Multi-Layered Simulation using the SGRS Simulator; Interaction of TE and Flywheel Controlled Dynamic System

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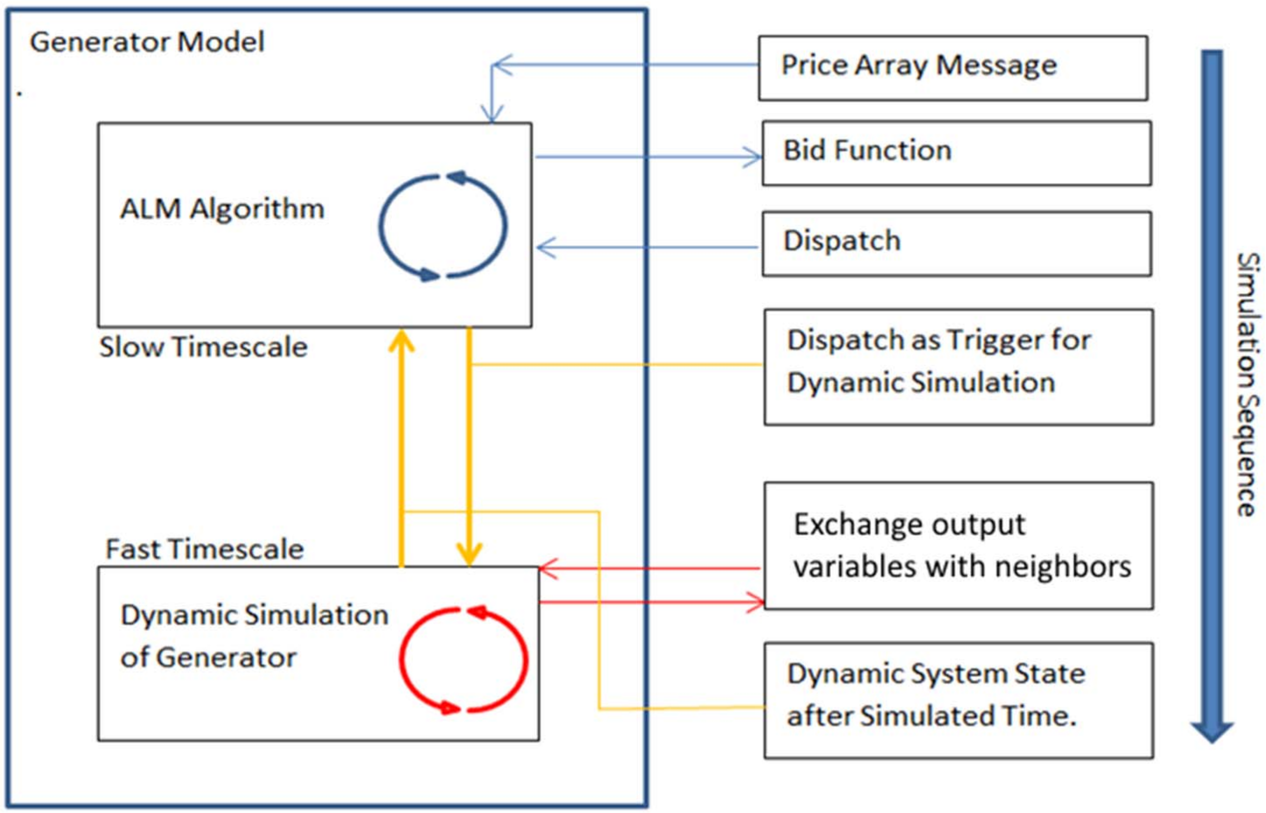
10th CMU Electricity Conference
Pre-conference Workshop
March 30, 2015

Outline

- Link multi-time scale simulations
  - Adaptive load management (ALM): slow time-scale
  - Fast dynamics with flywheel control: fast time-scale
- Market needs to specify reactive power set point
  - Reactive power set point is critical to whether there is an equilibrium
  - Depending on the reactive power set points, sometimes dynamics cannot be stabilized
- Demonstrate stable and unstable responses on Smart Grid in a Room Simulator

Interactive Communication

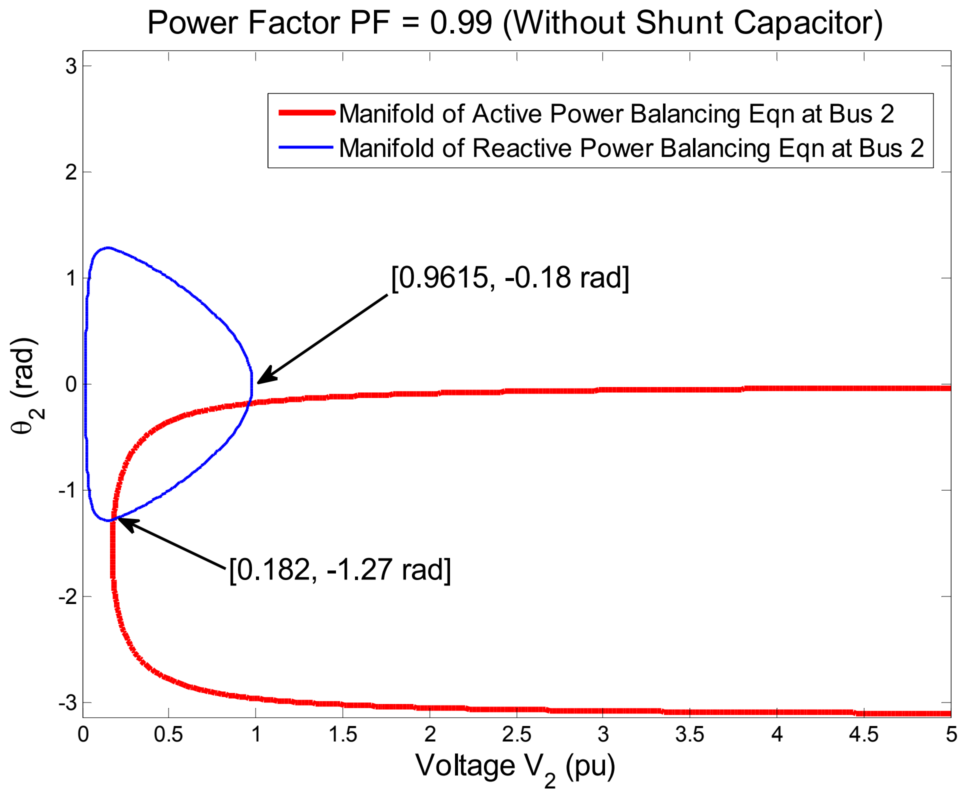
❖ Communication for multi time-scale simulation with ALM and fast dynamics for generators

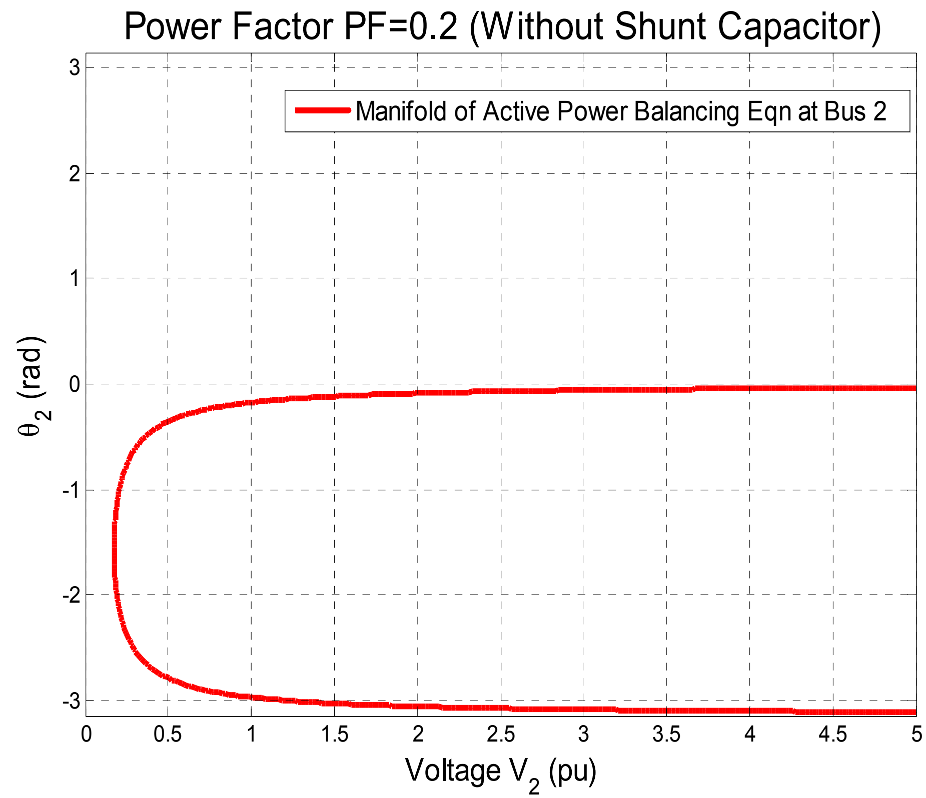


Source: M. R. Wagner, K. D. Bachovchin, M. D. Ilić, "Computer Architecture and Multi Time-Scale Implementations for Smart Grid in a Room Simulator," EESG Working Paper No. R-WP-1-2014, March 2015.

Importance of Reactive Power

- Typically the market only specifies the active power set point
- However the reactive power is critically important to the equilibria and stability of the system





Source: X. Miao, K. D. Bachovchin, M. D. Ilić, "Effect of Load Type and Unmodeled Dynamics in Load on the Equilibria and Stability of Electric Power System," EESG Working Paper No. R-WP-1-2014, March 2015.

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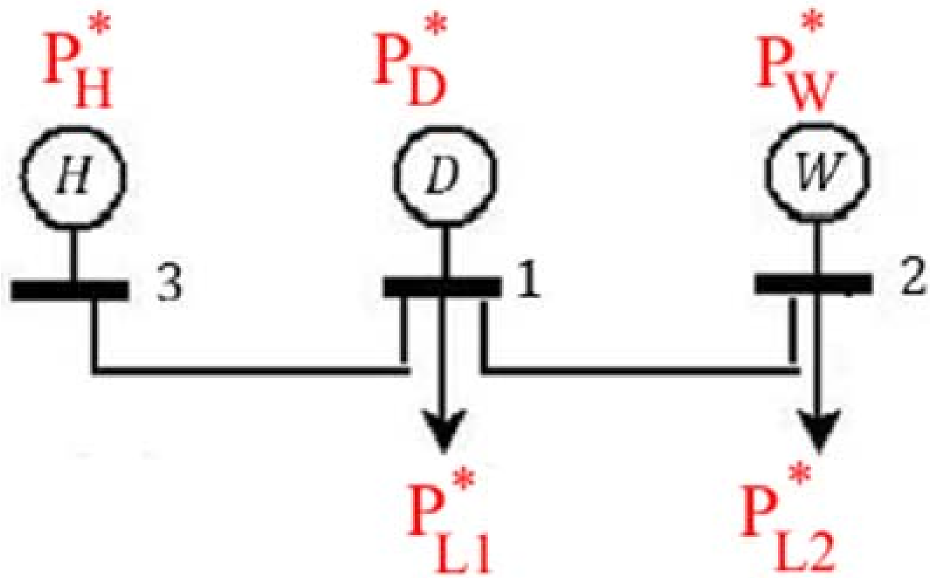
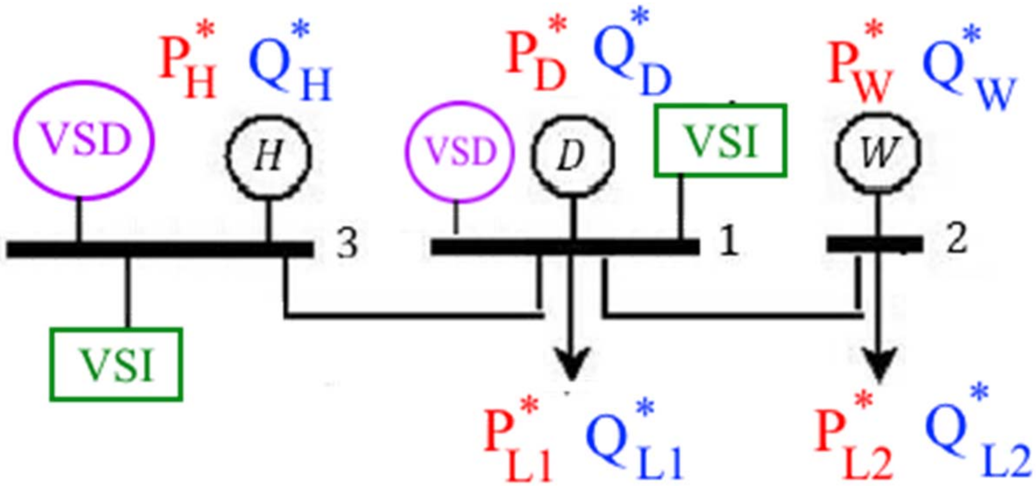
Flores Island – Market Control

- Based on prices, market computes active power set points P* from each component



Flores Island – Dynamics Control

- Since currently the market does not specify reactive power set points Q*, data for Q* is randomly created
- Place a voltage source inverter and the variable speed drive on the hydro and diesel generator buses
- Control the sum of the power out of the hydro and diesel generators to match the active and reactive power set points



Flores Island – Variable Speed Drive Control

- Determine the variable speed drive set points based on the set points from the market

- Controllable inputs for the variable speed drive are

$$\mathbf{u}_k = \mathbf{g}_k\left(x_k, y_{ck1}, y_k^{ref}\right)$$

$$\mathbf{u}_k = \begin{bmatrix} u_{1d} & u_{1q} & u_{2d} & u_{2q} \end{bmatrix}^T$$

$$\mathbf{x}_k = \begin{bmatrix} i_{1d} & i_{1q} & q_{C1} & i_{S2d} & i_{S2q} & i_{R2} & \omega & \theta \end{bmatrix}^T$$

$$\mathbf{y}_{ck1} = \begin{bmatrix} v_d & v_q \end{bmatrix}^T$$

$$\mathbf{y}_k^{ref} = \begin{bmatrix} \omega_2^{ref} & i_{1d}^{ref} & i_{1q}^{ref} \end{bmatrix}^T$$

- Set points for the variable speed drive are

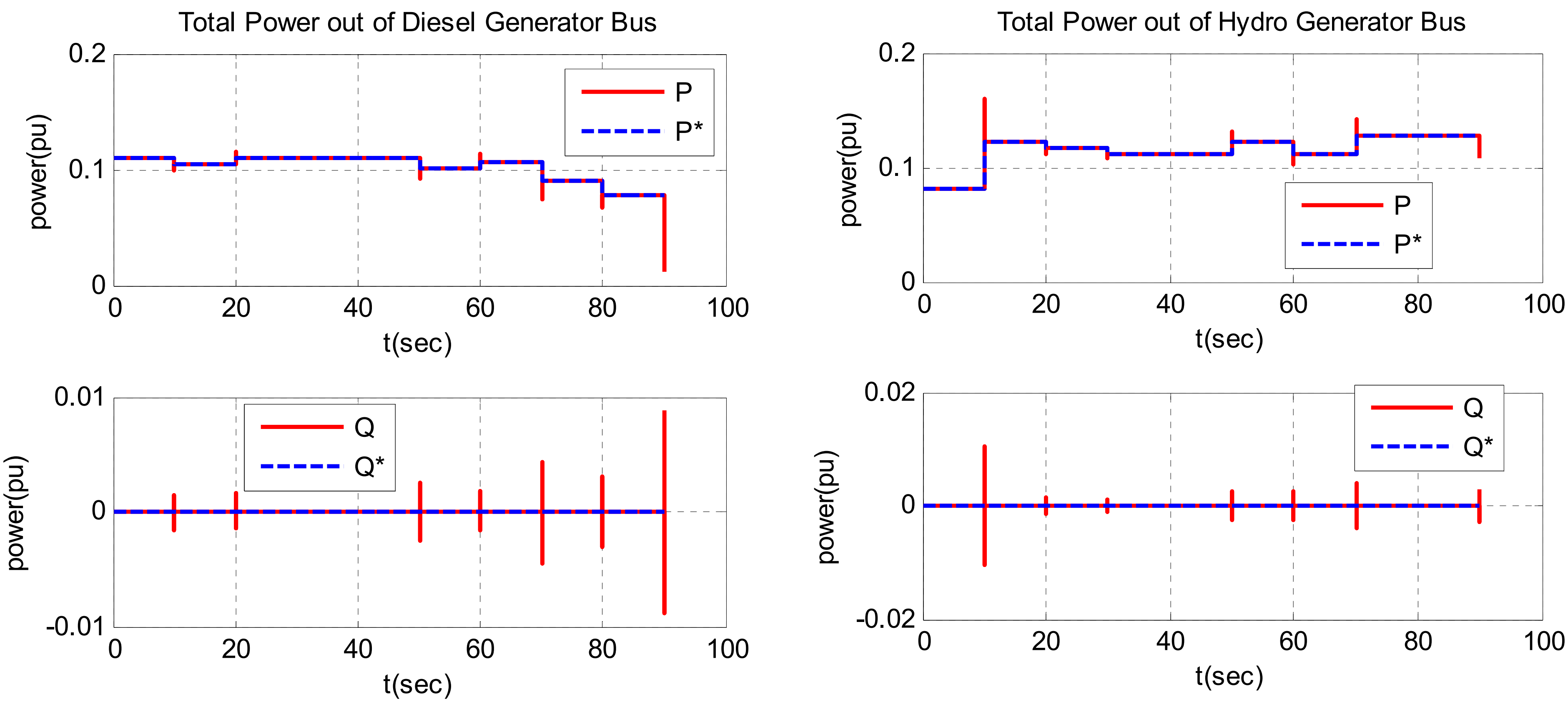
$$\mathbf{y}_k^{ref} = \mathbf{h}_k\left(y_{ck2}, r_k^{ref}\right)$$

$$\mathbf{y}_{ck2} = \begin{bmatrix} i_{Gd} & i_{Gq} \end{bmatrix}^T$$

$$\mathbf{r}^{ref} = \begin{bmatrix} P_G^* & Q_G^* \end{bmatrix}^T$$

$$\underbrace{\begin{aligned} P_G^* &= V_d\left(i_{1d}^{ref} + i_{Gd}\right) + V_q\left(i_{1q}^{ref} + i_{Gq}\right) \\ Q_G^* &= V_q\left(i_{1d}^{ref} + i_{Gd}\right) - V_d\left(i_{1q}^{ref} + i_{Gq}\right) \end{aligned}}_{Solve\ for\ i_{1d}^{ref}\ and\ i_{1q}^{ref}}$$

Simulation Results – Hydro/Diesel Generator Bus



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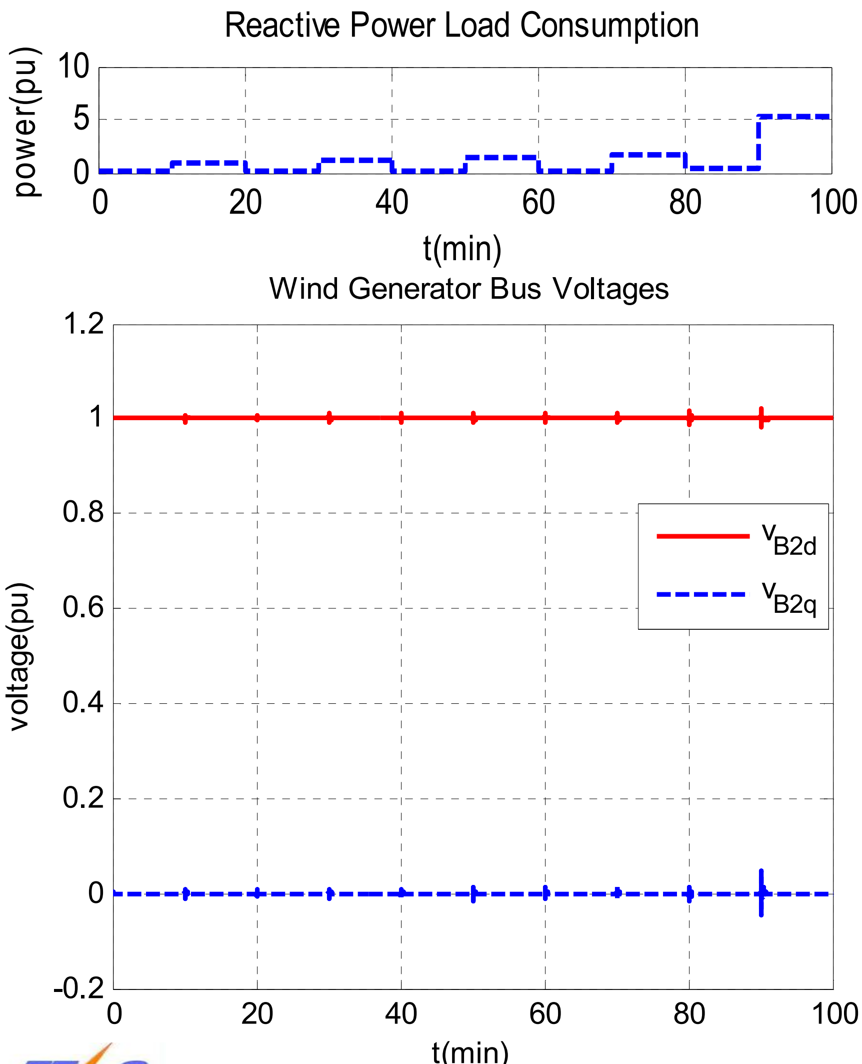
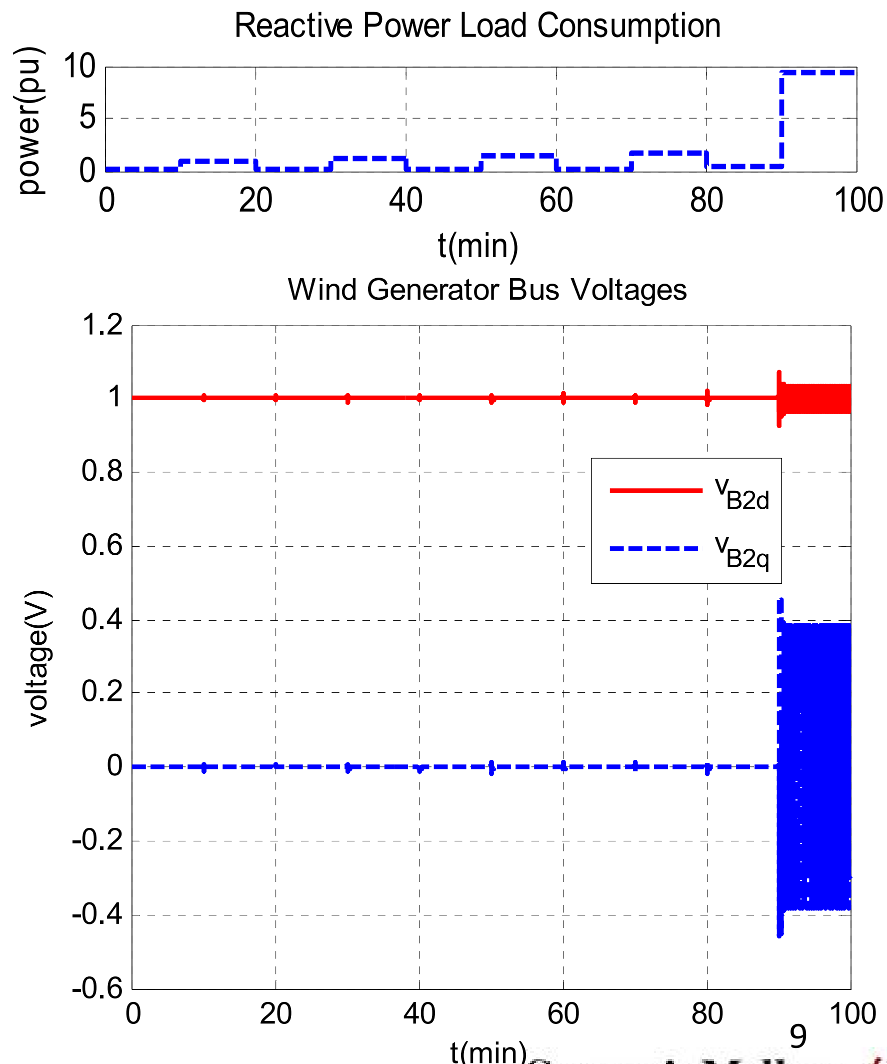
Simulation Results – Wind Generator Bus

Stable Case:



Unstable Case:



Conclusions

- Demonstrated multi time-scale simulation with feedforward market controller and feedback flywheel controller
- Showed that with a high reactive power load, the system may not reach a stable equilibrium

Future Work

- Market level controller specify the reactive power set point
- Design fast dynamic control, so that we don't need voltage source inverter at each bus
- Combine with other time-scale simulations (AGC)