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Demonstration of Single Phase of Switched Reluctance Motor Drives using MATLAB

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ABSTRACT: This paper studies non linear model of Switched Reluctance Motor Drives based on phase winding inductance. Matlab7.1 is used as a simulation tool to establish simulation model of SRM Drives .Experiment implement on a 4phases,8/6, 3kw model motor. Also the simulation of mechanical model of SRM is shown in paper.

KEYWORDS: Switched Reluctance Motor, simulation study.

I.INTRODUCTION

The switched reluctance motor (SRM) is an old member of the electric machine family. The main advantages of SRM are their simple structure, ruggedness, and that they are relatively inexpensive to manufacture. However, the primary disadvantages, such as the torque ripple, acoustic noise, and the difficulty in controlling, prevent it from being accepted by the industry extensively. During the past two decades, researches have been done to reduce the torque ripple and acoustic noise. Switched reluctance motor has simple and rugged construction, high robustness, high speed capability. But it has non linear behavior. This is because of complexity of magnetic field distribution and non linearity of phase winding inductance and flux linkages. As flux linkage is a multiplicative product of per phase winding inductance and current. Section II discussed mechanical model of switched reluctance motor Drive, simulation results. Electrical mathematical model i.e. For inductance L, phase current i, electromagnetic torque T and simulation result discussed in section III..In Section IV conclusion is explained

II. MECHANICAL MODEL

Fig. 1 shows mechanical model of SRM drive

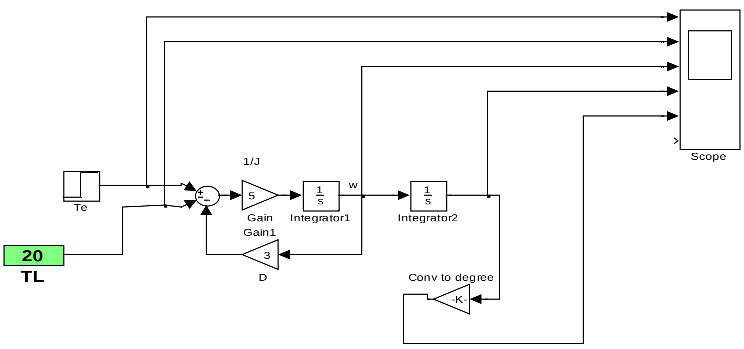

Fig.1: Simulation of mechanical model

The mechanical equation is-

$$Te - T_l = J\frac{d\omega}{dt} + D\omega$$

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--------(a)

where-
T_e- Motor torque,
T_l- load torque,
J- momentof inertia,
ω- Angular velocity,
D - Viscous friction coefficient.

$$\omega = \frac{d\theta}{dt}$$

where-
θ - rotor position
Therefore -

$$\theta = \int \omega \, dt$$

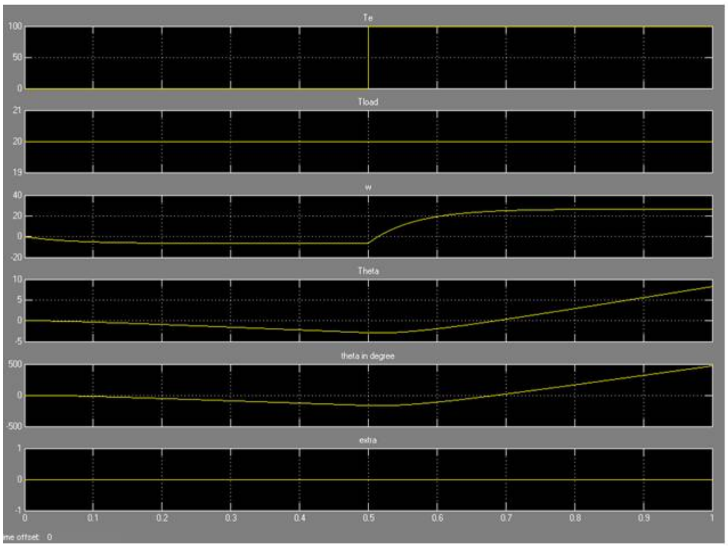

Fig.2: Simulation results of mechanical model

In (a) equation
When -

$$Te = Tl$$

i.e.

$$Te - Tl = 0$$

$$J \frac{d\omega}{dt} = -D\omega$$

$$\frac{d\omega}{dt} = -\frac{1}{J} D\omega$$

Therefore when motor torque (Te) and load torque (Tl) are equal then speed reduces exponentially.
Similarly as load torque increases torque ripple increases and speed reduces.

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III. ELECTRICAL MODELS

a). **Electrical Model for current I**
For phase SRM, the electrical equation is given by eqn 1

(1)

where-
λ- Fluxlinkages,
R- Resistance per phase,
V- Applied voltage

$$\lambda = \lambda(i,\theta) = L(i,\theta)i \quad (2)$$

L- Inductance per phase winding

$$V = R.i + \frac{\partial \lambda}{\partial i}\cdot\frac{di}{dt} + \frac{\partial \lambda}{\partial \theta}\cdot\frac{d\theta}{dt}$$

Substitute equation (2) in eq. (1)

$$V = R.i + \frac{\partial L(\theta,i),i}{\partial i}\cdot\frac{di}{dt} + \frac{\partial L(\theta,i),i}{\partial \theta}\cdot\frac{d\theta}{dt}$$

$$V = R.i + (L + i\frac{\partial L}{\partial i})\cdot\frac{di}{dt} + i\frac{\partial L}{\partial \theta}\cdot\frac{d\theta}{dt}$$

$$V - R.i - i\frac{\partial L}{\partial \theta}\frac{d\theta}{dt} = (L + i\frac{\partial L}{\partial i})\cdot\frac{di}{dt}$$

$$V - R.i - \omega\cdot i\frac{\partial L}{\partial \theta} = (L(\theta,i) + i\frac{\partial L}{\partial i})\cdot\frac{di}{dt}$$

$$\frac{di}{dt} = [V - R.i - i\frac{\partial L}{\partial \theta}\omega] \times \frac{1}{L(\theta,i) + i\frac{\partial L(\theta,i)}{\partial i}}$$

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b). Electrical Model for inductance L

Non –linear model of per phase winding inductance is given by [1]

$$L(\theta, i) = L_0 + \{(L_1 + L_3)[1 - \cos(Nr\,\theta - \phi_{0j})] + L_2[\cos 2(Nr\,\theta - \phi_0) - 1] + L_3[\cos 3(Nr\,\theta - \phi_0) - 1]\}\frac{a_1}{a_1 + i} \tag{3}$$

a_1-Constant and related to the changing current [1]
L_0, L_1, L_2, L_3- are constants related with positionof the rotor θ

Differentiate equation (3) with respect to θ, we have

$$\frac{\partial L}{\partial \theta} = [(L_1 + L_3)Nr \sin(Nr\,\theta - \phi_0) - 2L_2 Nr \sin(Nr\,\theta - \phi_0) - 3L_3 Nr \sin 3(Nr\,\theta - \varphi_0)]\frac{a_1}{a_1 + i} \tag{4}$$

Different Equation (3) with respect to i, we have

$$\frac{\partial L}{\partial i} = \{(L_1 + L_3)[1 - \cos(Nr\,\theta - \phi_0)] + L_2[\cos 2(Nr\,\theta - \phi_0) - 1] + L_3[\cos 3(Nr\,\theta - \phi_0) - 1]\}\frac{-a_1}{(a_1 + i)^2}$$

c). Electrical Model for Torque T

$$\therefore Te = \frac{dw_{mech}}{d\theta} = \frac{\int_0^i \lambda(\theta, i)\,di}{\partial \theta}$$

$$dw_{mech} = Te \cdot d\theta$$

$$Te = \frac{\int L(\theta.i)\cdot i \cdot di}{\partial \theta}[\because \lambda = L(\theta, i)i]$$

$$Te = \frac{\int L(\theta.i)\cdot i \cdot di}{\partial \theta}[\lambda = L(\theta, i)i] \tag{5}$$

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From equation (4) and (5) non- linear electromagnetic torque of per phase is obtained by

$$T_e = a_1[i - a_1 \ln(a_1 + i) + a_1 \ln a_1]$$
$$[(L_1 + L_3) Nr \sin(Nr\theta - \phi_0)$$
$$- 2L_2 Nr \cdot \sin 2(Nr\theta - \phi_0)$$
$$- 3L_3 Nr \cdot \sin 3(Nr\theta - \varphi_{0j})]$$

Given Data:
According to[2]
Stator resistance per phase - 0.747 Ω
Lo= 0.205,L1= 0.113,L2= 0.0025,L3=0.0016

Matlab electrical Model

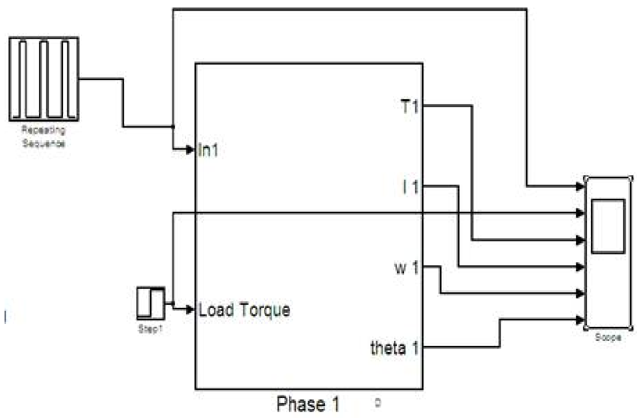

Fig.:3 Simulation model of single phase winding

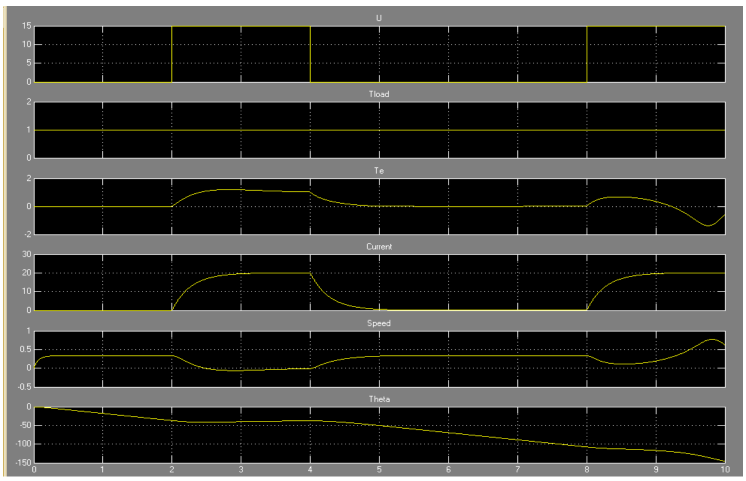

Fig.4:Simulation result of Te,Tl,ω ,θ .

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IV.CONCLUSION

This paper studies the non linear mathematical model of SRM based on inductance of phase winding. And then we developed the simulation model based on SRM and give the simulation results .The simulation results shows that when motor torque Te is present load torque is increases and speed ω also increases. But as soon as Te=Tl speed again reduces. Also load torque increases ,torque ripples increase . In future it is interesting to developed the non linear mathematical model for 6/4 model and effect of load torque on torque ripples.

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