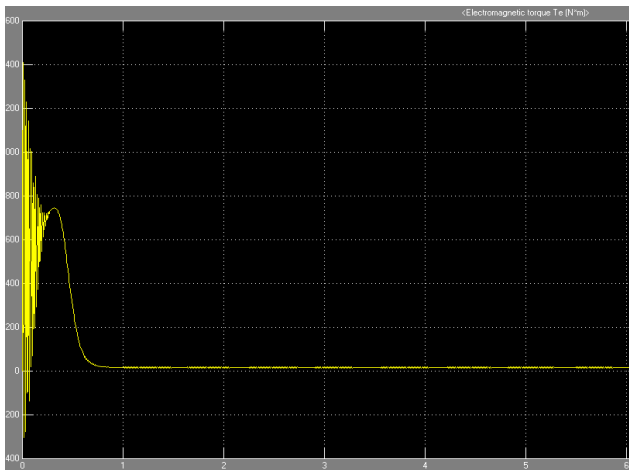


Fig. 2. Electromagnetic torque

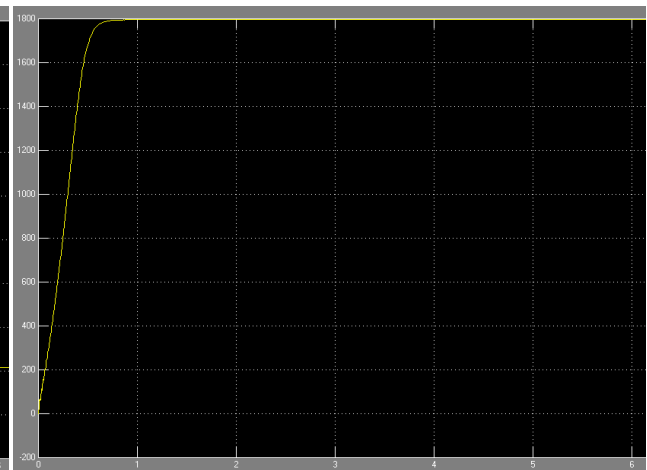


Fig. 3. Speed in rpm

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Fig. 4 and Fig.5 shows the characteristic of stator and rotor current and stator line-to-line voltage of the induction motor after simulation using the SIMULINK model.

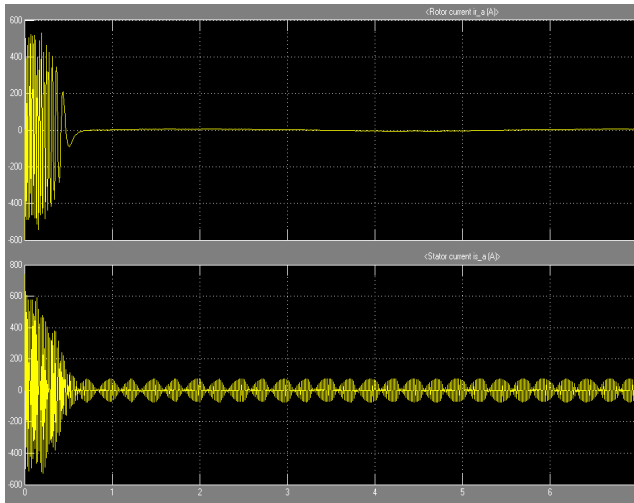


Fig. 4. stator and rotor current.

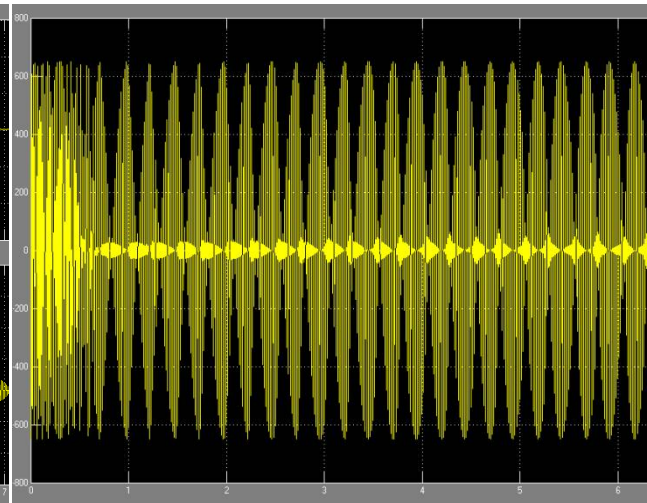


Fig. 5. Stator line-to-line voltage.

Fig. 6 shows the Torque speed characteristic of the induction motor after simulation using the SIMULINK model.

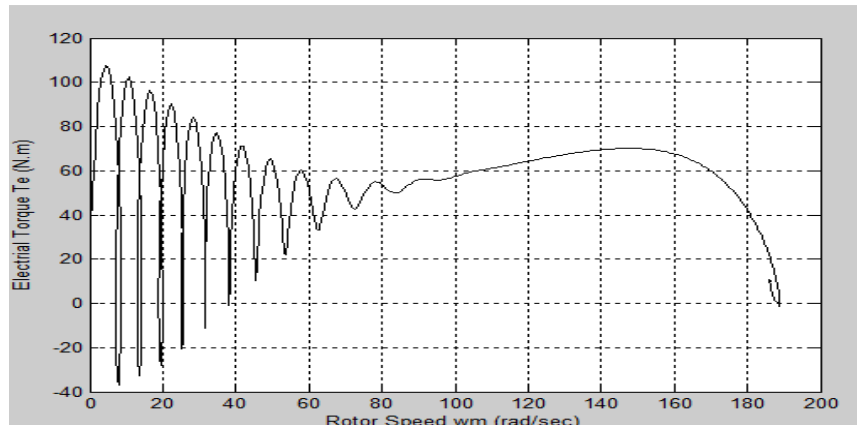


Fig. 6. Torque speed characteristic.

V. CONCLUSION

In this paper, a complete model of the three-phase induction machine with healthy condition is analysed. This model has successfully run as d-q model of three phase induction motor and all the three-phase quantities (Voltages, Currents, flux and inductances) are converted to the two-axis d-q notation. Different waveforms such as stator and rotor current, electromagnetic torque, speed torque characteristics has being analysed here. This MATLAB model is established for an induction motor at healthy condition, now it is to be introduced the different faults of induction motor like bearing fault, broken rotor fault, stator winding insulation fault, uneven air gap due to rotor damage in this MATLAB model. The current signature analysis of the condition monitoring of the induction motor at faulty and healthy condition is to be analysed by different graph analysis. Hence it would be so easier to find out the fault of the induction motor.



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