



Fuel Cell Activities at the University of South Carolina

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Power Electronics/Modeling and Simulation (M&S) Group

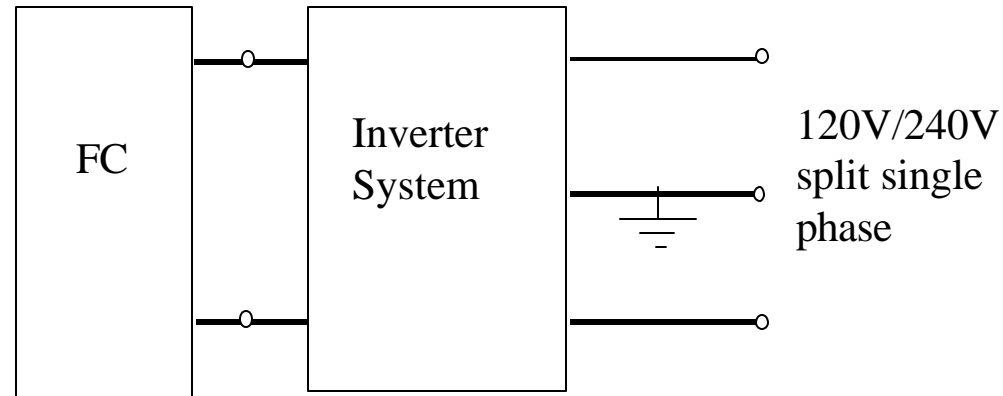
- Roger Dougal: M&S, power electronics
- Jerry Hudgins: semiconductor devices, pulsed power
- Antonello Monti: motor drives, M&S, control
- Charlie Brice: power systems, control
- Dean Patterson: motor design, drives, alternative energy
- Ferdinanda Ponci: motor design, wavelets
- Enrico Santi: power electronics, M&S, control



Contents

- Future Energy Challenge student competition: design low-cost high-performance fuel-cell-based power supply
- Proposed active filter solution
- Virtual Test Bed (VTB) Project
- HAPS Project

Inverter System Specifications



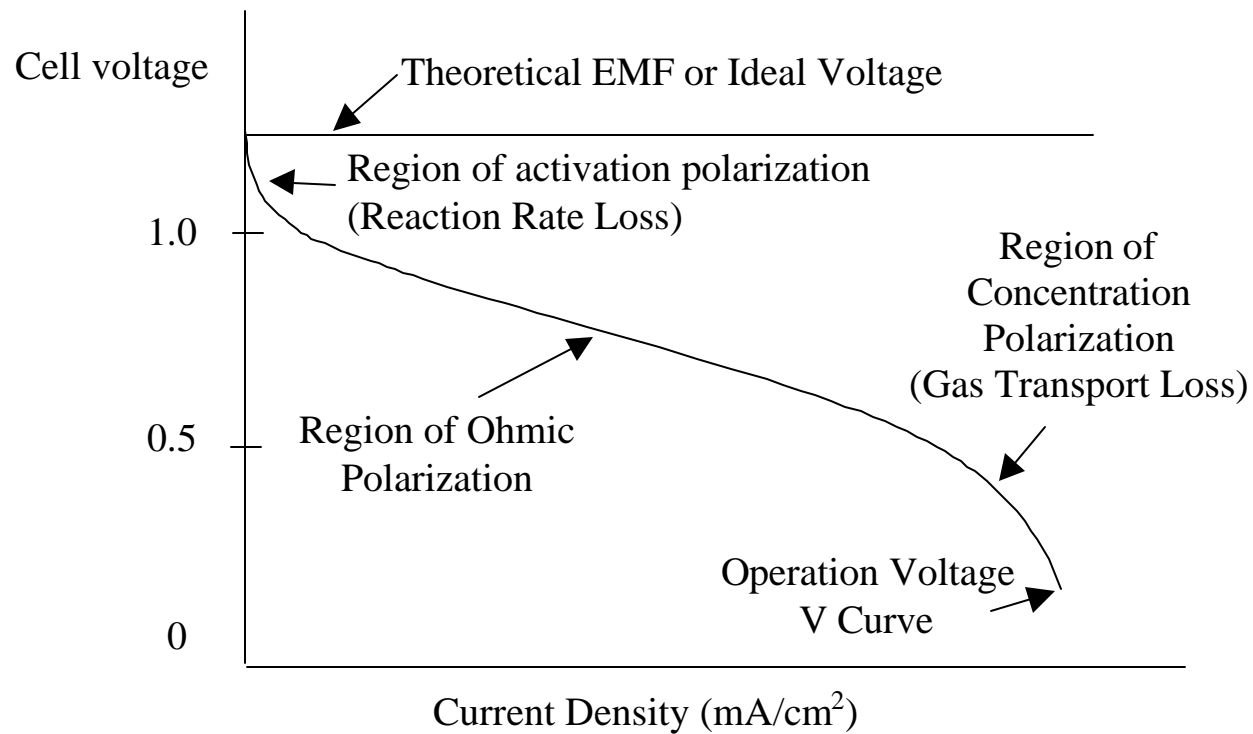
Input source	Fuel cell, 42 - 72V (48V nominal)
Output power	10kW continuous for paper design, 1.5kW for prototype
Phase(s)	split single phase
Output voltage	120V / 240V nominal, 60Hz



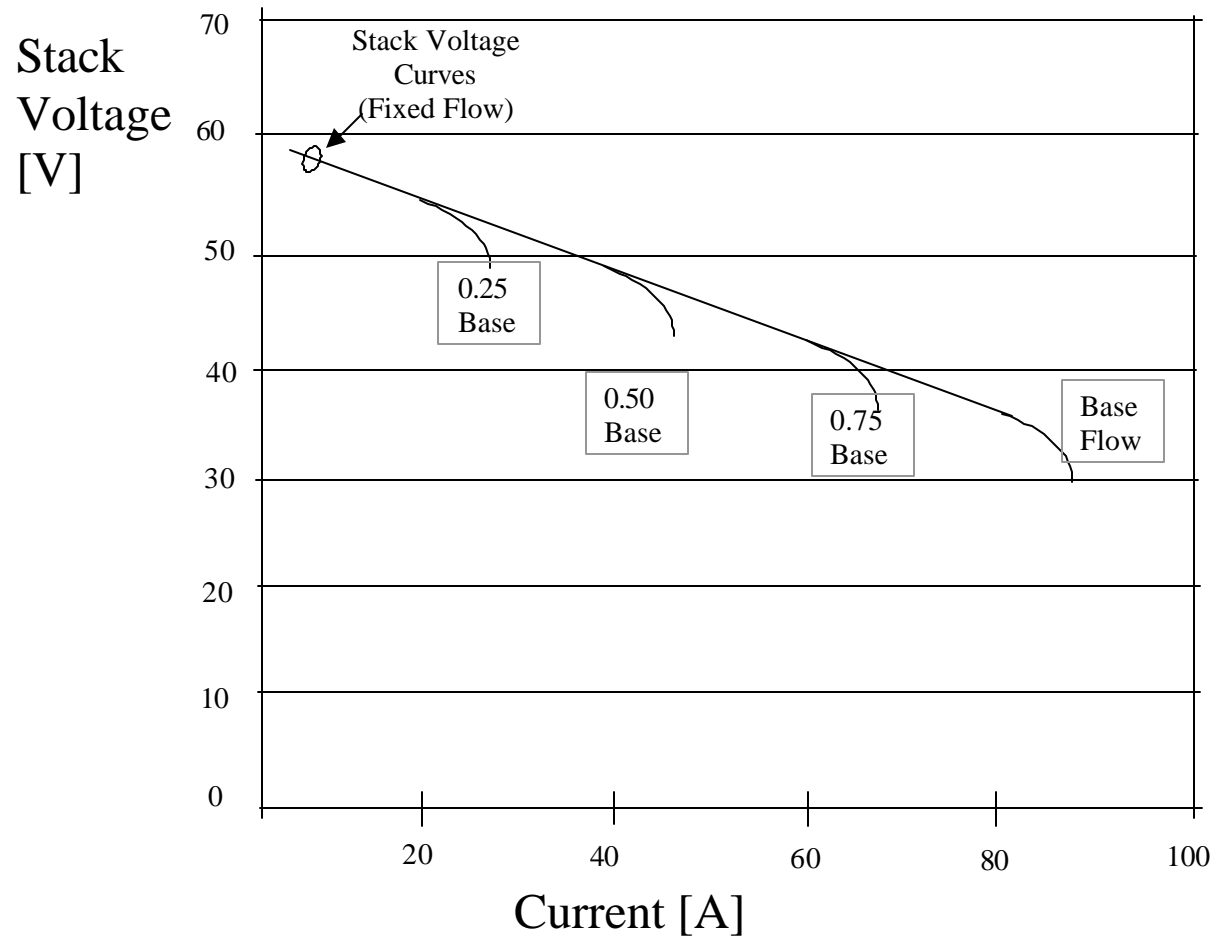
Fuel Cells as Electric Power Sources

- Fuel cells use H₂ and air (oxygen) as fuel
- Air compressor needed
- Hydrogen needed (tank or methanol reformer)
- $2 \text{ H}_2 + \text{ O}_2 \rightarrow 2 \text{ H}_2\text{O}$

Fuel Cell Static Characteristic



Static FC Characteristics for various hydrogen flow levels





Main Challenges

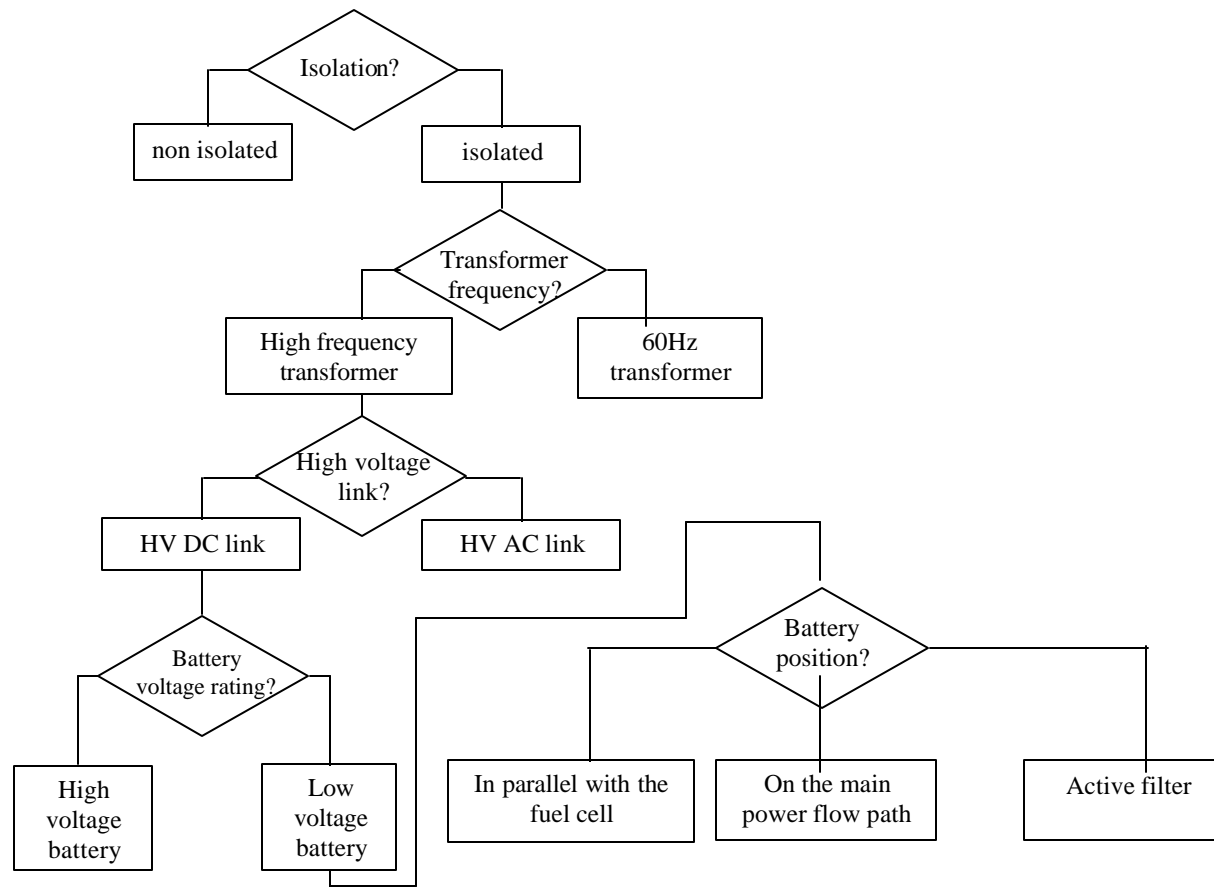
- Slow dynamics of fuel cell \Rightarrow battery
- Low fuel cell supply voltage \Rightarrow step-up needed
- No current backfeed allowed



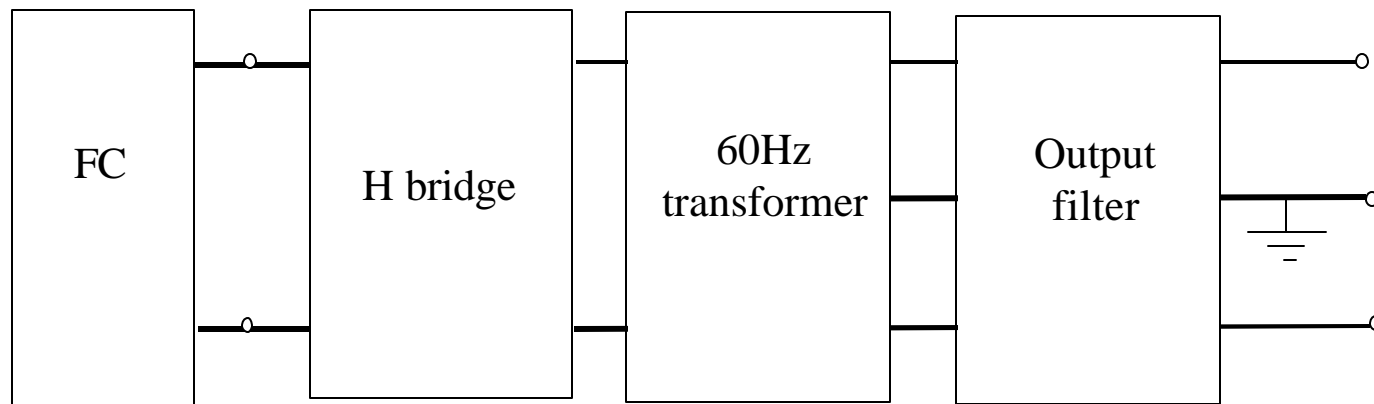
Design Decision Tree

- Isolation
- Transformer frequency
- High voltage DC link or AC link
- High or low voltage battery
- Battery position

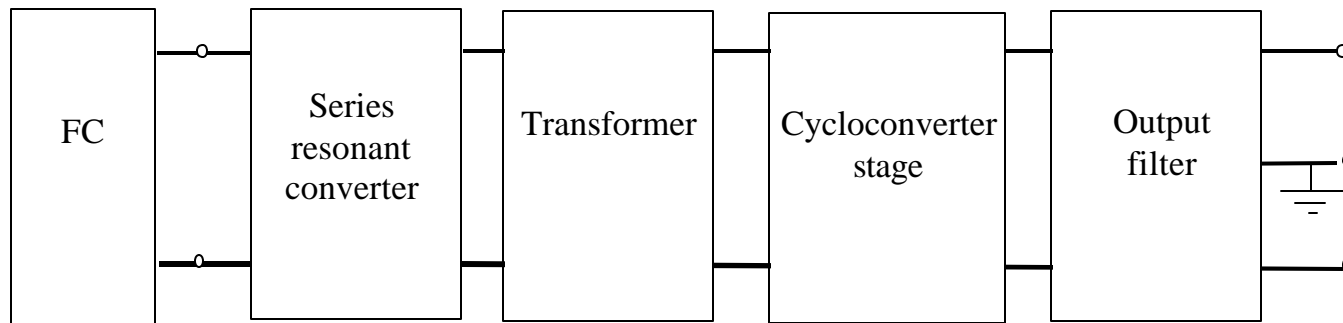
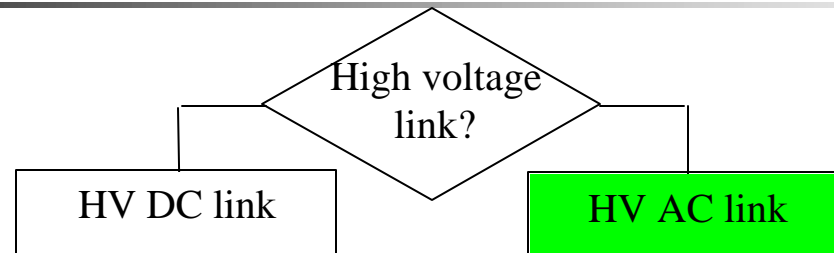
Design Decision Tree



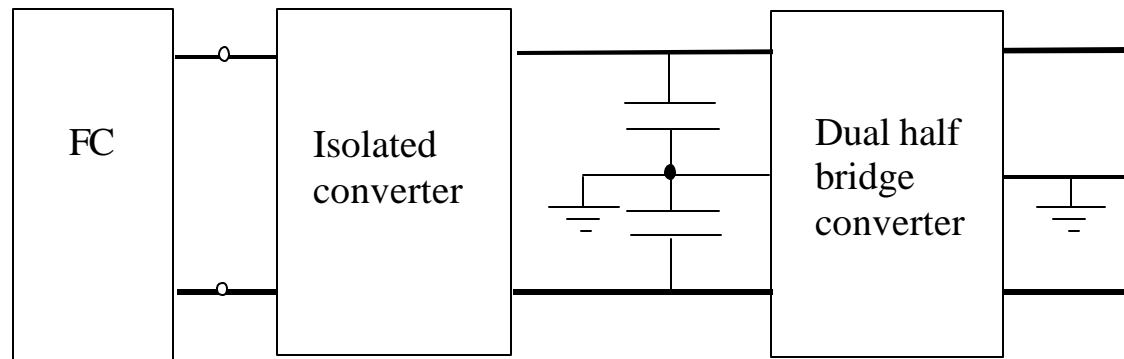
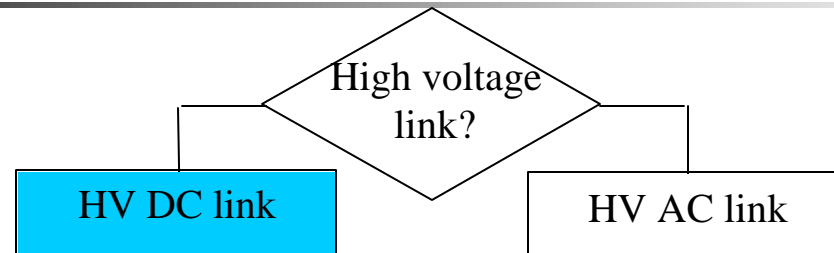
Solution with 60 Hz Transformer



HV DC or AC Link?

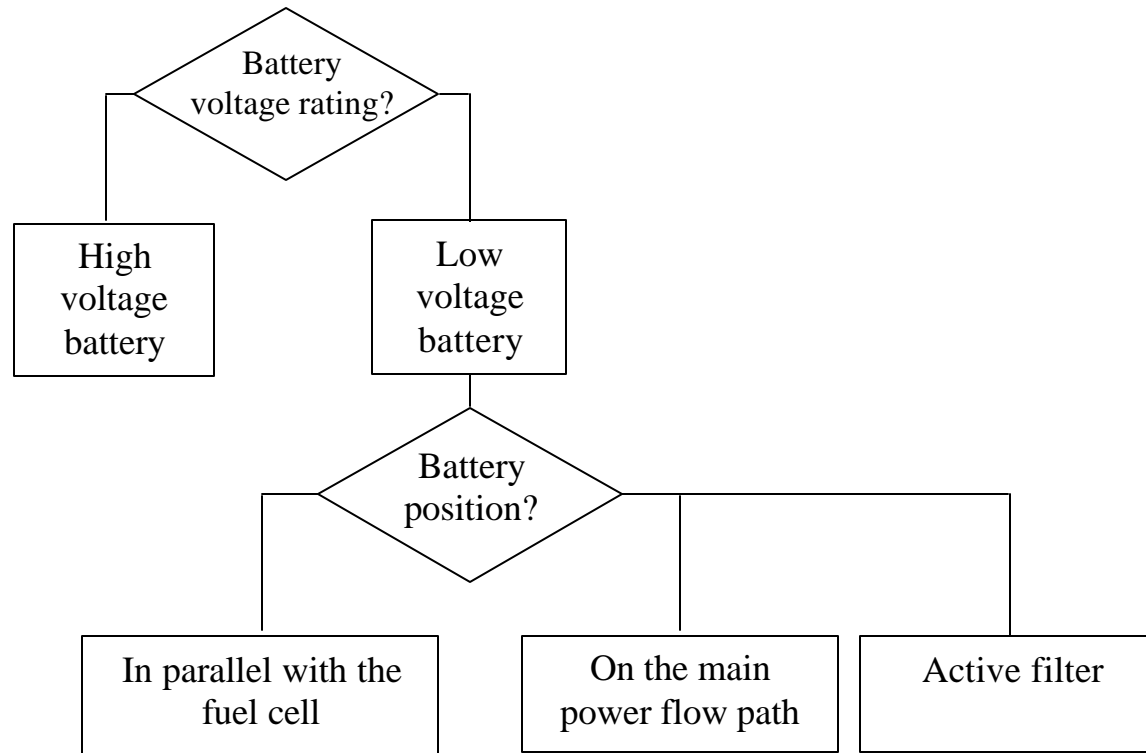


HV DC Link

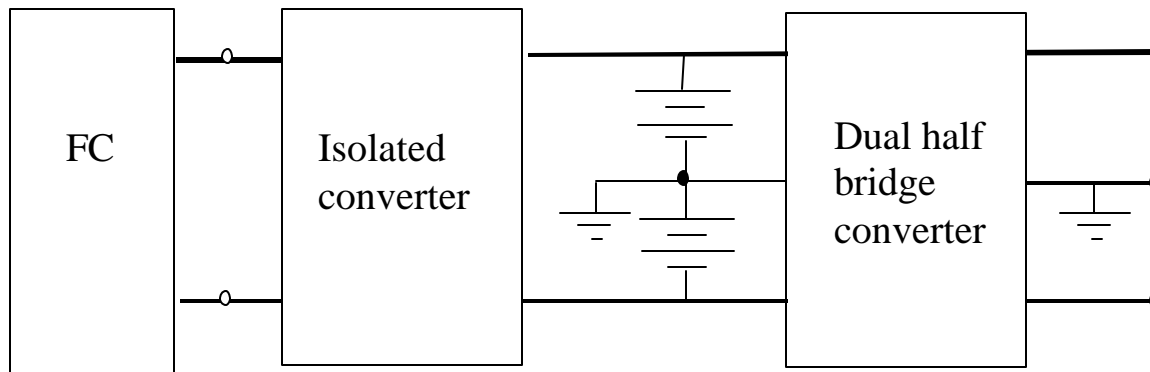




Battery Design Choices

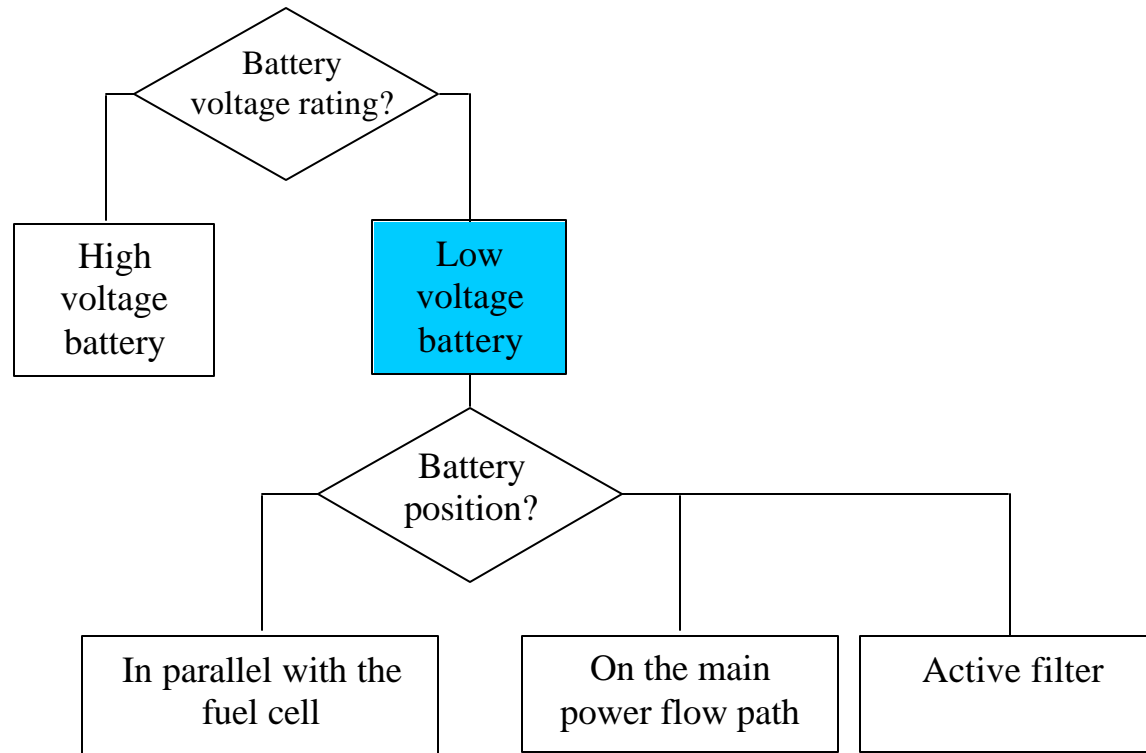


High Voltage Batteries

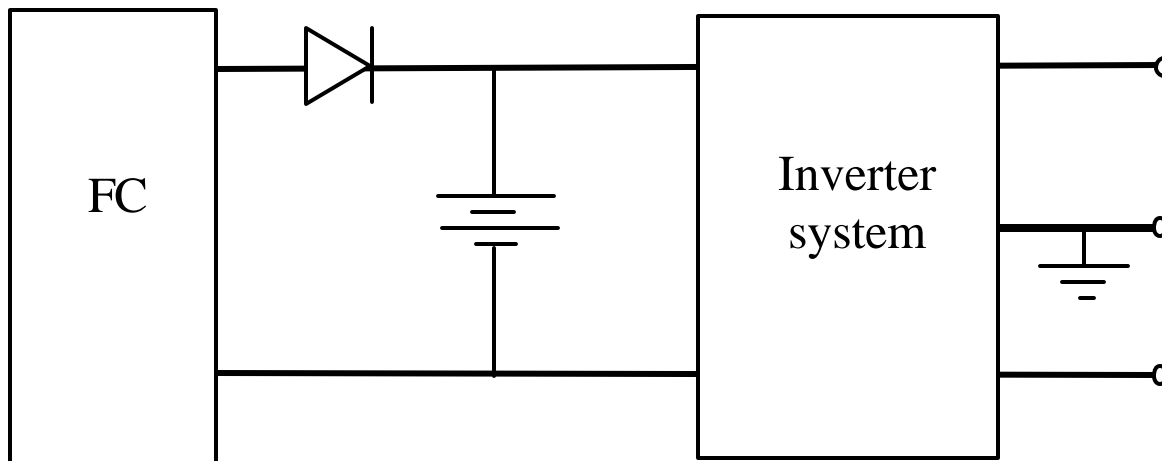


- Cost and reliability of high voltage batteries ↓

Battery Position

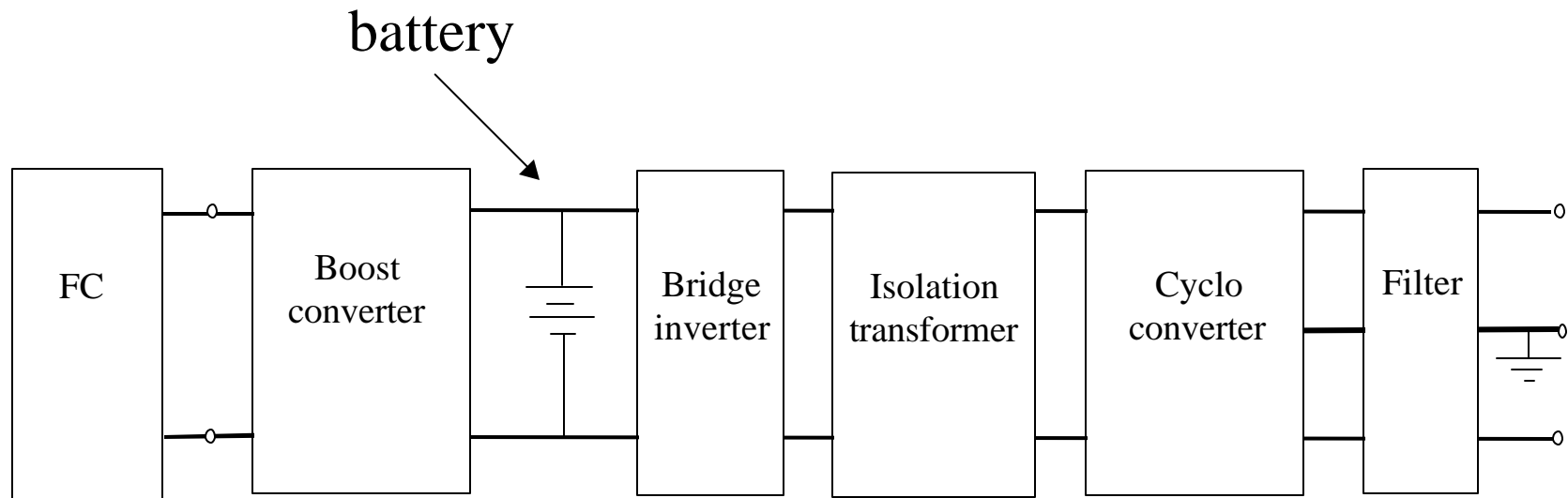


Battery in // with Fuel Cell



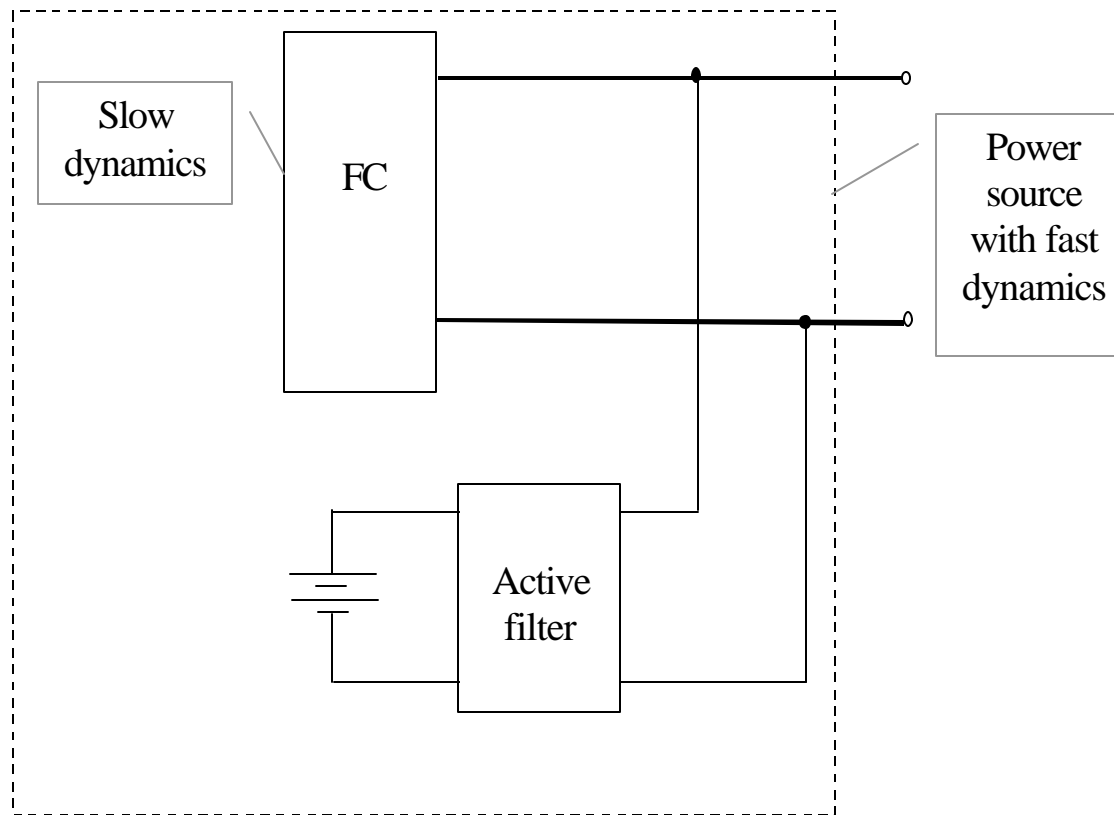
- Fuel cell current not directly controlled ↓
- Mismatch between fuel cell and battery impedance ↓

Battery on Main Power Flow Path

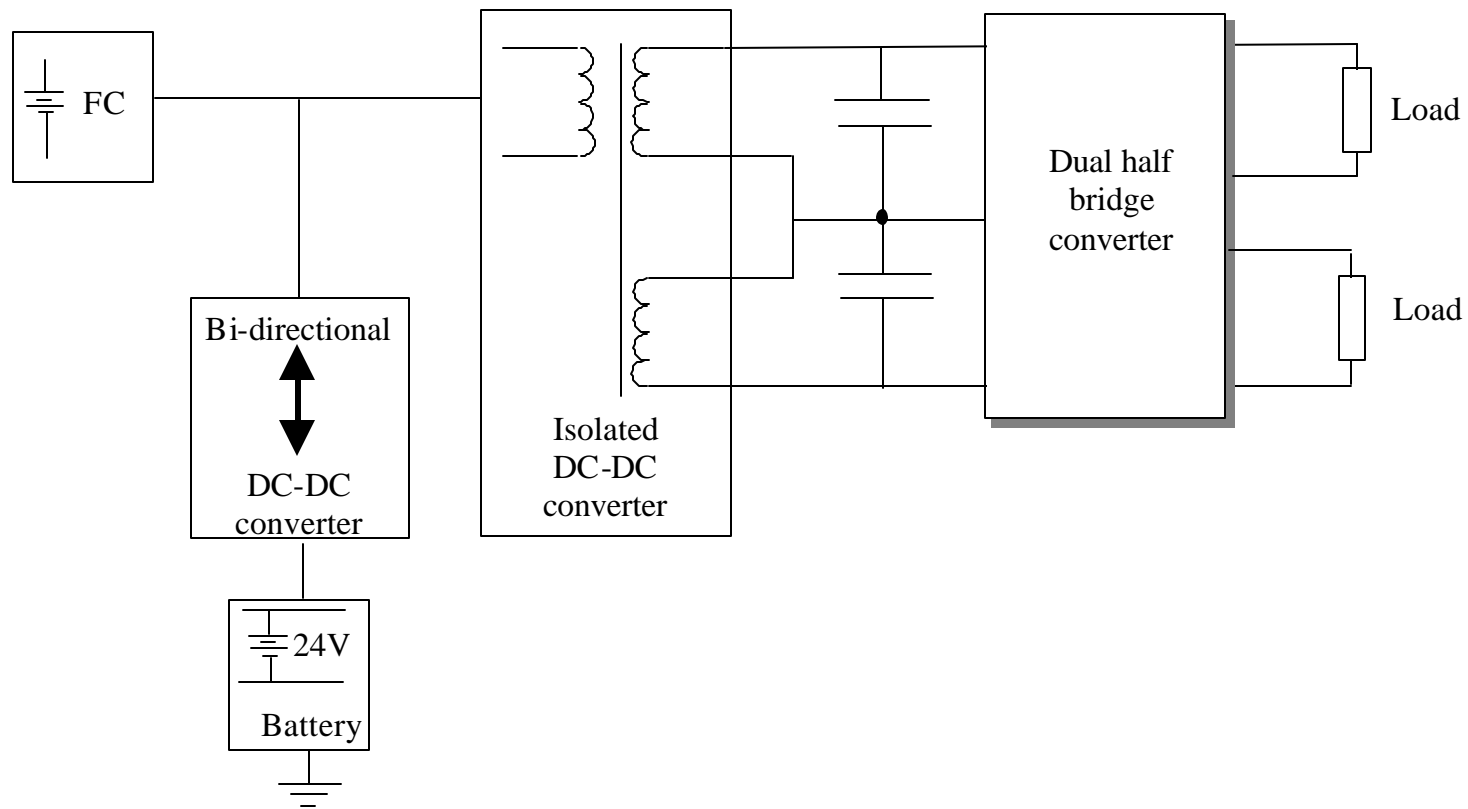


- Additional power conversion stage: efficiency ↓

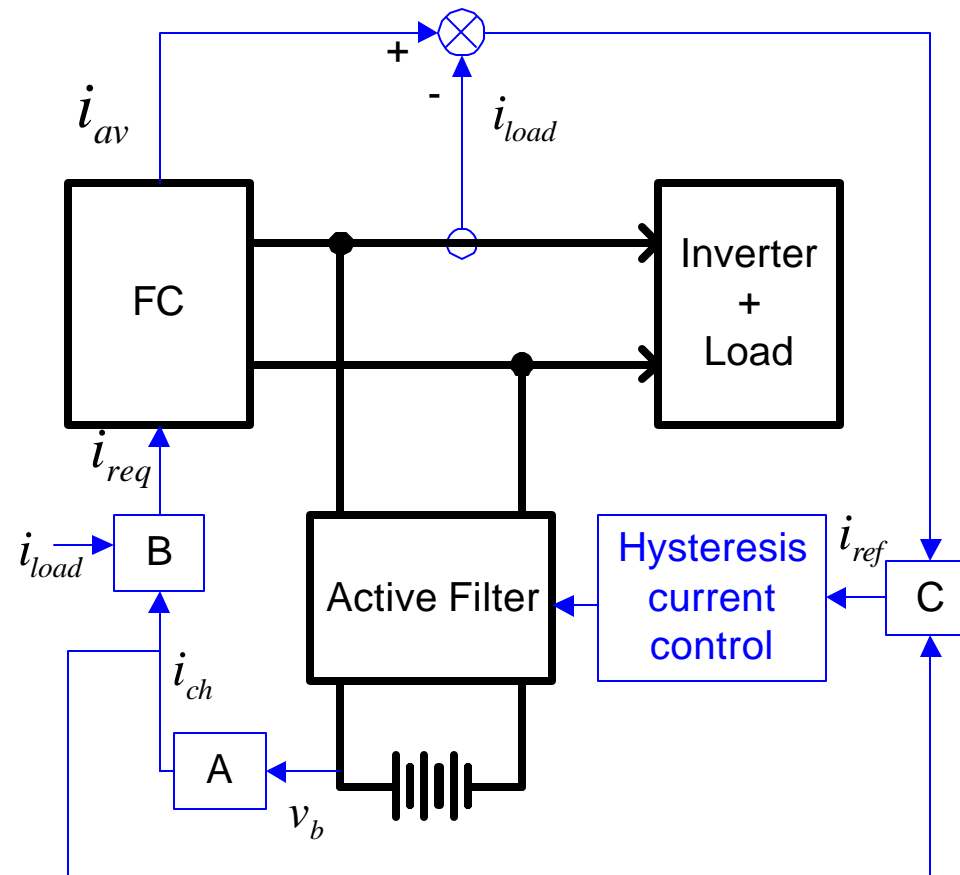
Our Solution: Active Filter



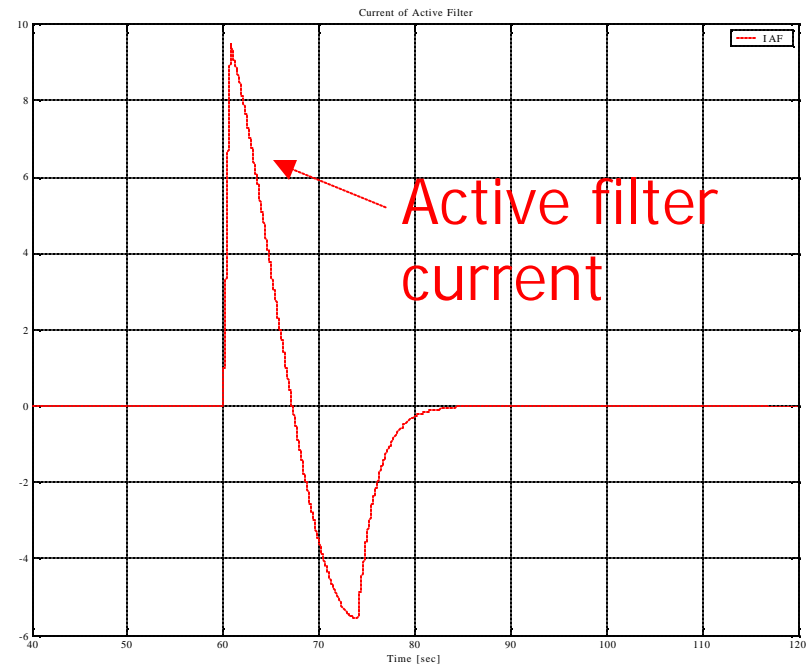
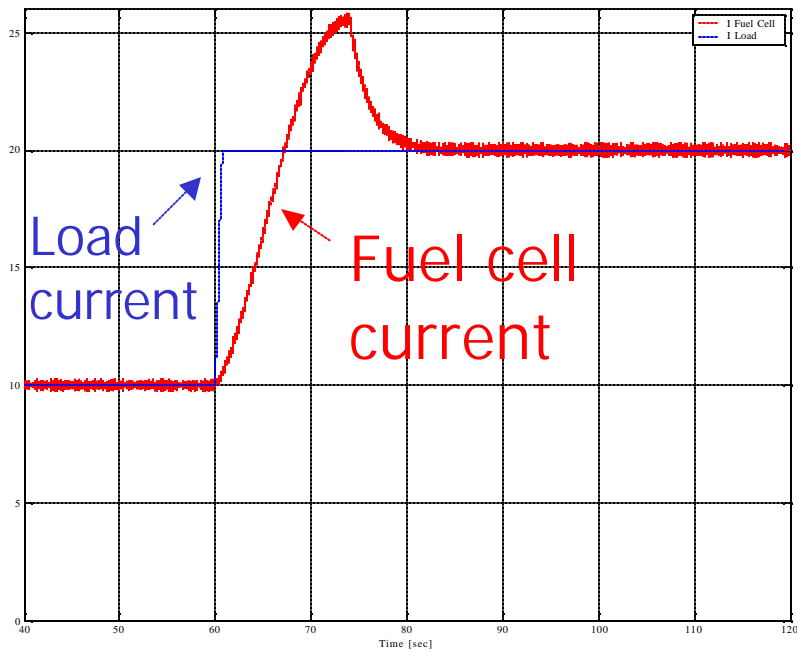
The Complete System



Active Filter Control



Active Filter Simulation

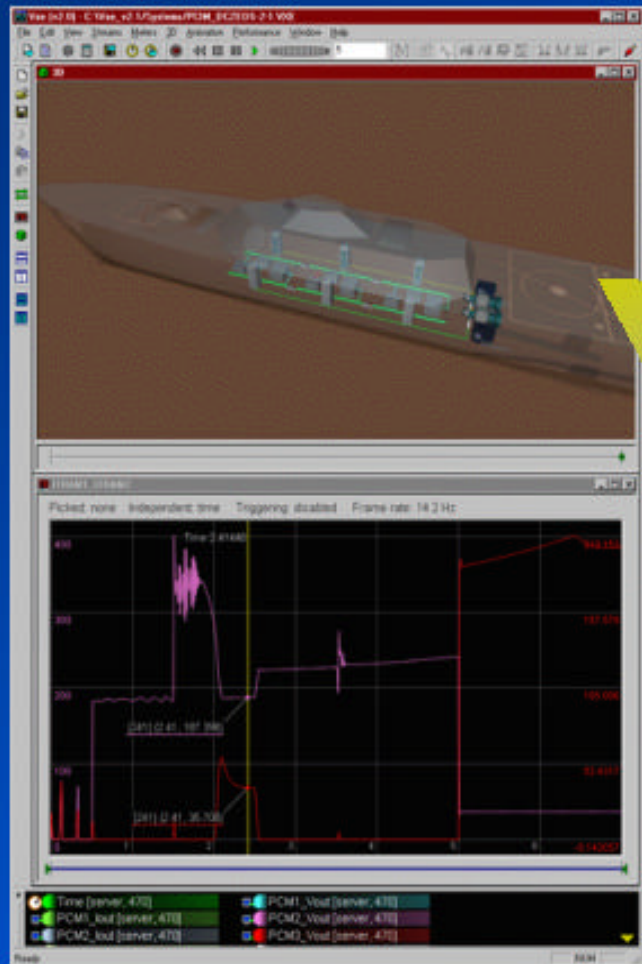
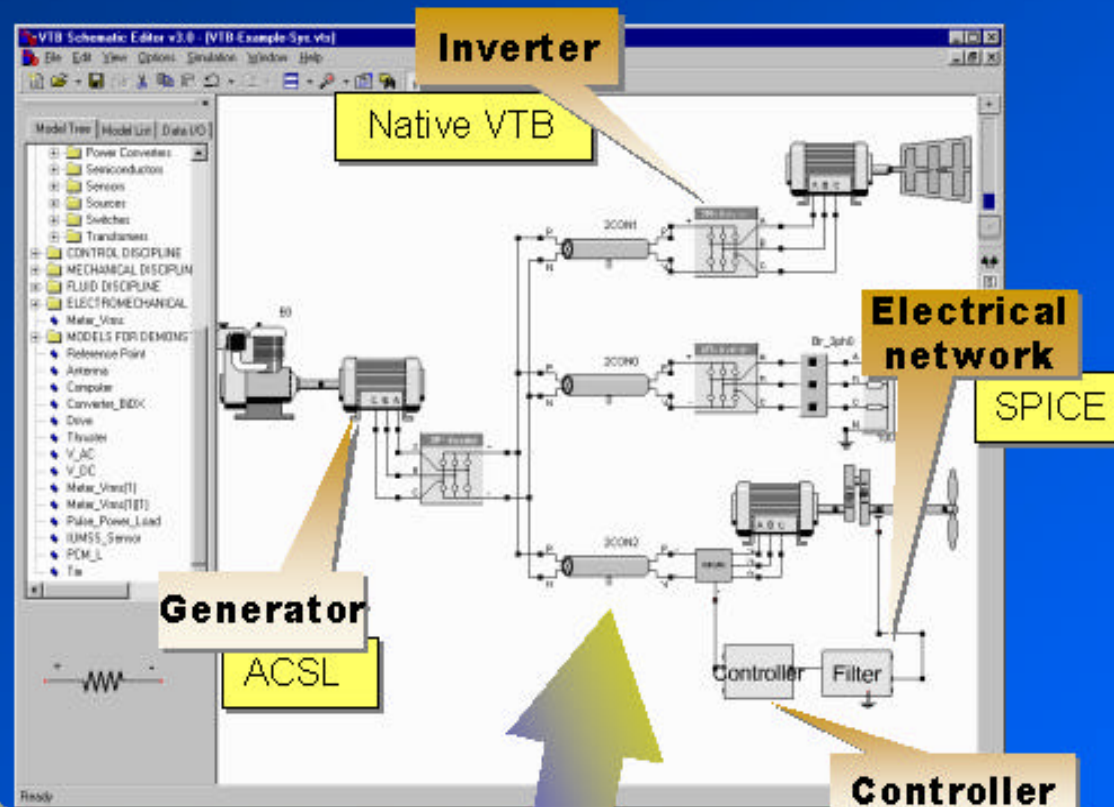




The Virtual Test Bed (VTB)

- Project sponsored by ONR
- Simulation and Virtual Prototyping environment for advanced power systems
- VTB supports
 - Multidisciplinary simulation (electromechanical, fluid flow, chemical...)
 - Multiformalism (Simulink, ACSL...)
 - Advanced visualization
 - Hardware in the loop
- Freely available at <http://vtb.ee.sc.edu/>

Virtual Test Bed



Advanced visualizations increase comprehension

Capture domain-specific expertise and preserve utility of existing models and modeling skills

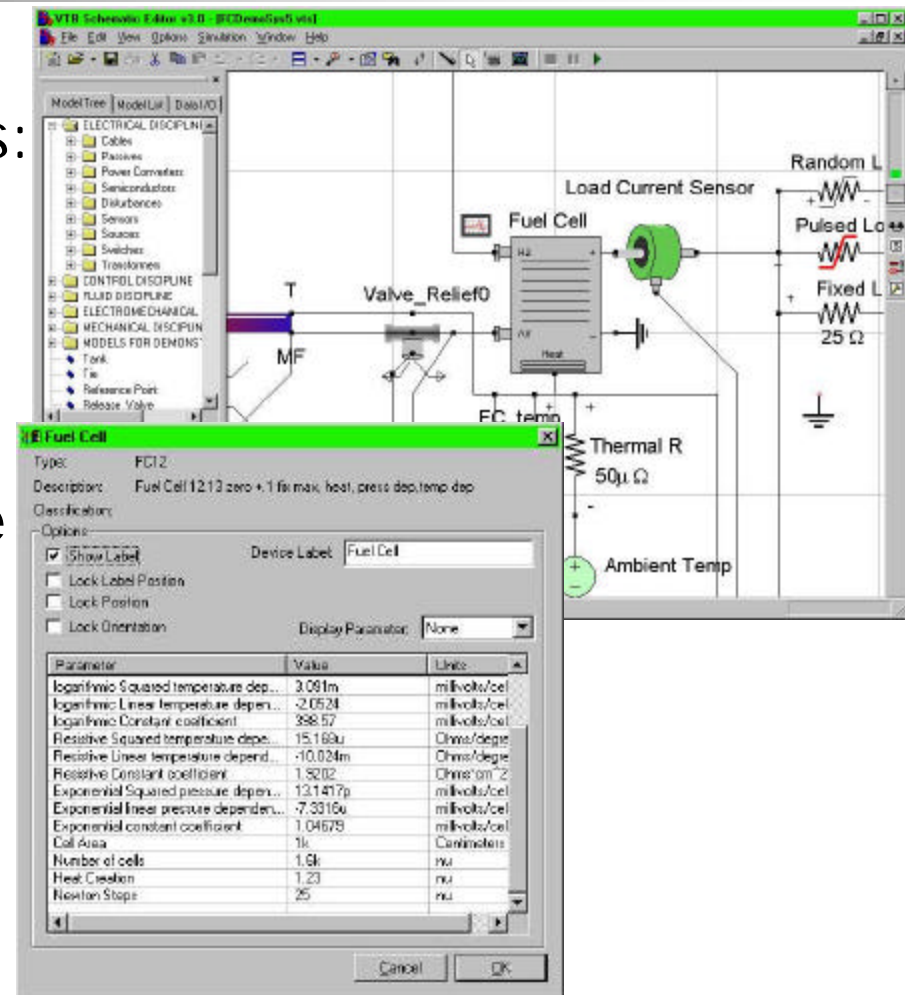
VTB

- Is an environment for integrating the work of interdisciplinary teams
- Provides a “common language” for expression of problems and solutions
- Enables virtual prototyping and tuning of complex dynamic systems.

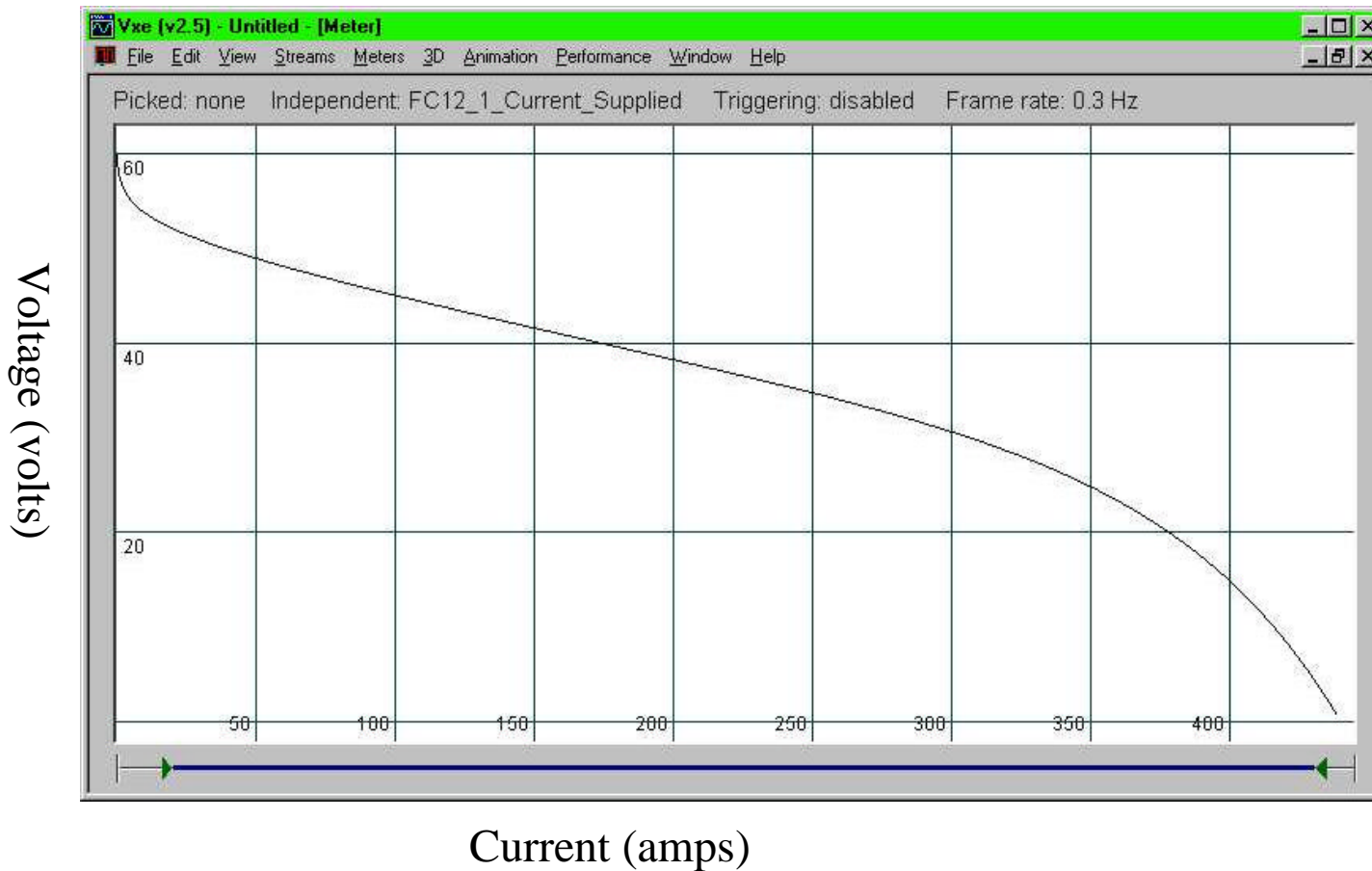
Example Schematic

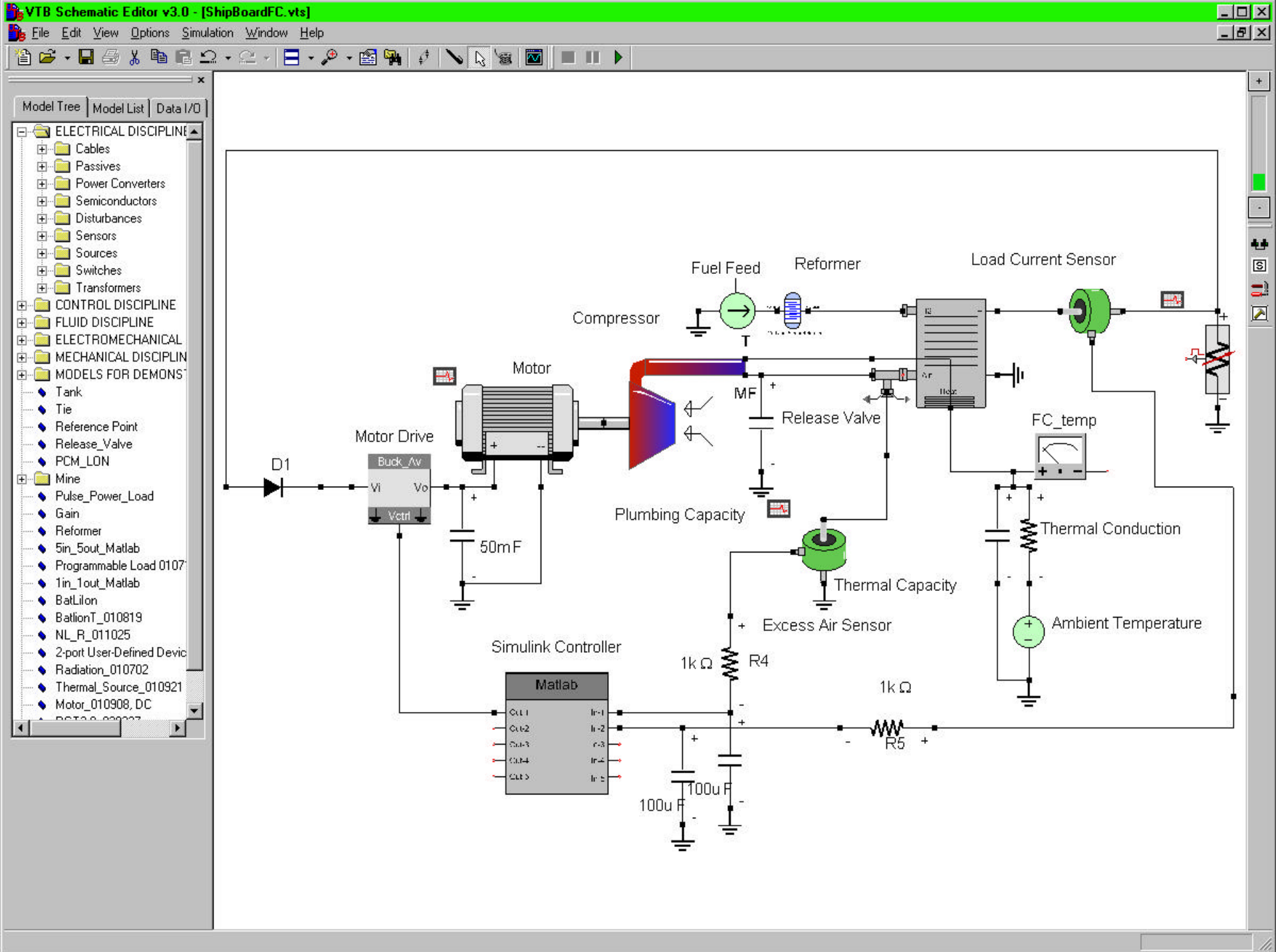
VTB fuel cell model includes:

- fuel and air consumption
- electrochemical voltage-current relationship
- thermal model
- temperature and pressure dependence



VTB PEM Fuel Cell V-I Characteristics





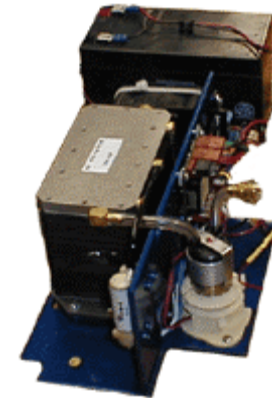
Hybrid Advanced Power Systems (HAPS)



Batteries



Super capacitors



Hybrid Systems



H2 storage



PEM Fuel cells



Objectives

- Collaboration with Chem Eng Dept (Prof. White, Van Zee, Weidner, Popov, etc.)
- Create accurate physics-based and system level models of electrochemical energy storage and conversion devices
- Apply those models in the design of portable power systems that optimally meet mission-specific power profiles
- Develop general methodology for system optimization

The 21st Century Soldier System

Helmet Equipment

Soldier Radio

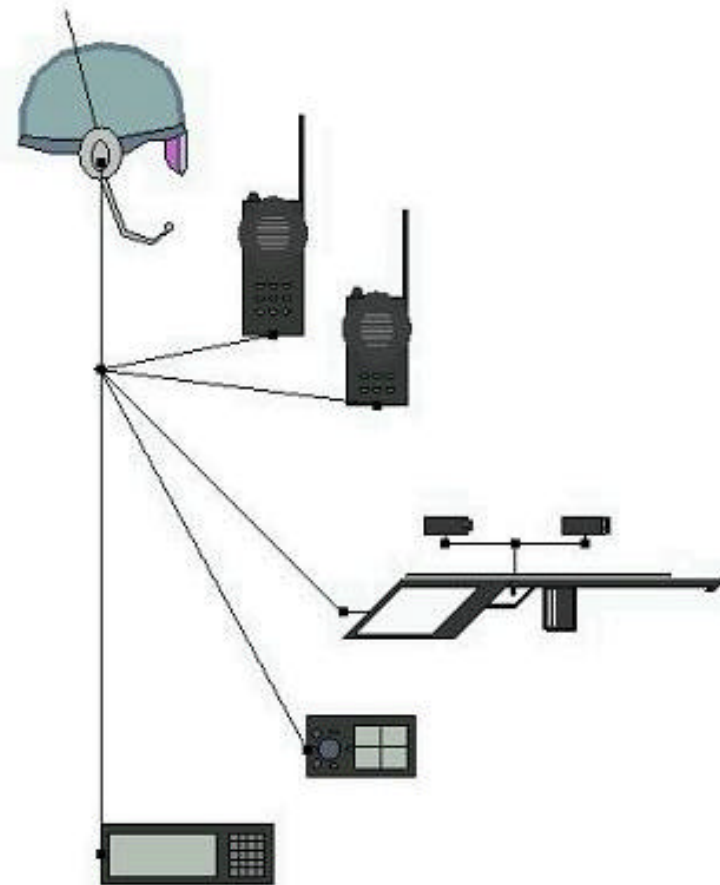
Squad Radio

Video Recorder

Thermal Weapon Sensor

Global Positioning Sensor

Portable Computer





Conclusions

- Active filter design for fuel cell system
- VTB as simulation tool (fuel cell model)
- HAPS project with Chem Eng Dept