Synchrophasor-Based Power System Control in Central America

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Schweitzer Engineering Laboratories, Inc.
Wide-Area Protection and Control Scheme Maintains Central America’s Power System Stability

WPRC – October, 2012

José Vicente Espinoza
AMM-Guatemala

Armando Guzmán, Fernando Calero,
Mangapathirao V. Mynam, and Eduardo Palma
Schweitzer Engineering Laboratories, Inc.
230 kV Backbone Connects Countries From Guatemala to Panama

- Mexico
- Guatemala
- El Salvador
- Honduras
- Nicaragua
- Costa Rica
- Panama

Key Points:
- Tapachula
- Los Brillantes
- Aguacapa
- Moyuta
- Ahuachapan
- Agua Caliente
- Sandino
- Ticuantepe
- Cañas
- Rio Claro
- Veladero
Guatemala Wheels Power From Mexico to Central America

Tapachula

THP

Los Brillantes
LBR

Moyuta
MOY

Aguacapa
AGU

Ahuachapan
AHUA

El Salvador

Belize

Guatemala

Mexico

Honduras

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Example Oscillations

![Graph showing oscillations in real power over time.](image-url)
Unstable Oscillation Separates Guatemala From Rest of Central America

![Graph showing real power over time on December 27, 2011]
Synchrophasor Technology in Guatemala

- 2008 – AMM identified synchronized measurements
- 2011 – AMM implemented system of synchrophasors
- 2012 – AMM enabled modal analysis scheme
Synchrophasor System Details

- 23 PMUs
- 30 samples per second
- Software PDC at control center
- Synchrophasor processing units (SPUs)
- System visualization and analytics
- Wide-area control
- Leased communications network
WAPS Architecture

- Client 1
- Client 2
- Client N

- PDC and Archiving
- Online SPU
- Offline SPU

- Control Center
- Stream 1
- Stream 2

- 2 GB/day

- Wide-Area Ethernet Provider

- Substations
  - PMCU
  - GPS Clock

- Stream 1
- Stream 2
PMCU

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PMCU

Fast IEC 61131 Logic Engine

Online SPU

IEEE C37.118 Stream

Embedded Command

Wide-Area Ethernet Provider

PMCU

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Synchrophasors Complement Traditional SCADA
Another Synchrophasor Display View
Supplementary Control Scheme (SCS) Trips Interconnection to El Salvador
Scheme 1 – Synchronized Power

![Graph showing synchronized power with three power levels: P_AGU, P_MOY, and P_TOT.](image-url)
Synchronized Power Levels

<table>
<thead>
<tr>
<th>Total Power (AGU+MOY)</th>
<th>Delay (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>1200</td>
</tr>
<tr>
<td>245</td>
<td>600</td>
</tr>
<tr>
<td>297</td>
<td>300</td>
</tr>
</tbody>
</table>

Not possible with 4 second asynchronous SCADA rate
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

PMCU01  •  •  •  PMCU20

Time-Alignment and Command Server

Gateway

Phasor and Frequency Measurements

PMCU01  •  •  •  PMCU20

Modal Analysis

Real-Time Engine

Power Calculator

Alarm and Remedial Action

Modes

MICL

User Configuration

Local PMCU

IEEE C37.118 Client
If SNR > SNR_{THRE}
Identify Mode
0.1 Hz < f_m < 0.3 Hz

A_m(k)
ζ_m(k)
A_m(k-1)
ζ_m(k-1)
A_m(k-2)
ζ_m(k-2)

A_m(k) > A_m(k-1) > A_m(k-2) > A_{thre}
ζ(k) < ζ(k-1) < ζ(k-2) < ζ_{thre}

Activate Alarms and Trips

Signal-to-Noise Ratio (SNR)
Mode Frequency (f_m)
Mode Amplitude (ζ_m)
Mode Damping Ratio (A_m)
Normal Operational Experience

![Graph showing real power (MW) over time (s)].

- **$P_{AGU}$**
- **$P_{TOT}$**
- **$P_{MOY}$**
MA Scheme Mitigates Unstable Oscillation – July 28, 2012

- MA scheme enabled in mid-June 2012
- Unstable mode shows after synchronizing two parts of Central American power system
Event Happens After Synchronization

- Mexico
- Guatemala
- Honduras
- Nicaragua
- Costa Rica
- Panama

Cities:
- Tapachula
- Los Brillantes
- Aguacapa
- Moyuta
- Ahuachapán
- Agua Caliente
- Sandino
- Ticuantepe
- Cañas
- Rio Claro
- Veladero

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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
Wide-Area Visualization, Analysis, and Control Summary

- Synchronized power measurements
- Real-time modal analysis
- System visualization displays
- Archived data analytics
- Operational experience
Questions?