LOS EXPERTOS EN MERCADOS xm

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Using PMUs to manage governor stability issues within the Colombian Power System

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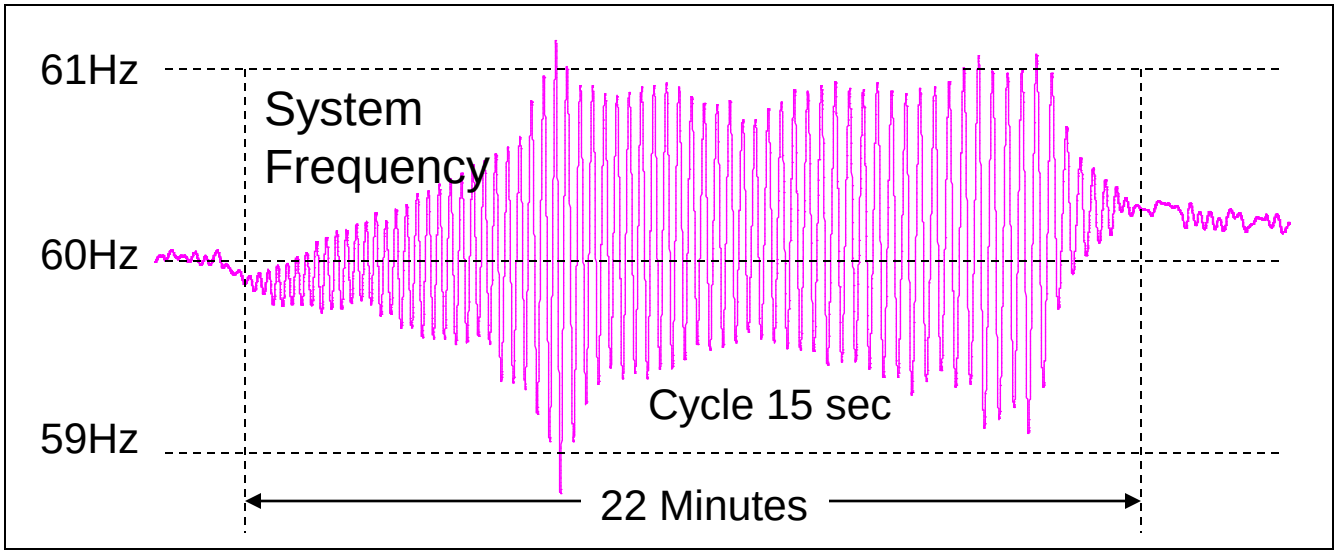
PSYMETRIX

Introduction

1. **Background of Colombian power system**
2. **Addressing a frequency stability problem**
   - Identifying the source of the problem
   - Governor parameter sensitivity tests
   - Model validation & modelling experiments
   - Resolution & testing
3. **Outlook for WAMS in Colombia**



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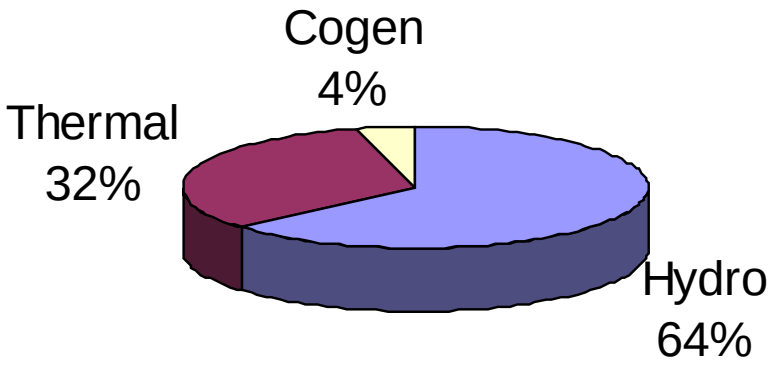
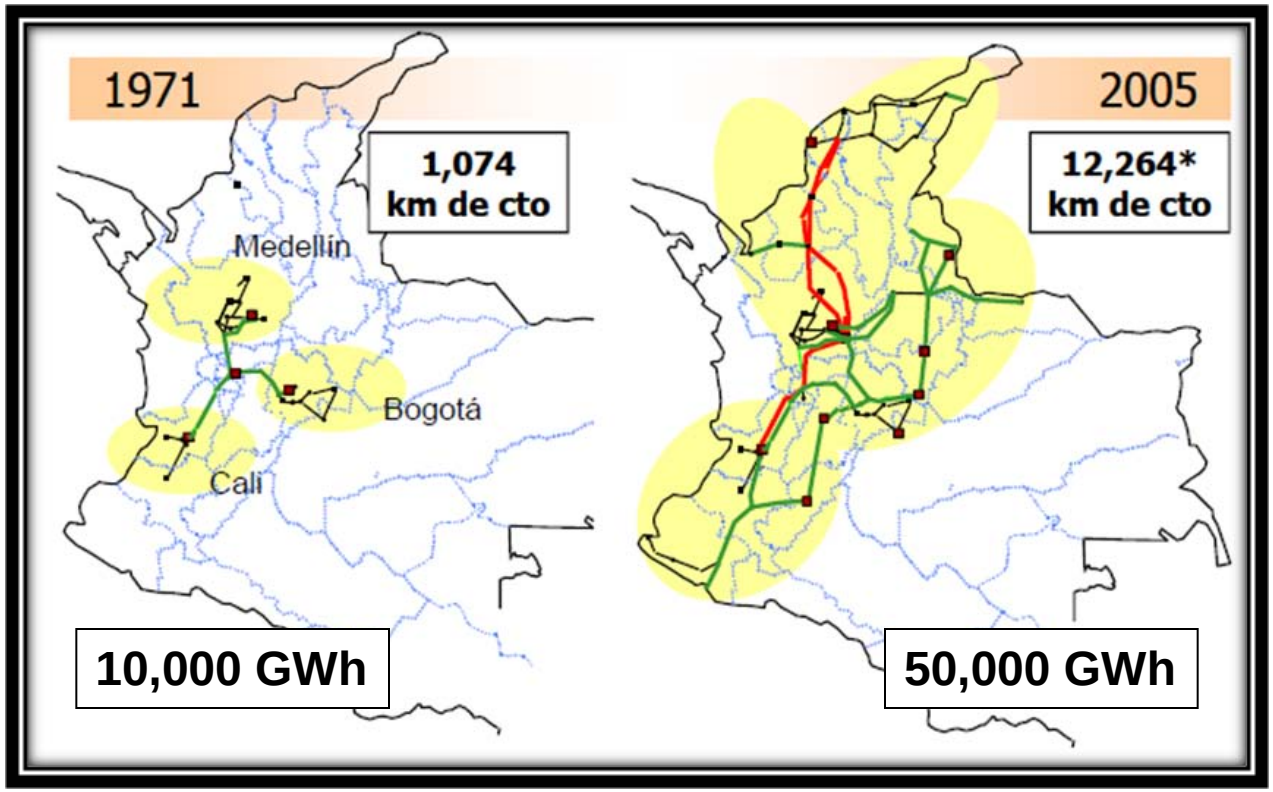
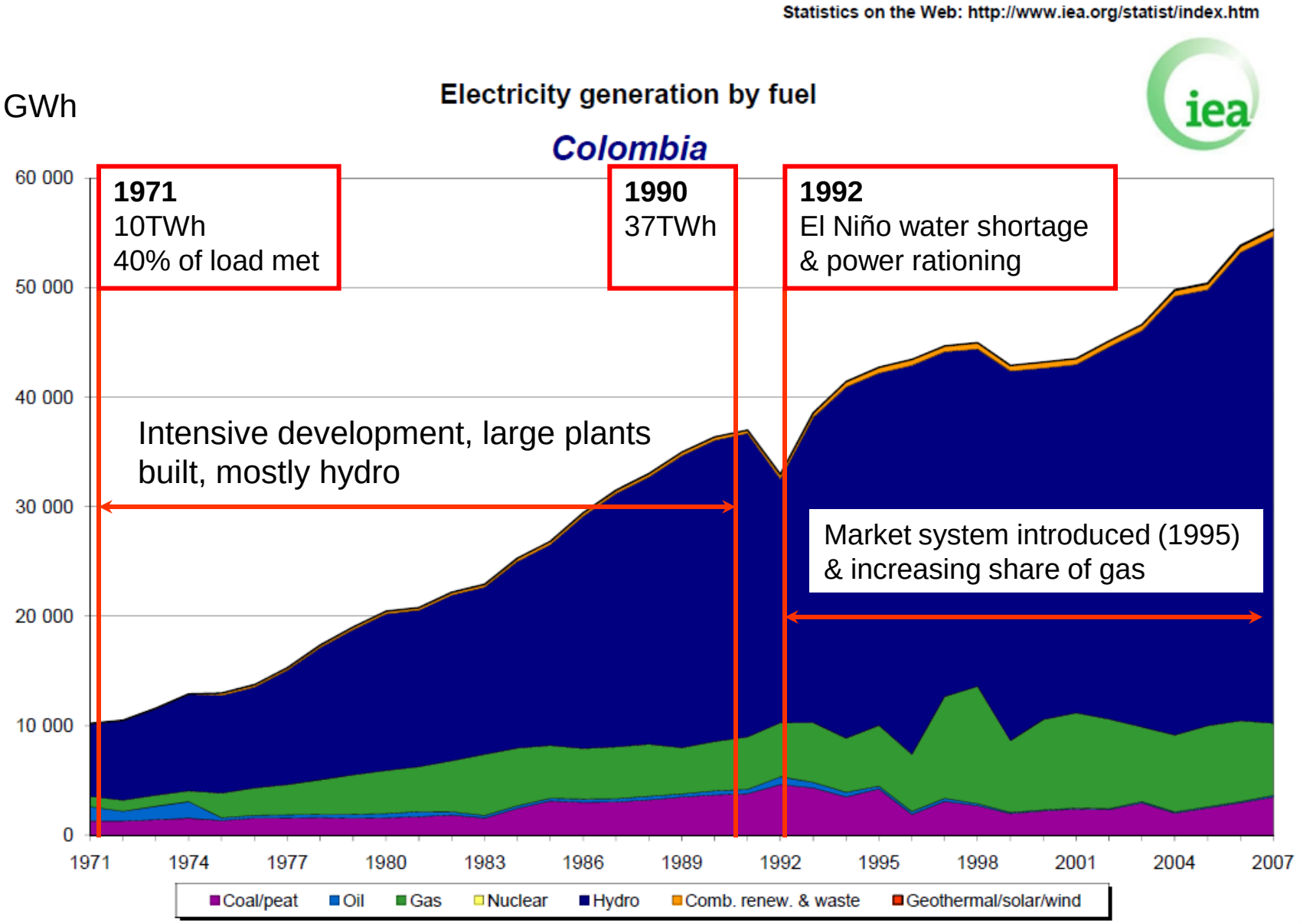
About XM & Colombian Power System

1. **XM: TSO & Market Operator**
2. **Formed 1995**
3. **13,327km 230/500kV lines**
4. **13GW installed capacity**





Colombian Generation Growth



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About Psymetrix

Wide-Area Solutions

Data Management - PDC's
Visualisation
Monitoring/Alarming
Advanced/Control Apps
EMS Integration

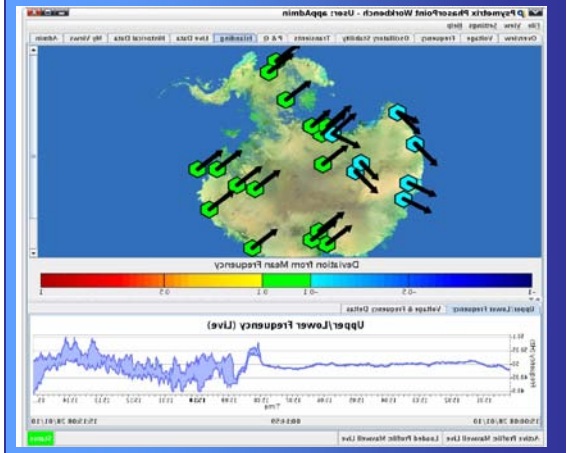
Dynamic Performance Improvement

Real-time DP Assessment
Transmission optimisation
System stability
Islanding response, blackstart
Renewables

Consulting Services

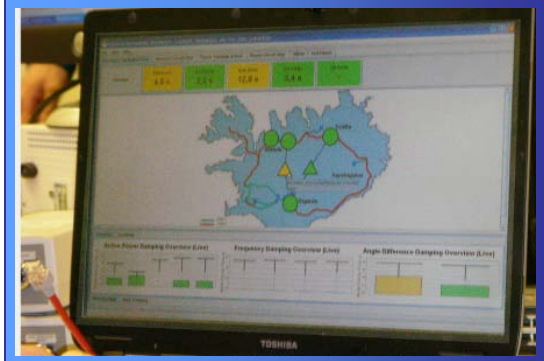
PSS / Governor tuning
Constraint relaxation
Model validation
Dynamics baselining
WAMS design & deployment

PhasorPoint



Applications
Solutions
Research
Published Papers

XM, Colombia
Landsnet, Iceland



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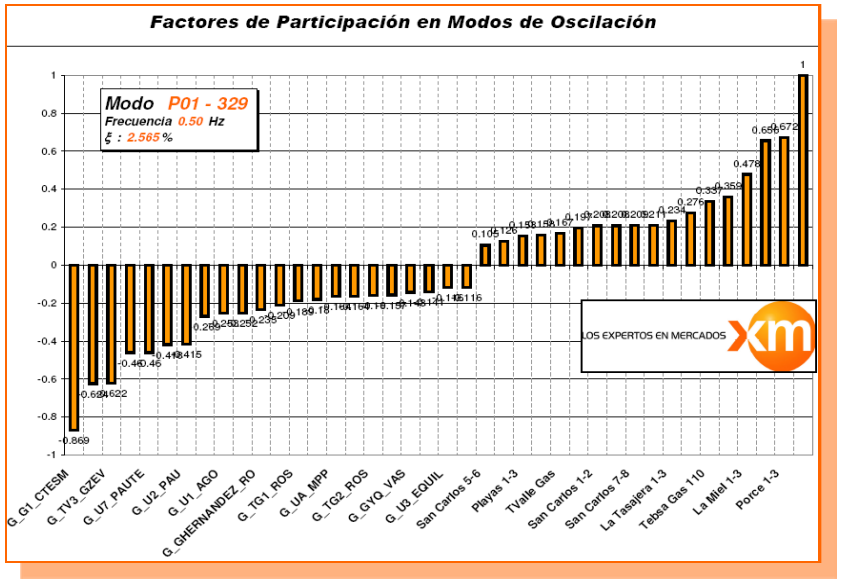
Colombian Power System in 2005

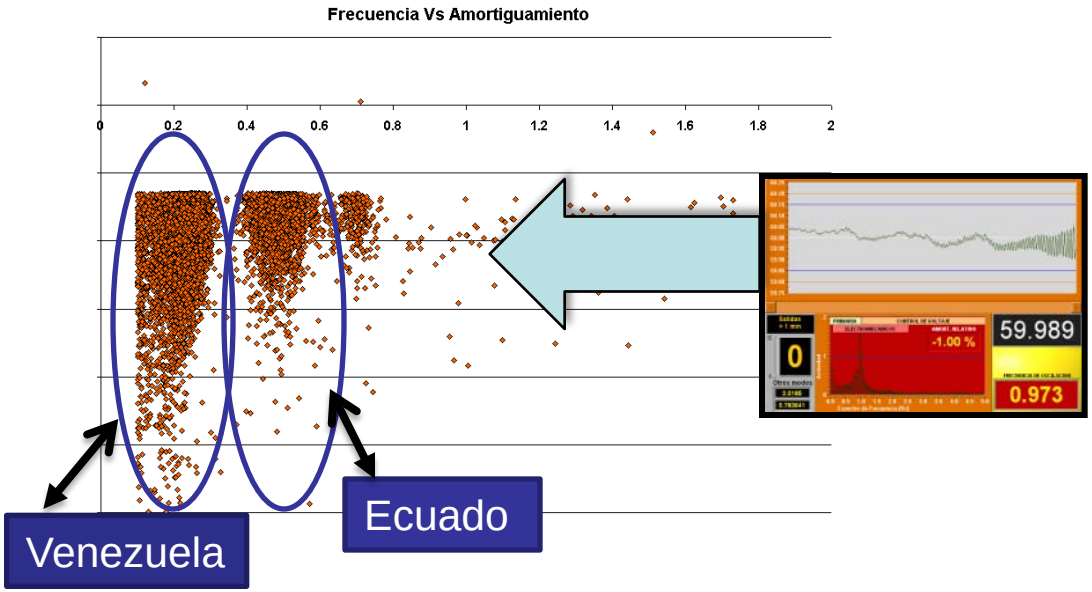
Small Signal Stability in 2005



Classical studies identified:

- 0.22Hz Colombia-Venezuela
- 0.34Hz N.Colombia- Venezuela
- 0.4Hz Colombia-Ecuador
- 1.2Hz Central & N. Colombia

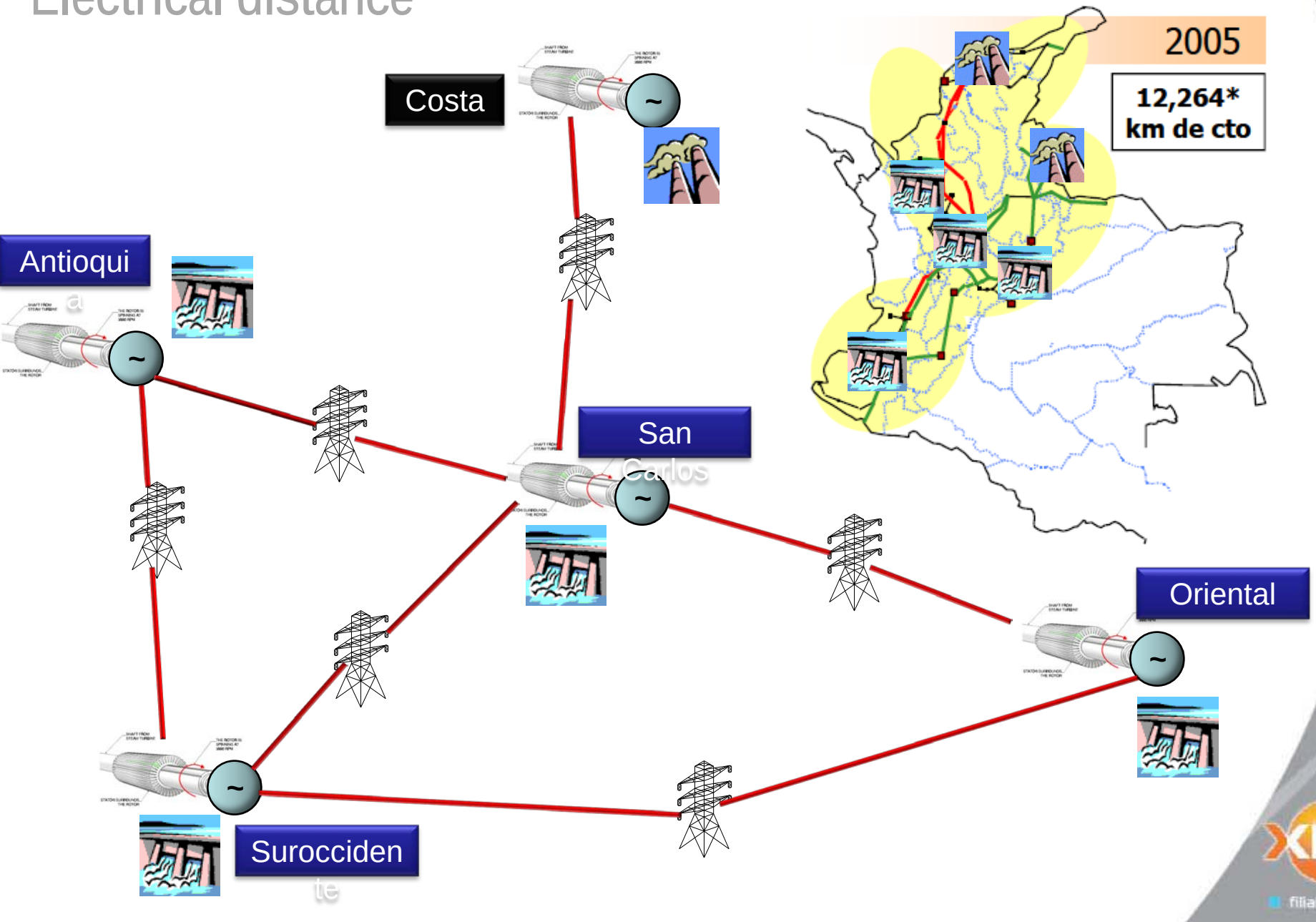
0.06Hz not simulated; measured from 2007



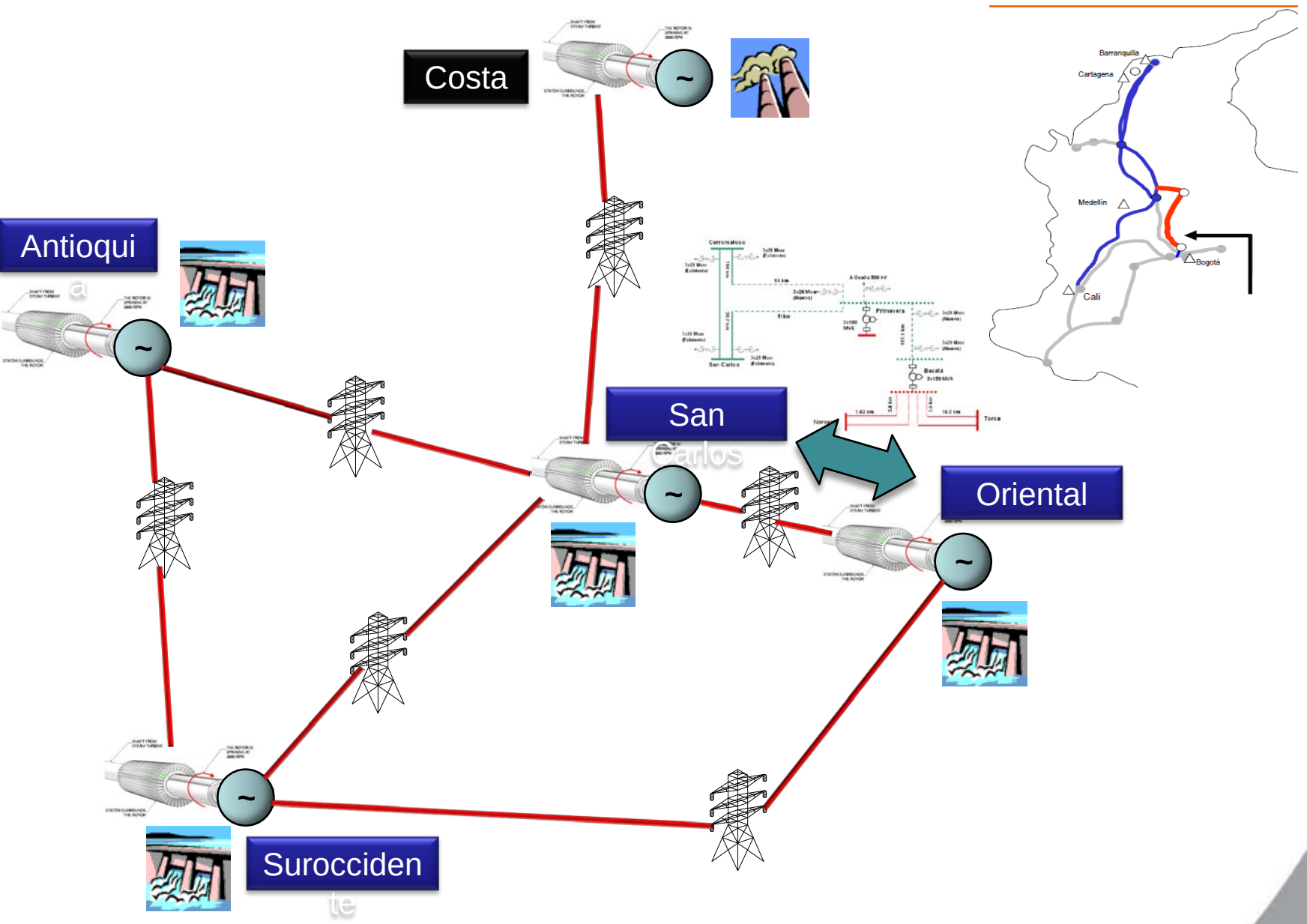
Study modes validated by F@Osnet frequency monitoring (pre-WAMS)

Colombian Power System in 2005

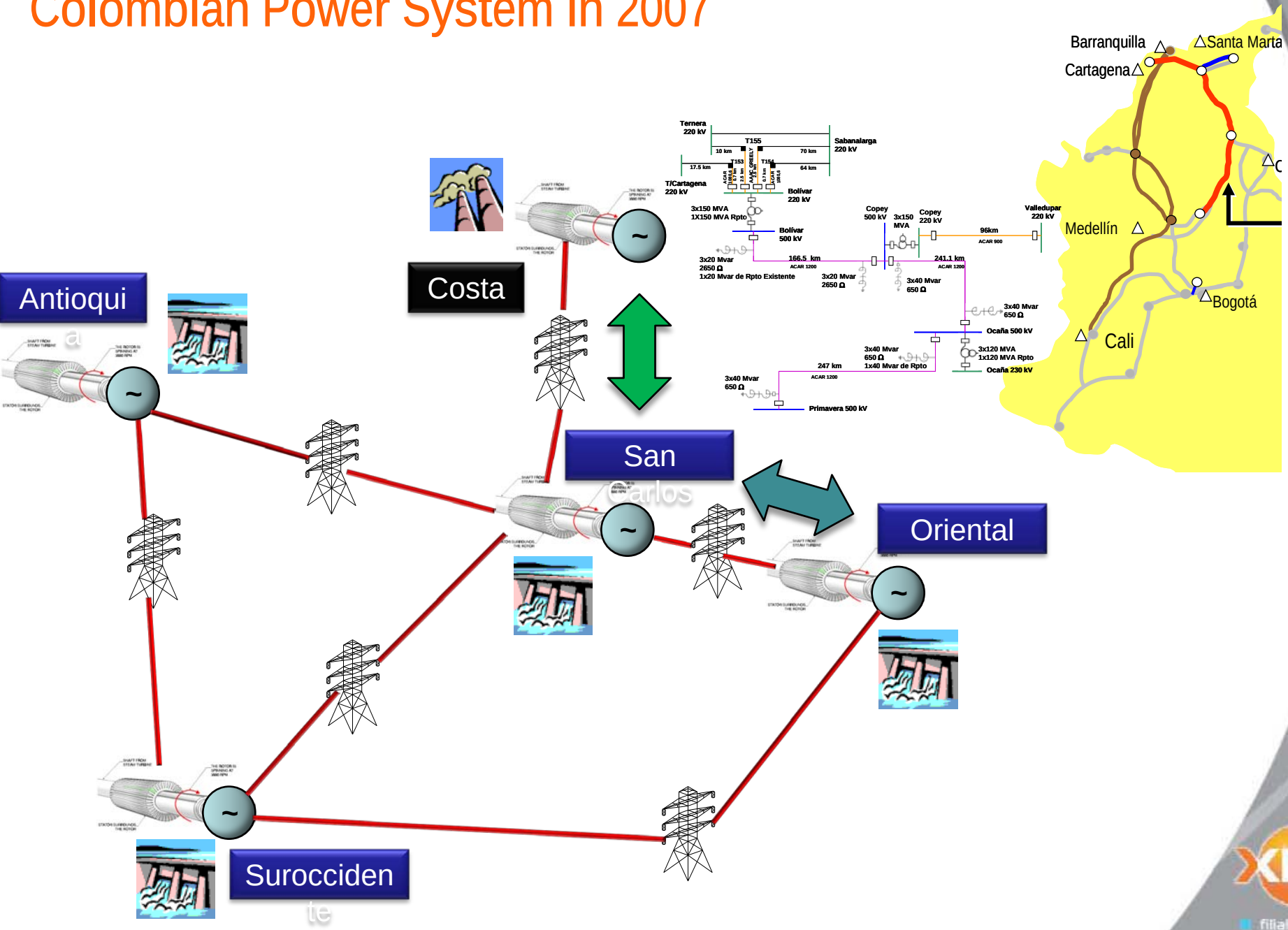
Electrical distance



Colombian Power System in 2006

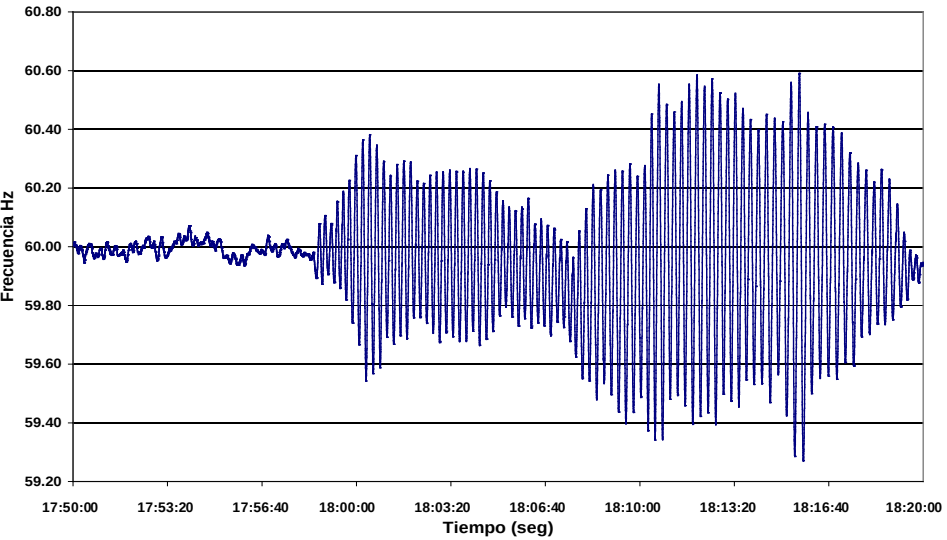


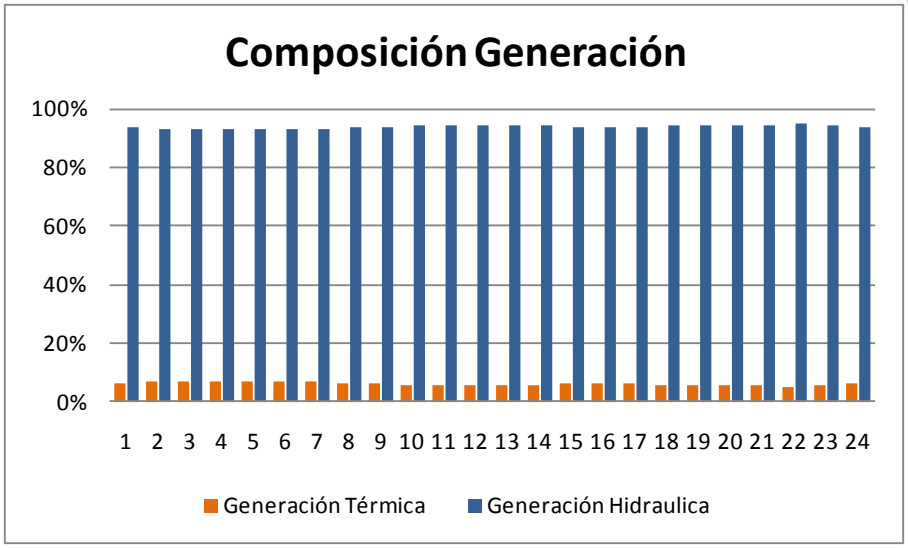
Colombian Power System in 2007

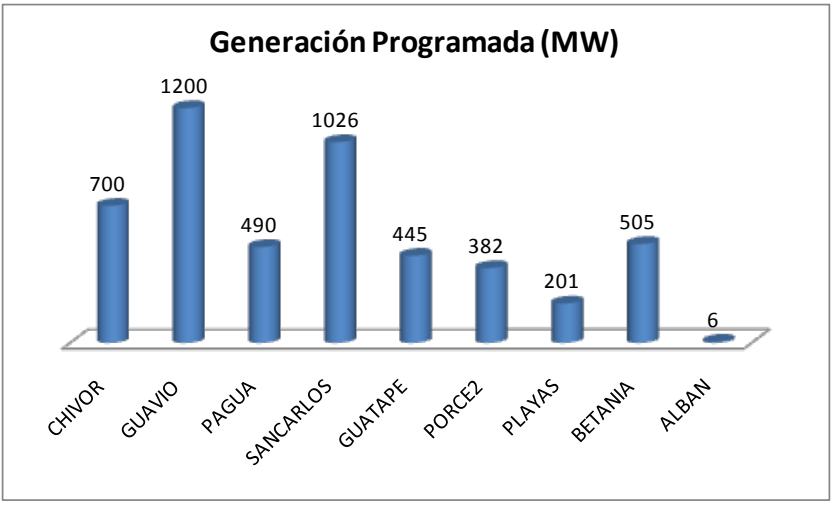


August 10, 2008, 18:01 hours

f = 0.06 Hz, duration 20 minutes

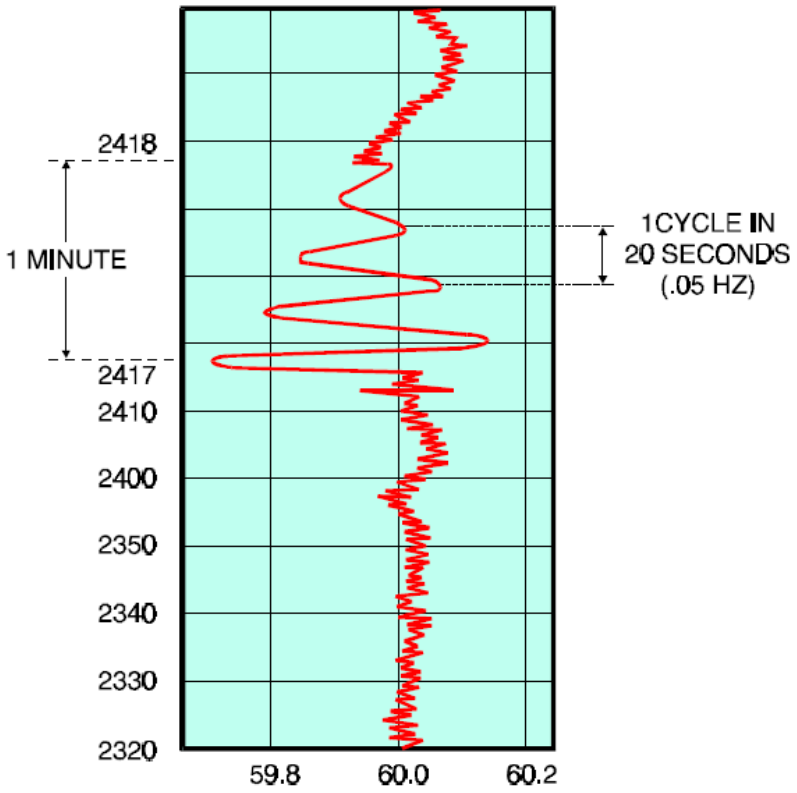






- Interconnector tripping
- Load shedding
- Generator stress
- Several recurrences
  - Up to 90 mins
  - Up to +/-1Hz
- Unknown source

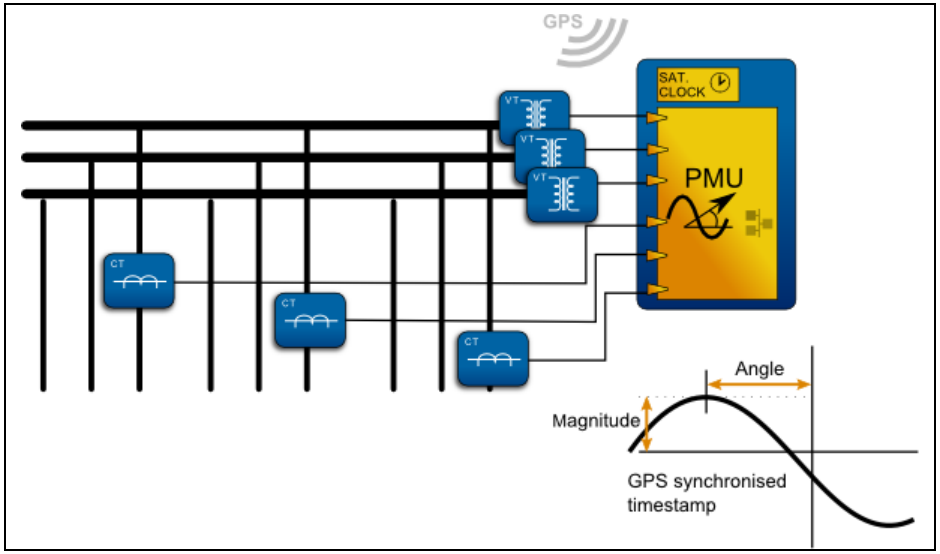
International Experience: Pacific Northwest in the 1960's
Frequency 0.05 Hz

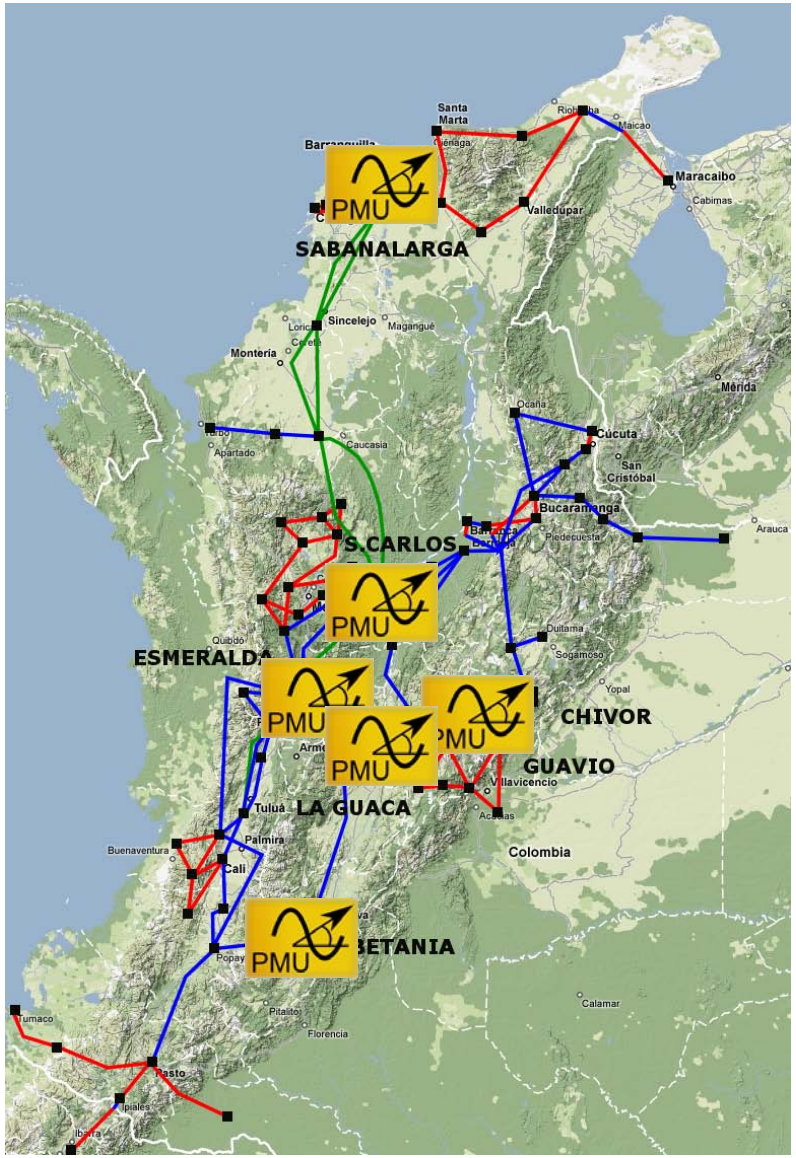


- Appeared with system growth 1955-60
- Mainly hydro (17.000 MW); little thermal (1500 MW)
- Various experiments with governor control
  - ⇨ Resolved by slowing governors (inserting dashpots)
- Oscillations <0.08Hz observed by Psymetrix in 3 other interconnections, 2007-2010

WAMS Implementation

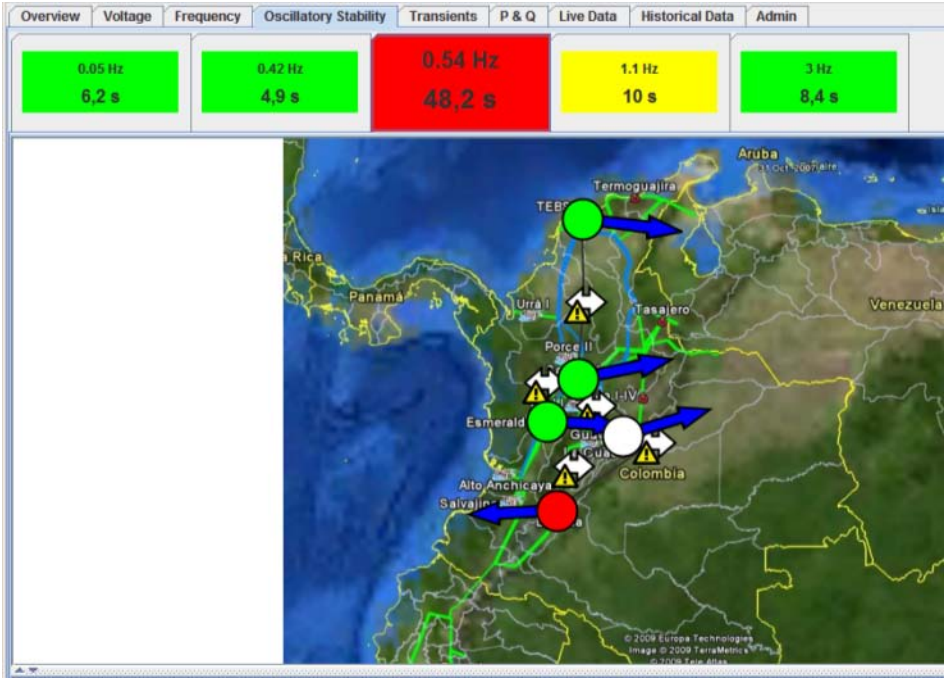
1. WAMS installation goals
   - Identify source of instability problem
   - Conduct non-intrusive generator tests
2. Maximise coverage of power from major generators
3. 6 PMUs
   PDC & Apps server at Medellin
   VPN link to Psymetrix





Modes observed e.g. 0.49 Hz (Ecuador) and 0.05 Hz

Inter-area mode at 0.49Hz (Colombia-Ecuador). Opposing phase in South



Governor common-mode: whole system oscillates in coherent phase

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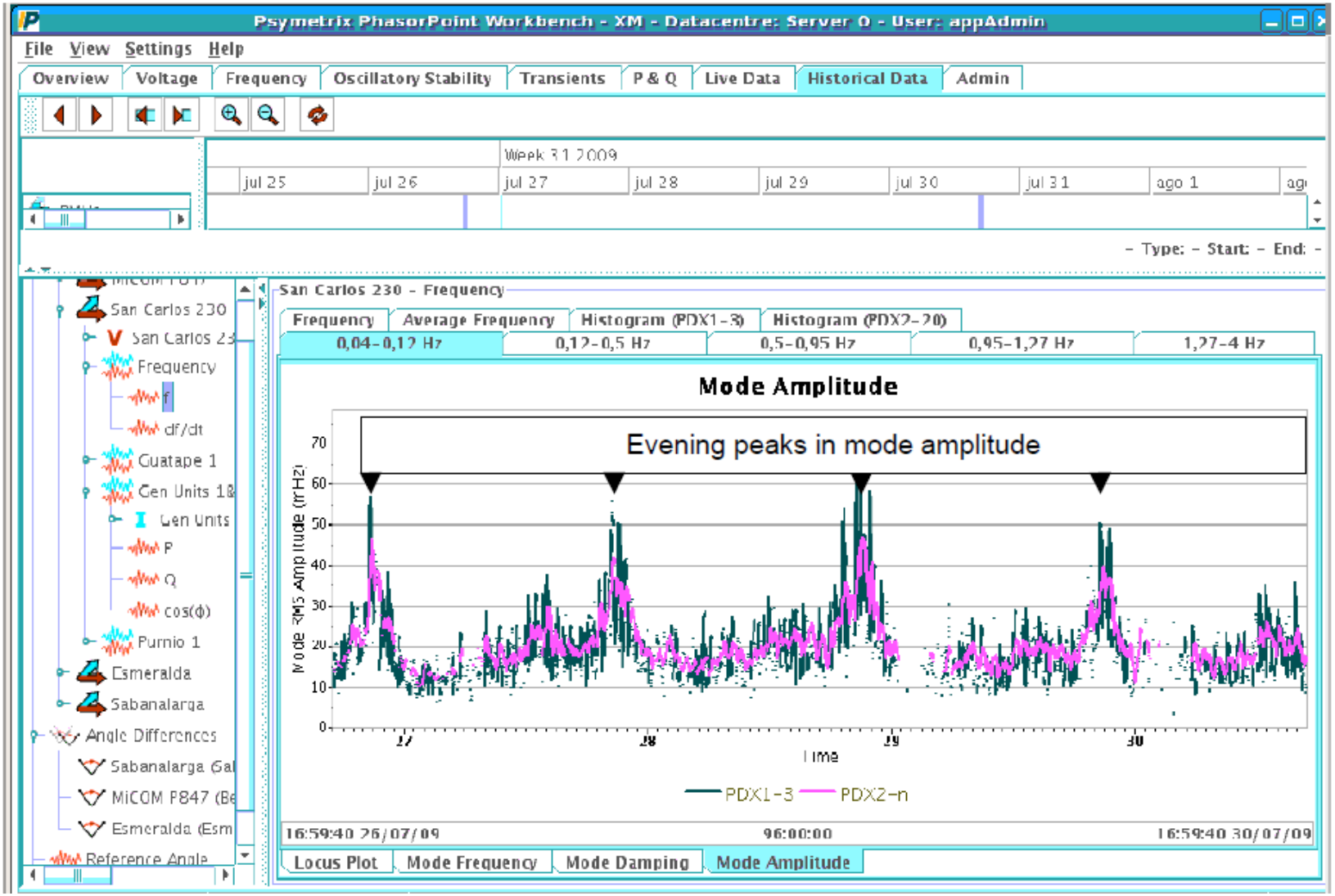
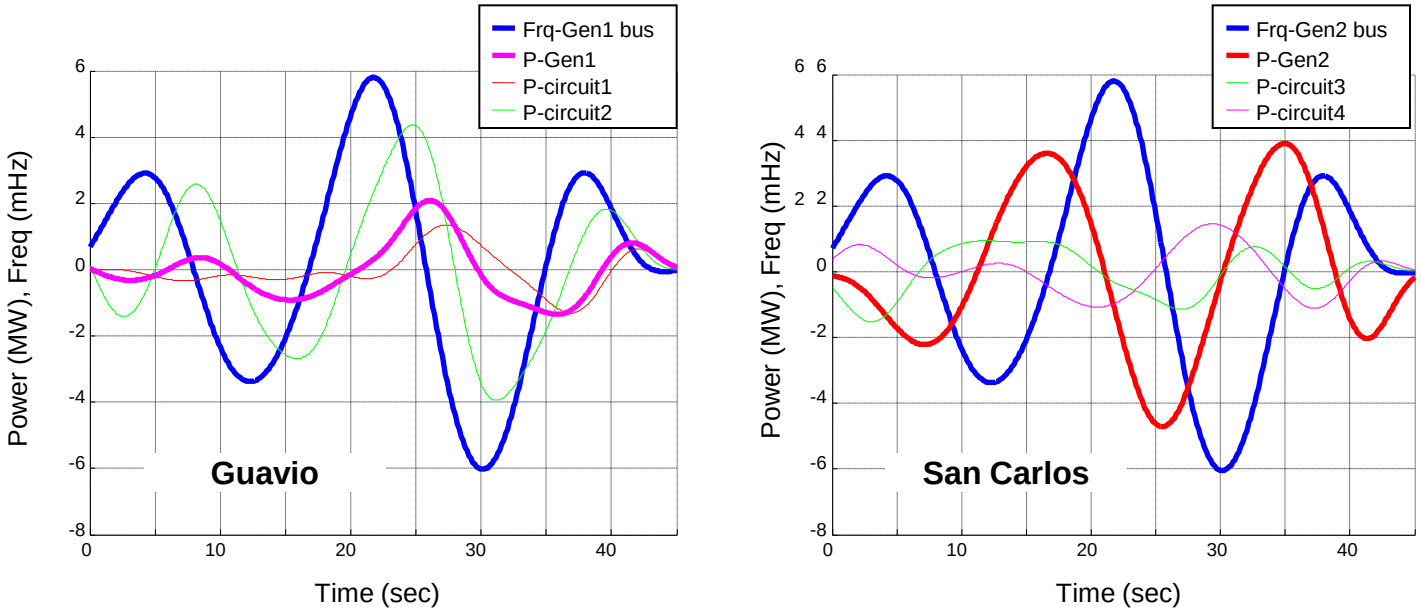
Identify Patterns - Regular Evening 0.06Hz Peaks

- Associated with generation patterns
- Suggests suitable times for system tests



Identify Contributions

1. **WAMS records of oscillations help identify source**
   - Identify generator, if it is monitored
   - Identify control area / region
2. **San Carlos plant contributed to mode**



- ***Plant contributing strongly to grid oscillation identified***
- ***Information to justify further investigation at plant***
- ***Significant time, effort and cost saving to identify source***

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San Carlos Hydro Plant

Rated 1300MW

8x 162MW Pelton turbines, commissioned 1979

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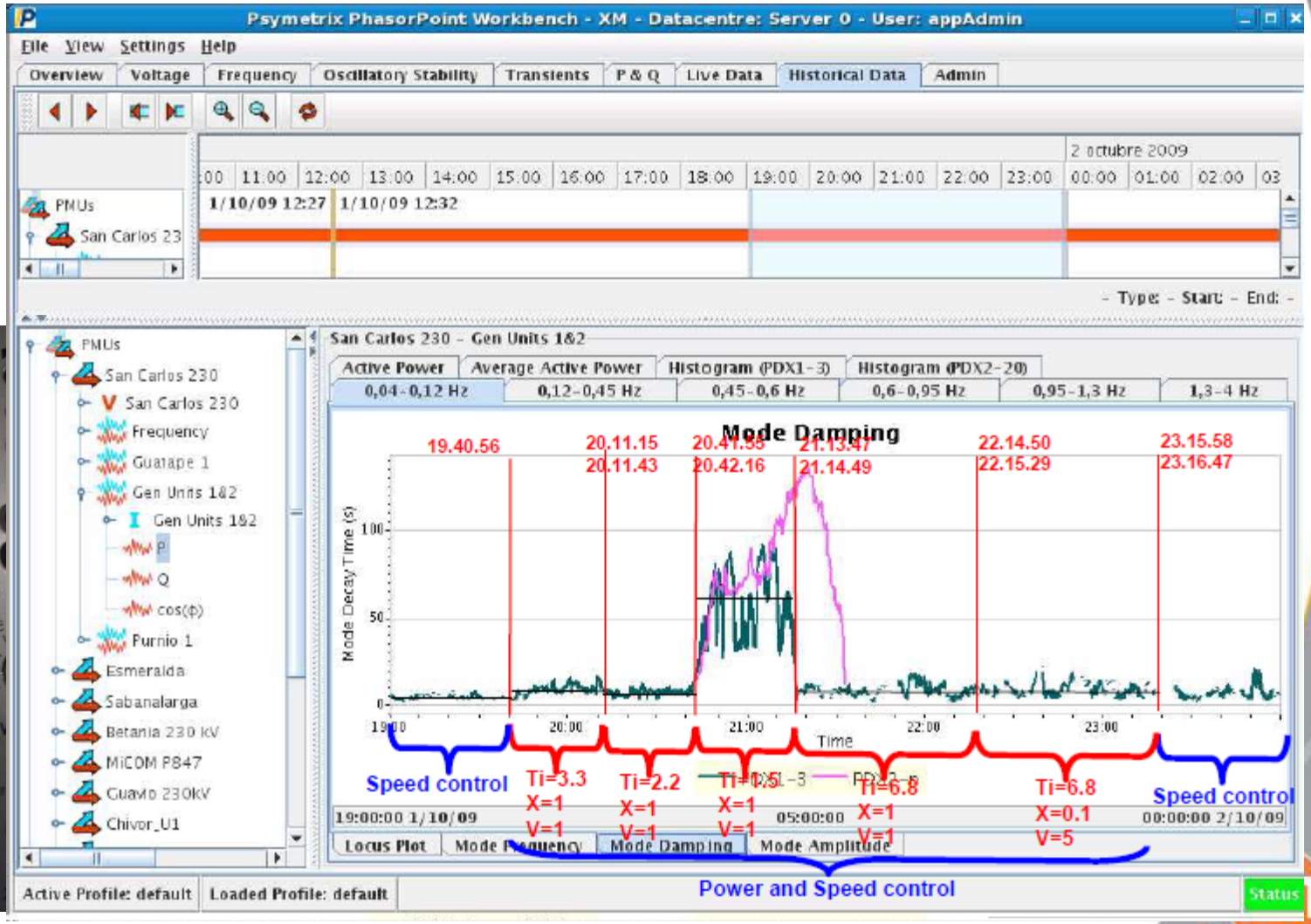
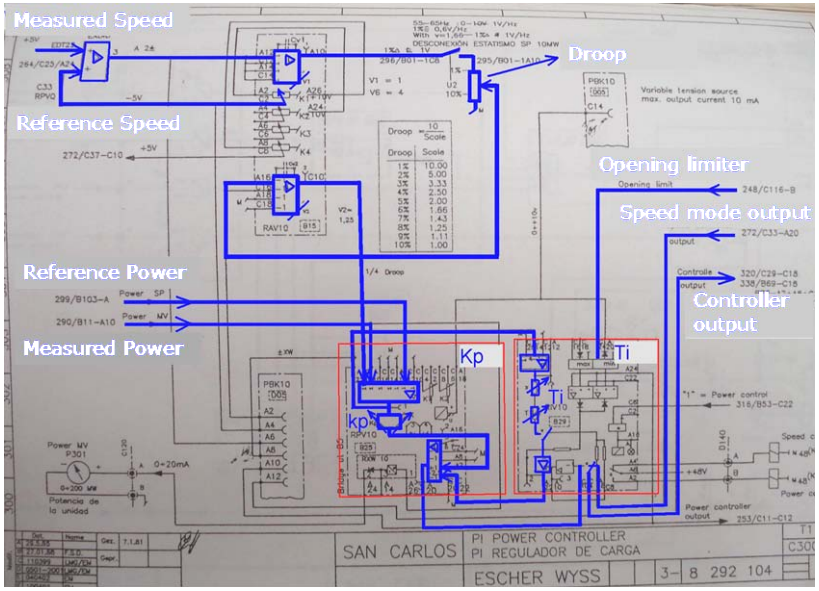
Sensitivity Tests: San Carlos Governor Parameters

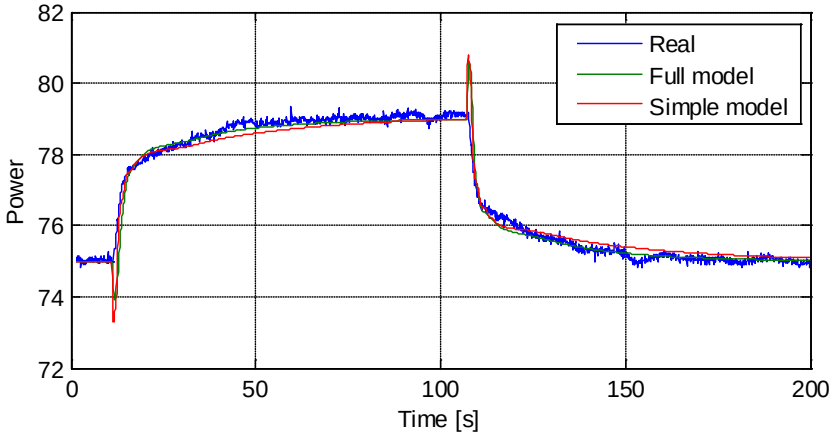
Units 1&2 K & integrator T_i adjusted
Mode amplitude & decay monitored

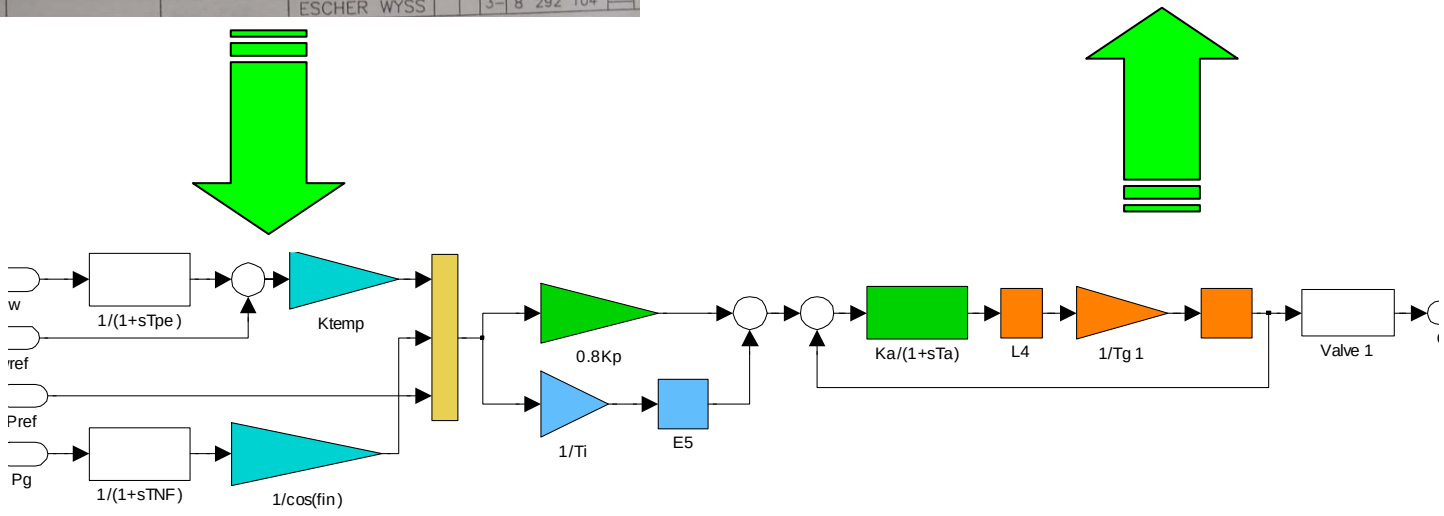
0.06Hz stability strongly influenced by governor controller time constant, T_i



Model Building & Validation

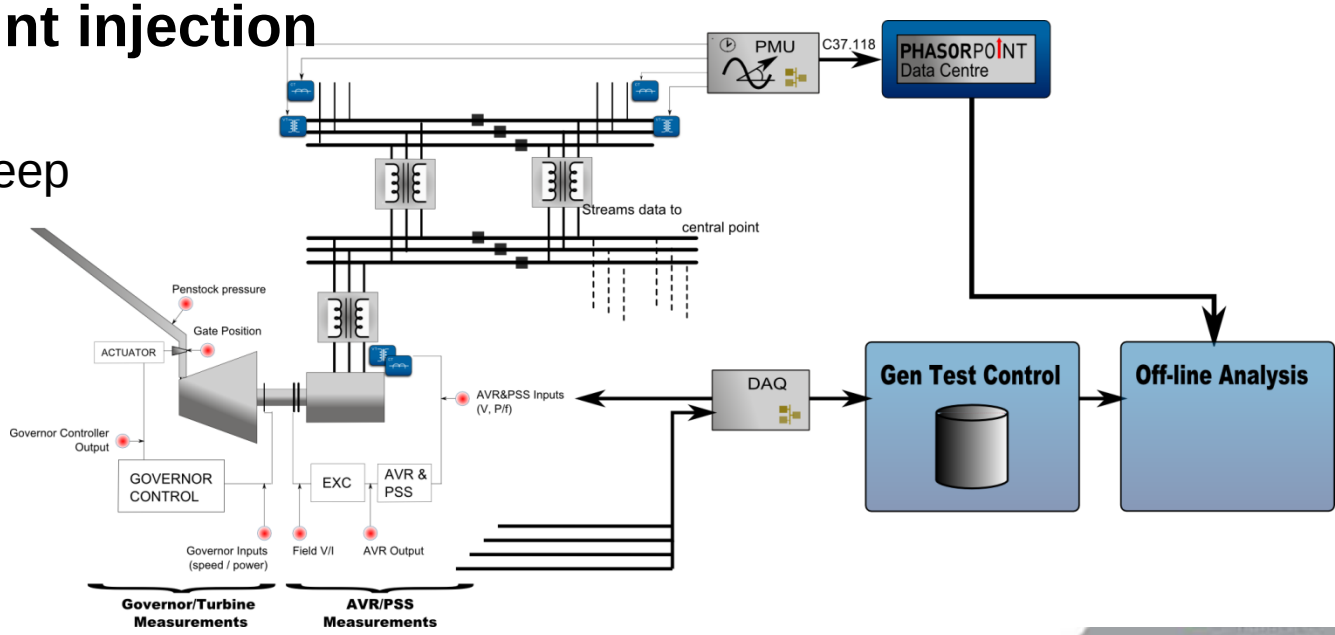






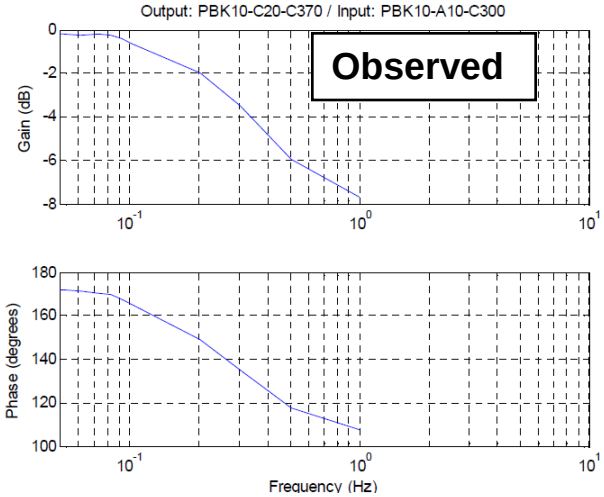
Governor Response Identification

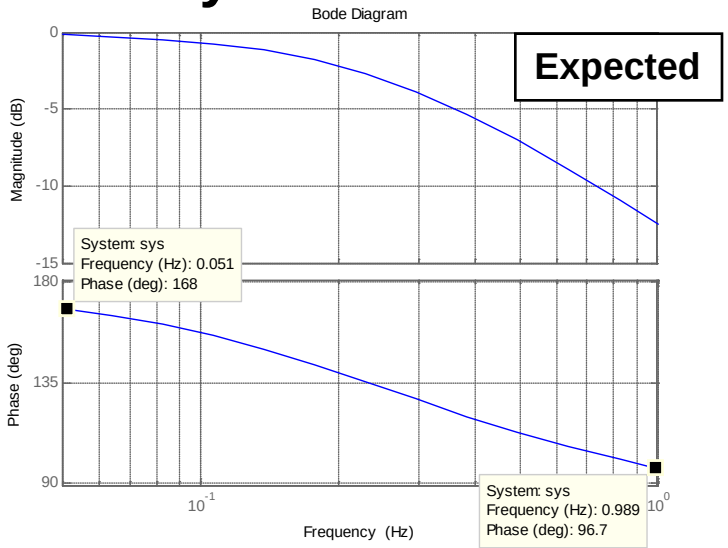
1. **Machine instrumented with continuous local monitoring**
   - 10 samples / second
   - Recording channels allocated to:
     - Governor controller test points
     - Needle valve actuator
     - Generator P/Q/V
     - etc.
2. **Governor setpoint injection**
   - Step response
   - Frequency sweep



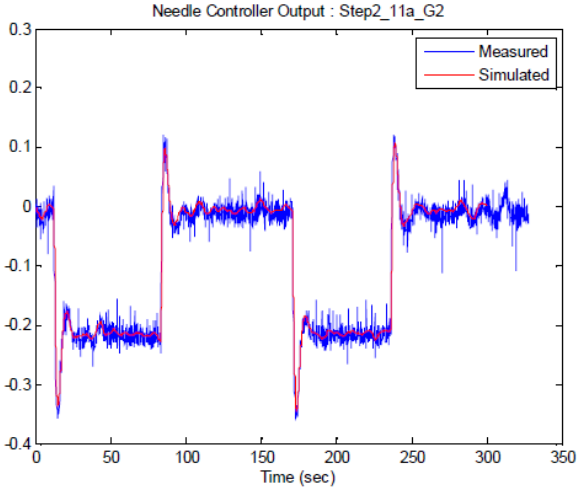
Model Validation

1. Frequency responses matched block-by-block



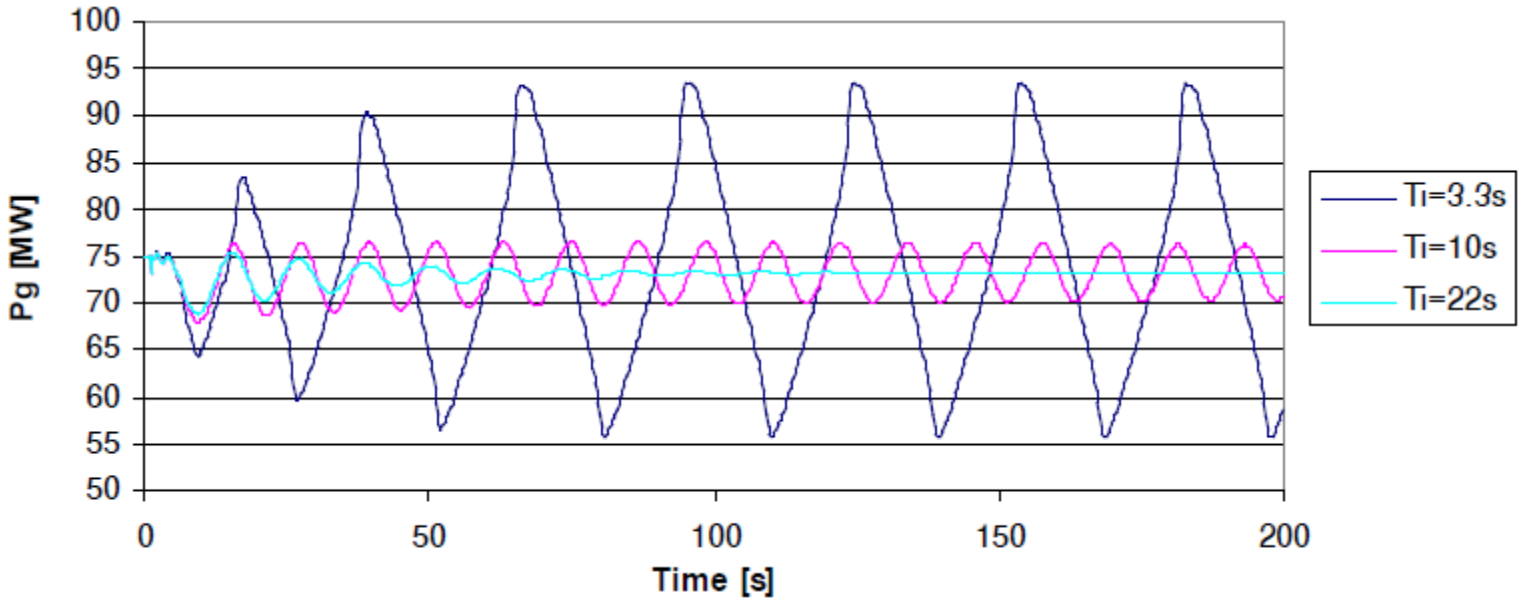


2. Step responses matched



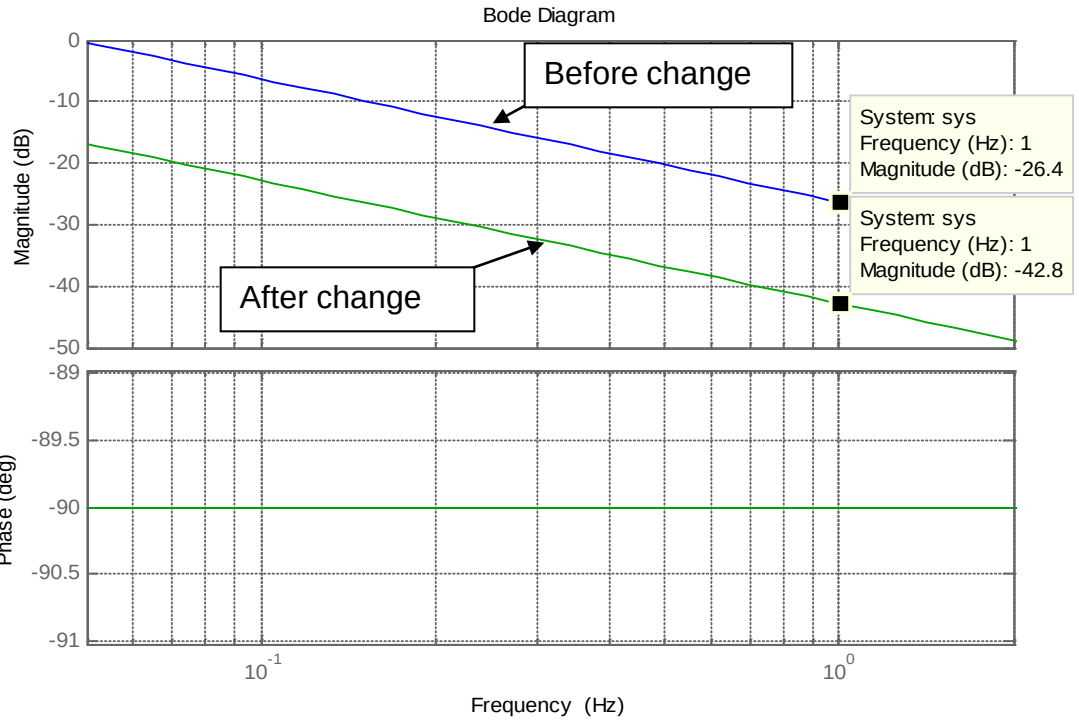
Simulation of Proposed Parameter Change

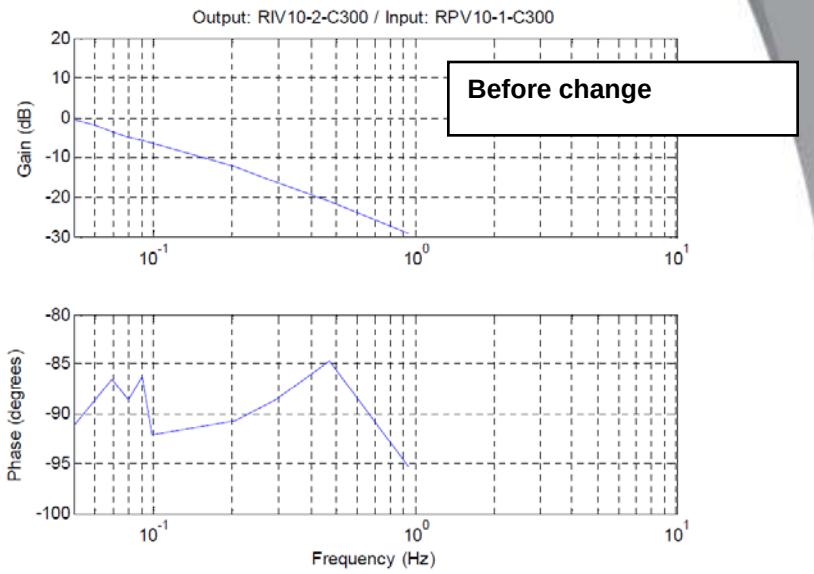
1. **Replication of 0.06Hz stability issue achieved**
2. **Proof by simulation that stability improved with target parameter change** (Integrator Ti from 3.3 sec to 22 sec)

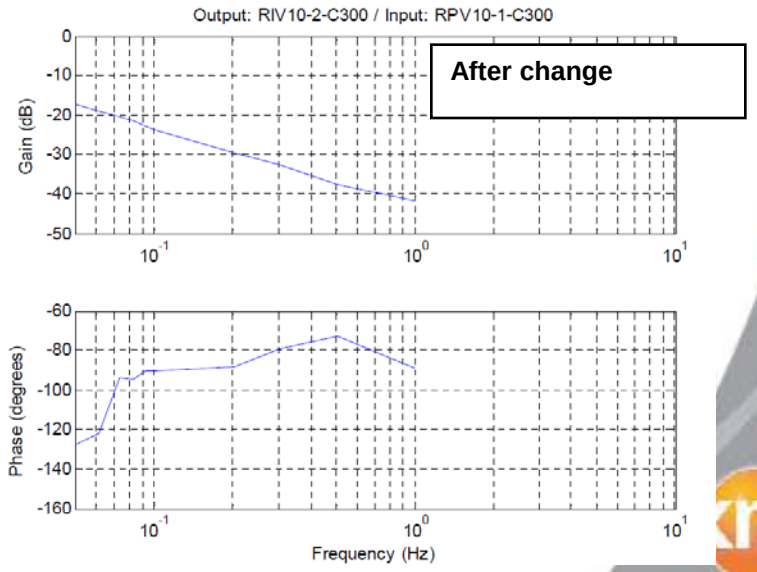


Deploying the Parameter Change

1. **Confirm correct transfer function applied**
2. **Confirm intended effect is observed**
   - Controller malfunction on one unit identified & card replaced

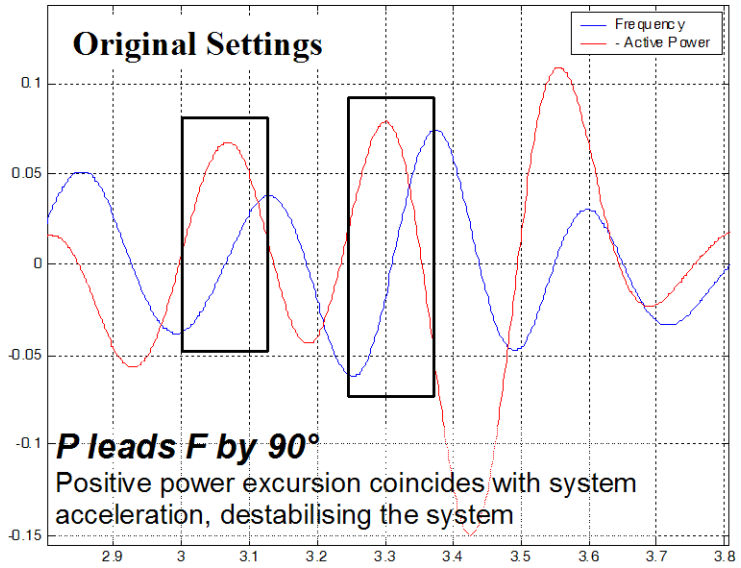






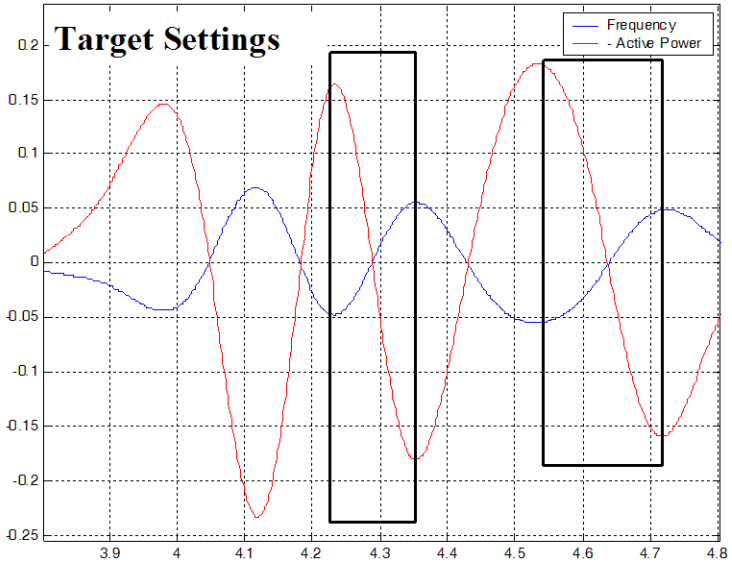
Deploying the Parameter Change

1. **Confirmed that change in power output in response to 0.06Hz oscillations as intended (using WAMS)**



P leads F by 90°
Positive power excursion coincides with system acceleration, destabilising the system

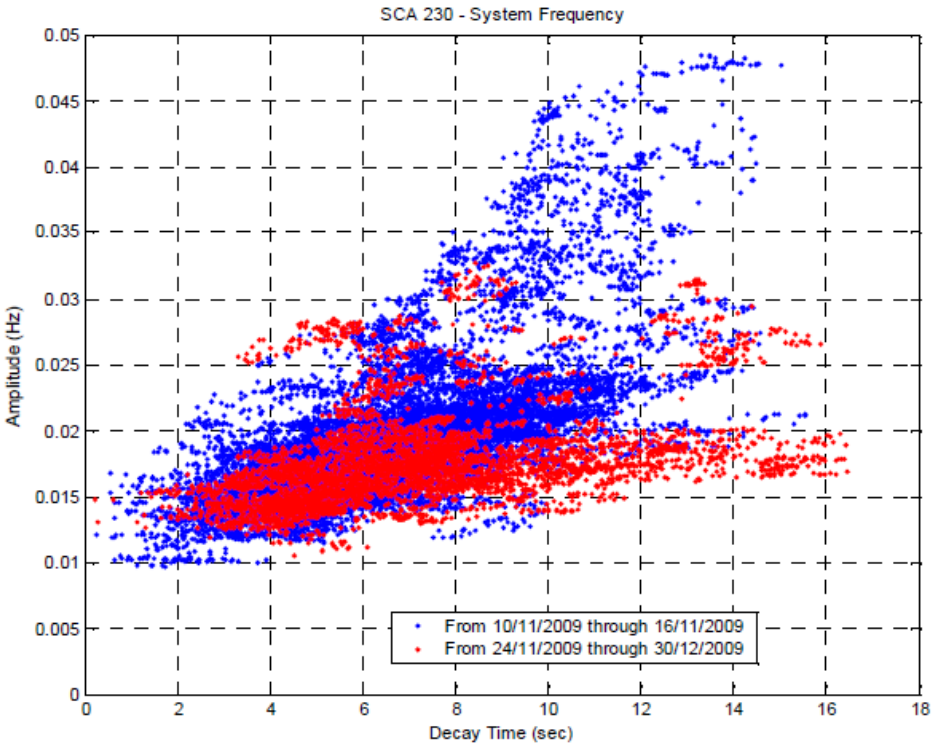
Power export from generator is *positive*

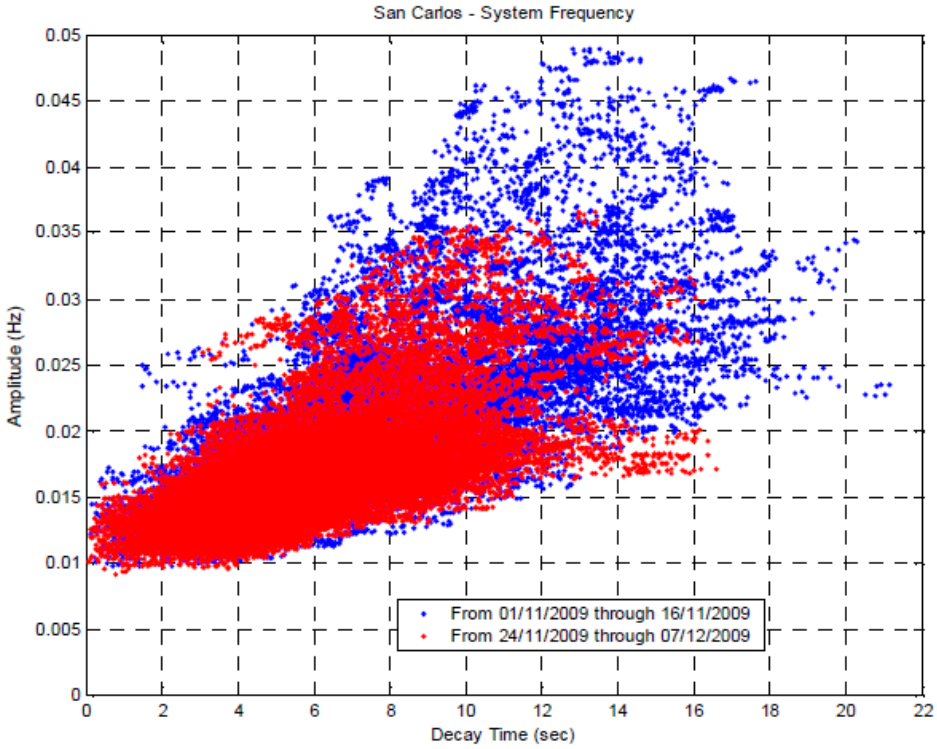


P leads F by 180°
Net contibution of power to the oscillation is approximately zero

Stability Review

1. **Stability baseline achieved prior to parameter change**
2. **New performance compared with baseline**





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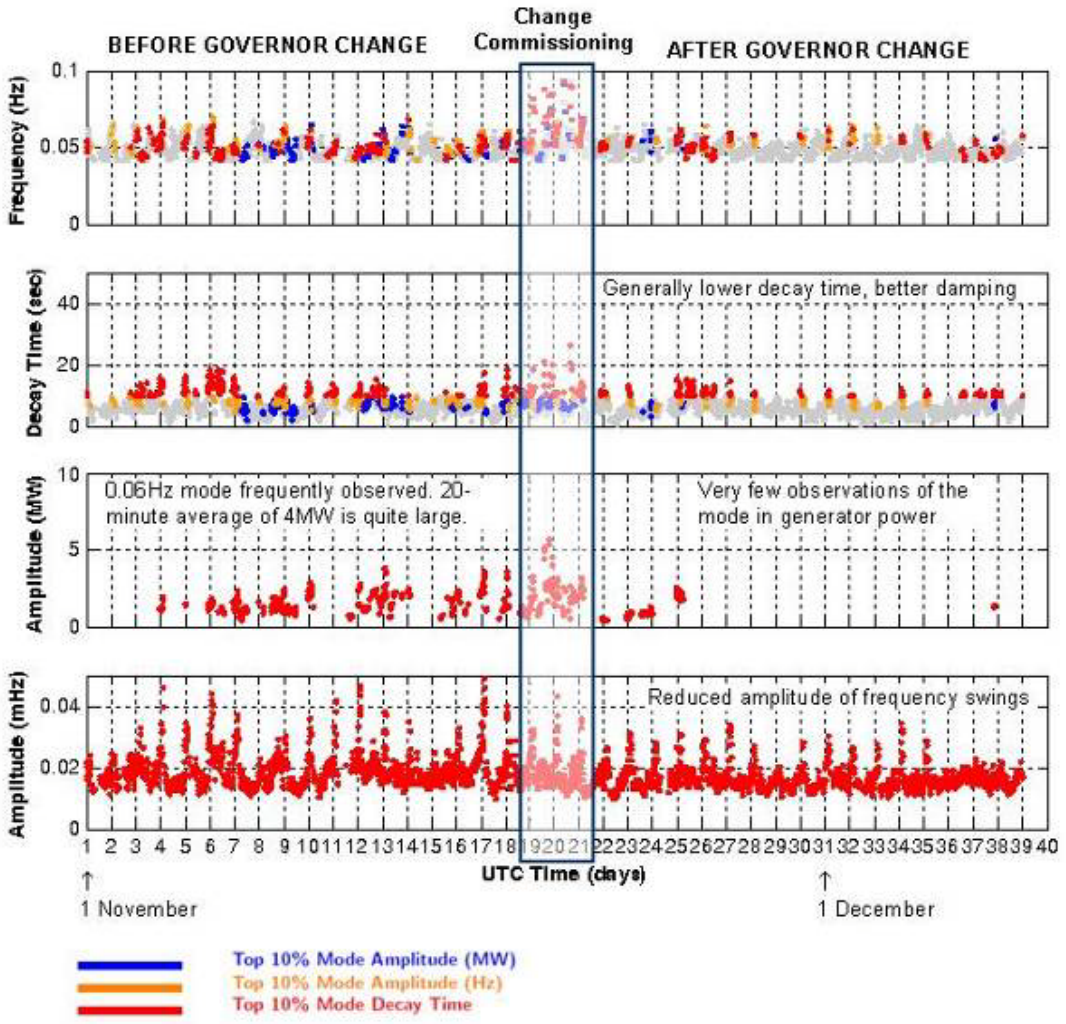


Outcome of 0.06Hz Stability Project

1. Project results

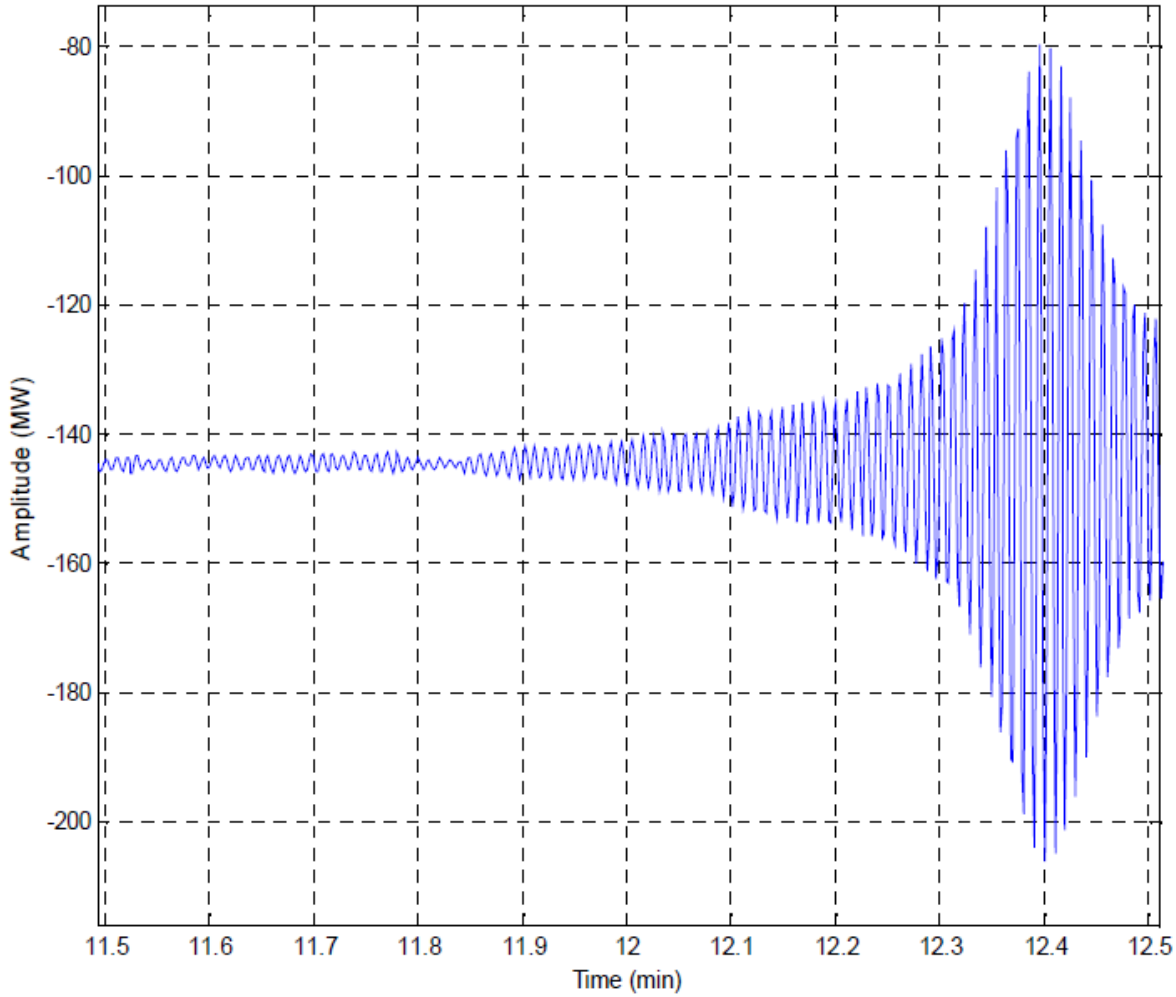
- Measurable improvement in 0.06Hz mode stability
- Reinstated normal ‘power & speed’ control at San Carlos
- Created an improved governor model
- Identified a controller malfunction
- No recurrence of frequency instability

2. Ongoing work

- San Carlos governor controllers to be replaced with digital units
- WAMS & dynamics tools used to ensure stability problem is not reintroduced

Other Stability Issues

1. **Other oscillations identified & characterised, e.g.**
   - Local mode oscillation (1 specific unit)



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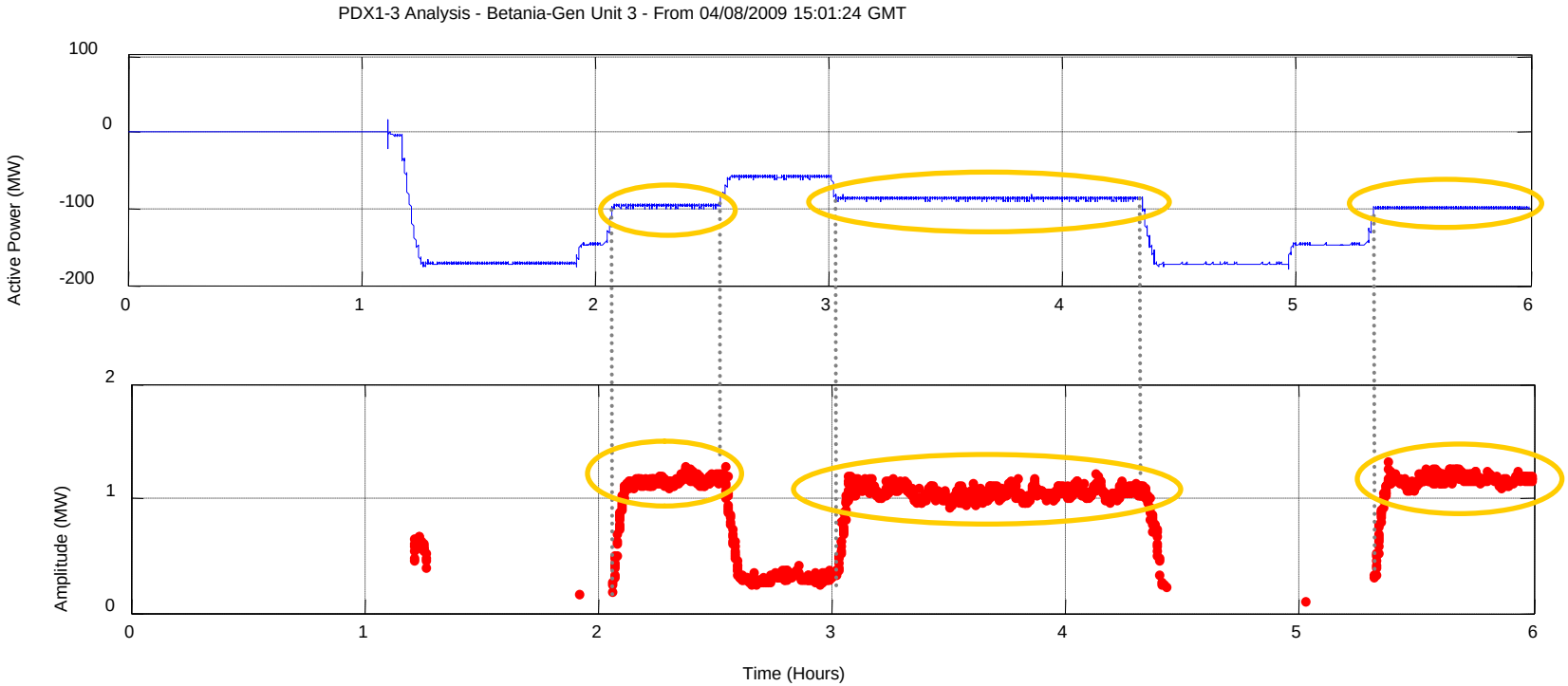
   - Local mode oscillation (1 specific unit)
   - 0.5Hz Forced oscillation - penstock cavitation?



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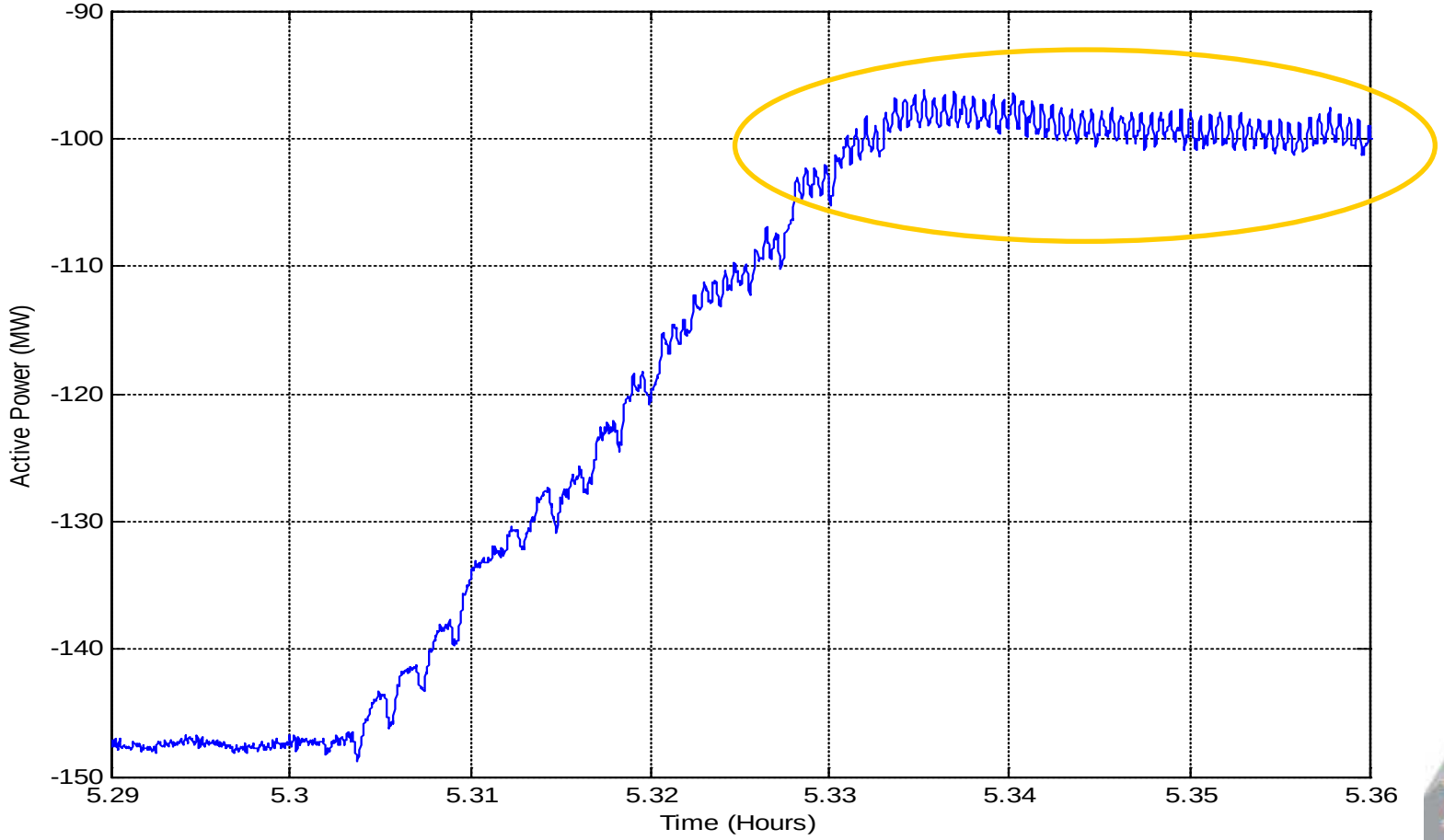
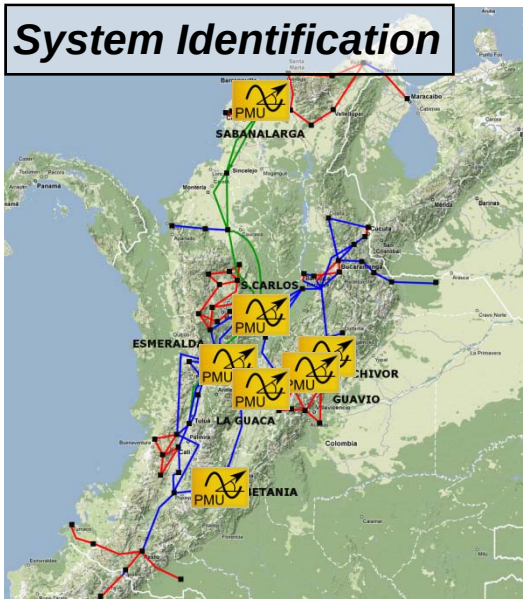


Dynamic Model Validation & PSS Tuning

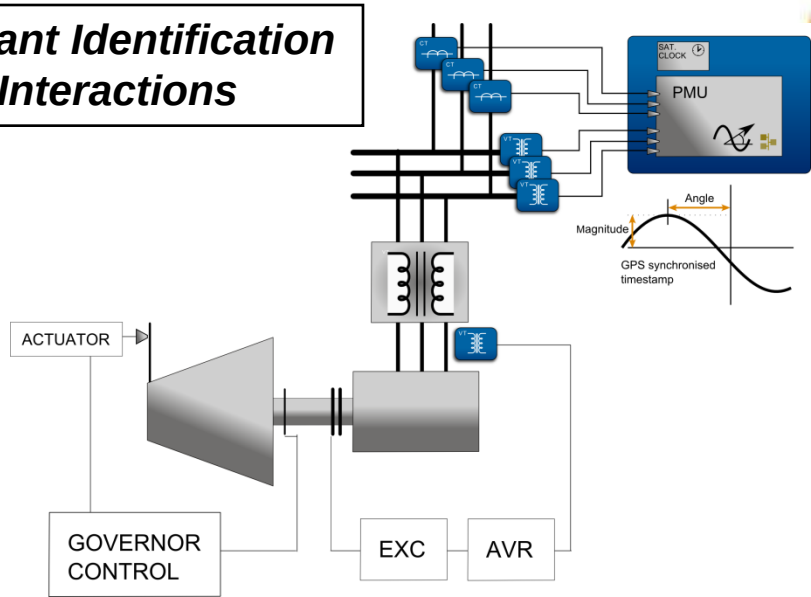
1. **Improve generator dynamic models**
   - Generator dynamic testing programme
   - System dynamic performance validation

2. **AVR & PSS replacement & revision programme**
   - Replacing analogue controllers
   - Systematic stability improvement
   - Addressing future stability issues with increasing international power transfer

System Identification



Plant Identification & Interactions



Conclusions

1. **Frequency stability project**
   - WAMS & Dynamics tools used to locate causes of frequency instability
   - Successful resolution of frequency instability
   - Measurable improvement in stability
   - On-going management to prevent recurrence

2. **Other benefits of WAMS project**
   - Identified other stability issues
   - Key part of wider effort to improve system stability

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