学　位　論　文　の　要　旨

論文題目：Research on Model Predictive Control for Interior Permanent Magnet Synchronous Motors Fed by Four-Switch Three-Phase Voltage Source Inverter（4 スイッチ三相電圧形インバータにより駆動される永久磁石埋込型同期モータのモデル予測制御に関する研究）

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Interior Permanent Magnet Synchronous Motor (IPMSM) has been widely investigated and applied in many industry applications due to its advantages, such as high efficiency, high power density, high torque-current ratio and wide speed range. IPMSM can produce reluctance torque because of the structure asymmetric of rotor magnetic circuit. If the reluctance torque is fully utilized, it can improve the overload output capacity of the motor and increase the efficiency of the system. In this thesis, a novel Maximum Torque Per Ampere (MTPA) control strategy of IPMSM is researched and developed.

The common Two-Level three-phase Voltage Source Inverter (2L-VSI) is the weak link of the motor control system. A short or open circuit fault of 2L-VSI may lead to open circuit of motor winding. Then, a large torque output and big mechanical noise will occur in motor system under such condition. The overall performance of the system is greatly reduced, or even unable to work. Therefore, the fault-tolerant control of 2L-VSI in motor drive system is of great significance. To enhance the fault-tolerant capability of the inverter, the fault bit is connected to the middle point of the dc-side capacitor, which constitutes a Four-Switch Three-Phase Inverter (FSTPI). Thus, to use this way to the regulation of reconstructed FSTPI can still operate steadily with reduced capacity. In addition, due to these advantages of low cost, simple topology and strong load capacity after fault tolerance, FSTPI has been widely used in motor speed control system as a fault-tolerant topology of 2L-VSI.

Two of the most widespread control methods for motor system are Field Oriented Control (FOC) and Direct Torque Control (DTC). FOC is based on stator current control. However, the system response of FOC is slow because of the existence of inherent inner current loop. The system response of DTC is fast, however, it generates large torque ripple. With the improvement of microprocessors, Model Predictive Control (MPC) is a class of prospective IPMSM strong characteristic regulatory countermeasures. It owns some obvious advantages, especially simple structure, fast dynamic response, easy achievement of multi-object control, and easy inclusion of nonlinearities and constraints. Therefore, this thesis adopts MPC strategy combined with DTC to control IPMSM system driven by FSTPI.

Improvements to the conventional predictive control algorithm of FSTPI are mainly proposed in this thesis. Aiming at the inherent problem of imbalance of capacitor midpoint voltage in the FSTPI, a voltage term to the cost function needs to be added in the conventional MPC algorithm to control it, which inevitably leads to the need to adjust the weighting factor of the voltage term. The small number of model predictive control for traditional single vector leads to poor control performance, and the multi-vector control is relatively complicated in the calculation process.

In order to effectively handle such issues, this thesis gives a type of fault-tolerant mode which has a switching sequence Model Predictive Direct Torque Control (MPDTC) method for IPMSM in switch open-circuit fault-tolerant. Under the MTPA regulation, the regulatory target has been converted to the d-q axis of the stator flux-linkage. Instead of selecting one space vector from the possible four space vectors, the proposed MPDTC method selects an optimized switching sequence from two well-designed switching sequences including three space vectors. The new type of fault-tolerant mode does not need to select one spatial vector from the possible four spatial vectors, while selecting one optimal switching sequence from two designed switches including three space vectors. Developed a cost function that does not require weighting factors. In order to complete the stator flux-linkage reference track, the operation method of the spatial vector continuous time used in the switch program is explored. In addition, a new capacitor voltage balancing method is designed by injecting dc offset into the fault phase. The new method can simplify the design of weighting factor. Finally, the results confirm the rationality and superiority of this scheme.