Proton Exchange Membrane Fuel Cell/Ultracapacitor Powered Computer

ProCell Engineering

Presented by:

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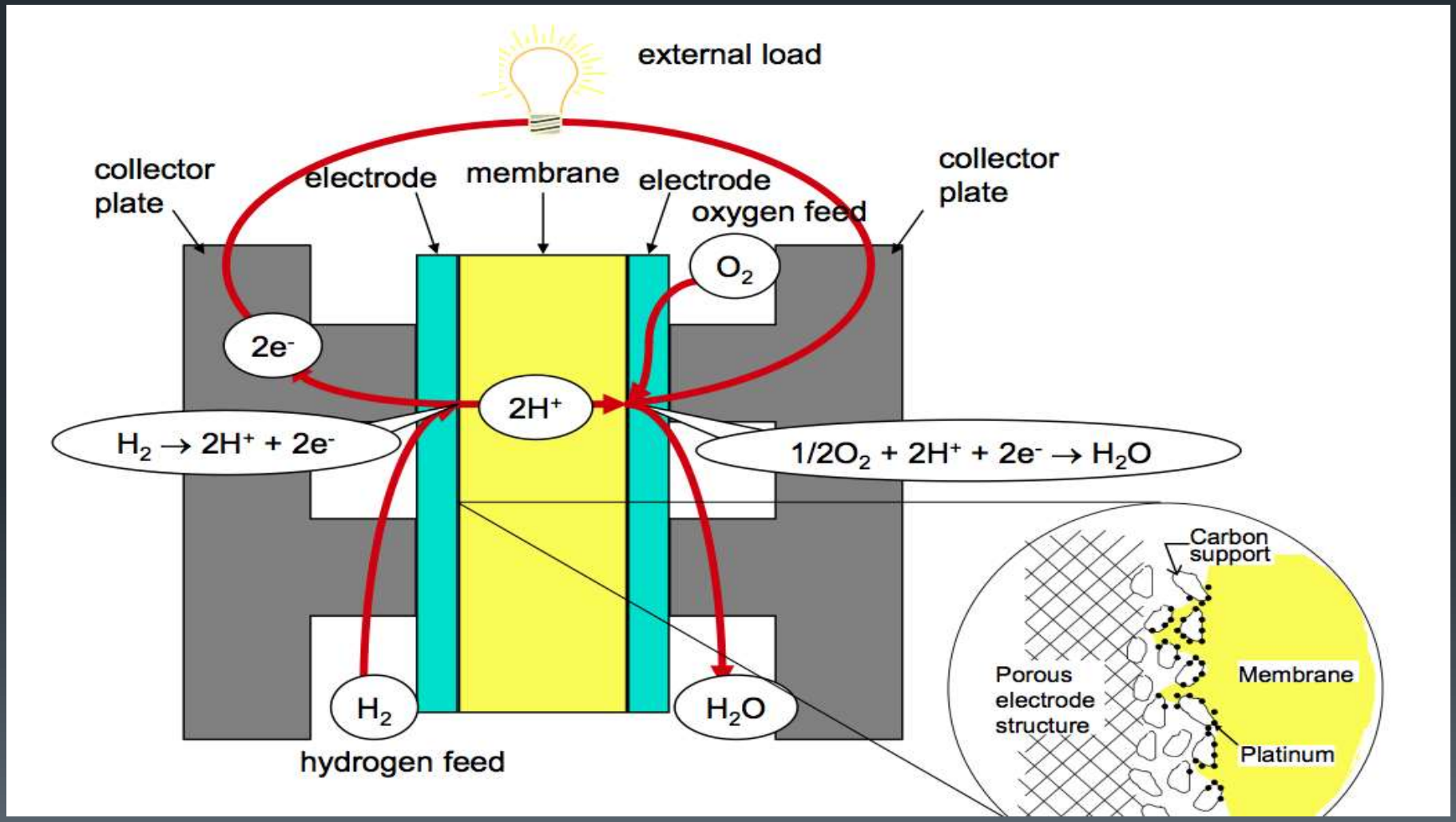
Introduction

- Microsoft™ data center
  - Methane
- Challenges
  - Rapid changes in power demand
  - Fuel cell slow to respond to load changes
- Ultracapacitors (UC) used to provide supplemental power

Project Scope

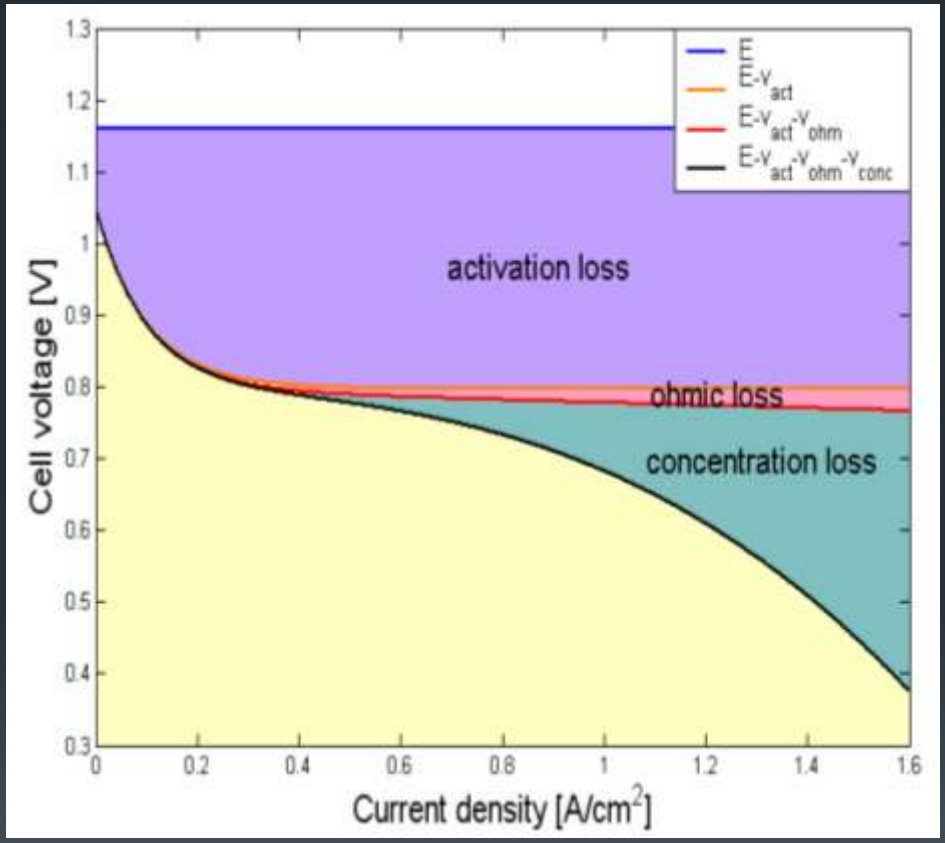
- Design and construct scaled model of Microsoft™ data center
  - 300 kW capacity
- Design scaled to 75 W
  - Laptop for varying load
- Demonstrate model with peak load

Fuel Cell


external load
collector plate
electrode
membrane
electrode
oxygen feed
collector plate
O_2
$2e^-$
$2H^+$
$H_2 \rightarrow 2H^+ + 2e^-$
$1/2O_2 + 2H^+ + 2e^- \rightarrow H_2O$
H_2
H_2O
hydrogen feed
Carbon support
Porous electrode structure
Membrane
Platinum

Fuel Cell Losses

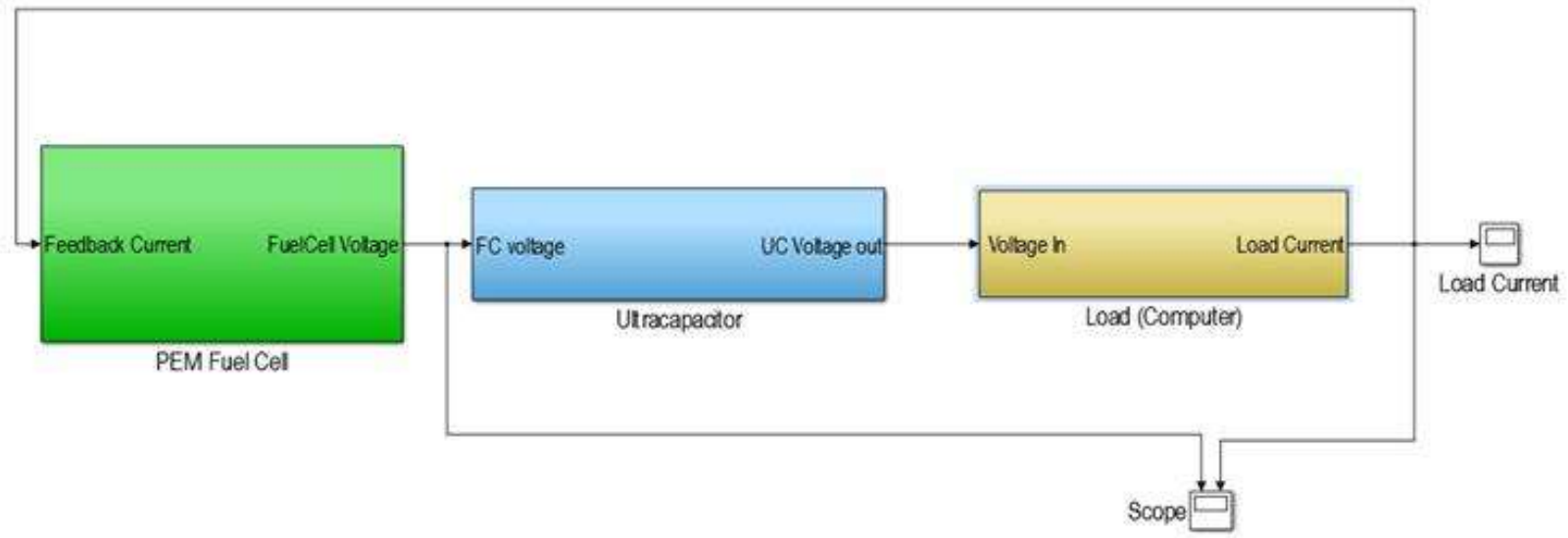
- Activation loss
  - Electrochemical over-potential during initial chemical reactions
- Ohmic loss
  - The resistance of fuel cell components
- Concentration Loss
  - Inconsistent flow of fuel and oxidizer



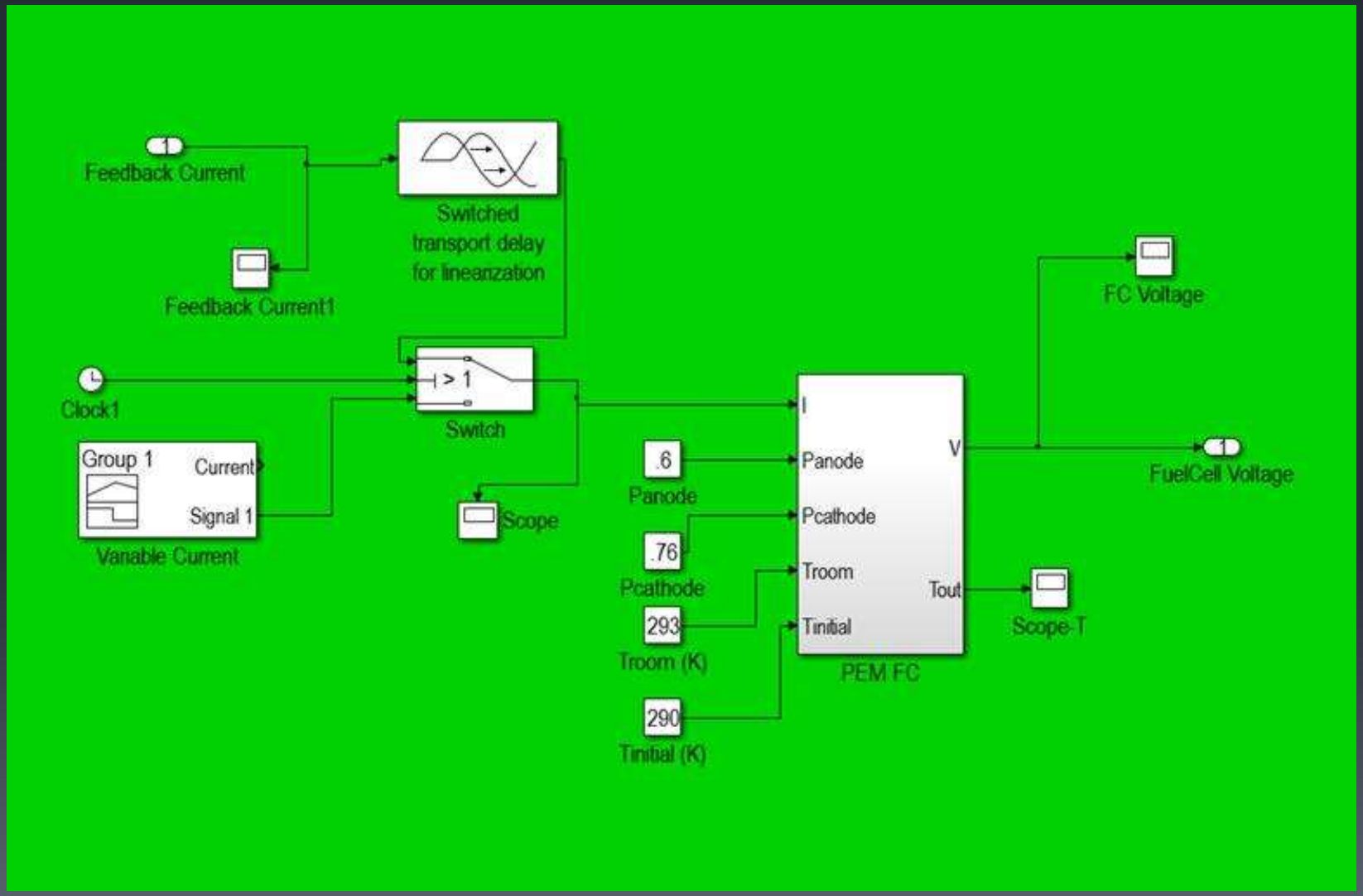
Model Governing Equations

- $V_{stack} = E - B\ln(CI_{fc}) - R^{int}I_{fc}$
- $R^{int} = A_R + R_0 e^{-I_{fc}/C_R} - B_R \ln(I_{fc})$
- $E = N_0\left[E_0 + \frac{RT}{2F}\log\left(\frac{p_{H_2}\sqrt{p_{O_2}}}{p_{H_2O}}\right)\right]$

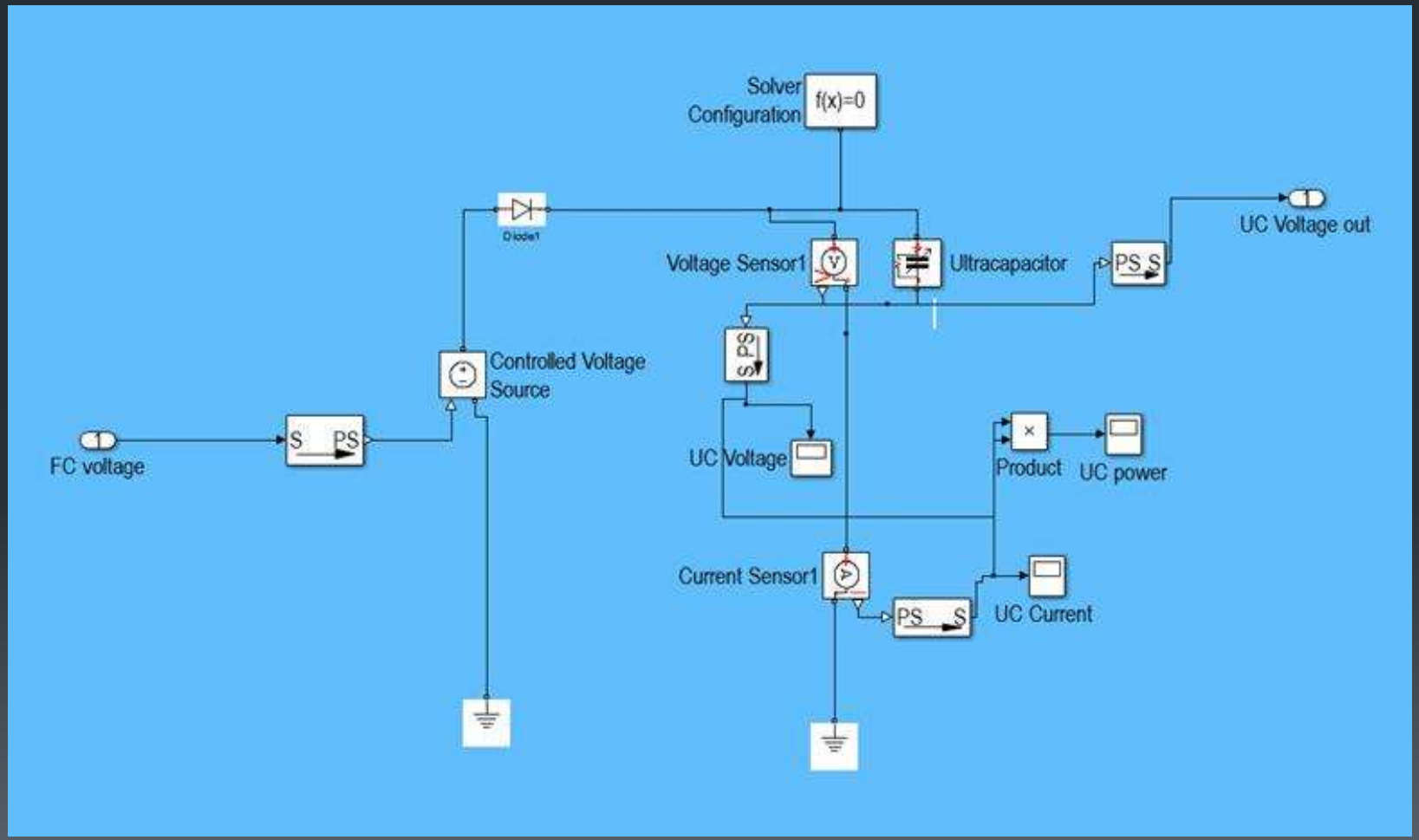
Model


Feedback Current
FuelCell Voltage
PEM Fuel Cell
FC voltage
UC Voltage out
Ultracapacitor
Voltage In
Load Current
Load (Computer)
Load Current
Scope

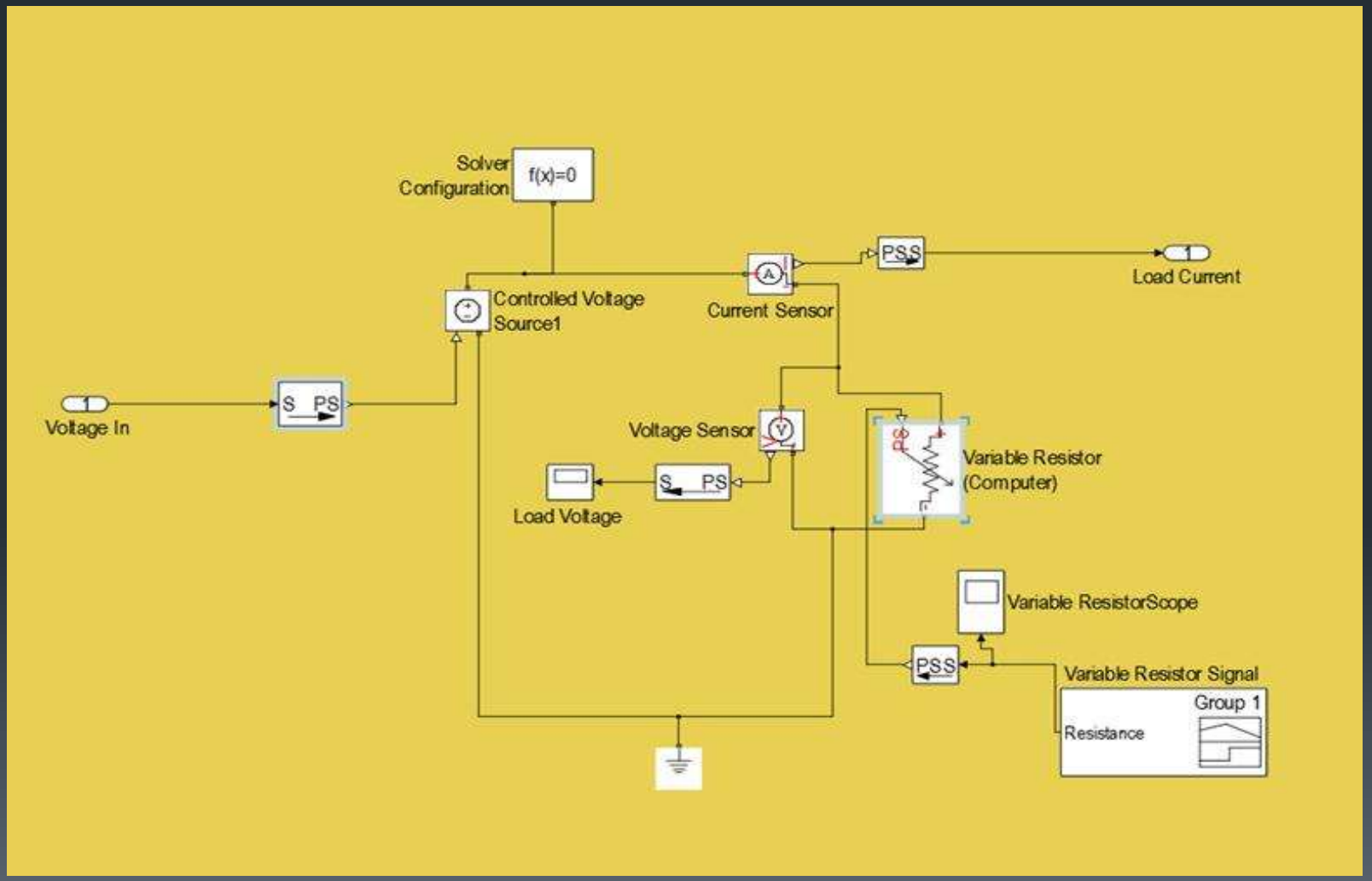
Fuel Cell Model



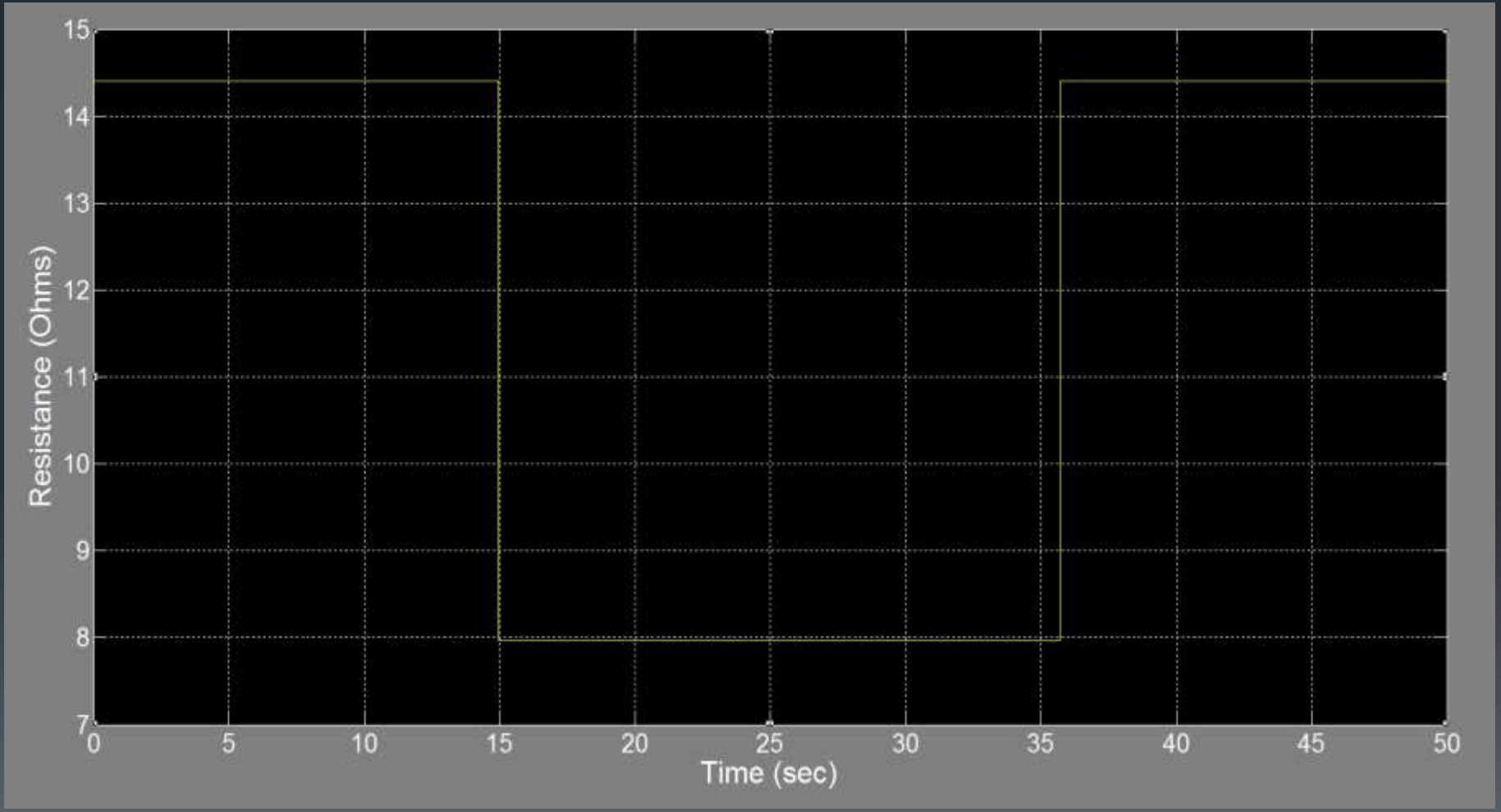
Ultracapacitor Model



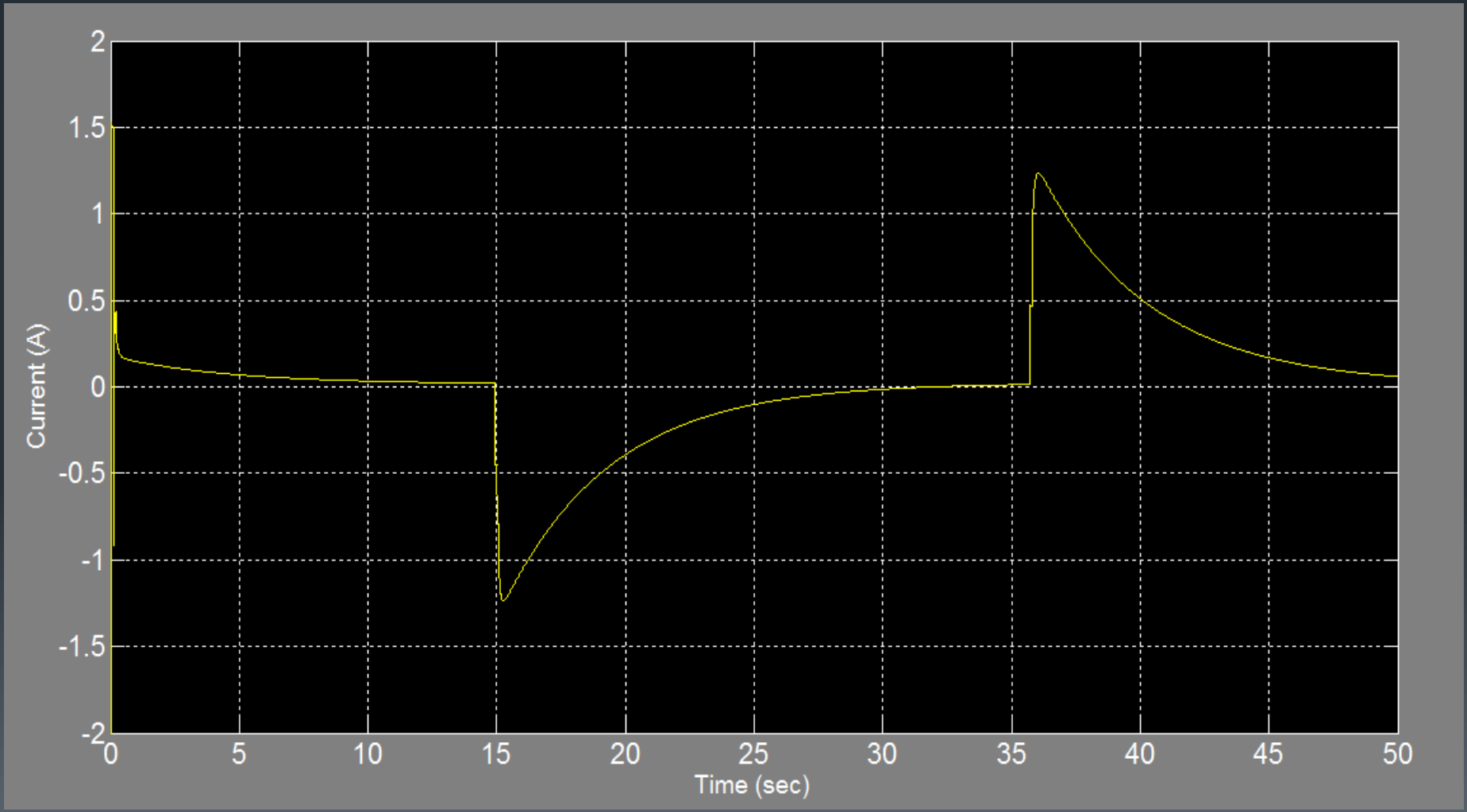
Computer Load Model



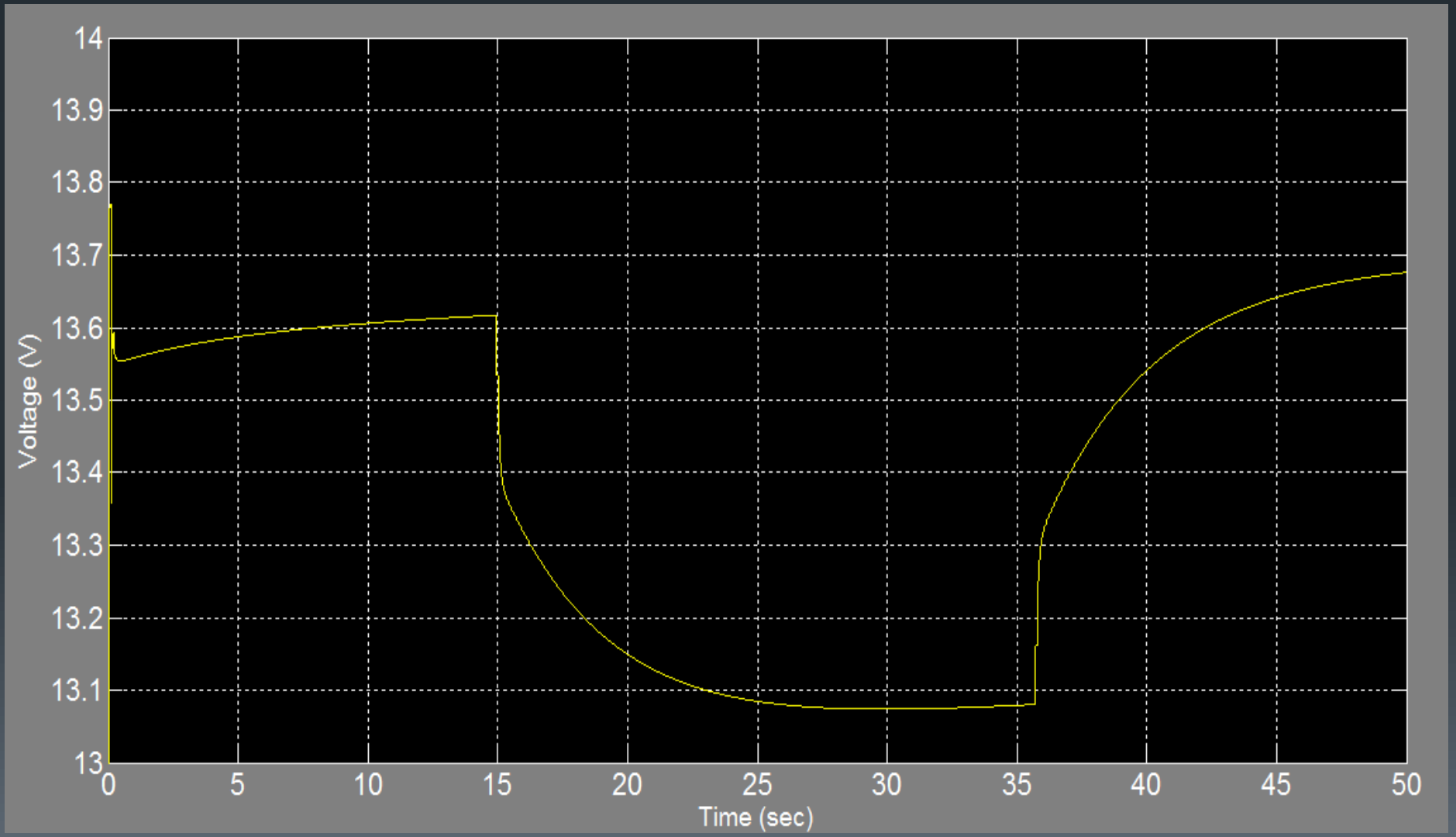
Model Variable Resistor



Model UC Current



Model Load Voltage



Laptop Computer

- Power provided to computer by power cable
  - V = 16V
  - I =3.66 A
  - P=59 W
- Cutoff Voltages
  - 6V for laptop screen
  - 5V for computer functionality

Fuel Cell Alternatives

- Selection of fuel cell manufacturers
  - Horizon Fuel Cell Technologies
  - Ballard Power Systems
  - Pragma Industries

- Consequences of fuel cell alternatives
  - Size
  - Availability

Pragma Industries Fuel Cell

- 75 watts
- 20 cells
- 12-18V
- Reactant gasses
  - Dry hydrogen and air

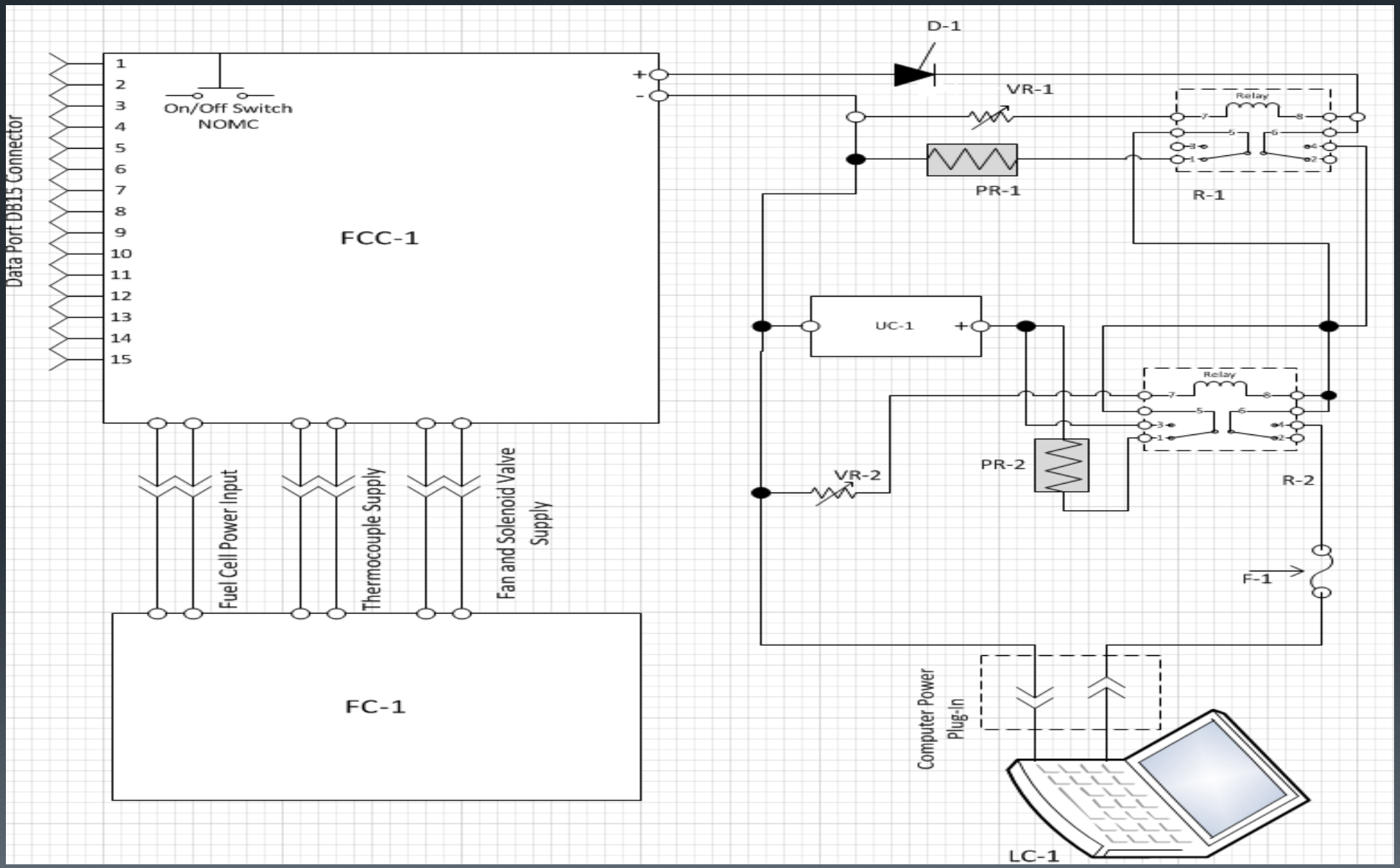
Pragma Industries Fuel Cell

- Open cathode design
  - Extracts required oxygen from surrounding air
- Hydrogen supplied to fuel cell at constant pressure
- Power function of
  - Membrane saturation
  - Pressure of hydrogen supply
- Controller Card

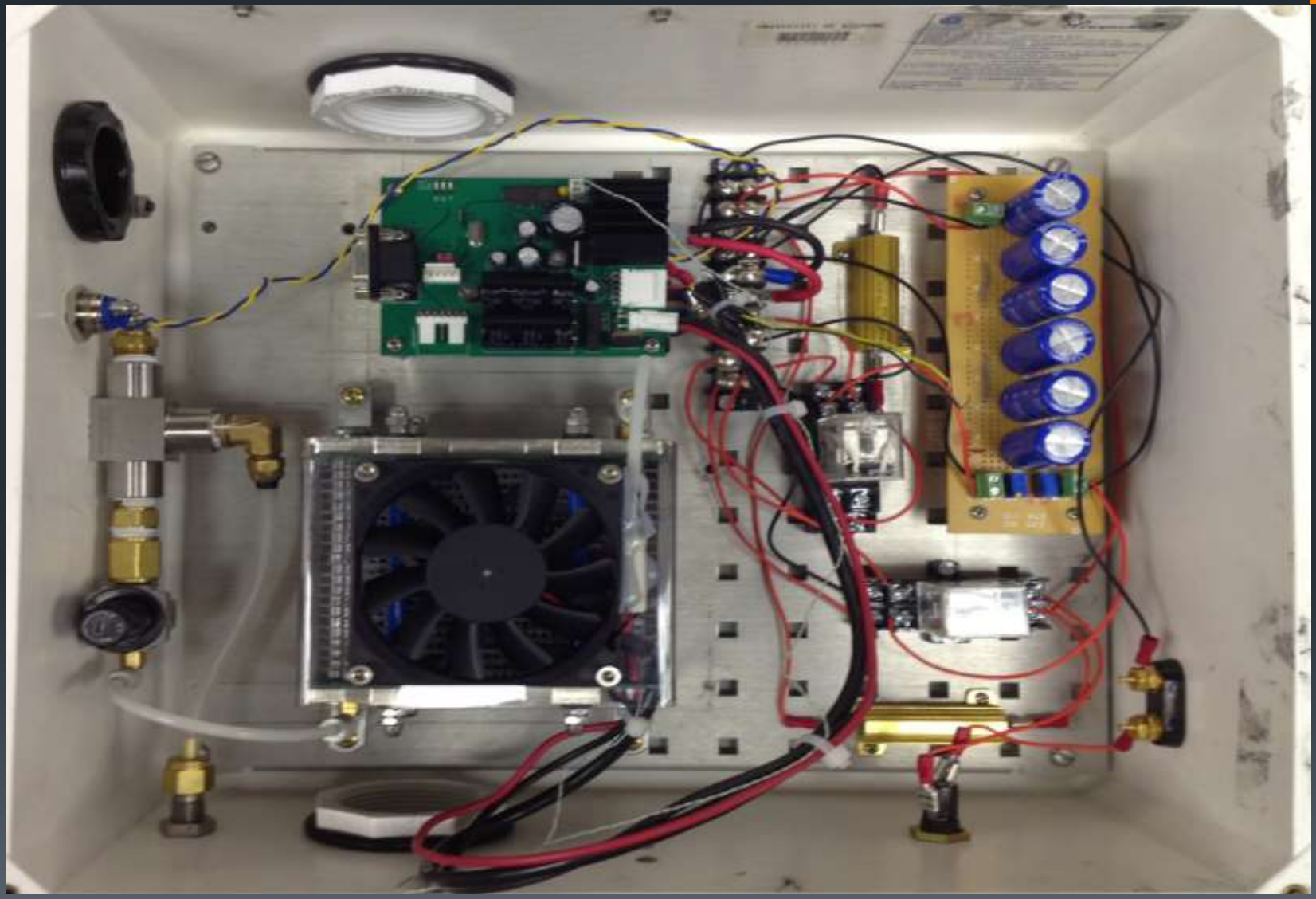
Ultracapacitors (UC)

- Supply interim power during fuel cell ramp-up
- Maxwell Technologies
  - 500,000 charge/discharge cycles
  - C = 50 F
  - V = 2.7 V
- Configuration
  - 6 in series
  - C = 8.3 F
  - V = 16.2 V

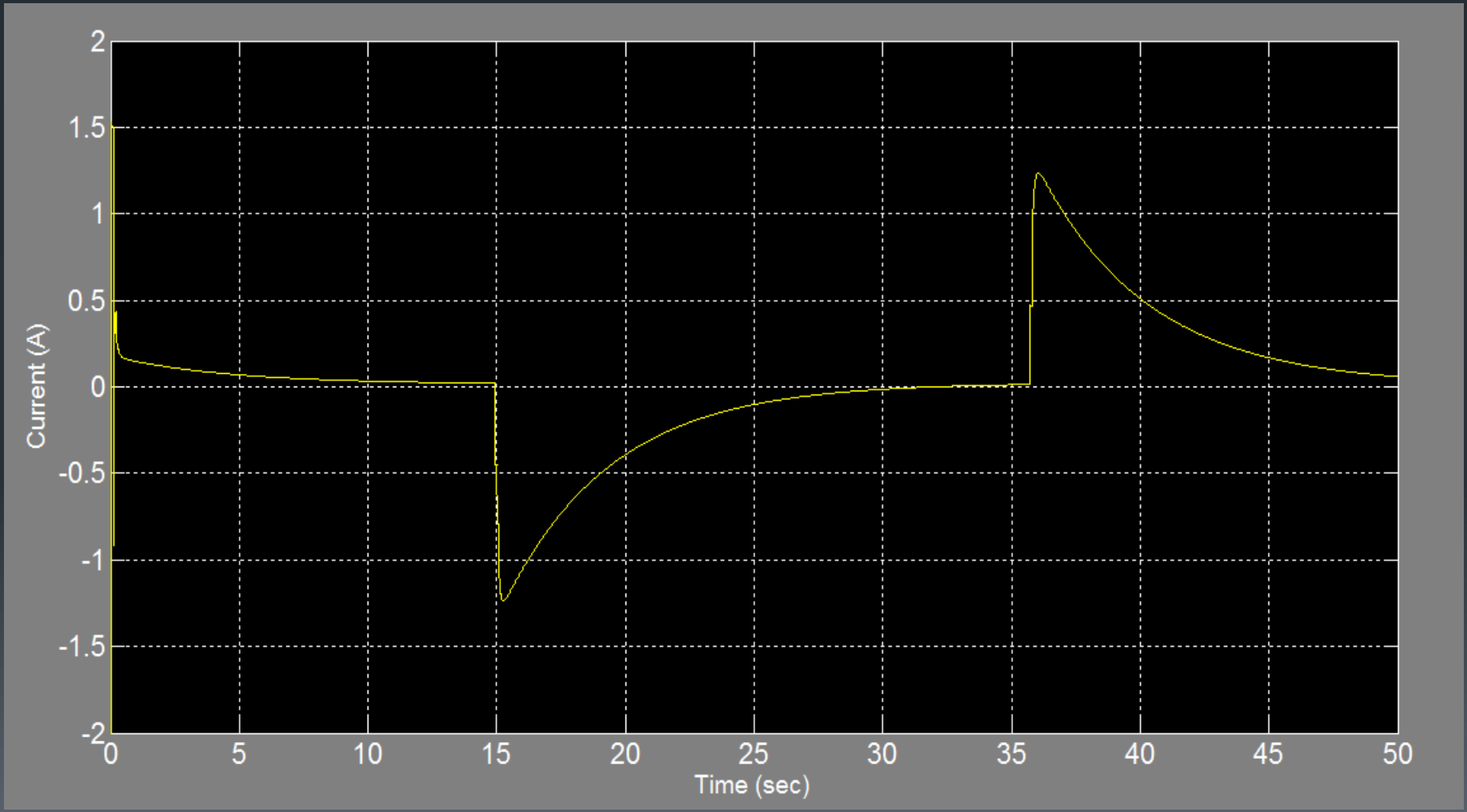
Overall System



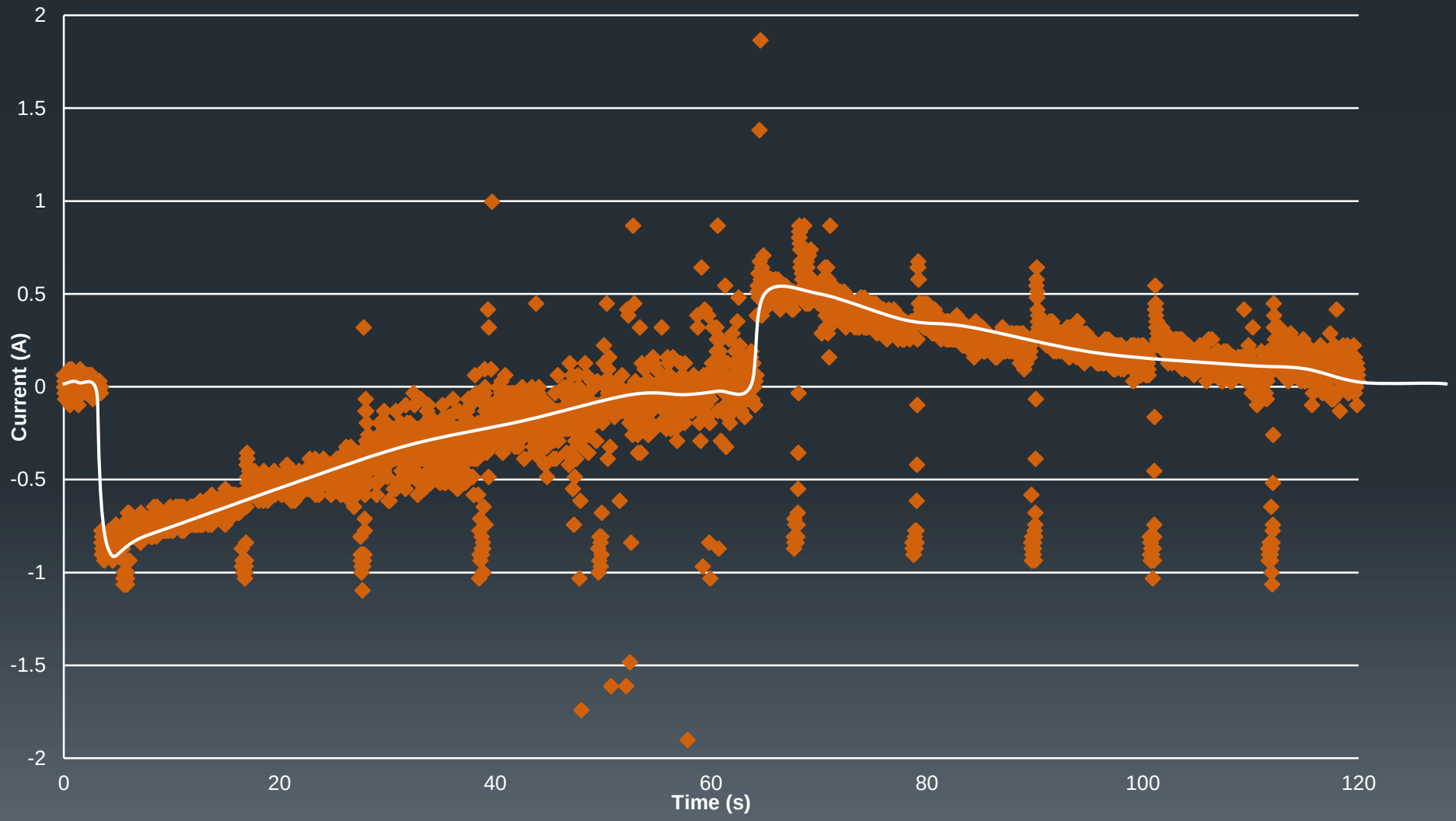
System Layout



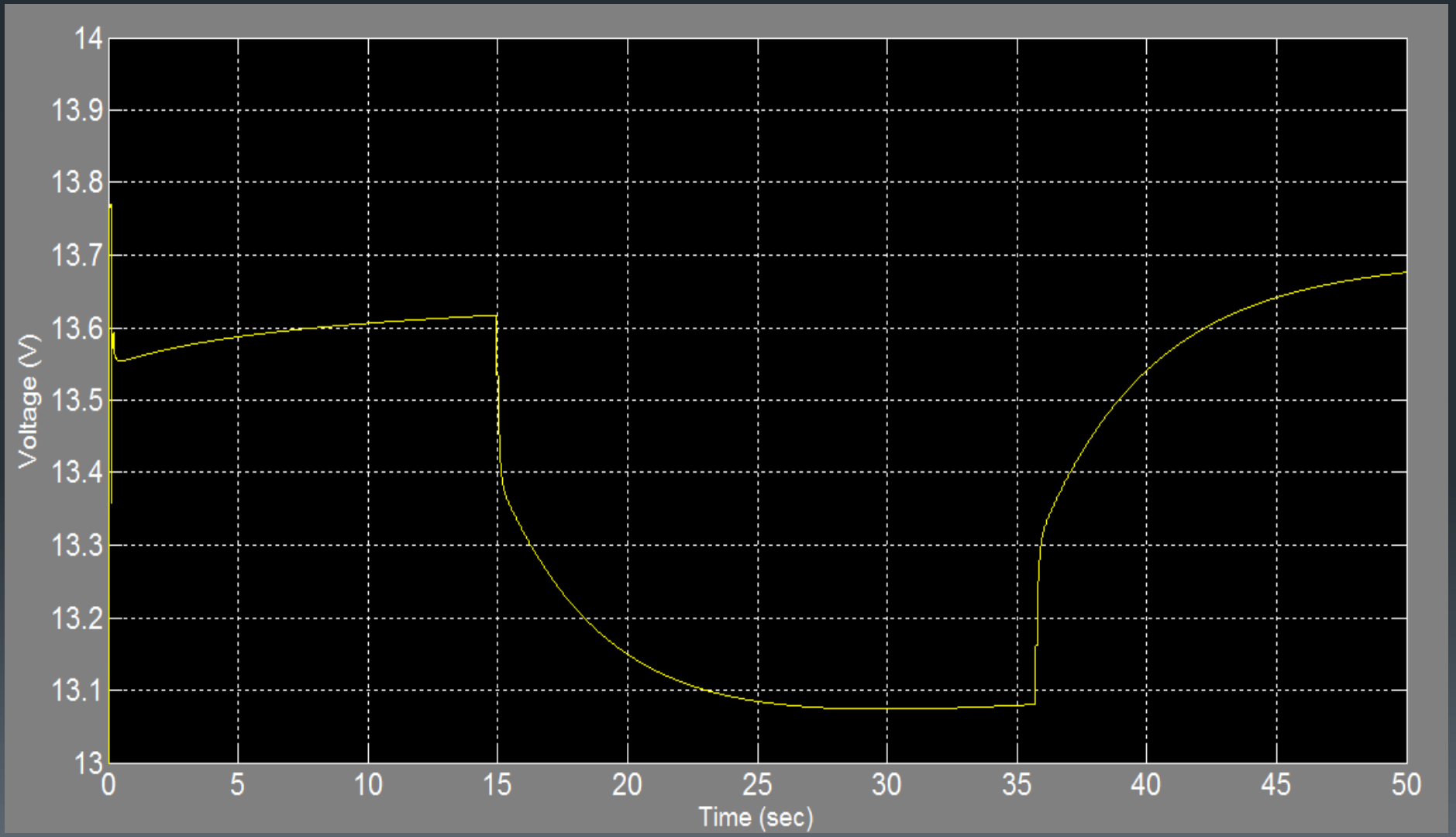
Model UC Current



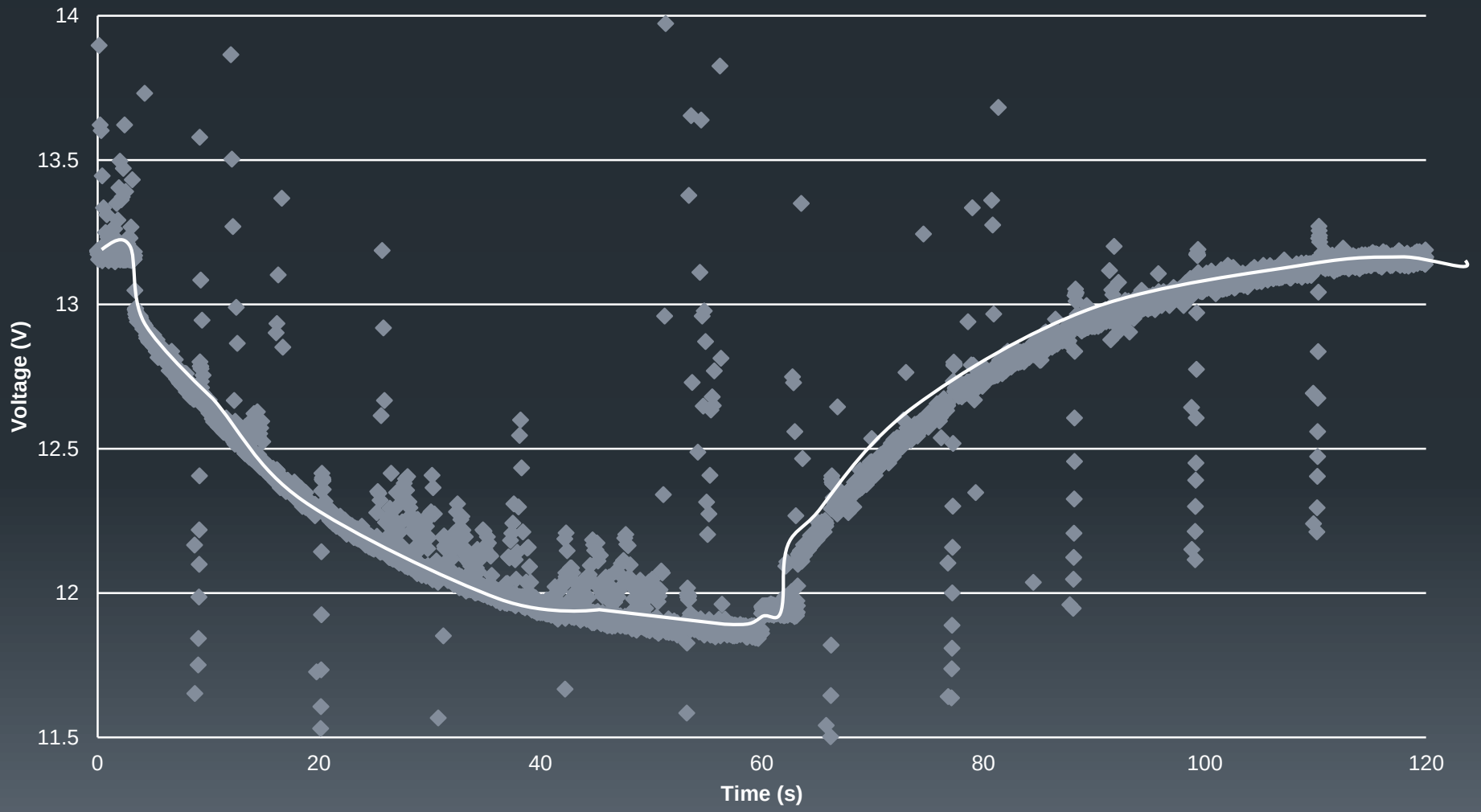
Compliance Test: UC Current



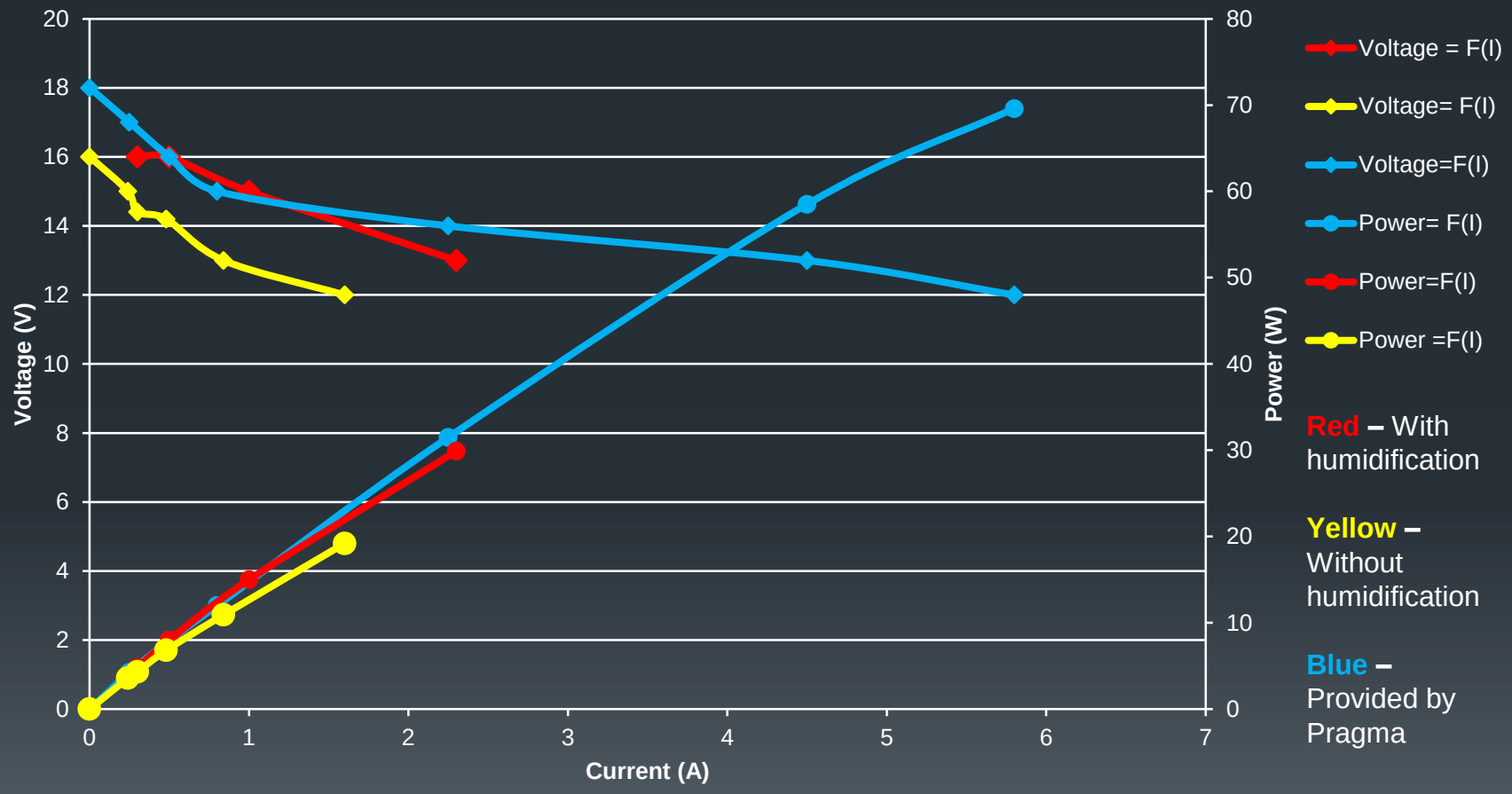
Model Load Voltage



Compliance Test: Load Voltage



Compliance Test: Polarization Curve



Red – With humidification

Yellow – Without humidification

Blue – Provided by Pragma

Issues

- SCU
- Membrane hydration
  - Humidification
- Operating temperature
  - Enclosure

Laboratory Safety

- Fume hood
- Test gas line for leaks
- Gas system startup/shutdown procedures
- PPE – Eyewear
- Eliminate ignition sources

Project Cost

Expense	Quantity (Hrs)	Total Cost
ProCell Engineering	1,027	$30,500
Materials		$2,200
	Total	$32,700

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Questions ?