SRM의 Dynamic Simulation과 Modelling에 관한 연구

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Dynamic Simulation and Modelling of the Switched Reluctance Motor

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ABSTRACT

The paper presents the component parts and their models of the Switched Reluctance motor drive system with the angle position-current chopping control and with the fixed angle pulse width modulation control. The calculation of the parameters and the simulated models based on the MATLAB SIMULINK software package are introduced by a four-phase 8/6 structure prototype with the four-phase asymmetric bridge power converter. The simulation of the prototype in the course of starting is made by the simulated models at the different control strategies and the different given rotor speed.

1. Introduction

The Switched Reluctance motor drive system could operate in a very wide speed range with high efficiency. There are no windings, no magnet and a brushless structure on the rotor. and there is only multi-phase centralized windings on the stator. Those give rise to its simple and firm structure. It has good prospects for application, such as the electric drive device in coal mine.[1][2] in family electrical equipment. in aircraft[3][4] and so on. It is necessary for the design and research of the drive system to set up the models and make the simulation. The dynamic simulation of the Switched Reluctance motor drive system is essential to analyze and study the drives. The mathematical models of the machine[5] and the mathematical models of the power converter[6] have been set up. respectively. The Switched Reluctance motor drive system is made up of the Switched Reluctance motor, the power converter and the controller. The models and the simulation of Switched Reluctance motor drive system should be done from the systematic point of view.

The Switched Reluctance motor drive system has the control parameters. There are some variable speed control strategies. such as the angle position-current chopping control[7] and the fixed angle pulse width modulation (PWM) control.[8]

In the angle position-current chopping control strategy, the current chopping control is used at the low speed ranges. The turn-on angle of the main switches in the power converter is fixed and also the turn-off angle fixed. The phase current of the motor is measured and compared with the limit of the current chopping. Of the phase current is bigger that the limit, the main switches in the power converter are turned off a certain time, then the main switches are turned on again, and so on. The output torque and the rotor speed are adjustable by regulating the limit value of the current chopping. The angle position control is applied at the high-speed ranges. The output torque and the rotor speed are variable by regulating the turn-on angle and the turn-off angle of the main switches in the power converter are fixed angle PWM control strategy, the turn-on angle and the turn-off angle of the main switches in the power converter are fixed, the triggering signals of the main switches are modulated by the PWM signal. The phase winding average voltage could be adjusted by regulating the duty ratio of the PWM signal so that the output torque and the rotor speed of the motor can be adjustable.

In the braking control of the Switched Reluctance motor drive system, the angle position control and the fixed angle PWM control[9] could be also adopted. The braking torque could be used to control by regulating the turn-on angle and the turn-off angle of the main switches in the power converter or by regulating the duty ratio of the PWM signal.

At present, MATLAB is one of the most effective simulation tools for control system. The SIMULINK toolbox is the picture input and simulation tool of control system models that is provided by Math Works company.[10] It has two main functions. such as the simulation and the link. It could transfer the patterns in the warehouse directly or could create the new patterns, and it could set up the structural frame drawing of the control system by connecting the patterns and then select the control parameters, finally, the simulation could be implemented. The SIMULINK toolbox is suitable for the simulation of the Switched Reluctance motor drive system. The paper introduces the founding models and simulation procedure of the drive system based on MATLAB software package.

2. Component Parts and Models

While the mechanical loss and the stray loss are neglected. there is the motional equation of the Switched Reluctance motor as follows.

$$T_a = J\frac{dw}{dt} + Dw + T_L \quad (1)$$

Where, J is the sum of the inertia movement of the motor and the loads. D is the coefficient of the viscous-damping. w is the rotor angular velocity. T_L is the torque of the loads that is the function of the angular velocity of the loads. T_ω is the average electromagnetic torque of the motor. The model of the Switched Reluctance motor could be expressed as follow.

$$T(S) - T_L(S) = (JS+D)w \quad (2)$$

The relationship between the average electromagnetic torque of the motor and the control parameters based on the angle position control or the foxed angle PWM control could be expressed as follows.[7]

$$T_\omega = K_\omega K_\theta \frac{U^2}{\omega^2} \quad (3)$$

$$K_m = m\frac{Z_r}{2\pi} \quad (4)$$

Where Zr is the number of the rotor poles. m is the phase number of the stator windings, U is the average phase winding supplied voltage, K_θ is the coefficient of the turn-on angle and the turn_off angle. which has the different value while the drive is operated at the different rotor speed range.

In the angle position control, the equation (3) and (4) could be expressed as follows.

$$T_{av} = K_m K_\theta \frac{U_R^2}{\omega^2} \quad (5)$$

Where U_R is the DC supplied voltage of the power converter.

In the fixed angle PWM control, the equation (3) and (4) could be expressed as follows.

$$T_{av} = K_m K_L \frac{U^2}{\omega^2} \quad (6)$$

Where K_L is a constant that is related to the fixed turn-on angle. the fixed turn-off angle, the structural parameters of the motor and the phase inductance. There is the voltage magnifying coefficient of the power converter with PWM signal chopping. "K_C". The process of PWM chopping is regarded as the process of sampling the output signal of the rotor speed regulator. The zero step keeper could be equivalent to a little inertial unit.

The relationship between the average electromagnetic torque of the motor and the control parameters based on the current chopping control could be expressed as follows.[7]

$$T_{av} = K_h L^2 \quad (7)$$

Where L is the expected value of the phase current. K_h is a constant that has the relationship with the fixed turn-on angle, the fixed turn-off angle, the structural parameters of the motor. and the phase inductance. and K_m

The rotor speed regulator is a PID regulator.

[11] the model is as follows.

$$D(S) = \frac{U_R}{U_g - U_L} = K_p(1 + \frac{K_L}{S} + K_D S) \qquad (8)$$

Where K_p is the proportional coefficient, K_L is the integral coefficient. K_p is the differential coefficient. U_g is the given voltage reference value of the rotor speed. and U_L is the feedback voltage value of the rotor speed.

The rotor position detector fixed on the end cover of the motor is the featured component of the Switched Reluctance motor drive that contributes to implement the rotor position closed-loop control and the rotor speed closed-loop control. The output signals of the rotor position give the feedback of the rotor speed that is implemented by a frequency/voltage transformer. The rotor speed feedback unit with a filter is equivalent to a small inertia unit. the model is as follows.

$$G_{n(S)} = \frac{K_n}{1 + T_n S} \qquad (9)$$

Where K_n is the feedback coefficient of the rotor speed, T_n is a time factor of the rotor speed feedback filter.

In order to equilibrate the delay of the rotor speed feedback filter, the rotor speed given filter with a time factor, T_g is essential. The model is as follows,

$$G_{g(S)} = \frac{1}{1 + T_g S} \qquad (10)$$

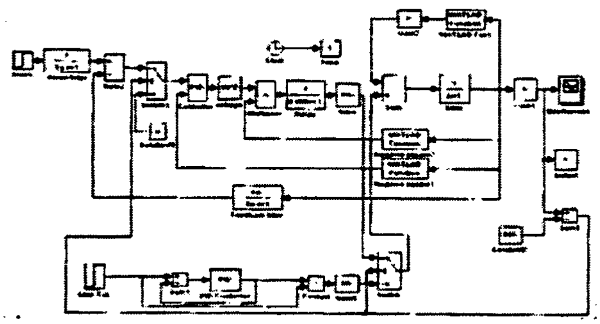


Fig. 1 Model of the drive with the angle position-current chopping control

Fig.1 gives the model of the Switched Reluctance motor drive system with the angle position-current chopping control based on MATLAB SIMULINK toolbox. Fig.2 gives the model of the drive system with the fixed angle PWM control

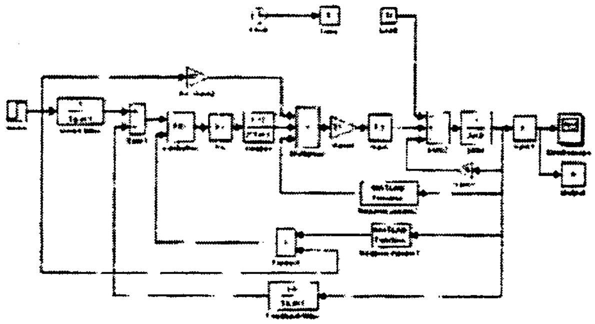


Fig. 2 Model of the drive with the fixed angle PWM control

4. Simulation

The simulation of the Switched Reluctance motor drive prototype is made. The step is *0.1 ms*, and the permissible error is 1.0×10^{-4}.

In the angle position-current chopping control, Fig.3 gives the simulated rotor speed curve of the drive in the course of starting, while the given rotor speed is 500 r/min. Fig. 4 gives the tested rotor speed curve of the drive at the same conditions.

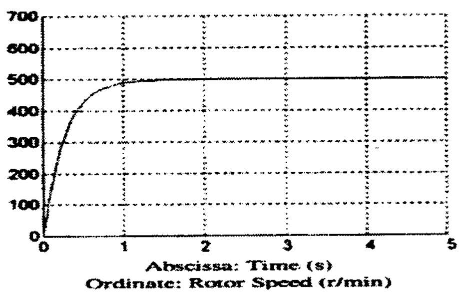
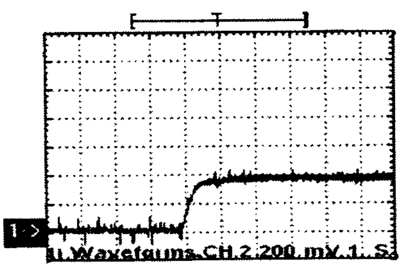


Fig. 3. The simulated rotor speed curve of the drive system



Scale: Abscissa: 1.0 s/div. Ordinate: 250 r/min/div.
Fig. 4 The tested rotor speed curve of the drive system

In the fixed angle PWM control, Fig. 5 gives the simulated rotor speed curve of the drive in the course of starting, while the given rotor speed is 1500 r/min. Fig. 6 gives the tested rotor speed curve of the drive in the same conditions. It is shown that the simulated rotor speed curve of the drive at the same conditions tally with the tested rotor speed curve of the drive in the experiments.

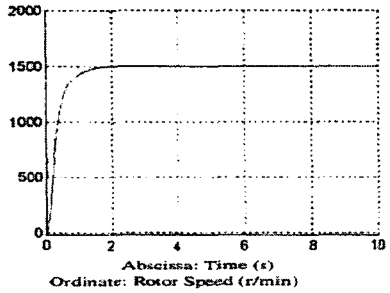
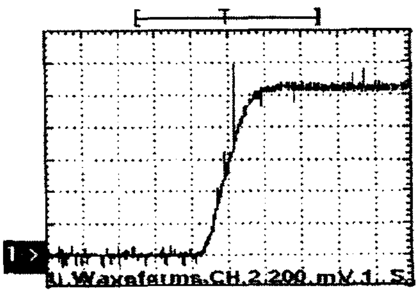


Fig. 5 The simulated rotor speed curve of the drive



Scale: Abscissa: 1.0 s/div. Ordinate: 288 r/min /div.

Fig. 6 The tested rotor speed curve of the drive system

5. Conclusions

The MATLAB SIMULINK software package contribute to set up the dynamic simulated models of the Switched Reluctance motor drive system precisely. Founding mathematical models of the Component Parts in the drive system determining the parameters in the model are the keys. The founding models and simulation procedure of the drive system with the angle position- current chopping control and with the fixed angle PWM control are given in the paper. The method and the procedure are suitable for the founding models and simulation of the Switched Reluctance motor drive system with other control strategies and with other construction.

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