Wide Area Monitoring System for Ecuador

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Outline

- Ecuador WAMS Overview
  - Architecture
- PMU Data Analysis
  - Angle Unwrapping
  - Difference Calculation
  - Fast Fourier Transform
- Visualization
- System Scalability
  - PI AF (Asset Framework)
  - PI AF Model-Based Parameter Substitution

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Wide Area Monitoring System for Ecuador

- Proportionally the largest WAMS project in South America
  - Area: 106,000mi^2 – Equivalent to the Size of Colorado

- Initial WAMS implementation: 2 Months
- Characterize the system as a function of the voltage phase angle

PMU

- Create procedures for the operation of the system
  - Training for CENACE personnel (Control Center Dispatchers, Engineers, etc.)
  - Understanding of Synchrophasor metrics
- Validate the dynamic model of the system

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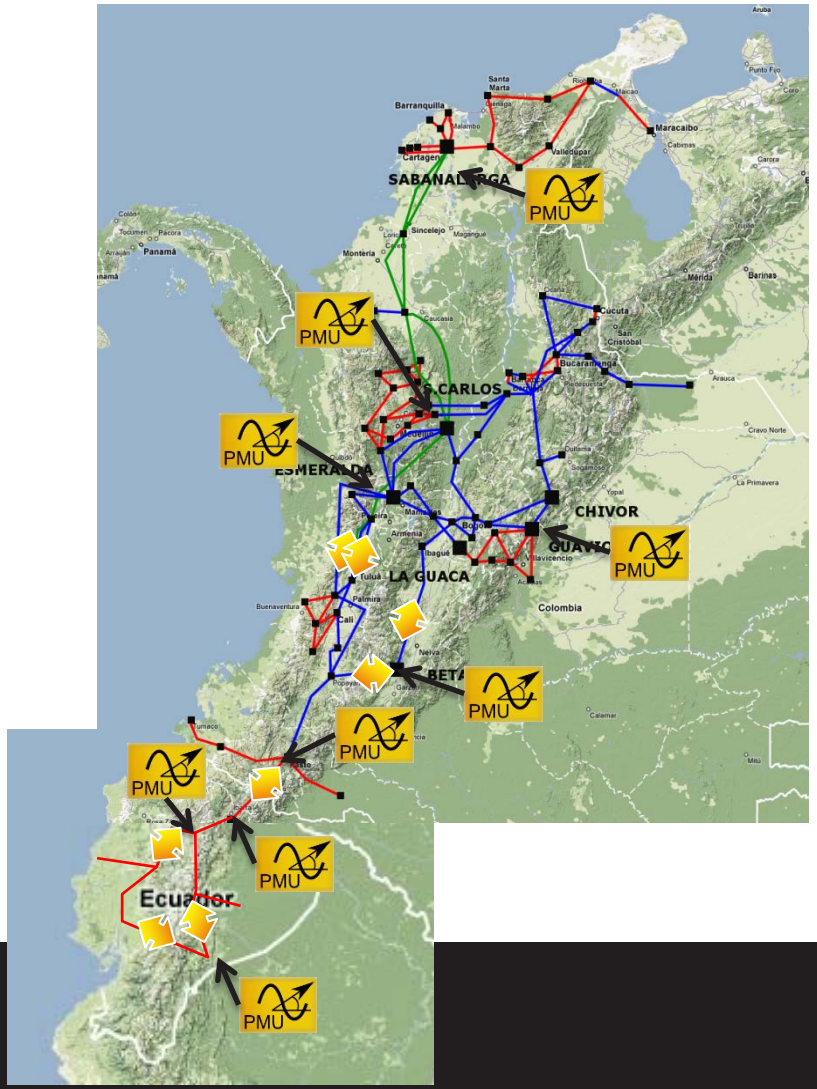
Wide Area Monitoring System for Ecuador

- Resolve Internal Oscillations with Colombia



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PMU Installation Phase I – Five PMUs

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PMU Installation Phase II – Fourteen PMUs (Dec 2012)

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PMU Installation Phase III – Twenty PMUs (2013)

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Total 27 PMUs (2014)

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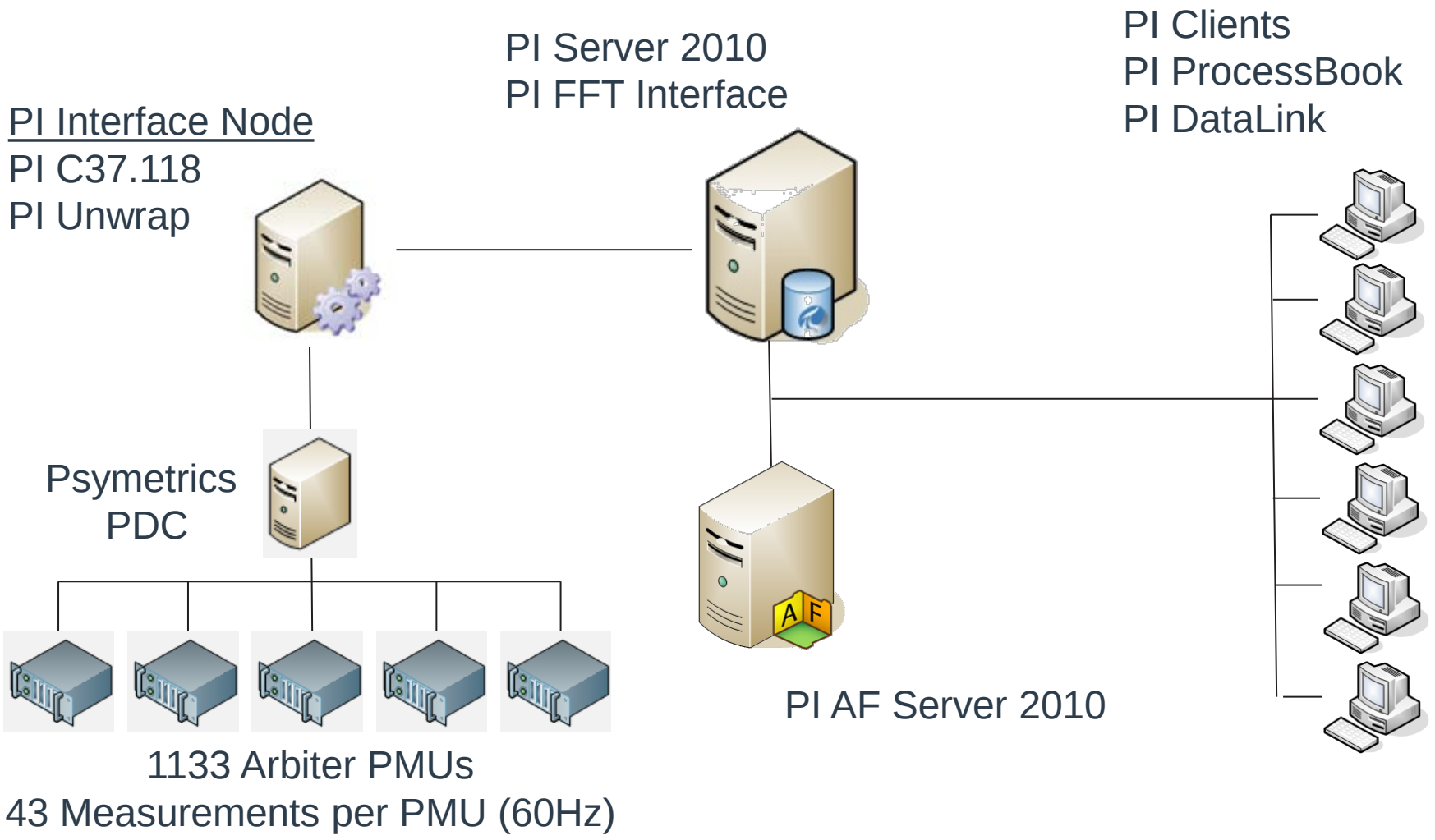
Architecture Overview



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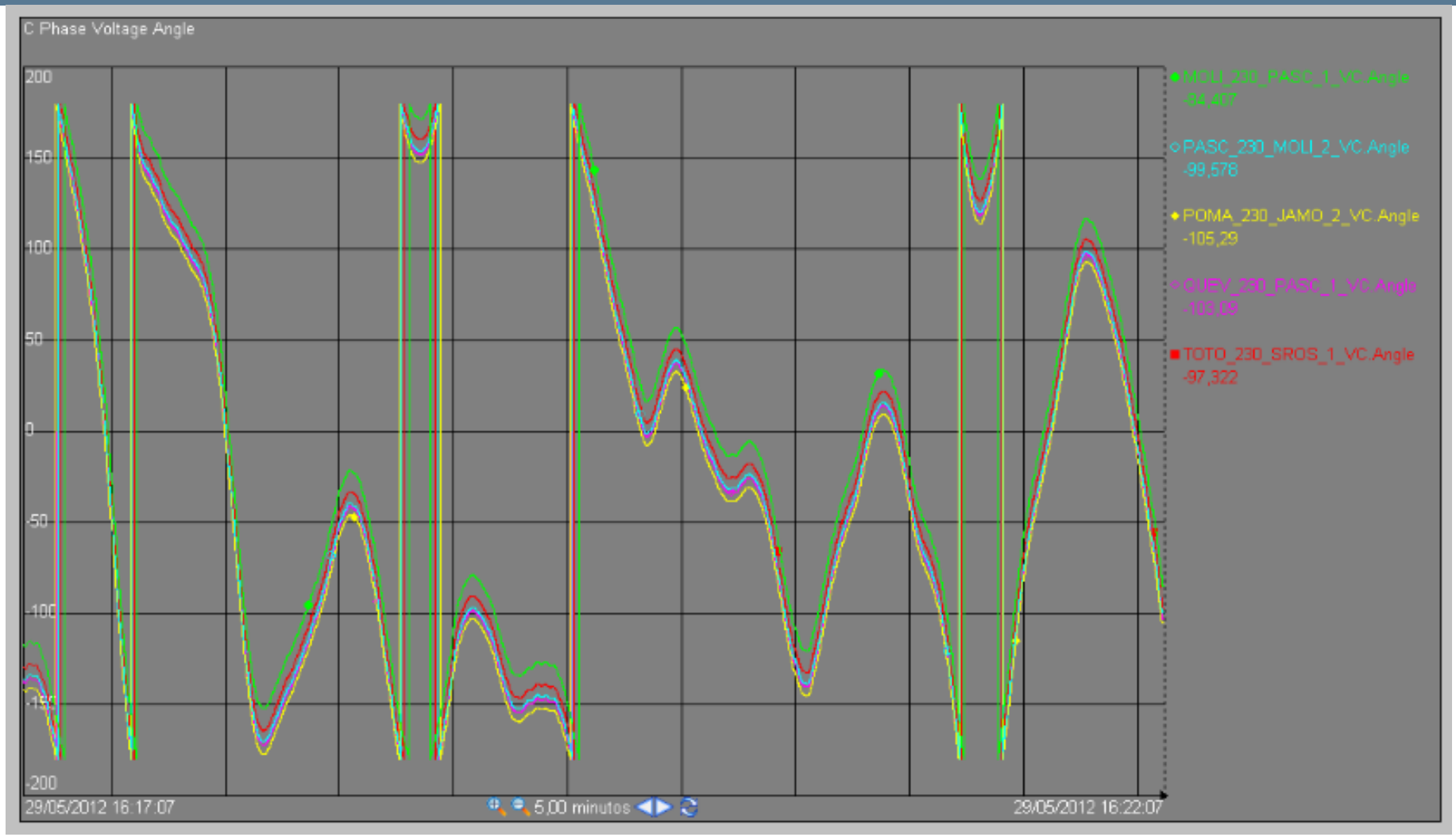
C Phase voltage angles



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PMU Data Analysis

- PI C37.118 Interface
  - Raw PMU data
- PI Phasor Angle Interface
  - Unwrap discontinuous voltage angle (± 180)
  - Compute differences for:
    - Unwrapped angles
    - Frequencies
- PI FFT Interface
  - Compute FFT of unwrapped angle/frequency differences
  - Several window widths are required to pick up events of interest
  - Compute damping coefficients at each mode.

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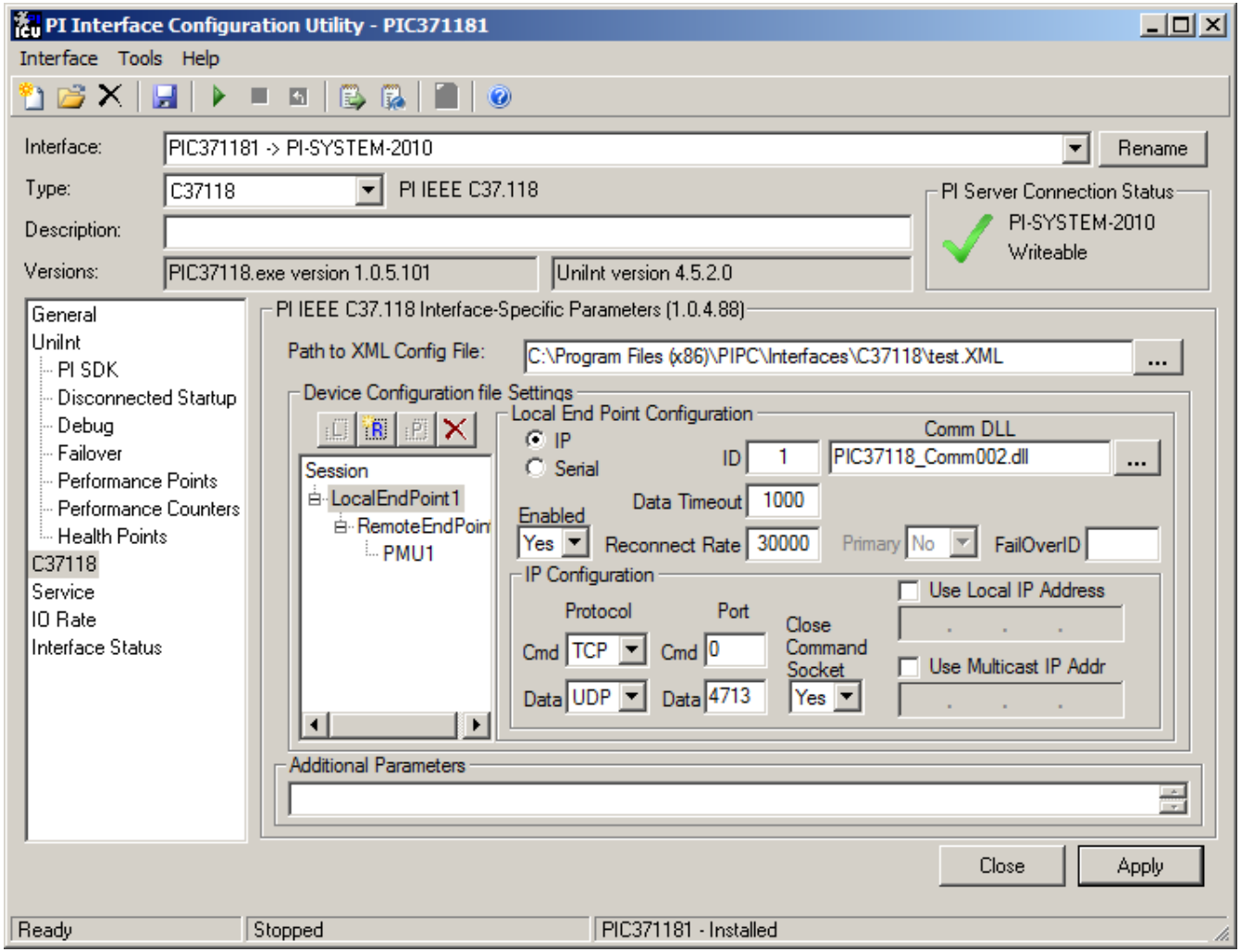
PI C37.118 Interface (raw data)



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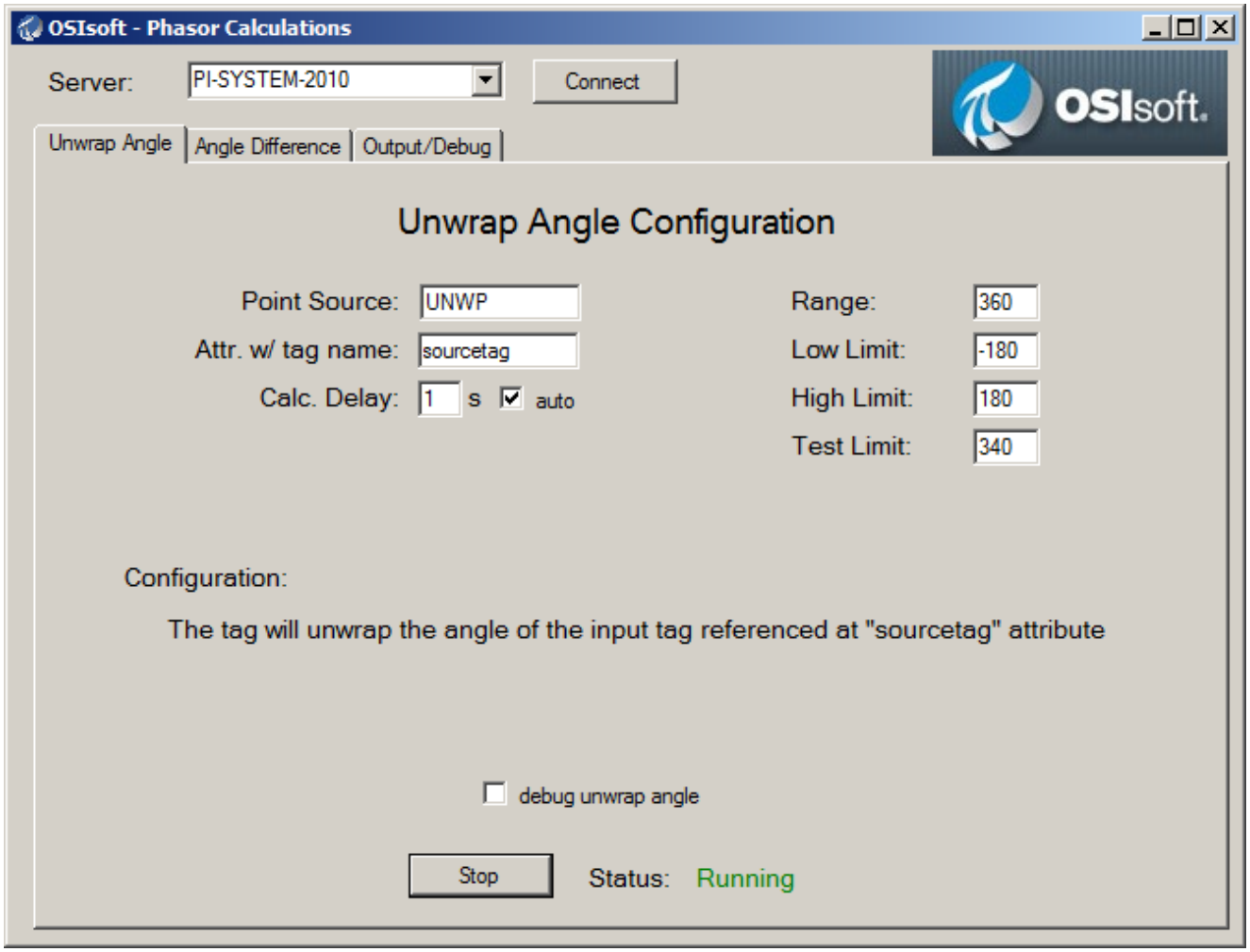
PI Phasor Unwrap Angle Calculation



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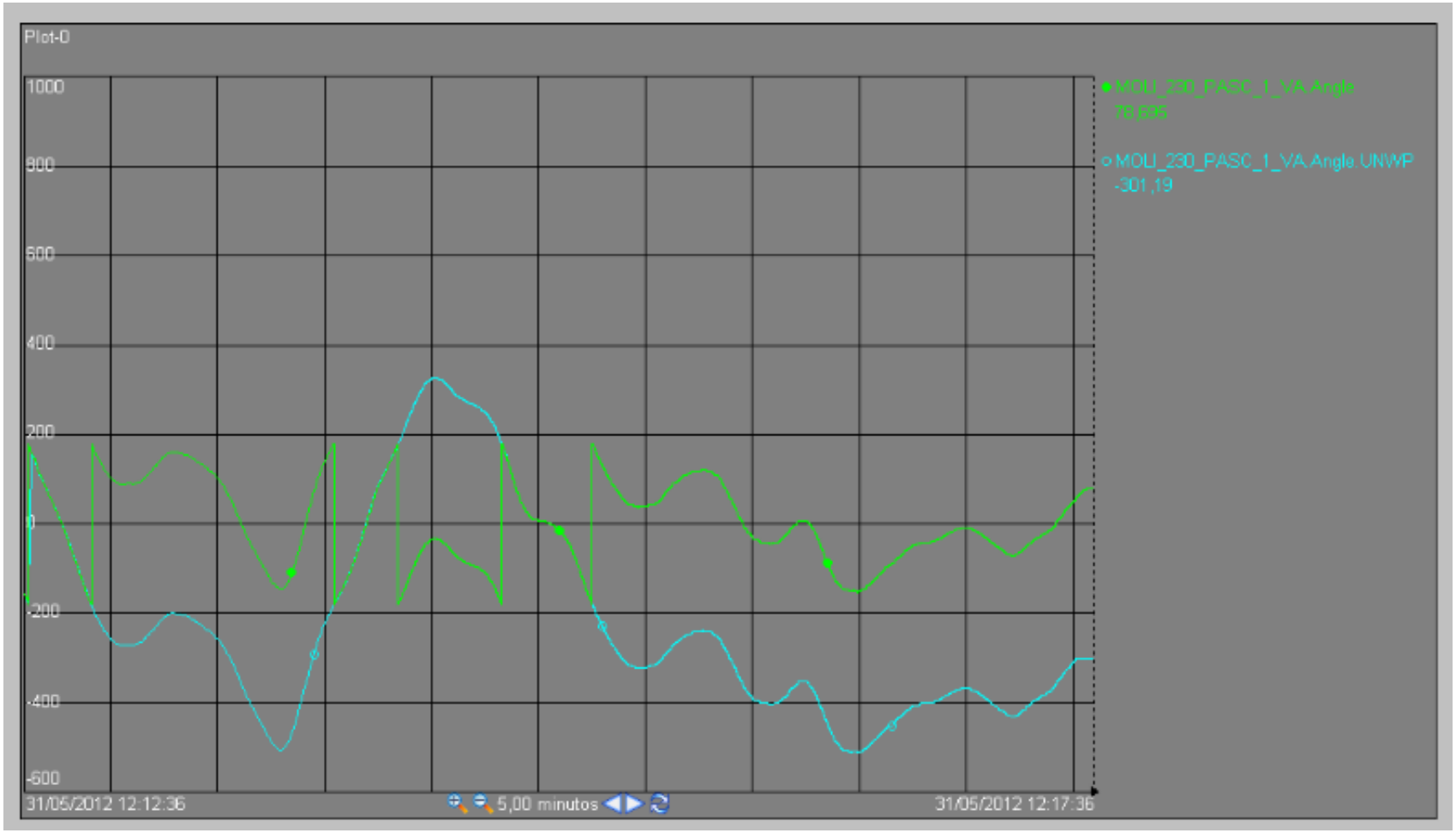
CENACE - Unwrapped Angle (Molino Station)



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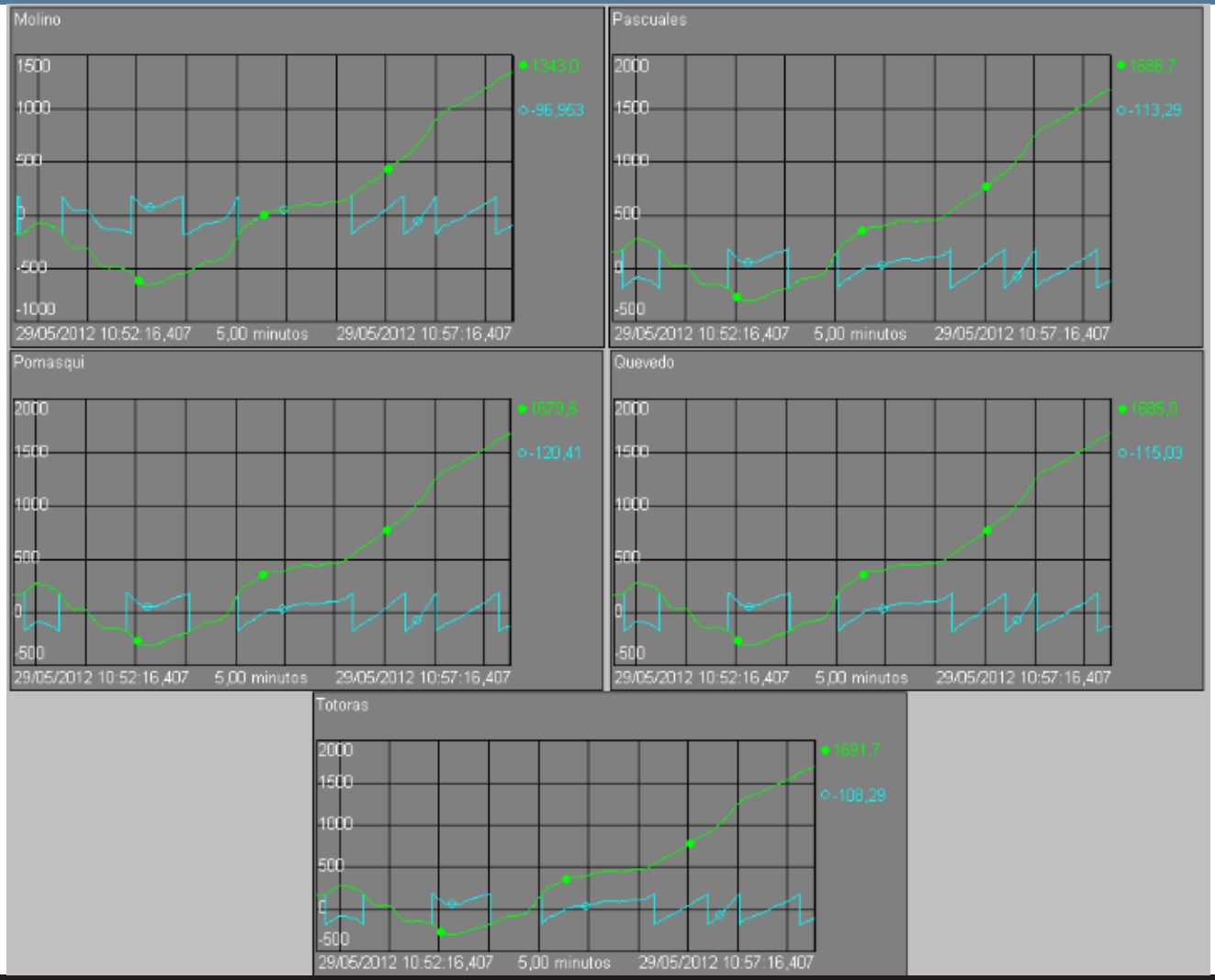
CENACE - Unwrapped Angles



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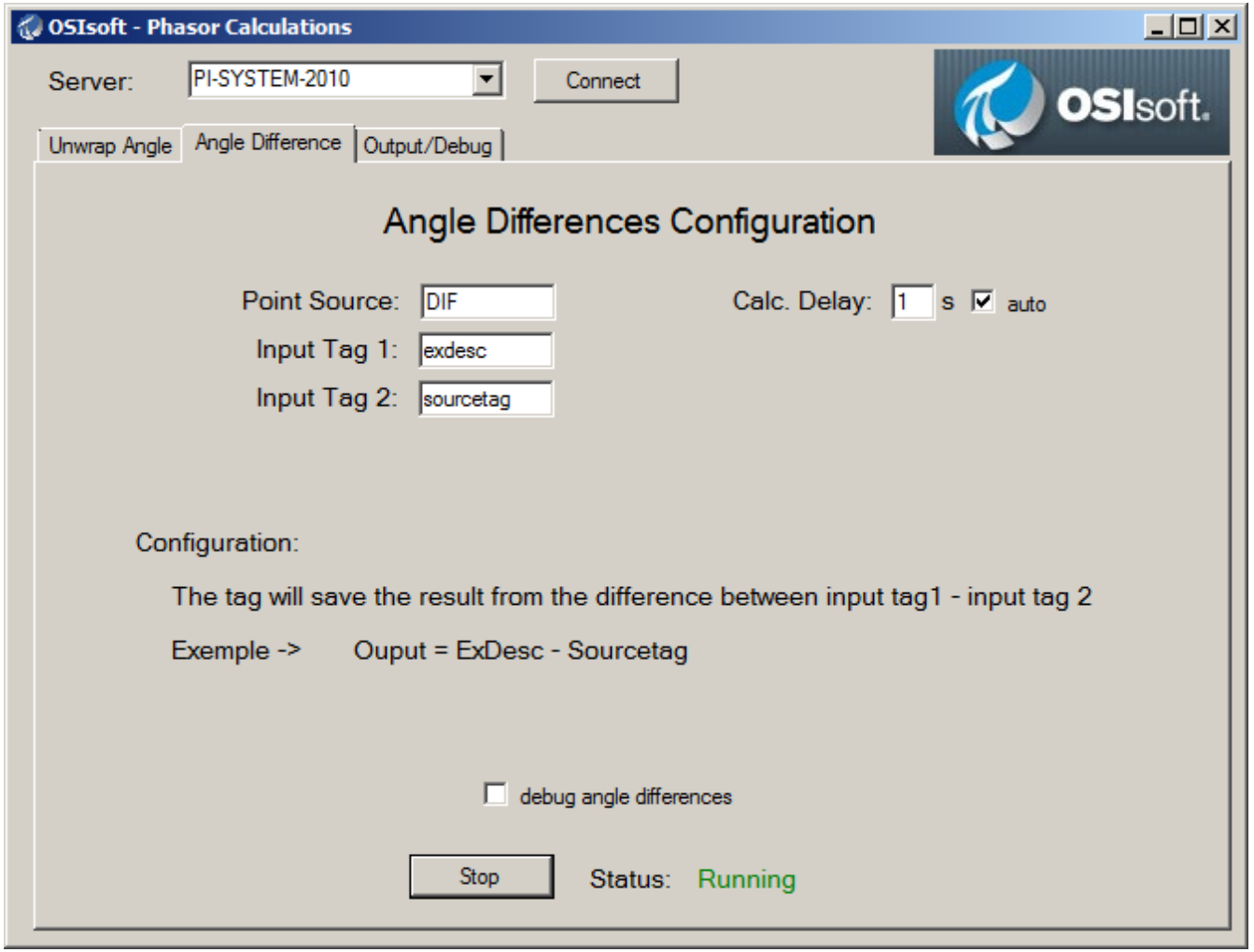
Frequency and Angle differences calculation



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Critical Differences

- Molino = Reference Angle
- 7 Critical Differences
  - Voltage Phase A
  - Frequency
- Calculate real time FFT
  - PI FFT Interface

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Frequency Differences Results

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Fast Fourier Transform of Differences

- PI FFT Interface (2 Instances)
  - Calculates Fast Fourier Transform in real time (Moving window)
  - 2 x Instances
    - 1 x unwrapped angles, 1 x frequencies
  - Configuration:
    - 60Hz
    - 64 Magnitudes, Angles and Damping Coefficient & window size
    - 10 Area, Integrals, Harmonics and Peak Locations
    - 232 Tags per difference (3,248 points total)

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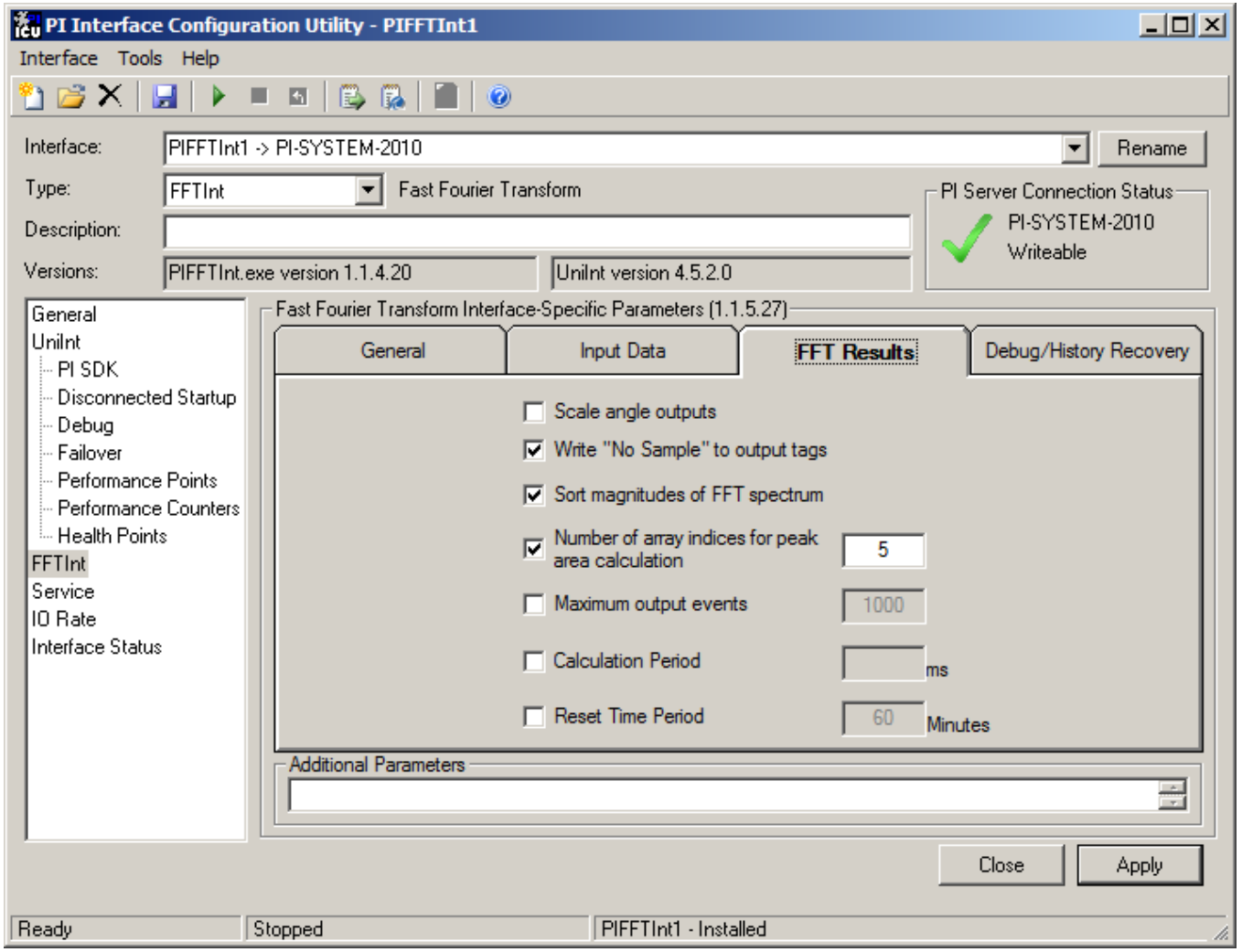
Fast Fourier Transform of Differences



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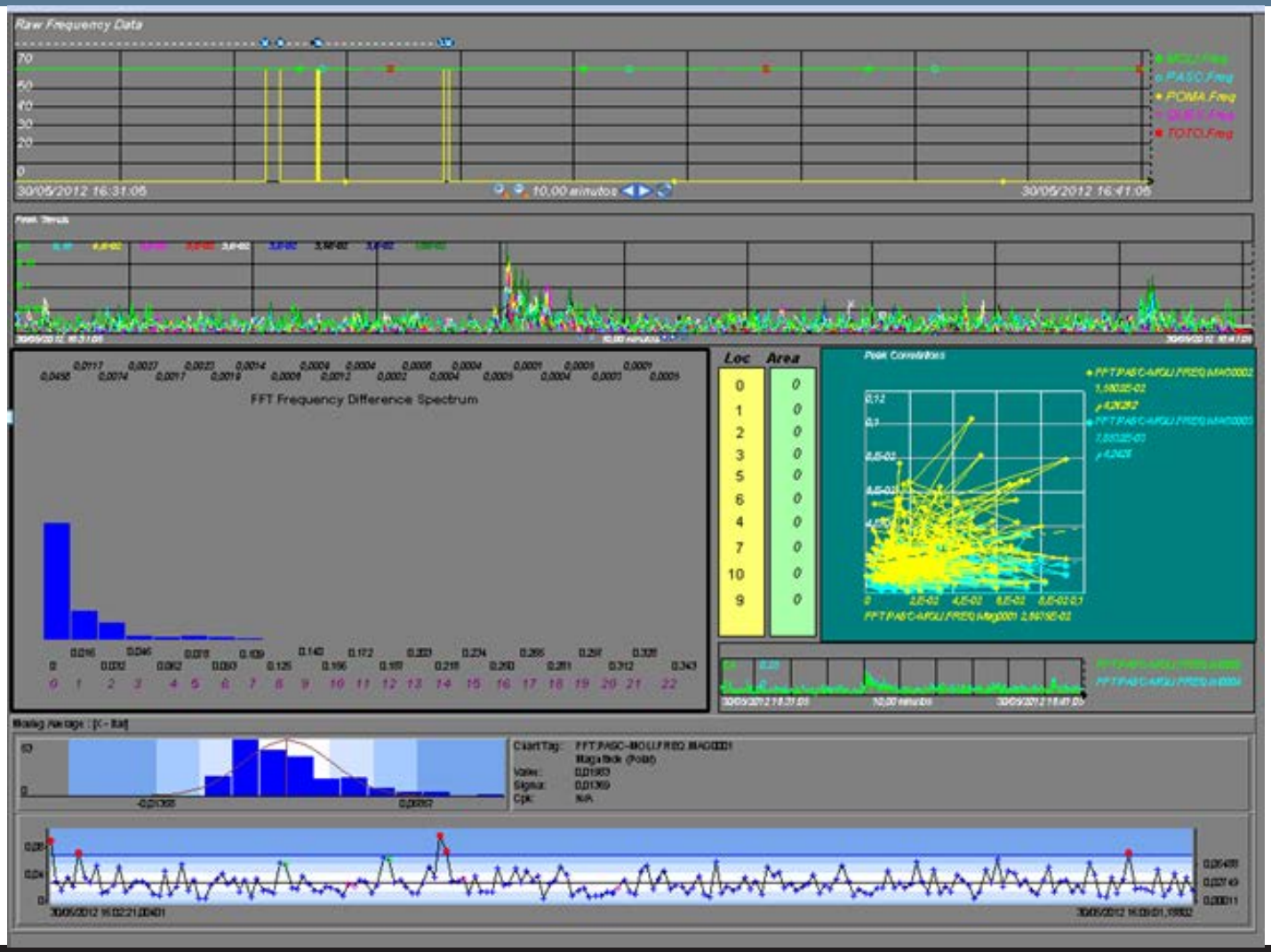
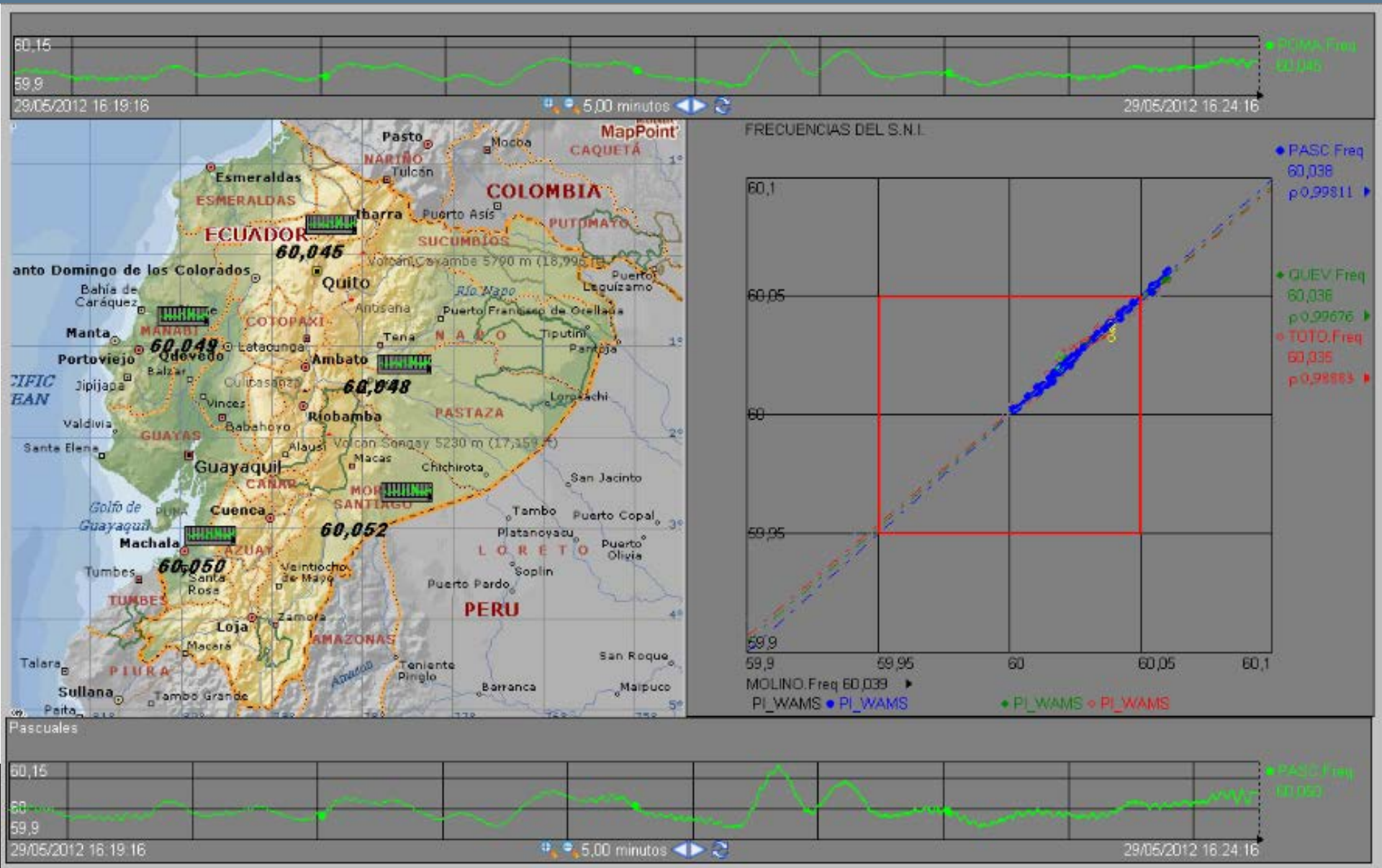
Fast Fourier Transform Spectrum



Synchrophasor Data Visualization



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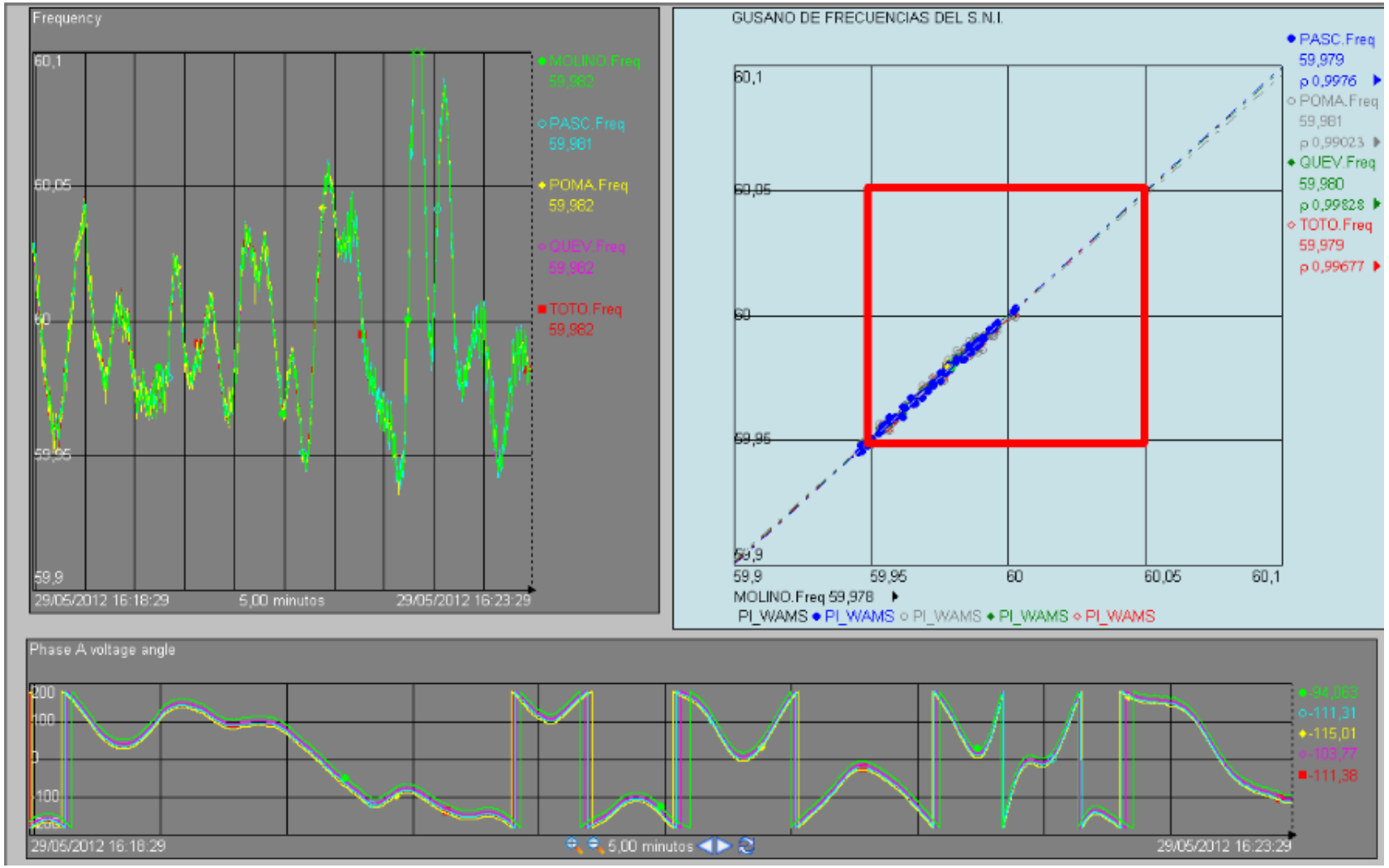
Synchrophasor Data Visualization



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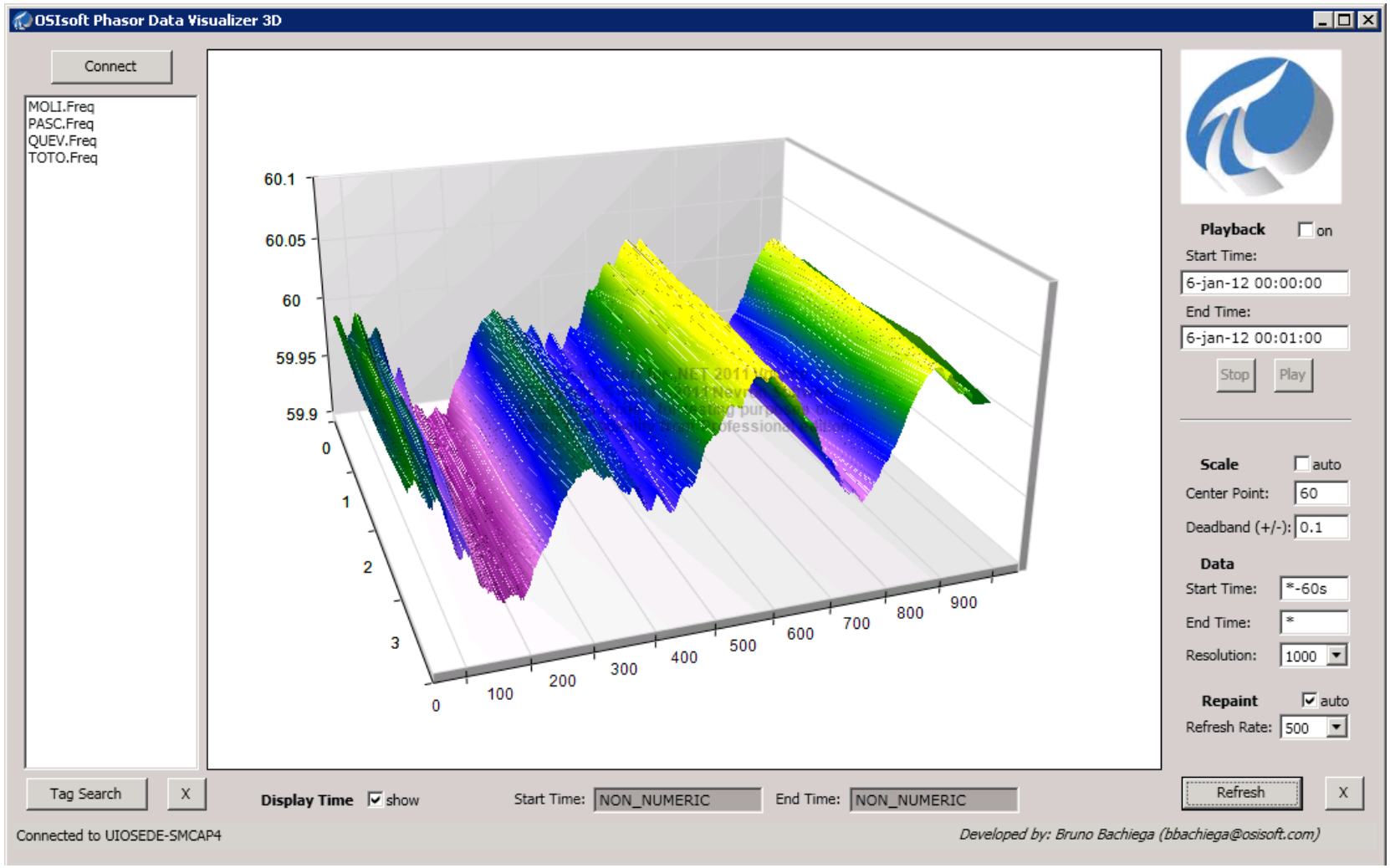
3D Synchrophasor Data Visualization



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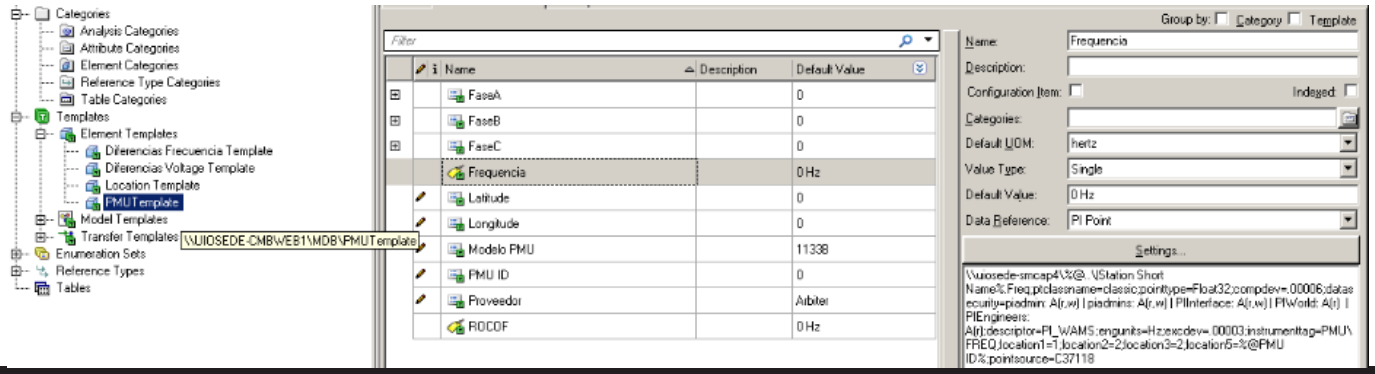
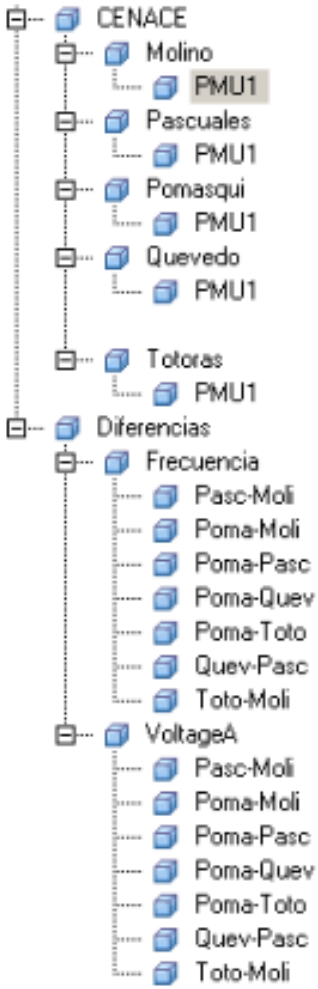
PI AF – Scalable and easy to Maintain

- PI AF
  - Building an Asset-Centric PI System
  - Organize data based on logical and physical objects
- Features
  - Fast deployment of new units
  - Auto creation of tags and connection to interfaces
  - Multiple notification delivery methods
  - Asset relative displays and reports





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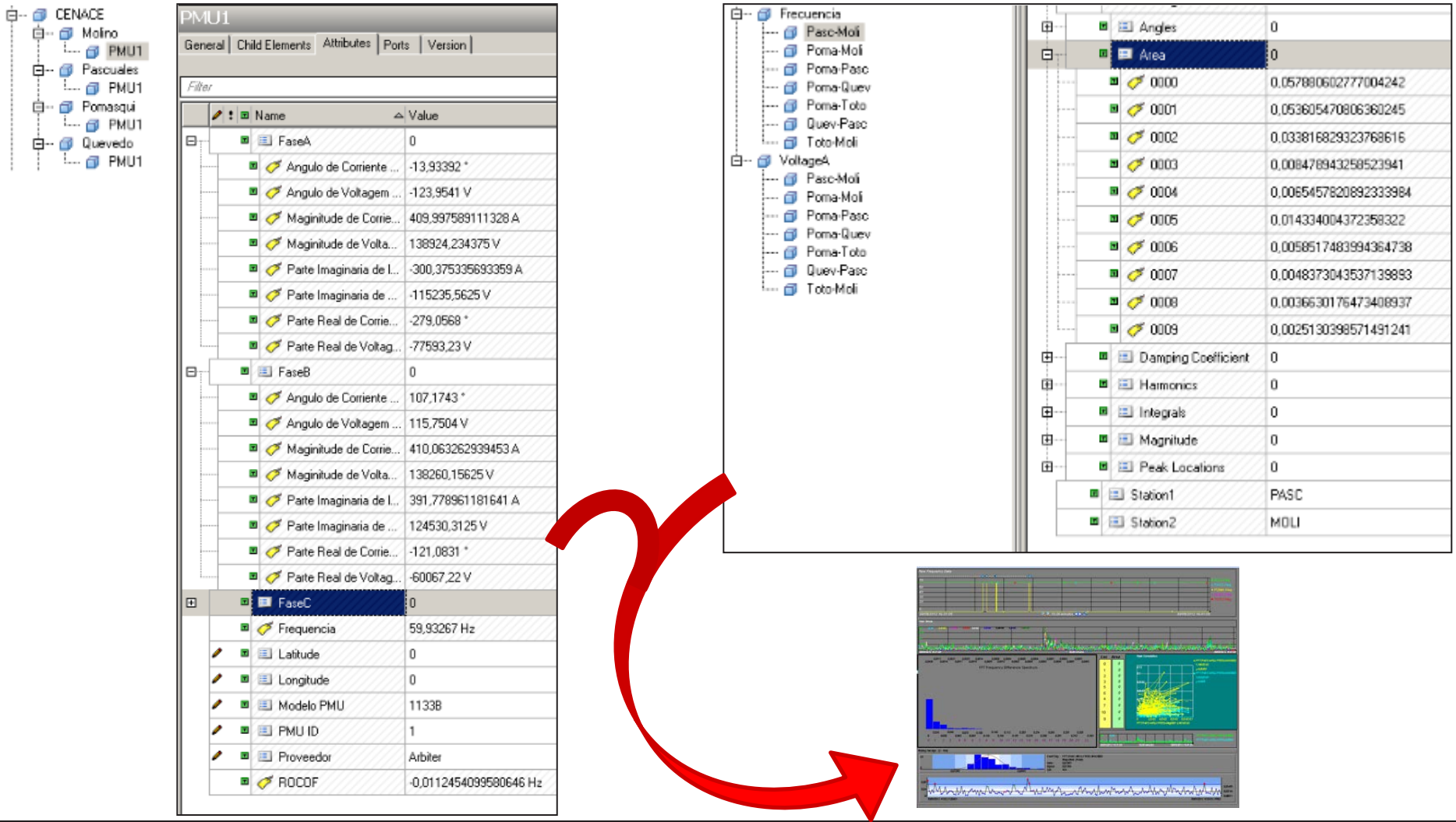
Similar Elements are based out of the same AF template



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Future Implementation

- Training classes for operators
- Use Positive Sequence voltage phase angles
- Analysis of Zero and Negative sequence angles
- Add Phase portrait displays
- Add Voltage stability displays QV charts and PV charts
- Automatic notifications of oscillations
- Plots of mode shapes
- Define Lyapunov stability regions for phase portraits
- Real time Bode plots of FFT differences

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Forthcoming Challenges and Developments

- Interarea Oscillations - Ecuador <> Colombia
  - Colombia's load is 4 times bigger than Ecuador
- Ecuador's generation will double in the next 5 years
  - New 500Kv Transmission Line
- Regional integration

Appropriate infrastructure and procedures to monitor and operate the grid are fundamental

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