Duty Cycle Determination for 3-phase SRM Drive

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Abstract— Torque ripple should be minimized in reluctance motor (SRM) operation. Minimizing torque ripple leads to higher efficiency improvement for SRM motor and reduces undesirable vibration. Proper duty cycle selection can improve the phase commutation by changing phase current of each phase. In this paper the duty cycle of the controller of motor drive for 6/8 and 6/10 SRMs were presented and compared.

Keywords—Switched reluctance motor, torque control, current control, turn on angle, torque ripple.

I. Introduction

SWITCHED reluctance motor (SRM) is a nonlinear machine with high efficiency. It requires nonlinear control for torque ripple minimization.. Torque ripple is a major problem of SRMs and it can be minimized by current controlling or SRM design. Current controlling involves time-interval of turn-on and turn off angles of each phase.

With current controlling the negative torque production is reduced especially in nonlinear region. In this paper the duty cycle of controller was suggested for the proper turn-on and turn-off angle for 6/4 and 6/10 SRMs.

II. Background

A. SRM

SRM consists of different number of rotor and stator poles. SRM has N_s stator poles and N_p rotors poles. For three phase SRM, stator phase are energized consequently with current pulse [1]. The pulse current forces the rotor pole to move from unaligned poles to be aligned position poles.. Inductance and rotor position has linear relationship but in nonlinear region SRM phase inductance has magnetic nonlinearity so that phase inductance is nonlinear respected to rotor position causing high torque ripple waveform. High current and negative torque production suppression during nonlinear region operation can be achieved by controlling phase current.

In this paper a duty cycle of controller was determined and suggested for the proper turn-on and turn-off angle for 6/4 and 6/10 SRM Drives

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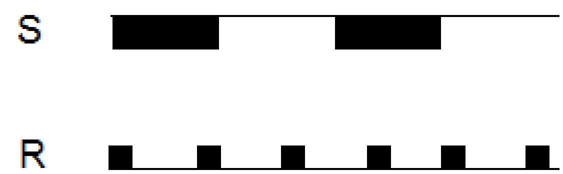

Fig 1. SRM pole position

At constant current, the electromagnetic torque per phase can be written as,

$$T = \frac{\partial (L \cdot i_p^2 / 2)}{\partial \theta} = \frac{1}{2} \cdot i_p^2 \cdot \frac{\partial L(\theta)}{\partial \theta} \qquad (1)$$

Total instantaneous torque is the sum of each phase torque, for 3-phase SRM it can be written as,

$$T(\theta, i) = T_1(\theta, i_1) + T_2(\theta, i_2) + T_3(\theta, i_3) \qquad (2)$$

Ttorque of each phase depends on rotor position at the minimum inductance value to the maximum inductance value of the energized phase.

B. Motor Drives

SRM can be controlled by motor drive using power electronic switch [3]. The fixed voltage and current source is converted to desired voltage and current level.

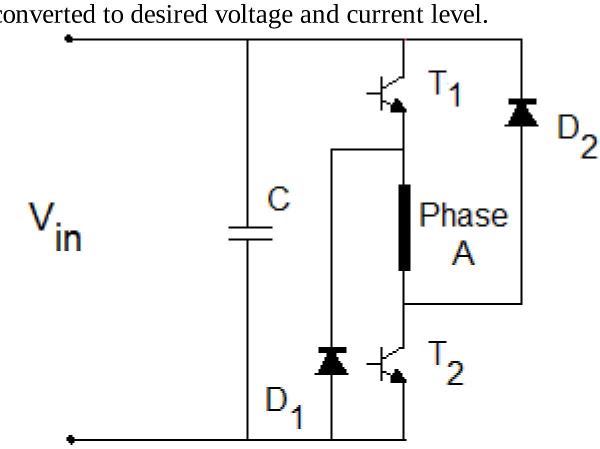

Fig 2. One phase motor drive cicuit

The motor drive consists of 2 diodes (D_1, D_2) and two power electronics switches (T_1, T_2).

When T_1, T_2 are ON-state, current passes through phase A of SRM from power source.

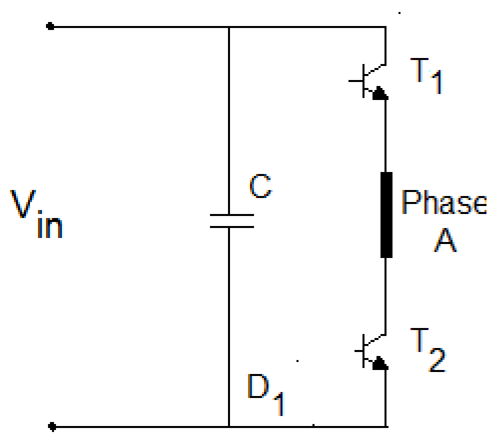

Fig 3. T_1, T_2 are ON-state

When T_1, T_2 are OFF-state and D_1, D_2 are ON-state, current flows from phase A to power source.

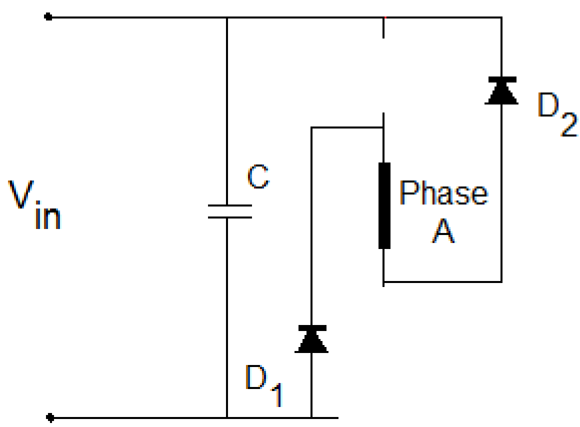

Fig 4. Fig 3. T_1, T_2 are OFF-state

For one phase, time period or time –interval starting from turn-on angle to turn-off angle to control power electronic switches in the same phase can be written as follows,

$$\Delta t_{on} = \frac{\Delta \theta_{on}}{\omega} \quad (3)$$

$$\Delta t_{off} = \frac{\Delta \theta_{off}}{\omega} \quad (4)$$

Where

Θ_{on} and Θ_{off} are turn–on and turn–off angles

ω is angular velocity

then The duty cycle can be calculated by,

$$D = \frac{\Delta t_{on}}{\Delta t_{on} + \Delta t_{off}} \quad (5)$$

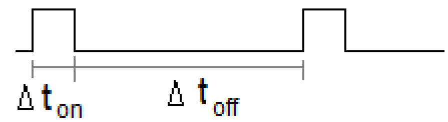

Fig 3.Duty cycle

III. Results

The results of the 6/8 and 6/10 SRMs were obtained through the computer simulation. The speed of the SRM ranges 300-5000 rpm was simulated in a computer program. The calculation results were presented in Table 1.

Table I
6/8 And 6/10 Calculation

Description	6/8 SRM	6/10 SRM
Aligned position, Θ_e	18.75	15
D	$148*10^{-4}$	$375*10^{-4}$

Due to higher number of rotor poles the 6/10 SRM needed faster switching frequency. The calculation of duty cycle for motor drives was presented. It can be seen that duty cycle of higher number of rotor pole such 6/8 SRM is slower than 6/10 SRM. The study is useful for speed and toque ripple control by motor drive.

IV. Conclusion

The duty cycle for torque reduction for the 6/8 and 6/10 SRM motor drives were presented and the results obtained through the computer simulation. The higher rotor pole required higher duty cycle. The duty cycles for the 6/8 and 6/10 SRM were 14.8us and 37.4 µs respectively.

Acknowledgment

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