Ecuadorian experiences in development and implementation of specialized applications using synchronized phasor measurement technology

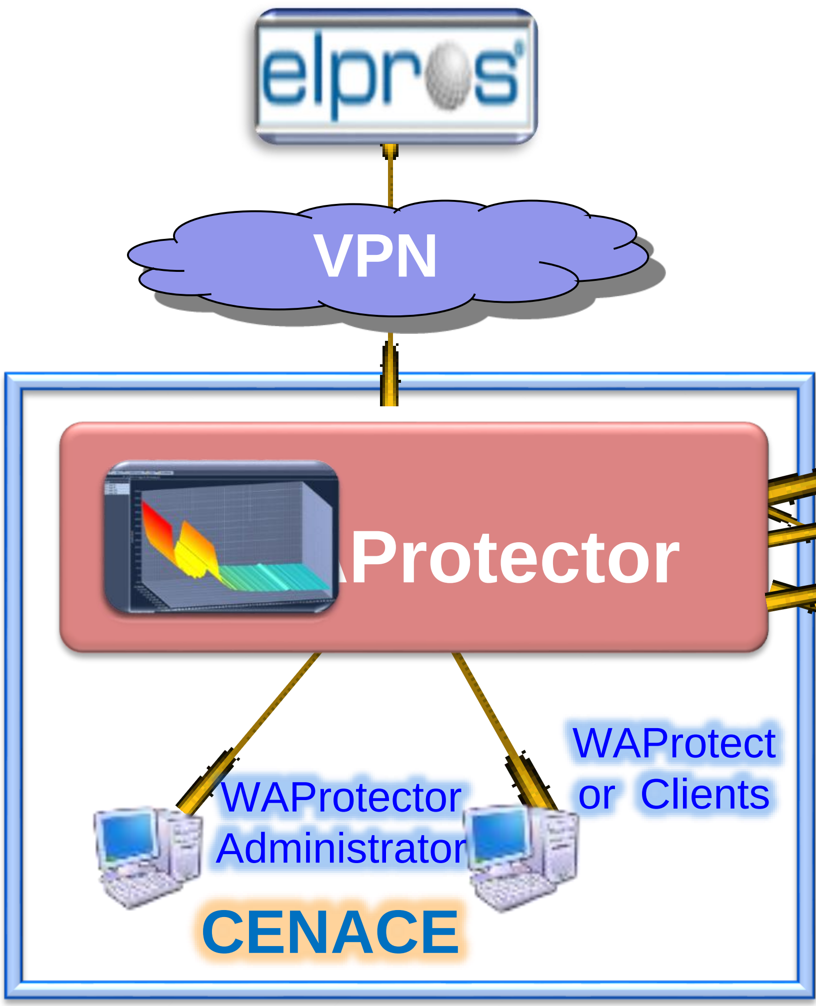
cenace
OPERADOR NACIONAL DE ELECTRICIDAD

Jaime Cepeda

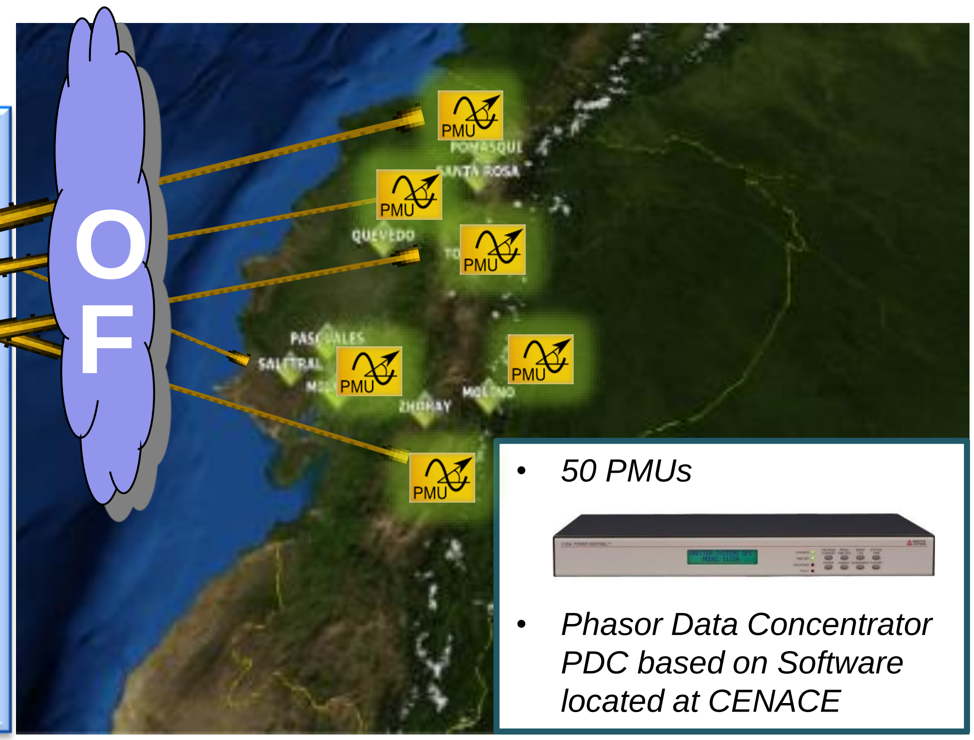
Real-Time Digital Simulation and Smart Grid Laboratory

- ***OPAL-RT Real-Time Digital Simulator***
- ***Low-power Amplifier***
- ***Medium-power Amplifier***
- ***PMUs***
- ***Digital Twin of PDC (WAProtector)***
- ***Protection Relays***
- ***Scope***
- ***Perturbation recorder***
- ***Signal injector***
- ***Video Wall***
- ***Training environment***

Ecuadorian WAMS



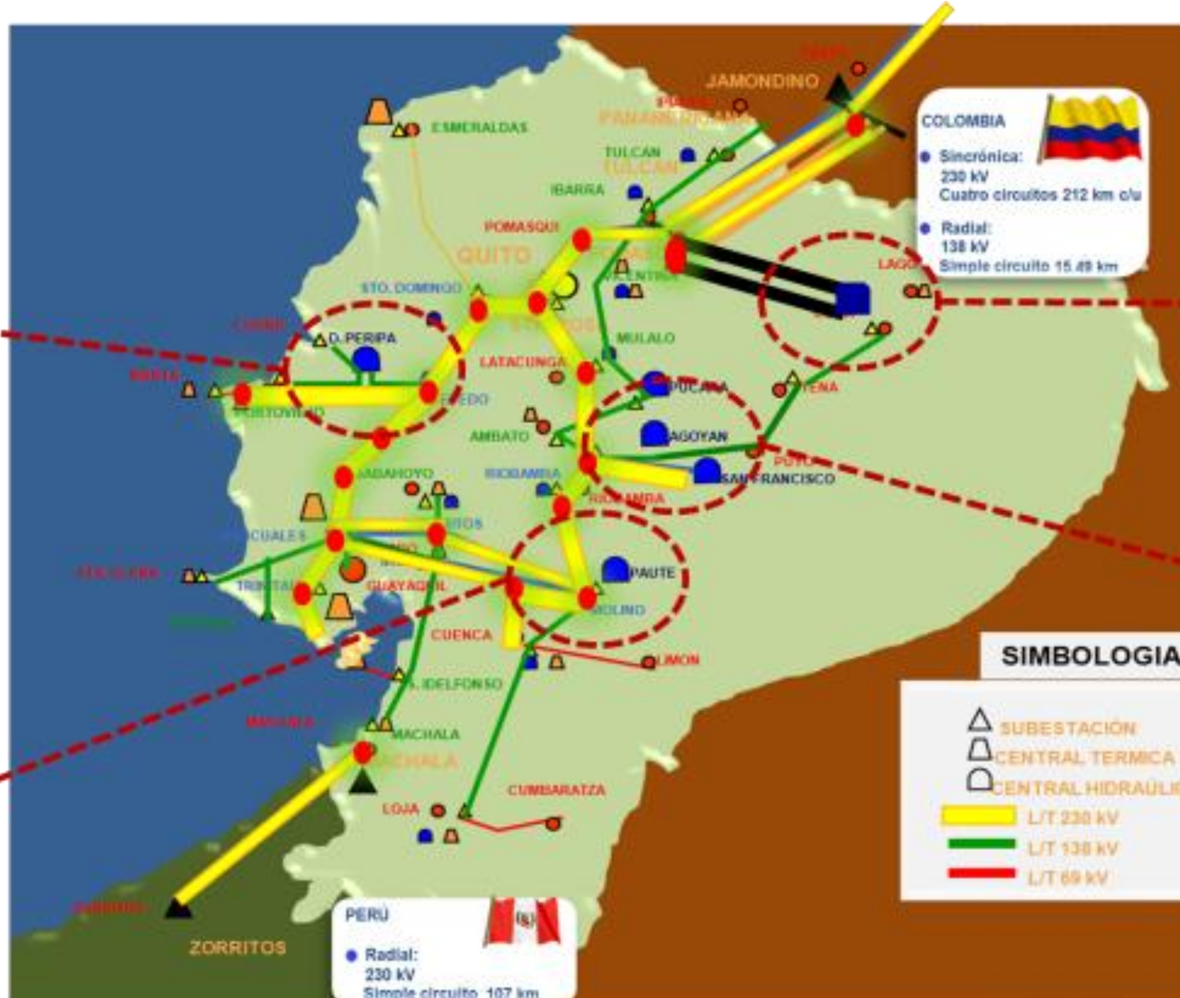
- TCP/IP Protocol
- Standard IEEE C37.118



Oscillatory Modes determined via Statistics from WAProtector

1.0 – 1.8 Hz
Local Mode

0.34 – 0.45 Hz
Inter-area Mode



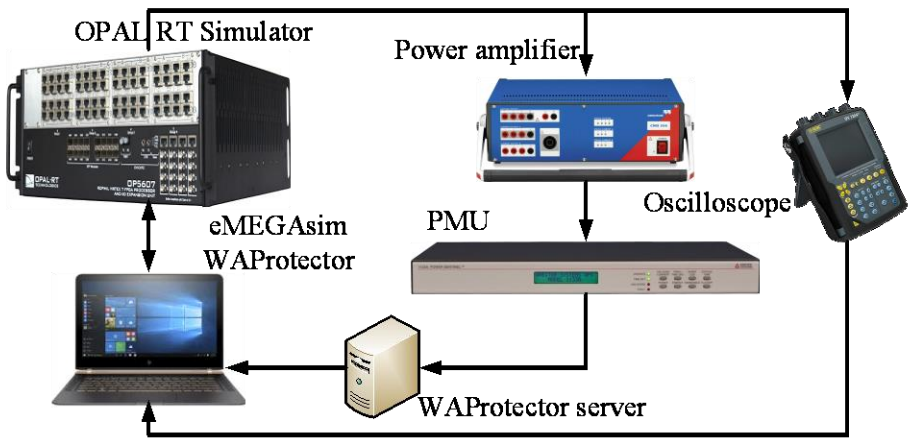
0.7 – 1.2 Hz
Local Mode

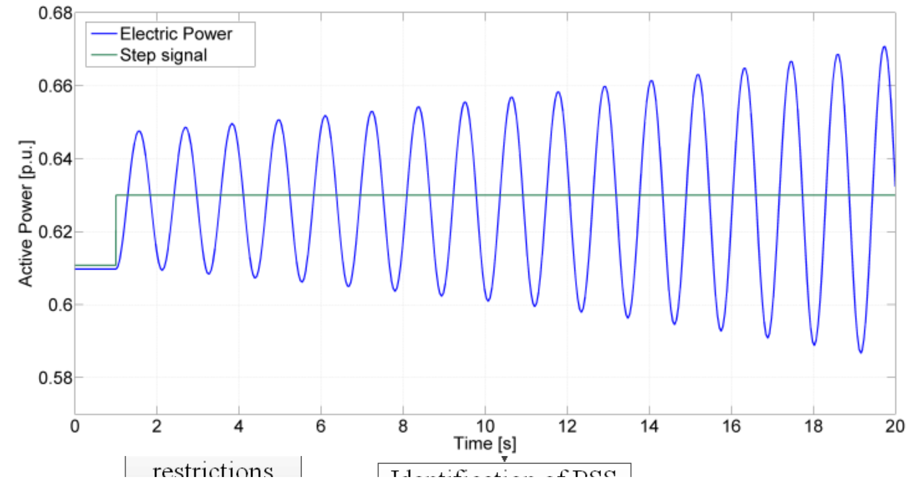
0.34 – 0.45 Hz
Inter-area Mode

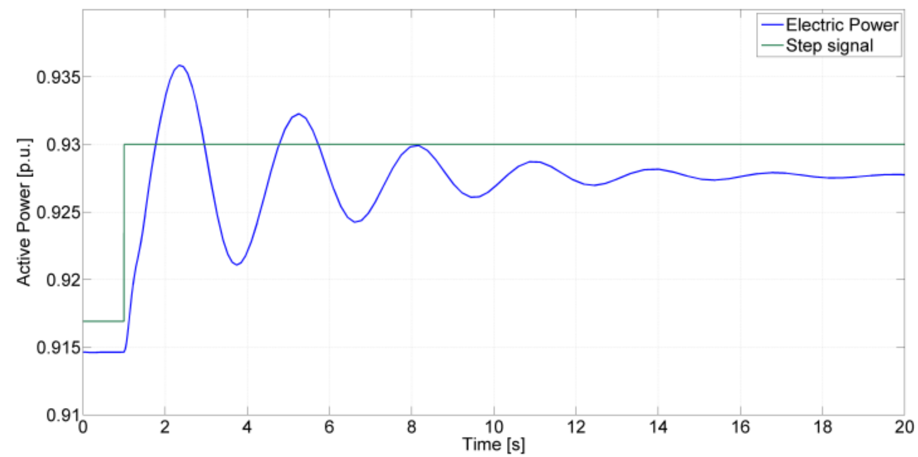
0.8 – 1.1 Hz
Local Mode

Local Oscillation mode at CCS - 0,75 Hz

Testbed for PSS Tuning using eMEGAsim and WAProtector







PSS Tuning Methodology

eMEGAsim

Installation of monitoring devices in the Generation power Plant: **PMUs**

Modeling of key system elements: generator, AVR and simplified network.

Model validation through field tests and real-time records (**WAProtector**)

Probabilistic Oscillatory analysis:

Modal Analysis

Frequency response

Time domain Simulation

Multiple scenarios (Monte Carlo)

PSS Tuning.- Robust Methodology:

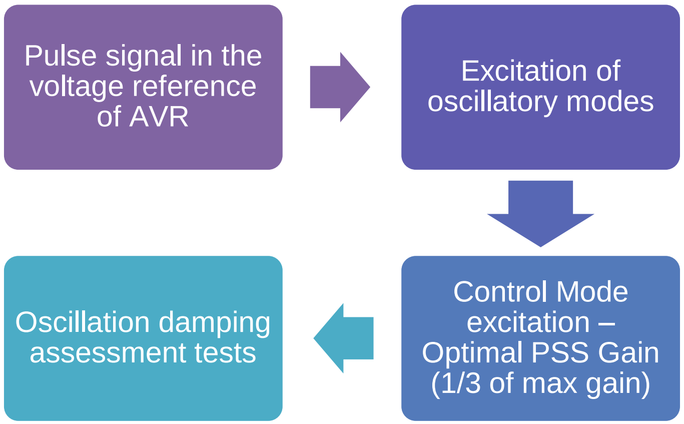
- Multiple scenarios (Monte Carlo)
- Heuristic optimization algorithm
- Frequency response (constraints)
- ***TestBed for PSS Tuning (Laboratory)***

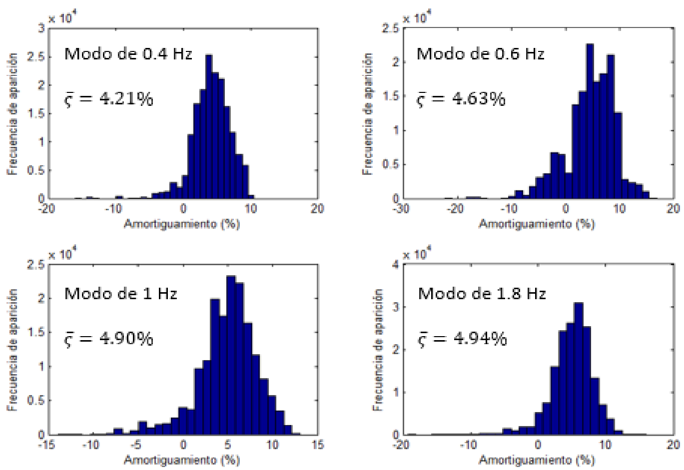
Field PSS tuning

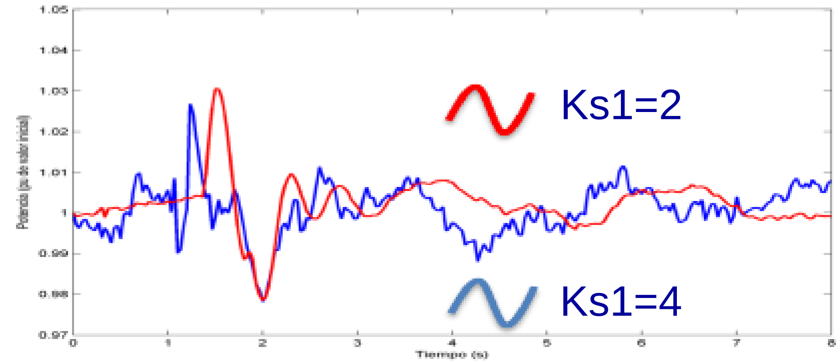
Tuning validation tests

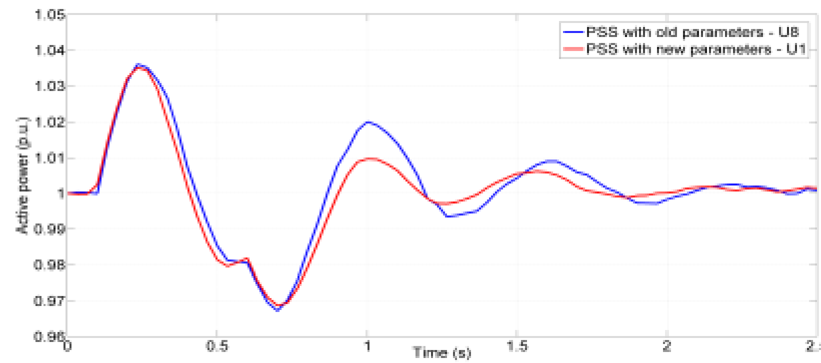
(WAProtector)

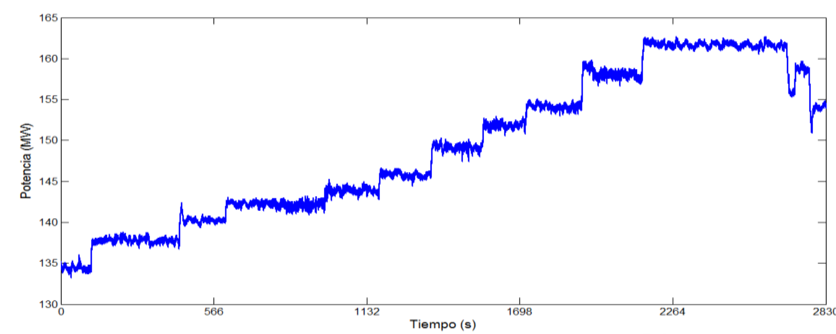
PSS Tuning Field Tests



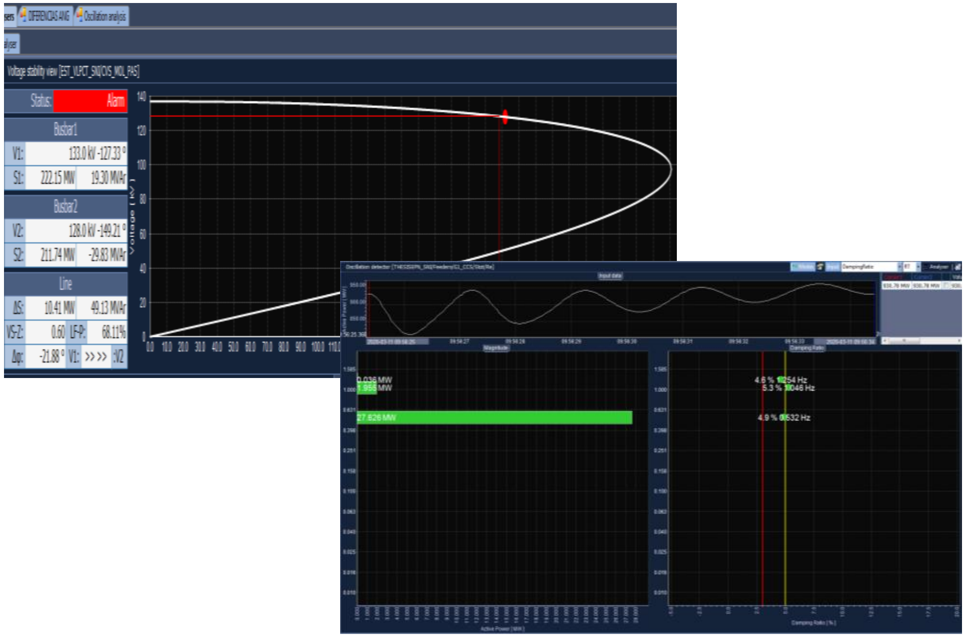








Operators’ training Environment using ePHASORsim and WAProtector



Implemented methodology

Power System

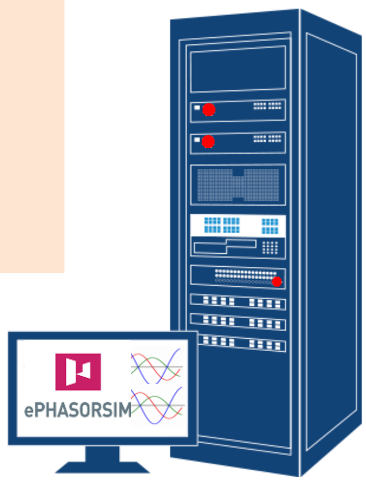
Dynamic Modelling

- Generator
- Automatic Voltage Regulator (AVR)
- Power System Stabilizer (PSS)
- Governor (GOV)

Static Modelling

- Load
- 2W, 3W Transformer
- Transmission lines

FMU



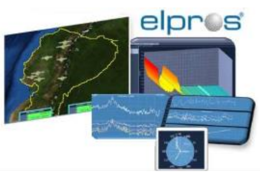
DGS

Implemented methodology

Real-Time Digital Simulator

Virtual PMU

C37.118



Wide Area Measurement Systems

WAMS' APPLICATIONS

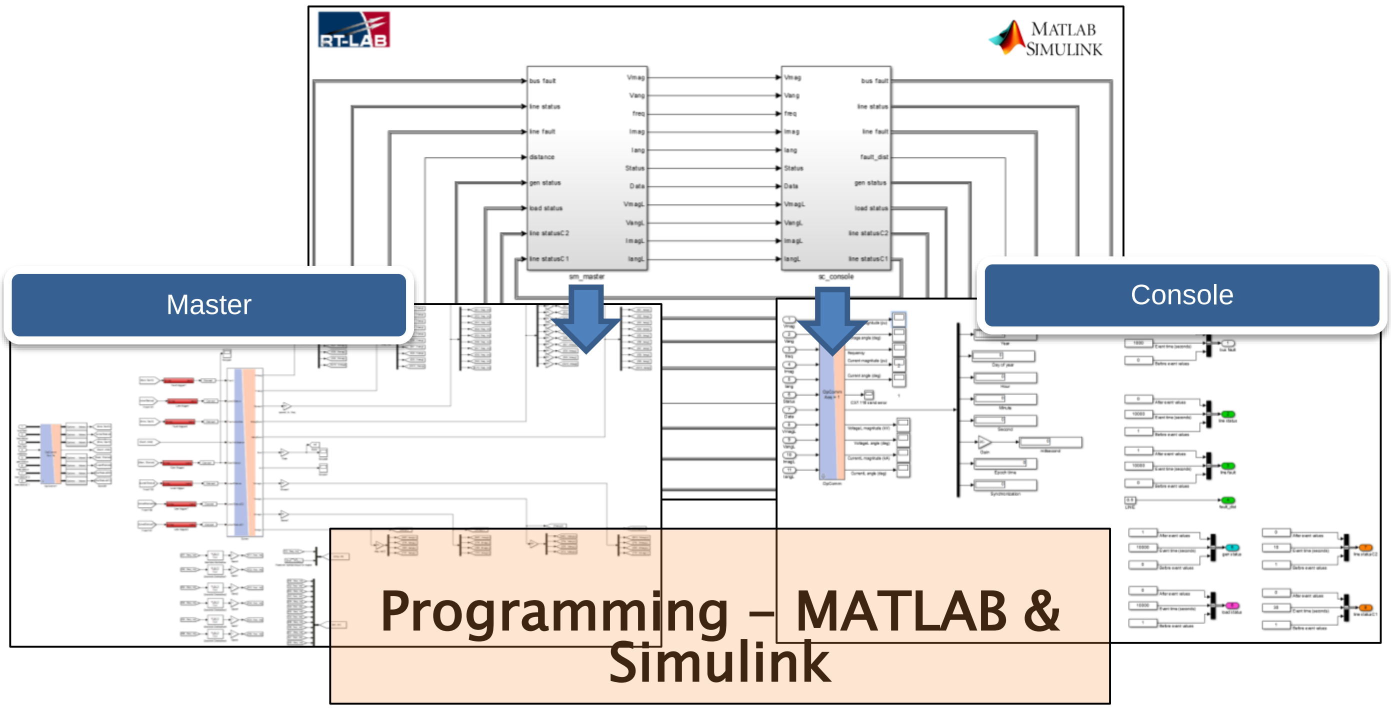
- Angular Difference
- Oscillatory Stability
- Voltage Stability of Transmission Corridors
- Frequency Monitoring

- Dynamic Simulation (Operation Commands)
- Power Flow Simulation

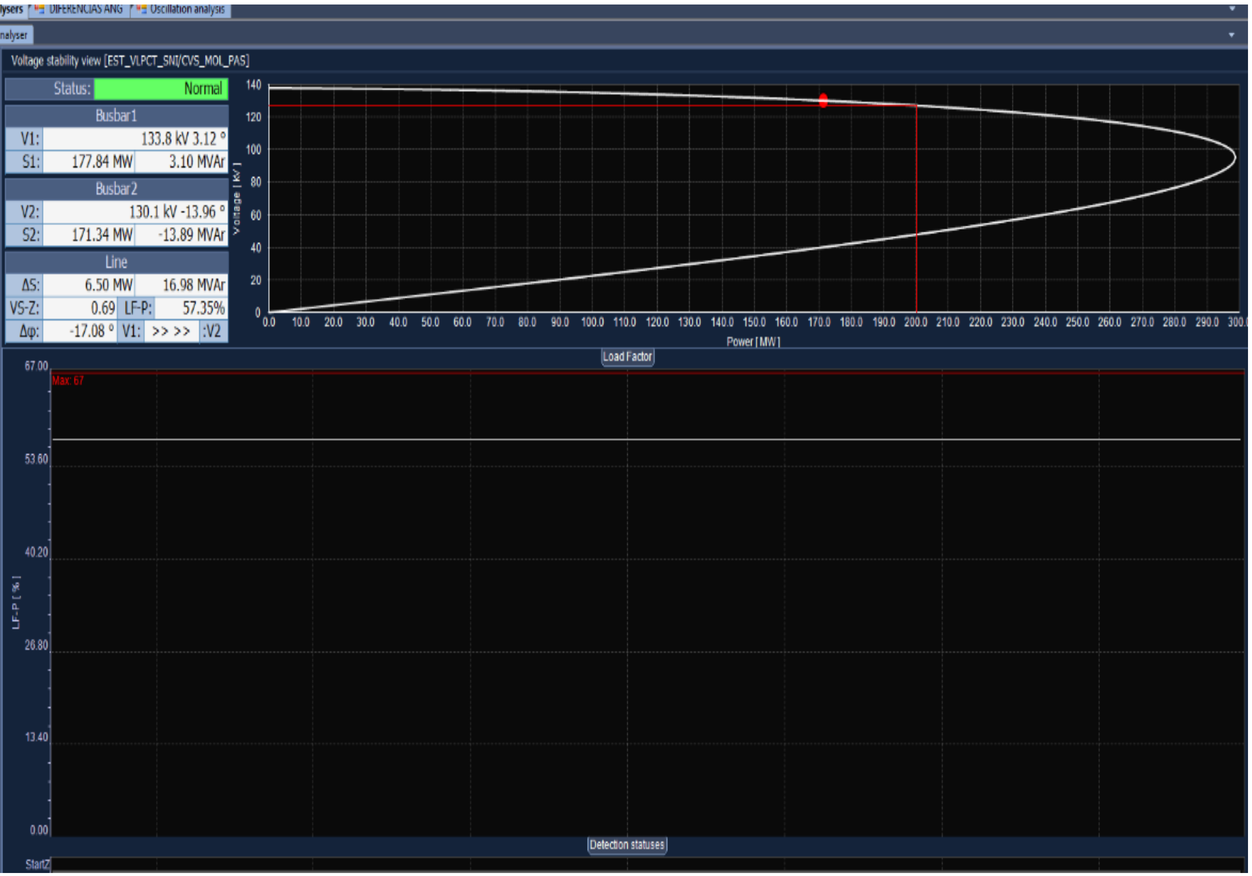
- Study Cases
- Generation and Demand

Training Environment

ePHASORsim Interface

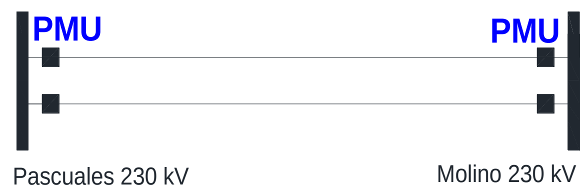


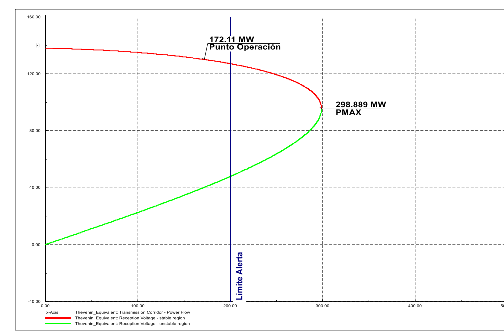
Real-Time Simulation and Results



Voltage Stability of Transmission Corridors (WAMS)

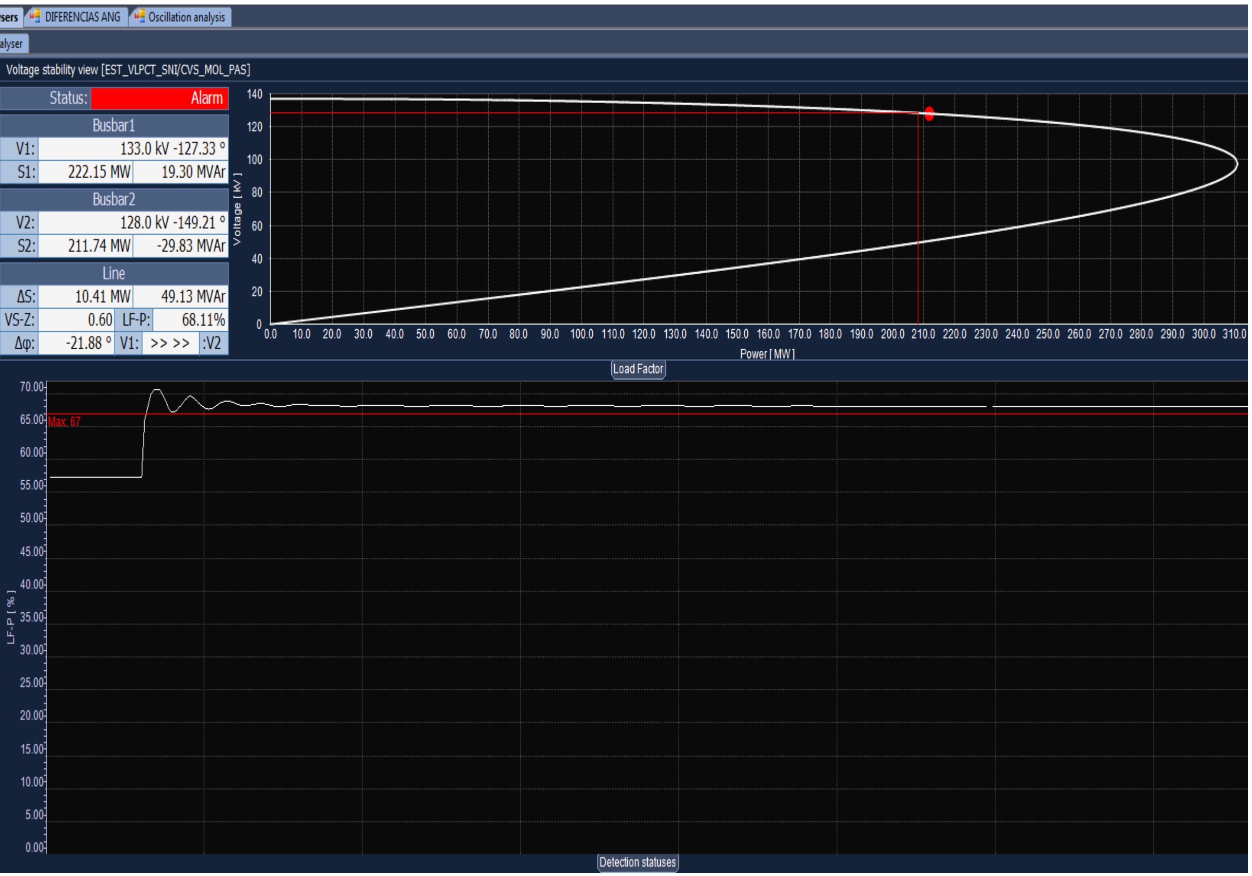
Medium demand – High hydrology Scenario





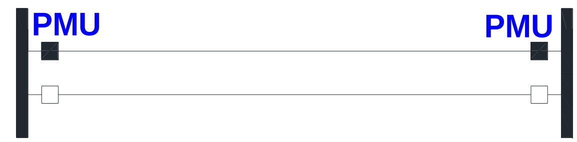
$$V_2 = \sqrt{\frac{V_{th}^2}{2} - (Q_c X_{th} + P_c R_{th}) \pm \sqrt{\frac{V_{th}^4}{4} - V_{th}^2 (Q_c X_{th} + P_c R_{th}) - (P_c X_{th} - Q_c R_{th})^2}}$$

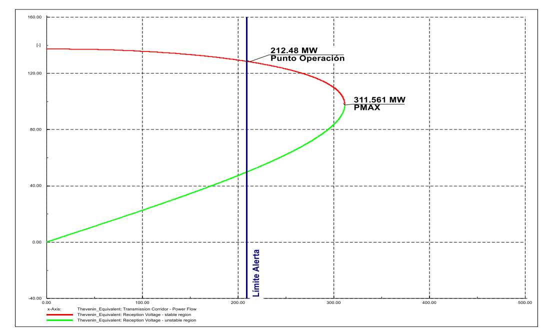
Real-Time Simulation and Results



Voltage Stability of Transmission Corridors (WAMS)

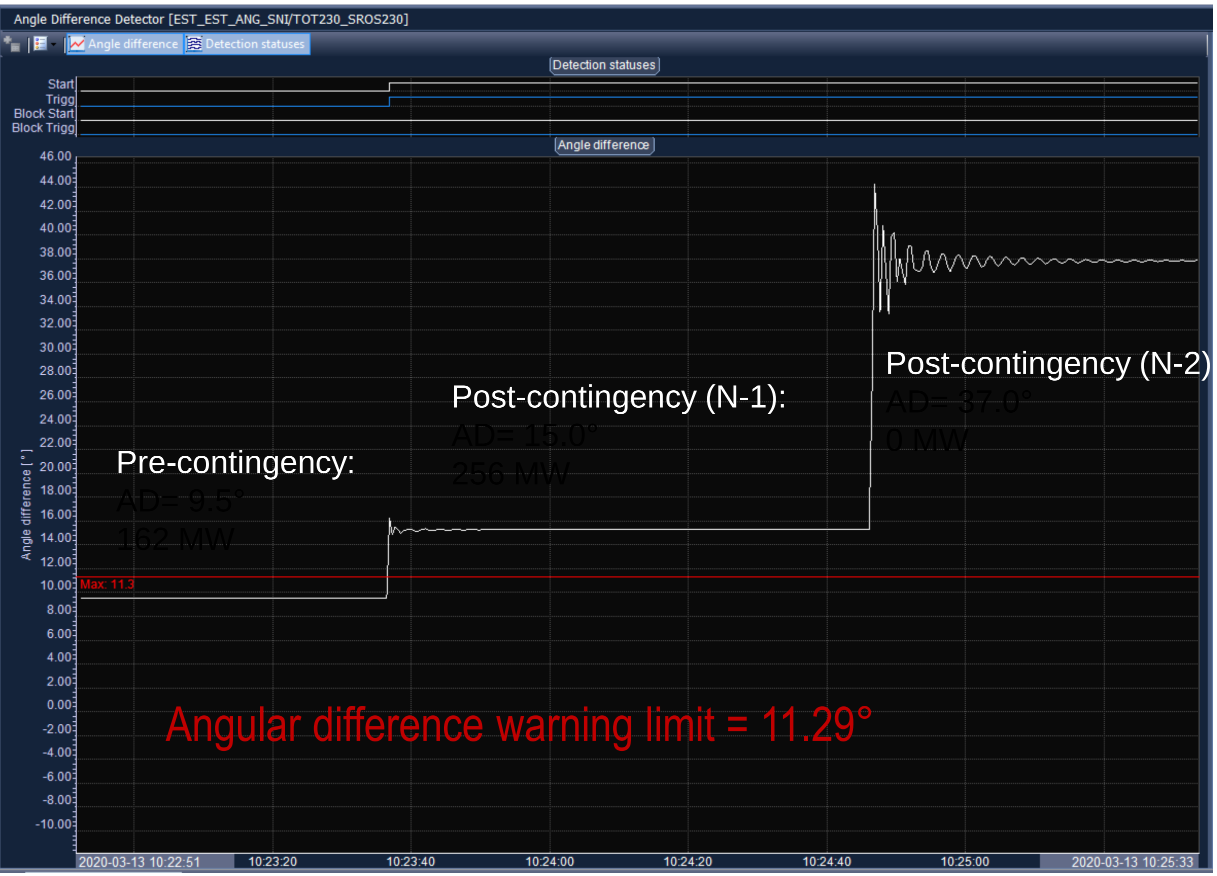
Medium demand – High hydrology Scenario





$$V_2 = \sqrt{\frac{V_{th}^2}{2} - (Q_c X_{th} + P_c R_{th}) \pm \sqrt{\frac{V_{th}^4}{4} - V_{th}^2 (Q_c X_{th} + P_c R_{th}) - (P_c X_{th} - Q_c R_{th})^2}}$$

Real-Time Simulation and Results

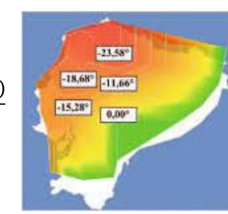


Angular Difference (WAMS)

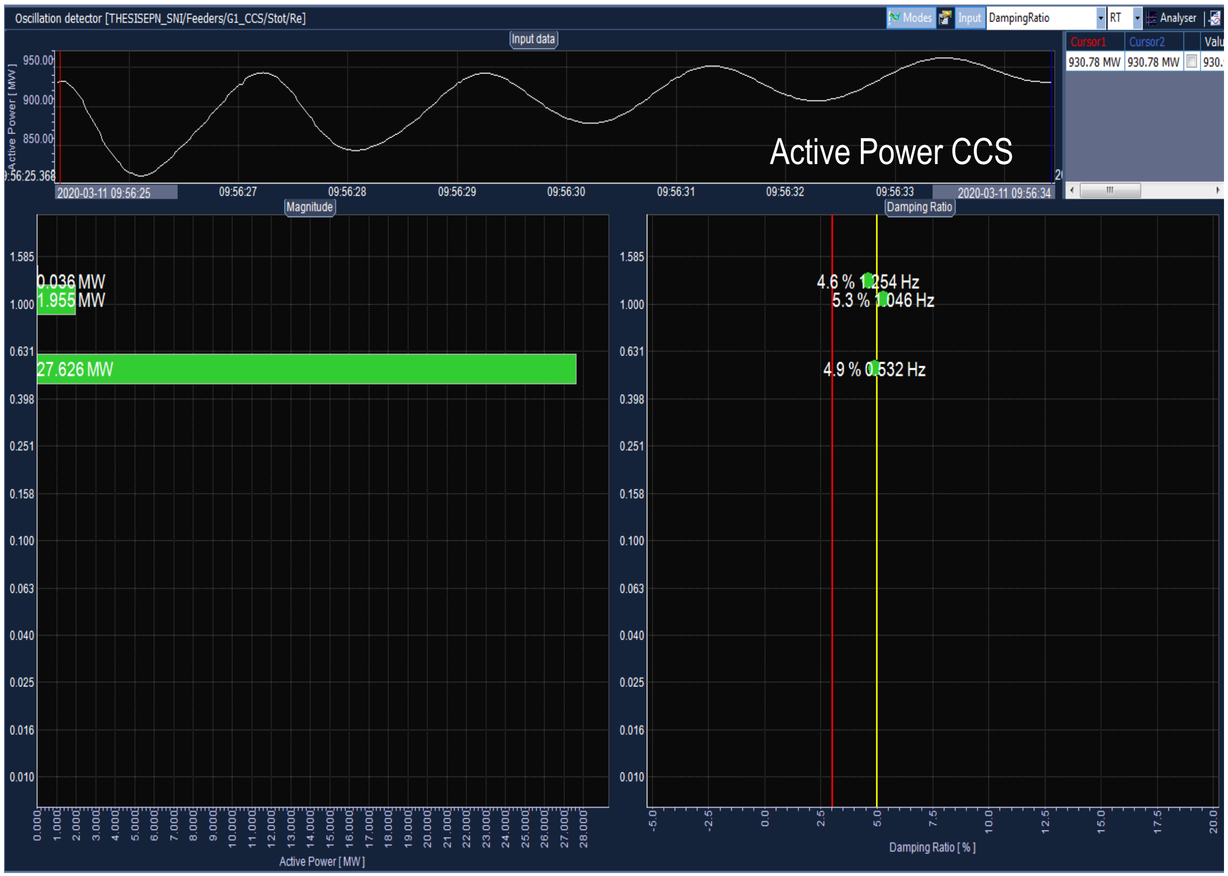
Medium demand – High hydrology Scenario

$$P_{AB} = \frac{V_A V_B \sin(\theta_A - \theta_B)}{x} \approx \frac{V_A V_B (\theta_A - \theta_B)}{x}$$

$$P_{AB} \; \alpha \; (\theta_A - \theta_B)$$

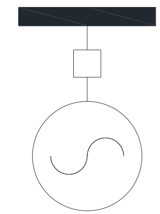


Real-Time Simulation and Results



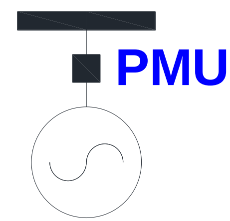
Oscillatory Stability (WAMS)

Medium demand – Low hydrology Scenario



Paute C

Generation Trip (260 MW)



Coca Codo Sinclair

$$\lambda = \sigma \pm j\omega$$

$$\xi = \frac{-\sigma}{\sqrt{\sigma^2 + \omega^2}}$$

$$f = \frac{\omega}{2\pi}$$

THANK YOU

Jaime Cepeda, Ph.D.

jcepeda@cenace.org.ec

cepedajaime@ieee.org

cenace
OPERADOR NACIONAL DE ELECTRICIDAD

IEEE PES
Power & Energy Society®

IEEE