Electric Power Supply System for Automobile

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Outline

- Introduction
- Electrical System in Internal Combustion Vehicle (ICVs)
- Electrical System in Electric Vehicles (EVs)
- Electrical System in Fuel-Cell Electric Vehicles (FCEVs)
- Conclusion
Introduction

Automotive

- ICVs
- EVs
- FCEVs

Electric system
- Usage
- Supply
- Storage
Electrical System in ICVs

- Circuit diagram
Electrical System in ICVs

- Usage
  - Starting System
  - Ignition System
  - Engine management

Engine needs an initial rotation speed to start its own operation.

“Automobile electrical and electronic systems”, Tom Denton, 2004
Need electricity to make a combustion

Electric power for
- Starting System
- Ignition System
- Engine management

https://en.wikipedia.org/wiki/Ignition_system
Electrical System in ICVs

- Electric power for
  - Starting System
  - Ignition System
  - Engine management

“Automobile electrical and electronic systems”, Tom Denton, 2004
Electrical System in ICVs

- Electric power supply
  - Alternator
  - = Generator + Rectifier

“Automobile electrical and electronic systems”, Tom Denton, 2004
Electrical System in ICVs

- Electric storage: battery

- Supply enough power for starting
- Supply enough energy for other accessories when not running

http://en.wikipedia.org/wiki/Automotive_battery
Electrical System in EVs

Usage

- Motor drive
- Control unit and accessory

[http://techon.nikkeibp.co.jp/english/NEWS_EN/20090729/173547/?SS=imgview_e&FD=91980885&ad_q](http://techon.nikkeibp.co.jp/english/NEWS_EN/20090729/173547/?SS=imgview_e&FD=91980885&ad_q)
Electrical System in EVs

http://www.semicon.toshiba.co.jp/eng/application/automotive/ecology/power_train/evs/
Electrical System in EVs: Charging storage

- **Battery**
  - Long time charging
  - Long range

- **Capacitor**
  - Quick charge
  - Short range

Li-ion battery
Electrical System in EVs: Charging

- Charging requirements
  - Charging electricity as fast as battery allows
    - Battery type
  - Monitoring charging process to avoid damage
    - Voltage
    - Current
    - Temperature
- Controlled by battery management unit

http://auto.howstuffworks.com/electric-car5.htm
Electrical System in EVs: Charging

**Electric Vehicle Batteries Charging System**

- **Electrical Grid**
- **AC-DC Converter**
- **DC-DC Converter**
- **Batteries**

**Digital Control System**

- $V_i$, $i_i$
- $V_{cc}$
- $V_o$, $i_o$

[Image: Diagram of an Electric Vehicle Batteries Charging System]

Electrical System in EVs: Charging source

- Charging station

http://en.wikipedia.org/wiki/Charging_station
Electrical System in EVs : Charging source

- Household charging
  - Convenience
  - Long charging time

[Image of a car charging at a household outlet]

http://auto.howstuffworks.com/electric-car5.htm
Electrical System in EVs: Charging source

- Inductive charging

Electrical System in FCEVs

- **Power Control Unit**: Governs the flow of electricity.
- **Electric Motor**: Propels the vehicle much more quietly, smoothly, and efficiently than an internal combustion engine and requires less maintenance.
- **Fuel Cell Stack**: Converts hydrogen gas and oxygen into electricity to power the electric motor.
- **High-Output Battery**: Stores energy generated from regenerative braking and provides supplemental power to the electric motor.
- **Hydrogen Storage Tank**: Stores hydrogen gas compressed at extremely high pressure to increase driving range.

Vehicle image courtesy of American Honda Motor Co., Inc.

Electrical System in FCEVs

- **Fuel Cell Stack**
- **DC/DC Conv**
- **Battery**
- **Inv**
- **Motor**
- **Auxiliary Devices**

- **Regeneration, Recharge Bat when needed**
- **Assist fuel cell when needed**
- **Power vehicle at high battery SOC**

**Cycle requirement**
Conclusion

- Electric system is necessary in every car.

- Control unit is important for many processes.
Design of a Battery Charger and Charging Management System for an Electric Vehicle

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Outline

- Introduction
- System Design Overview
- Power Module Design
- “Per-Cell” Circuit Design
- Charging Management System Design
- Conclusion
Introduction

- Swinburne University of Technology’s EV
  - A string of 80, 4.2V, 31 Ah rechargeable Li-ion battery

- Li-ion cells accept constant-current/constant-voltage (CC/CV) charging scheme

- Monitor and Equalize cell
System Design Overview

- **Power module**
  - Automatic controlled
  - Vary voltage from 216 V to 336 V, while current = 6 A

- **Per-cell monitoring system**
  - Li-ion requires careful monitoring each cell to avoid damage

- **Charging management system (CMS)**
  - Overall system integration
  - Control logic
System Design Overview

- Communicate via Two-wire interface (TWI)
- PIC microcontroller for each subsystem

Fig. 1 System Overview
Power Module Design

- 2 Choices
  - Buck Converter Approach
  - Digitally Controlled, Motorised VARIAC Approach

- Buck Converter Approach
  - Input 400 V
  - Control voltage from 216 V to 336 V
  - PIC monitors output and sends PWM to control duty-cycle
  - Get instruction from CMS
Power Module Design

- Digitally Controlled, Motorised VARIAC Approach
  - Use motor to move a contactor
  - Motor is controlled by PIC
  - Use rectifier to produce DC voltage
Power Module Design

- **Selected Approach**
  - Power delivered per cost
  - At the same price
    - \( \text{VARIAC} \rightarrow 7A \)
    - Buck converter \( \rightarrow 3A \)

- **Feedback Control**
  - Measure
    - Current using hall-effect sensor
    - Output voltage
  - Control
    - Modify output voltage to achieve constant current
    - Maintain constant voltage before complete
“Per-Cell” Circuit Design

- Monitor Voltage and Temperature not to exceed the limit
- Two-cell-per-circuit
- Measurement send to CMS
- Get instruction from CMS to equalize cell

“Per-Cell” Block Diagram
“Per-Cell” Circuit Design

- **Design Philosophy**
  - Scalable for flexibility in battery size
  - Replaceable in case of failure

- **Measurement**
  - Battery voltage $\rightarrow$ voltage divider $\rightarrow$ ADC
  - Temperature $\rightarrow$ thermistor $\rightarrow$ ADC
“Per-Cell” Circuit Design

- Capacity Balancing Load Circuit.
  - Equalization of state of charge (SOC)
    - Optimize capacity
    - Reduce risk of over voltage
“Per-Cell” Circuit Design

- Communication
  - Slave node on TWI bus
  - Get instruction from CMS
  - Photo coupler for electrical isolation
Charging Management System Design

- CMS Features
  - Master node on TWI communication bus
  - Receive data to change control logic
  - Control a relay for quickly termination
  - Display a process and collect detailed statistics
Charging Management System Design

- **Applied charging profile**
  - CC/CV cannot be applied all the time because of:
    - Too low voltage after discharge
    - Damaged cell
  - Trickle-charge must be applied:
    - To reach minimum required voltage
    - If it cannot reach, the cell was damaged

- **Algorithm**
  - $V < V_{\text{threshold}} \Rightarrow I_{\text{trickle}}$
  - $V > V_{\text{threshold}} \Rightarrow I_{\text{cc}}$
  - $V = V_h \Rightarrow \text{reduce current}$
Conclusion

- Three components: a power module, per-cell unit, CMS
- Motorised VARIAC for varying voltage
- CMS is a center controller
- Communication system: TWI bus