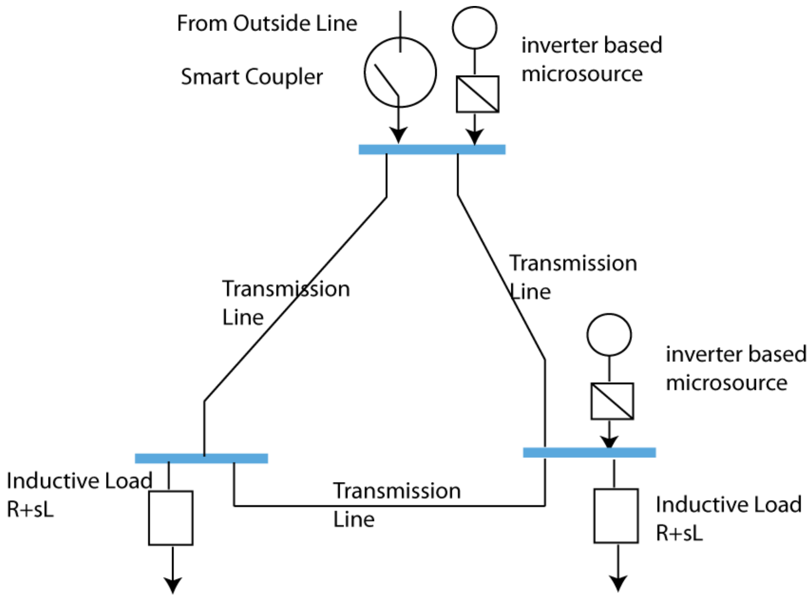
Mesh Microgrid



Phase I Microgrid

- Smart Coupler to Main Grid
- 3 buses , 2 loads
- 2 microsources
  - emulate droop controllers

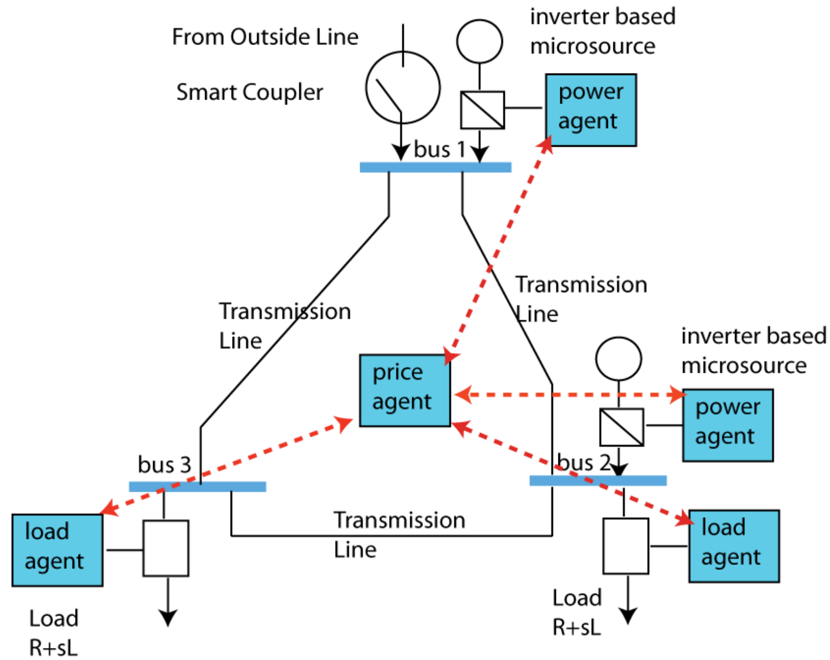
- Introduction of High-level distributed supervisory control to manage load shedding and power dispatch

Power Dispatch Results - Phase I

- Power Dispatch Problem

$$\begin{array}{ll} \text{minimize:} & C(p) = \sum_{i=1}^{2} C_i(P_i) \\ \text{subject to:} & \sum_{i=1}^{2} P_i = \sum_{i=1}^{2} P_{Li} \\ & 0 \leq P_i \leq 1 \end{array}$$

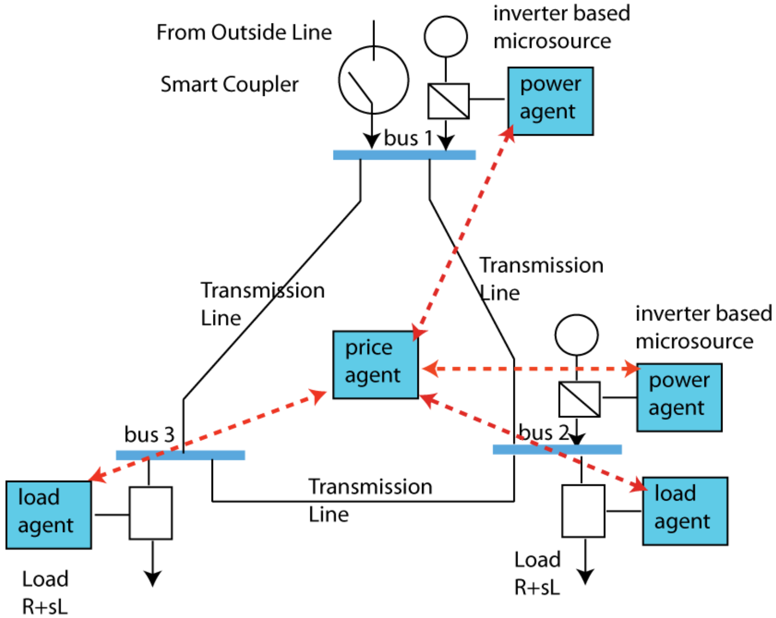
- Distributed Dispatch

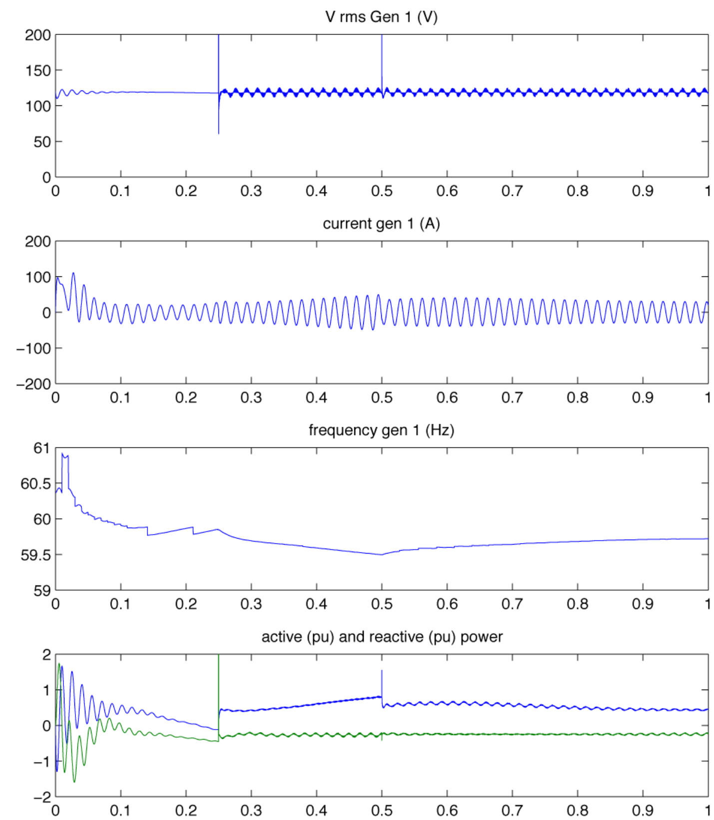


$$\begin{aligned} P_i[k+1] &= \arg\max_{P_i} \left[C_i(P_i[k]) - P_i[k] \sum_j \lambda_j[k] \right] \\ \lambda_j[k+1] &= \max\left(0, \lambda_j[k] + \gamma(P_1[k] + P_2[k] - c_j)\right) \end{aligned}$$

Power Dispatch Results - Phase I

- Disconnect from Main Grid (0.25)
- Turn on Power Dispatcher (0.5)

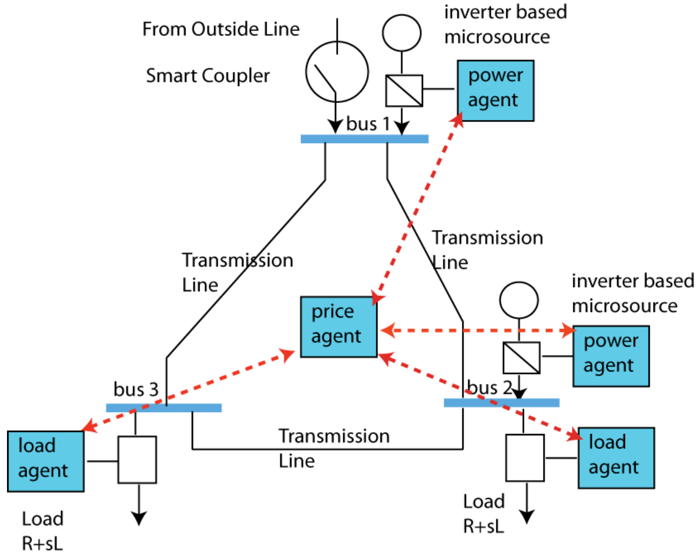


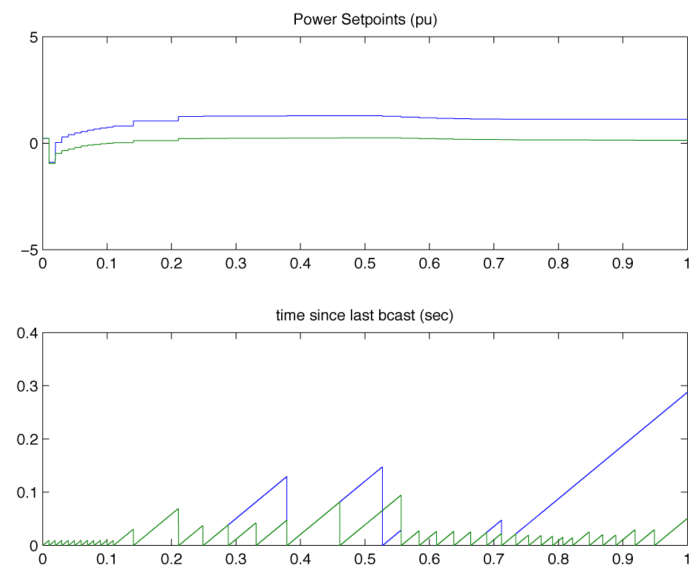


Power Dispatch Results - Phase I

- Event-Triggered Dispatch

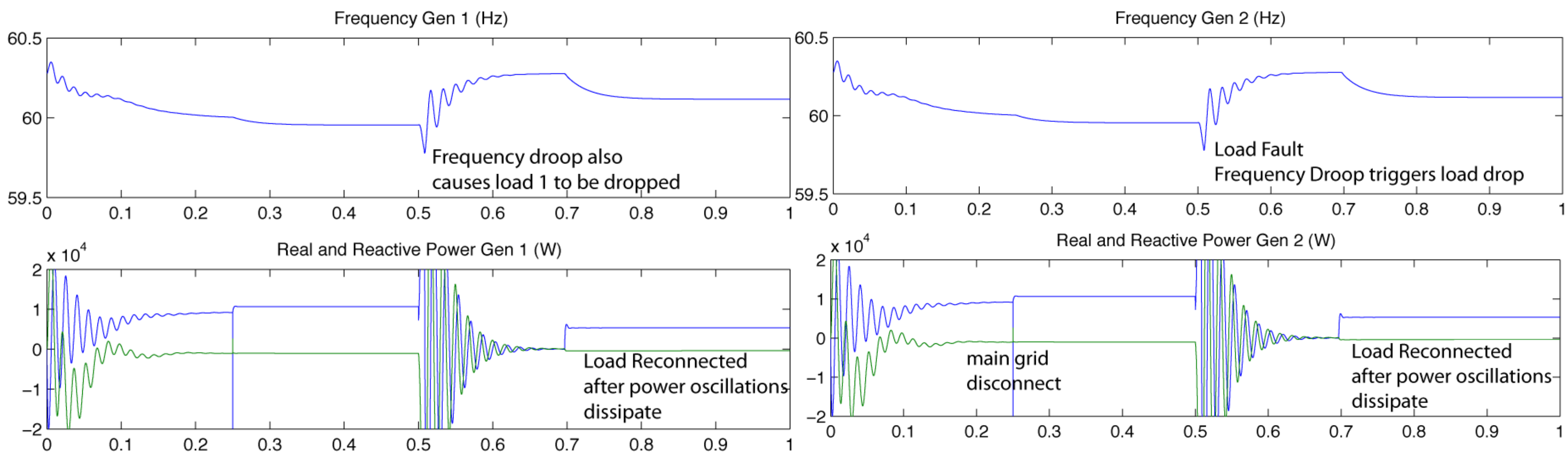
$$\begin{array}{ll} \text{Price Agent Broadcast Trigger:} & \|\lambda(t) - \lambda(b_\lambda[k])\| \leq \rho\|\lambda(t)\| \\ \text{Power Agent Broadcast Trigger:} & |P_i(t) - P_i(b_{Pi}[k])| \leq \rho|P_i(t)| \\ \text{Load Agent Broadcast Trigger:} & |P_{Li}(t) - P_{Li}(b_{Li}[k])| \leq \rho \end{array}$$





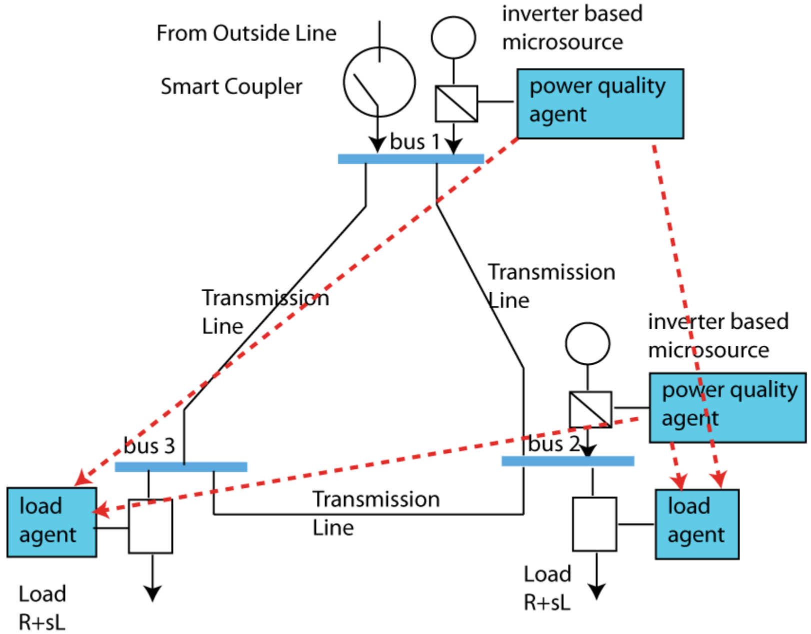
Load Shedding Results - Phase I

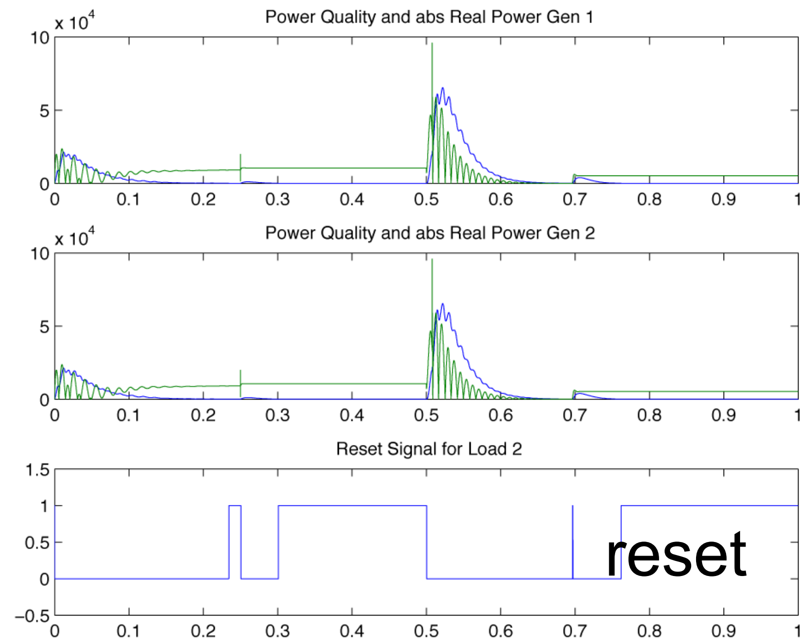
- Short on Bus 2 triggers all loads to be dropped
- Load Agent disconnects on frequency droop
- How to reconnect loads after fault cleared?



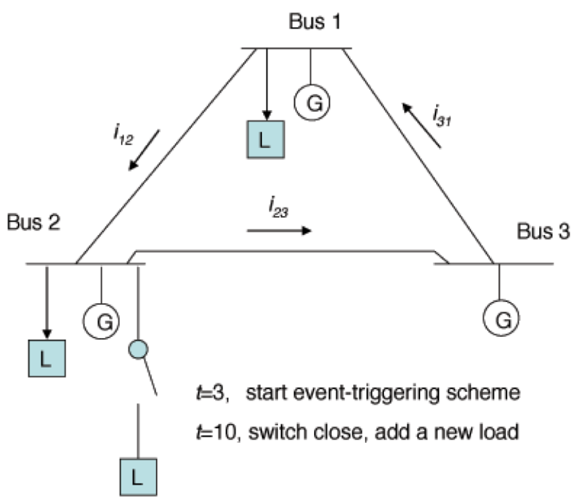
Load Shedding Results - Phase I

- Load Agent drops load on frequency droop
- Reconnection conditioned on reset signal from “power quality” agent
- Power Quality agent sends reset after it detects that power oscillations have subsided.



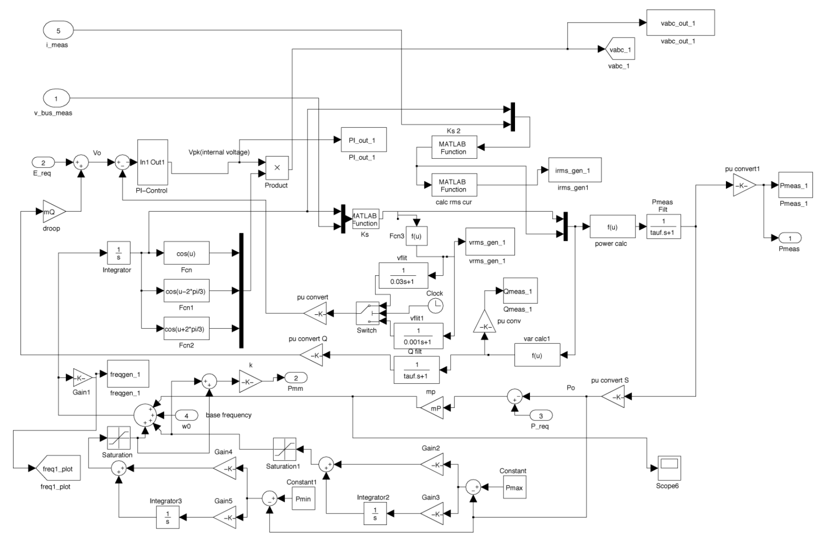


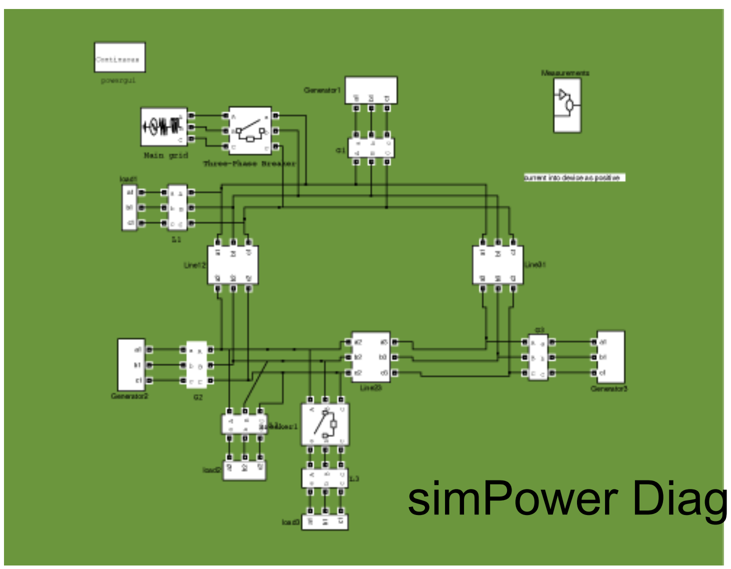
Mesh Microgrid - Re-examined



- simPower Model developed
  - Based on UIUC phase I model
  - Islanded operation
  - Discontinuous Load Change on Bus 2

Simulink Generator Model

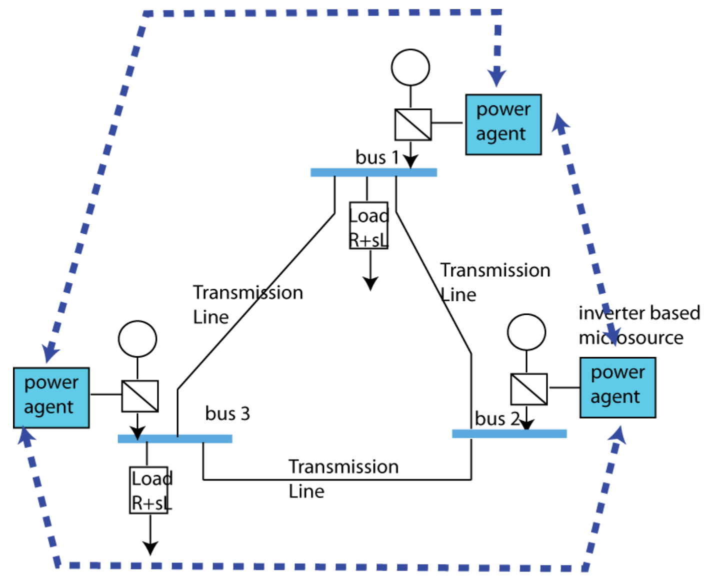




simPower Diagram

Power Dispatch with Transmission Line Constraints

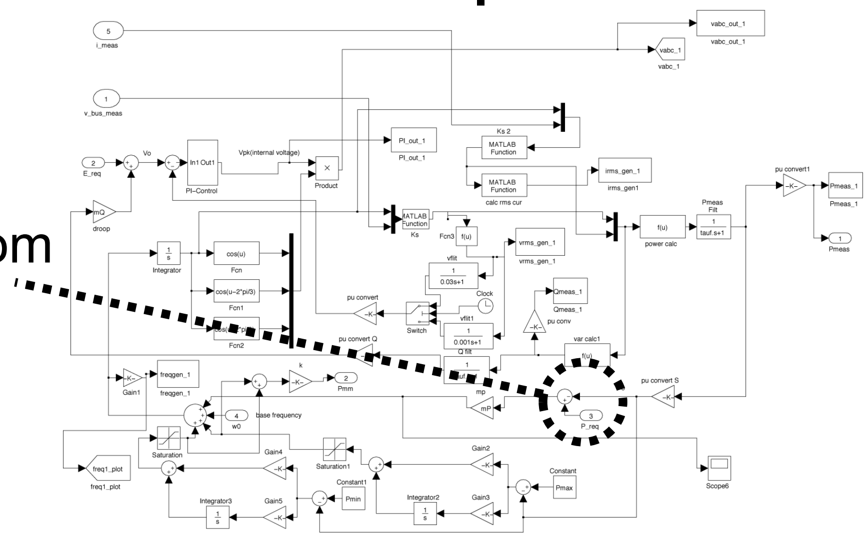
- Power agents monitor
  - Generator set points
  - Transmission line power
- Power balance relation always maintained by low level controller
- Dispatch Problem with transmission line constraints

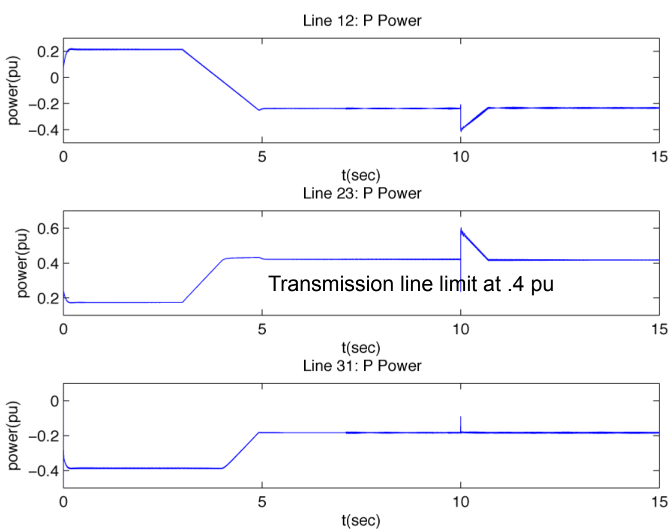


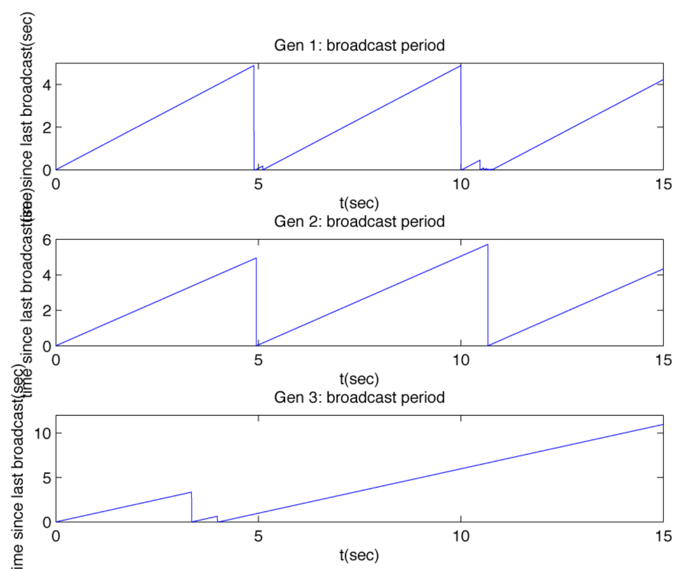
$$
\begin{aligned}
&\text{minimize:} && C(P) = \sum_{i=1}^{N} C_i((B\theta)_i + P_{Pli}) \\
&\text{with respect to:} && \theta = \text{generator phase angles} \\
&\text{subject to:} && \underline{P}_G - P_L \leq B\theta \leq \overline{P}_G - P_L \\
& && \underline{P} \leq A\theta \leq \overline{P}
\end{aligned}
$$

Event-Triggered Power Dispatch

- Insert Control that augments local control with feedback from neighboring generators
- Formal Convergence Proof (submitted ACC 2010)







Phase II Tasks - Notre Dame

- Task 1 Power System Simulation
  - Develop single-phase and three phase simPower simulation of candidate microgrids provided by UW
  - Integrate with UIUC simulation models of microsource inverters
  - Scalability and performance studies
- Task 2 Distributed Control Algorithm Development
  - Distributed power dispatch with transmission line constraints
  - Distributed Load Shedding and Reconnection algorithms
  - Provide UIUC with interface requirements for microsource inverter
  - Provide Odyssian with I/F requirements for eBoard Load Controller
- Task 3 Wireless Distributed Control Software
  - Assist with embedded coding of distributed control algorithms
  - Provide Odyssian with I/F requirements for communication system
- Task 4 Wireless Communication
  - Assist in integration of comm network with distributed control algorithms
  - Assist in improvement of communication network middleware

Recently Proposed and Awarded Projects

- **CPS:Small: Dynamically Managing the Real-time Fabric of a Wireless Sensor-Actuator Network**
  National Science Foundation (CNS-0931195) $525,000 - 2009-2012

  The objective of this research is to develop algorithms for wireless sensor-actuator networks (WSAN) that allow control applications and network servers to work together in maximizing control application performance subject to hard real-time service constraints. The approach is a model-based approach in which the WSAN is unfolded into a real-time fabric that captures the interaction between the network's cyber-processes and the application's physical-processes.
- **Distributed Optimization, Estimation and Control of Networked Systems Using Event-Triggered Message Passing**
  National Science Foundation (ECCS-0925229) $298,899 - 2009-2012

  The objective of this program is to develop event-triggered methods for message passing in the optimization, estimation, and control of networked dynamical systems. The project's impact will be broadened through interactions with industrial partners EmNet LLC and Odyssian LLC. EmNet LLC is interested in using event-triggered message passing on the CSOnet system, a wireless sensor-actuator network being used to control the frequency of combined sewer overflow (CSO) events. Odyssian LLC is interested in using event-triggered methods for the intelligent control of event-triggered microgrids.