State of Charge Estimation for an Electric Wheelchair Using a Fuel Gauge Model

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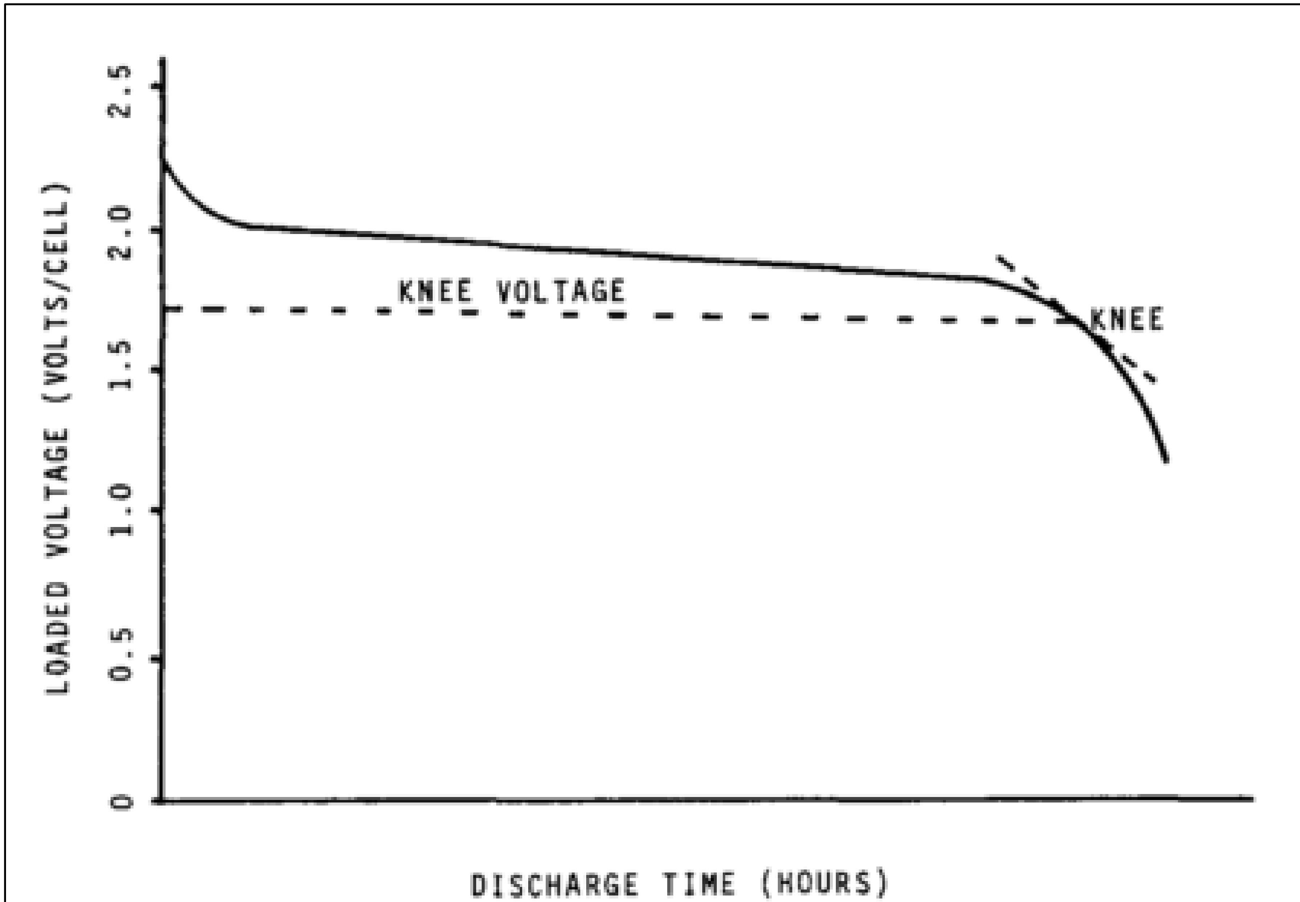
ASME 2016 Dynamic Systems and Control Conference

Wheelchair-dependent persons rely on a battery pack to ensure their freedom-of-mobility, thus accurate battery state-of-charge estimation for wheelchairs is critical for user safety and mobility.

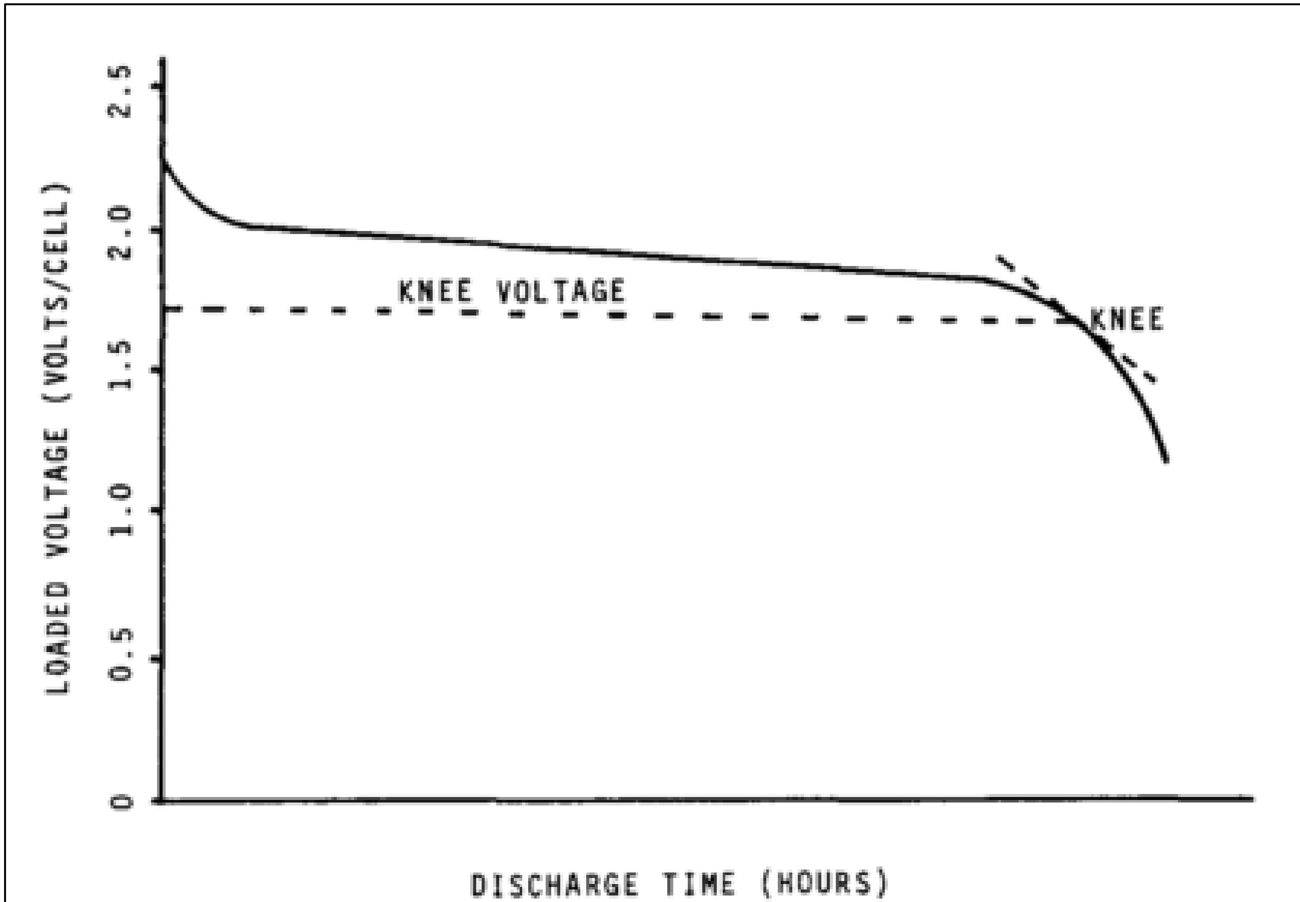
JazzyPride Wheelchair

In his widely-cited 1992 work, Aylor et al. estimated wheelchair battery SOC by measuring the wheelchair's battery pack's open-circuit voltage (OCV).



Aylor et al.

This work represents one of two “basic” methods for SOC estimation. Aylor et al. monitored the change in voltage with respect to charge.



Aylor et al.

Since the 1990's others have presented both novel systems to estimate SOC and methods to extend battery life.

Fuzzy Logic Energy Estimation

Chen et al.

Hybrid Hydrogen Wheelchair

Bouquain et al.

The purpose of this research is to expand upon existing wheelchair energy estimation by providing users with a more accurate estimate of remaining state-of-charge.

wisegeek.com

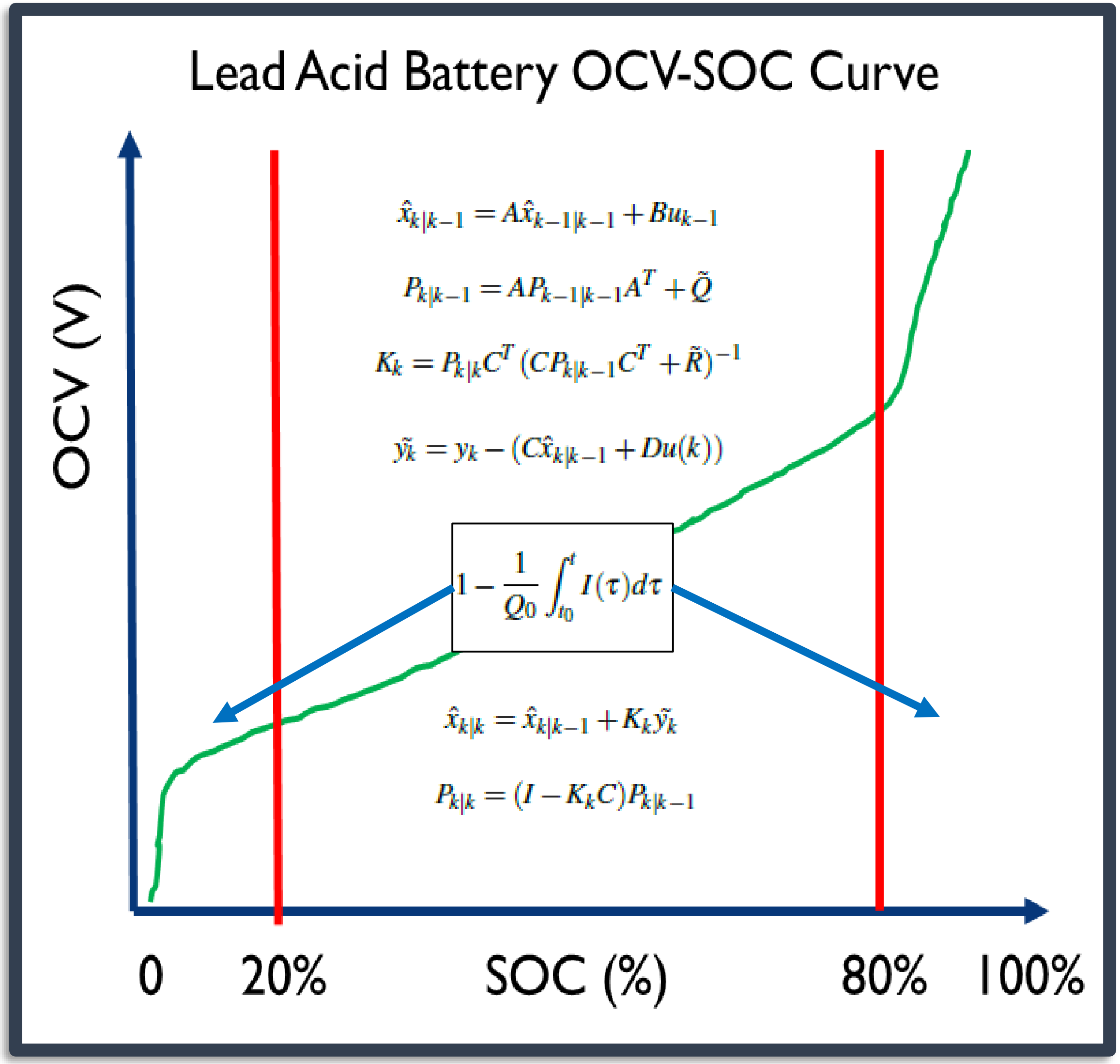
asia.nikkei.com

An vehicle's fuel gauge remains at full for a long time after the tank has been filled with gasoline and at empty even if some fuel remains in the tank due to tank geometry.

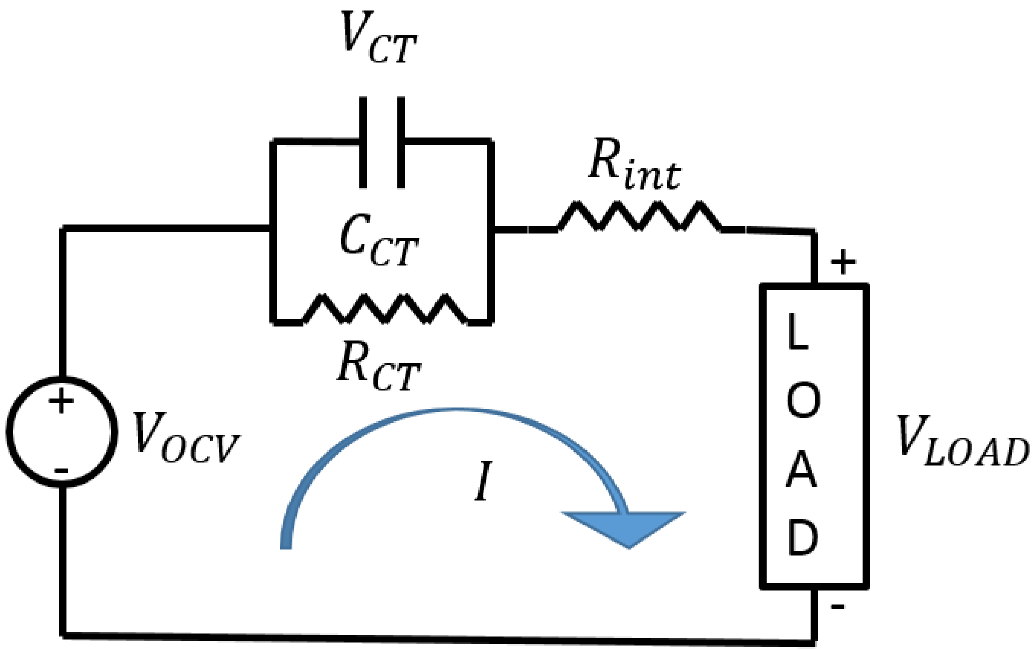
caranddriver.com

Allstate.com

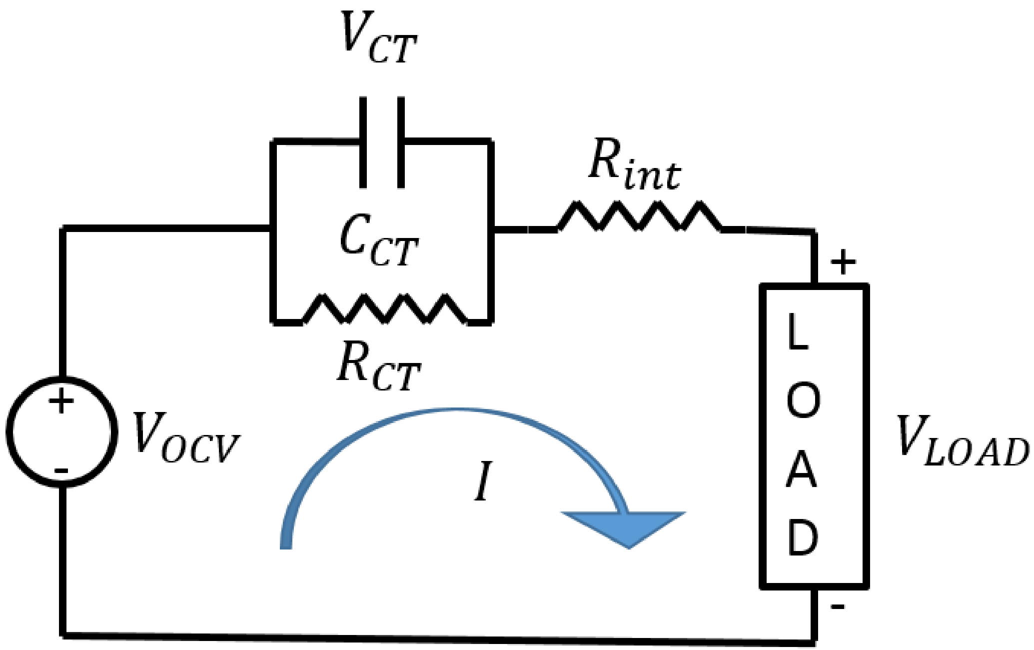
In the battery estimation fuel gauge model, a coulomb counter is used to estimate SOC at the extremes of the discharge and a Kalman filter for the middle part of the discharge.



To model the battery's dynamics in the linear region of the fuel gauge, a second-order equivalent circuit model was selected.

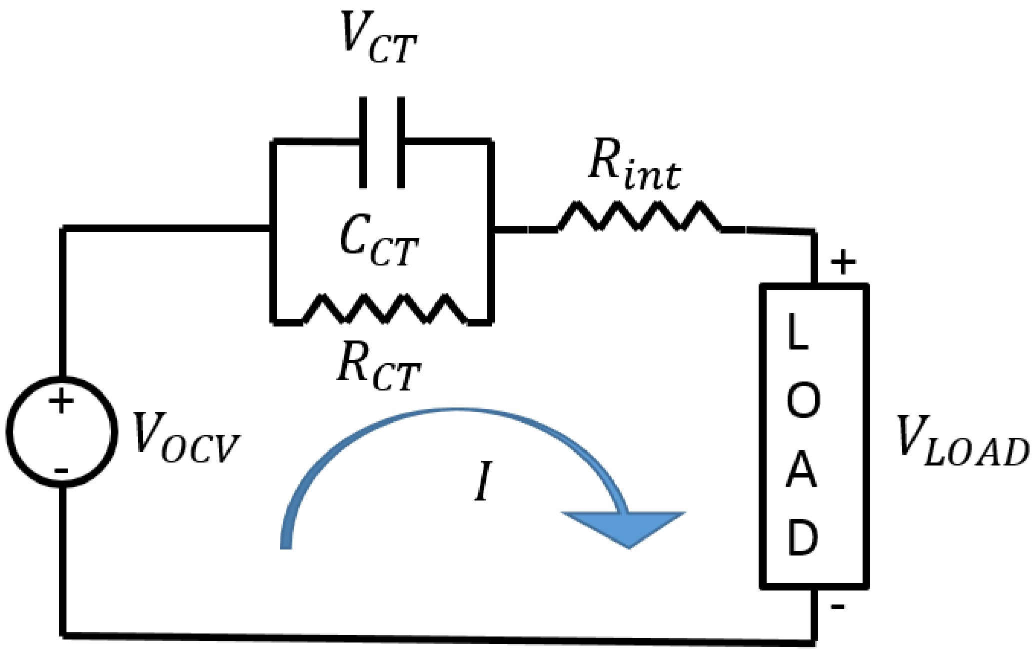


Kirchhoff's voltage laws were applied to this equivalent circuit battery model to derive the voltage across the battery pack.



$$V_{load} = \alpha SOC + \mu - R_{int} I - V_{CT}$$

Practical implementations of this battery model required conversion to state-space form and discretization using a zero-order hold.

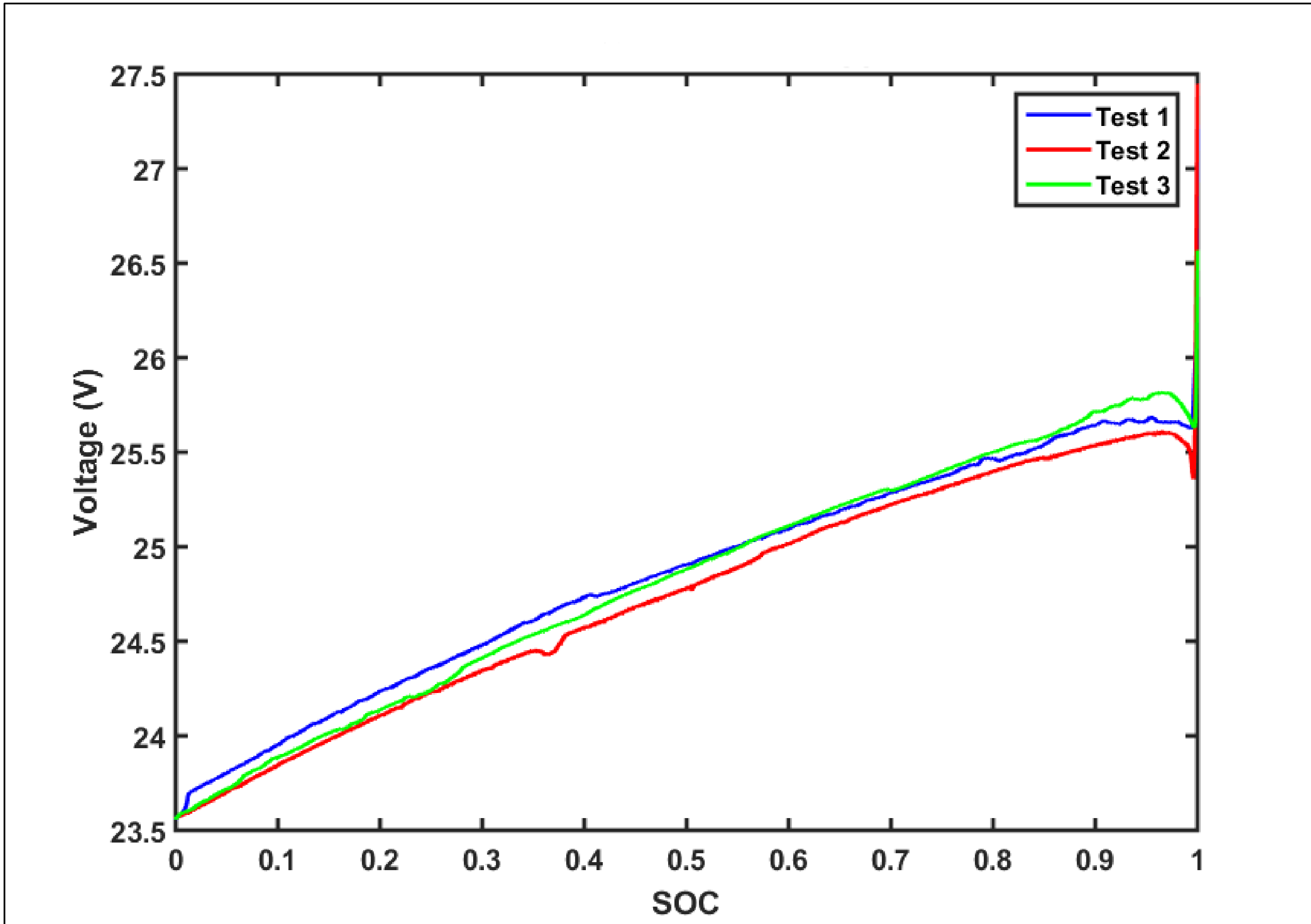


$$V_{load} = \alpha SOC + \mu - R_{int}I - V_{CT}$$

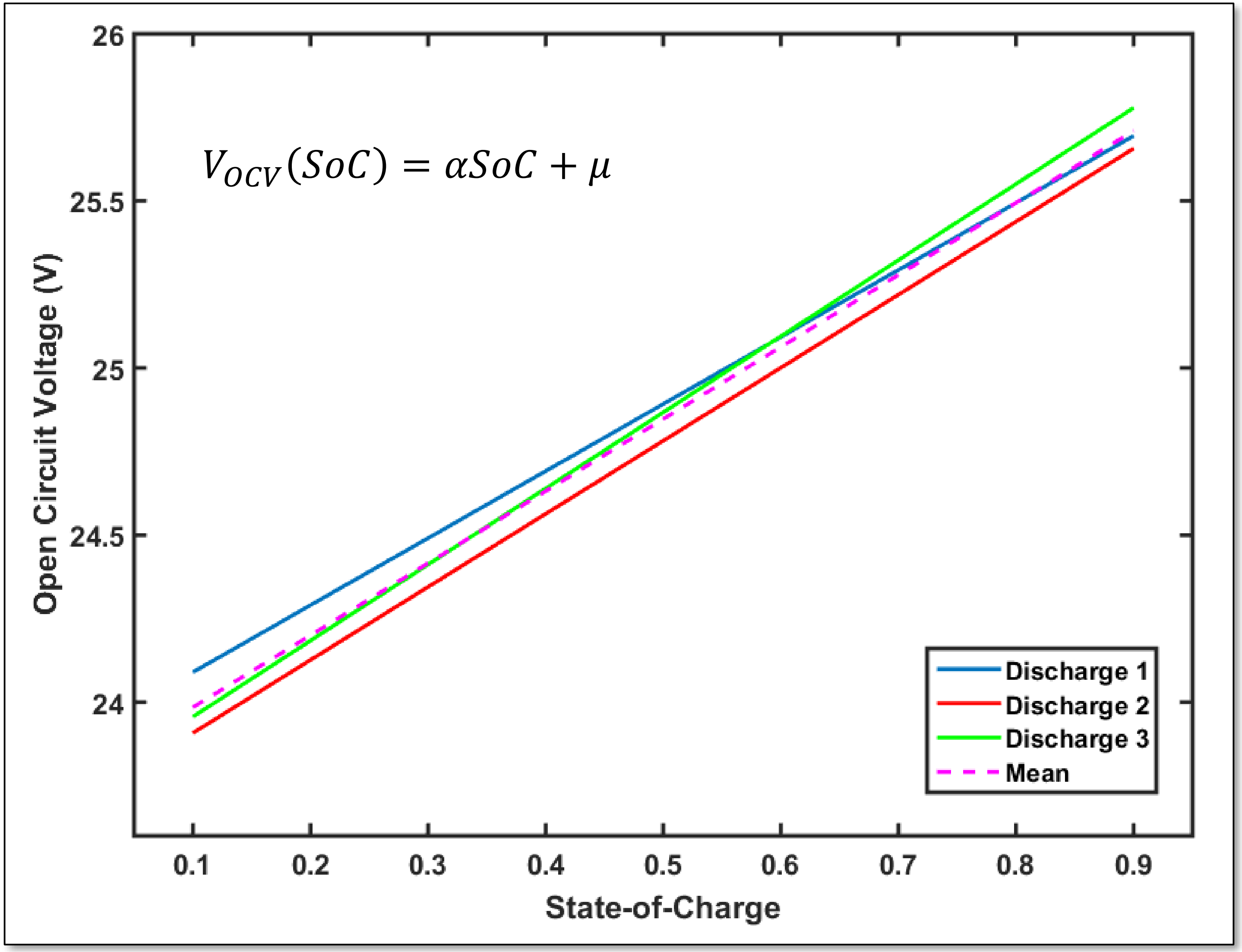
$$\dot{x} = \begin{pmatrix} -\frac{1}{\tau_{CT}} & 0 \\ 0 & 0 \end{pmatrix} x + \begin{pmatrix} \frac{1}{C_{ct}} & 0 \\ -\frac{1}{Q_0} & 0 \end{pmatrix} u(t)$$

$$y(t) = (-1 \quad \alpha) x + (-R_{int} \quad 1) u(t)$$

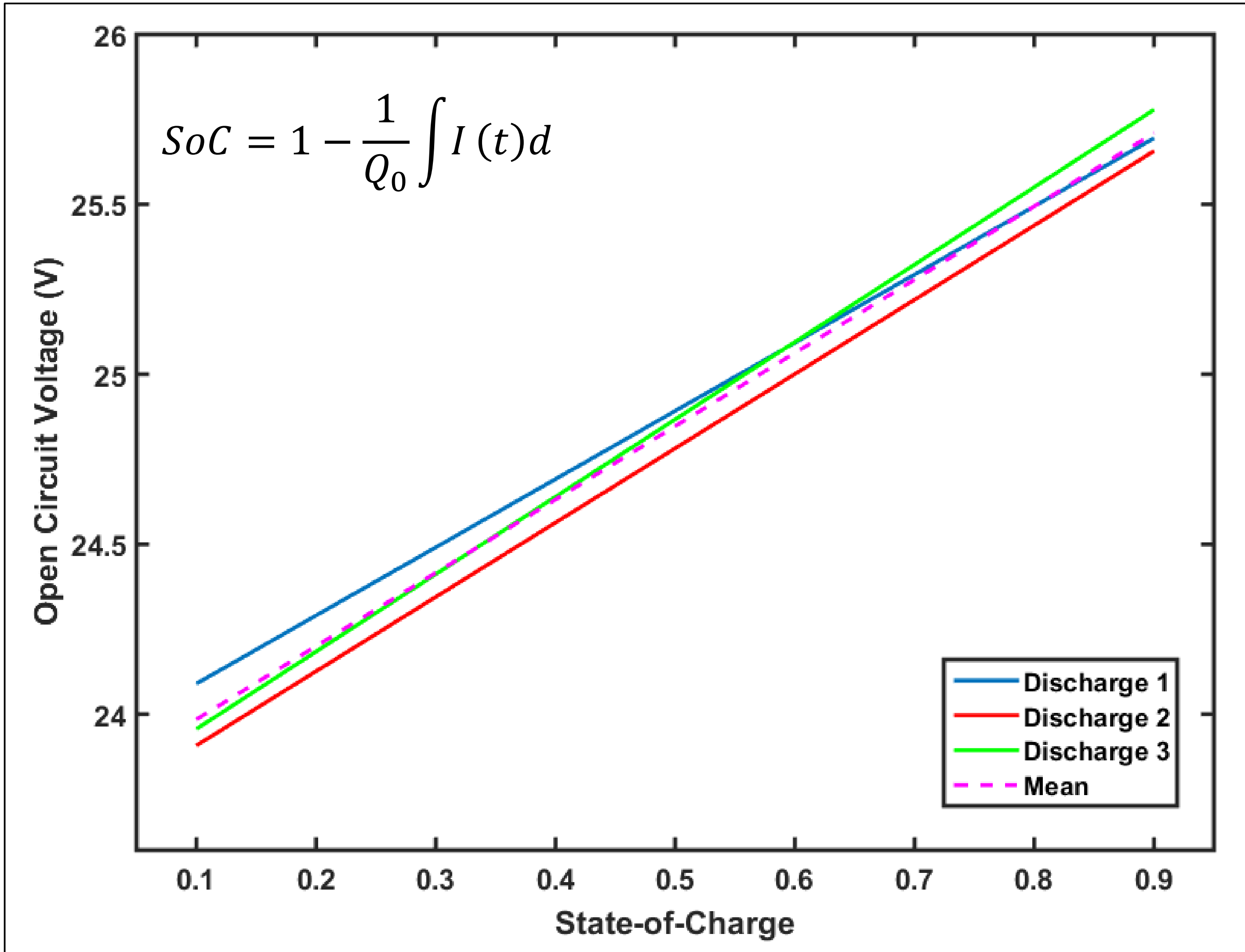
The model parameters α, μ, and Q_0 were found from the battery pack's Open Circuit Voltage vs. State of Charge curve.



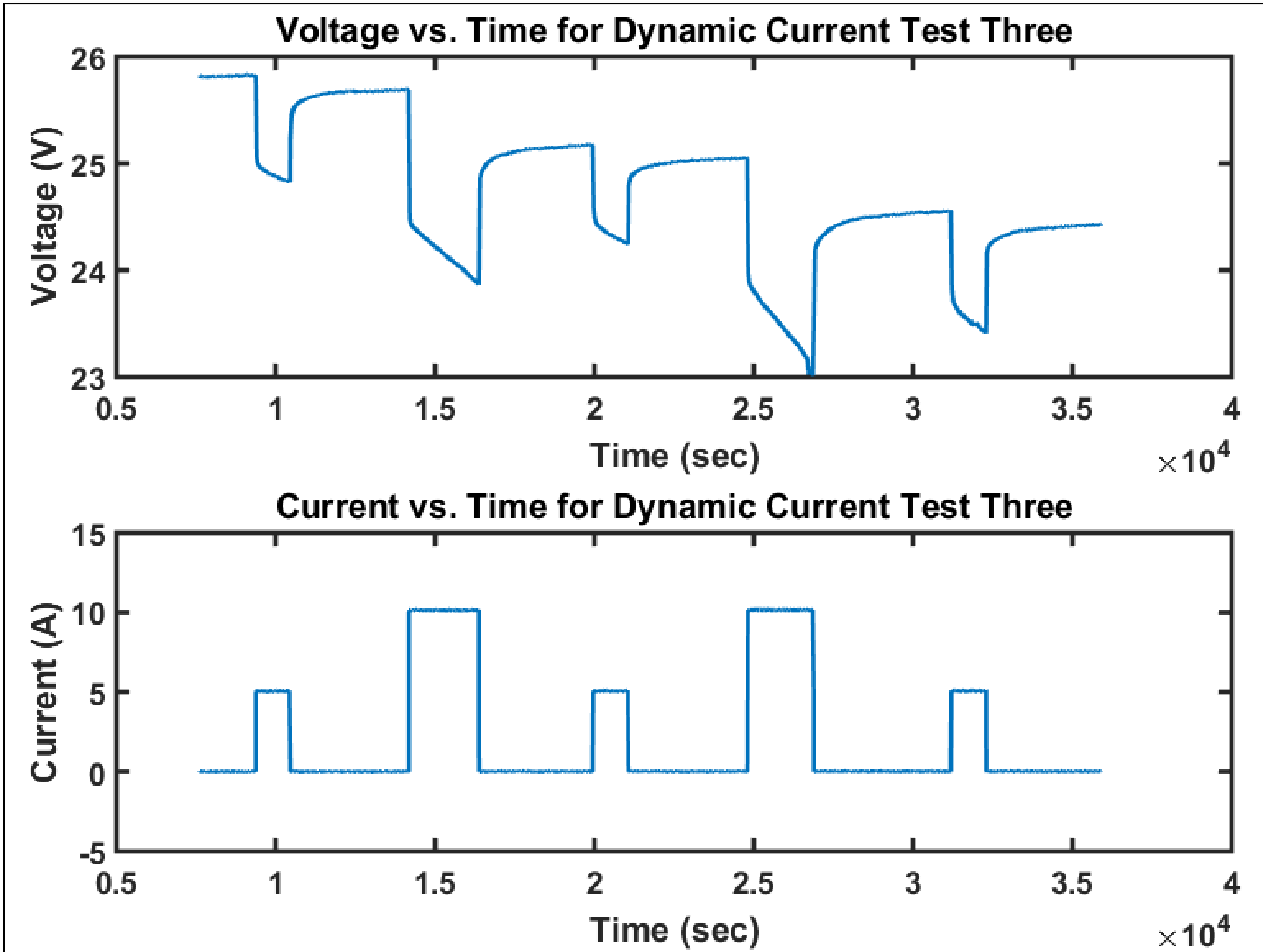
α and μ were found from a regression of the mean of the linear region of the discharge curve.



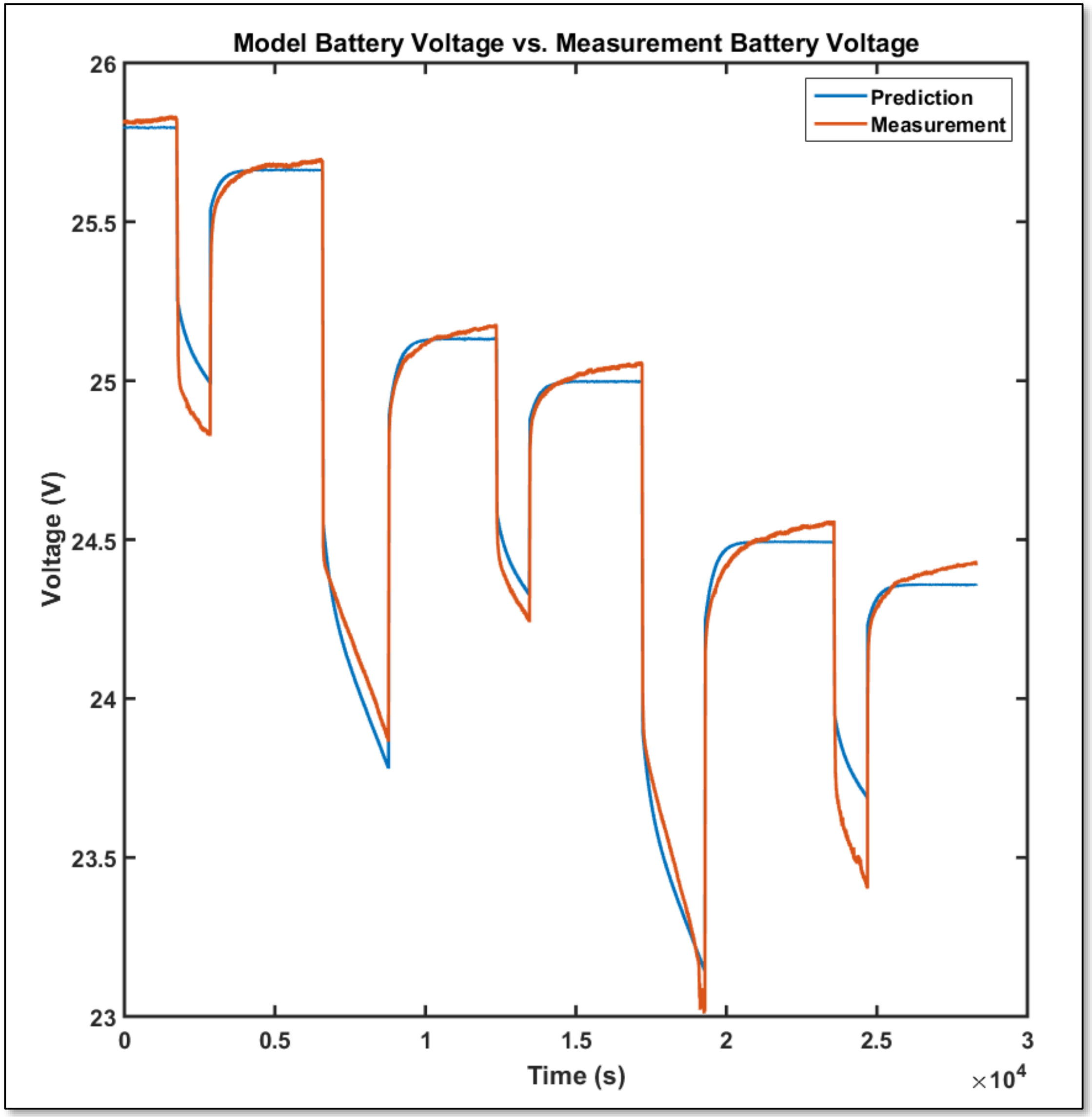
The battery's capacity, Q_0, was derived from the mean of the integral of the constant current used for each discharge test.



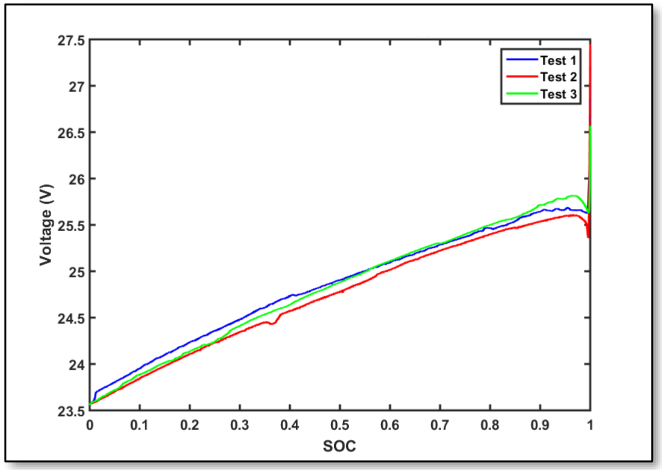
To identify the battery's dynamics, a pulse test was performed on the battery pack.

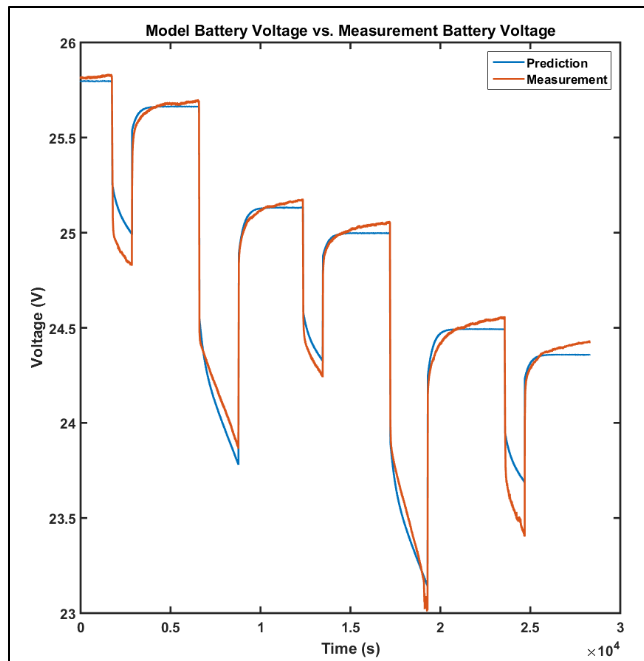


Using the battery's response to the pulse test and a least squares regression, the parameters τ_{CT}, R_{int}, C_{CT} were derived.



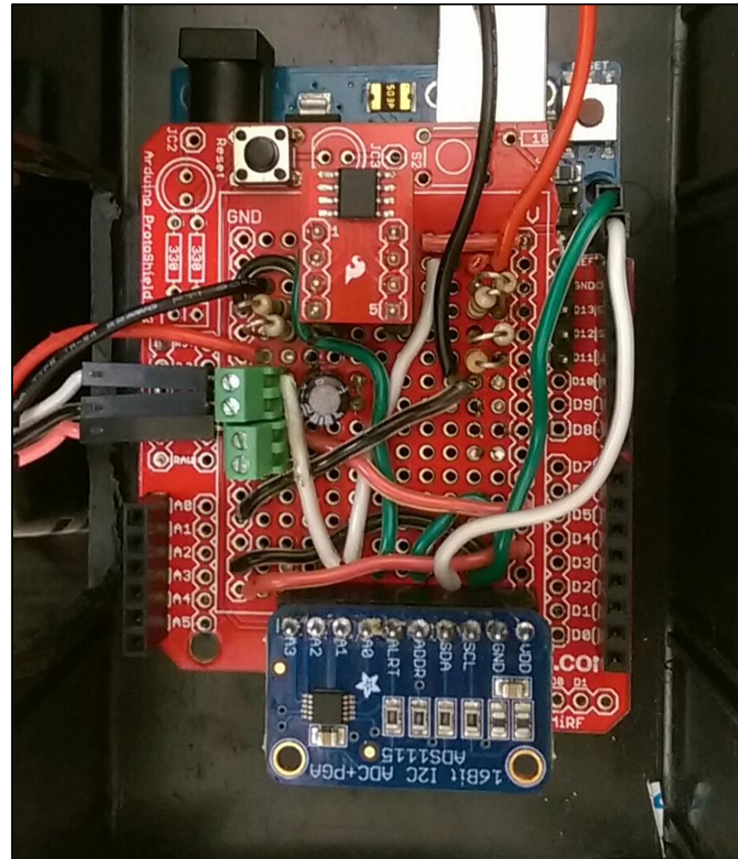
The process and sensor covariance matrices, were derived from the OCV-SOC error, the model-fit error, and the sensor noise characteristics.



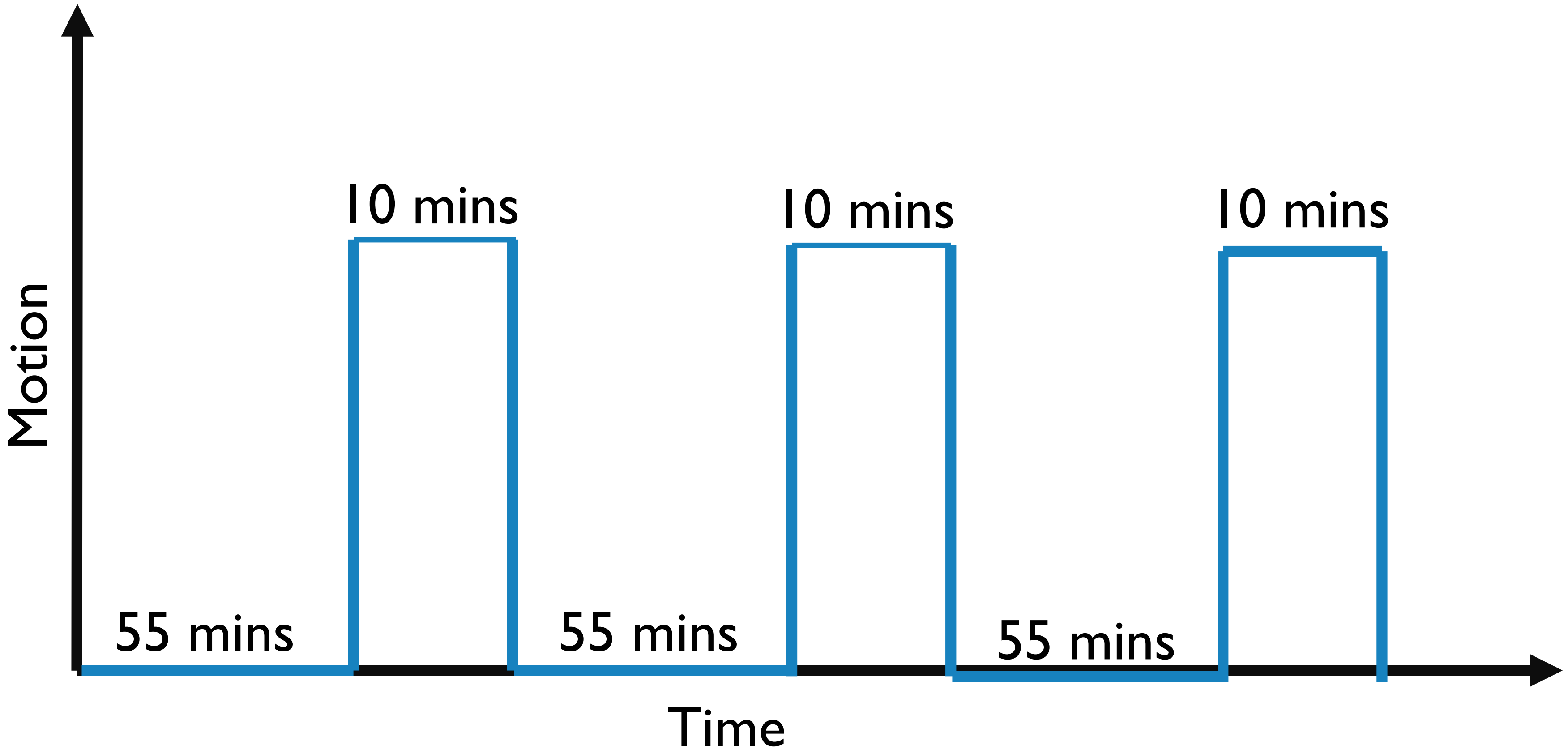


LEM.com

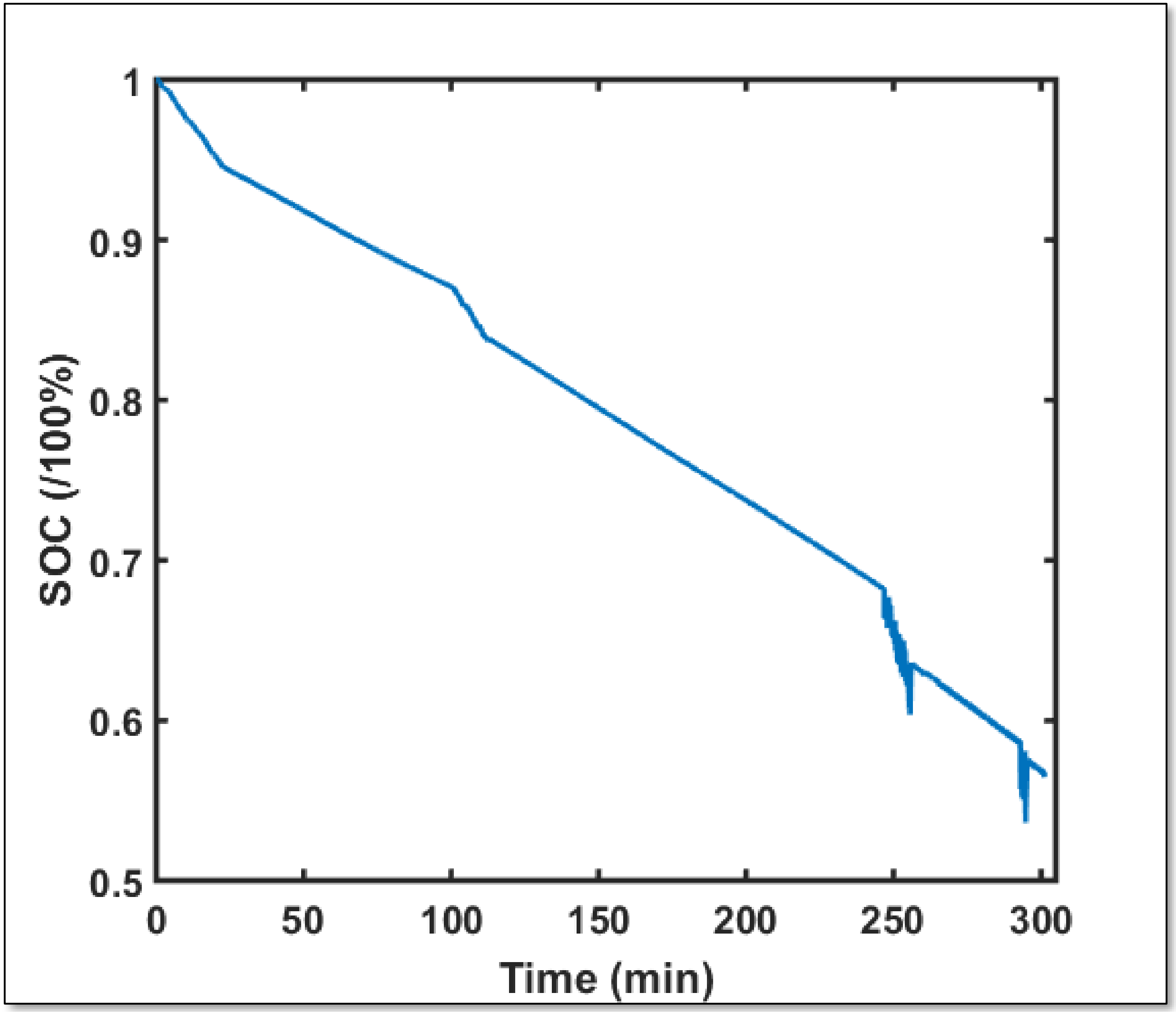
An intelligent, electric wheelchair retrofitted with power monitoring sensors was used to collect power data.



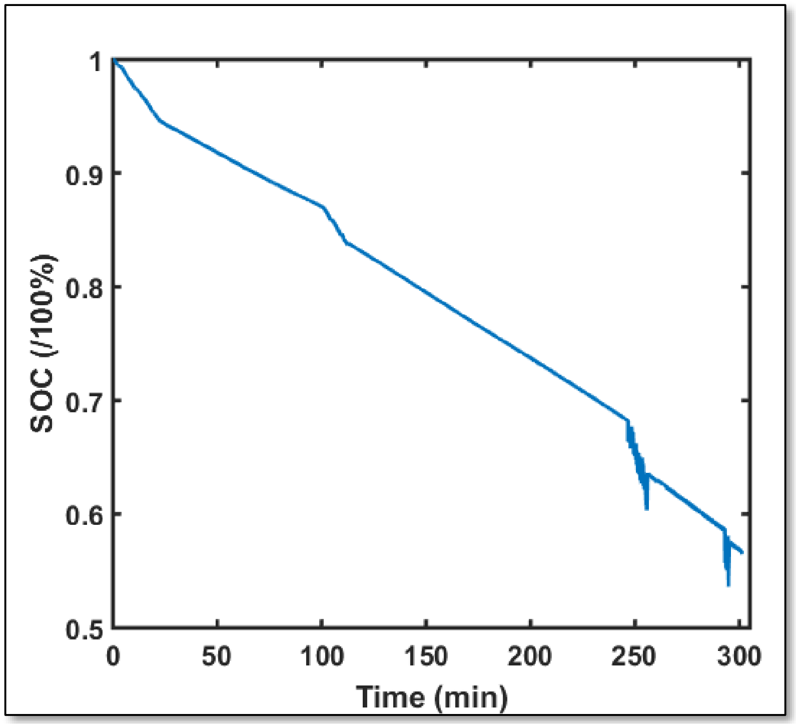
To test the model, the wheelchair was driven in a pattern similar to that of a typical college student attending classes.

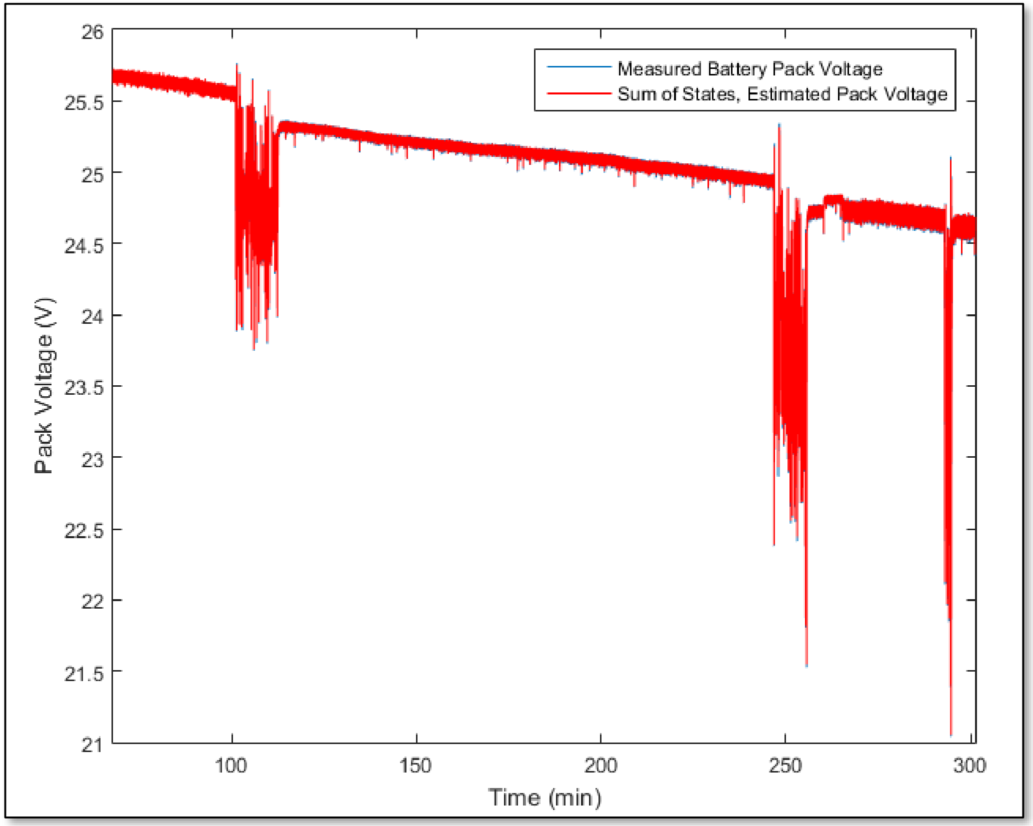


The SOC curve obtained during experimentation changes in slope where the wheelchair transitions from rest to motion.

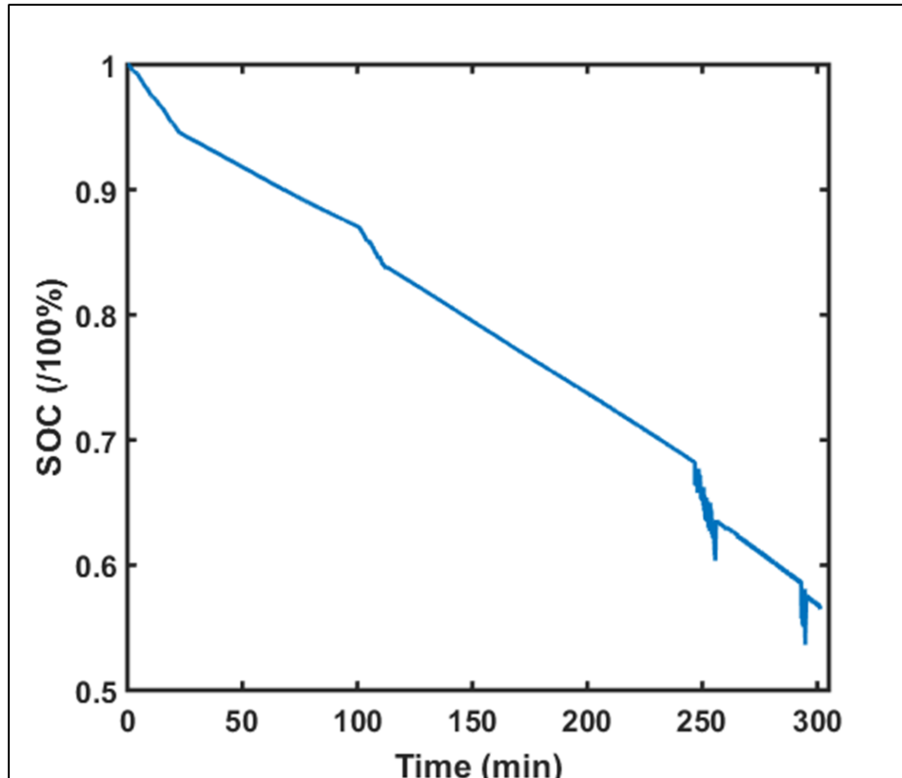


It’s observed that the estimator was able to track the measured voltage with an RMS error of 0.85%.



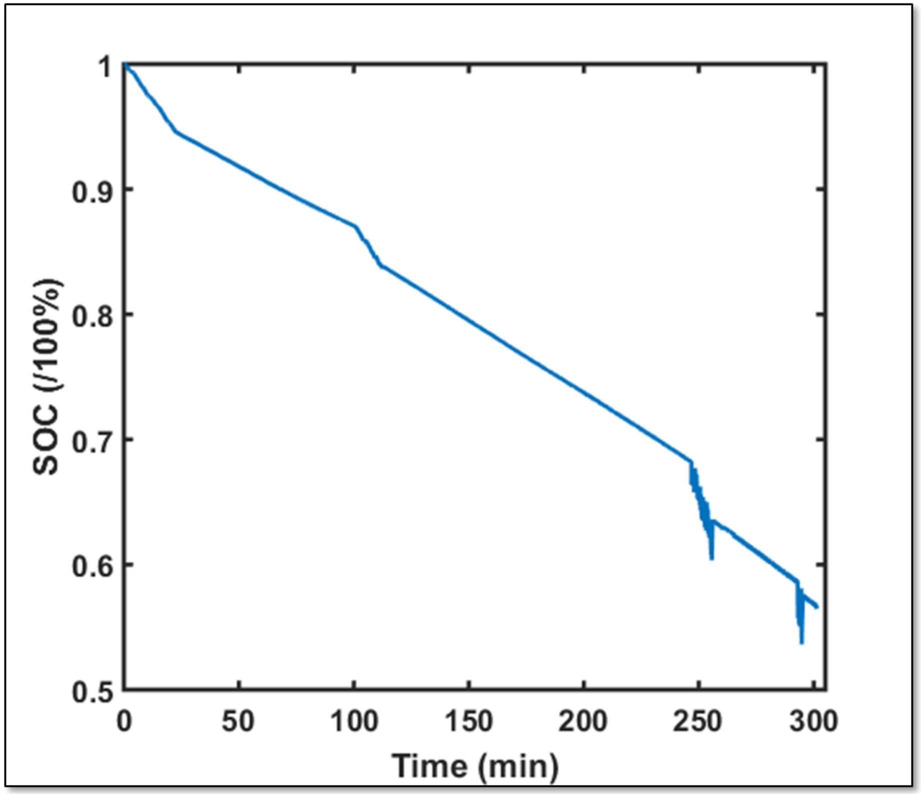


This work sought to improve the safety of electric wheelchairs through the design of improved battery pack state of charge estimation.



This work sought to improve the safety of electric wheelchairs through the design of improved battery pack state of charge estimation.

Thank you!



PennState College of Engineering