

雙動力驅動車輛之鋰鐵電池動態充電系統研製

黃稜絢、蔡耀文

E-mail: 9806453@mail.dyu.edu.tw

摘要

近年來傳統燃油車輛越來越多，使得地球上石油的存量越來越少，加上環境污染日益嚴重，節能減碳技術變成全世界最重要的研究課題。為了解決前述問題，電動車輛與複合電動車輛的開發是必要的，而發電機控制及電池管理技術，在電動車輛與複合電動車輛領域扮演著關鍵的角色。有鑑於此，本文研究雙動力驅動車輛之發電機控制及電池管理技術，基於高效能動力需求，本研究選用磷酸鋰鐵電池，此種電池具有高放電功率，可快速充電且循環壽命長之優良特性，是目前產業界認為符合環保、安全和高性能要求的動力電池。本文發展一個雙動力驅動車輛的鋰鐵電池動態充電系統，考慮電動車輛的充電電源會因為行車動態而不斷改變其電量大小，本文發展之新式動態充電系統，可以因應此種充電電量之不斷變化，對電池作最佳化的充電調配，使得此充電系統具有高充電效能、維護電池安全以及電量平衡充電三大優點。為了驗證本論文之正確性，我們也建構了一組雙動力驅動車輛平台，經實測之結果證明此動態充電系統的效能。

關鍵詞：複合電動車輛，磷酸鋰鐵電池，動態充電系統，發電機，數位訊號處理器

目錄

INSIDE FRONT COVER SIGNATURE PAGE AUTHORIZATION COPYRIGHT STATEMENT	
..... iii CHINESE ABSTRACT iv ENGLISH
ABSTRACT.....	v ACKNOWLEDGMENT..... vi
CONTENTS.....	vii LIST OF FIGURES.....
x LIST OF TABLES.....	xiii ABBREVIATIONS.....xiv
Chapter I INTRODUCTION 1.1 Motivation.....	1 1.2 Organization.....
.....	2 Chapter II INTRODUCTION TO LiFePO ₄ BATTERY 2.1 Characteristics of LiFePO ₄ battery.....
3 2.1.1 Safety performance of LiFePO ₄ battery.....	4 2.1.2 The chemical properties of LiFePO ₄
5 2.2 40138-LiFePO ₄ battery.....	6 2.2.1 The SOC of 40138-LiFePO ₄ battery.....
8 Chapter III FRAMEWORK OF DUAL POWER DRIVING SYSTEM 3.1 Introduction.....	10 3.1.1 Electric motor.....
11 3.1.2 The generator.....	14 3.1.3 Internal combustion engine.....
15 3.1.4 Magnetism powder type brake unit.....	17 3.1.5 Energy integration mechanism.....
18 3.2 The control mode of dual power driving system.....	19 3.2.1 BLDC motor mode.....
21 3.2.2 ICE only mode.....	22 3.2.3 ICE and generator mode.....
23 3.2.4 Dual power mode.....	24 3.2.5 Regenerative braking mode.....
25 3.2.6 Battery charging mode.....	26 Chapter IV THE DESIGN OF A GENERATOR ENERGY MANAGEMENT AND CHARGING SYSTEM 4.1 Introduction.....
27 4.2 TI TMS320LF2407A digital signal processor.....	27 4.2.1 PWM technique.....
31 4.3 The attention events of voltage measuring.....	32 4.3.1 Voltage measuring circuit.....
32 4.3.2 A/D protect circuit.....	34 4.3.3 A/D converter.....
35 4.4 Generator and LiFePO ₄ battery charging systems.....	35 4.4.1 Gate driver circuit of MOSFET module.....
37 4.5 Rectification control of the generator.....	39 4.5.1 The circuit of ac-dc converter.....
39 4.5.2 Control operation of rectification.....	40 4.6 The DSP interface of major controller.....
42 4.6.1 Energy management strategy of dynamic charging system.....	43 4.6.2 Control operation of dynamic charging system.....
47 Chapter V DYNAMIC EQUATIONS AND MODELS OF DUAL POWER DRIVING SYSTEM 5.1 Introduction.....	53 5.2 The generator model.....
53 5.3 The energy integration mechanism model.....	56 5.4 The lithium battery model.....
60 Chapter VI THE EXPERIMENTAL PROCEDURES AND RESULTS 6.1 Introduction the experimental platform.....	64 6.2 Experimental results.....
66 6.2.1 The charge state of driving pattern.....	72 Chapter VII CONCLUSIONS.....
75	

REFERENCE.....	76	LIST OF FIGURES
Fig.2.1 Photograph of the LiFePO ₄ battery	6	Fig.2.1 Photograph of the LiFePO ₄ battery
Fig.2.2 The discharge graph of 40138-LiFePO ₄ battery	8	Fig.2.2 The discharge graph of 40138-LiFePO ₄ battery
Fig.2.3 VOC(V)-SOC(%) of relationship drawing	9	Fig.2.3 VOC(V)-SOC(%) of relationship drawing
Fig.3.1 Dual power system concept	11	Fig.3.1 Dual power system concept
Fig.3.2 Photograph of the brushless DC motor	12	Fig.3.2 Photograph of the brushless DC motor
Fig.3.3 Driving efficiency and speed of characteristic curve	13	Fig.3.3 Driving efficiency and speed of characteristic curve
Fig.3.4 Driving torque and speed of characteristic curve	14	Fig.3.4 Driving torque and speed of characteristic curve
Fig.3.5 The relationship between voltage and speed of the generator	15	Fig.3.5 The relationship between voltage and speed of the generator
Fig.3.6 Sketch of ICE brake specific fuel consumption	16	Fig.3.6 Sketch of ICE brake specific fuel consumption
Fig.3.7 Schematic drawing of magnetism powder type brake	17	Fig.3.7 Schematic drawing of magnetism powder type brake
Fig.3.8 Schematic drawing of magnetism powder type brake controller	18	Fig.3.8 Schematic drawing of magnetism powder type brake controller
Fig.3.9 The mechanism of planetary gear	19	Fig.3.9 The mechanism of planetary gear
Fig.3.10 The framework of dual power system	20	Fig.3.10 The framework of dual power system
Fig.3.11 BLDC motor mode	21	Fig.3.11 BLDC motor mode
Fig.3.12 ICE only mode	22	Fig.3.12 ICE only mode
Fig.3.13 ICE and generator mode	23	Fig.3.13 ICE and generator mode
Fig.3.14 Dual power mode	24	Fig.3.14 Dual power mode
Fig.3.15 Regenerative braking mode	25	Fig.3.15 Regenerative braking mode
Fig.3.16 Battery charging mode	26	Fig.3.16 Battery charging mode
Fig.4.1 The TI TMS320LF2407A	28	Fig.4.1 The TI TMS320LF2407A
Fig.4.2 DSP interface of the charging system	30	Fig.4.2 DSP interface of the charging system
Fig.4.3 Switch output voltage waveform V _{out}	31	Fig.4.3 Switch output voltage waveform V _{out}
Fig.4.4 The block diagram of voltage measuring	32	Fig.4.4 The block diagram of voltage measuring
Fig.4.5 Series connection of battery module	33	Fig.4.5 Series connection of battery module
Fig.4.6 Voltage measuring circuit	34	Fig.4.6 Voltage measuring circuit
Fig.4.7 The A/D protection circuit of 1N4148	34	Fig.4.7 The A/D protection circuit of 1N4148
Fig.4.8 Voltage protect circuit of TL7726	35	Fig.4.8 Voltage protect circuit of TL7726
Fig.4.9 The block diagram of generator and LiFePO ₄ batteries charging system	36	Fig.4.9 The block diagram of generator and LiFePO ₄ batteries charging system
Fig.4.10 Gate driver circuit of power transistor	37	Fig.4.10 Gate driver circuit of power transistor
Fig.4.11 Signal process input/output voltage waveform	38	Fig.4.11 Signal process input/output voltage waveform
Fig.4.12 Topology of the switched-mode power converter	40	Fig.4.12 Topology of the switched-mode power converter
Fig.4.13 The control operation of rectification	42	Fig.4.13 The control operation of rectification
Fig.4.14 Circuit configuration for MOSFET module	43	Fig.4.14 Circuit configuration for MOSFET module
Fig.4.15 Energy management strategy of dynamic charging system	45	Fig.4.15 Energy management strategy of dynamic charging system
Fig.4.16 The control operation of the dynamic charging system situation I	49	Fig.4.16 The control operation of the dynamic charging system situation I
Fig.4.17 The control operation of the dynamic charging system situation II	50	Fig.4.17 The control operation of the dynamic charging system situation II
Fig.4.18 The control operation of the dynamic charging system situation III	51	Fig.4.18 The control operation of the dynamic charging system situation III
Fig.4.19 The control operation of the dynamic charging system situation IV	52	Fig.4.19 The control operation of the dynamic charging system situation IV
Fig.5.1 Schematic drawing of the generator	53	Fig.5.1 Schematic drawing of the generator
Fig.5.2 Block diagram of the generator for the simulations	55	Fig.5.2 Block diagram of the generator for the simulations
Fig.5.3 The curve of generator for the simulations	56	Fig.5.3 The curve of generator for the simulations
Fig.5.4 The planetary gear set	57	Fig.5.4 The planetary gear set
Fig.5.5 The front view of planetary gear set	57	Fig.5.5 The front view of planetary gear set
Fig.5.6 The schematic drawing of lithium battery RC model	61	Fig.5.6 The schematic drawing of lithium battery RC model
Fig.5.7 Block diagram of the lithium battery for the simulations	63	Fig.5.7 Block diagram of the lithium battery for the simulations
Fig.5.8 The curve of lithium battery for the simulations	63	Fig.5.8 The curve of lithium battery for the simulations
Fig.6.1 The experiment platform	64	Fig.6.1 The experiment platform
Fig.6.2 The block diagram of experiment platform	65	Fig.6.2 The block diagram of experiment platform
Fig.6.3 The LiFePO ₄ battery dynamic charging system	65	Fig.6.3 The LiFePO ₄ battery dynamic charging system
Fig.6.4 Circuit configuration for MOSFET module	66	Fig.6.4 Circuit configuration for MOSFET module
Fig.6.5 The constant-voltage to charge the battery group B1	67	Fig.6.5 The constant-voltage to charge the battery group B1
Fig.6.6 The constant-voltage to charge the battery group B2	67	Fig.6.6 The constant-voltage to charge the battery group B2
Fig.6.7 The constant-voltage to charge the battery group B3	68	Fig.6.7 The constant-voltage to charge the battery group B3
Fig.6.8 The constant-voltage to charge the battery group B4	68	Fig.6.8 The constant-voltage to charge the battery group B4
Fig.6.9 The constant-voltage to charge the battery group B5	69	Fig.6.9 The constant-voltage to charge the battery group B5
Fig.6.10 The constant-voltage to charge the battery group B6	69	Fig.6.10 The constant-voltage to charge the battery group B6
Fig.6.11 The constant-voltage to charge the battery group B12	70	Fig.6.11 The constant-voltage to charge the battery group B12
Fig.6.12 The constant-voltage to charge the battery group B34	70	Fig.6.12 The constant-voltage to charge the battery group B34
Fig.6.13 The constant-voltage to charge the battery group B56	71	Fig.6.13 The constant-voltage to charge the battery group B56
Fig.6.14 The constant-voltage to charge the battery group B123 and group B456	71	Fig.6.14 The constant-voltage to charge the battery group B123 and group B456
Fig.6.15 The constant-voltage to charge the battery group B123456	72	Fig.6.15 The constant-voltage to charge the battery group B123456
Fig.6.16 The driving pattern of the vehicle	73	Fig.6.16 The driving pattern of the vehicle
Fig.6.17 The charge state 1 of driving pattern	73	Fig.6.17 The charge state 1 of driving pattern
Fig.6.18 The charge state 2 of driving pattern	74	Fig.6.18 The charge state 2 of driving pattern
LIST OF TABLES		LIST OF TABLES
Table 2.1 Characteristics of lithium-ion batteries	4	Table 2.1 Characteristics of lithium-ion batteries
Table 2.2 Specifications of LiFePO ₄ battery	7	Table 2.2 Specifications of LiFePO ₄ battery
Table 3.1 Parameters of three-phase BLDC motor	13	Table 3.1 Parameters of three-phase BLDC motor
Table 3.2 The control mode logic	20	Table 3.2 The control mode logic
Table 4.1 Hardware features of TI TMS320LF2407A devices	29	Table 4.1 Hardware features of TI TMS320LF2407A devices
Table 4.2 Symbol table of battery	46	Table 4.2 Symbol table of battery
Table 4.3 Symbol table of voltage	46	Table 4.3 Symbol table of voltage

參考文獻

- [1] Te-Sheng Su, "Development of High Power 20kW Brushless DC Motor Driver and Application of Novel Parallel Hybrid Electric Vehicle", Department of Mechanical and Automation Engineering College of Engineering Dayeh university, 2008.
- [2] Chen. Chiang. Lin, Pao. Chung. shih, "Hybrid Electric Vehicle," Chwa book company, 2002.
- [3] The Auto Channel, 2009-03-11, "Toyota and Lexus Hybrids Top One Million Sales in the U.S.," Retrieved on 2009-03-28 [4] Padlhi A K, Nanjundaswamy K S, Goodenough J B. J. Electrochem. Soc., 1997, 144 (4): 1188-1194.
- [5] LiFePO₄.HK, "About LiFePO₄," retrieved from <http://www.lifepo4.hk/>, 2009.
- [6] L.Legers, "Meridian International Research," 29, May, 2008 [7] Jia-Hao Jhuang, "Development of Electrical Control System and Performance Analysis for a New Parallel Hybrid Electric Heavy Motorcycle", Department of Mechanical and Automation Engineering College of

Engineering Dayeh university, 2007.

[8] Hybrid Synergy Drive, " TOYOTA HYBRID SYSTEM THSII ", Toyota Motor Corporation, 15 Jun. 2007.

[9] Texas Instruments " TMS320LF2407A-EP DSP CONTROLLERS " Texas Instruments Inc., 2002.

[10] R. W. Erickson and D. Maksimovic, " Fundamentals of power electronics, " Kluwer Academic Publishers, 2nd, pp. 57-59, 2001.

[11] Ruei-Hong Dai, " DSP Based 20kW Generator/Lithium Battery Management System and Application of Parallel Hybrid Electric Vehicles " , Department of Mechanical and Automation Engineering College of Engineering Dayeh university, 2008.

[12]R. W. Erickson, Fundamentals of Power Electronics. New York: Chapman &Hall, 1997.

[13]B. Pevec, D. Voncina,D. Miljavec, and J. Nastran, " Extending the Low-Speed peration Range of PM Generator in Automotive Applications Using Novel AC – DC Converter Control " , IEEE Transactions on Industrial Electronics, vol.52, no. 2, Apr. 2005.

[14] S. Rees and U. Ammann, " New gate control unit for automotive synchronous rectifiers, " in Proc. PCIM Europe ' 03, Nuremberg, Germany, 2003, pp. 95 – 101.

[15] Ming-Che Su, " DSP-Based Energy Management System of New Parallel Hybrid Electric Heavy Motorcycle, " Graduate Institute of Electro-Mechanical Automation Engineering July, 2007.

[16] Yimin Gao and Mehrdad Ehsani, " A Torque Speed Coupling Hybrid Drivetrain Architecture, Control, and Simulation " , IEEE Fellow, vol. 21, no. 3, May.2006.

[17] V. Johnson, " Battery Performance Models in ADVISOR, " Journal of Power Sources, Vol.110, pp321~329, 2002.