Wide Area Control Systems (1.4)

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Task Objectives

- Wide-area control designs for future systems
- High percentage of renewable energy sources
- Fast wide-area monitoring systems with PMUs everywhere
- What control designs are feasible?
- Voltage stability issues at substations from reactive power demands of renewables
- Small-signal stability problems from interactions of power electronic devices with the grid
- Transient stability concerns from unforeseen operating conditions

Accomplishments

- Develop a new wide-area transient stability controller aimed at uncertain operating conditions of the future and for highly complex, unplanned for, large contingencies

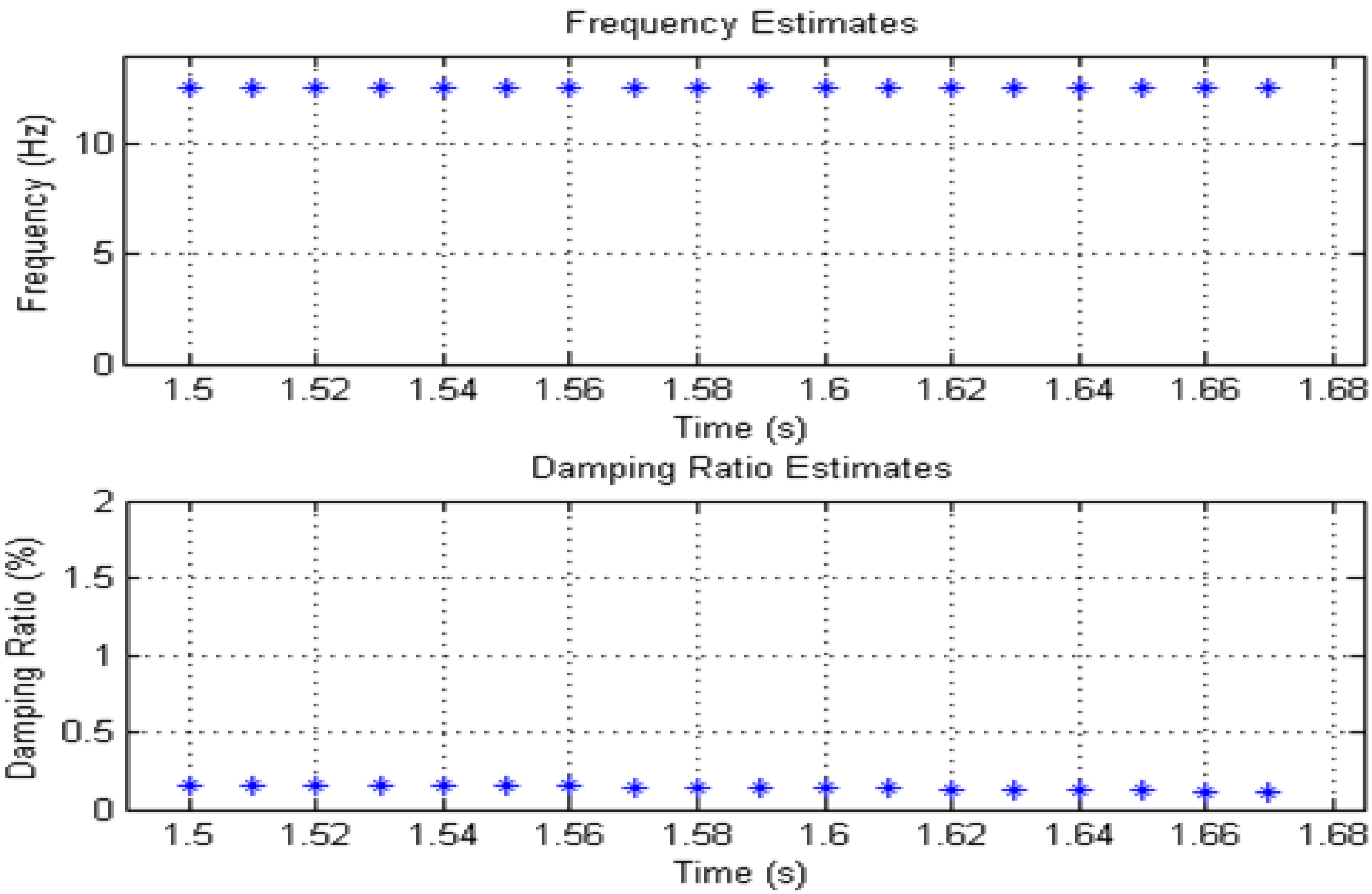
Benefits

- Improved controls resulting from better real-time system data, thus taking advantage of new synchrophasor technologies
- Response to system events that is faster and more efficient with less load loss

Small-signal stability

- Challenging problem from interaction of discrete and continuous dynamics
- Subsynchronous high frequency modes (5 Hz to 50Hz) from power electronic devices
- Controls on power electronic side may be culprits
- Detection and isolation crucial
- Which substation(s)? Which controls?
- New algorithms for monitoring and analysis of subsynchronous modes developed
- Tested on 12.5 Hz SSR Mode seen in certain wind farms in Oklahoma Gas & Electric (NASPI)

FDD Results from OGE data



12 Hz Mode Detection from 5760 Hz DFR data

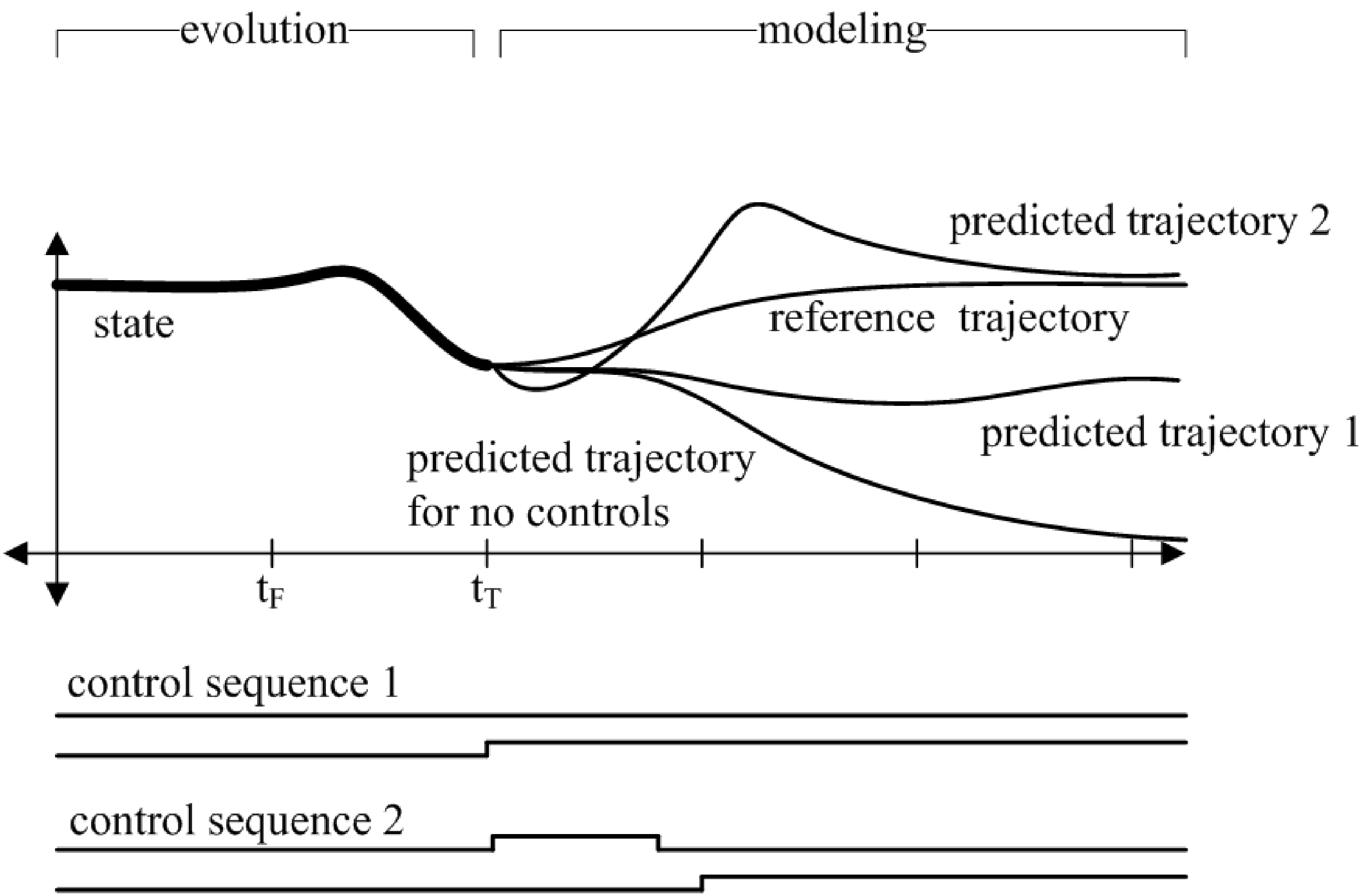
Wide-Area Transient Stability Controller

- New model prediction based real-time angle stability control developed
- Suited for uncertain operating conditions with unplanned high order contingencies
- PMUs assumed everywhere
- Fast communication and computation assumed
- Stable or unstable? What control actions? Algorithms developed.
- Can stabilize highly complex contingencies
- Doctoral dissertation work of **Greg Zweigle**
- IEEE PES Trans. paper

Wide-Area Transient Stability Controller

- Investigate stabilization of large contingencies
- Difficult to pre-plan for these cases
- Leverage advances in synchrophasors
  - Network measurements
  - Emerging generator measurements
- Model prediction formulation proposed
- Don’t try to predict contingencies
- Instead, predict state evolution
  - Run in real-time
  - Iterative application, with feedback
  - At each iteration, search for optimal control

Model Prediction Control (MPC)



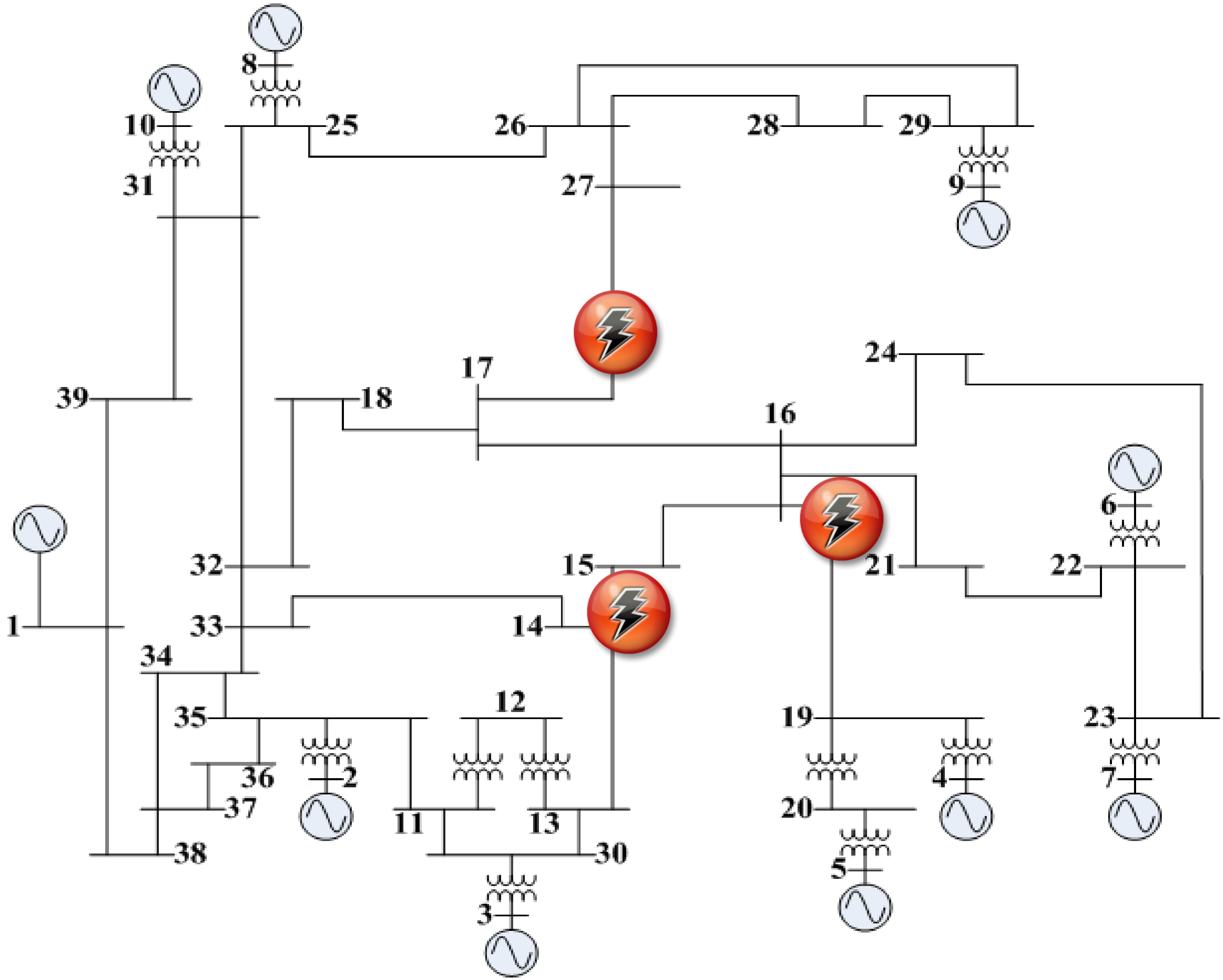
MPC & Transient Stability

- MPC originally for chemical process control
- Previously applied for slower power system phenomena
  - Voltage stability control
  - Small-signal rotor angle control
- Must act within seconds
- Doesn’t require as many control options
- Communications and computers getting faster

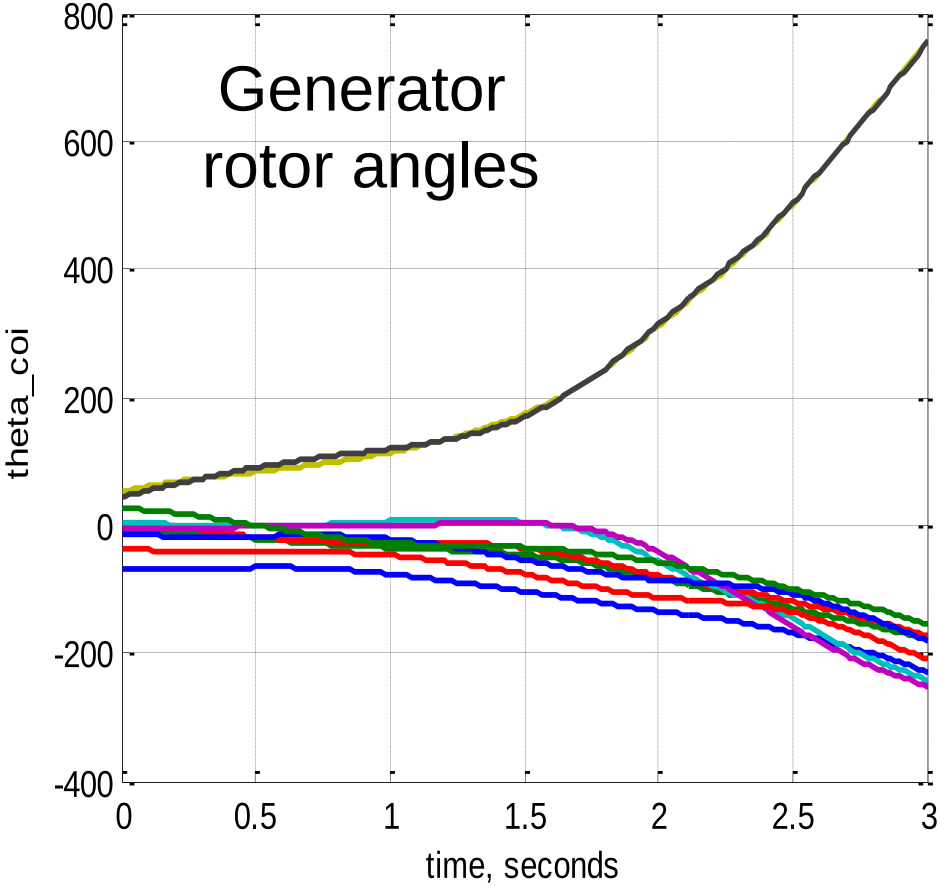
Transient Stability Controller Goal

After large contingencies,
effect recovery to stable operating point
through rapid and *minimal system changes*,
while also keeping the system
within specified constraints on
acceptable voltage deviations and
acceptable frequency fluctuations

Triple Line - Faults and Cleared



Iteration 1 Prediction Sequences

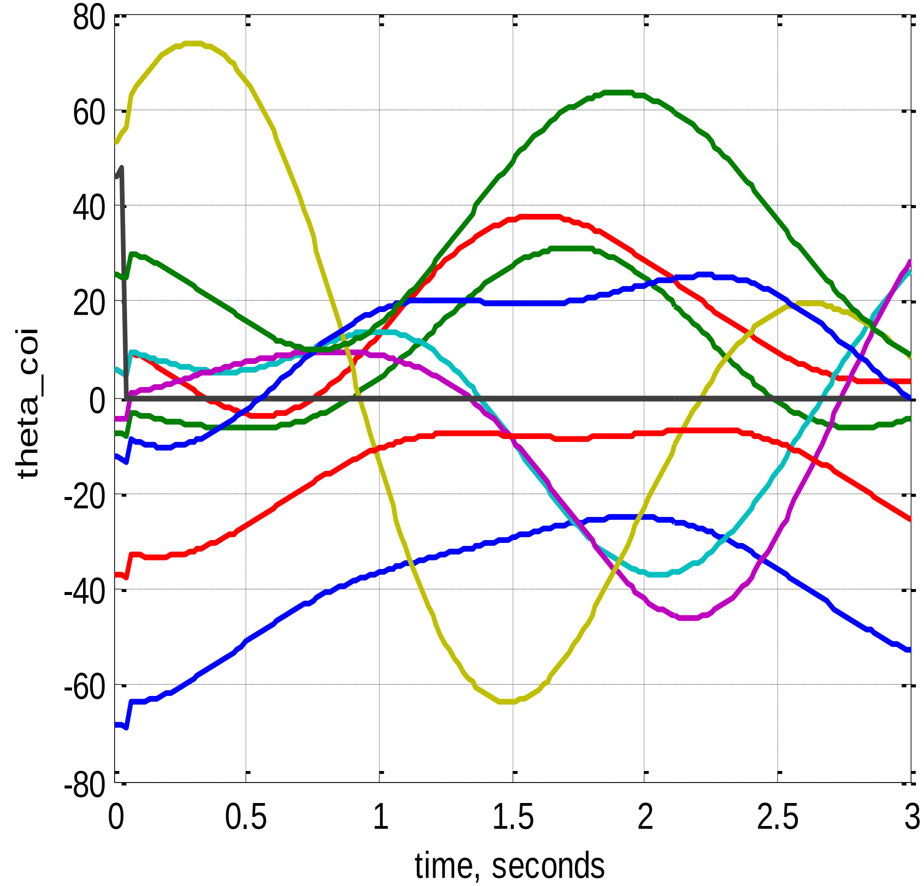


<u>No controls</u>

State Cost = 0.08

Control Cost = 2

Total Cost = 0.16



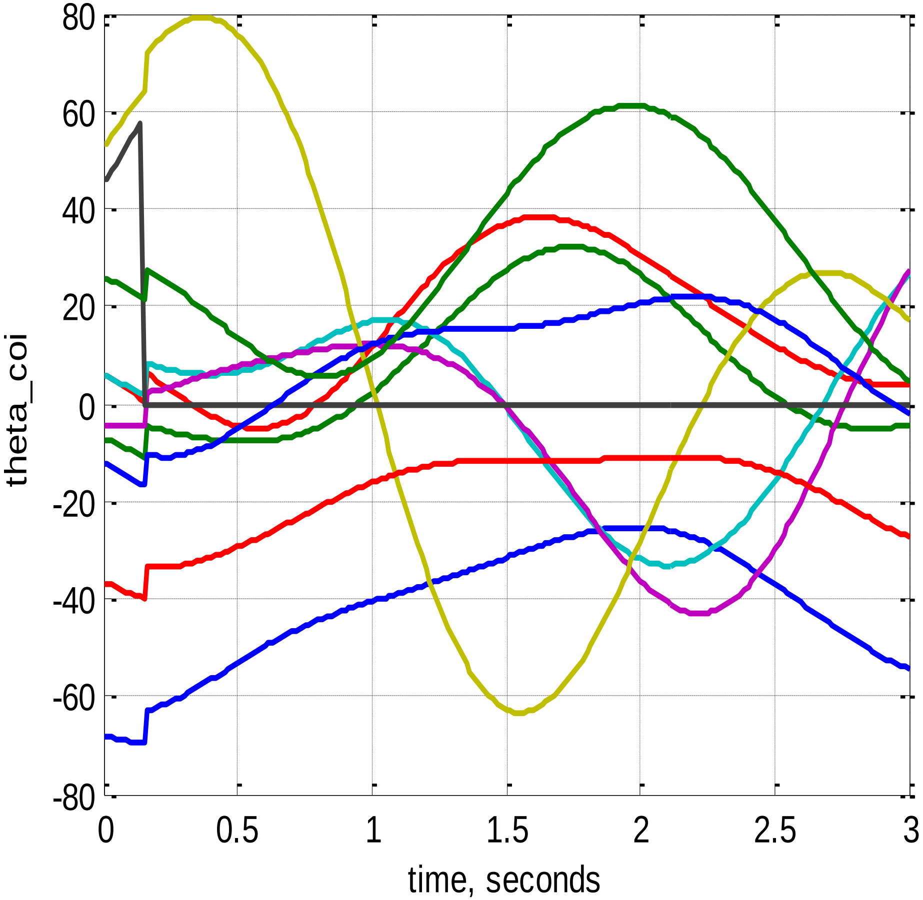
<u>Trip G7, then no control</u>

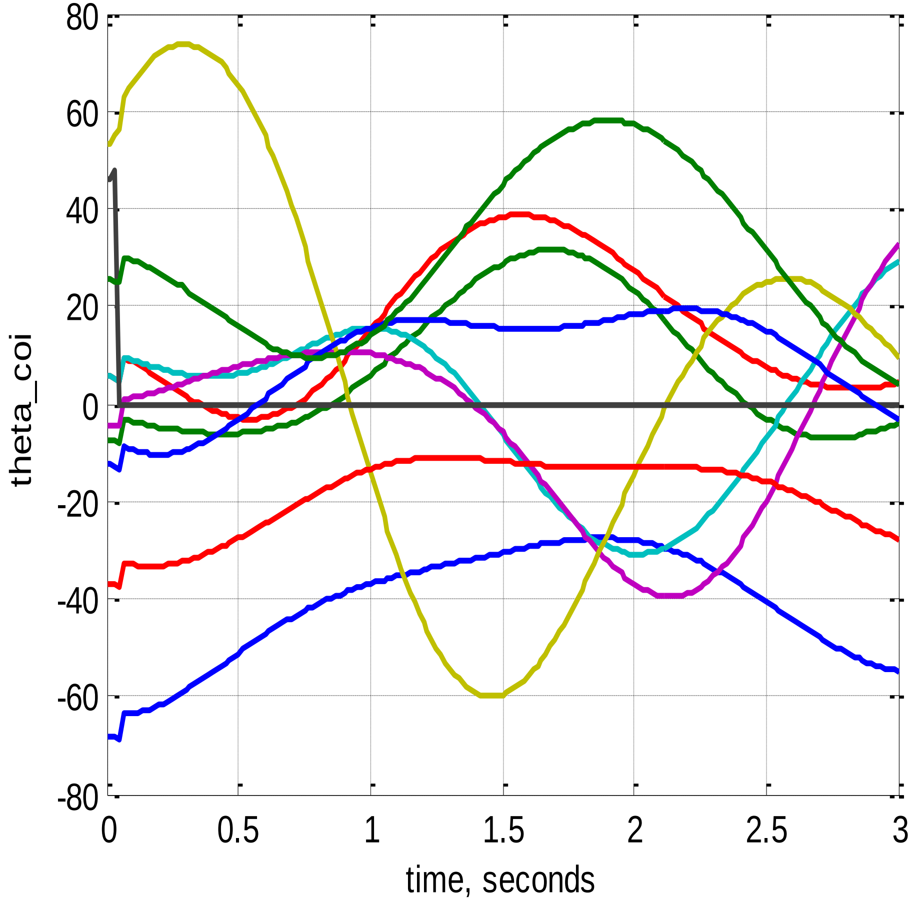
State Cost = 0.007

Control Cost = 3

Total Cost = 0.021

Iteration 1 Prediction Sequences





<u>Comp 31-32, then trip G7</u>

State Cost = 0.007

Control Cost = 4

Total Cost = 0.28

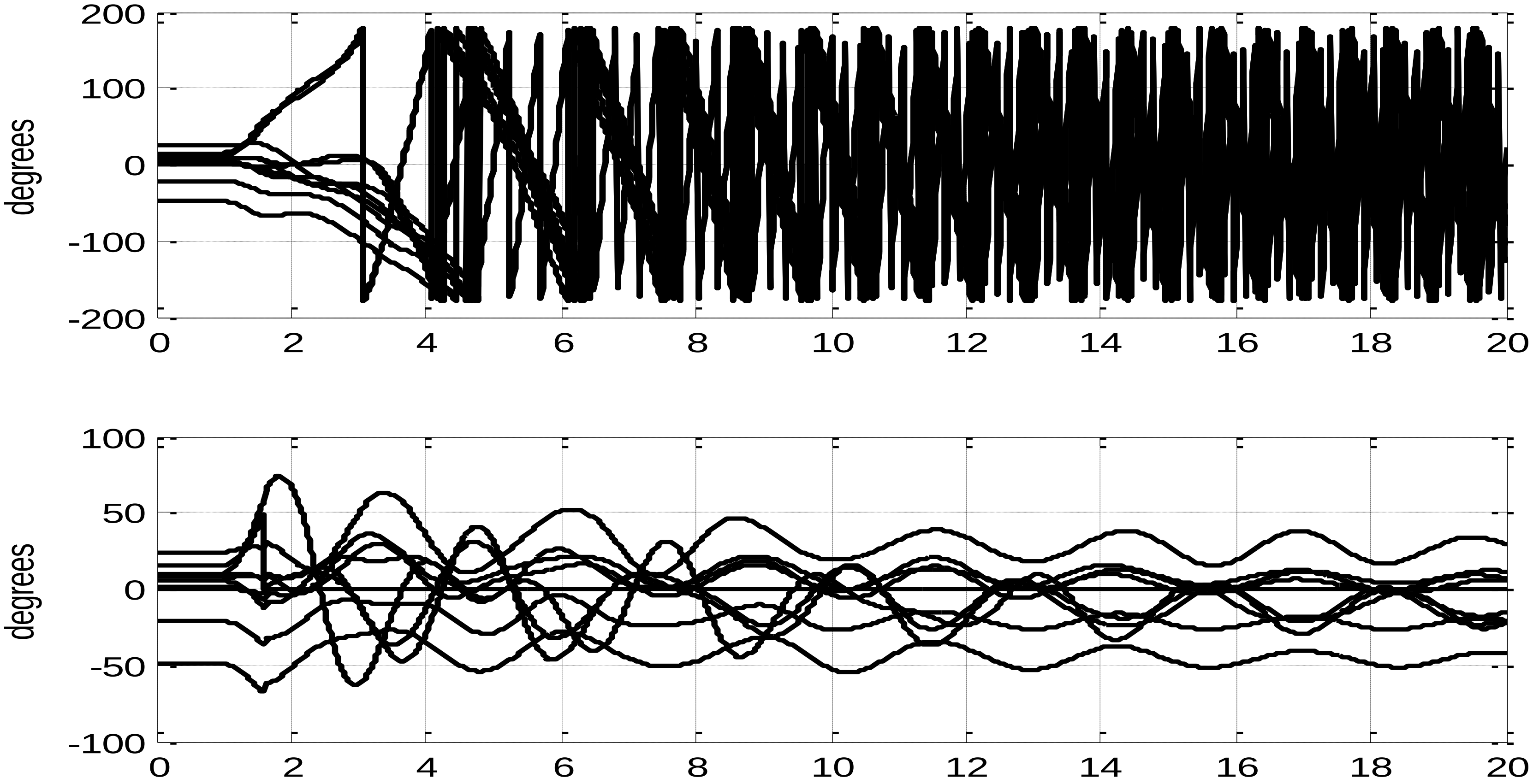
<u>Trip G7, then comp 31-32</u>

State Cost = 0.006

Control Cost = 4

Total Cost = 0.024

Machine Angles Before & After Control



Future Work

- This project focused on control designs for future power systems
- Transition road map needed
- Control designs with SCADA and PMUs
- Control designs with increasing availability of fast communication networks
- Road from here to the future needs to be planned out
- Implementations in phases
- Start working with utilities on actual designs and implementations

Publications

- G. Zweigle, and V. Venkatasubramanian. *Model Prediction Based Transient Stability Control*. Proc. IEEE PES Transmission and Distribution Conference and Exposition, Orlando, FL, May 2012.
- G. Zweigle, and V. Venkaatsubramanian, *Wide-area Optimal Control of Electric Power Systems with Application to Transient Stability for Higher Order Contingencies,* IEEE Trans. on Power Systems, to appear.
- J. Ning, X. Pan, and V. Venkatasubramanian, *Oscillation modal analysis from ambient synchrophasor measurements using distributed frequency domain optimization*, IEEE Trans. Power Systems, May 2013.