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Workshop on engineering models for advanced batteries vehicle OEM panel session model outputs—industry perspectives

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Abstract

The vehicle level requirements for a battery model have been defined. An introduction providing vehicle manufacturer experience in developing battery models to date and describing the ideal battery model characteristics has been provided. Battery performance and thermal model requirements are defined in terms of minimum and desired outputs. Model verification is discussed and recommended variables offered. Other complementary data needs are also included.

Keywords: Model output; HEV; 42 V; MATLAB®; Verification; Accelerated calendar life

1. Introduction

Electric (EV) and hybrid electric vehicle (HEV) manufacturers have developed custom devices for battery electronic monitoring and control. These devices are integrated into the vehicle control architecture. Battery control systems are a critical source of data in executing vehicle control strategies and defining the limits of battery usage. It is vital that quality battery models exist when developing both battery and vehicle level control strategies.

The general process utilized in the development of EV battery monitoring and control algorithms was primarily empirical in nature. Manufacturers acquired all available battery cell and module characteristic data from the respective supplier. With this data, a rudimentary model was defined and used to develop the basic battery control structure. This process allowed the determination of missing data.

Testing was then initiated in order to complete the data set. Using the complete data set, a model was produced and the battery control algorithm developed. The process described was borne of necessity and is, obviously, extremely time consuming and resource intensive.

The preferred vehicle battery control algorithm development process begins with a quality battery model. The ideal battery model not only defines a response to a defined input, but is predictive in nature. This allows the opportunity for preventative actions in advance of system failures. Contemporary battery models must exhibit extremely quick response time in order to be applicable to dynamic full HEV and soft hybrid (42 V) applications. Finally, to gain broad acceptance, the models must be in MATLAB®, or a compatible format, which is already a familiar tool in the vehicle development.

2. Battery performance model

Battery performance model development is the first priority. Certain, basic battery characteristics must be well described by the performance portion of a battery model in order to have utility in vehicle system simulation. The minimum model output requirements are defined in Table 1.

There are additional battery performance model characteristics which are desired, but of less immediate importance. The additional (desired) model outputs are provided in Table 2.

3. Battery thermal model

Battery thermal model development is the second priority. A few fundamental battery characteristics must be defined by the thermal portion of a battery model in order to adequately assess the vehicle system thermal interface requirements. The minimum model output requirements are defined in Table 3. Additional (desired) thermal model outputs are provided in Table 4.

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Table 1
Minimum battery performance model outputs

Performance model output	Required accuracy
Battery SOC (%)	±5
Voltage[a] (V) as a function of SOC, temperature (T), age and recent history (charge, discharge, idle) (%)	±2
R_i as a function of SOC, T and age (%)	±5
Maximum available charge and discharge power as a function of SOC, T and age (%)	±10
T (°C)	±1

[a] This should include hysteresis effects; aging of OCV curve must also be comprehended.

Table 2
Additional (desired) battery performance model outputs

Performance model output
Charge acceptance as a function of SOC, T and age
Battery life (cycle and calendar) remaining
Internal resistance transients as current is applied or removed

Table 3
Minimum battery thermal model outputs

Thermal model output
Heat generation as a function of: SOC, T and I (charged and discharged)
Heat transfer (removal) as a function of coolant T
Temperature distribution within the battery system

Table 4
Additional (desired) battery thermal model outputs

Thermal model output
Cell specific heat as a function of SOC and T
Coolant flow pattern prediction as a function of inlet pressure
Coolant pressure drop as a function of flow rate

4. Battery model validation

The quality of a model is only as good as the process by which it is validated. In general, model validation or verification involves a comparison between model output and actual battery hardware test data. In order to develop a robust model verification procedure, it is necessary to take as many potential variables into account as possible. Due to typical cost and timing constraints, complete battery system testing under all possible conditions proves impractical. Therefore, general guidelines are being provided to optimize the quality of the model verification process:

- utilize a dynamic (HEV) cycle;
- vary the initial state of charge (SOC) from maximum to minimum values;
- vary the input and output current (I) from maximum to approximately 50% of the battery system capability;
- vary battery characteristics (open circuit voltage (OCV), internal resistance (R_i), etc.) from beginning of life (BOL) to end of life (EOL) behavior;
- a matrix should be prepared to define the required test data points to compare with the model output.

Other complementary model user data needs have been defined for the battery modeling community. First, an accelerated calendar life test should be available for advanced technology batteries such as nickel/metal hydride (NiMH) and lithium-ion (Li-ion). It is acknowledged that such an effort for high power (HEV) Li-ion batteries is already underway at Sandia National laboratory (SNL). However, a calendar life model must also be developed and verified for NiMH batteries. Second, Nyquist plots for a temperature range between −30 and 70 °C and over the full SOC range should be provided. These are useful tools in understanding the model basis.

5. Conclusions

Battery model output requirements have been defined from the standpoint of vehicle manufacturers (OEM's). Historical battery model development by OEM's, while of high quality and quite essential, has been a very expensive and time-consuming process. It is recommended that contemporary battery models be extremely responsive and developed in MATLAB®. Minimum performance and thermal model outputs, with required accuracy, have been provided. Additional (desired) model outputs have been included. Model validation has been discussed and a recommended process outlined. Other complementary data needs have also been explained.

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