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유압펌프시스템의 직접 순시 토오크 제어

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Direct Instantaneous Torque Control of Hydraulic Oil Pump System

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Abstract —In hydraulic oil pump system, pressure has a linear relationship with output torque of motor. Torque control of pump drive can easily output stable pressure, and it can retain required pressure at minimum speed to save power consumption. Switched reluctance motor(SRM) has many advantages such as low cost and low inertia. It can generate high torque at low speed. But inherent high torque ripple of SRM influences performance of pressure control in hydraulic oil system.

This paper presents direct instantaneous torque control(DITC) of hydraulic oil pump system. DITC method can reduce inherent torque ripple of SRM, and output smoothing torque to load. So the proposed hydraulic oil pump system can support smooth pressure and fast dynamic power supply to the hydraulic pump system. At last the proposed hydraulic oil pump system is verified by computer simulation and experimental results.

1. Introduction

A hydraulic pump system is very widely used in building machinery, brake system of vehicles and automatic control system of industrial applications[1]. In a conventional hydraulic pump system, induction motor is much used due to the cost and simplicity of the motor driving. But it has more power consumption at pressure retained. Recently, saving power consumption and high performance motor drive for hydraulic pump system is much interested in hydraulic pump system[2].

Switched Reluctance Motors(SRM) is investigated for wide industrial applications due to the mechanical strength and cost advantages. Comparing with conventional hydraulic pump system, SRM has a widely variable speed range which can save power consumption at pressure maintenance. And it can generate high torque at low speed, which obtains fast dynamic pressure response as pump system required.

This paper presents direct instantaneous torque control(DITC) of hydraulic oil pump system. DITC method can reduce inherent torque ripple of SRM, and output smoothing torque to load. Since pressure has a linear relationship with output torque of motor, the proposed hydraulic oil pump system can stable pressure and fast dynamic power supply to the hydraulic pump. At last the proposed hydraulic oil pump system is verified by computer simulation and experiment results.

2. Proposed DITC of SRM in hydraulic oil pump system

2.1. Basic concept of hydraulic pump

For hydraulic pump system with SR drive, the maximum torque and rated speed are obtained from the mechanical specifications of hydraulic pump. The maximum flux of hydraulic pump is determined by volume efficiency and pump speed as follows:

$$Q_{\max} = n_m \cdot v_p \tag{1}$$

where, Q_{max} is maximum output flux, n_m is pump speed, V_P is pump capacity [cm^3/min].
And the pressure of oil is determined with the assumption of constant output flux and no loss of hydraulic pump as follows:

$$P_p = T_m / v_p \tag{2}$$

where Pp is oil-pressure [MPa], T_m is pump torque [Nm].

2.2. Conventional asymmetric converter for SR drive

The conventional asymmetric converter can provide independent control of each phase and phase overlap, which is essential condition for DITC operation. The conventional asymmetric converter and its operating modes are shown in Fig. 1 and Fig. 2.

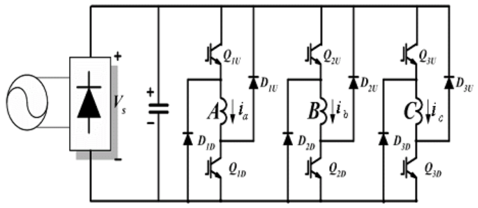
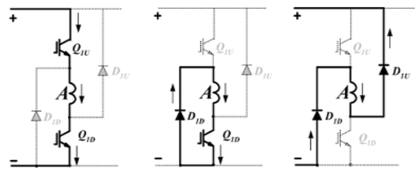


Fig. 1. Conventional asymmetric converter

The asymmetric converter has three modes, which are defined as magnetization mode, freewheeling mode and demagnetization mode. The magnetization mode is defined as state 1 shown in Fig. 2(a). The freewheeling mode is defined as state 0 shown in Fig. 2(b). The demagnetization mode is defined as state -1 shown in Fig. 2(c).



(a) (b) (c)

Fig. 2. Operation modes of asymmetric converter
(a) Magnetization mode (b) Freewheeling mode
(c) Demagnetization mode

2.3. Proposed DITC method for SR drive

In order to eliminate a torque ripple, DITC method is introduced. Fixed frequency PWM is popular in a motor control. But fixed frequency of PWM brings a fixed switching loss, which reduces efficiency of drive system. Hysteresis control generates variable frequency of PWM, so frequency of power switches can be reduced. By the given hysteresis control rules, appropriate torque of each phase can be produced and constant total torque can be obtained. In this method, the phase inductance has been divided into 3 regions shown as Fig. 3.

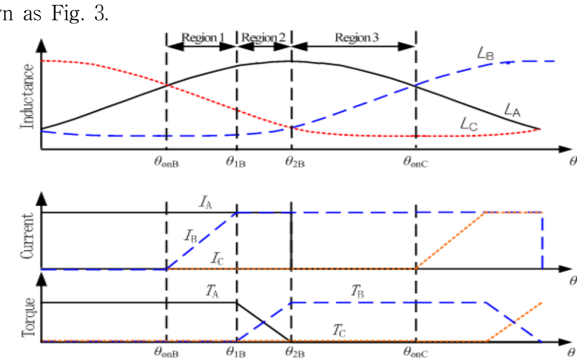
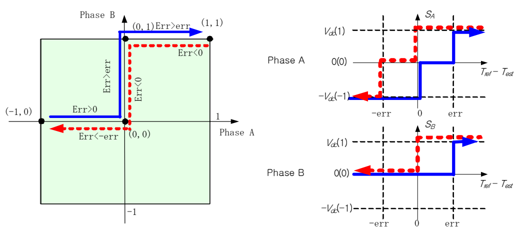


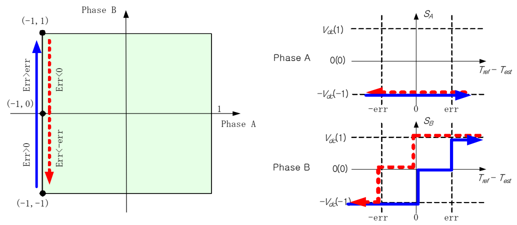
Fig. 3. Principle of 3 regions DITC method

The regions depend on the geometrical structure and load. The boundaries of 3 regions are Θ_{onB}, Θ_{1B}, Θ_{2B} and Θ_{onC} in Fig. 3. Θ_{onB} and Θ_{onC} are turn-on angle of phase B and phase C, respectively. The Θ_{1B} is a rotor position which is the inflexion of inductance in phase B. And Θ_{2B} is mid point of inductance in phase A. Total length of those regions is 120 electrical degrees in 3 phases SRM. Assuming the outgoing phase is phase A and incoming phase is phase B in Fig. 3. When the first region 3 is over, the outgoing phase will be replaced by phase B in next 3 regions.

In order to carry out the principle of 3 regions DITC method, hysteresis controller and hysteresis rules are used in control system. The two different control schemes will be assigned to 3 regions. DITC scheme of conventional converter is shown in Fig. 4. In order to reduce switching frequency, every action just opens or closes only one switch at a time. It can reduce frequency of the switches. In DITC scheme of asymmetric converter, region 1 and region 2 have same control scheme shown in Fig. 4(a). Combinatorial states of (-1, 1), (0, 0), (0, 1) and (1, 1) are selected into this control scheme. Torque error is importance input parameter in proposed DITC method. If torque error satisfies the condition of rising or falling rule, actual state will turn to next combinatorial state. Jumping state is not accepted in this hysteresis control. As a similar, control scheme in region 3 is shown in Fig. 4(b).



(a)



(b)

Fig.4. DITC scheme of conventional converter
(a) control scheme 1 (b)control scheme 2

Control diagram of DITC SRM hydraulic oil pump system is shown in Fig. 5. Because of DITC of SRM, hydraulic oil pump system can output smooth pressure and fast dynamic flux response.

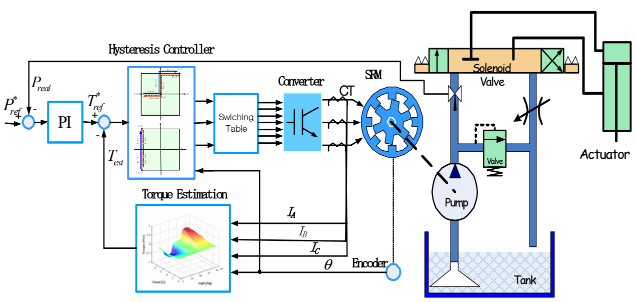
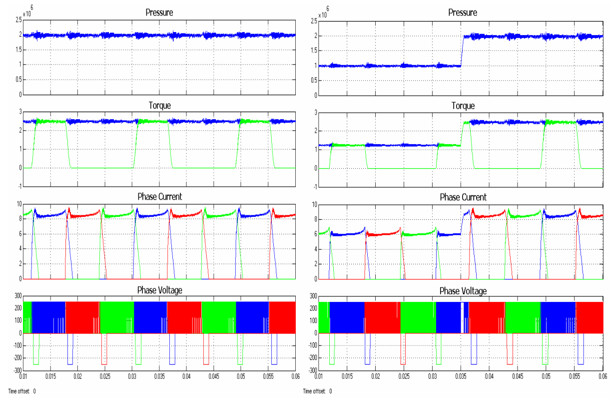


Fig. 5. Control diagram of DITC SRM hydraulic oil pump system

3. Simulations and Experiments

In order to verify proposed DITC SRM in hydraulic pump system, simulation is executed. The simulation result is shown in Fig. 6. The output pressure is 2[*MPa*], and smoothing torque and pressure can obtained from DITC of SRMin hydraulic pump system, and the simulation waveform is shown in Fig. 6(a).

The simulation of pressure step response is shown in Fig. 6(b). The output pressure has a step from 1[*MPa*] to 2[*MPa*]. The output pressure obtains a fast pressure response shown in Fig. 6(b).



(a) (b)

Fig. 6. Simulation results of hydraulic oil pump system
(a) 2[*MPa*] operation (b) pressure step response

The experiment results of the proposed method are shown in Fig. 7 and Fig. 8. From the experiment results, stable control pressure and a fast pressure response can be obtained..

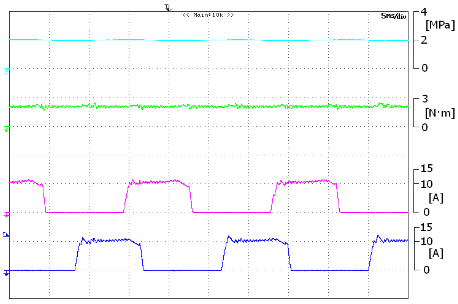


Fig. 7. Experimental result of 2[MPa] operation

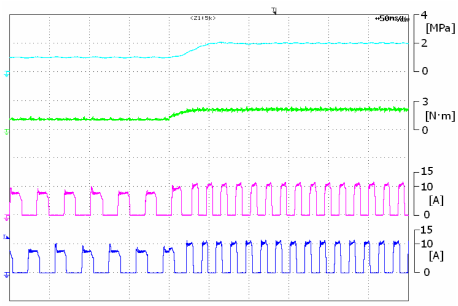


Fig. 8. Experimental result of pressure step response

4. Conclusions

This paper presents DITC of hydraulic oil pump system.. DITC method can reduce inherent torque ripple of SRM, and output smoothing torque to load. The proposed hydraulic oil pump system can stable pressure and fast dynamic power supply to the hydraulic pump. At last the proposed hydraulic oil pump system is verified by computer simulation and experimental results.

[References]

[1] Jame L. Johnson et al, Introduction to Fluid Power, Science & Technology, 2004.
[2] B.C. Kim, D.H. Lee, J.W. Ahn, "Performance of SR Drive for Hydraulic Pump", ICEMS2004, 2004, pp. 659-663.
[3] J.N. Liang, Z. G. Lee, D. H Lee, J. W. Ahn, "DITC of SRM Drive System Using 4-Level Converter" ICEMS2006, pp. 2006
[4] J.N. Liang; D. H. Lee, J. W. Ahn, Y. J. An, "A Novel 4-Level Converter for High Speed SR Drive"in Conf. PESC '06. 37th IEEE, 18-22 Jun. 2006 pp:1 - 6