

Modelling of Single Sided Linear Induction Motor by MATLAB/SIMULINK

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Abstract- This paper describes a generalized model of the single sided linear induction motor and its computer simulation using MATLAB/SIMULINK. Constructional details of various sub-models for the single sided linear induction motor are given and their implementation in SIMULINK is outlined. SLIM is studied using the simulation model developed.

Keywords: MATLAB modelling; simulation; SIMULINK; SLIM modelling.

LIST OF SYMBOLS

- L s** stator inductance(Primary inductance)
- L r** rotor inductance (Secondary inductance) **M** mutual inductance
- Rs** stator resistance
- Rr** rotor resistance
- Rc** cable resistance
- P** pole number
- Vds,Vqs** d-axis and q-axis components of the stator voltage vector **Vs**
- Vdr,Vqr** d-axis and q-axis components of the rotor voltage vector **Vr**
- ids, iqs** d-axis and q-axis components of the stator current vectors **is**
- idr,iqr** d-axis and q-axis components of the rotor current vectors **ir**
- J** moment of inertia of rotor

I. INTRODUCTION

Simulation of the single sided linear induction machine is well documented in computer hardware and software, new simulation packages which are faster and more user friendly are now available. This paper discusses the use of one such product, the SIMULINK software of MATLAB, in the dynamic modelling of the SLIM. The main advantage of SIMULINK over other programming software is that, instead of compilation of program code, the simulation model is built up systematically by means of basic function blocks. A set of machine differential equations can thus be modelled by interconnection of appropriate function blocks, each of which performing a specific mathematical operation. Programming efforts are drastically reduced and the debugging of errors is easy. Since SIMULINK is a model operation programmer, the simulation model can be easily developed by addition of new sub-models to cater for various control functions. As a

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sub-model the SLIM could be incorporated in a complete electric motor drive system.

II. SLIM MOTOR MODEL CONSTRUCTED USING SIMULINK

A generalized dynamic model of the induction motor consists of an electrical sub-model to implement the three-phase to two-axis (3/2) transformation of stator voltage and current calculation, a torque sub-model to calculate the developed electromagnetic torque, and a mechanical sub-model to yield the rotor speed. In addition, a stator current output sub-model is needed for calculating the voltage drop across the supply cables.

A. Electrical sub-model of the SLIM

The three-phase to two-axis voltage transformation is achieved using the following equation

$$\begin{bmatrix} V_{ds} \\ V_{qs} \end{bmatrix} = \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_{as} \\ V_{bs} \\ V_{cs} \end{bmatrix} \quad \text{Eqn(1)}$$

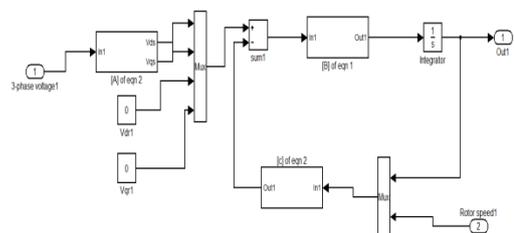


Fig.1 Electrical model of an SLIM in SIMULINK

Where V_{as} , V_{bs} , and V_{cs} are the three-phase stator voltages, while V_{ds} and V_{qs} are the two-axis components of the stator voltage vector V_s . In the two-axis stator reference frame, the current equation of an induction motor can be written as

$$\begin{bmatrix} \frac{d}{dt} \begin{bmatrix} i_{ds} \\ i_{qs} \end{bmatrix} + \begin{bmatrix} -\omega_r \\ \omega_r \end{bmatrix} \begin{bmatrix} i_{qs} \\ i_{ds} \end{bmatrix} \\ \frac{d}{dt} \begin{bmatrix} i_{dr} \\ i_{qr} \end{bmatrix} + \begin{bmatrix} -\omega_r \\ \omega_r \end{bmatrix} \begin{bmatrix} i_{qr} \\ i_{dr} \end{bmatrix} \end{bmatrix} = \begin{bmatrix} -\frac{R_s}{L_s} & 0 \\ 0 & -\frac{R_s}{L_s} \end{bmatrix} \begin{bmatrix} i_{ds} \\ i_{qs} \end{bmatrix} + \begin{bmatrix} \frac{M}{L_s} & 0 \\ 0 & \frac{M}{L_s} \end{bmatrix} \begin{bmatrix} i_{dr} \\ i_{qr} \end{bmatrix} + \begin{bmatrix} \frac{1}{L_s} & 0 \\ 0 & \frac{1}{L_s} \end{bmatrix} \begin{bmatrix} V_{ds} \\ V_{qs} \end{bmatrix}$$

As shown in Fig 1, Matrix [A] in Equation (1) and MATRIX [B] IN EQUATION (2) CAN BE IMPLEMENTED BY THE 'Matrix Gain' block of SIMULINK, while matrix [C] in Equation (2) can be implemented by four 'Fcn' blocks of SIMULINK whose detail is illustrated in Fig. 2. In the electrical model,

the three-phase voltage [Vas, Vbs, Vcs] is the input and the current vector [ids, iqs, idr, iqr] is the output vector. The rotor voltage vector is normally zero because of the short-circuited

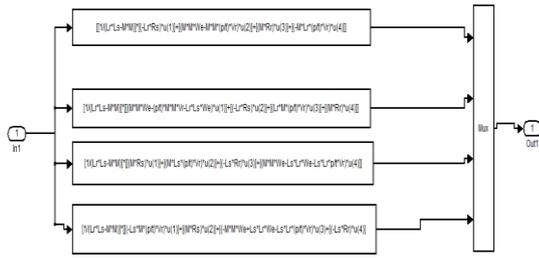


Fig.2 Matrix[c] implemented using four functional blocks of SIMULINK

cage rotor winding, i.e. Vdr=0 and Vqr=0.

B. Thrust sub-model of SLIM

In the two-axis stator reference frame, the thrust T is given by

$$F = (Vdriqs - Vqrids) \quad \text{Eqn. (3)}$$

Fig 3 shows how the thrust sub-model is realized in SIMULINK.

C. Mechanical sub-model of SLIM

From the thrust balance equations and neglecting viscous friction, the linear synchronous speed Vs may be obtained as follows

$$Vs = \int_{\tau=0}^{\tau} \frac{F - Fl}{J} d\tau \quad \text{Eqn. (4)}$$

Where J is the moment of inertia of the rotor and load and Fl is the load thrust. Fig. 4 shows the implementation of the mechanical sub-model.

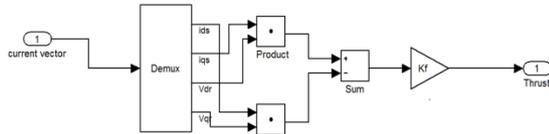


Fig.3 Thrust sub-model

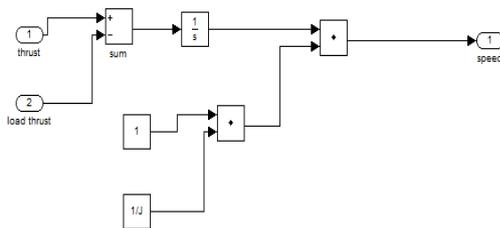


Fig.4 Mechanical sub-model

D. Stator current output sub-model

The stator current output sub-model is used to calculate the stator current amplitude according to the following equation 6.

$$|is| = \frac{2}{3} \sqrt{ids^2 + iqs^2} \quad \text{Eqn. (5)}$$

A SIMULINK function block is used to implement the above equation. The electrical sub-model in Fig. 1, the thrust sub-model in Fig. 3, the mechanical sub-model in Fig. 4, and

the stator current output sub-model are grouped together to form the SLIM model as shown in Fig 5.

III. SIMULATION SYSTEM OF SLIM

The complete simulation system of the SLIM includes the single sided linear induction motor model in Fig 5 and a power supply sub-model.

E. Power supply sub-model

The voltage supply block consists of a three-phase sinusoidal voltage generator and a terminal voltage calculation block which accounts for the voltage drop in the supply cable. The three-phase sinusoidal voltage generator is based on Equation (6) and the three phase voltages is modelled as shown in Fig. 6.

$$\begin{cases} V_{as} = |V| \cos(\omega t + \theta) \\ V_{bs} = |V| \cos(\omega t - \frac{2\pi}{3} + \theta) \\ V_{cs} = |V| \cos(\omega t + \frac{2\pi}{3} + \theta) \end{cases} \quad \text{Eqn. (6)}$$

Where |V| is the amplitude of the terminal voltage, Due to the voltage drop in the supply cable, the terminal voltage is given by Equation 7.

$$|V| = E - Rc|ic| \quad \text{Eqn. (7)}$$

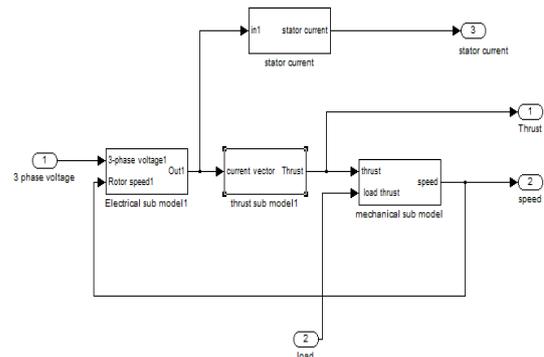


Fig.5 SLIM model in SIMULINK

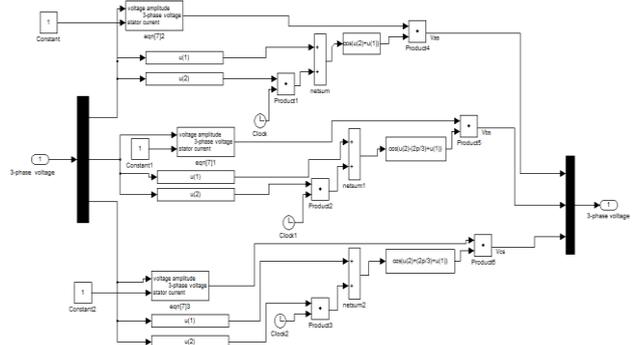


Fig 6 Modelling supply phase in SIMULINK

Where E is the supply voltage and Rc is the cable resistance. Fig. 7 shows how the equation is modelled in SIMULINK. Grouping the voltage generator block of Fig. 6 and terminal-voltage calculation block of Fig. 7, the power supply block is formed as shown in Fig. 8.

E. Simulation model of SLIM

The SLIM model in Fig. 5 and the power supply sub-model in Fig. 8 are grouped together to form the complete induction motor simulation model as shown in Fig. 9. The XY-graph is used to display the dynamic



thrust/linear synchronous speed characteristic of the SLIM, while the scope block enables the speed, stator current, and stator voltage of the motor to be observed.

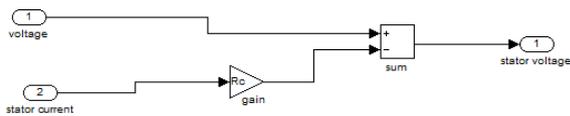


Fig.7 Terminal-voltage calculation block

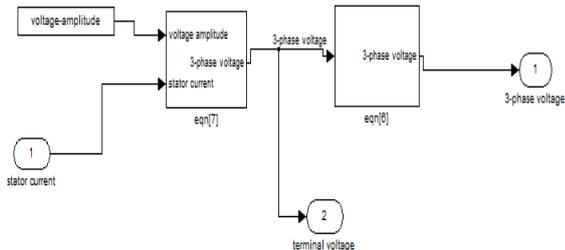


Fig.8 Power supply block

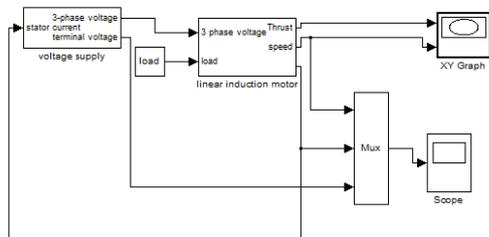


Fig.9 Simulation system of an SLIM in SIMULINK

IV. SIMULATION RESULTS

The SLIM chosen for the simulation studies has the following specifications.

Three-phase, 2.1 KVA,415V, 2-pole,short primary stator,length of stator(max) 300mm,Length of reaction plate 4m(max), maximum current turns per active slot 1000AT/inch²,maximum running time 10mints,rated slip 5-10%

$R_s=0.288$ V/ph $R_r=0.158$ V/ph

$L_s=0.0425$ V/ph $L_m=0.0412$ V/ph

$L_r=0.0418$ V/ph $J=0.4$ kg m²

Fig. 10 and Fig.11 show the results of computer simulation using the SIMULINK model.

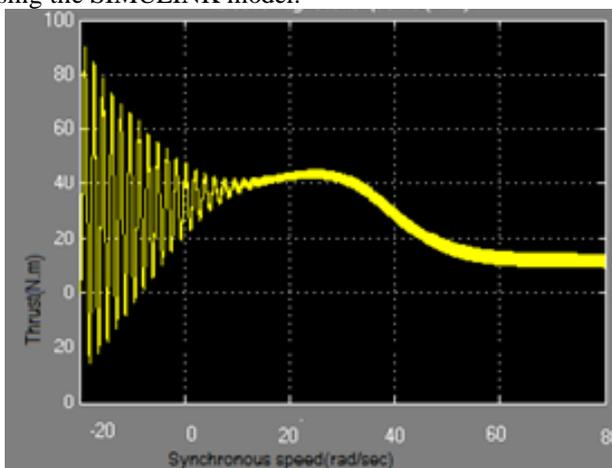


Fig.10 Thrust/linear synchronous speed characteristics

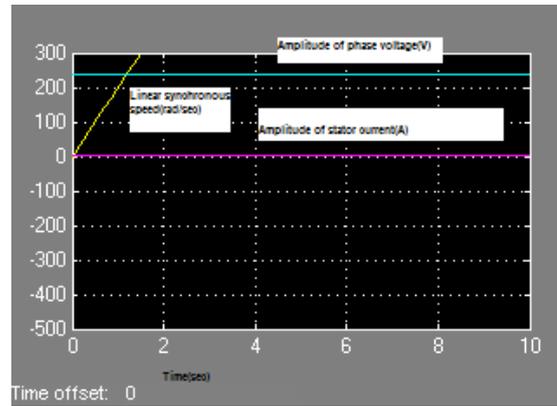


Fig.11 Simulation results

V. CONCLUSION

SIMULINK is a powerful software package for the study of dynamic SLIM. Using SIMULINK, the simulation model can be built up systematically starting from simple sub-models.

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