Parameter Identification for a Battery Equivalent Circuit Model

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Agenda

- Introduction
- Battery Equivalent Circuit Model (ECM) and Parameter Identification
- A&D Technology — Battery Testing Solution
- ANSYS — ECM Tool
- Conclusion
Introduction
Background

- Energy Management System of HEV and EV
- Battery Management Functions
- Battery Modeling and Parameter Identification
  - Electrochemical Model
  - Equivalent Circuit Model
Battery ECM and Parameter Identification
Equivalent Circuit Model

- Battery OCV
- Ohmic resistance
- Two sets of parallel resistor-capacitor combination
  - mass transport effects
  - double layer effects
Parameter Identification Tests

Constant current pulse discharge and charge tests at various SOC and current rates

![Graph showing current and battery voltage over time](image-url)
Model Equations

\[ V_t = V_{oc} - V_0 - V_1 - V_2 \]

\[ V_0 = iR_0 \]

\[ C_1 \frac{dV_1}{dt} + \frac{V_1}{R_1} = i \]

\[ C_2 \frac{dV_2}{dt} + \frac{V_2}{R_2} = i \]
Jiang and Hu’s Method

\[ U(t) = V_{10}e^{-\frac{t}{\tau_1}} + V_{20}e^{-\frac{t}{\tau_2}} \]

\[ X = \int_0^t U(\tau) \cdot d\tau \]

\[ Y = \int_0^t X(\tau) \cdot d\tau \]

\[ Y = (\tau_1 + \tau_2)(-X) + \tau_1 \tau_2 (U_0 - U) + (V_{10} \tau_1 + V_{20} \tau_2)t \]
Jiang and Hu’s Method

\[
\begin{bmatrix}
Y_1 \\
Y_2 \\
\vdots \\
Y_m
\end{bmatrix} =
\begin{bmatrix}
-X_1 & U_0 - U_1 & t_1 \\
-X_2 & U_0 - U_2 & t_2 \\
\vdots & \vdots & \vdots \\
-X_m & U_0 - U_m & t_m
\end{bmatrix}
\begin{bmatrix}
\tau_1 + \tau_2 \\
\tau_1 \tau_2 \\
V_{10} \tau_1 + V_{20} \tau_2
\end{bmatrix}
\]

A&D Battery Testing Solution
**Key Features**
Control up 16 cell test circuits
- 1 PPS with 16 circuits
- 4 PPS each with 4 circuits
iTest can be remote or local to cluster

**Standard System**
iTest PC
iTest software & application
iConnect I/O, Set of cables

**iTest interface (flexible)**
- 16 Analog In
- 16 Temperature
- 8 Digital In
- 8 Digital Out
- 2 Ethernet
- 1 Serial

**iTest Application Content**
GUI & Interface
- I/O
  - Programmable Power Supply
  - Thermal Chamber

Tests with Reports
- Hybrid Pulse Power Characterization
- General Static Capacity
- US06 Drive Cycle
- Cycle Life Test
- Calendar Life Test

Simulation mode
Data Acquisition and Control

Demonstration Mode

Battery
- Specification
  - Sample Battery SOC
  - Start/Stop Sequences Ready
- Monitoring
  - Voltage
    - CANNODC
    - CAN Voltage
    - Max Cell V
    - Avg Cell V
    - Min Cell V
    - Cell Balance
    - Cell Voltages
- Status
  - Shut Down
  - Monitoring
  - Calculations
    - Actual Capacity
    - Battery SOC
    - Battery SOC

Temperature
- Batt Temp
- Max Temp
- Min Temp
- Ambient Temp
- Cell Temp
- Cell Delta
- Cell Delta
- Cell Delta

Cycler
- Control/Monitor
  - Manual
  - Monitor
- Setpoint
  - Voltage
    - Current
    - Power
  - 200.000 V
  - 12.506 A
  - 200.000 KW
- Feedback
  - Status
  - Running
  - Discharge

Test Information
- Test Request: TR234
- Test Engineer: David Prettenhofer
- Project: Sample Project Folder
- Battery ID: Batt1
- Test Name: Sample_DST
- Test Status: Running
- Data File: TR234_Batt1_Sample_DST_V500_Ced1_30Apr2012_18

Charge Taper Routine: Batt1 Taper Charge

Graphs:
- Voltage vs. Time
  - Voltage: 323.849 V
  - Current: -12.506 A

A&D Technology
ANSYS ECM Tool
ECM Parameter Extraction Tool

V_{oc} vs. SOC

Pulse Discharge
ECM Parameter Extraction Tool

ECM Model Workflow
Conclusion
Conclusion

- Innovative method for the parameter identification of a battery equivalent circuit model
- Battery testing solution for parameter identification data collection
- Easy to use battery ECM tool
Thank You!

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