

# LiFePO<sub>4</sub>-battery-based electric control system for hybrid electric vehicles

黃柏雄、賴元隆

E-mail: 321889@mail.dyu.edu.tw

## ABSTRACT

In recent years, owing to the environmental protection concept and the international oil price has risen, it causes to inflict losses the economic development with people life and wealth of many country. For this reason, there is fast growing interest in electric vehicle (EV) and hybrid electric vehicles (HEVs) globally. But the electric vehicle 's battery charging equipment is not popular and inefficiency, these defects create in the limitations of development. Therefore, at the moment, the hybrid electric vehicles become one of development mainstream in vehicle industry. The central purpose of this thesis is the design and development of a new type coupling mechanism system and its controller for the hybrid vehicle system. To make use integrated of different power resources output connection alteration, the goal of the function electronic continuously variable transmission (E-CVT) is achieved. The coupling mechanism drive by slow-start control, its rests on the different power resources speed to make it coupling modulation that to safeguard power resources output apparatus. Electric control systems used by digital signal processor (DSP) as a control core to communication and operation between various components. In electric motor control, the application of space vector pulse width modulation (SVPWM) technique is applied to the BLDC motor. Lithium iron phosphate battery (LiFePO<sub>4</sub>) is used as a storage medium and the provision of electricity to provide a more efficiency hybrid electric vehicles. A balance charging circuit is designed to extend battery cycle life. Finally, according to the construction of the experiment platform, the system has been integrated and tested to verify the electric control coupling mechanism function. Experiment results demonstrated to achieve the objective of the thesis. Key Words: Electric vehicles, Hybrid electric vehicle, digital signal processor, space vector pulse-width-modulation, LiFePO<sub>4</sub>

Keywords : Electric vehicles、 Hybrid electric vehicle、 digital signal processor、 space vector pulse-width-modulation、 LiFePO<sub>4</sub>

## Table of Contents

INSIDE FRONT COVER.....	i
SIGNATURE PAGE.....	ii
AUTHORIZATION COPYRIGHT STATEMENT.....	iii
ENGLISH ABSTRACT.....	iv
CHINESE ABSTRACT.....	v
ACKNOWLEDGMENT.....	vi
CONTENTS.....	vii
LIST OF FIGURES.....	x
LIST OF TABLES.....	xiii
ABBREVIATIONS.....	xiv
Chapter 1 INTRODUCTION	
1.1 Motivation.....	1
1.2 The hybrid electric vehicles (HEVs) background.....	1
1.3 Organization of this thesis.....	3
Chapter 2 FRAMEWORK OF THE ELECTRIC CONTROL DRIVER SYSTEM	
2.1 Introduction.....	4
2.1.1 BLDC Motor/ Generator.....	5
2.1.2 Magnetism powder type brake unit.....	8
2.1.3 LiFePO <sub>4</sub> batteries.....	9
2.2 The framework of the electric control driver system.....	11
2.2.1 BLDC motor operation mode.....	13
2.2.2 ICE and generator operation mode.....	14
2.2.3 ICE operation mode.....	15
2.2.4 Hybrid power mode.....	16
Chapter 3 SYSTEM DYNAMIC EQUATIONS	
3.1 Mathematical model of BLDC motor/generator.....	18
3.2 Dynamic mathematical model of LiFePO <sub>4</sub> batteries.....	21
Chapter 4 THE REALIZATION OF SVPWM DRIVER MODULATION SYSTEM DESIGN	
4.1 Pulse-width modulation (PWM) control strategy.....	23
4.2 Space vector pulse-width modulation (SVPWM) technique.....	24
4.3 SVPWM driver system.....	24
4.4 TI-TMS320LF2407 digital signal processor (DSP).....	25
4.5 Gate driver module.....	26
4.6 Three-phase voltage-source inverter (VSI).....	28
4.7 Snubber.....	29
4.8 Optical rotary encoder and Hall sensor.....	30
4.9 Principle of SVPWM Control.....	33
4.10 BLDC speed controller.....	45
Chapter 5 THE REALIZATION OF LIFEPO <sub>4</sub> BATTERY MANAGEMENT SYSTEM DESIGN	
5.1 Introduction.....	46
5.2 LiFePO <sub>4</sub> batteries management system.....	46
5.3 Photocoupler isolator gate driver and power MOSFET module.....	47
5.4 High-linearity analog optocouplers.....	48
5.5 Batteries management strategy.....	49
Chapter 6 ELECTRIC CONTROL SYSTEM OF HYBRID DRIVER SYSTEM EXPERIMENTAL PROCEDURES AND RESULTS	
6.1 Introduction the experimental platform of electric control system for hybrid electric vehicles.....	58
6.2 The specification of electric control system of hybrid electric vehicles experimental platform.....	61
6.2.1 Tachometer.....	61
6.2.2 Memory HiLogger.....	62
6.3 Experimental results.....	62
6.3.1 BLDC motor operation mode.....	63
6.3.2 BLDC motor operation mode.....	64
6.3.3 Hybrid electric vehicles mode.....	67
Chapter VI CONCLUSIONS.....	70
REFERENCE.....	71

## REFERENCES

- [1]Hybrid Synergy Drive, “ TOYOTA HYBRID SYSTEM THSII ” , Toyota Motor Corporation, 15 Jun. 2007.
- [2]K.T CHAU, senior member, and C. C. CHAN, fellow, “ Emerging Energy-Efficient Technologies for Hybrid Electric Vehicles ” , IEEE Apr. 2007.
- [3]S. Eriksson and C. Sadarangani, “ A four-quadrant HEV drive system ” ,in Proc. IEEE Vehicular Technology Conf., Sep. 2002, pp. 1510 – 1514.
- [4]M. J. Hoeijmakers and M. Rondel, “ The electrical variable transmission in a city bus ” , in Proc. IEEE Power Electronics Specialists Conf., Jun. 2004, pp. 2773 – 2778.
- [5]Royal Institute of Technology, Sweden, “ Integrated Energy Transducer For Hybrid Electric Vehicles ” , IEEE Conference Publication No.444 Sep. 1997.
- [6]A123 system “ High Power Lithium Ion ANR26650ml ” , A123 system Inc., 2008.
- [7]吳漢宏, “ Space Vector PWM Control for 3kW Brushless Motor Driver Design and Application for Novel Parallel Hybrid Electric Vehicles ” , Department of Mechanical and Automation Engineering College of Engineering Dayeh university, 2008.
- [8]Z. Yang Pan and F. Lin Luo, “ Novel Soft-Switching Inverter for Brushless DC Motor Variable Speed Drive System ” , IEEE Trans. on Power Electronics, Vol. 19, no. 2, pp. 202-207, Mar. 2004.
- [9]V. Johnson, “ Battery Performance Models in ADVISOR ” , Journal of Power Sources, Vol.110, pp321~329, 2002.
- [10]黃稜綸, “ Development of Dynamic LiFePO4 Battery Charging Systems for Dual Power Driving Vehicles ” , Department of Mechanical and Automation Engineering College of Engineering Dayeh university, 2009.
- [11]劉昌煥, “ 交流電機控制:向量控制與直接轉矩控制原理 ” , 東華書局, 2001.
- [12]Texas Instruments “ TMS320LF2407A-EP DSP CONTROLLERS ” Texas Instruments Inc., 2002.
- [13]Kilian, Christopher T., “ Modern Control Technology: Components and Systems ” , Thomson Delmar Learning, 2006.
- [14]Texas Instruments “ Implementation of Vector Controlled for PMSM Using TMS320F240 ” , Literature number: SPRA494, Texas Instruments Inc., 1998.
- [15]黃致愷, “ 交流永磁馬達驅動器之設計與應用 ” , 南台科技大學電機研究所, 2005.
- [16]HEWLETT PACKARD “ High-Linearity Analog Optocouplers ” , HEWLETT PACKARD Inc., Hewlett-Packard Development Company, L.P.