퍼지제어기 기반의 새로운 BLSRM의 축방향지지력 제어

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Levitation Control of BLSRM using Adaptive Fuzzy PID Controller

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ABSTRACT

BLSRM is a nonlinear, strong coupling and multi-variable system. The conventional control method is vulnerable to uncertain factors such as the load disturbance and satellite parameters change. It is difficult to obtain satisfactory control effect. Basing on a 8/10 BLSRM, whose suspending force control is separated with the torque control, this paper presents adaptive fuzzy PID controller for levitation control, which apply the fuzzy logic control to the conventional PID controller for parameters self-tuning. Both fuzzy and parameters of PID controller are self-tuning on-line, which improve the performance of controller. Finally, simulation and experimental results show the performance of the proposed method.

1. INTRODUCTION

Switched-reluctance motors(SRMs) have substantial benefits in many applications. Their particular characteristics are simple construction, low cost, fault tolerance, high efficiency, and the ability to operate in a high-temperature environment. However, mechanical bearing limits SRMs' highspeed ability. Bearingless switched reluctance motors (BLSRMs) can avoid the contact and the lubrication between motor shaft and bearing, and they can generate radial forces to levitate the rotor by changing the flux density in the motor air gap [1] - [3].

The torque production in SRM drive is highly nonlinear due to the dependency of the machine torque on rotor position and phase current. Several methodshave been reported in the literature for fault-tolerant SRM drive. Current profiling and extended conduction of the healthy phases are few amongst those methods.

In the proposed control scheme, a simple PI controller is used to regulate the speed of the proposed BLSRM, and two adaptive fuzzy PID controller are used to generate the desired suspending force commands to keep the rotor in the center position. The validity of control scheme are verified by the simulation results.

2. Structure and Operate Principle of 8/10 BLSRM

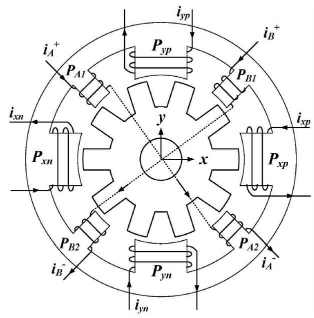

Fig. 1. Basic structure of the 8/10 BLSRM

Fig. 1 shows the basic structure of 8/10 BLSRM which consists of one 8-stator poles and 10-rotor poles. As shown in Fig. 1, there are two types of stator poles in the motor. One type is torque pole presented as PA1, PA2, PB1 and PB2. Windings on pole PA1 and pole PA2 are connected in series to construct torque winding A, and windings on the pole PB1 and pole PB2 are connected in series to construct torque winding B, which is used to generate rotational torque. Once torque winding is excited, The other type is suspending pole such as Pxp, Pxn, Pyp and Pyn, which mainly generate suspending force to suspend the shaft and rotor. Windings on the suspending poles Pxp, Pxn, Pyp and Pyn are controlled independently.

3. CONTROL SCHEME OF 8/10 BLSRM

Eccentric displacements of rotor in both X direction and Y directions are detected by four eddy current displacement sensors. And these four detected displacement signals can be feedback for suspending force control. And the torque control loop use a PI controller to regulate the motor speed. PWM duty ratio can be obtained from PI controller. The in-coming phase and off-going phase can be determined, combining with rotor position detected from encoder. Furthermore, speed can be adjusted by turning on and turning off of corresponding torque winding switches according to PWM duty ratio. With two independent close-loop suspending force controllers, which is adaptive fuzzy PID controller, the motor radial position can be regulated, one for X direction and another for Y direction, respectively. These two adaptive fuzzy PID controllers generate the desired command suspending force, to keep the rotor position in the center. Two suspending force windings are selected and there current, are also calculated. Further, actual current values of selected suspending force windings can be controlled through hysteresis method according to these two current command signals

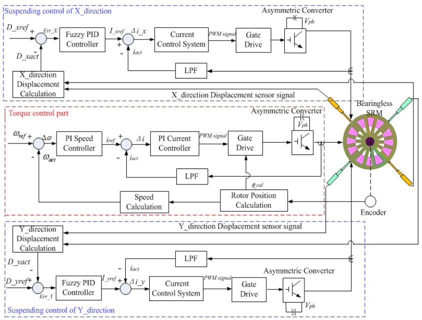

Fig. 2. Control scheme of the 8/10 BLSRM

4. EXPERIMENT RESULTS

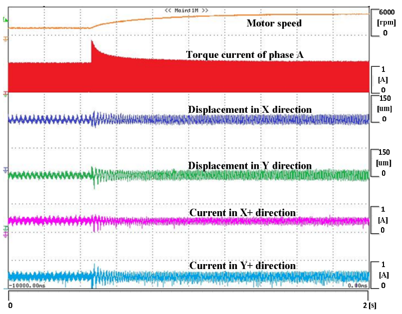

Fig. 4. Speed variation from 1500 rpm to 4500 rpm

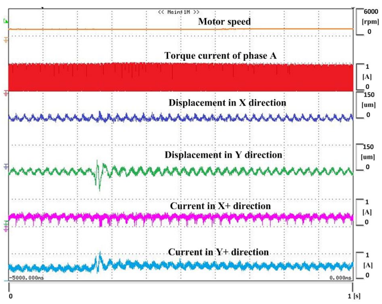

Fig. 5. Eccentric load increased from 2N to 4N at 1500rpm

Fig. 4 show the experimental results of eccentric load variation when the motor rotate at a constant speed (1500rpm). As shown in these figures, when the eccentric load changing in the -Y direction, the rotor has an eccentricity displacement in the corresponding direction immediately, but the rotor can be pulled back to the center position rapidly by the suspending force generated by +Y direction suspension winding(Pyp). As shown in these figures, the torque winding current will also change a little with suspending load variation due to the friction between the shaft and the suspending force load. The response of suspending load variation of the other three directions is similar with the waveforms displaying on these figures.

Fig. 5 show the operation waveforms of proposed control scheme under the speed variation. As shown in this figure, the torque winding current is increased to handle the speed changing from 1500 to 4500rpm. From the air-gap displacement in the X direction and Y directions, it is seen that the rotor can still be steadily suspended even the motor speed is changed. Furthermore, with the current changing in the torque winding, the suspending current is almost same as before, which means that the torque winding current has no effect on the suspending force. And the frequency of the suspending current is higher than before, when the motor speed increase.

4. CONCLUSIONS

In this paper, basing on a novel 8/10 bearingless switched reluctance motor, a control scheme of adaptive fuzzy PID controller is proposed and an experimental system is established. The adaptive fuzzy PID control is developed for the suspending system which possesses the property of nonlinearity and uncertainty. The self-tuning factors are made to modify the parameters of FLC(fuzzy logic controller) online. The hybrid control is designed to eliminate the static error that FLC inheres and fulfil non-error control and achieve requirement for real-time and high precision. According to the experimental results, it can be seen the motor can operate steadily up to 4500rpm with an effective and quick response suspension controller, and the maximum of rotor eccentric error is about 30μm at this speed. The experimental results show that the proposed method has the strong adaptive ability, fast dynamic response and the strong robustness. Main parameters of novel BLSRM

감사의 글

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