出國報告（出國類別：國際會議）

電動車用智慧型鋰離子電池充電管理系統之開發

服務機關：國防大學理工學院電機電子系
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派赴國家：日本
出國期間：106/05/12-106/05/18
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摘要

2017 年「IEEE 系統創新應用國際研討會」(2017 IEEE International Conference on Applied System Innovation, IEEE ICASI 2017)係由國際電機電子工程師學會中華民國第一分會 (IEEE Tainan Section Sensors Council, IEEE TSSC)及台灣知識創新研究所(Taiwanese Institute of Knowledge Innovation, TIKI)共同舉辦，並於 106 年 5 月 13 日至 17 日在日本北海道札幌艾米西亞酒店（Hotel Emisia Sapporo）舉行，本人投稿該研討會論文乙篇，論文題目：電動車用智慧型鋰離子電池充電管理系統之開發，因榮獲刊登及大會議程安排於 5 月 16 日上午 0900-1020 場次進行海報發表，故於 5 月 16 日搭機前往與會。當日該場次會議中，計有來至台灣、日本、南韓、義大利、美國等數篇論文發表，期間發表人均詳細報告其研究成果，報告完後，台下與台上學者討論熱絡，彼此交流受益良多。

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壹、目的：

2017 年「IEEE 系統創新應用國際研討會」係由(IEEE Tainan Section Sensors Council, IEEE TSSC)，由主辦單位國際電機電子工程師學會中華民國第一分會於 106 年 5 月 13 日至 17 日在日本北海道札幌艾米西亞酒店（Hotel Emisia Sapporo）舉行，該研討會主要為訊息技術、創新設計，通訊科學、工業設計、應用數學、計算機科學、設計理論、文化創意研究、電機電子工程、機械自動化工程、綠色能源與建築工程、材料科學等等廣泛領域的研究人員提供統一跨科學平台，以提供研究人員和學者彼此交流和分享各方面的研究成果與實務經驗。而本次參與發表之專家學者，計有來至台灣、日本、南韓、美國及義大利等各國專家學者，合計發表海報與論文達數百餘篇。藉由參加本次國際研討會，除了獲得創新知識外更能瞭解國際研究趨勢與脈動，進而增進研究動力與方向。此外，本會議所投稿之論文均經由國際相關領域之學者、專家審查，因此一旦獲得大會收錄刊登，亦可增加本院的能見度。

貳、過程：

會議議程

May 16, 2017: 09:00-10:20

本人發表之論文名稱：

Development of an Intelligent Lithium-Ion Battery-Charging Management System for Electric Vehicle

作者：

Chien-Wu Lan, Shih-Sung Lin, Kuang-Hsiung Tan (談光雄), Sih-Yan Syue, Hao-Yen Hsu, Tien-Cheng Huang

(Chung Cheng Institute of Technology, National Defense University, ROC)

本次赴日本北海道參加 2017 IEEE 系統創新應用國際研討會，因國人赴日本免簽證及當地交通便利之因素，故僅委託旅行社代訂來回機票，而相關住宿則自行決定住 UNIZO Inn Sapporo　(札幌優尼佐酒店)六晚，因本次研討會舉辦地點 Hotel Emisia Sapporo（札幌艾米西亞酒店）在新札幌附近離 JR 地鐵站相當便利，因而決定住宿札幌附近之札幌優尼佐酒店以節省開支。研討會舉行時間為 106 年 5 月 13 日至 17 日，故委由旅行社代訂 5 月 12 日上午 06 時 55 分搭乘長榮航空 BR0166 班機赴日本北海道新千歲機場，抵達北海道新千歲機場時已逾當地時間約中午 12 時餘，辦好出關手續，即自行搭乘 JR 新千歲機場往札幌站，再步行約 10 分鐘後抵達下榻飯店，此時已逾 15 時，辦好入住手續後，當晚則在飯店稍作準備與休息。5 月 13 日當日為大會準備會前事宜，本日無議程活動；5 月 14 日早上 11 時到達會場並完成報到手續，當日並擇感興趣之場次聆聽相關論文發表；5 月 15 日早上 10 時到達會場並擇感興趣之場次聆聽相關論文發表。5 月 16 日海報發表當日早上 08:30 抵達會議地點，海報發表場次為上午 09 時 00 分場次，發表場次一開始則向各專家學者及委員報告與說明研究成果內容，由於所研究之領域具相關性，因此與各專家學者討論相當熱絡。發表完後，學者亦提出相關見解及寶貴建議，對於本次參加國際研討會，使自身能更瞭解國際研究趨勢與脈動，因此對於未來研究方向將有更多動力。

本人所發表之論文為「Development of an Intelligent Lithium-Ion Battery-Charging Management System for Electric Vehicle」，內容報告摘要如下：近年來，電動車已廣泛的在各處被使用。然而，對大容量的電池充電是困難的。如何解決這樣的問題已變為一項重要的課題。在本研究中，提出了一個智慧型鋰離子電池充電管理系統，本系統整合了電池監控與平衡平台及充電站。根據電池監控與平衡平台的資訊與使用者需求，本研究所提出之雙充電機制被使用於控制充電機之充電電壓或充電電流。該雙充電機制包含快速充電及智慧型多階段充電等兩種方法。此外，智慧型多階段充電方法在充電期間能抑制溫升以保護電池。在另一方面，本系統在電腦或智慧型裝置上亦提供友善的使用者圖型操作介面，讓使用者能夠選擇想要的充電方法，並即時監看電池狀態。本系統在快速或安全的充電需求上提供了一個便利的解決方案。

5 月 13 日下午，當日為承辦單位會前準備事宜，本日無相關活動議程：

5 月 14 日，當日旁聽其他學者、專家發表議題，摘錄如下：

(1) Tilted Fiber Bragg Grating sensor graphene oxide coating for humidity sensing：

在本研究中，作者提出了利用相位掩模法和石墨烯塗層製造之傾斜光纖布拉格光柵（TFBG）濕度感測器。由實驗結果證明，波長靈敏度為 0.0038nm / RH，線性度為 0.994。此外由測量結果可得出，當相對濕度增加時，其折射率將隨之上升，進而使得 TFBG 包層模式譜波長紅移。因此，所提出的石墨烯薄膜 TFBG 濕度感測器具有潛在的監測相對濕度。

(2) Resource Allocation with NOMA for Multiuser Multicarrier Systems：

本文提出了一種利用正交頻率複合的非正交多重技術資源分配演算法，以減少總發射功率。在該系統中，可以將每個子載波分配給兩個用戶進行數據傳輸。因為在相同頻譜，所以非正交多重的主要問題是同頻道干擾。由於主用戶比次級用戶更為重要，因此系統利用正交頻率多重技術，以確保主用戶擁有所有分配副載波傳輸系統資源，而二級用戶將在一些子載波上與主用戶傳輸數據。在 NOMA 分配中有兩種情況，作者討論主用戶和次用戶如何在不同子載波和訊號增益下執行資源分配。基於開發考量，使用非正交多重技術資源分配，在模擬結果證明，所提出的方法在傳輸功率或容量等性能上均優於目前常用之 OFDM 系統。

(3) A Wireless Network Simulator Based on Design Patterns for WiMAX and LTE：

在無線網絡的研究中，網絡模擬器是對研究人員評估理論的重要工具。如果所採用的模擬器本身架構較差，那麼將來維護上將會變得更加困難。因此，為了提高模擬器架構的靈活性，本文提出將設計模式當作系統架構設計的規範，作者提出了一種網絡模擬器架構，命名為 CCGns，它是一個離散事件虛擬網絡模擬器，並依據 IEEE 802.16-2009 規範標準。CCGns 的主要貢獻遇有下列五個方面：1.可擴展 MAC 訊息管理和處理架構、2.適用於多中繼網絡架構、3.具兩階段最小方差頻寬分配演算法、4.復合因子的公共調度器操作界面架構、5.用於 WiMAX 和 LTE 之可交換結構。通過使用數學計算來驗證模擬結果，CCGns 已經被證明具有較佳的仿真性。

5 月 15 日，當日旁聽其他學者、專家發表議題，摘錄如下：

(1) Blind Residual CFO Estimation with Computational Efficiency for Interleaved OFDMA Uplink Systems：

本文提出利用交錯正交頻率多址（OFDMA）鏈路系統的簡單殘餘載波頻率偏移（CFO）評估方法。雖然，傳播方法（PM）具有較低計算量，且在無噪聲環境中是較有效的。然而，PM 對噪聲並不具備強健性。因此利用前向（FB）矩陣和傳播方法（PM），所結合之的 FBPM 估測器將可提高 CFO 精確度。而為了減輕噪聲之影響，作者首先利用 FBPM 中 FB 相關矩陣的 QR 和 LU 因子，分別構建了 U-FBPM 和 R-FBPM 估測器。透

過多項式生根方法實現 CFO 估測之相對高精確度與低複雜度。最後，由模擬結果可得到理論的可行性。

(2) Evolution Towards Small Cell Enhancement System in D2D Architecture for LTE-A Technologies：

本文提出了小區增強（SCE）系統對於增強型節點 B（eNB）在無線覆蓋設備（D2D）轉換架構（如地鐵，高速鐵路和地鐵）的應用。依據理論分析和現實工程技術，本文提出了鏈路設計指導方法，幫助設計人員可全面控制和分析單輸出功率光纖中繼器和行動基地台。最後，所提出之系統可成功應用於臺北大眾捷運系統室內無線網路覆蓋設計，並可輕鬆安裝在 WCDMA / LTE / LTE-A 技術下之光纖網路中，並成為無處不在的互聯網（IOE）實體層次電訊。

(3) A High Efficiency Transparent Digital Television Antenna Based on Nano-Structured Thin Film Coating Technology：

本文提出了高透明數位電視（DTV）天線。所提出的材料是利用奈米結構薄膜塗覆的玻璃基板，以設計製造透明度為 80%的天線。作者所提出的設計基板尺寸為 200×150mm^2。模擬輻射圖可與常用之偶極天線的全向匹配。此外，所提出的天線效率大於50%，操作頻寬為 490-590MHz。因此，所提出的天線與數位電視信號接收上具有極高兼容性。

5 月 16 日，當日為海報展示與提報，中文摘要如下：

近年來，電動車已廣泛的在各處被使用。然而，對大容量的電池充電是困難的。如何解決這樣的問題已變為一項重要的課題。在本研究中，提出了一個智慧型鋰離子電池充電管理系統，本系統整合了電池監控與平衡平台及充電站。根據電池監控與平衡平台的資訊與使用者需求，本研究所提出之雙充電機制被使用於控制充電機之充電電壓或充電電流。該雙充電機制包含快速充電及智慧型多階段充電等兩種方法。此外，智慧型多階段充電方法在充電期間能抑制溫升以保護電池。在另一方面，本系統在電腦或智慧型裝置上亦提供友善的使用者圖型操作介面，讓使用者能夠選擇想要的充電方法，並即時監看電池狀態。本系統在快速或安全的充電需求上提供了一個便利的解決方案。

5 月 17 日，當日旁聽其他學者、專家發表議題，摘錄如下：

(1) 1.35 GHz Programmable Gain Amplifier for 5G Mobile Communication：

本文介紹了一種用於 5G 移動通訊的頻寬可編程增益放大器（PGA）。PGA 由四個 5bits 控制 MOSFET 共源級放大器構成，來實現 1 dB 中-16 至 4 dB 的線性增益。PGA 在 40nm CMOS 製程中實現，其最小頻寬為 1.35GHz。在 1.1V 電源操作下，PGA 消耗 9.8 mW。在 1.26 Vpp 的訊號輸入情況下，增益誤差約在 0.15 dB 以內，總諧波失真為-30.3 dBv。而本文製作之晶圓面積為 0.5 平方毫米。

(2) Applying Big Data Analysis Technique to Students’ Learning Behavior and Learning

Resource Recommendation in a MOOCs Course：

通過 MOOC 和社交媒體平台，用戶間可以彼此分享資訊，尋找其感興趣的資訊。因此，用戶可以對多媒體平台和學習課程進行交互討論及社交媒體之學習。因此本文提出了一個關於學習行為的大數據分析技術，以探討 MOOC 和社交媒體平台學習使用者之間的互動，並認識使用大數據分析學生的學習行為。因此，藉由大數據分析學習行為將可建議今後教師參考與利用。

(3) Adaptive Control of Nonholonomic Mobile Robots Using Fuzzy Approximation：

本文提出了一種使用非完整輪式移動機器人（WMR）的模糊近似的自適應追蹤控制器。在運動設計階段，Levant 的微分器被採用以減輕所謂的複雜性。其主要優點是其具快速收斂性，進而可以提高追蹤控制性能。此外，在動態控制設計方面提出了一種自適應模糊控制器，以確保運動控制器漸近式追蹤。最後，由模擬結果可知所提設計方法具有效性及可行性。

參、心得報告：

本次赴日本參加國際研討會，看到許多專家學者對於現實所發生之問題提出解決方案，深感佩服，例如:有學者提出利用大數據分析技術來分析學生在社群網路的學習行為，可做為未來教師研究參考依據等。因此，體會到學者做研究應以解決當前所遇到之問題，以改善或增進人們生活品質。另外，本次研討會在日本北海道舉行，其交通相當便利，因此在研討會期間利用搭乘該地區的鐵路系統前往會場，沿途景觀可以充分感受到日本的進步。最後，參加國際研討會是一項很有意義的學術活動，也非常感謝科技部經費補助，校院部各級長官的協助，使得此次研討會能順利成行。

肆、參考資料：
圖片為研討會內外場與會議現場等

研討會地點指示牌

註冊報到(1)

註冊報到(2)

研討會場外(1)

研討會場外海報展示區(1)

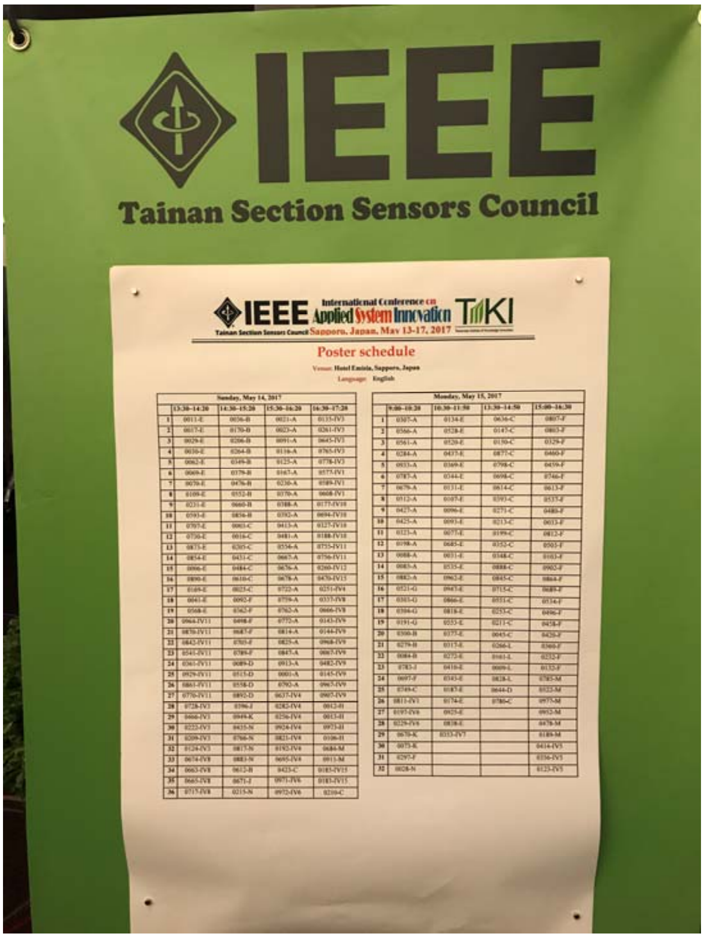
研討會場外海報展示區(2)

研討會場內(1)

研討會場內(2)

研討會場內(3)

研討會場內(4)



研討會議程表

伍、建議事項：

對於參加國際研討會，將可增進學術交流亦可開闊國際觀，利用參加國際學術研討會，使各國瞭解我們的學術成就。所謂學術無國界，藉由各國的專家學者互相研討，彼此激勵出火花，對於學術而言也是一項寶貴收穫，因此，在經費有限的情況下，期許能鼓勵老師們能多出去走走，瞭解目前各國學術研究方向，增進學校能見度，以提升自己本職學能。最後，感謝科技部的經費提供，使得本次研討會能順利成行。

陸、會議資料：

收錄論文光碟片(摘要論文電子檔數百餘篇)

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Development of an Intelligent Lithium-Ion Battery-Charging Management System for Electric Vehicle

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Keywords: Smart Charging Method, Battery Management System, Lithium-Ion Battery, Electric Vehicle

Abstract:

In recent years, electric vehicle has been gradually used everywhere. However, charging to large capacity batteries is difficult. How to manage it has become an important issue. In this research, an intelligent lithium-ion battery-charging management system is proposed. The system integrates the battery monitoring and balance platform (BMBP) and charging station. According to the battery information of BMBP and the user needs, A proposed dual charging method (DCM) is used to control the charging voltage or current of charging station. The DCM contains the rapid and the smart multi-stage charging methods. In addition, the smart multi-stage charging methods depress the temperature rising during charging to protect the batteries. On the other hand, the system also provides a friendly graphic user interface on PC or smart devices for user to select the charging method and monitoring the state of batteries. The system proposes a convenient solution for both quickly or safely charging needs.

Development of an Intelligent Lithium-Ion Battery-Charging Management System for Electric Vehicle

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Abstract

In recent years, electric vehicle has been gradually used everywhere. However, charging to large capacity batteries is difficult. How to manage it has become an important issue. In this research, an intelligent lithium-ion battery-charging management system is proposed. The system integrates the battery monitoring and balance platform (BMBP) and charging station. According to the battery information of BMBP and the user needs, a proposed dual charging method (DCM) is used to control the charging voltage or current of charging station. The DCM contains the rapid and the smart multi-stage charging methods. In addition, the smart multi-stage charging methods depress the temperature rising during charging to protect the batteries. On the other hand, the system also provides a friendly graphic user interface on PC or smart devices for user to select the charging method and monitoring the state of batteries. The system proposes a convenient solution for both quickly or safely charging needs.

Key words: Lithium-Ion Battery, Electric Vehicle, Battery Management System, Smart Charging Method

Introduction

Lithium-ion batteries, such as LiNi0.8Co0.2O2, LiNiO2, LiMn2O4 and LiFePO4, are widely used due to their high power density, large capacity, high operating voltage, low self-discharge, small size, and freedom from memory effect [1-2]. The life-span of a lithium-ion battery depends largely on how it is charged [3-6]: increasing battery life-span requires that batteries be charged to their maximum power in the least amount of time without increasing the temperature. In this study, we focused on LiFePO4 batteries.

Several charging methods have been proposed to achieve this. The constant voltage method [7] is the simplest approach: the voltage is kept constant while the current gradually decreases over time. This means that as the battery approaches saturation, charging slows down. However, attempts to increase the voltage in order to reduce time spent charging can damage the battery. Another approach is the constant current method [8], in which the current is maintained at a constant value by increasing the charge voltage. This method achieves maximum charge rapidly. However, the unlimited charge voltage can damage the battery, and determining when the battery has reached saturation can be challenging. Moreover, without taking into account the electrochemical reaction balance of the battery, the voltage of the battery drops rapidly when the charging process is halted.

The constant voltage and constant current methods are combined in the constant voltage - constant current (CC-CV) method [8], which is also referred to as the two-stage charge method. In the first stage, the constant current method is used to increase the charge speed. When the voltage reaches a given threshold, the system switches to constant voltage. Despite the fact that much of the total charging can be completed in the first stage, the second stage is usually quite extended and the threshold is still difficult to define.

Some researchers have sought to increase the efficiency of the charging process using the pulse charge method [9] and ReflexTM charge method [10]. By starting and stopping the charge repeatedly for short bursts of time, the pulse charge method can be used to balance the electrochemical reaction that occurs while charging. This largely resolves the problem of voltage drop found in the constant voltage method; however, this approach is unsuitable for aging batteries. In contrast, the ReflexTM charge method is switch charge and discharge in a rapid time to increase efficiency beyond what can be achieved using the pulse charge method. Unfortunately, this approach requires equipment capable of continuously switching between charge and discharge states.

In this study, we developed a five-stage charging method [10]. Unlike the CC-CV charge method, constant current is used in all five stages with a specific current value defined for each stage. When the voltage reaches a given threshold, the charging process is halted to maintain electrochemical balance and then switched to the following stage. This decreases the charge time and protects the battery from being over-charged. We employed the Taguchi method to determine the current threshold in each stage [2,10,11]. We also took into account the effects of temperature increasing on the charging process and lifespan of the batteries.

On the other hand, prolonged charging and uncertainty concerning the state of the battery are particularly problematic when dealing with large capacity batteries. This study employed wireless technology with advancements in intelligent devices [12-13] in the development of a PIBMS to check the status of batteries while being charged and eliminate wait times. Battery usage is recorded to determine the SOH and aging condition of the battery.

The rest of this paper is organized as follows. In Section 2, we introduce the architecture of the PIBMS. In Section 3, we outline the means by which design parameters were determined for adaptive charging. Experiment results and a brief discussion are presented in Section 4. Conclusions are drawn in Section 5.

Description of PIBMS

A. Architecture

In Fig. 1, the PIBMS (comprising a programmable charger), the portable BMS (containing a battery pack), and the user device are illustrated. First, the programmable charger includes a personal computer (PC), which controls the charger according to the charging algorithm using information provided by the portable BMS. Second, the portable BMS comprises (i) a communications interface, (ii) a controller, (iii) a battery measurement unit (BMU), (iv) a data save unit (DRU), and (v) a battery pack. The power of portable BMS is provided by the battery pack. The BMU detects the state of the battery pack and transmits this data to the controller to be stored in the DRU. When the portable BMS is connected to the charger, the controller transmits battery-related data to the charger via the communications interface for the configuration of the charging algorithm. Finally, the controller can also send battery-related information to the user device, such as a smart phone or tablet, by using Bluetooth.

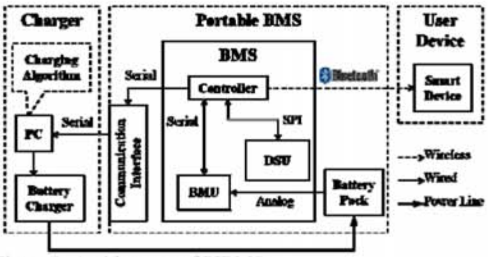

Figure 1: Architecture of PIBMS

B. Functional Design of PIBMS

The PIBMS conducts three basic functions: (i) adaptive charge mode, (ii) wireless transmission and (iii) data collection. Suitable charge parameters for adaptive charge mode are set in the PC as outlined in the following section. These parameters are converted into control commands used to drive the charger in providing power to the batteries. Battery temperature and voltage data is transmitted back to the PC to enable in the determination of whether to switch to the following stage of charging, as shown in Fig. 2. This function can also be used to transmit information between a portable BMS and the user device wirelessly. The smart device first locates and connects to the BMS Bluetooth device in order to obtain battery-related information using the proposed application. The DRU then records the battery information as a function of data collection.

Adaptive Charging

The selection of suitable charge parameters for the proposed five-stage charging method was achieved using the Taguchi method, as follows: (i) selection of quality characteristics (QC), (ii) selection of control factors (CF), (iii) orthogonal table arrangement, (iv) experiments based on selected control factors, (v) comparison of quality characteristics and determination of convergence of control factors. The overall process is illustrated in Fig. 3.

A. Selection of Quality Characteristics

Suitable charge current parameters were determined according to quality characteristics, which is composited by three experiment conditions: charge power P, elapsed time t, and increase in temperature . Symbol refers to the average temperature during the experiment, and is the initial temperature of the battery at the start of the experiment. These factors are used to determine the suitable charge quality according to the following rules: (i) larger filled power, (ii) less elapsed time and (iii) small elevated temperature. Quality characteristics Q is defined using Eq. (1), wherein a larger value for characteristics Q indicates charge parameters of greater suitability.

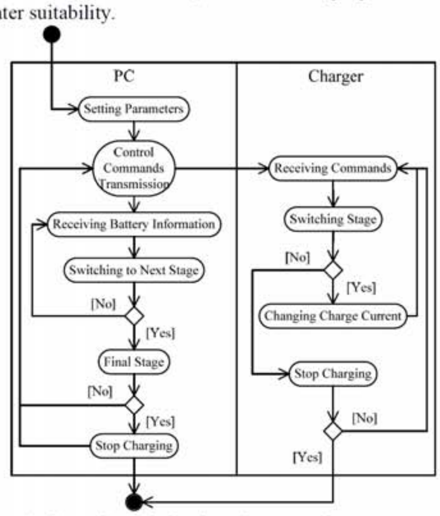

Figure 2: Operation of adaptive charge mode

Experiment Results and Discussion

A. Implementation of Portable Intelligent BMS

In the portable BMS, a 15W, 16 series voltage input sensor board (DCMax Power Tech.) connected to a 48V 50Ah battery pack is used as a BMU, which obtains data related to the temperature and voltage of the batteries to be sent to the controller. We employed an Arduino Mega Board with extended SD card module as a controller and DRU. The communication interfaces were integrated to the 25 pins D-type plug. Fig. 6 illustrates the structure of the portable BMS. When the information of BMU is received, it is passed to the DRU and saved as a text file, as shown in Fig. 7.

We also developed an application for smart devices to receive the battery-related information wirelessly. On the left of Fig. 8 is illustrates the initial screen of the application when the smart device is connected to the BMS. Linking the application to the controller makes it possible to download temperature and voltage data to the smart device, as shown in the middle image of Fig. 8. In the event of error wherein the smart device is unable to receive data from the BMS, an alarm is sounded to alert the user, as shown in the right image of Fig. 8.

B. Adaptive Charging Result

The programmable charger includes (i) a Chen Tech. 2 kW ET-100A charger, and (ii) a personal computer with an Intel(R) Core(TM) i7-2600/3.4GHz CPU running the Windows 7 64-bit operating system. To reduce the influence of ambient temperature, the (iii) batteries were held within an (iv) incubator during the experiments. The experiment setup is presented in Fig. 9.

Table 3 presents the level table based on the CFs initialized rules outlined in Section III, which is used in the arrangement of orthogonal tables for the first round of experiments. The experiment results with the qualities obtained using Eq. (1) are presented in Table 4. The charged power is measured by discharge step for the sake of accuracy. From the results obtained in Table 4, the 8th experiment shows which achieved the largest quality result of 4.992. In which the CFs in the orthogonal table were as follows: , and were used to modified the level table for the second round experiment. Finally, the Table 5 lists the level table used in the third round of experiments, in which CFs in the orthogonal table were as follows: . In the third experiment in table 6, the results from the 5th experiment produced the highest quality value of 5.63. The CFs between levels is equal to 0.025 C at each stage in Table 5, the level table is no longer modified, and the suitable charge current of five stage are 0.9 C, 0.825 C, 0.65 C, 0.525 C and 0.425 C.

Fig. 10 presents a comparison of the proposed five-stage charging method with the CC-CV charge method with regard to increases in temperature. As shown, the increase in temperature associated with the five-stage charging method is less than that of the CC-CV charging method.

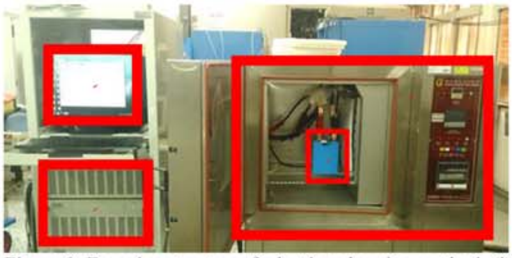

Figure 9: Experiment setup of adaptive charging method: (i) 2 kW charger, (ii) PC, (iii) battery and (iv) incubator

Conclusions

In this study, we developed an intelligent portable BMS based on adaptive charging with a number of useful management functions. Adaptive charging was designed as a five-stage charging method to extend the charge time and correspondingly moderate the increase in temperature. The Taguchi method with orthogonal tables was used to determine suitable charging parameters for each of the five stages: 0.9 C, 0.825 C, 0.65 C, 0.525 C and 0.425 C. We also developed functions for the collection and wireless transmission of data to smart devices. Battery-related data can be saved in an SD card or passed to a smart device using Bluetooth. An application was also developed for the display of information related to charging and the state of batteries. In the case of error in the transmission of data, an alarm is sounded to alert the user. This device represents an intelligent effective approach to the management of battery systems.

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