Wide-Area Protection and Control Scheme Maintains Central America's Power System Stability

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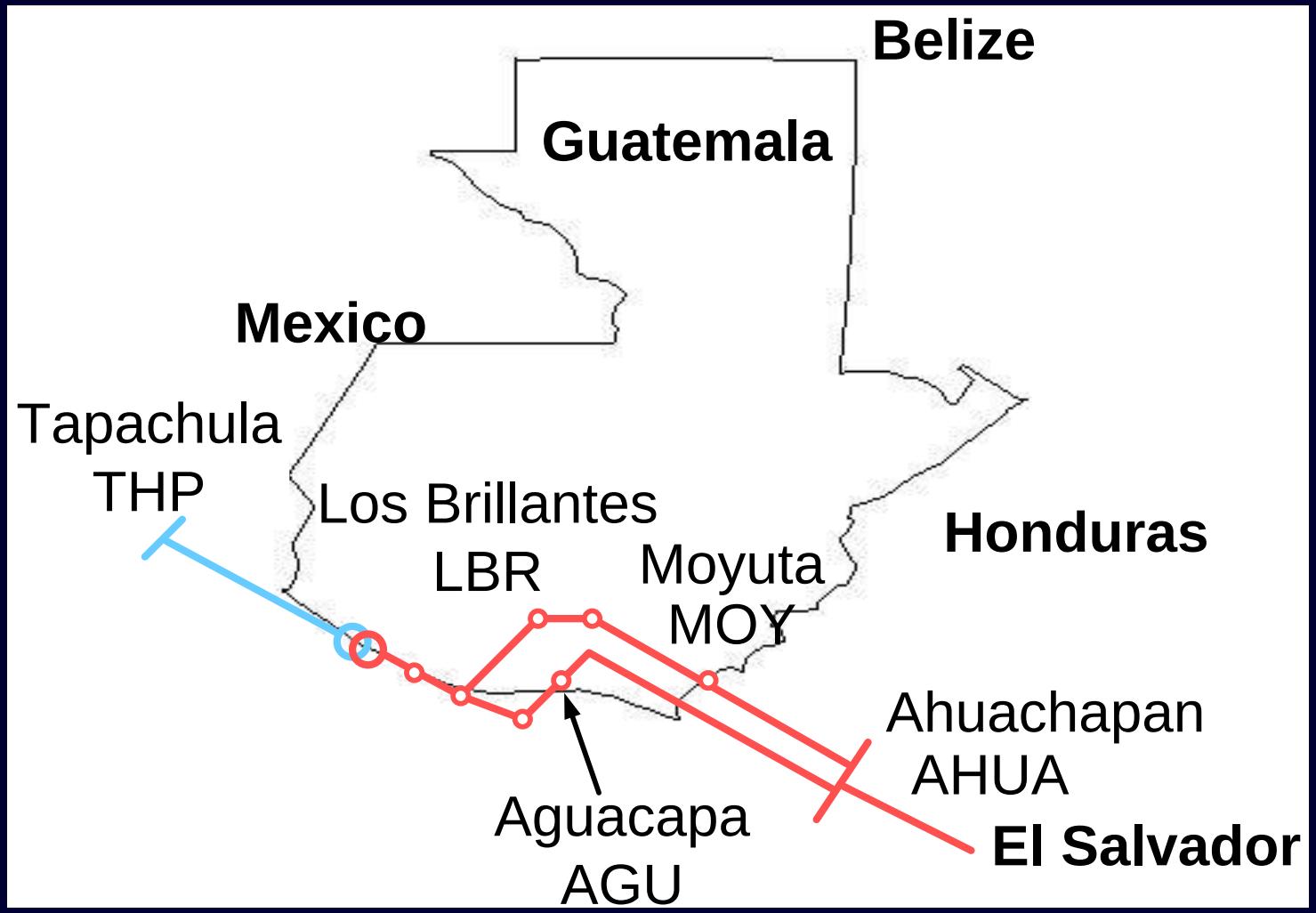
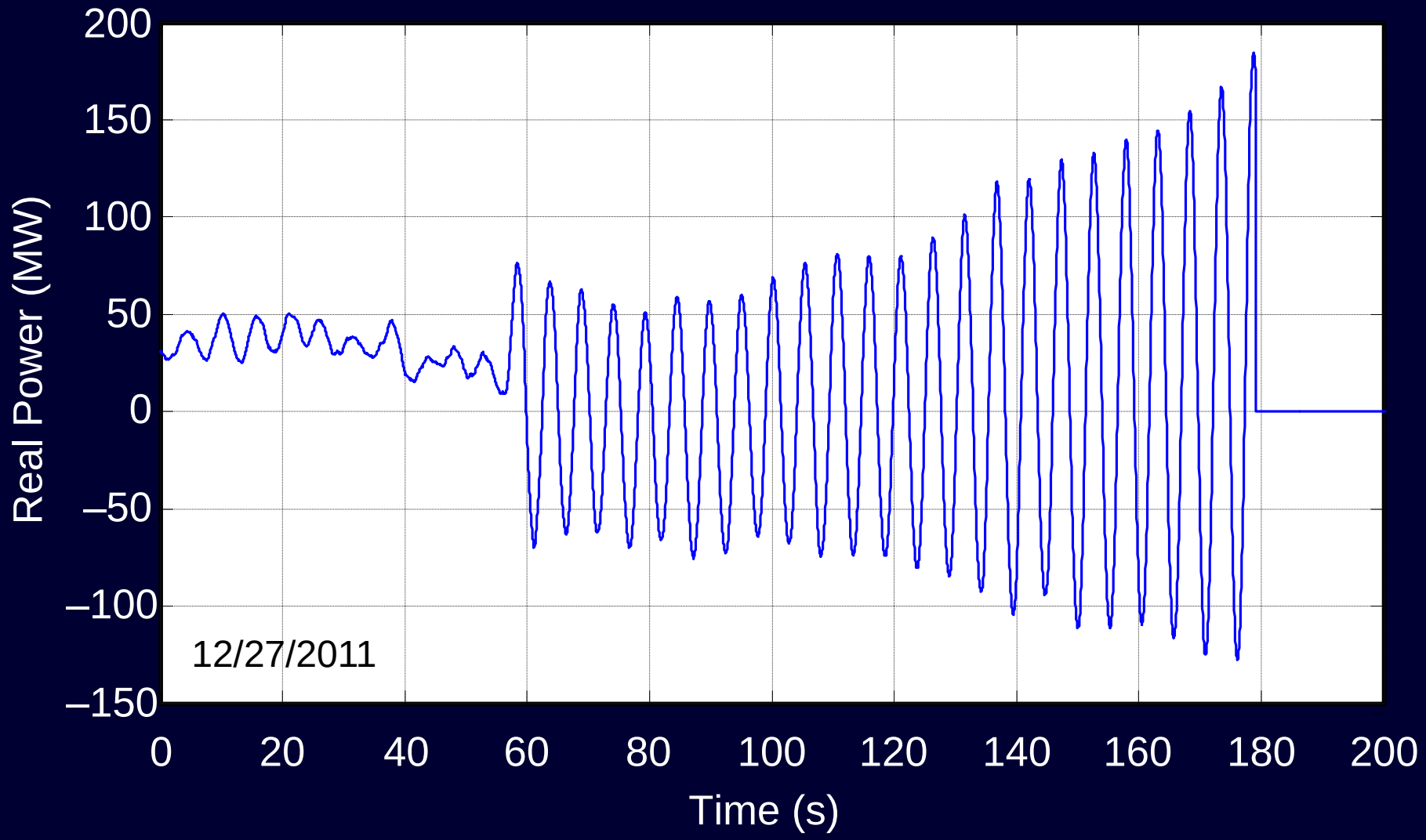
230 kV Backbone Connects Countries From Guatemala to Panama

Guatemala Wheels Power From Mexico to Central America



Unstable Oscillation Separates Guatemala From Rest of Central America

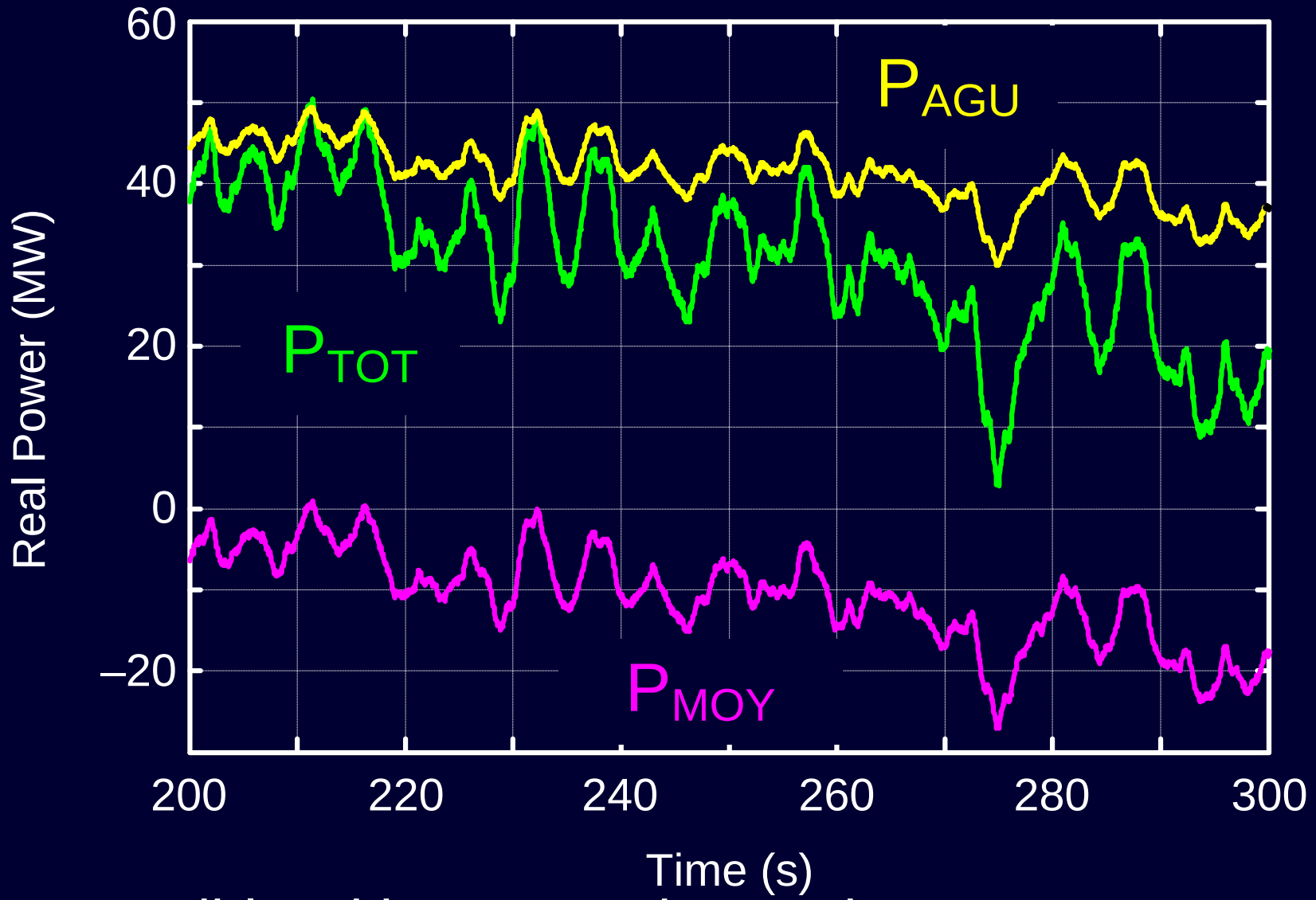


Synchrophasor System Details

- 23 PMCUs (30 message/sec)
- Leased communications network
- Synchrophasor processing units (SPUs)
- Software PDC at control center
- System visualization and analytics

Synchrophasors and Traditional SCADA

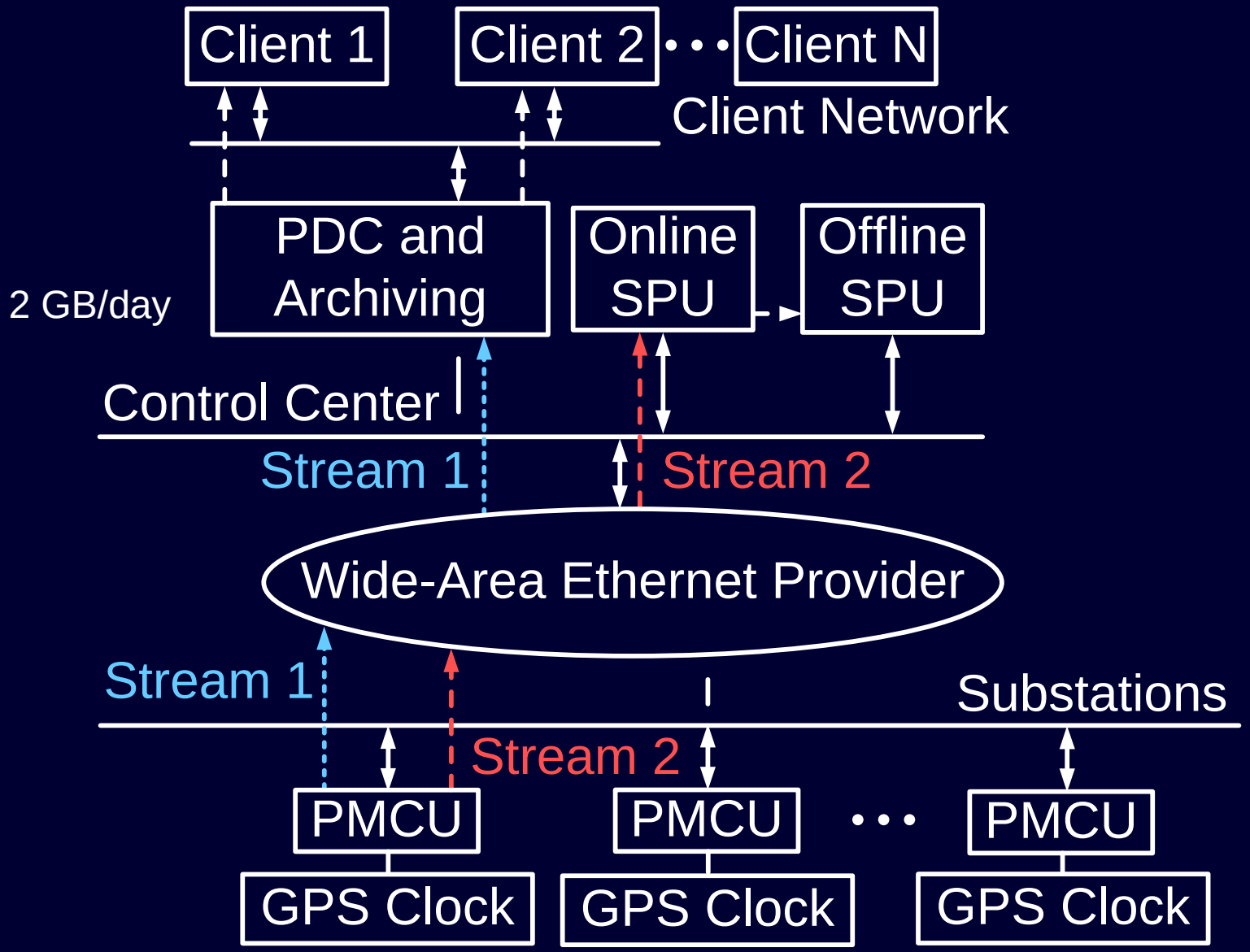
Normal Operational Experience



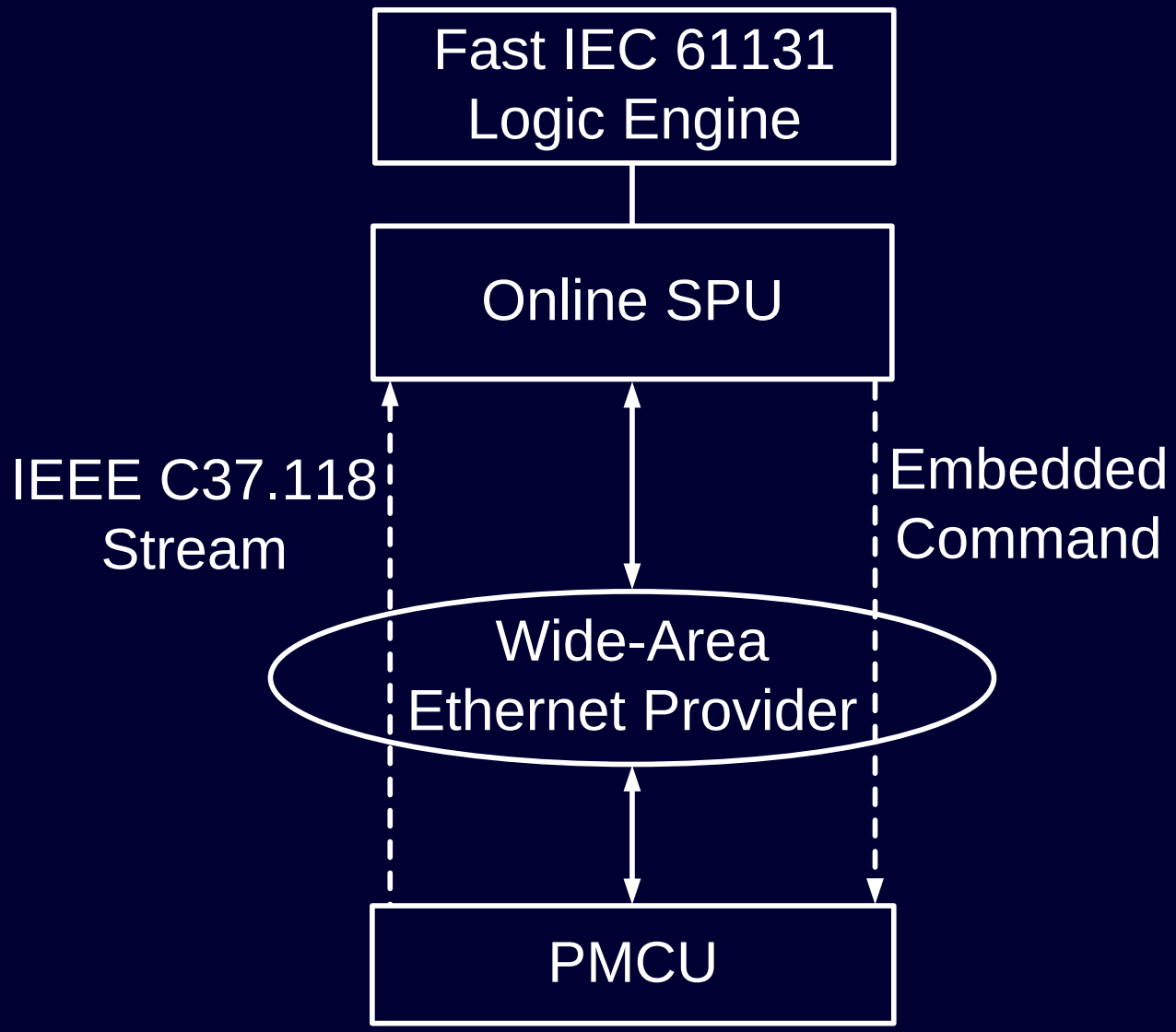
Not possible with 4 second asynchronous SCADA rate

Event Happens After Synchronization

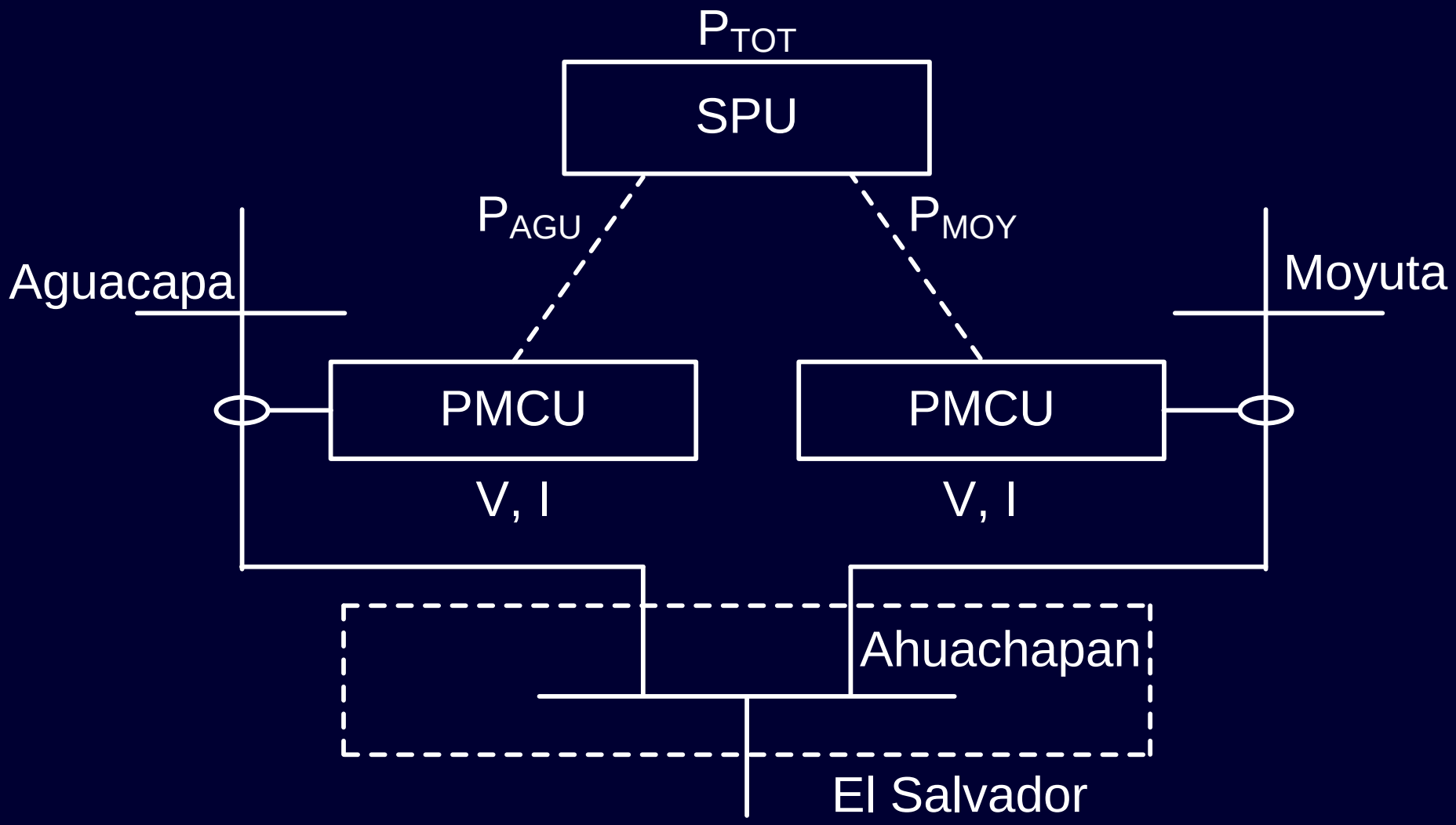
Wide-Area Prot. Scheme Architecture



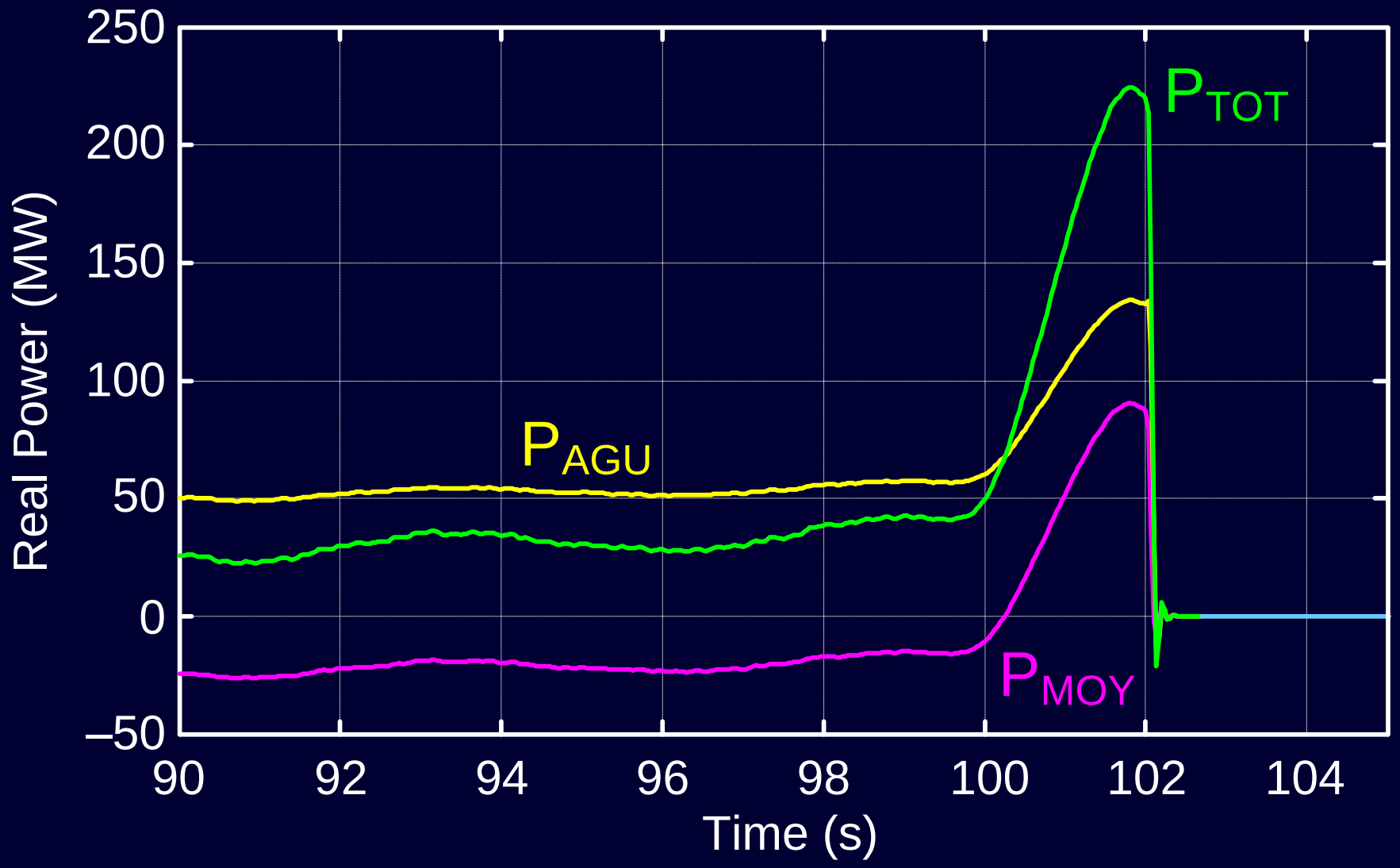
PMCUs Receive Control Commands and Provide Synchronized Measurements



Protection Scheme Trips Interconnection to El Salvador



Scheme 1 – Synchronized Power



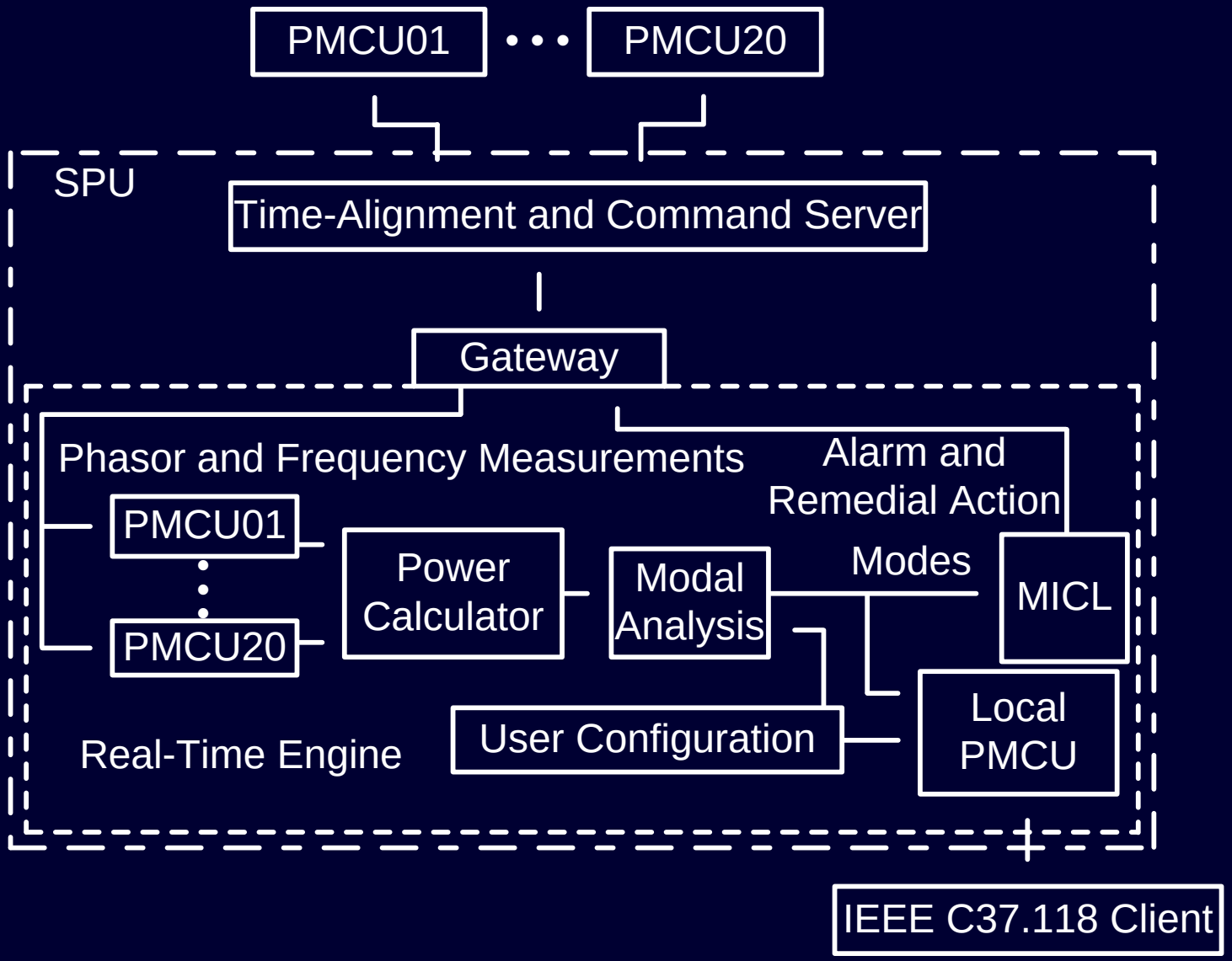
Synchronized Power Levels

Total Power (AGU+MOY)	Delay (ms)
200	1200
245	600
297	300

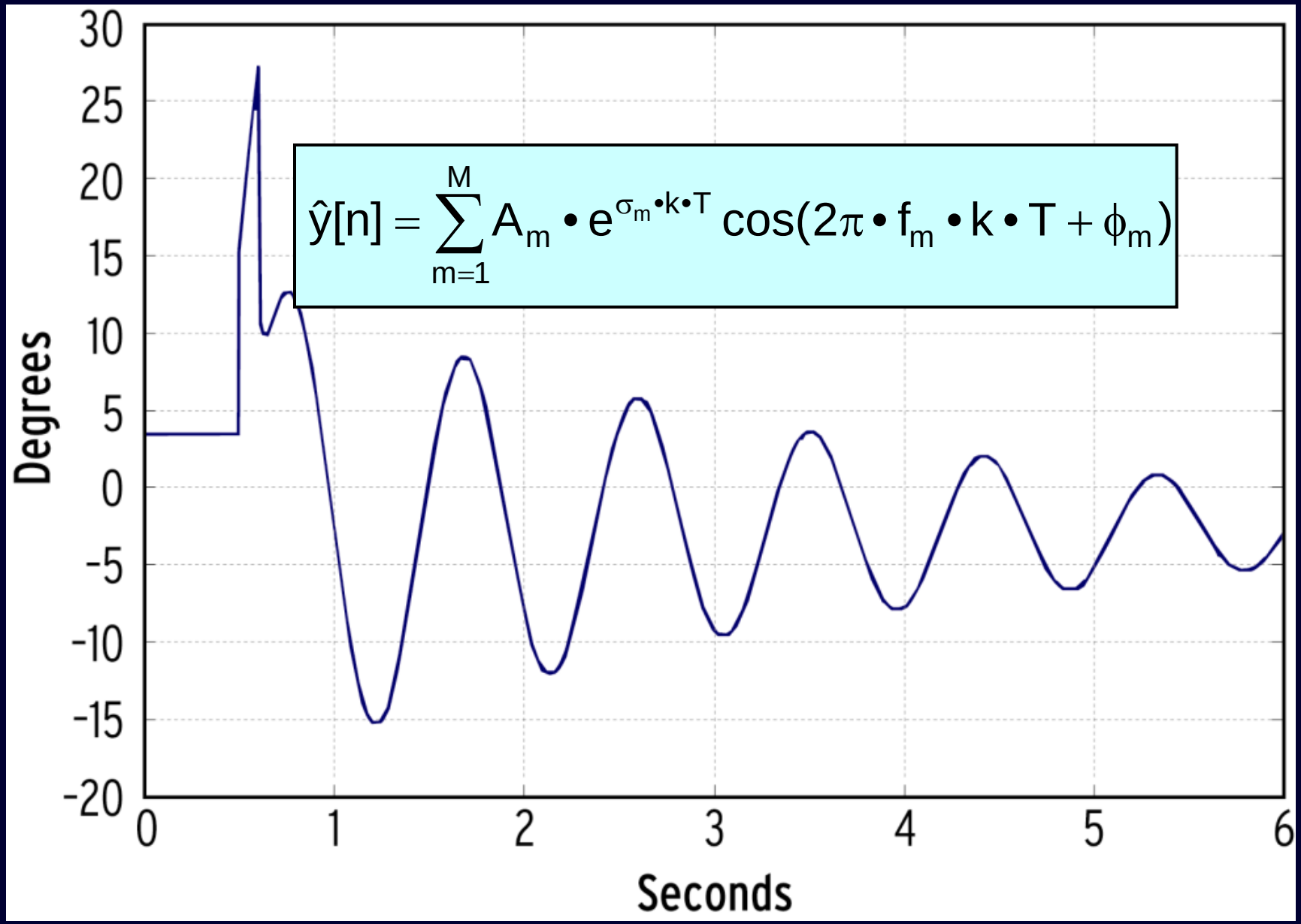
Scheme 2 – Modal Analysis

- Central American interconnection shows possible 0.17 Hz unstable mode
- 20-second observation window
- 2 bands are defined
  - 0.1 to 0.3 Hz unstable band
  - 0.5 to 0.9 Hz steady-state oscillations

Real-Time Modal Analysis Detects Unstable Oscillations



Signal Estimation Using Modal Analysis



Damping Ratio and SNR

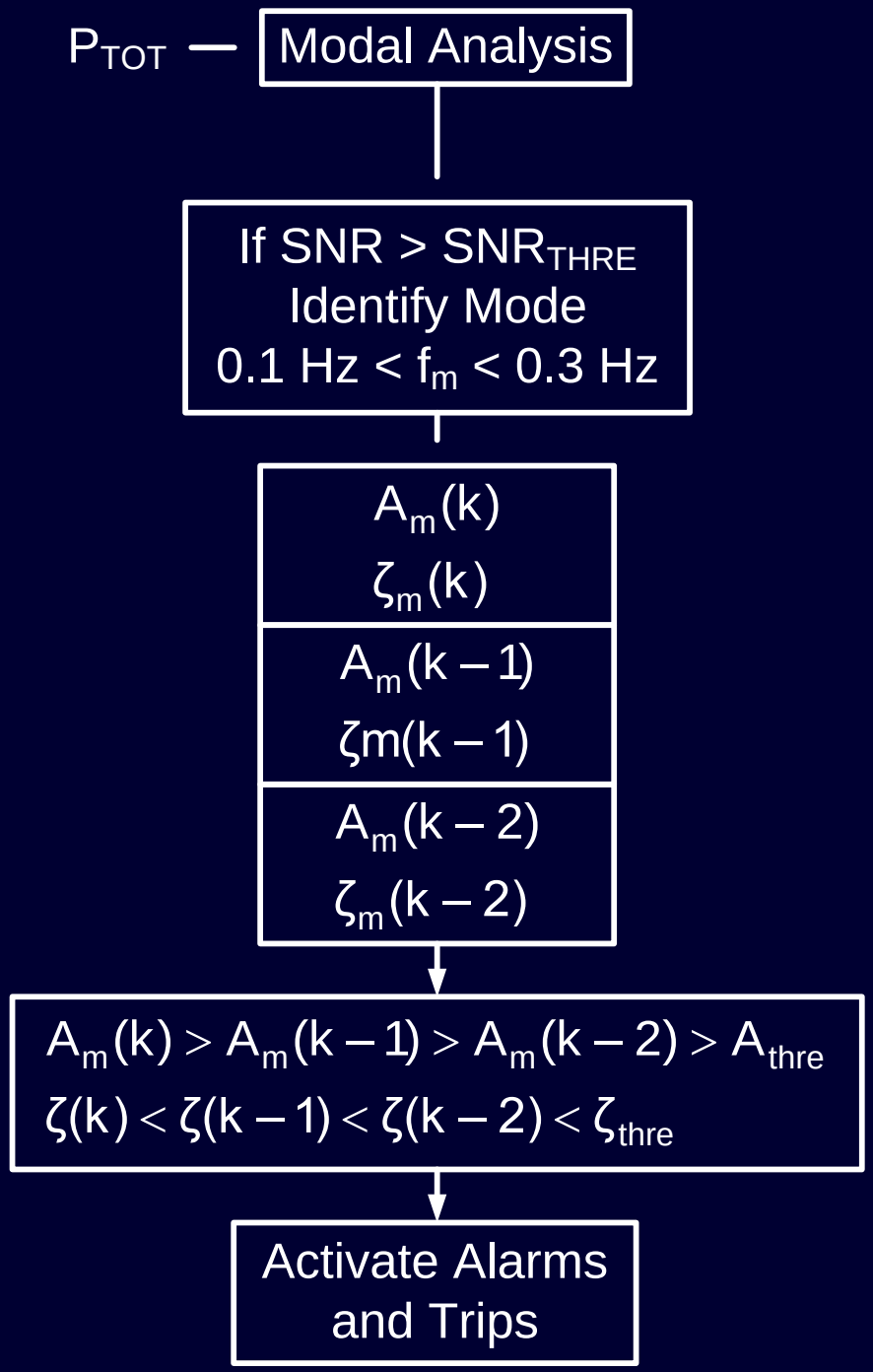
Damping Ratio

$$\zeta_m = -\frac{\sigma_m}{\sqrt{\sigma_m^2 + (2\pi f_m)^2}}$$

σ_m Damping constant
f_m Oscillation frequency

Signal to Noise Ratio

$$SNR = 10log\left(\frac{\sum_{n=0}^{N} y[n]^2}{\sum_{n=0}^{N}(\hat{y}[n] - y[n])^2}\right)$$



Real-Time Modal Analysis Decision Logic

Signal-to-Noise Ratio (SNR)

Mode Frequency(f_m)

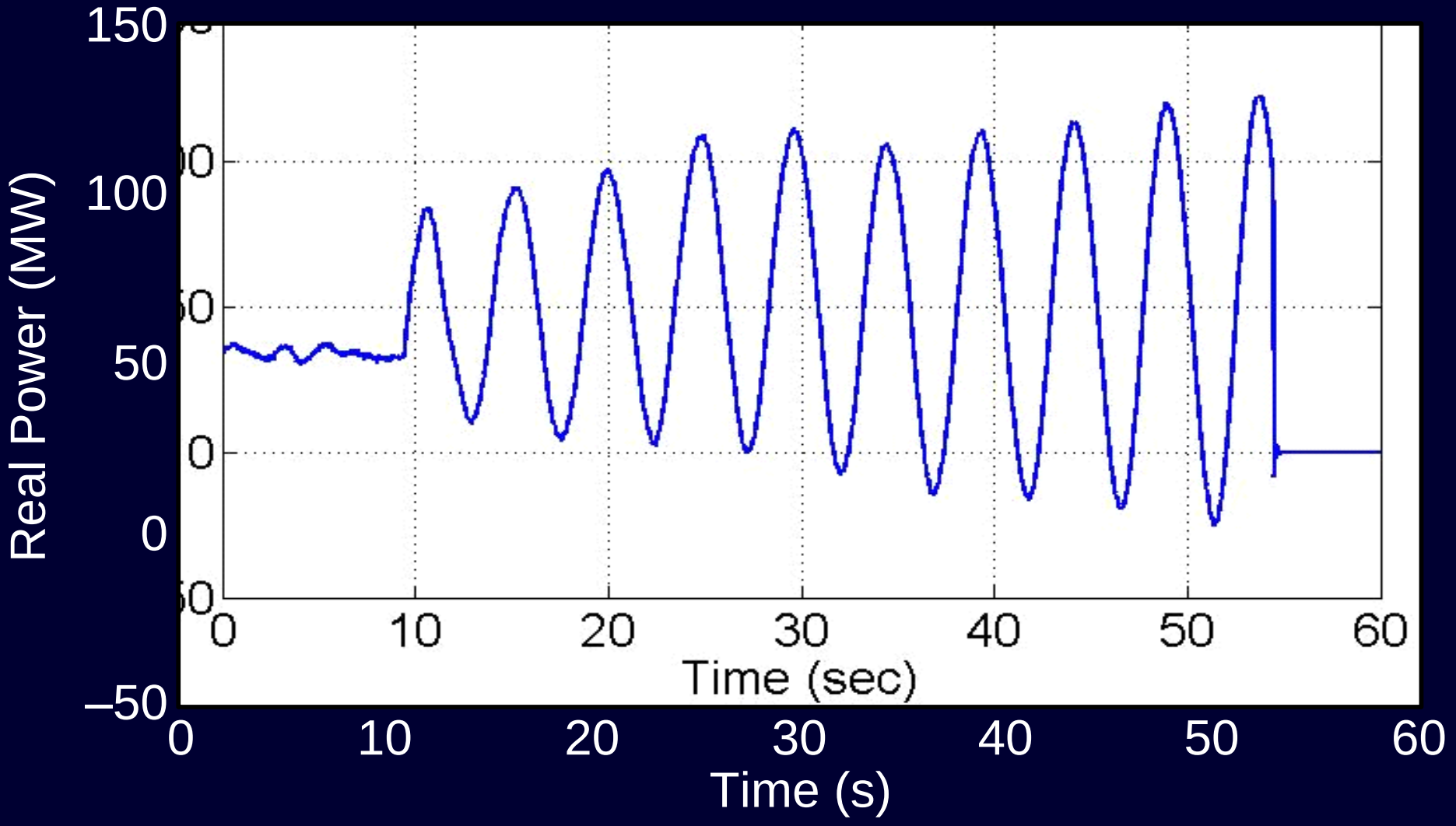
Mode Amplitude (ζ_m)

Mode Damping Ratio (A_m)

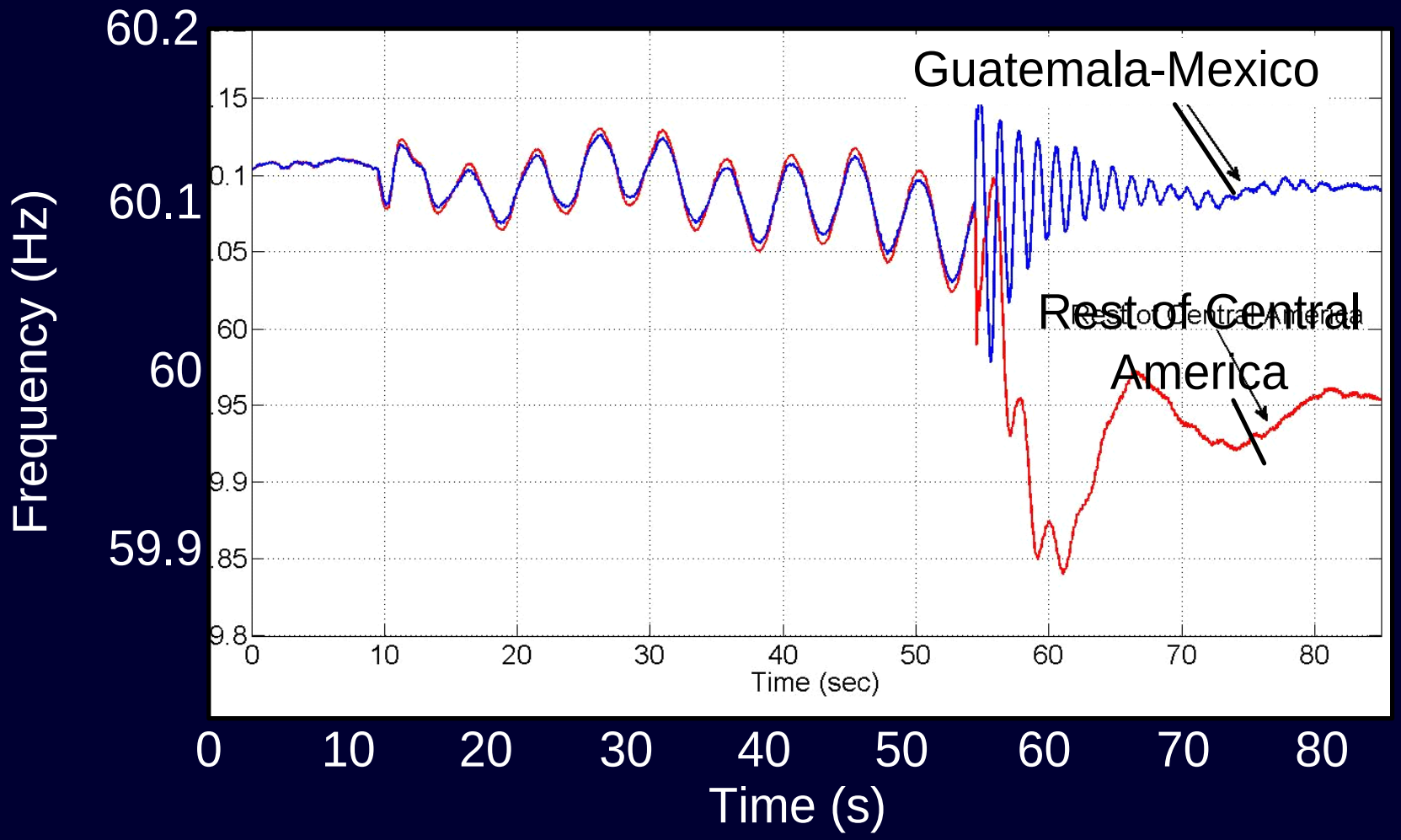
MA Scheme Mitigates Unstable Oscillation – July 28, 2012

- MA scheme enabled in mid-June 2012
- Unstable mode appears after synchronizing two parts of Central American power system

MA Scheme Mitigates Unstable Oscillation – July 28, 2012

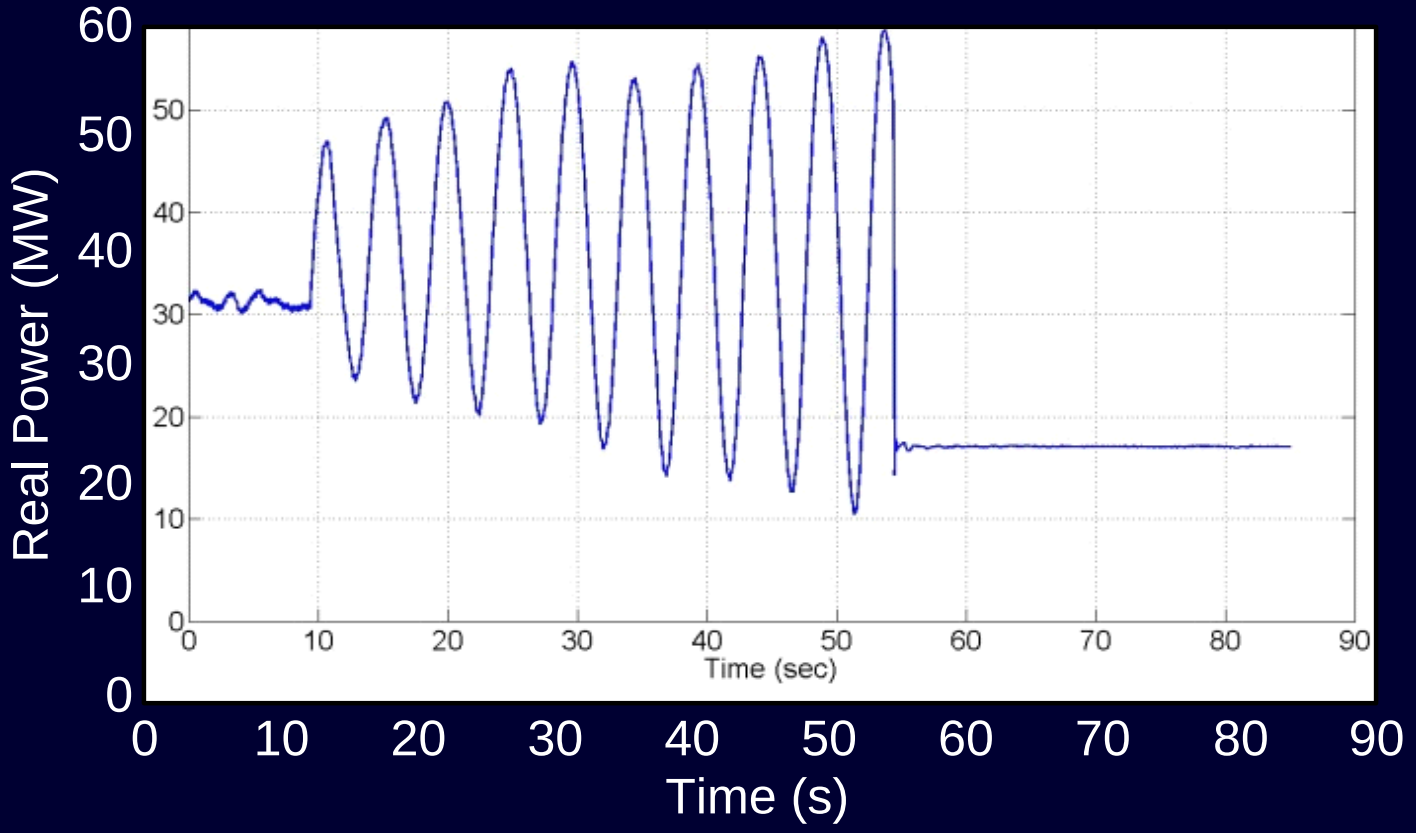


Synchrophasor-Based Control Successfully Stabilizes System



Guatemala Remains Stable

- Guatemala reaches new steady state
- Mexican power system largely contributes



Additional Operations of System

- Several scheme operations in July and August 2012
- Four operations in a single day, August 12, 2012
- Central America has maintained stability for all scheme operations

Questions?