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Battery SOC and SOH Estimation using a Hybrid Machine Learning Approach

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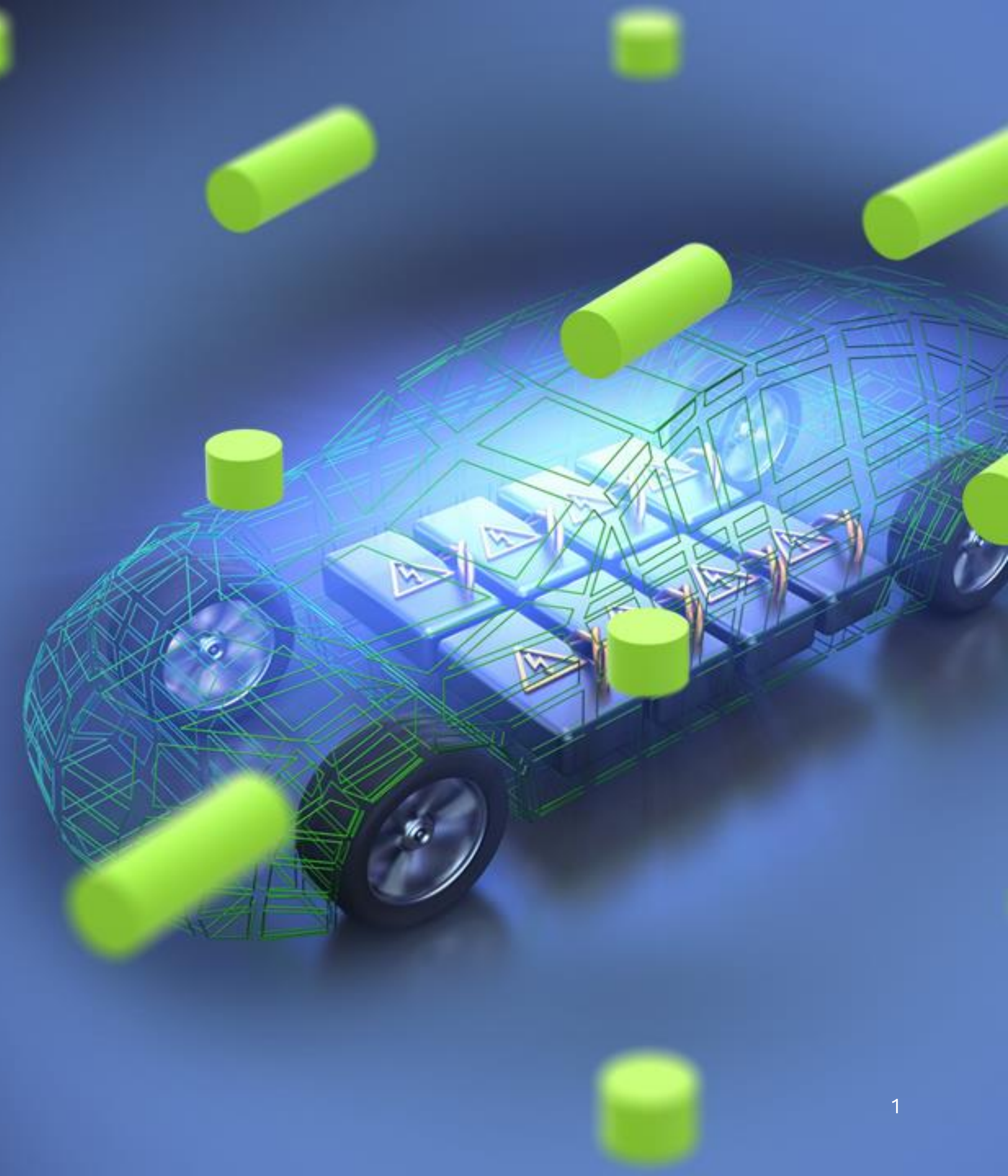
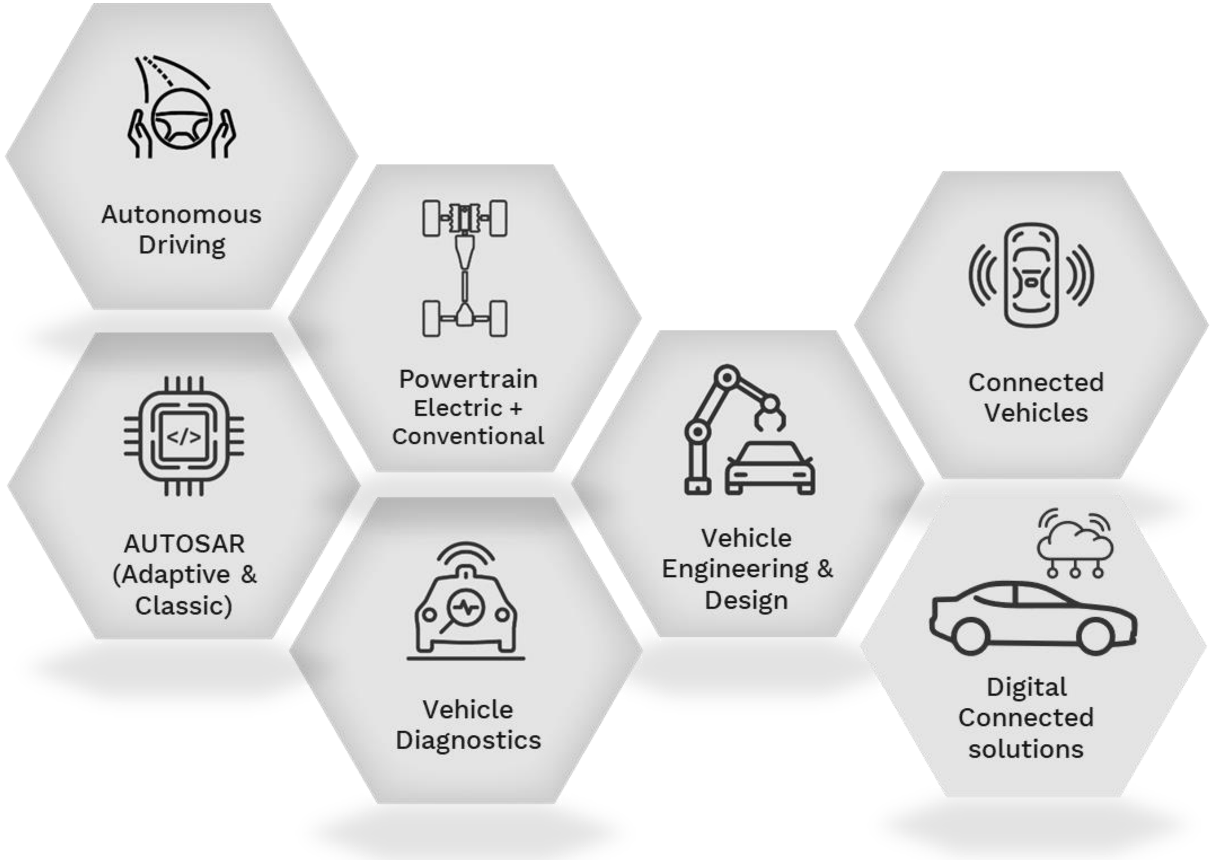


Who We Are

Independent software integrator partner bringing scale and dependability
to build and integrate software features to accelerate the journey from prototype to production



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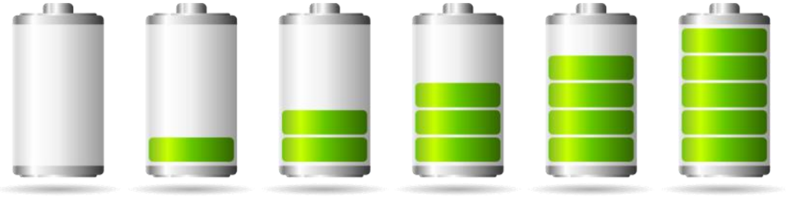
Challenges in conventional methods for estimating SOC & SOH

- Measurement Noise
- Integration Error
- Initial SOC calculation error
- Peukert’s Coefficient
- Incorrect Battery Parameterization of battery models
- Best fit tuning challenge

Proposed methodology

In the **hybrid approach, SOC's generalization** and **nonlinearity approximation** capability are significantly enhanced



SoC : State of Charge | **SoH** : State of Health

Machine learning based *Hybrid Approach*

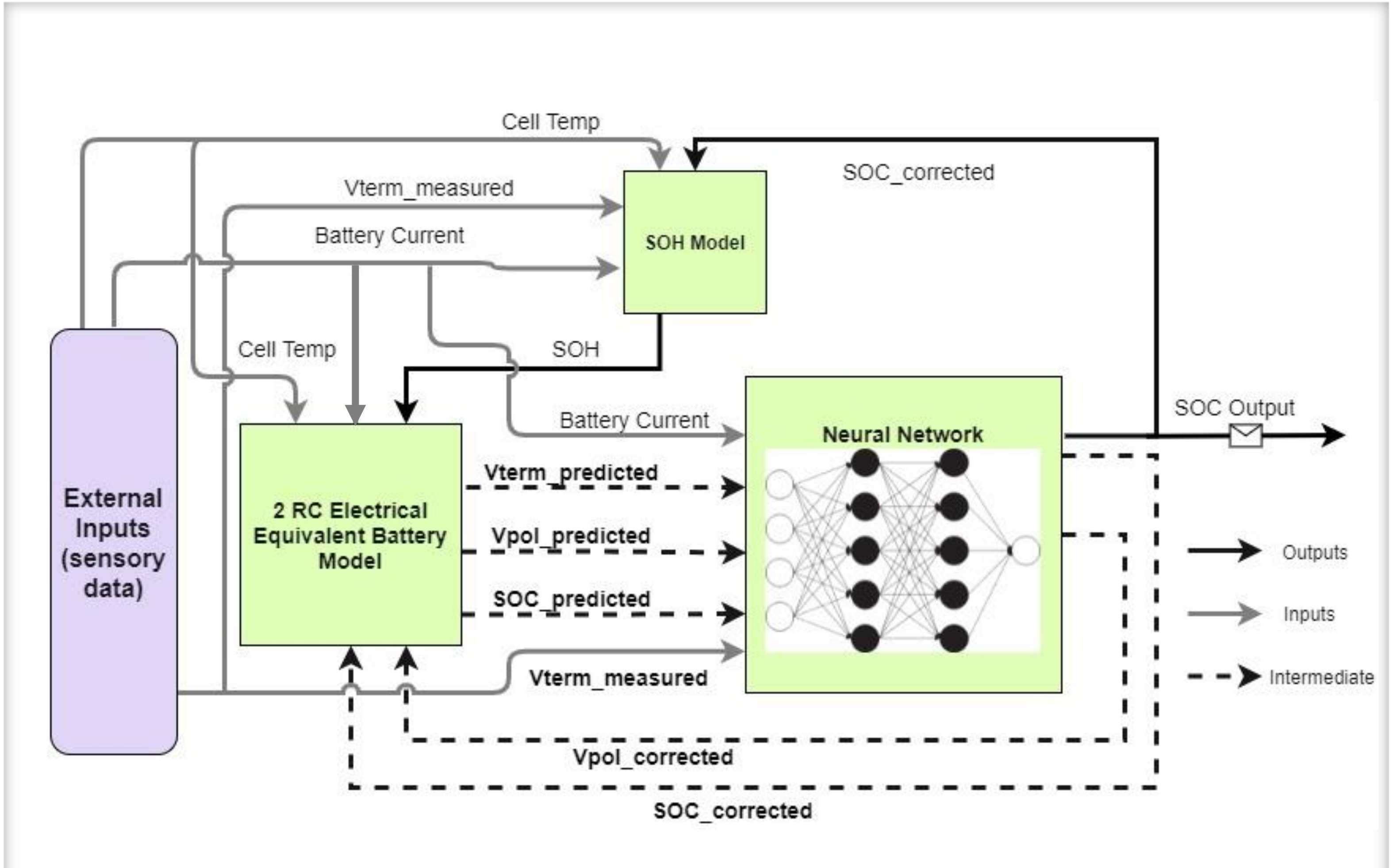
Influencing Factors of SOC

01 **Current Measurement**
Sensor resolutions and inaccuracy

02 **Voltage Measurement**
DC Offset Errors, AC noise

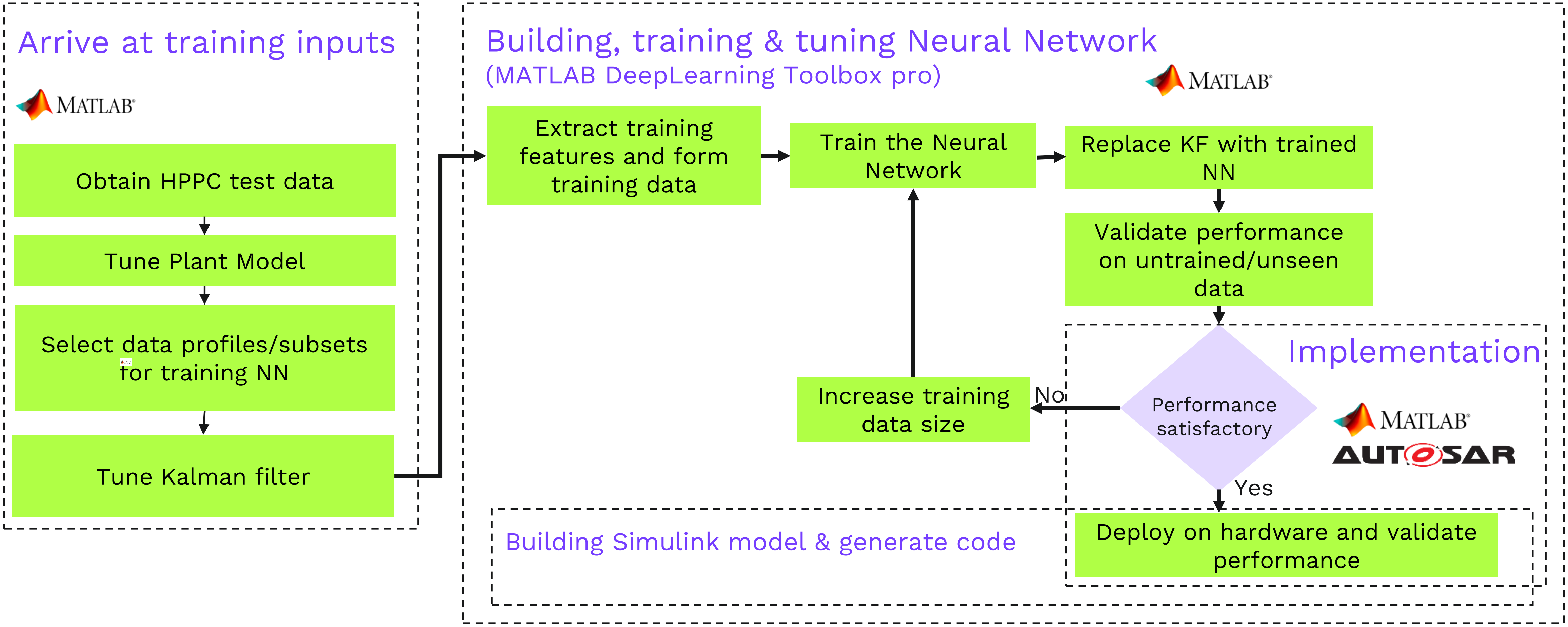
03 **Temperature Dependency**
Incorrect Battery Characterization

04 **Internal Resistance**
Calculation inaccuracies



Patent # 202021049709

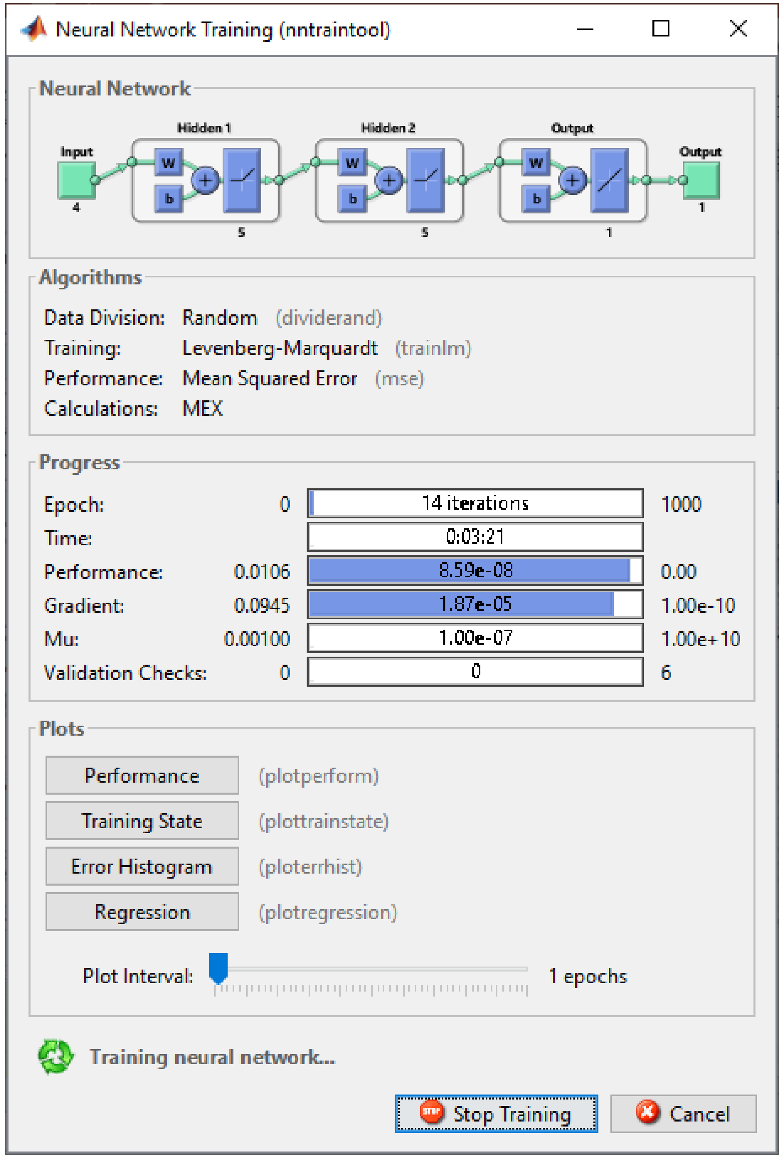
Workflow of proposed hybrid SOC estimation approach



Training Process for a Neural Network

Training Stages

1. A model with a Kalman filter is used to collect data from two open-source runs
2. The collected data includes the features and the target variable
3. MATLAB's Deep Learning Toolbox is used to train a NN to map input features to the target output
4. To prevent overfitting, a portion of the data is held out for validation checks
5. Several networks are trained to find the one that generalizes well across all the unseen datasets

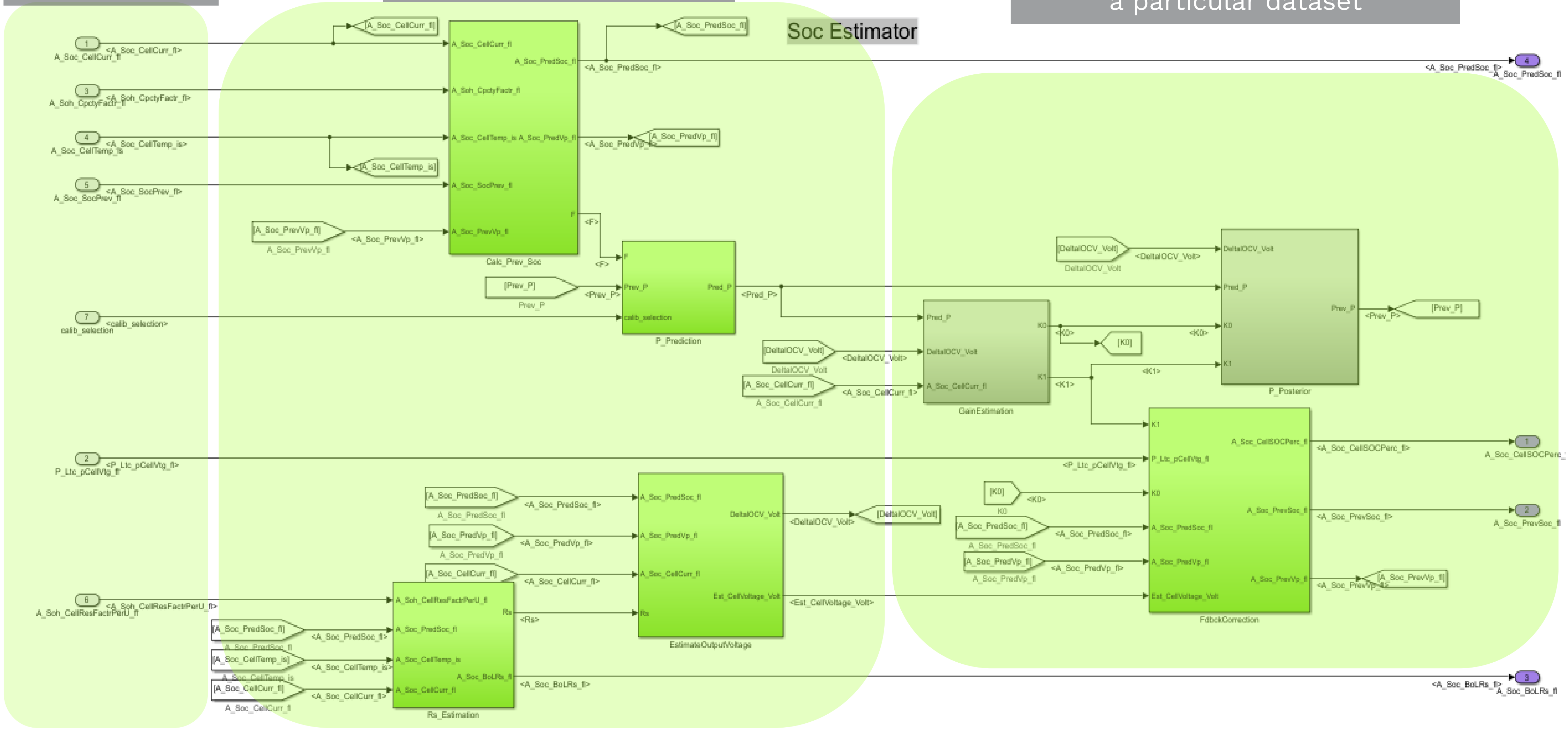


Arrive at training inputs

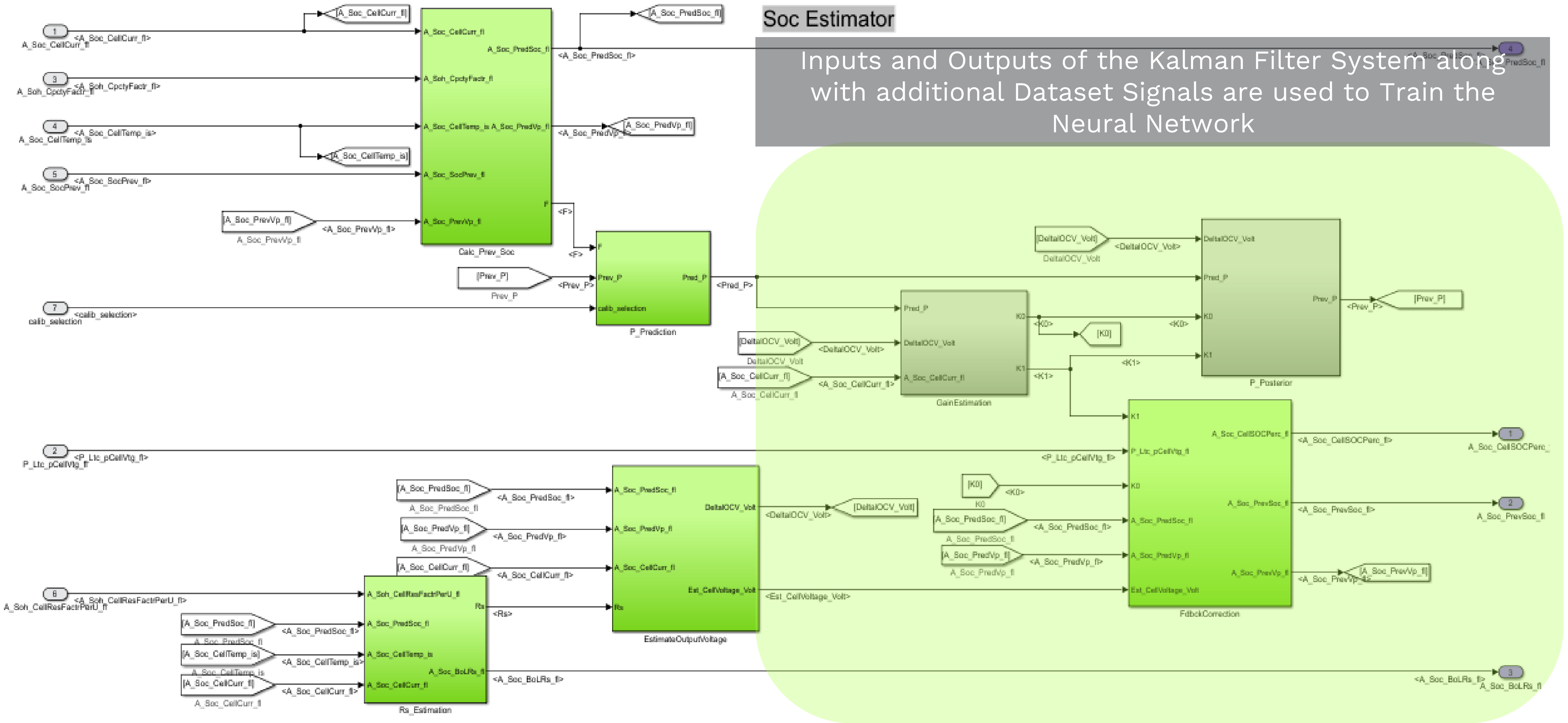
Dataset Inputs

Tuned Battery Plant Model

Kalman Filter Co-efficients tuned for best case accuracy on a particular dataset



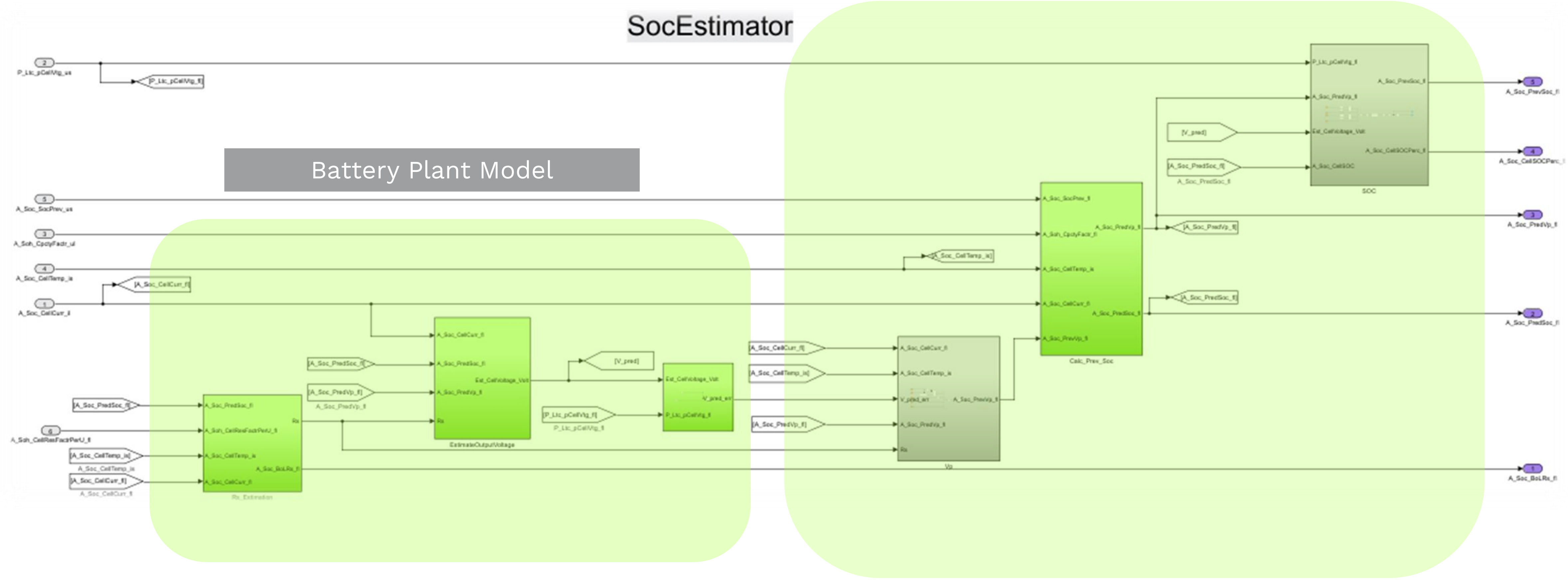
Arrive at training inputs



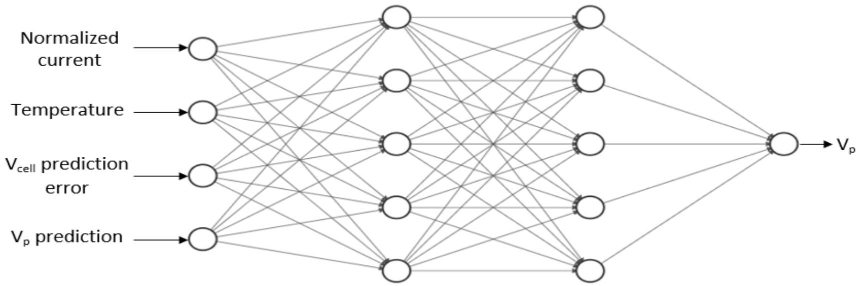
Inputs and Outputs of the Kalman Filter System along with additional Dataset Signals are used to Train the Neural Network

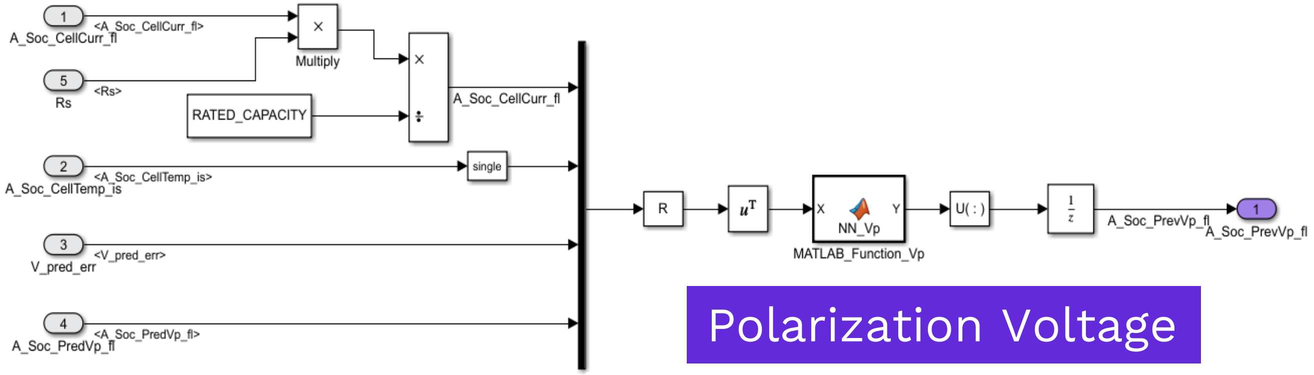
Final Model design

Neural Network Simulink Systems replace the Kalman Filter of previous design

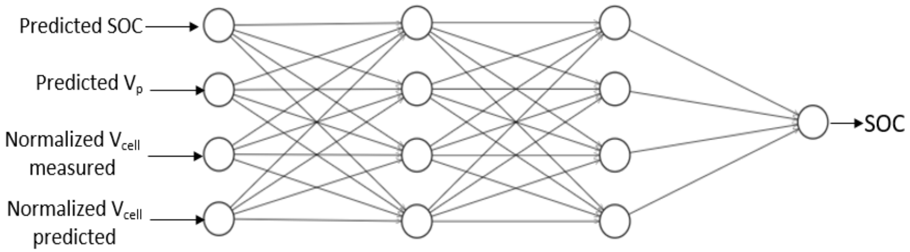


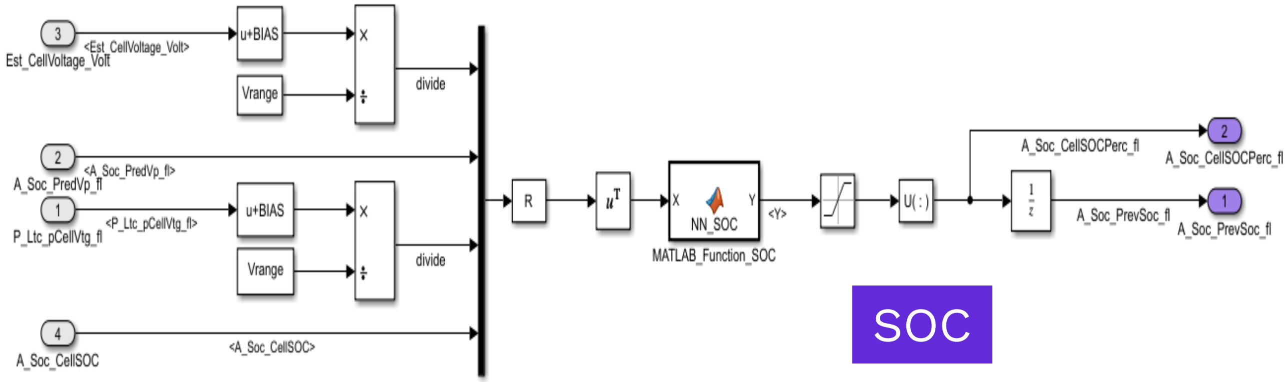
Neural Network design





Polarization Voltage

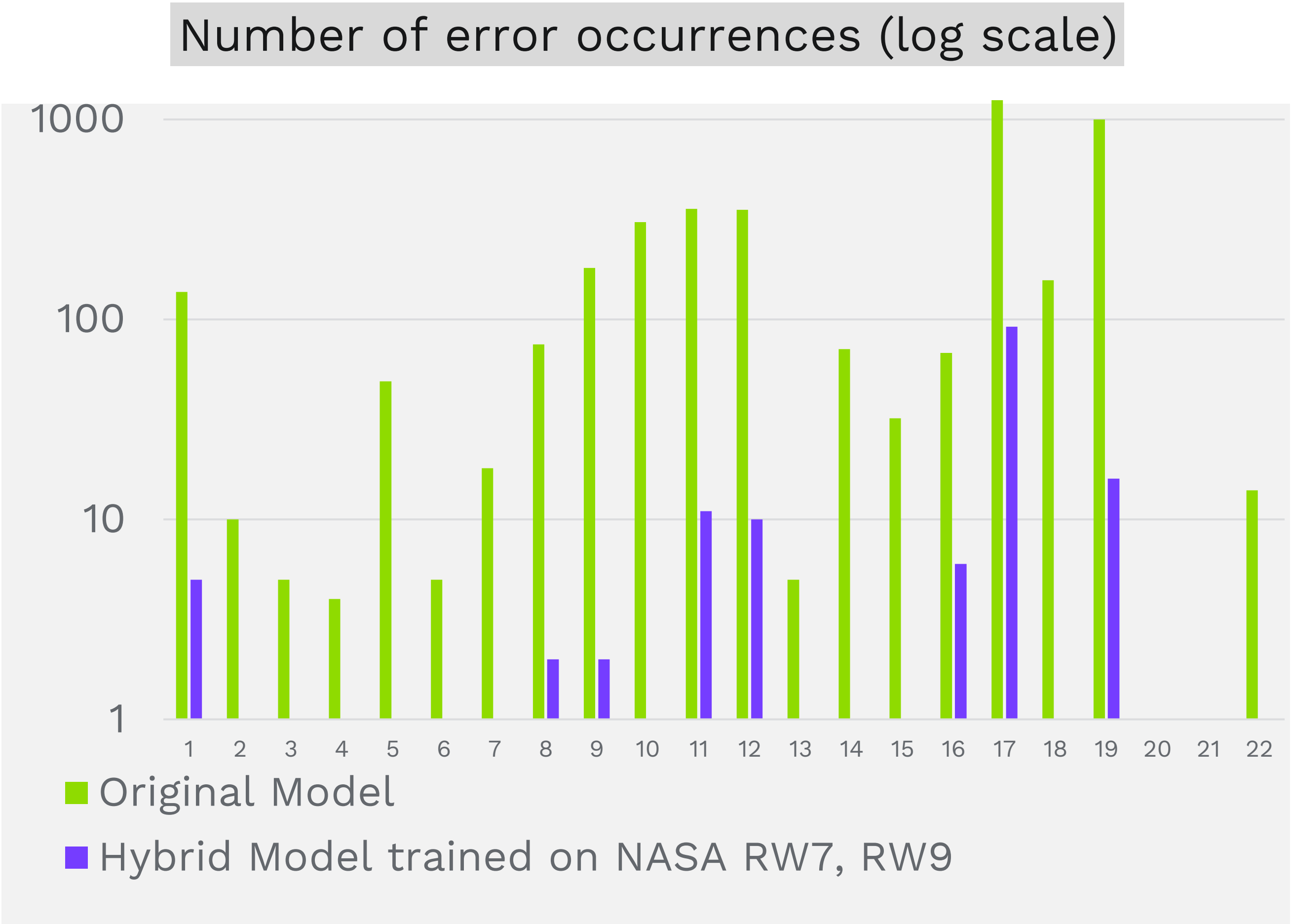




SOC

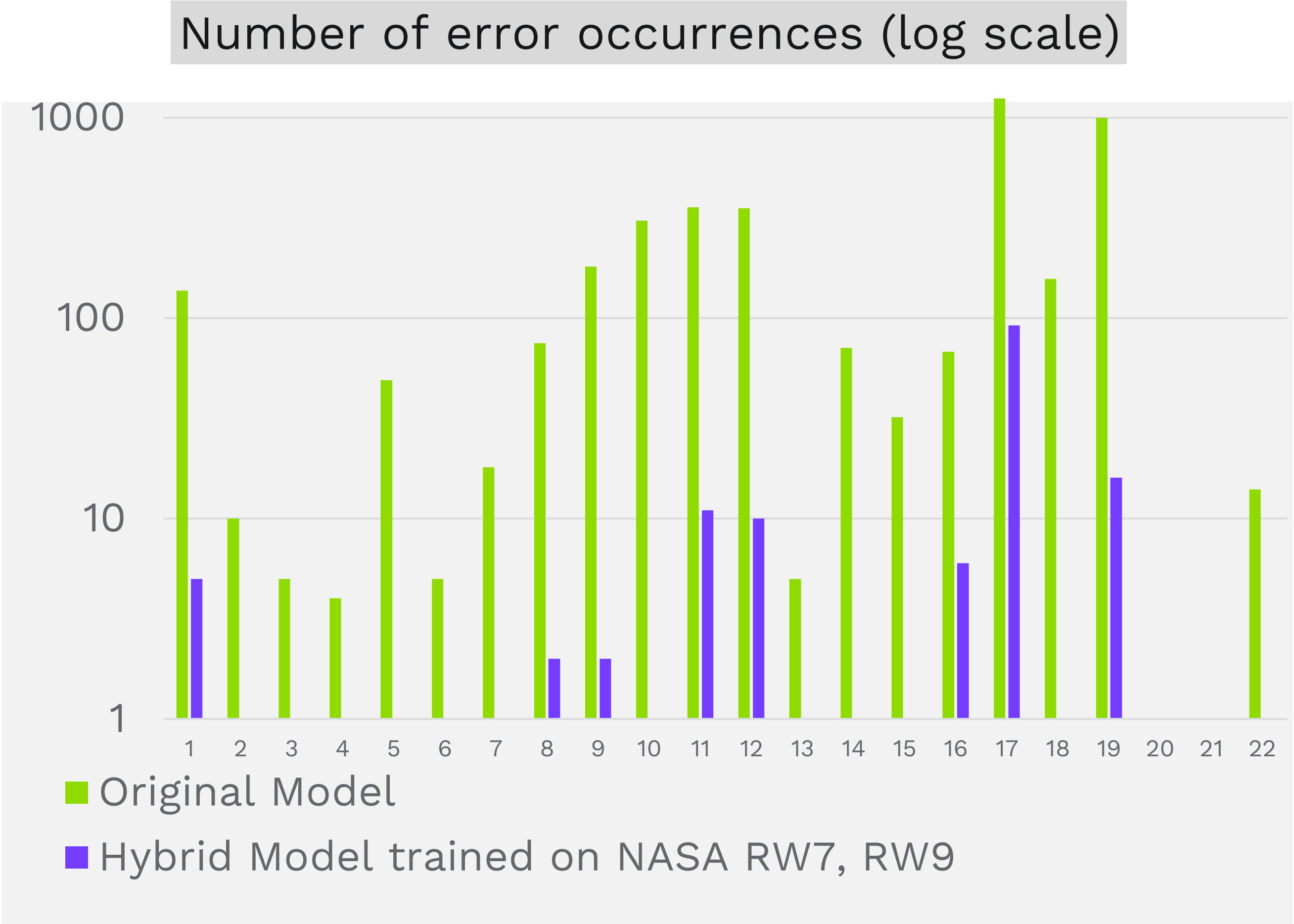
Simulink NN Model

Model performance



Error = abs(Vpred - Vmeas)
Error_Occurence = focv(error) > 5%

Model performance



ACG Performance using Simulink Embedded Coder

Memory Segment	Memory Sub-Segments	NN-SW Design Hosted on MPC5746R
RAM		515 Bytes
ROM	Code	8730 Bytes
	Constants	388 Bytes
Stack		623 Bytes

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Summary

- Application of AI/ML along with domain has consistently yielded the desired estimate of cell SOC at acceptable accuracy levels.

- Conventional methods were less complex and accurate, the increase in computational power and usage of powerful toolchain from MathWorks has encouraged to explore the complex techniques to enhance the algorithms

- The MathWorks environment provided the required computational and design toolboxes to seamlessly enable this workflow of designing and training the neural network, simulating in a closed-loop environment, and generating production-grade embedded code for deployment on hardware.

- Further, this study was mainly for mild hybrid applications; for fully battery electrical, the computational aspect becomes more challenging. Further, these algorithms of SOC and SOH can be extended to integrate with a vehicle control unit and thereby improve the electrical range and achieve better fuel economy. And all this development is possible in a shorter time due to powerful simulation toolchains from Mathworks.

Thank You

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Programs executed on Hybrid and Electric Vehicles

Domains

BMS, Charger, Inverter, DC-DC Converter, VCU – BEV, HEV

Software integrator partner, managing vehicle programs with multiple clients

Production ready software components for EVCC, CCS, GB/T, CHAdeMO and BMS

Global delivery model (Germany, US, India, Thailand)

End-to-end validation partner for xEVs - SIL, MIL and HIL testing | Automation strategy