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Real Time Control of Power Grids

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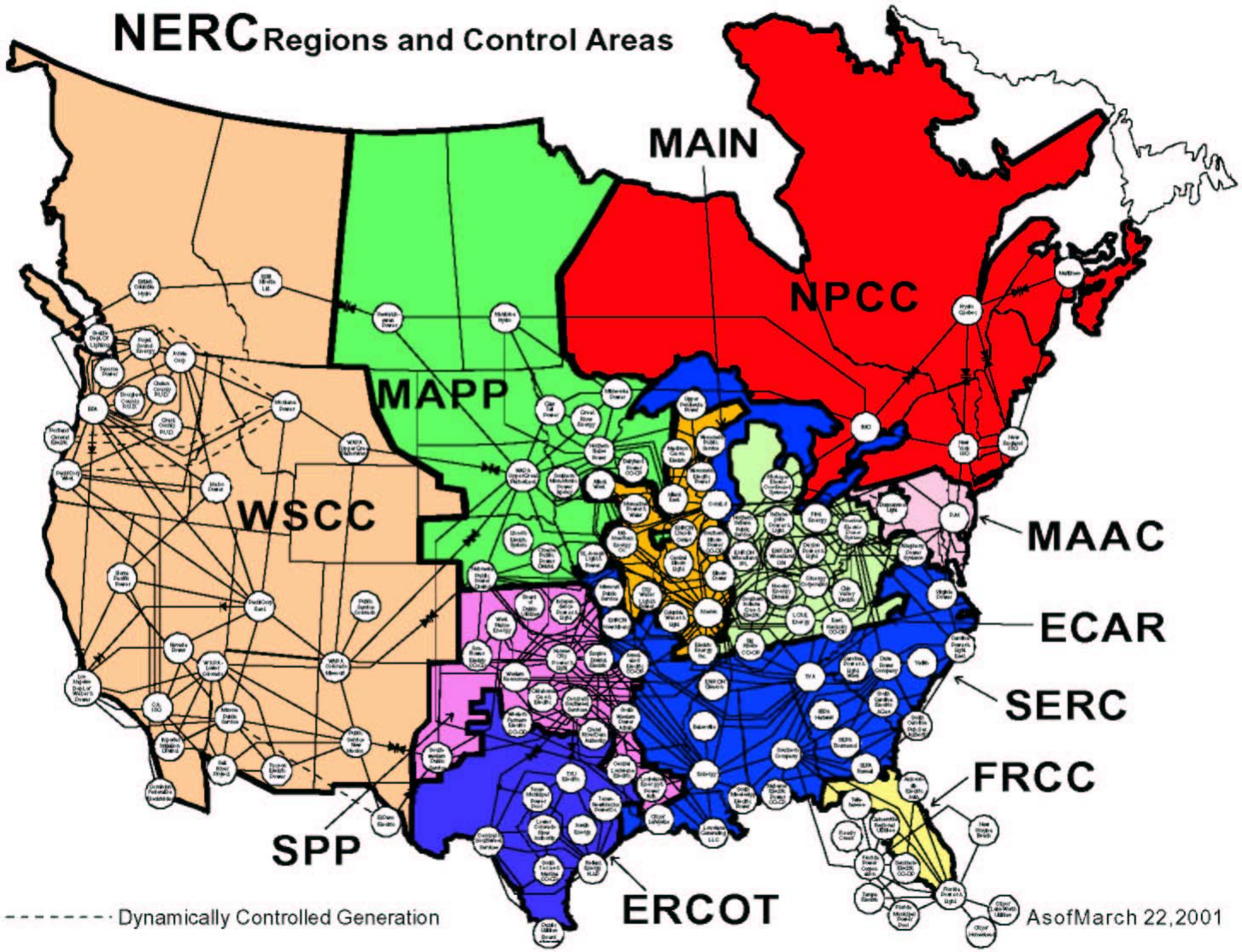
NERC Regions and Control Areas
MAIN
NPCC
MAPP
WSCC
MAAC
ECAR
SERC
FRCC
SPP
ERCOT
Dynamically Controlled Generation
AsofMarch 22,2001

Control of the Power Grid

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- 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

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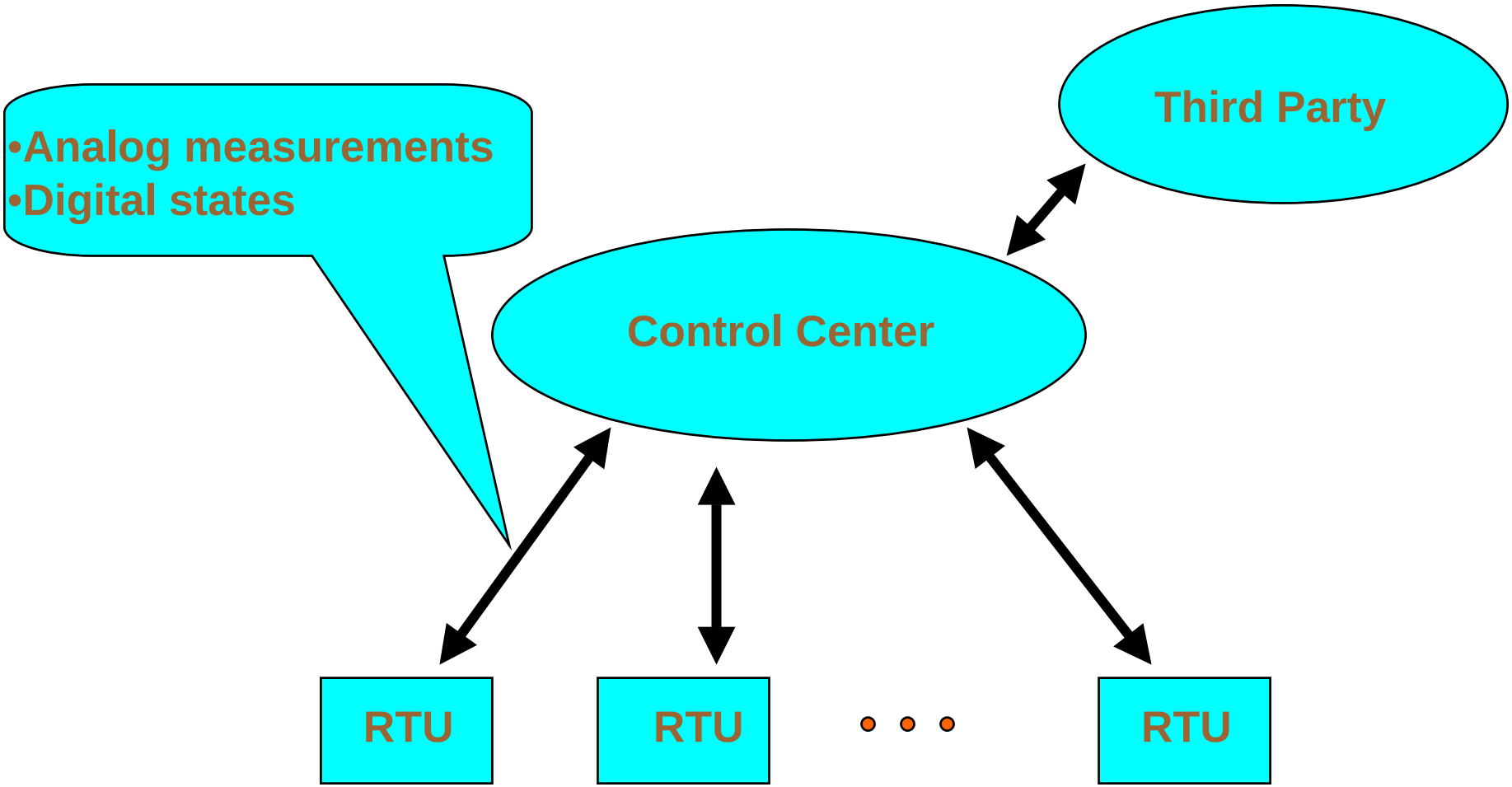

Monitoring the Power Grid

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- 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

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- 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

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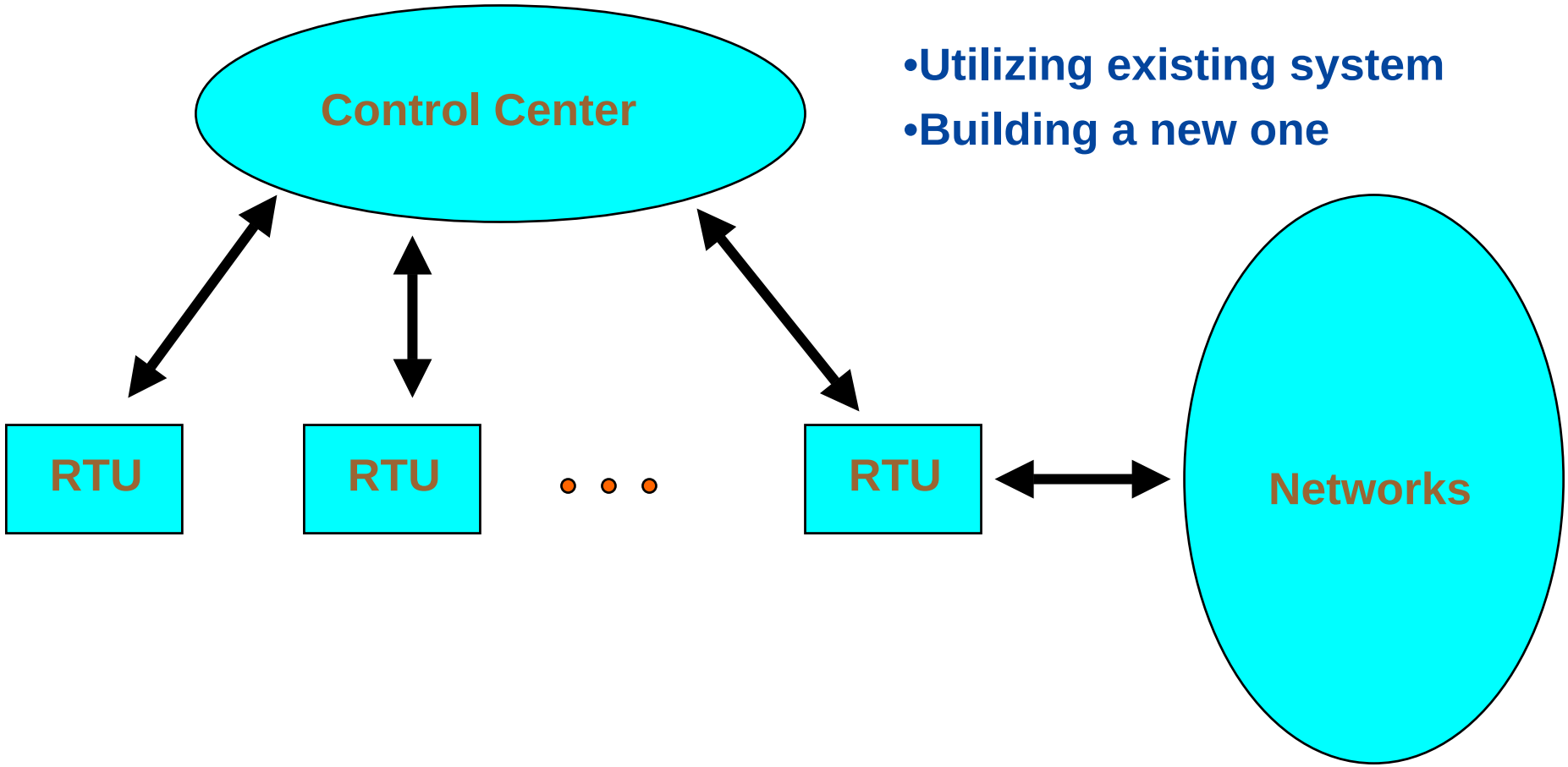

- Utilizing existing system
- Building a new one

Communication for Power System (future)

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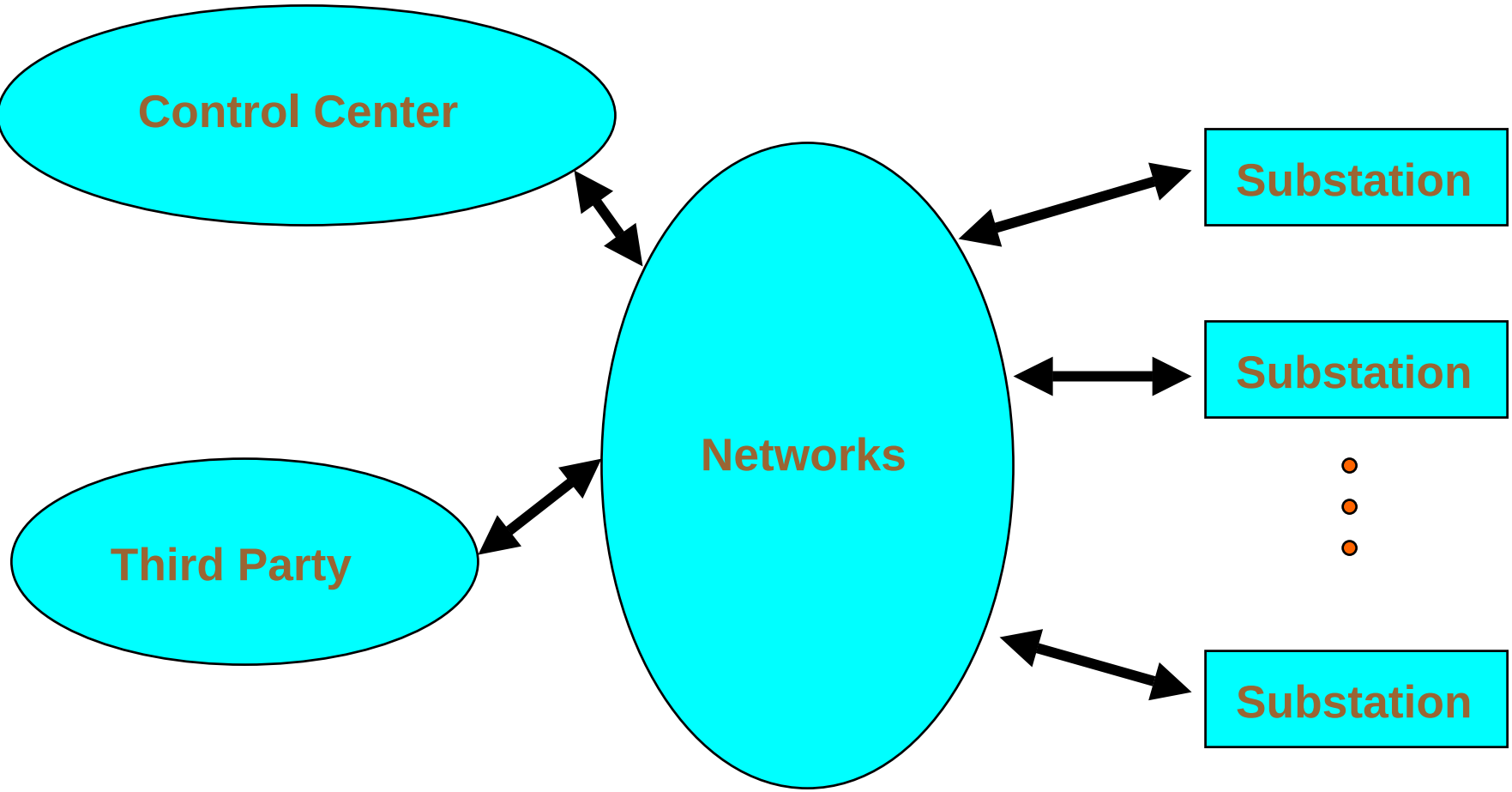

WSU Real Time Control Project

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- 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

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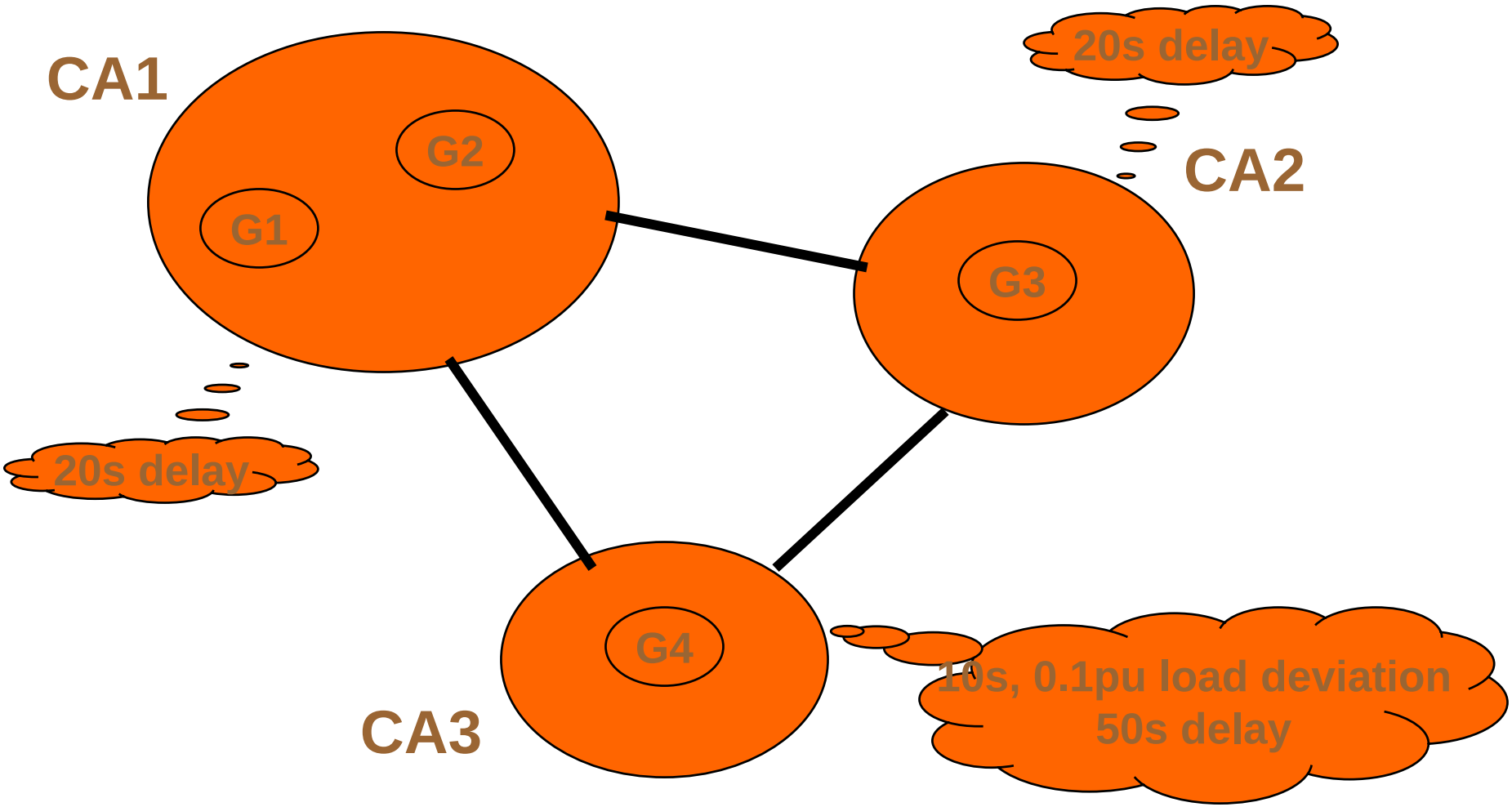
- Load Frequency Control (Load Following)
  - Present method adequate
  - Single-buyer or Bilateral
  - Who pays for control performance?
- Voltage Control
  - Only local control in No America
  - Do we need area-wide control?
  - Again, who pays?

Example System - AGC

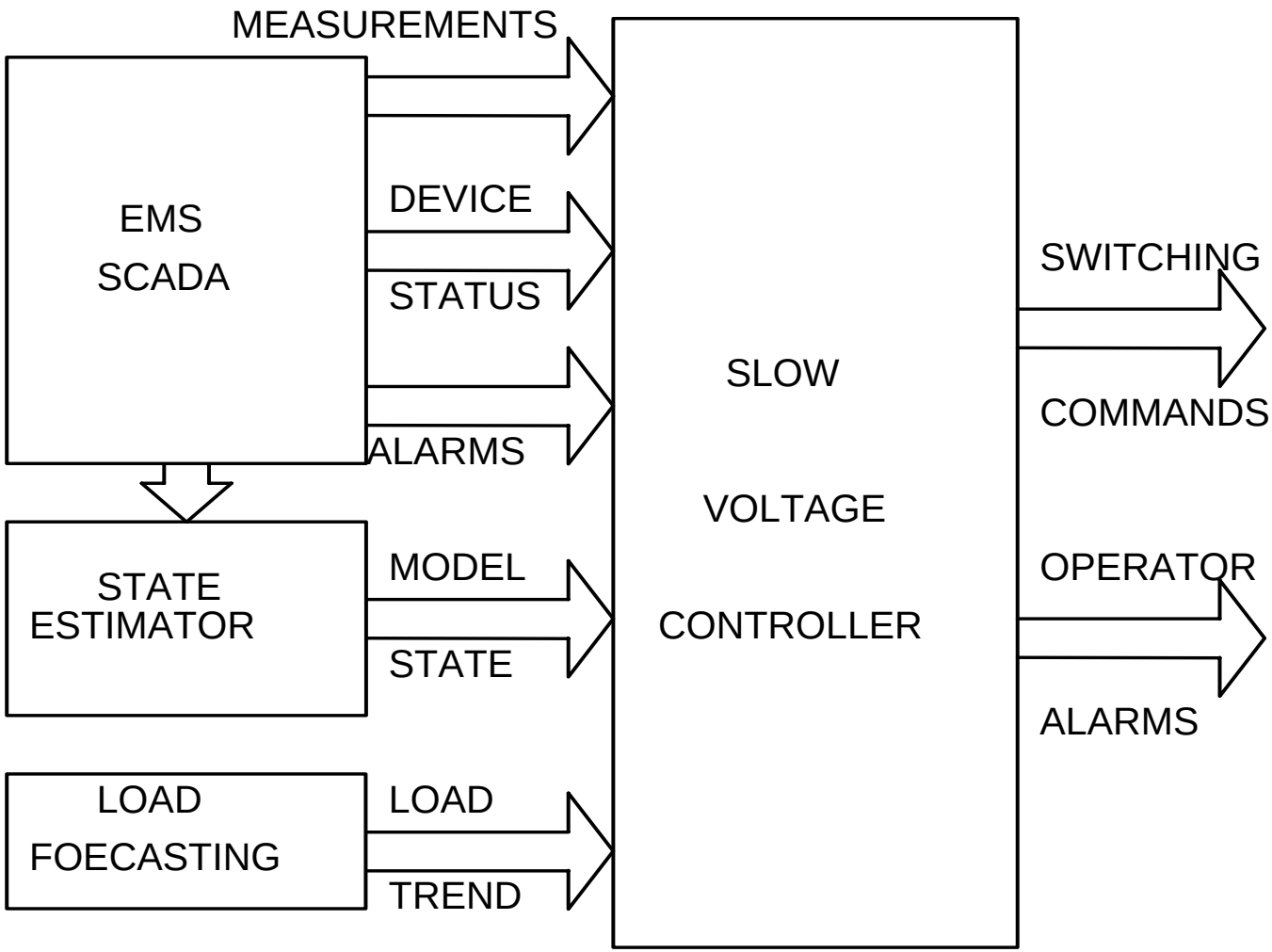


Example AGC Results

Simulations for three control areas various configurations

Scenario	Traditional AGC	Bilateral	Mixed AGC and Bilateral
Random delay	Unstable in certain situations with random delay in all generators. No adverse affects from random delay in single generator.	Fail to meet customer demand and may become unstable.	System not adversely affected if in bilateral units only but those parties cannot meet the contractual schedule.
Both fixed and random delays	--	--	System may become unstable for short delays.

Area Voltage Control Framework



New scheme for Voltage Control

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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

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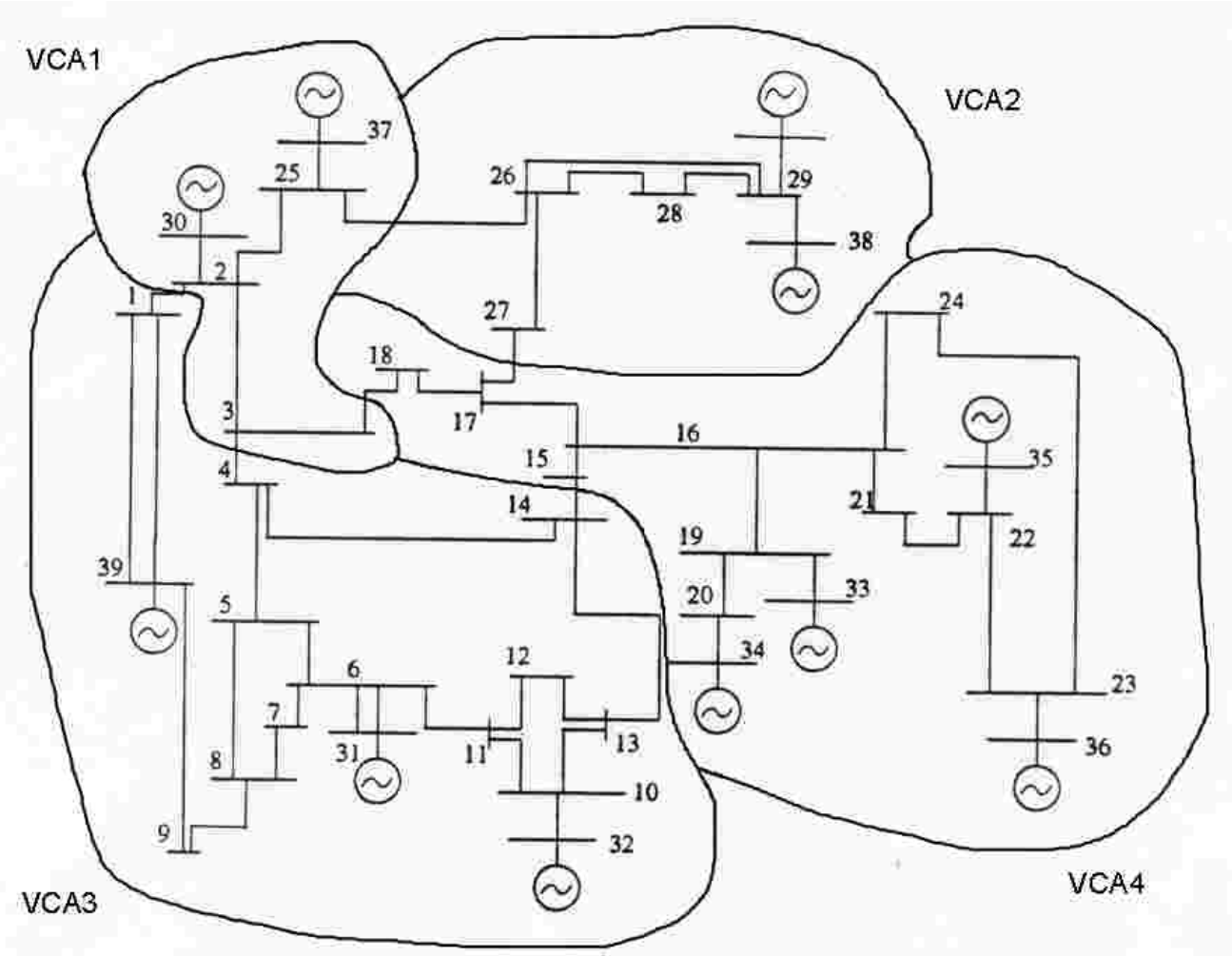

RAS/SPS

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- 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

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- 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

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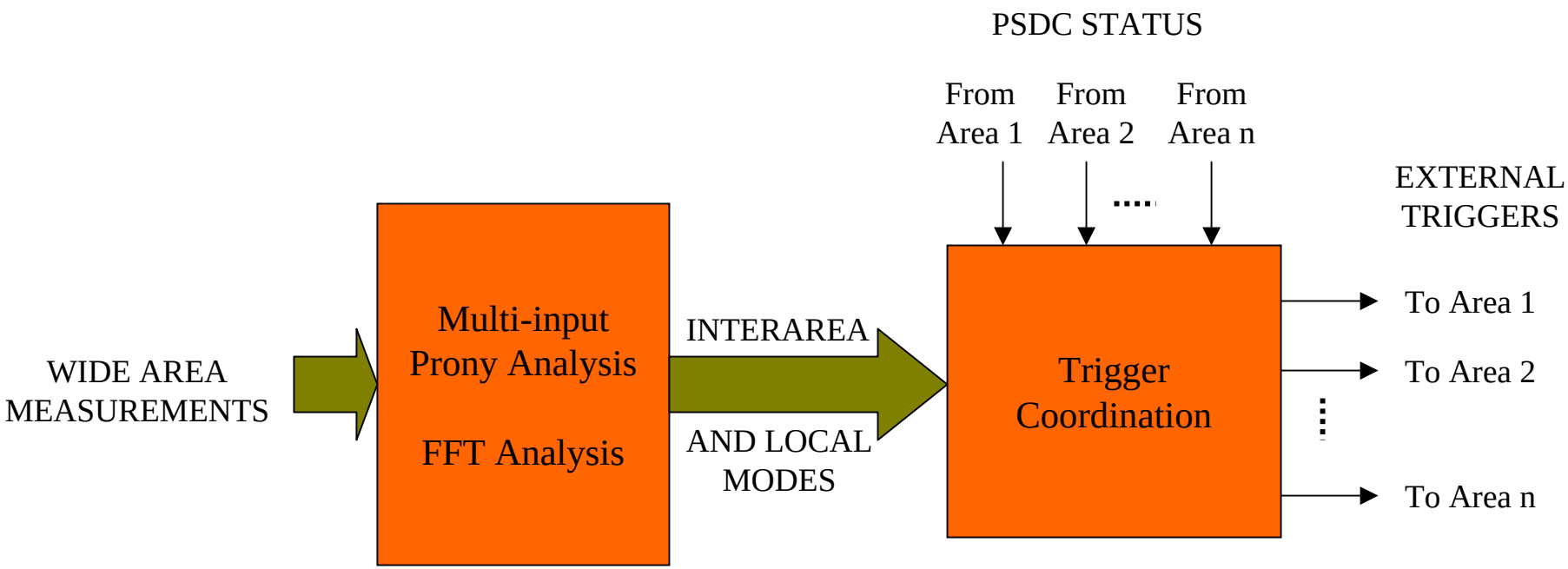

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Proportional Voltage Controller

- 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

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- 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