A New Equivalent Circuit Model for Rechargeable Batteries

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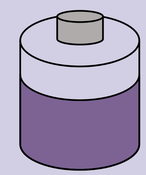
Back to Basics Corner

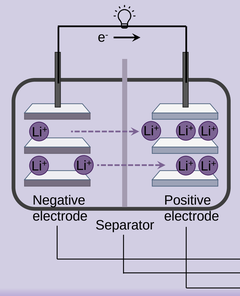
Why do we need battery modeling?

1. Estimation of battery performance

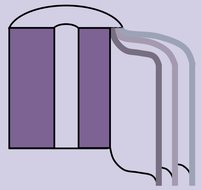


How to know its charge status?
How to do that in a simple but accurate way?
What if it is a battery pack? …

2. Battery design



"Jelly roll" battery structure

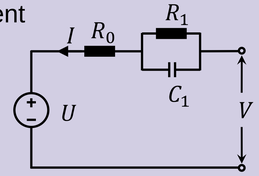


Introduction

Batteries are not only indispensable for our life today but also a key technology for moving the world forward into a sustainable energy era.

Batteries are vulnerable to over-charge/ discharge, temperature effects and abusive ambient conditions. Battery management is a must to ensure the safety, performance and longevity of the batteries.

Practical real-time battery management systems often require the use of equivalent circuit models, which are structurally concise and computationally efficient. Despite some existing models, there is a continual demand for equivalent circuit models capable of capturing complex battery behavior at high accuracy.



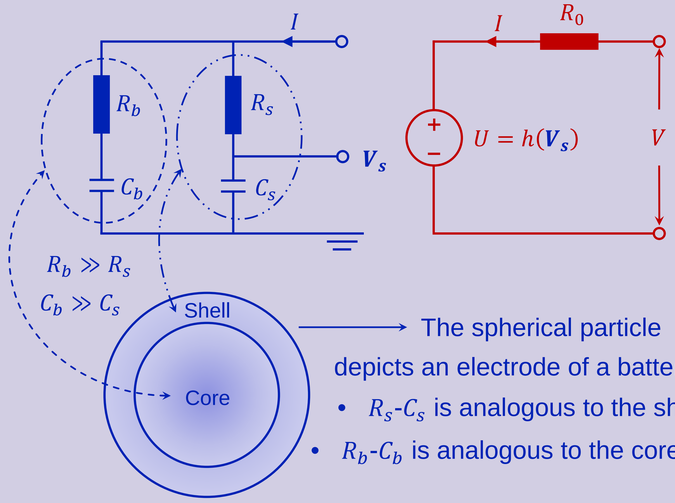
Thevenin model

Research motivation: Develop a new equivalent circuit model that can emulate the charge transfer within an electrode and the nonlinear voltage response simultaneously.

Our effort transforms an existing linear equivalent circuit model to be a nonlinear one that can offer higher accuracy.

Modeling

The **new** equivalent circuit model is



The spherical particle depicts an electrode of a battery:

- R_s-C_s is analogous to the shell
- R_b-C_b is analogous to the core

In this model:

- The double capacitors provide storage for electric charge like an electrode depicted as the above spherical particle. When parallelly connected, they simulate charge migration between the shell and the core region in the electrode.
- Nonlinear function $h(\cdot)$ enables this model to capture the nonlinear relationship between state of charge and open-circuit voltage.

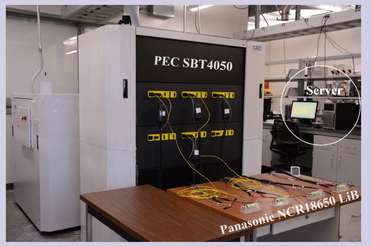
Advantages of this model:

- Concise structure
- Physical reasonableness
- High predictive accuracy

Prospective applications of this model:

- State of charge estimation
- State of health estimation
- Fast charging protocol design (now is under research)
- Aging prognostics

Experimental Validation



Experimental facility

- PEC® SBT4050 battery tester
- Support dis/charging with arbitrary current-, voltage- and power-based loads up to 40 V and 50 A
- Run with a server that configures tests and collects data

Experimental battery

- Panasonic NCR18650B, 3.25 Ah

Validation of the predictive capability of this model