VANDERBILT UNIVERSITY

System Level Prognostics Framework for a UAV Powertrain System

Timothy Darrah

Supported in part by

Institute for Software Integrated Systems

Overview

Background
Powertrain System
The Battery
The Motors
Prognostics Architecture
Results
Future Work

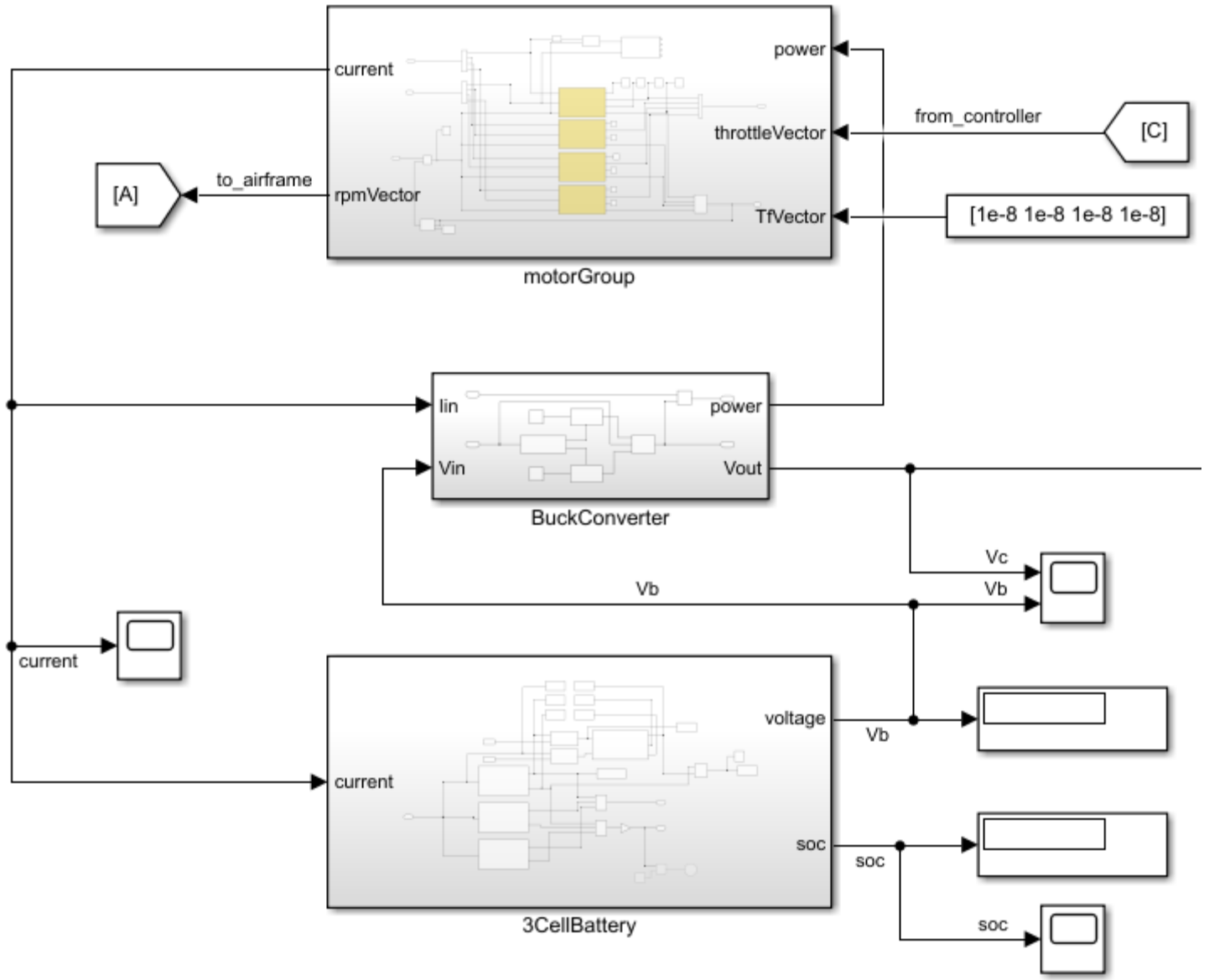
Oaxaca, MX Helicopter Crash Feb 17, 2018, 13 dead, 13 injured
https://mexiconewsdaily.com/news/oaxaca-chopper-crash-kills-14-injures-13/

Powertrain System

Consists of the motor group, a buck converter, and a 3-cell battery

Buck converter provides constant voltage output

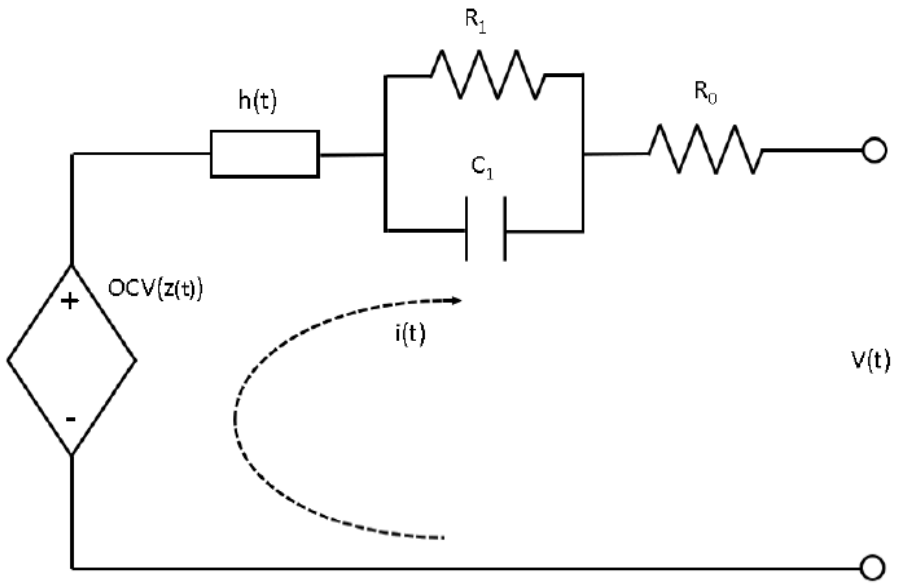
Motors and battery are monitored with UKFs



The Battery

Parameter	Value
Q	$3800mAh$
η	.9929
γ	.1199
M_0	$1e^{-4}$
M	$1e^{-6}$
R_0*	.0112Ω
R_1	.1Ω
C_1	250μ F
V_0	$4.2v$

* *Degradation parameter*



$$z[k+1] = z[k] - \frac{\eta[k]\Delta t}{Q} i[k]$$

$$i_R[k+1] = I_{mat} i_R[k] + (1 - I_{mat}) i[k]$$

$$h[k+1] = H_{mat} h[k] + (H_{mat} - 1) sign(i[k])$$

$$v[k] = ocv(z[k]) + M_0 sign(i[k]) + Mh[k] - \sum (Ri_R[k]) - R_0 i[k]$$

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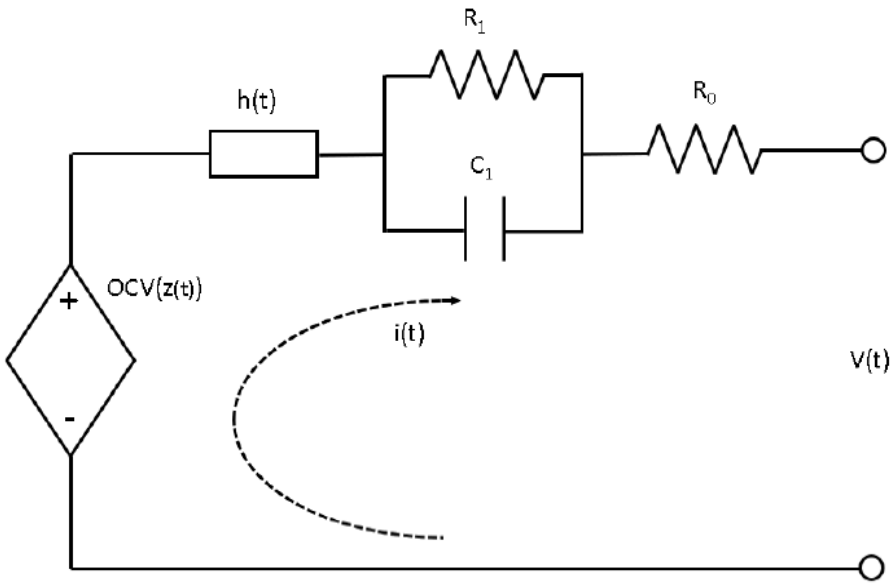

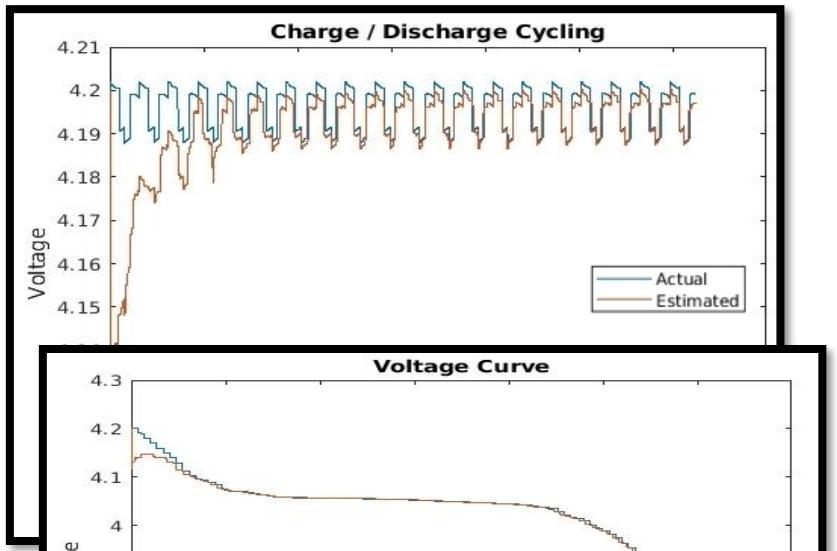

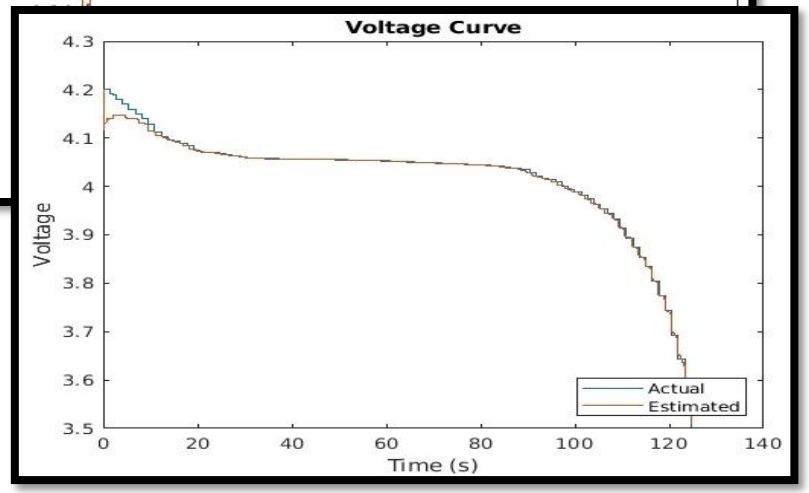

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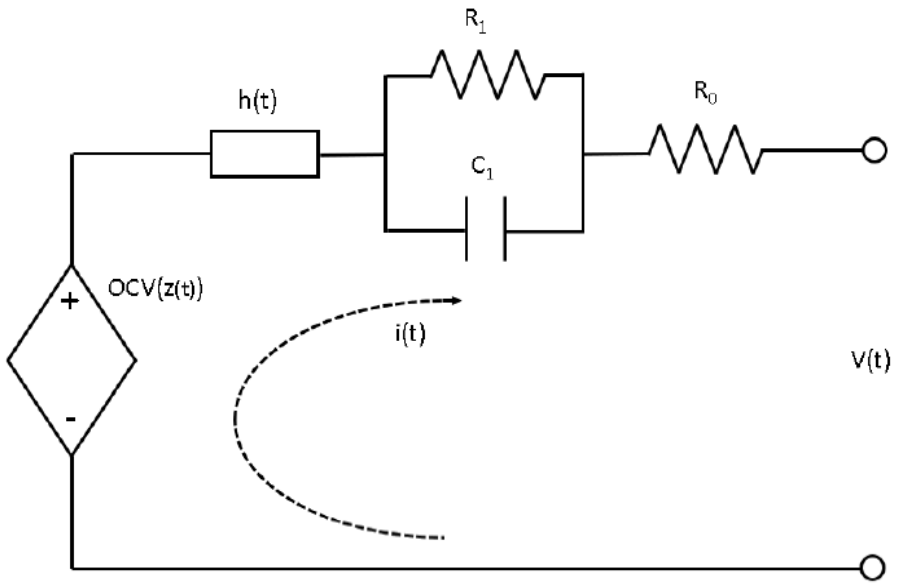

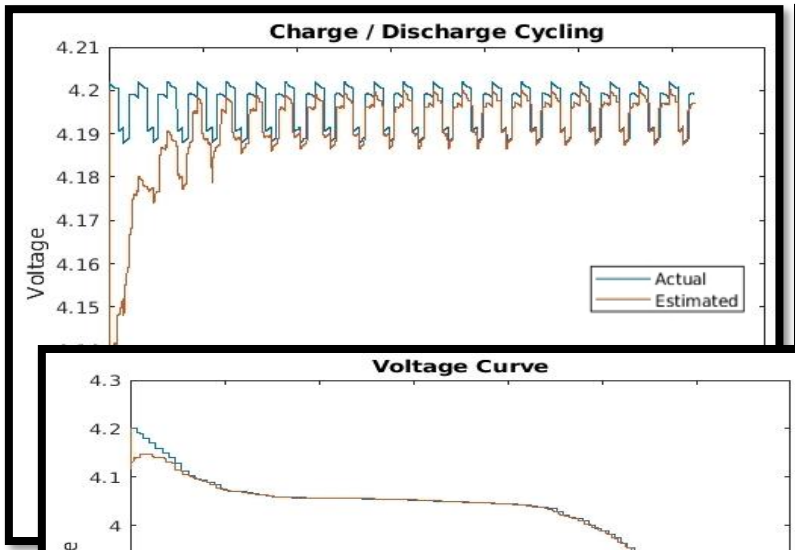

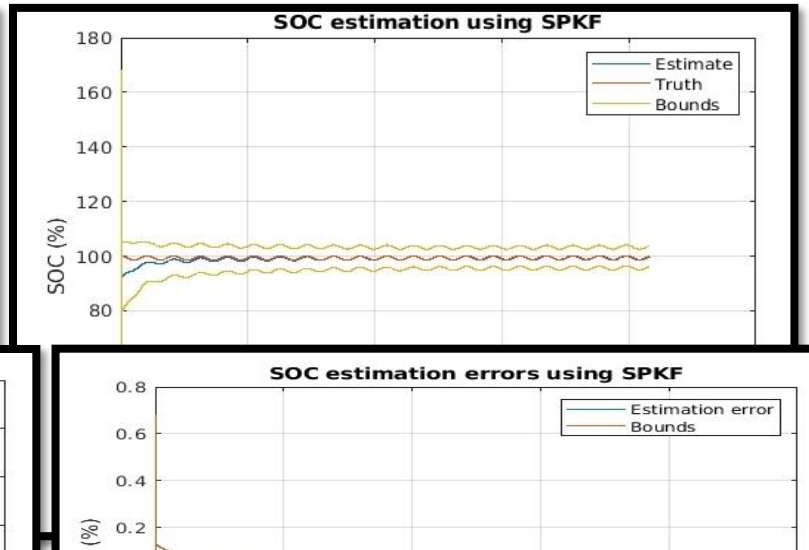

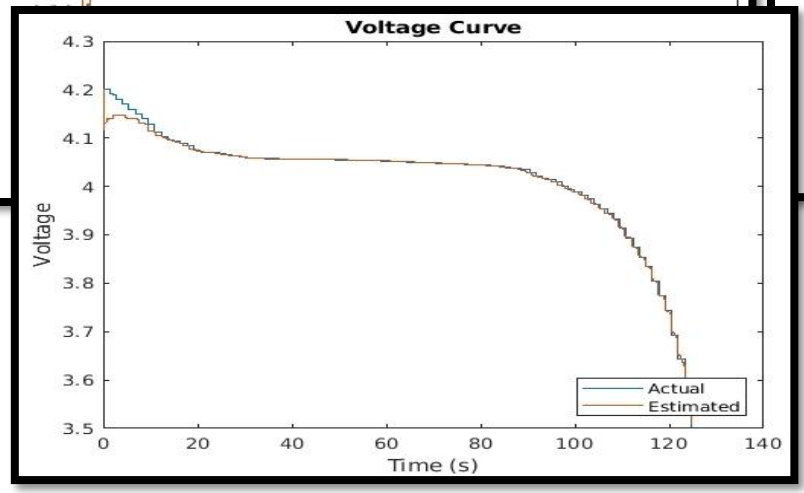

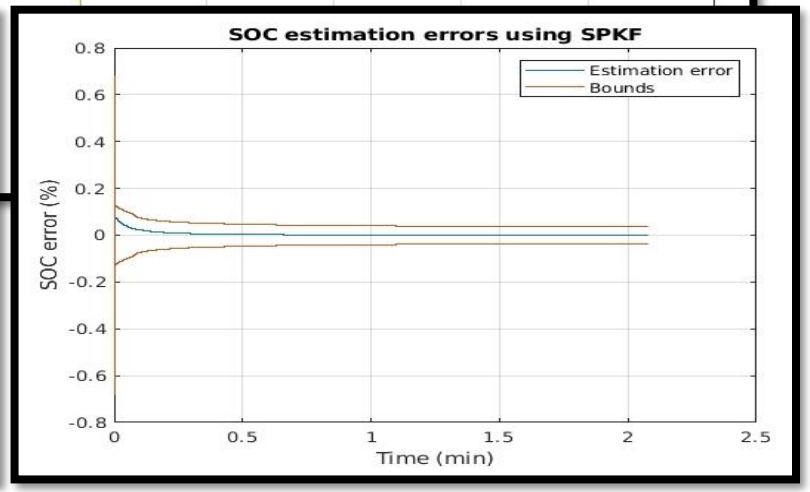

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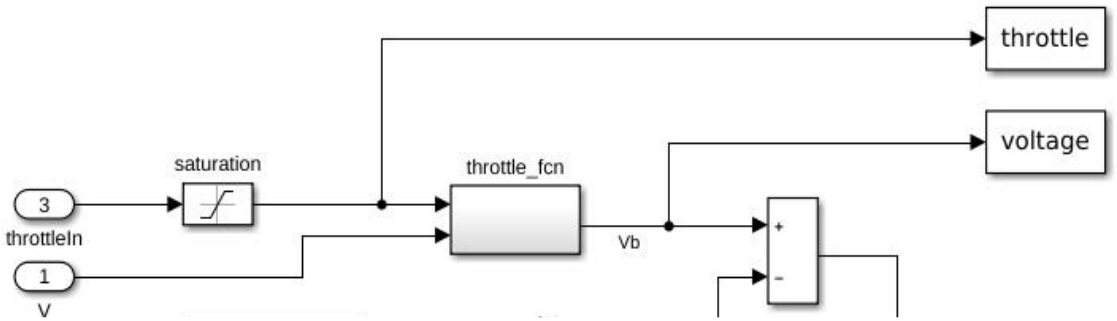
The Motors



$$\begin{aligned} \bar{v}_{batt_i} &= R\bar{i}_{batt_i} + K_E\omega_i, \\ \dot{\omega}_i &= \frac{1}{J_m}(K_E\bar{i}_{batt_i} - d\omega^2 - D_f\omega_i - T_{fric}) \end{aligned}$$

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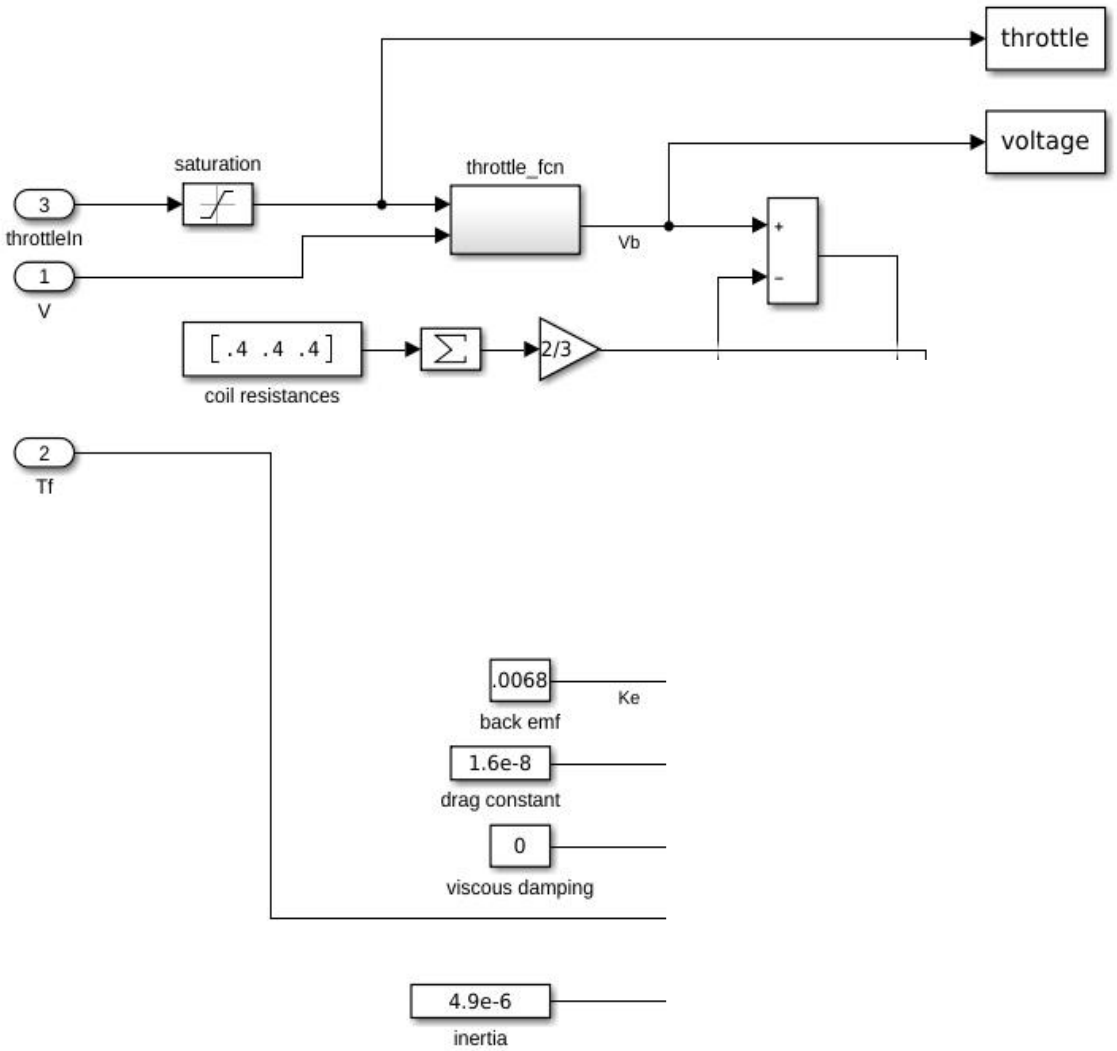

Parameter	Desc	Value
R	coil resistance	$.8\Omega$
Ke	back EMF	.0068
$Tf*$	friction torque	$1e^{-8}$
Df	viscous dampening	$1e^{-9}$
d	drag constant	$1.6e^{-8}$
j	inertia	$4.9e^{-6}$

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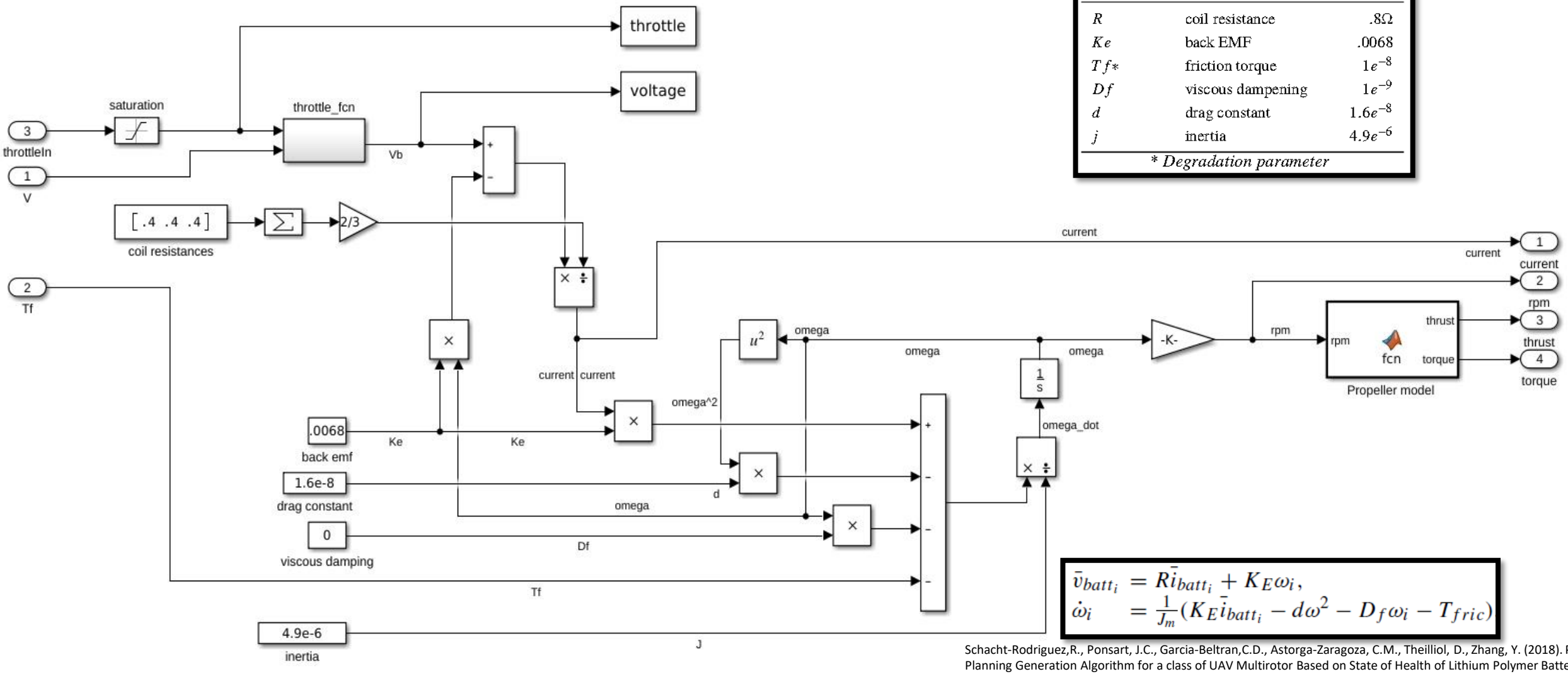

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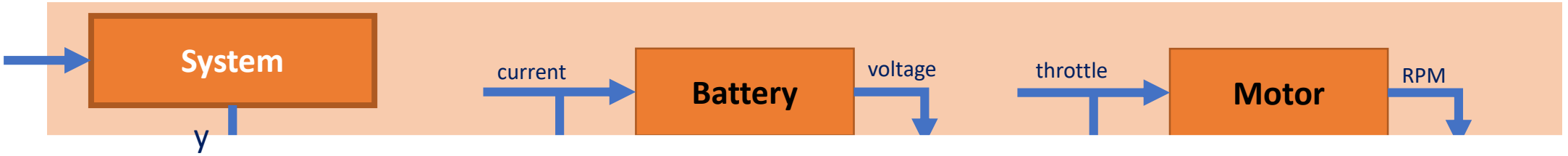
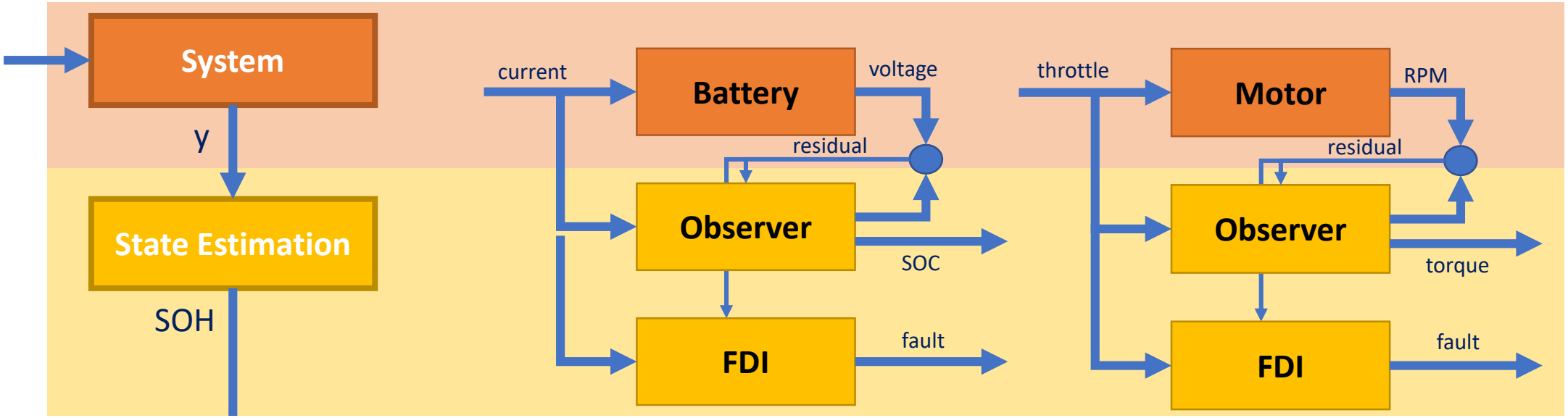
Schacht-Rodriguez,R., Ponsart, J.C., Garcia-Beltran,C.D., Astorga-Zaragoza, C.M., Theilliol, D., Zhang, Y. (2018). Path Planning Generation Algorithm for a class of UAV Multirotor Based on State of Health of Lithium Polymer Battery. Journal of Intelligent & Robotic Systems.

Prognostics Architecture



Prognostics Architecture



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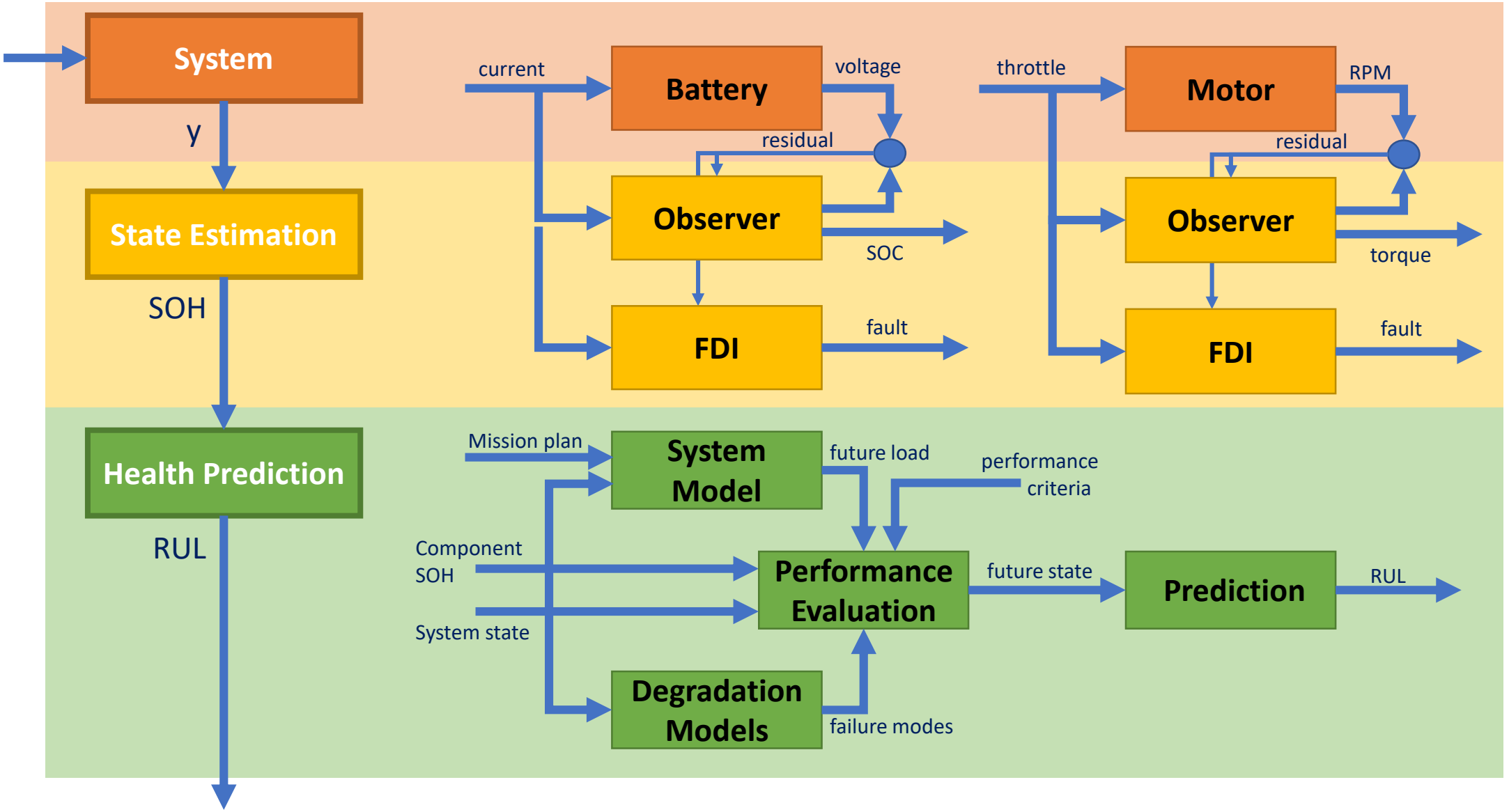
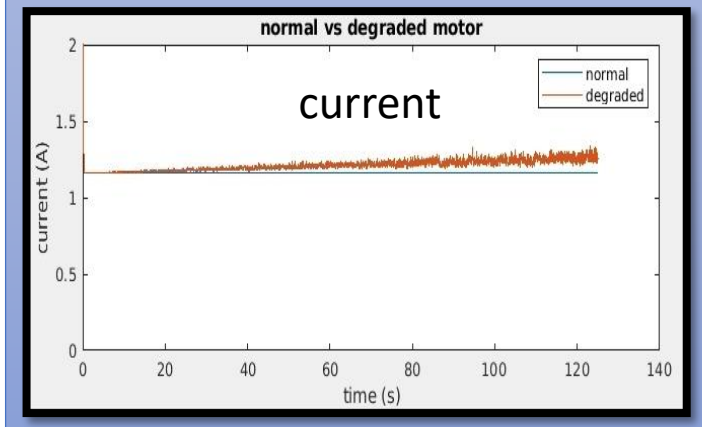
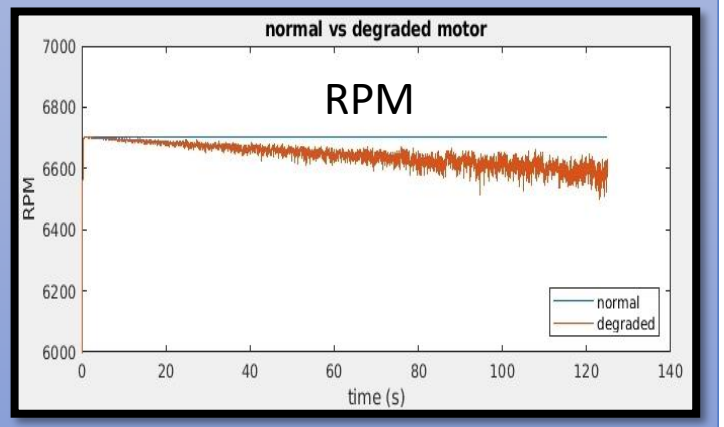


Results

Motor Degradation





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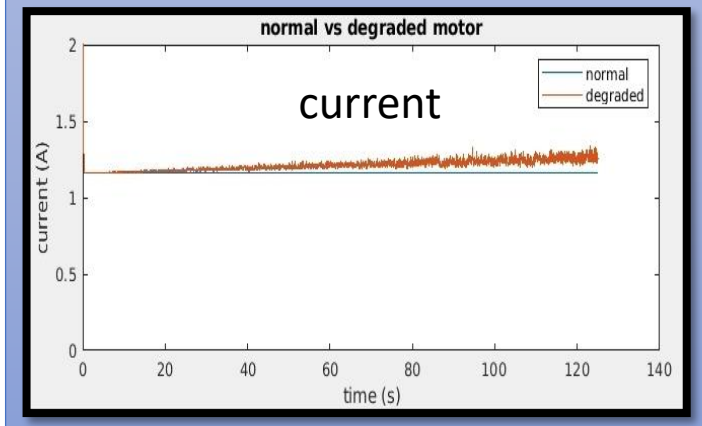
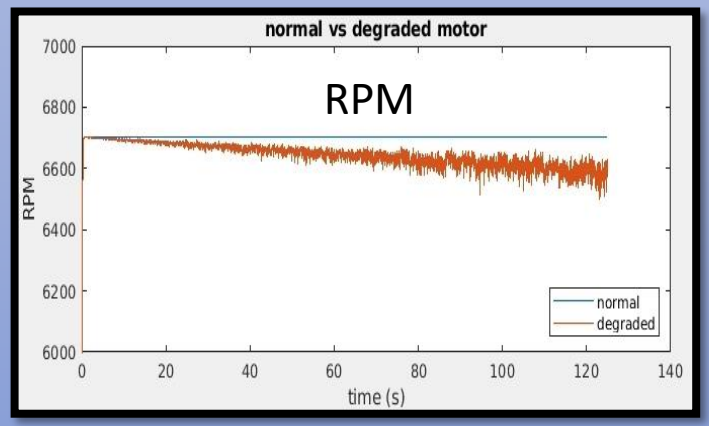
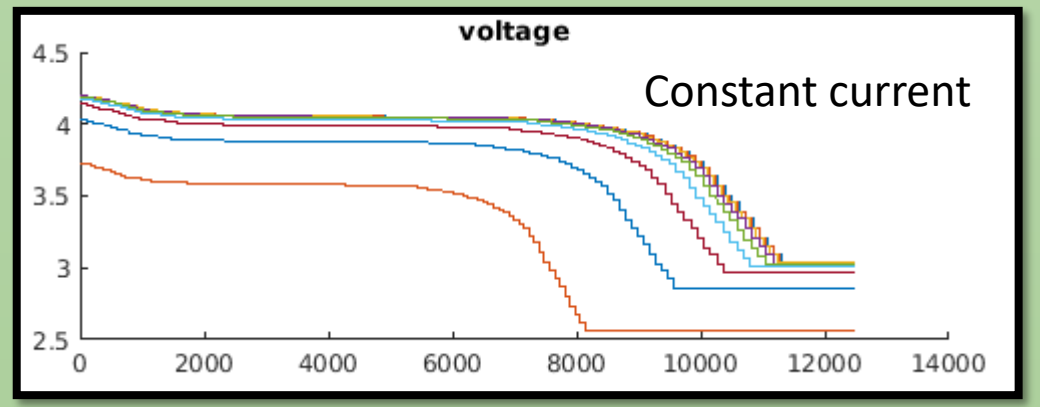
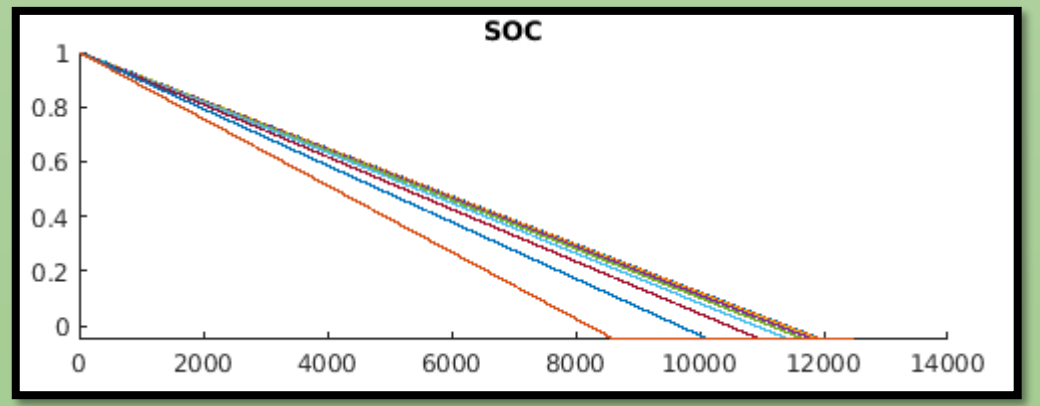
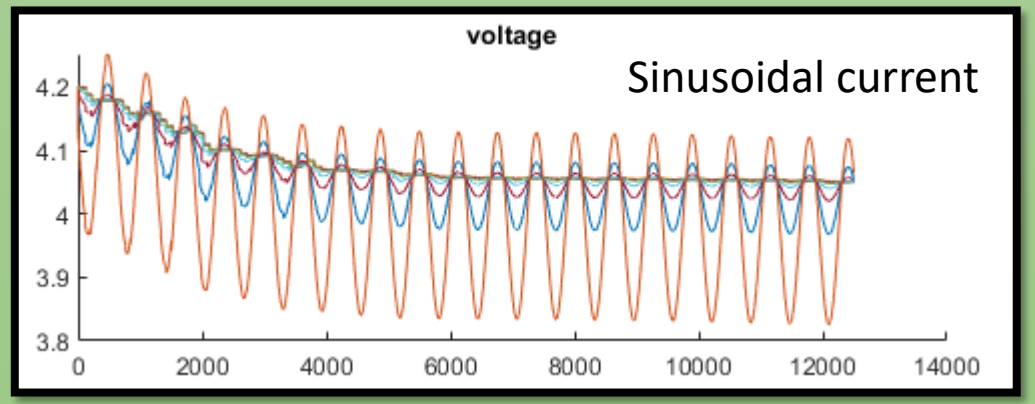




Battery Degradation







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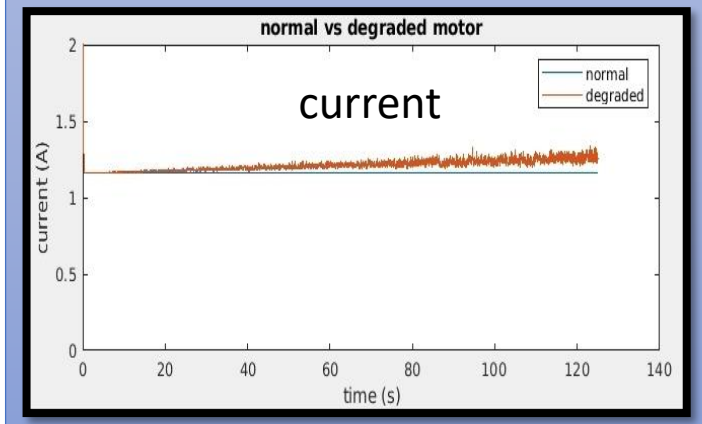
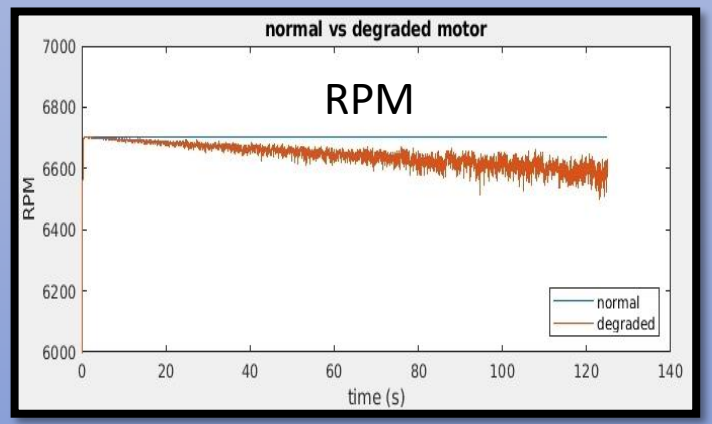
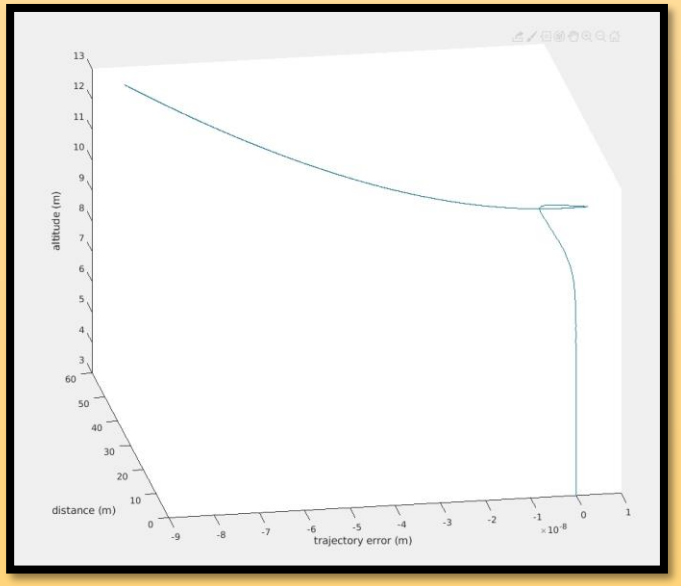
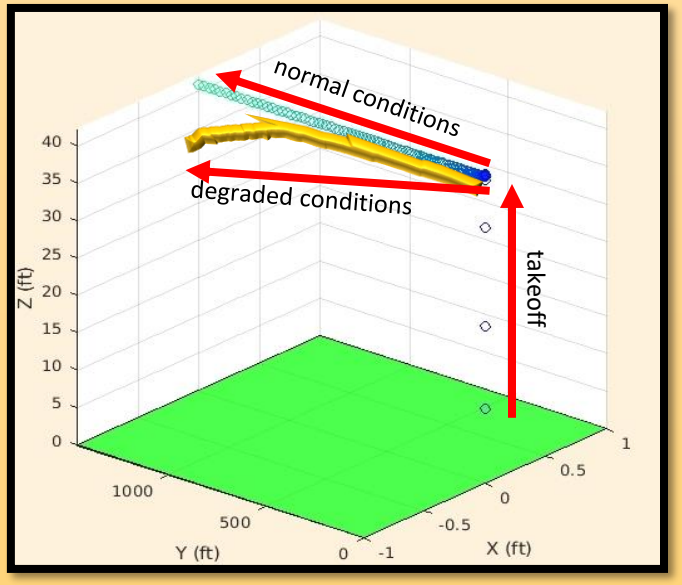




System Degradation





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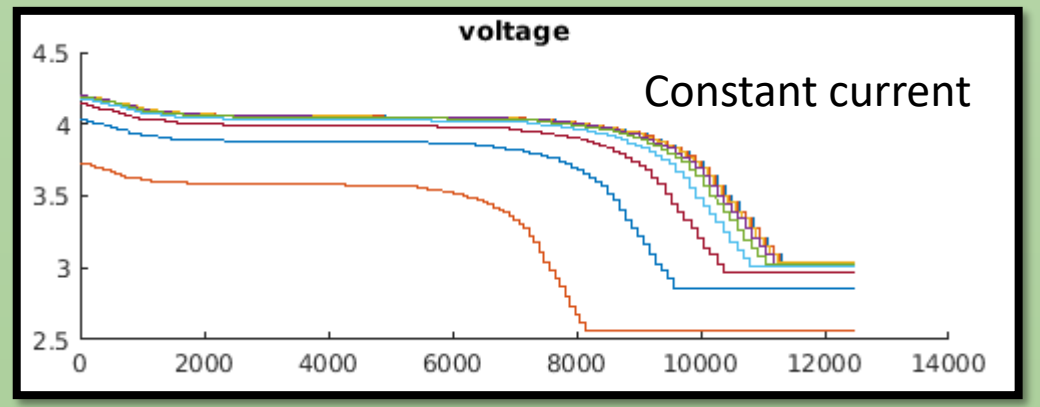

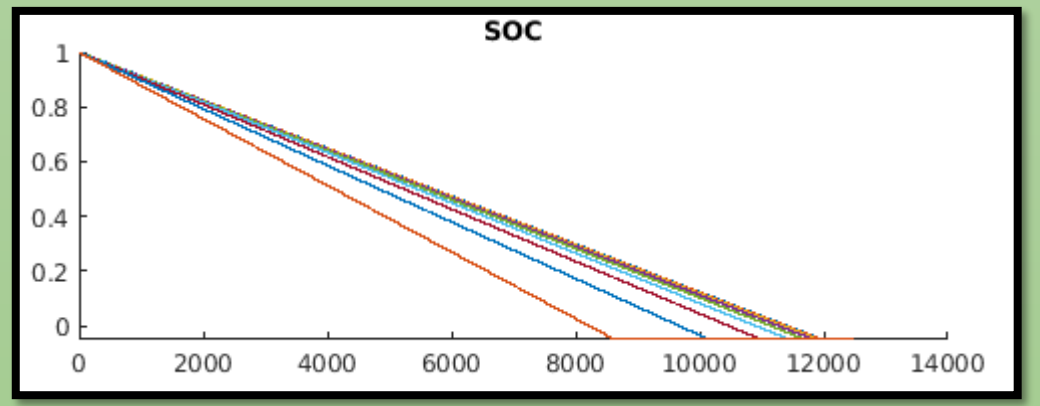

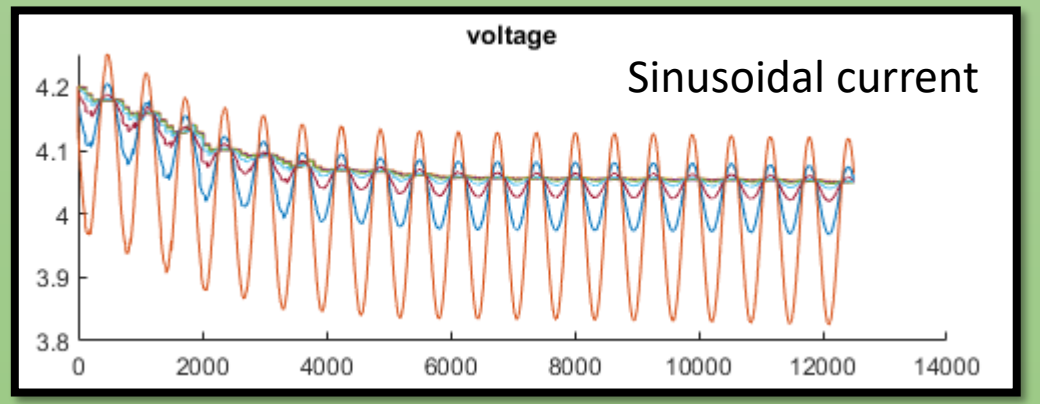

Future Work

The actual prognostics framework!

- Particle Filter
- Monte Carlo simulations
- RUL predictions

Prognostics based decision making

- Knowledge representation (Tree/Graph)
- Solution searching (CSP)
- Communication (NLP)

Thank You!