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SRM의 고성능구동을 위한 새로운 제어방식

°오 석 규,*, 안 진 우**, 추 영 배*, 황 영 문*
* 부산대학교, ** 경성대학교

Novel Control Scheme for High Performance Switched Reluctance Motor Drive

S.G Oh*, J.W. Ahn**, Y.M. Hwang*

* Dept. of E.E, Pusan Nat'l Univ.
Keumjung-Ku, Pusan 609-735, KOREA
** Dept. of E.E, Kyungsung Univ.
Nam-Ku, Pusan 608-736, KOREA

Abstract-A novel control scheme for a Switched Reluctance Motor(SRM) drive is described. The control scheme which is to increace torque, to decrease torque ripples and easy to commutate is suggested. The conditions for high torque drive which includes flat-topped phase current and voltage control are analyzed and adopted in this control scheme. Flat-topped current is achived via dc-link voltage control. The suggested control system was tested to verify this suggestion.

Keywords : SRM, DC-link voltage control, Flat-topped current, P-I control

I. Introduction

Recently, SRM is researched more for its advantages such as simple and robust construction, high efficiency, excellent reliability, high speed capability and good thermal characteristics.[1] However, these machines also have some disadvantages such as relative high torque ripple, high non-linearity, current commutation difficulty during high speed operation.

So, to reduce torque ripple and to develop high torque, flat-topped phase current is desirable.[1] And to achieve easy commutation, commutation angle is predicted and/or calculated from the motor conditions.

In this paper, novel control scheme for high torque drive is proposed. The conditions for high torque drive which includes flat-topped phase current control are analyzed and adopted in this control scheme. Flat-topped current is achived via dc-link voltage control. And this scheme has easy commutations characteristics in a wide speed range.

II. Suggestion of novel control scheme

In general, the torque-speed charateristics for SRM are similar to DC series motor and changable by the control method. To get a high efficiency, high torque, low torque ripple and easy commutation, flat-topped phase current and appropriate switching angle calculation is essential.[1] It's because that the curent shoule be flat-topped for low torque ripple and the effective torque is not developed during current build-up and tail region.

The switching angle for flat-topped current is derived as followings.

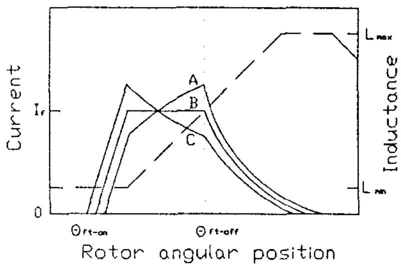

Fig. 1. Phase current in a SRM

Voltage equation for a phase in a SRM is as Eq.(1).

$$V = Ri + L(\theta, i)\frac{di}{dt} + i\frac{dL(\theta, i)}{d\theta}\frac{d\theta}{dt} \tag{1}$$

where R is winding resistance,
L is inductance.

If magnetic saturation and winding resistance are neglected for simple analyis, the flat-topped phase current is as eq.(2).

$$i_f = \frac{V}{k\,\omega_r} \tag{2}$$

Where $k = \dfrac{dL(\theta, i)}{d\theta}$

And to build up this current as flat-topped phase current at the end of minimum of inductance profile, the advance angle $\theta_{f\text{-}on}$ is derived from equation (1) as follow

$$\theta_{f\text{-}on} = \frac{L_{min}}{k_1} \qquad (3)$$

And this flat-topped current is to be benished within a maximum period of inductance profile not to generate negative torque. This maximum turn off angle $\theta_{f\text{-}off}$ is

$$\theta_{f\text{-}off} = L_{max}\,\frac{V}{K_1 V_b} \qquad (4)$$

Where V_b is applied voltage during demagnetization.

So, the developed torque by this flat-topped current is as eq (5).

$$T(\theta) = \frac{1}{2}\,\frac{dL(\theta,i)}{dt}\,i^2 = \frac{1}{2}\,\frac{dL(\theta,i)}{dt}\,\frac{V^2}{(R+k\,\omega_r)} \qquad (5)$$

From above analysis and equations, approprcate applied voltage and switching angle are enables to drive a motor with the flat-topped phase current and the reduced torque ripple drive. Eq.(2) shows the similar charactristics to the V/F=contst. speed control of ac motors.

III. Experiments and Results

To verify this proposed control scheme, control system is constructed for 1 HP 8/6 pole SRM. The inverter with chopper circuit is as Figure 2.

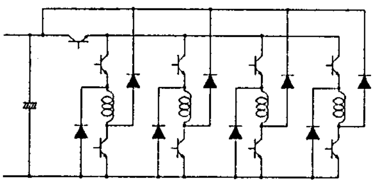

Fig. 2 Proposed power converter circuit

(a) Hardware design

The power converter used in this experiment is classic inverter with chopper. The chopper is to control dc-link voltage for flat-topped phase current by equation(2). The classic inverter is to maintain DC link level demagnetizing voltage. So, in this configuration, switching angle is almost constant in variable torque, variable speed control operation. Other inverter configuration is difficult to maintain same magnetizing/demagnetizing voltage and it demands the calculation process to predict turn-off angle and degrade driving performances.

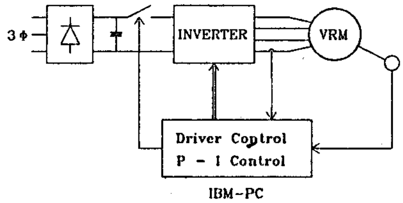

Fig. 3 SRM control scheme

(b) Software design

The closed-loop speed control system for SRM drive is controled by digital computer. From Eq.(3), (4), switching-on, -off angle could be fixed and DC link voltage is controlled via chopper.

The speed control loop is excuted by software. The speed is controlled by P-I controller which regulate DC-link voltage.

Using proposed control scheme, phase current is as Figure 4. But the smoothing reactor is elimimated and sustituted by the phase winding of motor and hardware incompleteness, the phase current is not completely flat-topped. Step response of speed control loop is shown in Fig. 5.

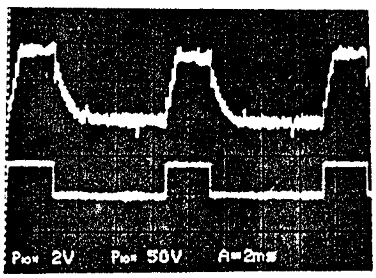

Fig. 4 Phase current(upper) and gate signal(lower)
(Ver. ; 2A/Div., Hor. ; 2msec/Div.)

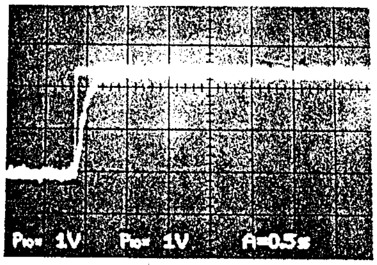

Fig. 5 Step response of SRM drive system
(Ver. : 500rpm/Div. Hor. : 0.5sec/Div.)

Ⅳ. Conclusion

This paper describes novel control scheme for a SRM drive. The control scheme which is to decrease torque ripples and to increace torque is suggested. The voltage and switching angle for the flat-topped phase current is derived and this technique is advantages to reduce torque ripple, to maximize torque and easy to commutate.

Some considerations including saturation effect, winding resistance are take into account for the industrial application.

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