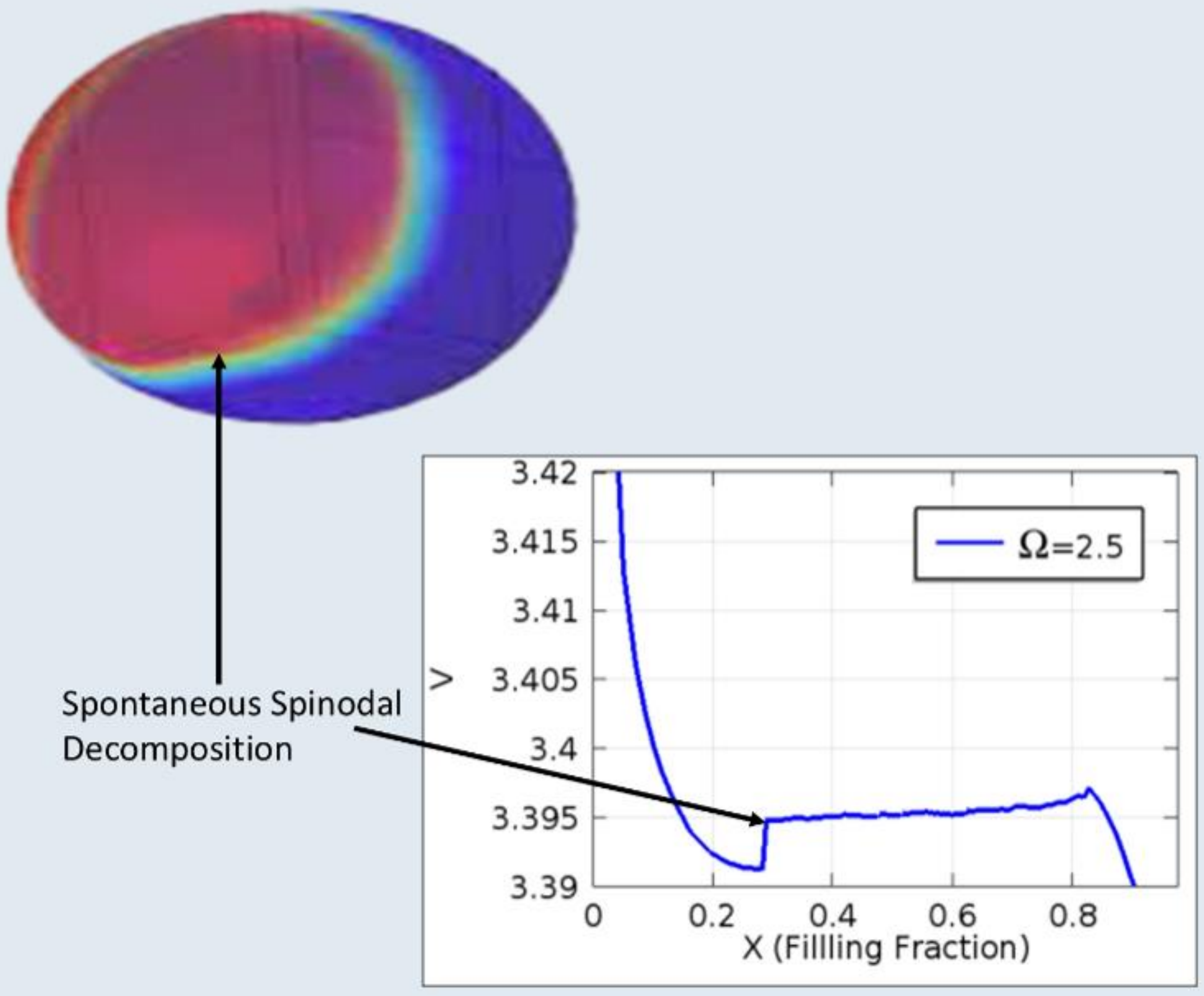

A Digital Twin Approach For Battery Management Systems For Electric Vehicles

Realizing the digital twin concept for electric vehicle battery management systems through multi-physis, multi-scale simulation and machine learning.

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Abstract

The digital twin concept enables the integration of complex multiphysics and multidimensional models and simpler reduced order models (ROM). Our approach to developing a digital twin simulation of lithium-ion batteries for electric vehicles utilized a dataset generated from the COMSOL® Multiphysics simulation of the Cahn-Hilliard equation for a single particle model (SPM) of a lithium iron phosphate (LiFePO4) cathode. The ROM was then developed by utilizing experimental data for an A123 Systems 26650 2.3 Ah cylindrical battery to train a self-normalizing neural network (SNN). Finally, the ROM was verified as an on-board battery management system (BMS) for ambient temperatures ranging from 253 to 298 K and discharge rates ranging from 1 C to 20.5 C.

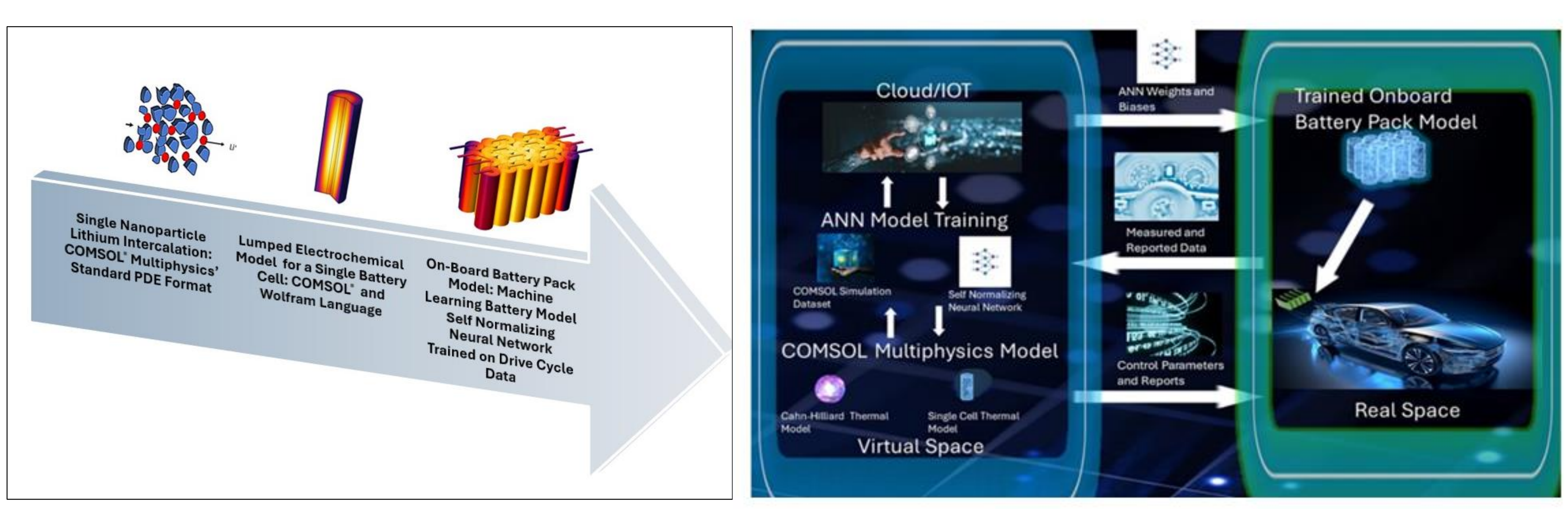

FIGURE 1. Left: Depiction of our Multi-Physics, Multi-Scale Lithium-Ion Battery Model and Simulation. Right: Visualization of the Implementation of the On-board Self Normalizing Neural Network Model.

Methodology

We applied the 3D Cahn-Hilliard phase field SPM for LiFePO4 nanoparticles to serve as a test-bed for the development and verification of the SNN. The diffusional chemical potential based on the regular solution model and acquired from the Cahn–Hilliard free energy functional is

$$\bar{\mu} = -k_b T \, ln\left[\frac{\bar{c}}{1-c_m}\right] + \frac{\bar{\Omega}(c_m-\bar{c})}{c_m} - \frac{KV_S}{c_m}\bar{\nabla}^2\bar{c}$$

Results

We tested and verified the SNN for a 1 C discharge rate for ambient temperatures ranging from 253 to 298 K. The model results were also compared to experimental results for discharge rates ranging from 1.0 to 10.6 C for an ambient temperature of 298 K. Finally, we validated the trained SNN using the harsh road test dataset: Up Mount Sano in Huntsville, AL as shown in Figure 2.

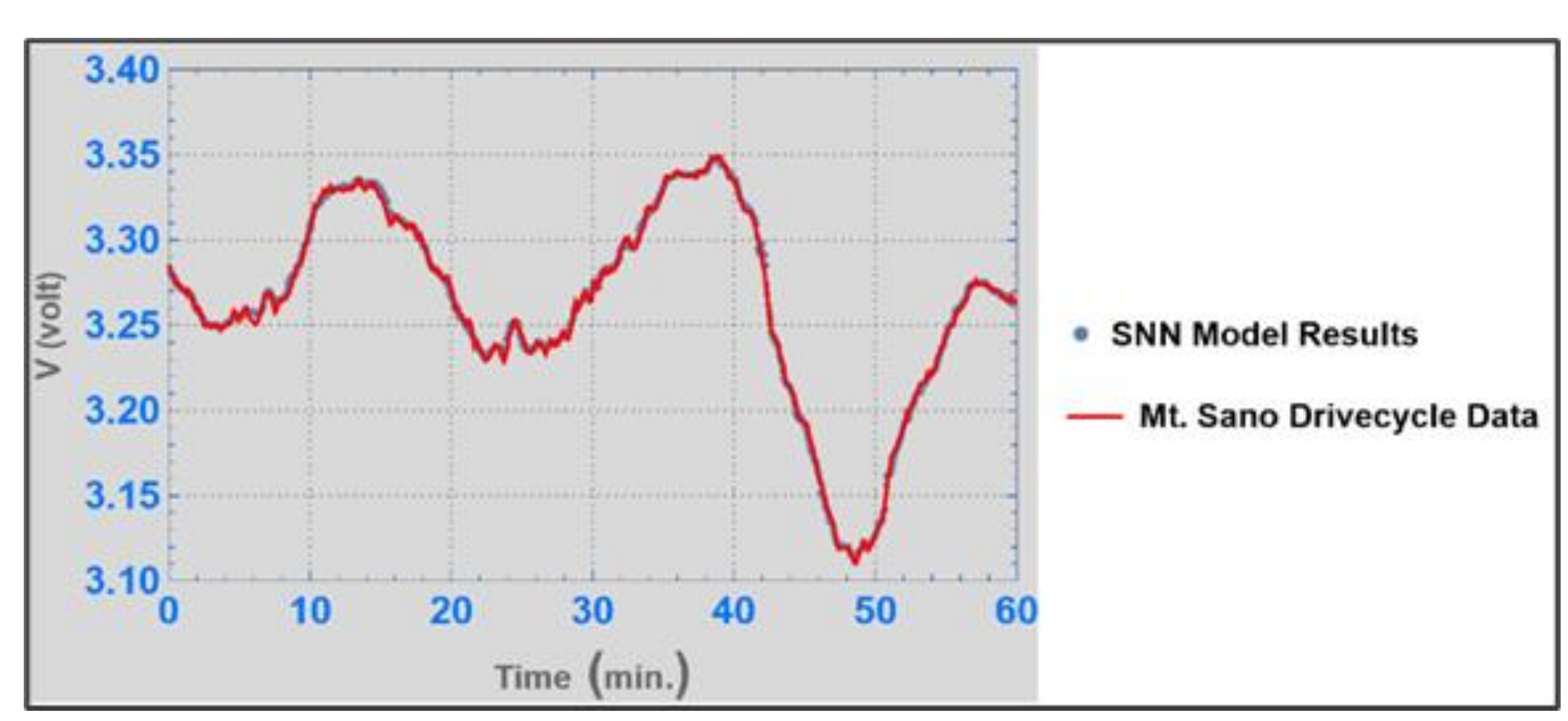

FIGURE 2. Validation Of the Self Normalizing Neural Network Model for Harsh Drive-Cycle Data.

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