PHOTOVOLTAIC AND WIND TURBINE IN A DC MICROGRID

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Benjamin Schenkman

Dave Wilson

Joe Williams

SANDIA NATIONAL LABORATORY

UNITED STATES

BLSCHEN@SANDIA.GOV

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Overview

- Project
- Controls
- Wind Model
- Photovoltaic Model
- DC Microgrid
- Agent Based

Project

- **Mission: Create a scalable microgrid using advanced non-linear controls including agents.**
- **Phase 1: Create models in a software platform: Matlab/Simulink for components that will be within the microgrid. Model simulations will develop hardware specifications.**
- **Phase 2: Build hardware for the microgrid that includes the advanced controls. Hardware will be flexible enough to allow for future controls to be tested.**
- **Phase 3: Test the microgrid in various scenarios which will include performing tests with the OPAL-RT in the loop.**

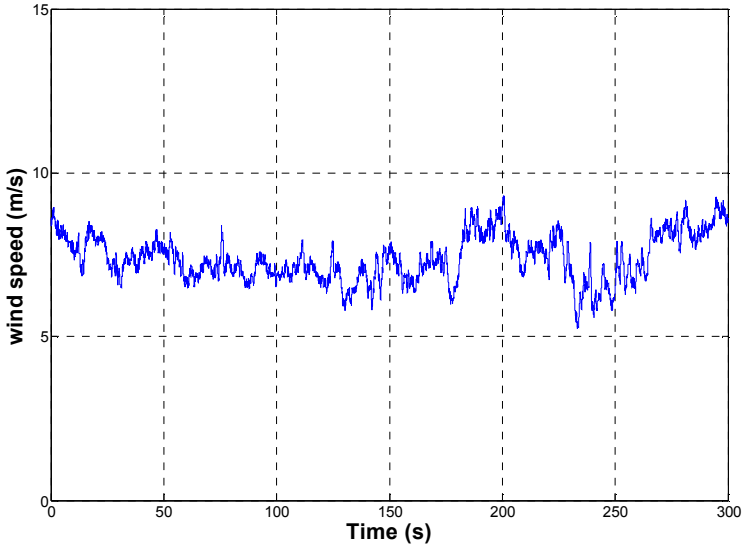
Controls

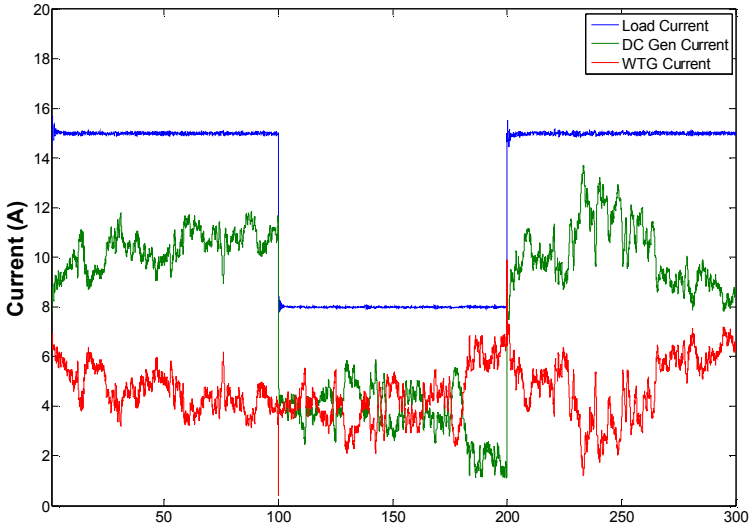
- **Unique Features:**
  - **Nonlinear controller for nonlinear systems**
    - Power flow approach balances generation and dissipation subject to power storage (kinetic and potential energies) for Hamiltonian systems
    - Hamiltonian surface shaping provides static stability conditions
    - Identifies limit cycles as part of dynamic stability conditions
    - Provides both necessary and sufficient conditions for stability while simultaneously allowing for performance specifications
    - Seamlessly integrates information theory concepts (information vs. energy storage)
    - Does not require linearization about a nominal operating point
    - Approach not limited to conventional passivity control design
    - Conventional nonlinear control design energy shaping techniques unaware of what shaping the surface provides in sense of static stability

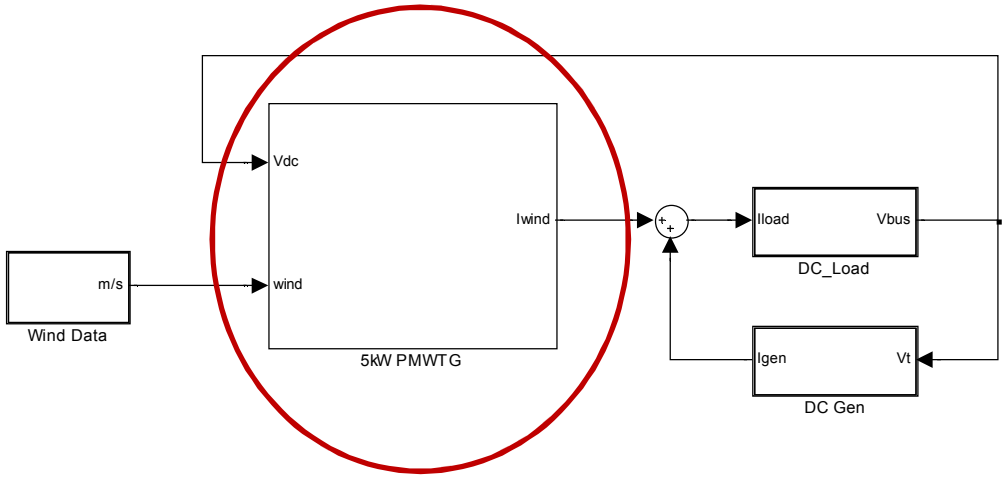
Wind Model

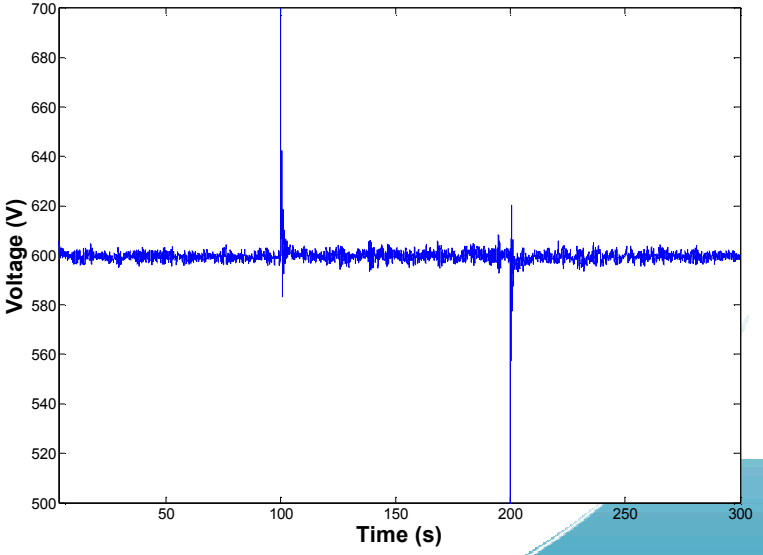
- **Wind Turbine is modeled as a 5kW permanent magnet generator used in residential/commercial applications**
- **Wind data based on actual wind speeds collected from Sandia's Test Site**
- **Inverter of these systems are ignored, AC power output rectified to DC bus voltage of (600V)**
- **Combustion turbine model coupled to DC generator regulates DC bus voltage**

Wind with DC System









Photovoltaic Model

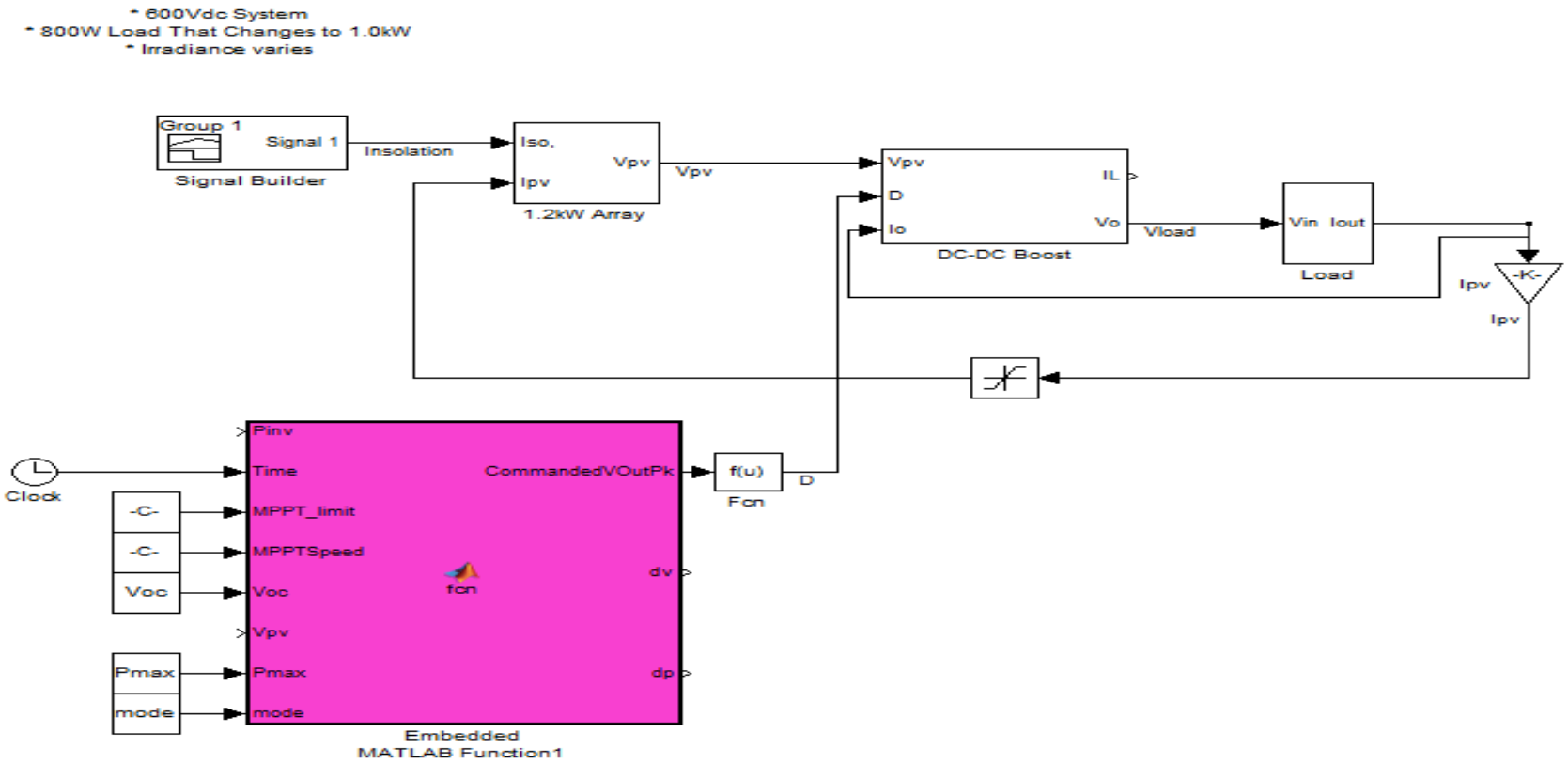
- **PV array is modeled using the Schottky Diode equations at a rating of 1.2kW**

$$-I = Is * [exp((V - I * Rs)/(\eta * Vth)) - 1]$$

- **Irradiance fed into the array model input are from actual w/m^2 measured at Sandia's test site**

- **Max Power Point Tracking (MPPT) is done using the Perturb and Observe method controlling the DC boost circuit**

Photovoltaic Model



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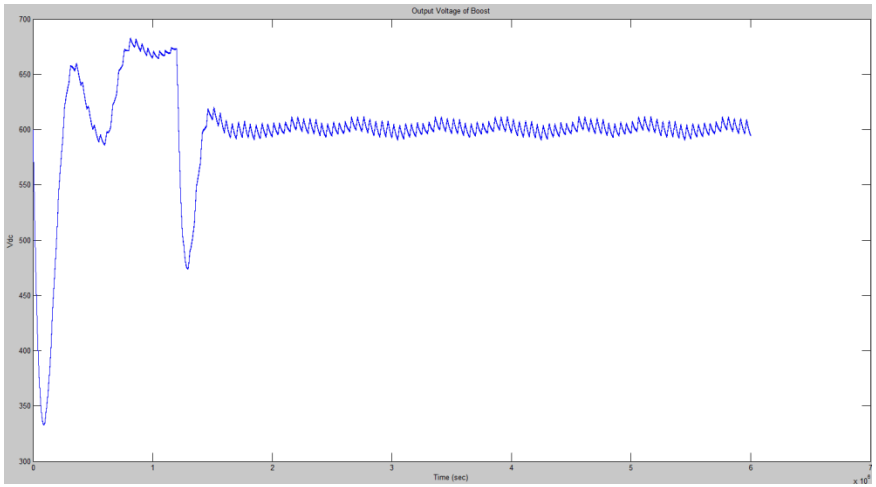
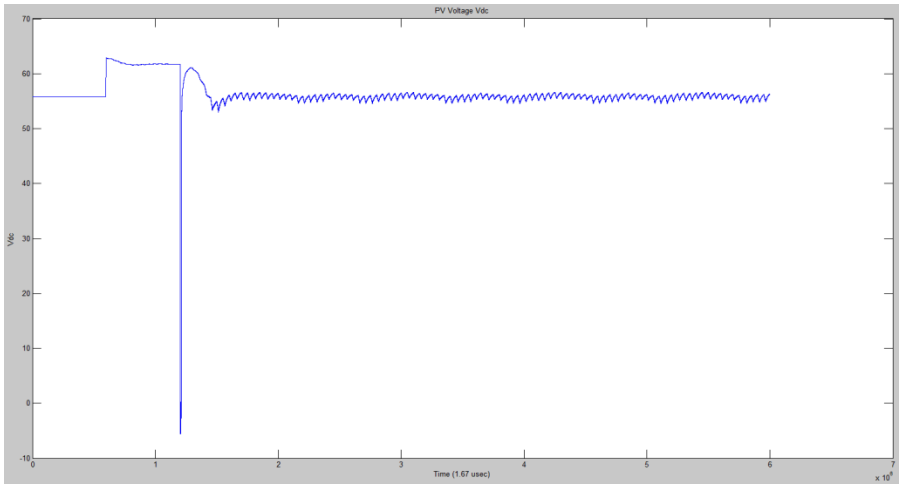
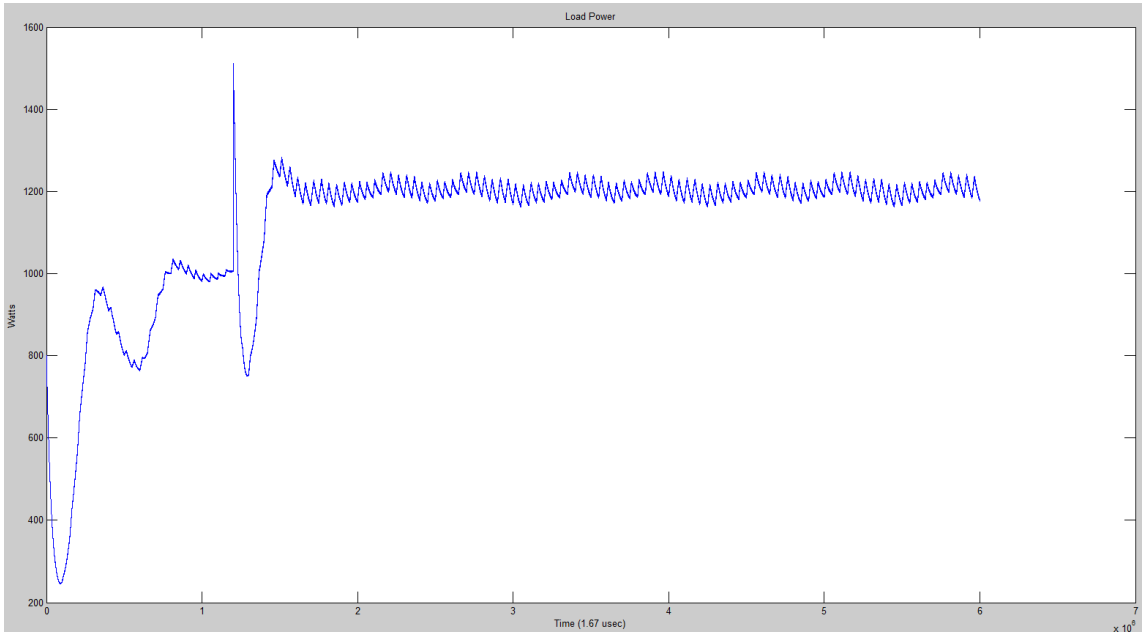
Photovoltaic Model







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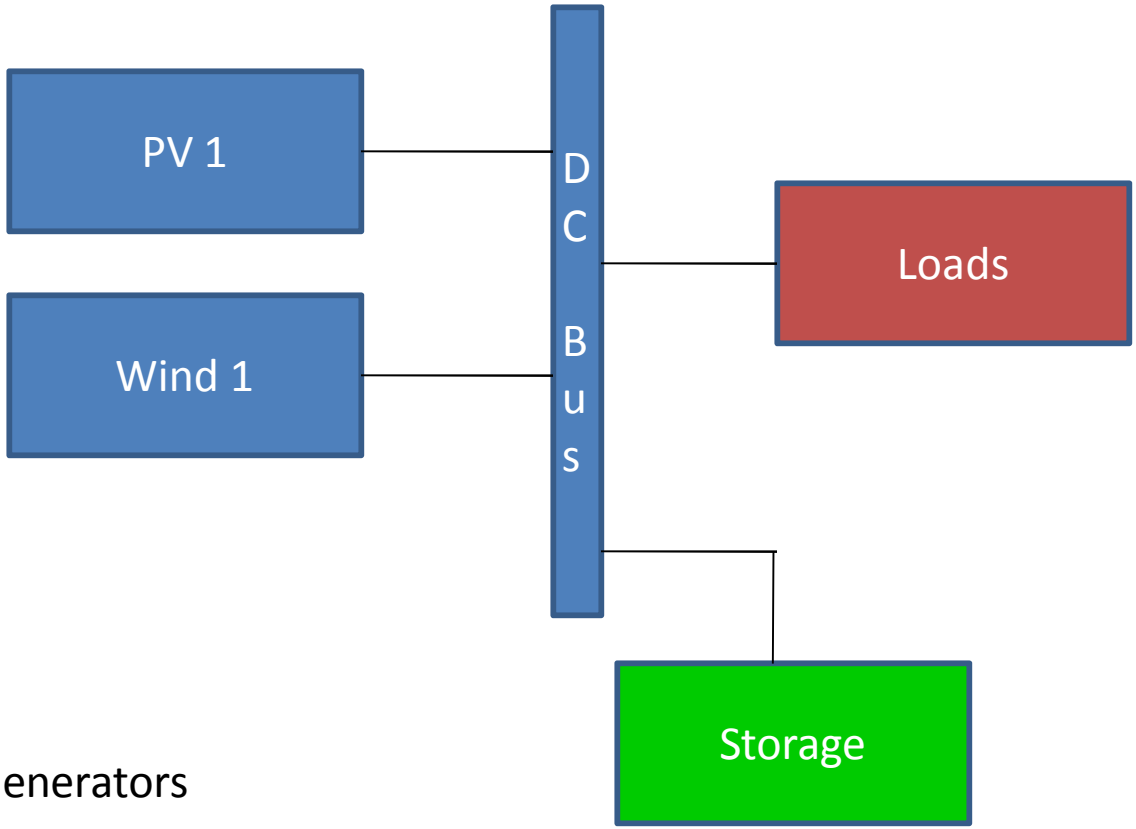
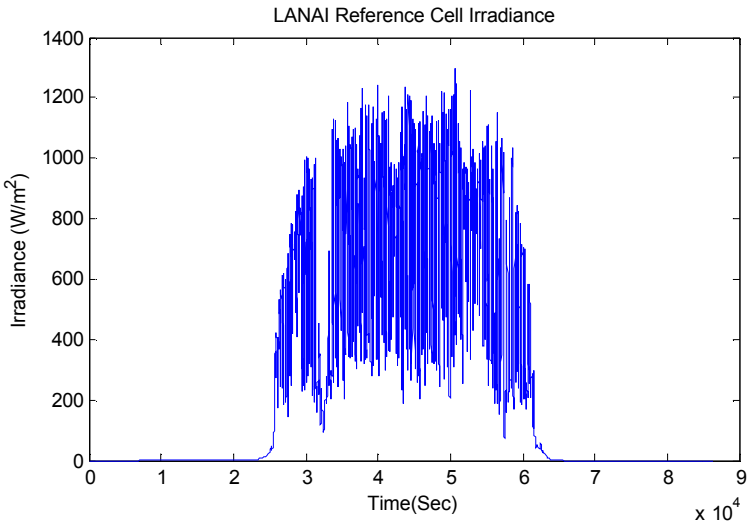
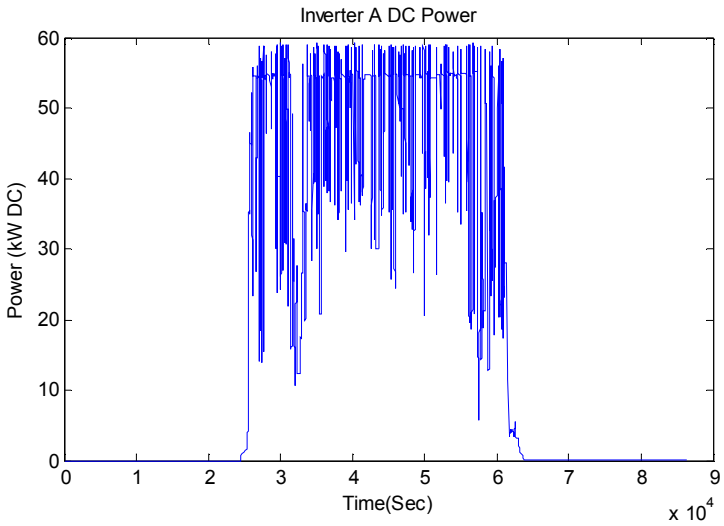
DC Microgrid

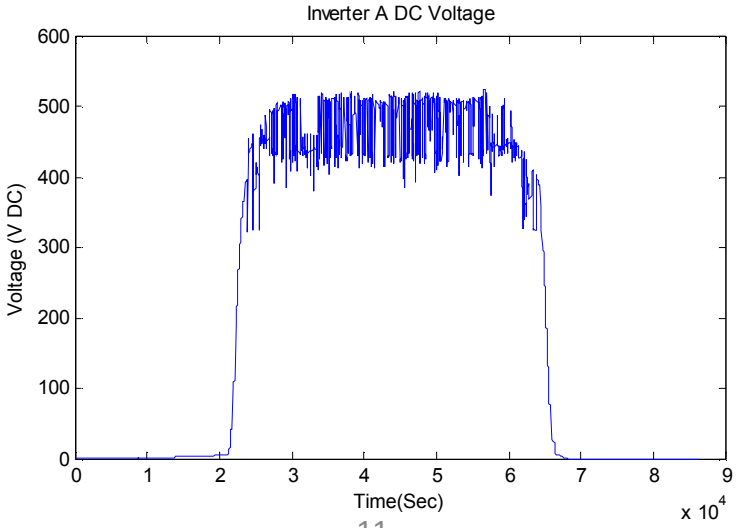


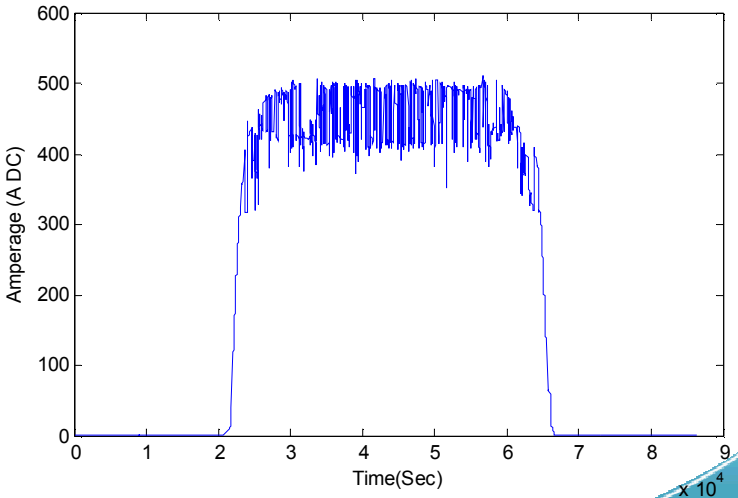
- 2 Variable Generators
- Storage
- Variable Loads

PV Data Lanai System









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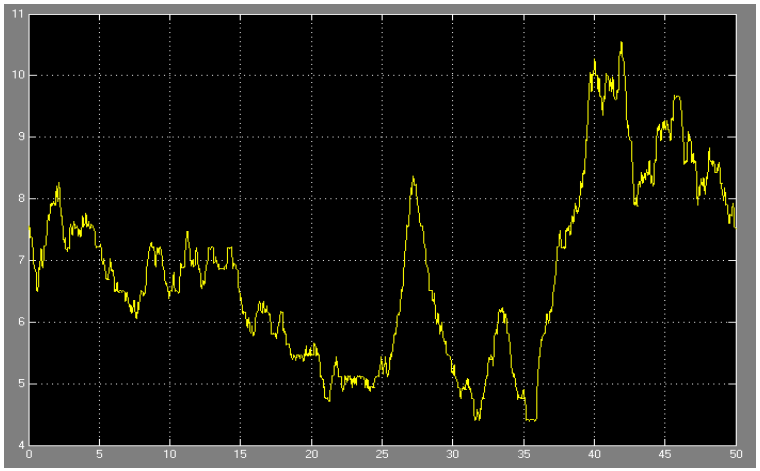
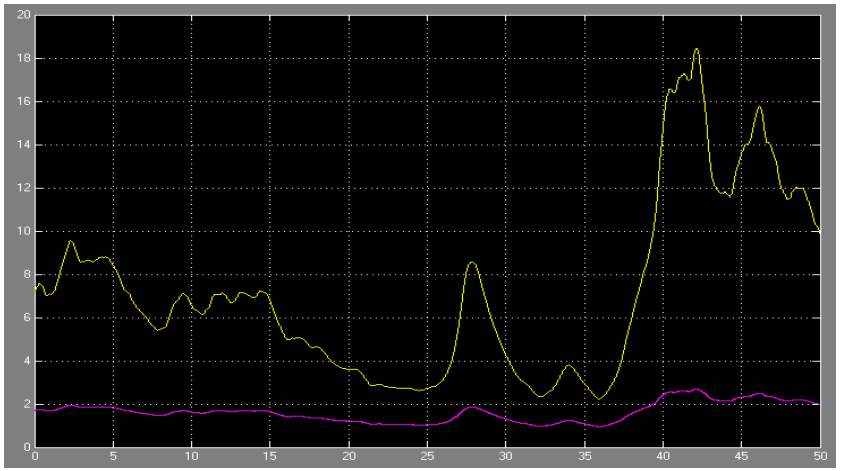
Variable Speed Wind Turbine Utilizing Bushland Test Site Data

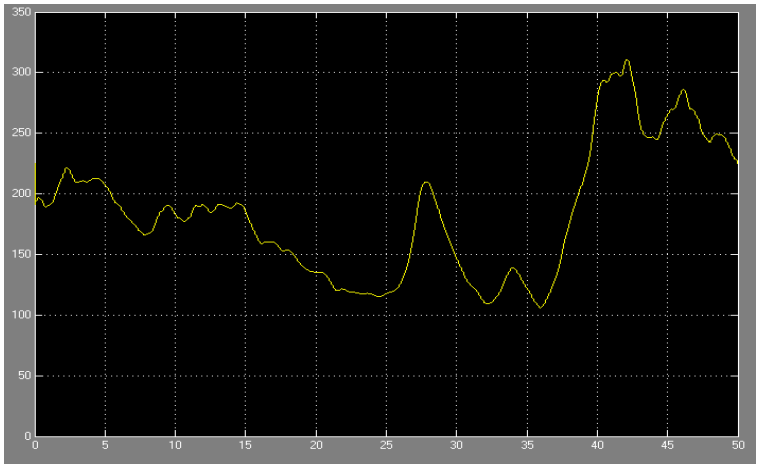
Wind Speed (m/s) *data from Bushland test site*



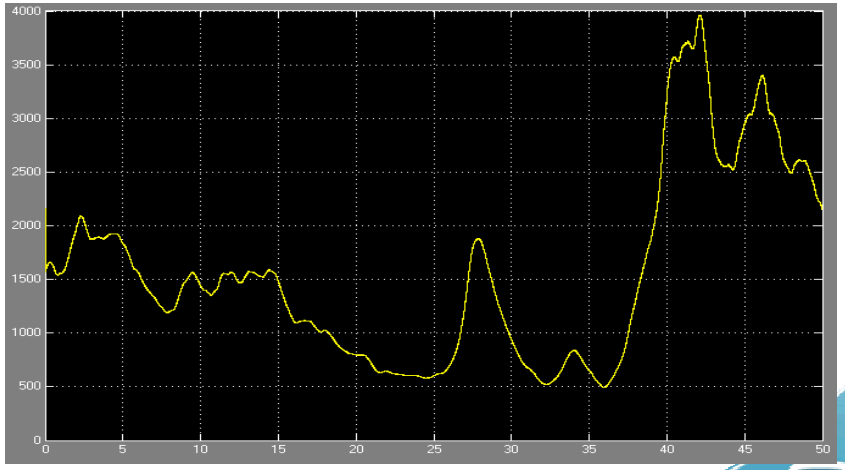
d and q axis currents (Amps)



Rotor speed (RPM)



Real Power Out (W)



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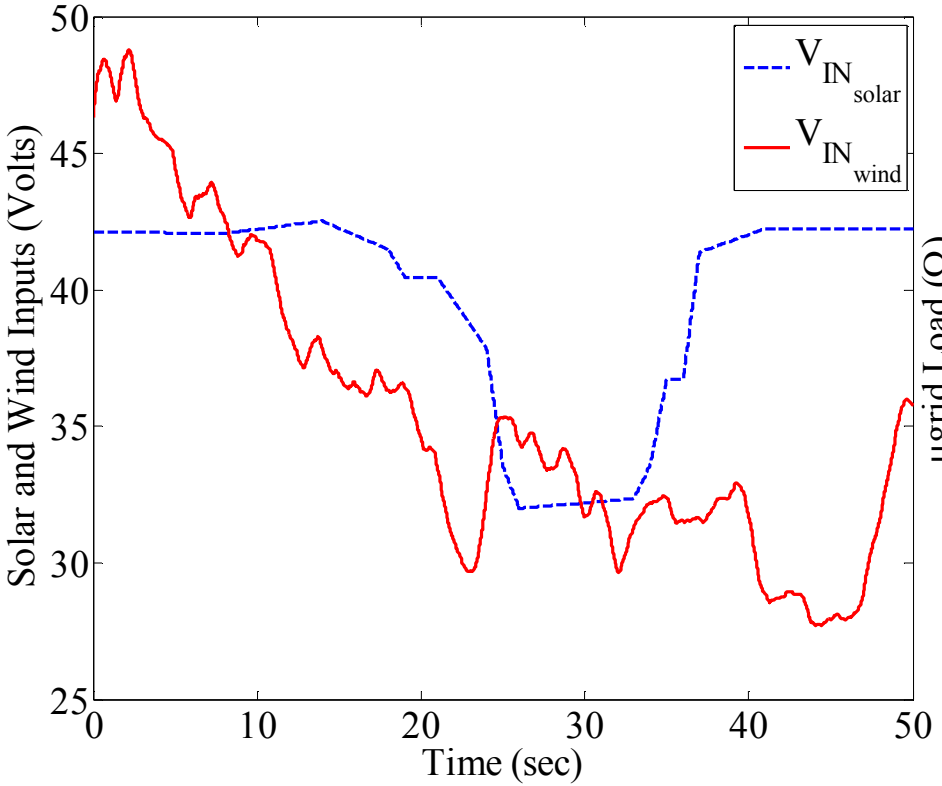
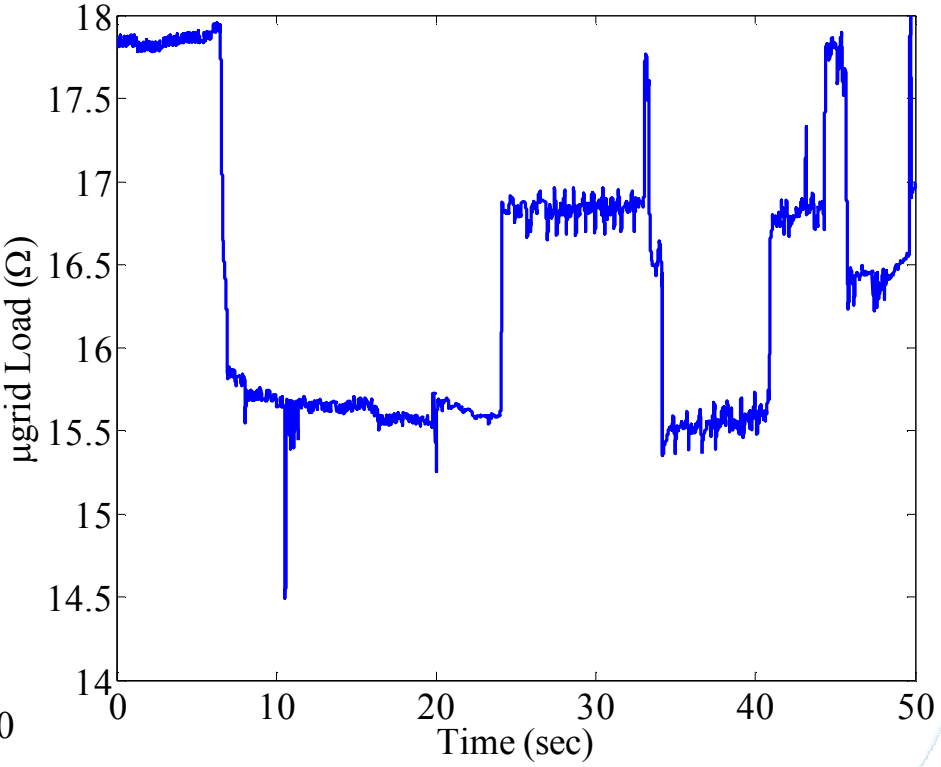
Numerical Results Solar, Wind and Loads Test Data

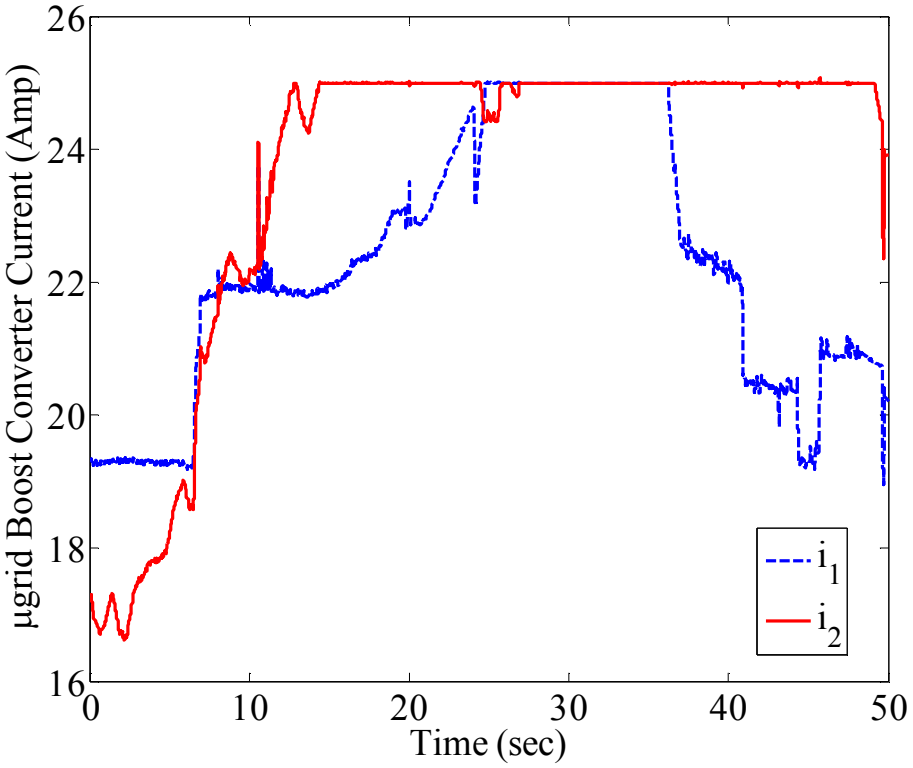


Solar and Wind Inputs from Test Data

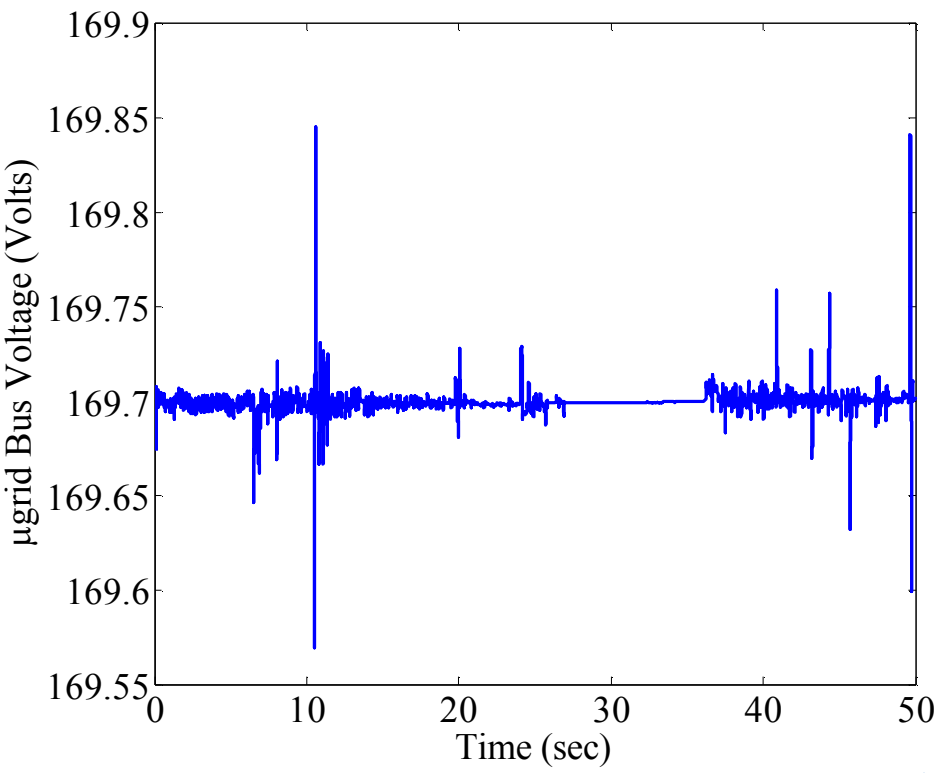


Actual Load Profile

Numerical Simulation Results Boost Converter Currents and Bus Voltage



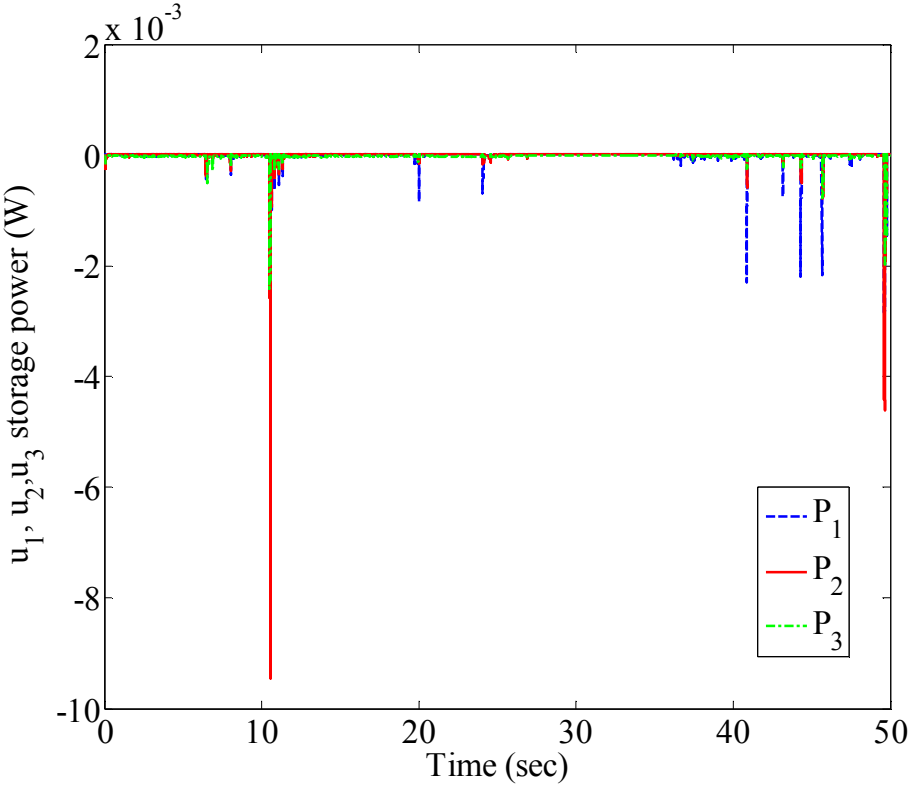
Boost Converter Currents
(Current saturation at 25 Amps)

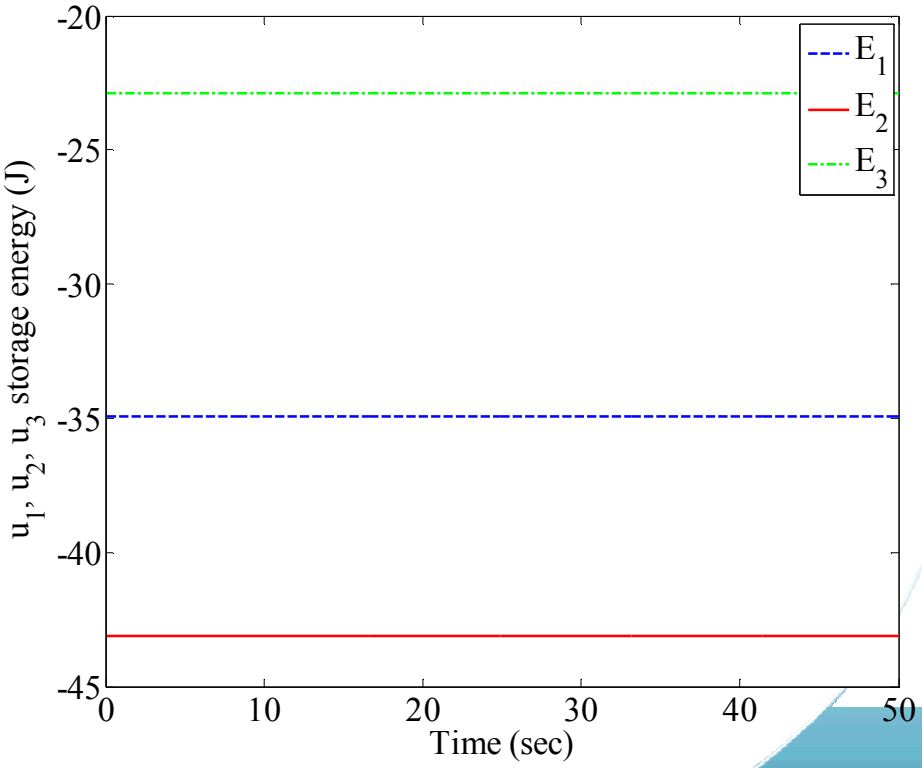


Bus Voltage
(Bus regulation 120*sqrt(2) +/- 5%)

Energy Storage Requirements

- **Power Requirements**
- **Energy Requirements**
- **Frequency Response Requirements (see next chart for individual channels)**





Specifications for the microgrid and/or UPFC based on:
(Power, Energy, Frequency PSDs)

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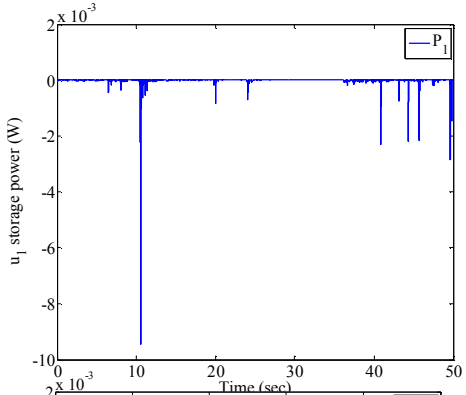
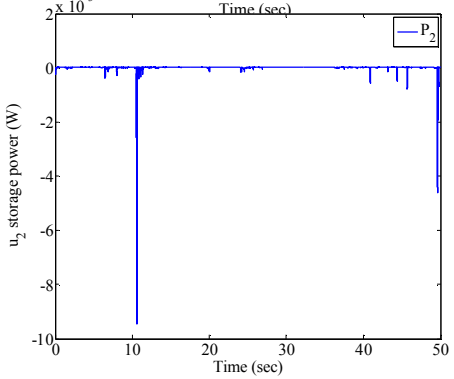
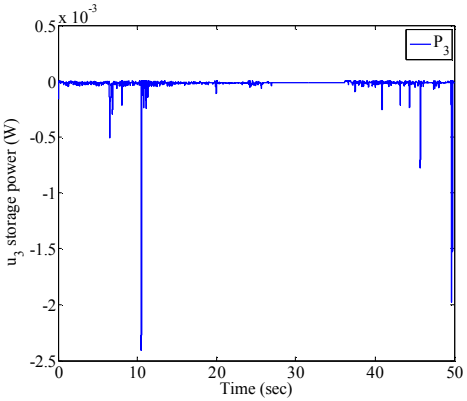
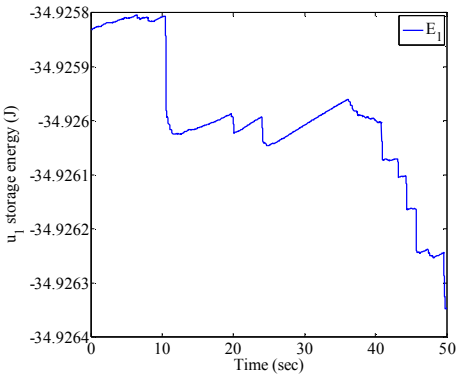
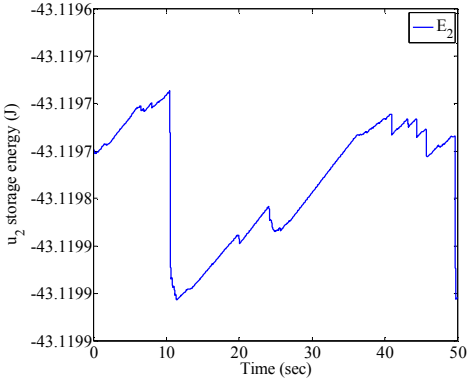
Energy Storage Requirements

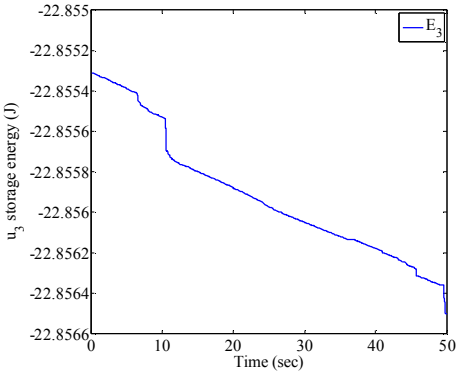


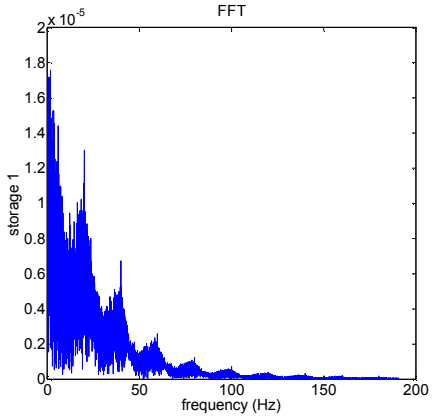


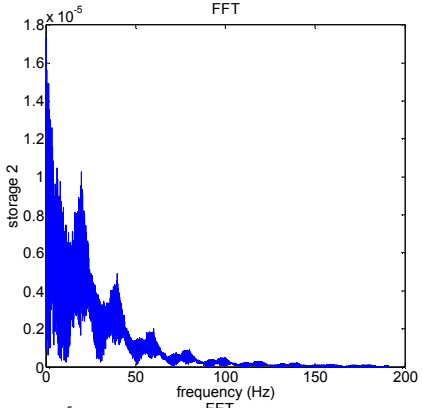


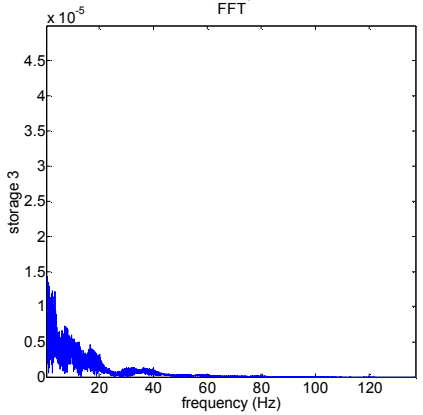












DC Boost 1

DC Boost 2

DC Bus

Power Requirements | Energy Requirements | Frequency Response

(requirements displayed for each channel - along the row)

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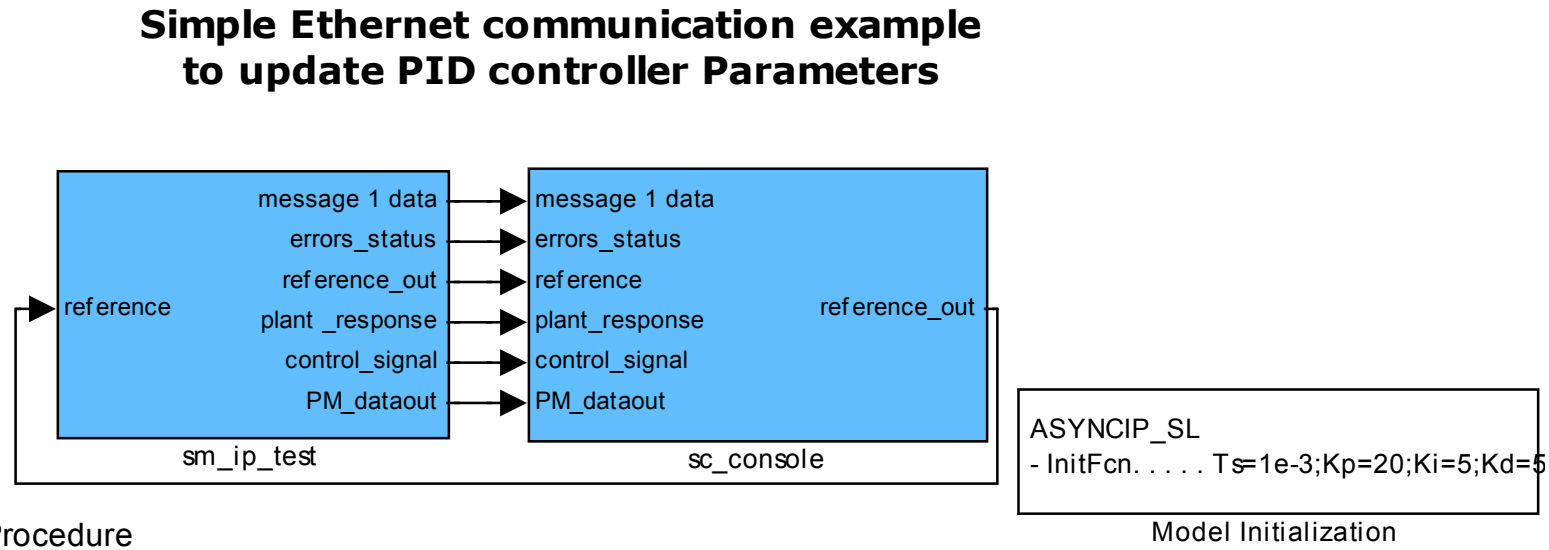
Agent/Control Interaction Scenario

- **First interaction that can be replicated with Agent Control Hardware Interaction with plant/control models, HIL, hardware testbeds**



Procedure

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- Launch the executable Server.exe located in the model's folder.
- Specify a Port number.
- Make sure that the OpIPAsyncCtrl icon uses the same Parameters displayed by the Server application.
- Compile, Load and Execute this model.

OPAL-RT

- Speed up simulation time by parsing out the model
- HIL with the single-phase microgrid being developed by Sandia
- Communicate with Agent based controls
- Allow Human interaction control using the Labview Testdrive

Questions