Real Time Control of Power Grids

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Control of the Power Grid

- Load Following – Frequency Control
  - Area-wise
  - Slow (secs)
- Voltage Control
  - Local
  - Slow to fast
- Protection
  - Local (but remote tripping possible)
  - Fast
- Stability Control
  - Local machine stabilizers
  - Remote special protection schemes
  - Fast
Communication for Power System

- Analog measurements
- Digital states

Control Center

Third Party

RTU

RTU

...
Monitoring the Power Grid

• Alarms
  • Check for overloaded lines
  • Check for out-of-limit voltages
  • Loss of equipment (lines, generators, feeders)
  • Loss of communication channels
• State estimator
• Security alerts
  • Contingencies (loading, voltage, dynamic limits)
  • Corrective or preventive actions
Substation Automation

• Many substations have
  • Data acquisition systems at faster rates
  • Intelligent electronic devices (IED)
  • Coordinated protection and control systems
  • Remote setting capabilities

• Data can be time-stamped by satellite
Evolution of Communication System

- Utilizing existing system
- Building a new one
Communication for Power System (future)
WSU Real Time Control Project

• Study feasibility of different levels of area-wide real time controls for the restructured power system
  • Slow controls
    • Automatic Generation Control (AGC)
    • Voltage control
  • Adapting special protective schemes (SPS) or remedial action schemes (RAS) for stability
  • Real time stability control using soft-computing – neural networks, pattern recognition, etc.
  • Real time stability control (the holy grail)
Slow Controls

• Load Frequency Control (Load Following)
  • Present method adequate
  • Single-buyer or Bilateral
  • Who pays for control performance?

• Voltage Control
  • Only local control in No America
  • Do we need area-wide control?
  • Again, who pays?
Example System - AGC

- CA1
- G1
- G2
- CA2
- G3
- CA3
- G4

10s, 0.1pu load deviation
50s delay
20s delay
20s delay
# Example AGC Results

Simulations for three control areas various configurations

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Traditional AGC</th>
<th>Bilateral</th>
<th>Mixed AGC and Bilateral</th>
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</thead>
<tbody>
<tr>
<td><strong>Random delay</strong></td>
<td>Unstable in certain situations with random delay in all generators.</td>
<td>Fail to meet customer demand and may become unstable.</td>
<td>System not adversely affected if in bilateral units only but those parties cannot meet the contractual schedule.</td>
</tr>
<tr>
<td></td>
<td>No adverse affects from random delay in single generator.</td>
<td></td>
<td></td>
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<tr>
<td><strong>Both fixed and random delays</strong></td>
<td>--</td>
<td>--</td>
<td>System may become unstable for short delays.</td>
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</table>
Area Voltage Control Framework

- EMS SCADA
- STATE ESTIMATOR
- LOAD FOECASTING
- MEASUREMENTS
  - DEVICE
  - STATUS
  - ALARMS
- SLOW VOLTAGE CONTROLLER
  - MODEL
  - STATE
  - LOAD
  - TREND
  - SWITCHING
  - COMMANDS
  - OPERATOR
  - ALARMS
An automatic voltage control scheme would dynamically manage the reactive power available in a certain geographic region called Voltage Control Area (VCA).

A local ancillary service market for reactive power can consequently be developed in that specific VCA, granted that generation-based voltage control is the only voltage control recognized as an ancillary service by NERC.
IEEE 39bus system divided in VCAs
RAS/SPS

• Present Day State-of-the-Art
  • Hard-wired
  • Parameters set by off-line studies
  • Armed in real time according to system condition
  • Mainly activates switching (circuit breakers)
  • Can activate FACTS controllers

• Possibilities
  • Soft-wired (set according to system condition)
  • Parameters set by on-line computation
  • Continuous control
Real Time Control for Stability

• Oscillatory Stability
  • Number of modes finite and detectable
  • Possible control in hundreds of ms
  • Possible area-wide control of system stabilizers

• Transient Stability
  • Control needed in tens of ms
  • Fast detection is difficult

• Soft-computing
  • Use ANNs, pattern recognizers, etc instead of model-based computation
Oscillation Damping Controller

WIDE AREA MEASUREMENTS

Multi-input Prony Analysis
FFT Analysis

INTERAREA AND LOCAL MODES

PSDL STATUS
From Area 1
From Area 2
From Area n

EXTERNAL TRIGGERS
To Area 1
To Area 2
To Area n
Proportional Voltage Controller

• Real-time switching of remote generation, shunt and series capacitor banks coordinated by the controller.

• Control actions typically during the first swing of large disturbances.

• Improved version of the controller being implemented at BPA – Wide Area Control System.
Some Research Issues

- Theoretical basis for control issues that incorporate communication and computation
- Simulation tools that incorporate control, communication and computation
- What is a reasonable framework of the communication system for the power grid
- What controllers (FACTS) will be readily available to consider in such wide-area control
- We should be ready with practical control schemes in anticipation of the technology