MODEL PREDICTIVE CONTROL OF ELECTROMAGNETIC TORQUE IN PERMANENT MAGNET SYNCHRONOUS MACHINES

by

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CERTIFICATE OF AUTHORSHIP/ORIGINALITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Student

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LIST OF SYMBOLS

*	Reference value
$\alpha\beta$	Stationary stator reference frame axes
dq	Rotary rotor reference frame axes
f	Frequency (Hz)
f_{av}	Average switching frequency (Hz)
f_{sp}	Sampling frequency
J	Inertia
$\psi_a,\ \psi_b,\ \psi_c$	Three-phase flux linkages (Wb)
ψ_α, ψ_β	α- and β- axis stator flux linkages (Wb)
ψ_d, ψ_q	d- and q-axis stator flux linkages (Wb)
θ_r	Angle between two stator reference frame and rotor reference frame
L_d, L_q	d- and q-axis inductance (H)
ψ_f	Flux linkage generated by the rotor permanent magnet (Wb)
ψ_{rip}	Flux ripple
p	Number of the machine pole pairs
u_a, u_b, u_c	Stator voltages (V)
u_α, u_β	α- and β- axis stator voltages (V)
i_a, i_b, i_c	Stator currents (A)
i_α, i_β	α- and β- axis stator currents (A)
i_d, i_q	d- and q-axis stator currents (A)
R_s	Per-phase stator winding resistance (Ω)
T_e	Electromagnetic torque (Nm)
T_L	Load torque applied on the rotor shaft
T_{rip}	Torque ripple

$u_0 \cdots u_6$	Space voltage vectors produced by the two level inverter (V)
P_{in}	Total input power of a motor (W)
P_{em}	Electromagnetic power obtained by subtracting the mechanical loss from the input power (W)
ω_r	Rotor mechanical speed
ω_e	Electrical speed
C_T	Torque constant gain
C_ψ	Flux constant gain

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ABSTRACT

This study focuses on the development of novel model predictive control method for PMSM drive system. The aims of the proposed control method are flux and torque ripples reduction. The performances of the proposed model predictive control method and conventional direct torque control (DTC) are comparatively studied in both simulation and experimental tests.

In recent years, various variable speed drive strategies and structures for PMSMs have been widely investigated and reported. Among these control strategies, the six-step control, field oriented control (FOC) and DTC are the most popular ones. Among them, the conventional DTC, which selects the desired voltage vector based on hysteresis comparators and switching table, features a fast dynamic response and very simple structure. The major demerits of DTC are large torque and flux ripples, variable switching frequency, and acoustic noises. Recently, the model based predictive control (MPC) was introduced to overcome these problems. However, the improvement was limited for the purposes of torque and flux ripple reduction and the MPC still suffered from variable switching frequency.

The conventional DTC and MPC are similar in that they both select only one voltage vector per sampling period. This may result in overregulation, which is the key issue for torque and flux ripples and excessive acoustic noise. In this thesis, an improved MPC method with duty ratio optimization was proposed for PMSMs. The proposed method features low torque and flux ripples and relatively stable switching frequency. It is of most benefit when the drive system is working at a low sampling frequency because in the low frequency range, the proposed MPC drive system can achieve much lower torque and flux ripples than the original MPC and DTC, which is a very desirable feature for high power applications (e.g. electric vehicles). Finally, the numerical simulation and experimental test results of the conventional DTC, MPC, and improved MPC were presented to verify its effectiveness.