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COMPUTER ANALYSIS OF AN 8/6 SWITCHED RELUCTANCE MOTOR DRIVE

V. Trifa, Ramona Galatus, A. Szekely
Technical University of Cluj
e-mail: trifa@edr.utcluj.ro

Abstract. Mathematical modeling and simulation of the 4-phase 8/6 switched reluctance motor (SRM) drive is presented, using Matlab 5.2 with Simulink 2.0 environment. There are shown various simulation results in respect to electrical and mechanical magnitudes.

1. INTRODUCTION

The SRM models have as main objective to analyze the commutation of its phases in order to improve static and dynamic characteristics. Simulink model of the SRM drive has been built as it contains logic modules that allow investigating various control modes with 4-quadrant operation [1]. SRM phases can be controlled in two ways: 1. Time control, which is similar to open-loop stepping motors [2], but is not convenient for SRM due to rotor oscillations and 2. Space control, which refers to self-commutation of motor phases with respect to rotor position, which is preferable for SRM.

Various ways to control the SRM phases are known [3]. The most used is based on a multi-sensor angular transducer that enables the self-commutation of motor phases. Transducer signals are logically processed in order to provide phase control and a PWM inverter of current source type enables the phase energizing in accordance to control signals.

Mathematical modeling of the SRM includes motor voltage and torque equations, inverter commutation conditions, and transducer logic. A comprehensive model as Simulink enables a rigorous numerical simulation that can provide a wide palette of variation curves for both electrical and mechanical magnitudes. But the main problem of SRM drives refers to commutation process and its link with speed variation.

2. COMMUTATION OF SRM PHASES

For the particular chase of 4-phase 8/6 SRM there are used 4 sensors A-B-C-D [2] placed on the stator as shown in figure 1.

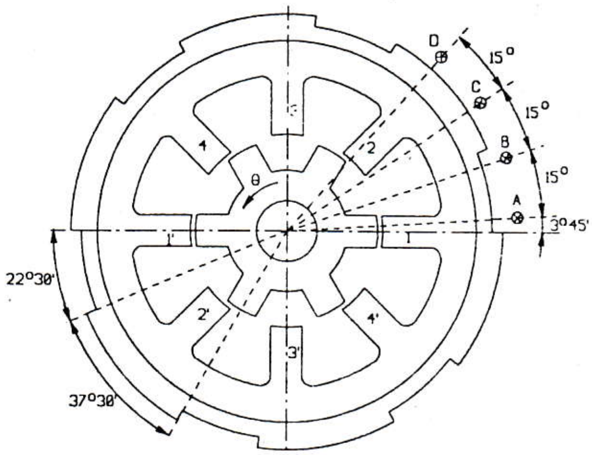

Fig.1. 8/6 SRM and transducer configuration.

The sensors are of opto-electronic type and they are excited by a slotted disk mounted on rotor shaft, as it is represented on external circumference of figure 1. This geometry gives the symmetry of operation in the forward-reverse directions of SRM. By logical processing of the 4-transducer signals A-B-C-D, the control pulses for SRM phases are deduced. Several modes of logical combinations are available, which give distinct operation modes of the motor.

a) normal mode – which corresponds to one-phase-on supplying of motor phases 1-2-3-4, with a commutation angle of θ_{sh}=3.75^0 [5] behind the unaligned rotor position (with respect to phase 1);
b) boost mode – also one-phase-on supplying with a commutation angle of θ_{sh} before unaligned rotor position;
c) long-dwell mode – with the same commutation angle as boost mode, but each phase is maintained energized for an extra $2\theta_{sh}$ angle. In this case a superposition of $2\theta_{sh}$ of phase supplying is obtained;
d) two-phase-on mode – with the same commutation angle as boost and long-dwell modes, but with an extra supply of $2\theta_{sh}$ with respect to long-dwell mode. In this case a classical two-phase-on supply is produced;
e) brake mode – in which motor phases are supplied in one-phase-on sequence with a commutation angle of θ_{sh} before the aligned rotor position, which is on negative slope of inductivity.

3. THE SIMULINK MODEL

The drive model originates from SRM equations, which are written with the following assumptions:

- mutual inductivities are null due to particular connection of pole windings [1];

- leakage inductivities are neglected;
- self-inductivities are of sinusoidal shapes with respect to rotor angle, as deduced from experimental measurements [4];
- magnetic saturation is neglected for an easier investigation.

Simulink model starts with motor equation, in final form as [1]:

$$\frac{di_k}{dt} = \frac{1}{L_0 + L_1\cos(\theta - \frac{k-1}{2}\pi)}[u_k - Ri_k + \omega L_1 i_k \sin(\theta - \frac{k-1}{2}\pi)], \quad k = 1 \div 4$$

$$\frac{d\omega}{dt} = -\frac{z_r^2 L_1}{2J}\sum_{k=1}^{4} i_k^2 \sin(\theta - \frac{k-1}{2}\pi) - \frac{B}{J}\omega - \frac{z_r M_r}{J} sign(\omega) \qquad (1)$$

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

where, beyond usual notation: L_0 and L_1 are average respectively the amplitude of inductivity variation with respect to electrical angle θ, J is total moment of inertia, B is the coefficient of viscous friction and M_r is load torque.

The four voltages $u_1 \div u_4$ correspond to unipolar PWM supplying provided by a current source-type inverter. A hysteresis unit that processes the voltage between -60V and +60V with an average current up to 9A, models the PWM inverter.

With the transducer logic as described before, a Simulink model has been built to use it for numerical simulation.

4. SIMULATION RESULTS

Electrical and mechanical magnitude variations are provided from numerical simulation. Figure 2 shows a few electrical magnitudes as: phase currents (a), phase voltages (b), back e.m.f. (c). The influence of PWM commutation is observed.

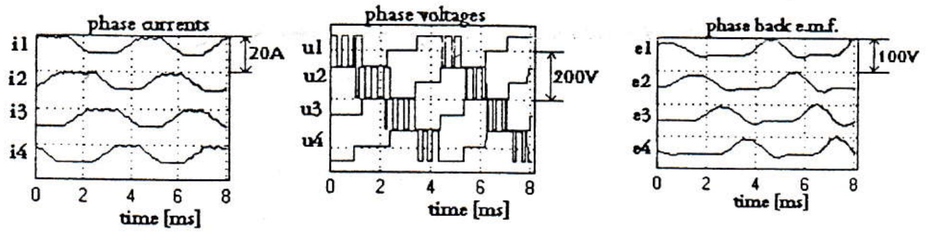

Fig. 2. Electrical magnitudes variations.

Among the mechanical magnitudes the angular speed and electromagnetic torque versus angular position are presented as depicted in figure 3.

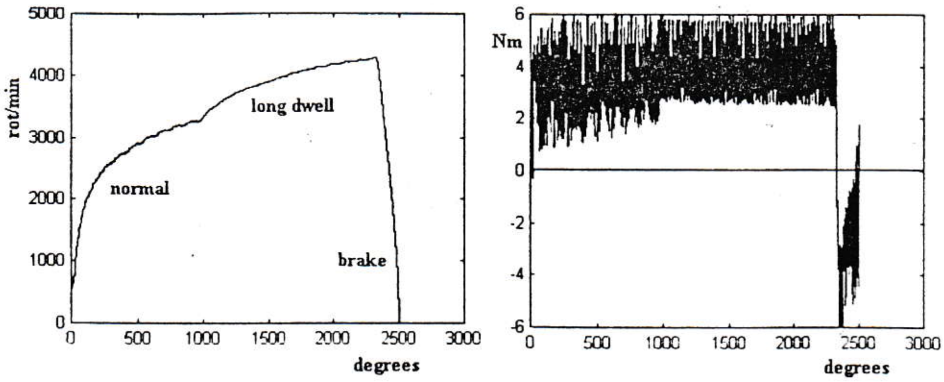

Fig. 3. Main mechanical magnitudes.

A 2-quadrant operation is simulated, when the motor is controlled in normal mode, switched to long-dwell mode and then to brake mode. Higher speed is reached in long dwell mode and rapid braking is achieved in brake mode.

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ANALIZA PE CALCULATOR A ACŢIONĂRII CU MOTOR CU RELUCTANŢĂ AUTOCOMUTAT

Se prezintă modelul matematic şi simularea unui motor cu 4 faze tip 8/6, folosind mediul Matlab 5.2 cu Simulink 2.0. Sunt arătate rezultatele simuării cu referire la mărimile electrice şi mecanice.