

**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.

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## TABLE OF CONTENTS

CERTIFICATION	i
ACKNOWLEDGEMENTS	ii
TABLE OF CONTENTS	iii
LIST OF SYMBOLS	vi
LIST OF FIGURES	vii
LIST OF TABLES	xiii
ABSTRACT	1
CHAPTER 1. INTRODUCTION	2
1.1 Background and Significance	2
1.2 Thesis Outline	3
REFERENCES	4
CHAPTER 2. A LITERATURE SURVEY ON PERMANENT MAGNET SYNCHRONOUS MACHINES AND CONTROL STRATEGIES	6
2.1 Introduction	6
2.2 The State of the Art of PMSMs	7
2.2.1 Permanent magnets on rotor	7
2.2.2 Permanent magnets on stator	8
2.3 History of Control Methods	13
2.3.1 Six-step control	13
2.3.2 Vector control	17
2.3.3 Direct torque control	19
2.3.4 Model predictive control	23
2.3.5 Qualitative comparison of control methods	26
2.4 Vector Control of PMSM	28
2.5 Direct Torque Control of PMSM	30
2.6 Conclusion	32
REFERENCES	32
CHAPTER 3. MODEL PREDICTIVE CONTROL OF PERMANENT MAGNET SYNCHRONOUS MACHINES	40

3.1 Introduction	40
3.2 Model of PMSMs	41
3.3 Model Predictive Control of PMSM	47
3.3.1 One-step delay compensation	51
3.3.2 Linear multiple horizon prediction	53
3.4 Numerical Simulation of DTC and MPC	54
3.4.1 Combined load test at 500 rpm	54
3.4.2 Combined load test at 1000 rpm	59
3.4.3 Combined load test at 1500 rpm	63
3.4.4 Combined load test at 2000 rpm	67
3.4.5 Deceleration test (from 1500rpm to 500 rpm)	71
3.5 Experimental Testing of DTC and MPC	74
3.5.1 Steady state responses at 500 rpm	76
3.5.2 Steady state responses at 1000 rpm	78
3.5.3 Steady state responses at 1500 rpm	80
3.5.4 Steady state responses at 2000 rpm	82
3.5.5 Start-up test	84
3.5.6 Deceleration test (from 1500rpm to 500 rpm)	87
3.5.7 2Nm load test	90
3.6 Quantitative Analysis and Comparison of Control Methods	93
3.7 Conclusion	98
REFERENCES	99
CHAPTER 4. MODEL PREDICTIVE CONTROL WITH DUTY RATIO OPTIMIZATION	102
4.1 Introduction	102
4.2 Model Predictive Control with Duty Ratio Optimization	104
4.3 Numerical Simulation of DTC and MPC with Duty Ratio Optimization	107
4.3.1 Combined simulation test of MPC with duty ratio optimization	108
4.3.2 Reversing test (from 1000rpm to -500 rpm)	111
4.4 Experimental Testing of DTC and MPC with Duty Ratio Optimization	112
4.4.1 Steady state responses	112
4.4.2 Dynamic response	114

4.5 Comparison of DTC, MPC, and MPC with Duty Ratio Optimization	117
4.6 The Influence of Variable Sampling Frequency on Drive Performance	120
4.6.1 Simulation test	120
4.6.2 Experimental tests	123
4.7 Conclusion	127
REFERENCES	128
CHAPTER 5. CONCLUSIONS AND FUTURE WORK	131
5.1 Conclusion	131
5.2 Future Work	132
APPENDIX A. LIST OF PUBLICATIONS FROM THIS WORK	133

## 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)
$\psi_\alpha, \psi_\beta$	$\alpha$ - and $\beta$ - axis stator flux linkages (Wb)
$\psi_d, \psi_q$	$d$ - and $q$ -axis stator flux linkages (Wb)
$\theta_r$	Angle between two stator reference frame and rotor reference frame
$L_d, L_q$	$d$ - and $q$ -axis inductance (H)
$\psi_f$	Flux linkage generated by the rotor permanent magnet (Wb)
$\psi_{rip}$	Flux ripple
$p$	Number of the machine pole pairs
$u_a, u_b, u_c$	Stator voltages (V)
$u_\alpha, u_\beta$	$\alpha$ - and $\beta$ - axis stator voltages (V)
$i_a, i_b, i_c$	Stator currents (A)
$i_\alpha, i_\beta$	$\alpha$ - and $\beta$ - axis stator currents (A)
$i_d, i_q$	$d$ - and $q$ -axis stator currents (A)
$R_s$	Per-phase stator winding resistance ( $\Omega$ )
$T_e$	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)
$\omega_r$	Rotor mechanical speed
$\omega_e$	Electrical speed
$C_T$	Torque constant gain
$C_\psi$	Flux constant gain



## LIST OF FIGURES

Fig. 2.1 Structure of PM machines	7
Fig. 2.2 Cross sectional view of (a) PM hysteresis hybrid machine, (b) 4-layer hybrid winding machine, and (c) double rotor synchronous PM machine	8
Fig. 2.3 Cross sectional view of (a) the first proposed DSPM and (b) stator doubly fed DSPM	9
Fig. 2.4 Structure of SHEDS-PM	10
Fig. 2.5 Structure of (a) 4/2 pole flux-switch alternator, (b) 4/6 pole flux-switch alternator, and (c) FSPM proposed by E. Hoang in 1997	10
Fig. 2.6 Topologies of modern FSPM, (a) conventional FSPM, (b) fault-tolerant FSPM, (c) E-core FSPM, (d) C-core FSPM, (e) multi-tooth FSPM, (f) segmental rotor FSPM, (g) hybrid excited FSPM, and (h) axial laminated structure FSPM	12
Fig. 2.7 Back <i>emf</i> waveform of BLDC and PMSM	14
Fig. 2.8 Disassembled view of a BLDC motor: PM rotor, winding and Hall elements	14
Fig. 2.9 Feedback signals generated by Hall elements	15
Fig. 2.10 Inverter diagram and conduction modes for six-step control	16
Fig. 2.11 Torque generation under different conduction modes	17
Fig. 2.12 Diagram of vector control drive system	18
Fig. 2.13 Diagram of direct torque control drive system	21
Fig. 2.14 Development of DTC scheme	22
Fig. 2.15 Finite control set MPC scheme	25
Fig. 2.16 Voltage and current vectors	28
Fig. 2.17 Block diagram of PMSM VC drive system	30
Fig. 2.18 Block diagram of PMSM DTC drive system	31
Fig. 2.19 Voltage vector and spatial sector definition	31

Fig. 3.1 Per phase equivalent circuit diagram for SM	41
Fig. 3.2 Relationship between different reference frames	43
Fig. 3.3 PMSM equivalent circuits in (a) $d$ -, and (b) $q$ -axes	45
Fig. 3.4 Block diagram of MPC drive system	50
Fig. 3.5 One-step delay in digital control systems	52
Fig. 3.6 Combined load test for DTC at 500 rpm	55
Fig. 3.7 Combined load test for MPC at 500 rpm	56
Fig. 3.8 Combined load test for MPC with one-step delay compensation at 500 rpm	56
Fig. 3.9 Combined load test for MPC with linear multiple horizon prediction at 500 rpm	57
Fig. 3.10 Combined load test for MPC with both linear multiple horizon prediction and one-step delay compensation at 500 rpm	57
Fig. 3.11 Combined load test for DTC at 1000 rpm	59
Fig. 3.12 Combined load test for MPC at 1000 rpm	60
Fig. 3.13 Combined load test for MPC with one-step delay compensation at 1000 rpm	60
Fig. 3.14 Combined load test for MPC with linear multiple horizon prediction at 1000 rpm	61
Fig. 3.15 Combined load test for MPC with both linear multiple horizon prediction and one-step delay compensation at 1000 rpm	61
Fig. 3.16 Combined load test for DTC at 1500 rpm	63
Fig. 3.17 Combined load test for MPC at 1500 rpm	64
Fig. 3.18 Combined load test for MPC with one-step delay compensation at 1500 rpm	64
Fig. 3.19 Combined load test for MPC with linear multiple horizon prediction at 1500 rpm	65
Fig. 3.20 Combined load test for MPC with both linear multiple horizon prediction and one-step delay compensation at 1500 rpm	65

Fig. 3.21 Combined load test for DTC at 2000 rpm	67
Fig. 3.22 Combined load test for MPC at 2000 rpm	68
Fig. 3.23 Combined load test for MPC with one-step delay compensation at 2000 rpm	68
Fig. 3.24 Combined load test for MPC with linear multiple horizon prediction at 2000 rpm	69
Fig. 3.25 Combined load test for MPC with both linear multiple horizon prediction and one-step delay compensation at 2000 rpm	69
Fig. 3.26 Deceleration test for DTC	71
Fig. 3.27 Deceleration test for MPC	72
Fig. 3.28 Deceleration test for MPC one-step delay compensation	72
Fig. 3.29 Deceleration test for MPC with linear multiple horizon prediction	73
Fig. 3.30 Deceleration test for MPC with both linear multiple horizon prediction and one-step delay compensation	73
Fig. 3.31 Experimental setup of testing system	75
Fig. 3.32 Dynamo-meter controller DSP6000	75
Fig. 3.33 Steady-state response at 500 rpm	76
Fig. 3.34 Steady-state response at 500 rpm	76
Fig. 3.35 Steady-state response at 1000 rpm	78
Fig. 3.36 Steady-state response at 1000 rpm	78
Fig. 3.37 Steady-state response at 1500 rpm	80
Fig. 3.38 Steady-state response at 1500 rpm	80
Fig. 3.39 Steady-state response at 2000 rpm	82
Fig. 3.40 Steady-state response at 2000 rpm	82
Fig. 3.41 Start-up response from standstill to 2000 rpm for DTC	84
Fig. 3.42 Start-up response from standstill to 2000 rpm for MPC	85
Fig. 3.43 Start-up response from standstill to 2000 rpm for MPC with one-step delay compensation	85
Fig. 3.44 Start-up response from standstill to 2000 rpm for MPC with linear	86

multiple horizon prediction	
Fig. 3.45 Start-up response from standstill to 2000 rpm for MPC with both linear multiple horizon prediction and one-step delay compensation	86
Fig. 3.46 Deceleration test for DTC	87
Fig. 3.47 Deceleration test for MPC	88
Fig. 3.48 Deceleration test for MPC with one-step delay compensation	88
Fig. 3.49 Deceleration test for MPC with both linear multiple horizon prediction	89
Fig. 3.50 Deceleration test for MPC with both linear multiple horizon prediction and one-step delay compensation	89
Fig. 3.51 Response to external load for DTC	90
Fig. 3.52 Response to external load for MPC	91
Fig. 3.53 Response to external load for MPC with one-step delay compensation	91
Fig. 3.54 Response to external load for MPC with linear multiple horizon prediction	92
Fig. 3.55 Response to external load for MPC with both linear multiple horizon prediction and one-step delay compensation	92
Fig. 4.1 Diagram of a MPC drive system with duty ratio optimization	107
Fig. 4.2 Combined load test for MPC with duty ratio optimization at 500 rpm	108
Fig. 4.3 Combined load test for MPC with duty ratio optimization at 1000 rpm	109
Fig. 4.4 Combined load test for MPC with duty ratio optimization at 1500 rpm	109
Fig. 4.5 Combined load test for MPC with duty ratio optimization at 2000 rpm	110
Fig. 4.6 Reversing test for MPC with duty ratio optimization	111
Fig. 4.7 Steady-state response at 500 rpm	112
Fig. 4.8 Steady-state response at 1000 rpm	113
Fig. 4.9 Steady-state response at 1500 rpm	113
Fig. 4.10 Steady-state response at 2000 rpm	114
Fig. 4.11 Start-up response from standstill to 2000 rpm for MPC with duty ratio optimization	115

Fig. 4.12 Reversing test for MPC with duty ratio optimization	115
Fig. 4.13 Response to 2 Nm external load at 500 rpm for MPC with duty ratio optimization	116
Fig. 4.14 Response to 1 Nm external load at 1000 rpm for MPC with duty ratio optimization	116
Fig. 4.15 Torque ripple vs. sampling frequency (simulation)	121
Fig. 4.16 Flux ripple vs. sampling frequency (simulation)	122
Fig. 4.17 Torque ripple vs. switching frequency (simulation)	122
Fig. 4.18 Flux ripple vs. switching frequency (simulation)	123
Fig. 4.19 Torque ripple vs. sampling frequency (experimental)	124
Fig. 4.20 Flux ripple vs. sampling frequency (experimental)	125
Fig. 4.21 Torque ripple vs. switching frequency (experimental)	125
Fig. 4.22 Flux ripple vs. switching frequency (experimental)	126

## LIST OF TABLES

Table 2-1 Qualitative comparison of control methods	27
Table 2-2 Switching table of classic DTC scheme for PMSM drive	31
Table 3-1 Motor parameters	54
Table 3-2a Steady-state response at 500 rpm (simulation)	93
Table 3-2b Steady-state response at 500 rpm (experimental)	93
Table 3-3a Steady-state response at 1000 rpm (simulation)	93
Table 3-3b Steady-state response at 1000 rpm (experimental)	93
Table 3-4a Steady-state response at 1500 rpm (simulation)	94
Table 3-4b Steady-state response at 1500 rpm (experimental)	94
Table 3-5a Steady-state response at 2000 rpm (simulation)	94
Table 3-5b Steady-state response at 2000 rpm (experimental)	94
Table 4-1 Motor and control system parameters	107
Table 4-2a Steady-state response at 500 rpm (simulation)	117
Table 4-2b Steady-state response at 500 rpm (experimental)	117
Table 4-3a Steady-state response at 1000 rpm (simulation)	117
Table 4-3b Steady-state response at 1000 rpm (experimental)	117
Table 4-4a Steady-state response at 1500 rpm (simulation)	118
Table 4-4b Steady-state response at 1500 rpm (experimental)	118
Table 4-5a Steady-state response at 2000 rpm (simulation)	118
Table 4-5b Steady-state response at 2000 rpm (experimental)	118

**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.