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Direct Control of Bearingless Permanent Magnet Slice Motor Based on Flux Linkage Observer Using Phase-locked Loop

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A bearingless permanent magnet slice motor (BPMSM) has compact structure and high efficiency, which can realize the rotor magnetic suspension at five degrees of freedom. The rotor magnetic field oriented strategy can realize the decoupling control of torque and suspension force, but it is difficult to meet the high performance requirements of torque and suspension force. The theory and method of direct torque control are applied to the BPMSM in this paper. With the reference of the direct torque control, a double-closed-loop control system of rotor displacement and radial suspension force is designed. Meanwhile, aiming at the low-accuracy stator flux linkage estimation and complex control structure of the traditional direct control, a stator flux linkage observer based on the phase-locked loop is proposed and implemented to improve the accuracy and performance of the BPMSM control. Firstly, the mathematic models of torque and suspension force are deduced. Secondly, a flux linkage observer based on the phased-locked loop is designed, and the principle of the flux linkage estimation and the control algorithm of the direct control are analyzed. Thirdly, the direct control system of the BPMSM is constructed. The correctness of the mathematic model and control algorithm are verified by Matlab/Simulink. The simulation results indicate that the start-up time is reduced by 20%. Finally, the proposed strategy is applied to a 4kW prototype. The peak value of displacement vibration is decreased by 25% when the BPMSM operates stably in no load, and the recovery time of displacement in the x-direction is reduced from 100ms to 50ms when a 10N interference force is added in the x-direction. The experimental results show that the robustness of the system is effectively improved, as well as the dynamic and static performance.

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