Battery Performance, Thermal, and Life Modeling for Southern California Edison

Cooperative Research and Development Final Report

CRADA Number: CRD-17-00656

NREL Technical Contact: Partha Mishra

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

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Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-5400-80686
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National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

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Report Date: August 10, 2021

In accordance with requirements set forth in the terms of the CRADA agreement, this document is the CRADA final report, including a list of subject inventions, to be forwarded to the DOE Office of Scientific and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

Parties to the Agreement: Southern Californian Edison (SCE)

CRADA Number: CRD-17-00656

CRADA Title: Battery Performance, Thermal, and Life Modeling for Southern California Edison

Responsible Technical Contact at Alliance/ National Renewable Energy Laboratory (NREL):

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Sponsoring DOE Program Office(s): Office of Energy Efficiency and Renewable Energy (EERE), Vehicle Technologies Office

Joint Work Statement Funding Table showing DOE commitment:

No NREL Shared Resources

Estimated Costs	NREL Shared Resources a/k/a Government In-Kind
Year 1 Year 2	$0.00 $0.00
TOTALS	$0.00

Executive Summary of CRADA Work:

The objective of this project is to develop battery performance models, thermal models and life models for SCE to use in simulation and analysis of grid services involving energy storage. NREL will fit the models to three separate chemistries using test data provided by SCE. The dataset for each chemistry will include electrical, thermal and aging response to different temperatures and cycling conditions, measured under a variety of cell-level and module-level experiments described in SCE test protocol documents. Once tuned to a test dataset, the battery system model software will provide predictions of battery energy and power loss, and thus cycle and calendar life, for any energy storage grid service power profile of interest to SCE. The automated battery life modeling and simulation tool can also be applied to any other grid battery systems as long as necessary input data is available to accelerate battery model development and battery lifetime analysis.

Summary of Research Results:

The project was to develop custom battery electrical/thermal/life models for battery technologies of interests to SCE using SCE's testing data. The project was planned in three subtasks as follows.

1. Test planning, model development and documentation

1.1 Test planning and documentation

SCE had performed battery life experiments and provided with NREL team the testing planning documentation. In the beginning of this project, NREL and SCE discussed and agreed on the testing data format and measurements that SCE was to provide to NREL for custom battery model development.

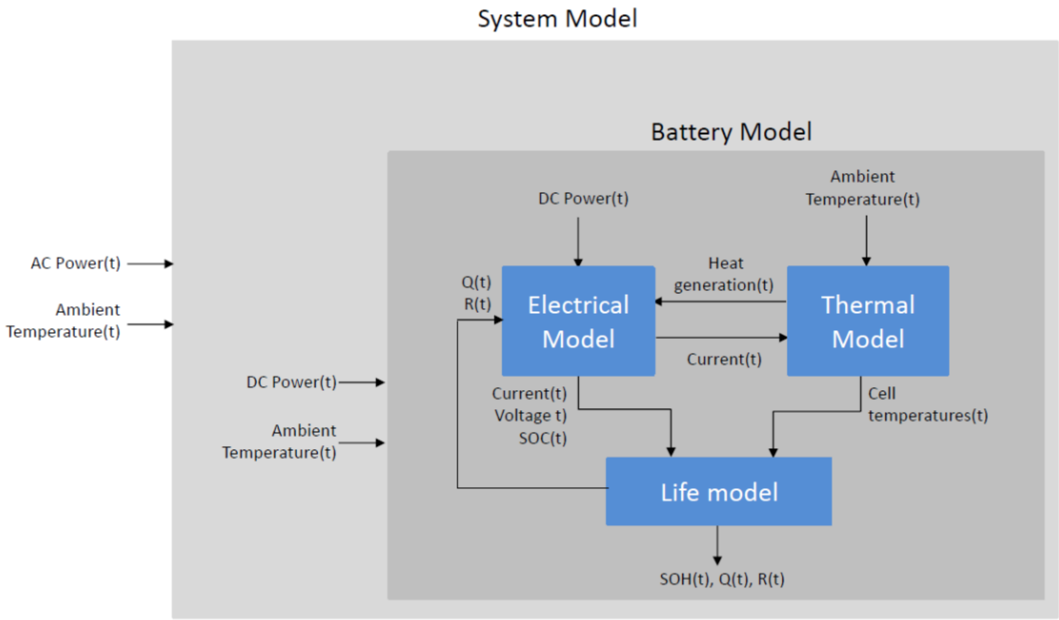

Figure 1 Model Framework

1.2 Electrical/thermal/life model development and integration

NREL was tasked to develop and integrate electrical, thermal and life models into a MATLAB system simulation tool that can predict battery lifetime for any energy storage power profiles. An equivalent circuit model (ECM) represented the pack voltage, current and heat generation response. A pack system thermal model predicted pack temperature distribution and heat transfer. The thermal and electrical models provided SOC, T, and cycling history inputs to the life model. The models were integrated into a simulation tool, as shown in Figure 1, to calculate battery capacity loss and resistance growth. Accumulated over time, capacity loss and resistance growth, causing energy loss and power loss, define the state of health of a battery. NREL team developed a MATLAB APP (a software wrapper with a user interface) for the simulation tool and wrote a user manual to level out the learning curve for any users to adopt this tool which is described with more details in Task 1.3 below. Figure 2 shows an example of the modeling outputs.

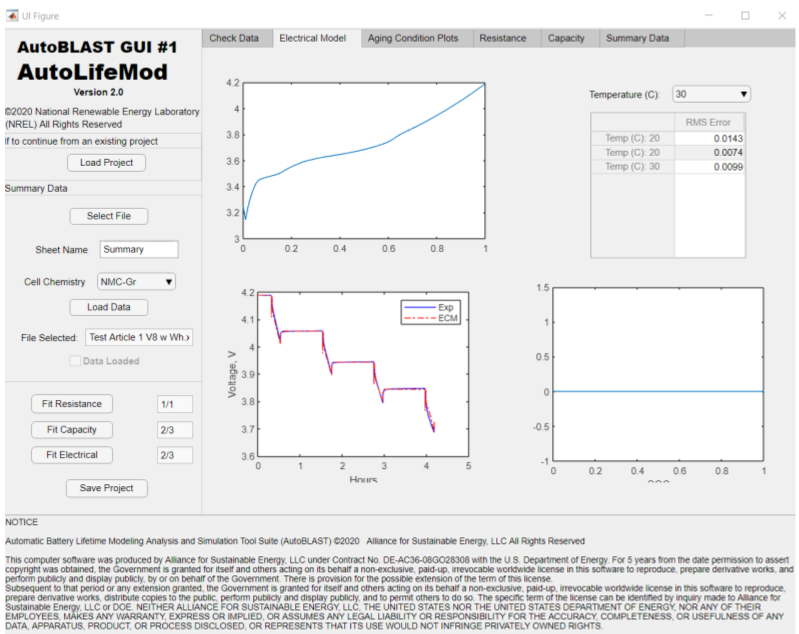

Figure 2 Example of Modeling Outputs

1.3 Automation of model identification procedure from test data

NREL was tasked to apply optimization techniques to regress electrical, thermal and life models from test data provided by SCE. NREL targeted to automate the model parameterization process and make model identification a turn-key process that SCE can perform in-house routinely in the future. Based on custom model development done under Task 2, NREL team developed an automated battery modeling tool that optimizes and automates the model regression process for electric/thermal/life models. The team also developed a MATLAB APP which has a user-interface and a user manual to guide users to input data and run the modeling tool - the automatic battery lifetime modeling analysis and simulation tool, AutoBLAST. It contains two components: the automatic lifetime modeling (AutoLifeMod) tool and the automatic lifetime simulation (AutoLifeSim) tool. AutoLifeMod has an interface shown in Figure 3. It takes battery life degradation testing data as input and automatically generates battery life models predicting battery lifetime capacity loss and impedance growth, which are key metrics reflecting battery usable energy and power.

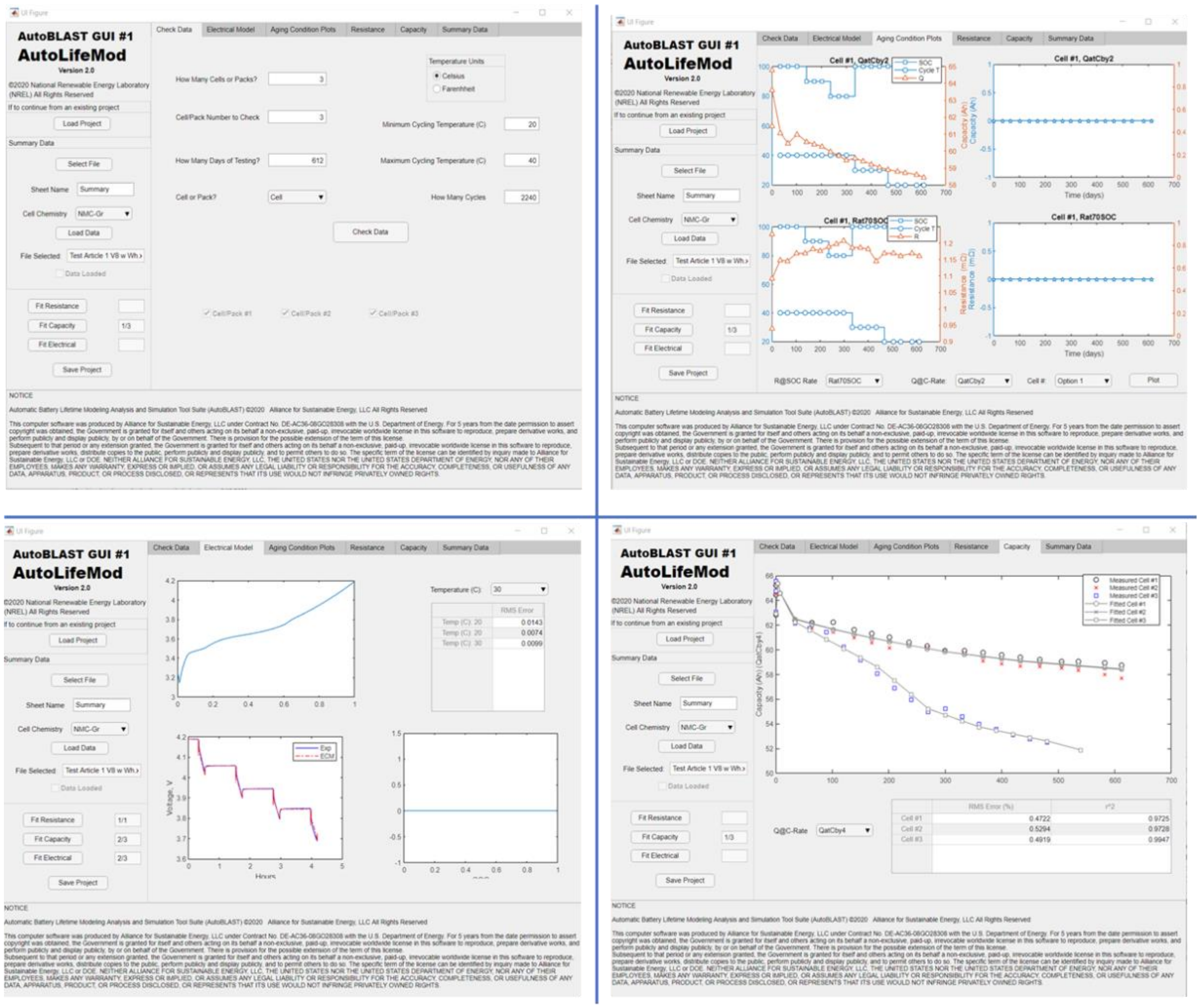

Figure 3 User Interface of AutoBLASTGUI-AutoLifeMod

AutoLifeSim has an interface shown in Figure 4. It takes two inputs: the life model parameters from the AutoLifeMod GUI and an aging sequence spreadsheet defined by the user, describing the expected battery lifetime operation conditions. The GUI then simulates the battery lifetime degradation based on the life model and the aging sequence.

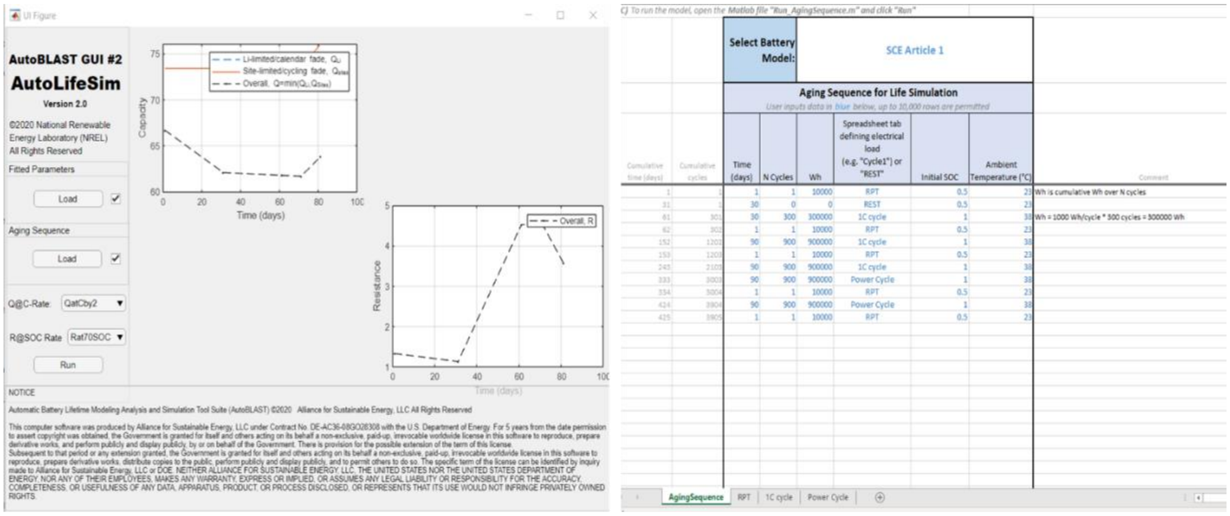

Figure 4 User Interface of AutoBLASTGUI-AutoLifeSim

2. Model identification for Chemistry #1

SCE provided data to NREL for a first battery chemistry/technology chosen by SCE. NREL analyzed the testing data and developed custom electrical, thermal and life models for Chemistry #1. NREL verified the models with SCE's testing data. NREL also developed the automated battery modeling tool based on the modeling process done and data models used in Task 2. Table 1 shows the final model prediction accuracy.

Table 1 Life Model Prediction Accuracy for Chemistry #1

	R^2 error	RMS error	R^2 error	RMS error
Test case #1	0.99799	0.29433%	0.94421	1.6452%
Test case #2	0.98887	0.31743%	0.84578	2.1997%
Test case #3	0.99095	0.24237%	0.72097	2.0716%

3. Model identification for Chemistry #2

NREL would develop/modify the battery system electrical/thermal/life models following the same procedures in Task 1 and 2 for Chemistry #2. But because of delays from COVID-19, SCE cannot complete testing for Chemistry #2 within the project performance of period. Given the limited time and funding on the project, SCE waived Task 3. NREL team presented the results to SCE team on the fitting with the initial testing data provided and

Table 2 is the life model prediction accuracy.

Table 2 Life Model Prediction Accuracy for Chemistry #2

	R^2 error	RMS error	R^2 error	RMS error
Test case #1	0.80748	0.1812%	0.79196	2.0767%
Test case #2	-1.3872	0.61043%	0.89238	2.1333%

Subject Inventions Listing:

None

ROI #:

None