



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

Wide Area Monitoring System for Ecuador

- Proportionally the largest WAMS project in South America
 - Area: 106,000mi² – Equivalent to the Size of Colorado
- Initial WAMS implementation: 2 Months
- Characterize the system as a function of the voltage phase angle



- 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

Wide Area Monitoring System for Ecuador

- Resolve Internal Oscillations with Colombia



PMU Installation Phase I – Five PMUs



PMU Installation Phase II – Fourteen PMUs (Dec 2012)



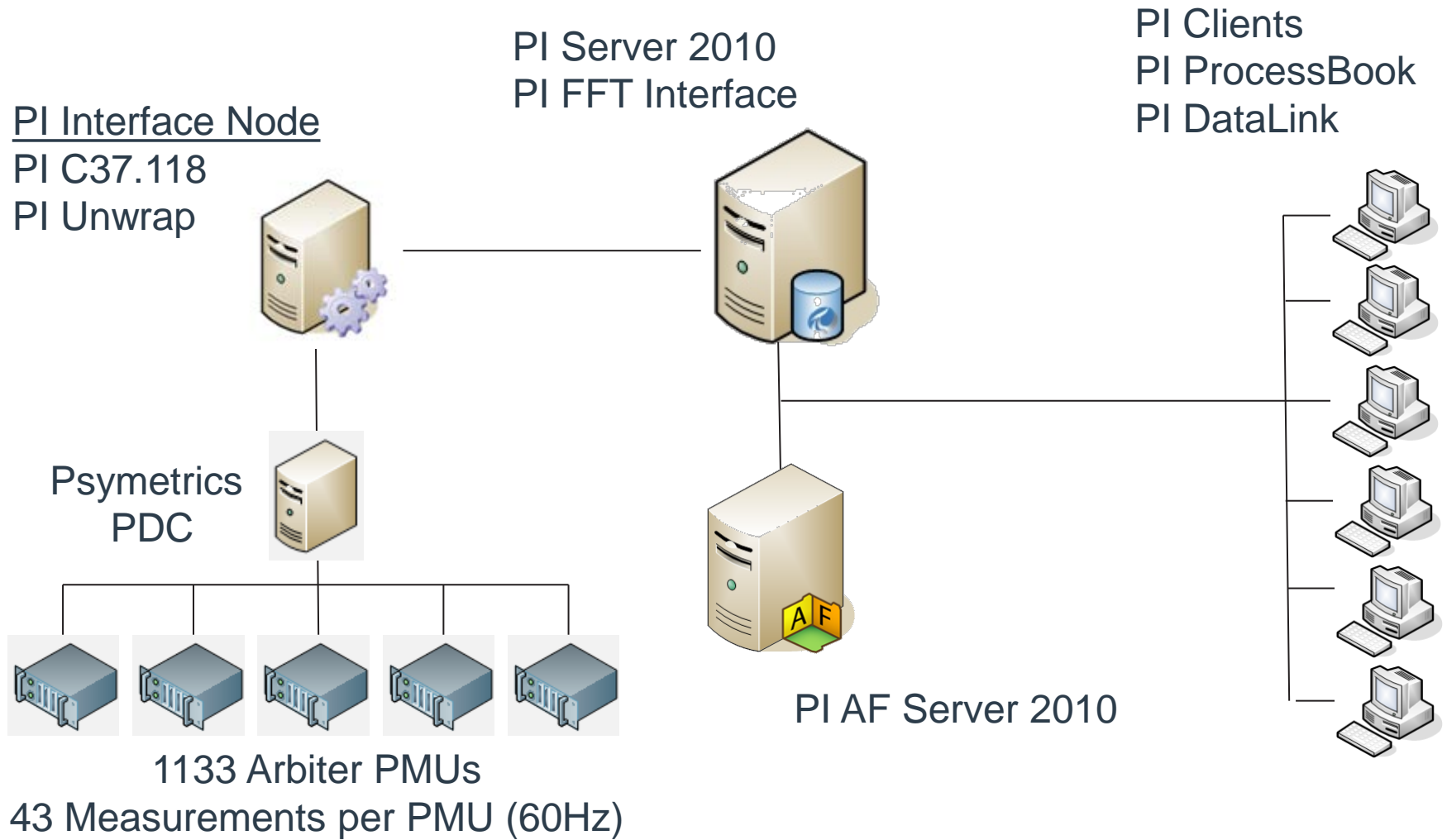
PMU Installation Phase III – Twenty PMUs (2013)



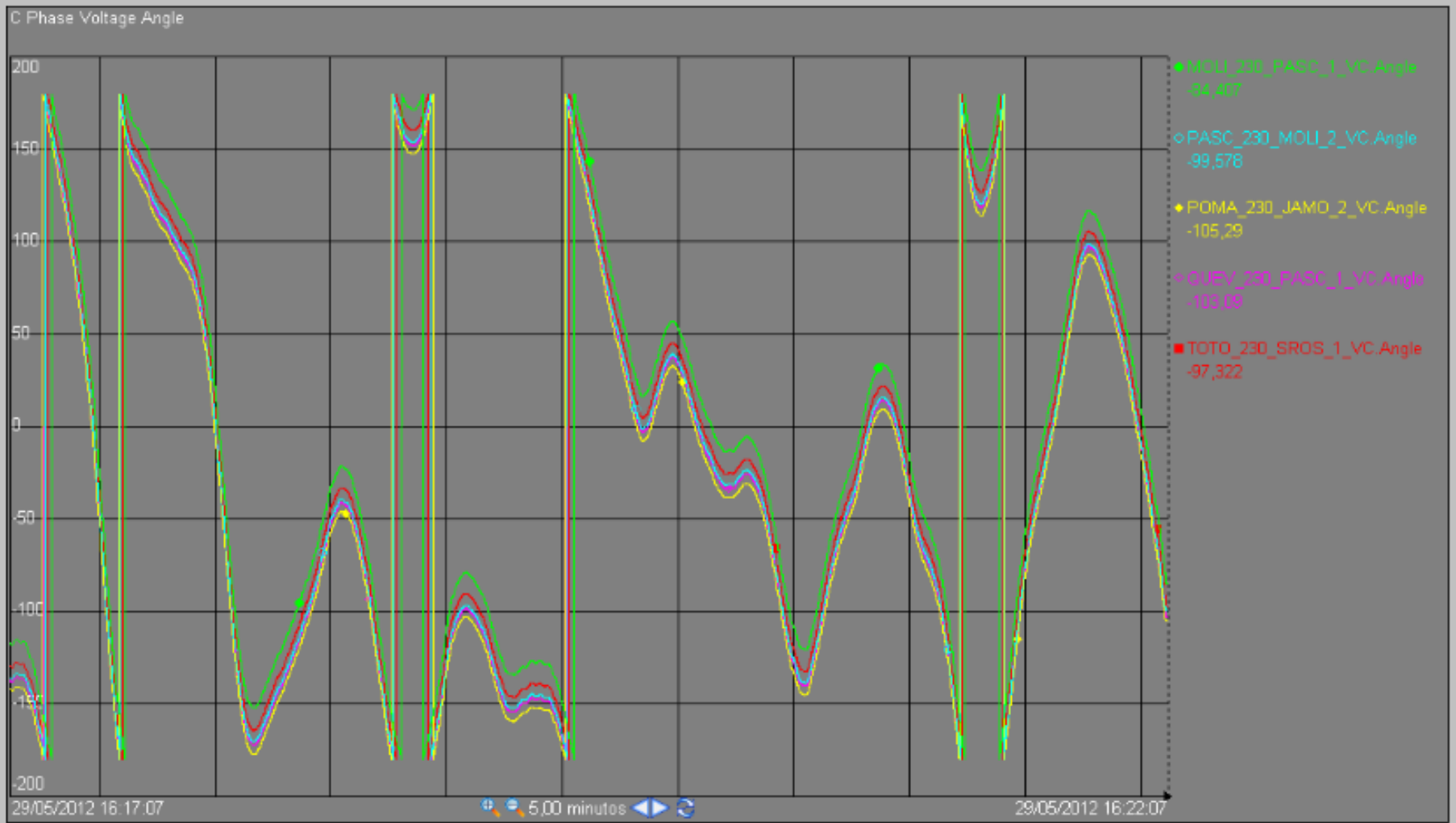
Total 27 PMUs (2014)



Architecture Overview



C Phase voltage angles



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.

PI C37.118 Interface (raw data)

The screenshot displays the 'PI Interface Configuration Utility - PIC371181' window. The interface is configured for 'PI-SYSTEM-2010' with type 'C37.118'. The status is 'Writeable'. The configuration includes a path to an XML file, device settings for IP and Serial, and IP configuration details like protocol (TCP/UDP) and port (4713).

Interface: PIC371181 -> PI-SYSTEM-2010 [Rename]

Type: C37.118 PI IEEE C37.118

Description: [Empty]

Versions: PIC37118.exe version 1.0.5.101 | Unilnt version 4.5.2.0

PI Server Connection Status: PI-SYSTEM-2010 Writeable

General

- Unilnt
- PI SDK
- Disconnected Startup
- Debug
- Failover
- Performance Points
- Performance Counters
- Health Points
- C37118**
- Service
- IO Rate
- Interface Status

PI IEEE C37.118 Interface-Specific Parameters (1.0.4.88)

Path to XML Config File: C:\Program Files (x86)\PIPC\Interfaces\C37118\test.XML

Device Configuration file Settings

Local End Point Configuration

- IP ID: 1 Comm DLL: PIC37118_Comm002.dll
- Serial

Enabled: Yes [Data Timeout: 1000]

Reconnect Rate: 30000 Primary: No FailOverID: [Empty]

IP Configuration

Protocol	Port	Close Command Socket
Cmd: TCP	Port: 0	<input type="checkbox"/> Use Local IP Address
Data: UDP	Data: 4713	<input type="checkbox"/> Use Multicast IP Addr

Additional Parameters: [Empty]

Close Apply

Ready Stopped PIC371181 - Installed

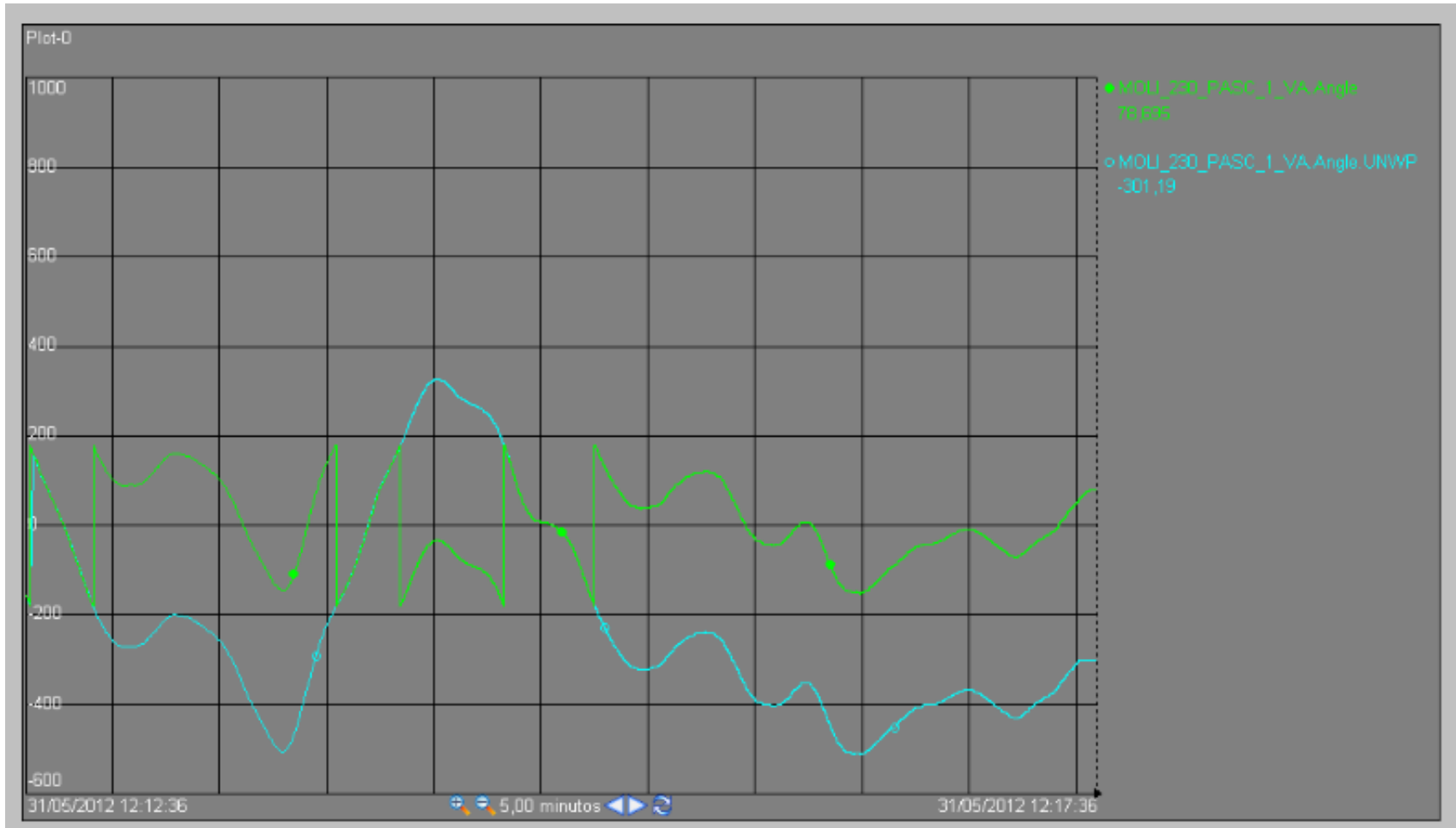
PI Phasor Unwrap Angle Calculation

The screenshot displays the 'OSIssoft - Phasor Calculations' application window. At the top, there is a 'Server:' dropdown menu set to 'PI-SYSTEM-2010' and a 'Connect' button. The OSIssoft logo is visible in the top right corner. Below the server information, there are three tabs: 'Unwrap Angle', 'Angle Difference', and 'Output/Debug', with 'Unwrap Angle' being the active tab. The main area is titled 'Unwrap Angle Configuration' and contains several input fields and checkboxes:

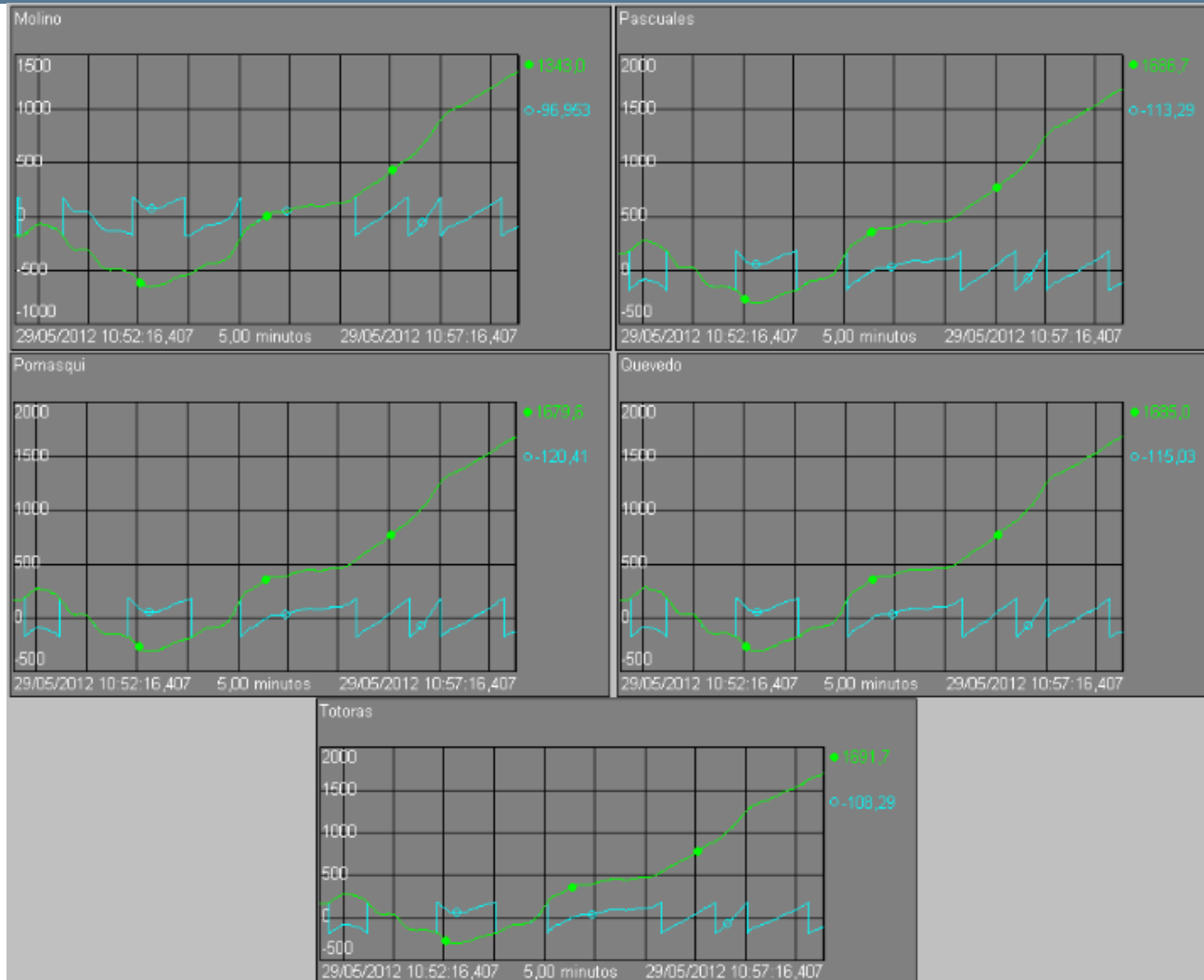
- Point Source: UNWP
- Attr. w/ tag name: sourcetag
- Calc. Delay: 1 s auto
- Range: 360
- Low Limit: -180
- High Limit: 180
- Test Limit: 340

Below the configuration fields, there is a 'Configuration:' section with the text: 'The tag will unwrap the angle of the input tag referenced at "sourcetag" attribute'. At the bottom, there is a checkbox for 'debug unwrap angle' which is currently unchecked, and a 'Stop' button. The status is shown as 'Status: Running' in green text.

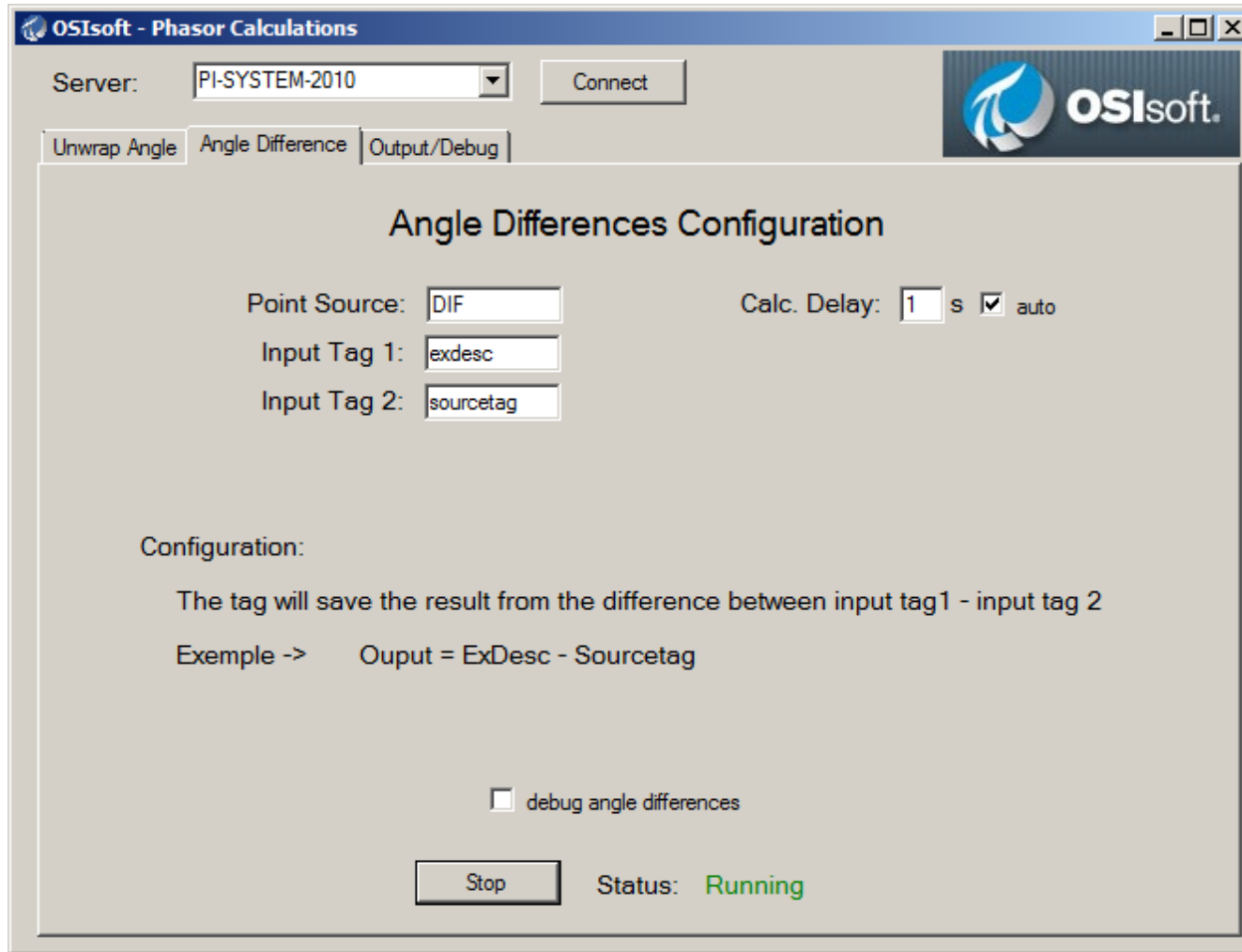
CENACE - Unwrapped Angle (Molino Station)



CENACE - Unwrapped Angles



Frequency and Angle differences calculation



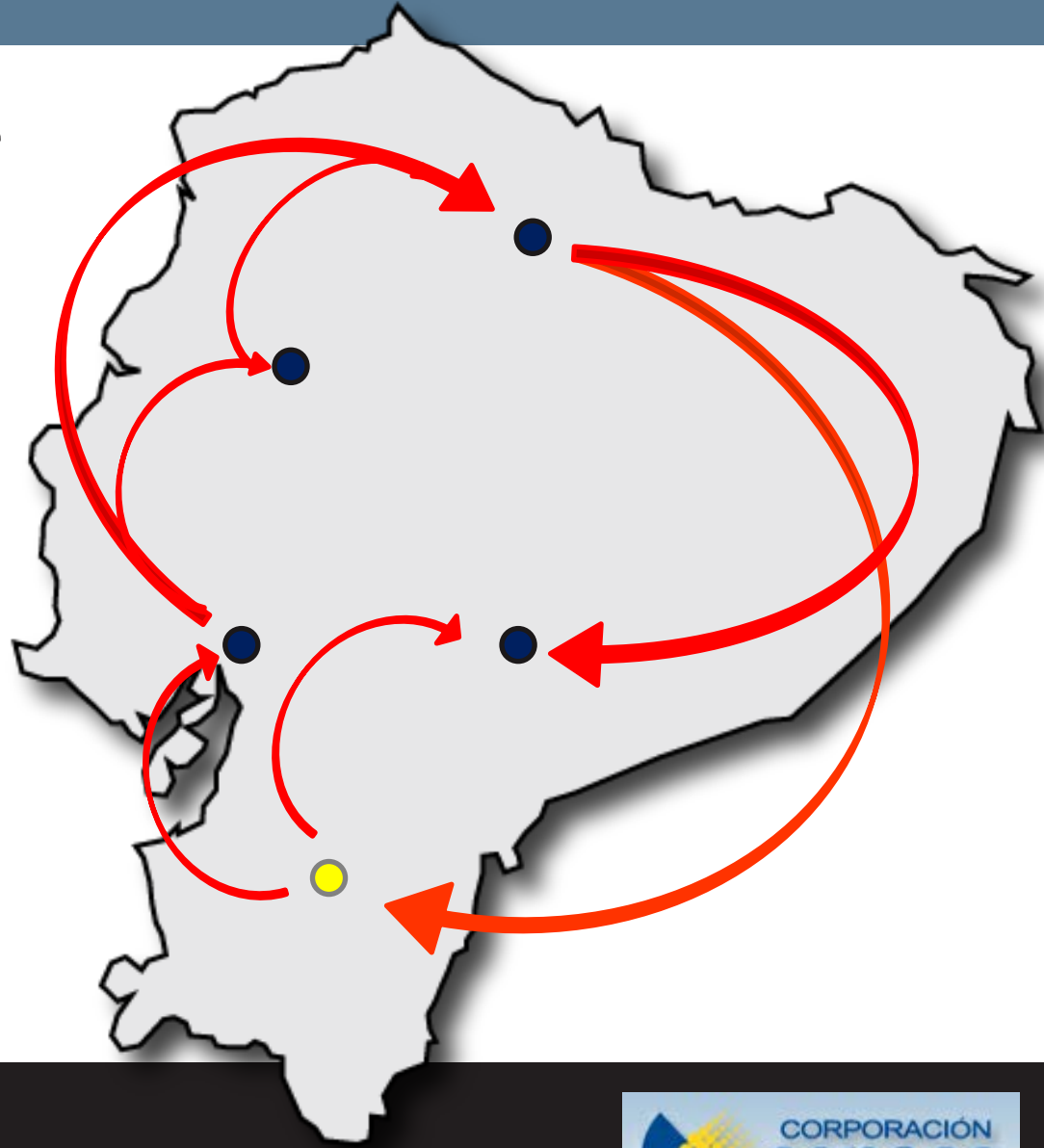
The screenshot shows the 'OSISoft - Phasor Calculations' application window. At the top, there is a 'Server:' dropdown menu set to 'PI-SYSTEM-2010' and a 'Connect' button. The OSISoft logo is in the top right corner. Below the server information, there are three tabs: 'Unwrap Angle', 'Angle Difference' (which is selected), and 'Output/Debug'. The main area is titled 'Angle Differences Configuration'. It contains the following fields and controls:

- 'Point Source:' dropdown menu set to 'DIF'
- 'Calc. Delay:' input field set to '1' with a unit 's' and a checked 'auto' checkbox
- 'Input Tag 1:' input field set to 'exdesc'
- 'Input Tag 2:' input field set to 'sourcetag'

Below these fields, there is a 'Configuration:' section with the text: 'The tag will save the result from the difference between input tag1 - input tag 2'. An example is provided: 'Exemple -> Ouput = ExDesc - Sourcetag'. At the bottom, there is a checkbox for 'debug angle differences' which is unchecked, and a 'Stop' button. The status is displayed as 'Status: Running'.

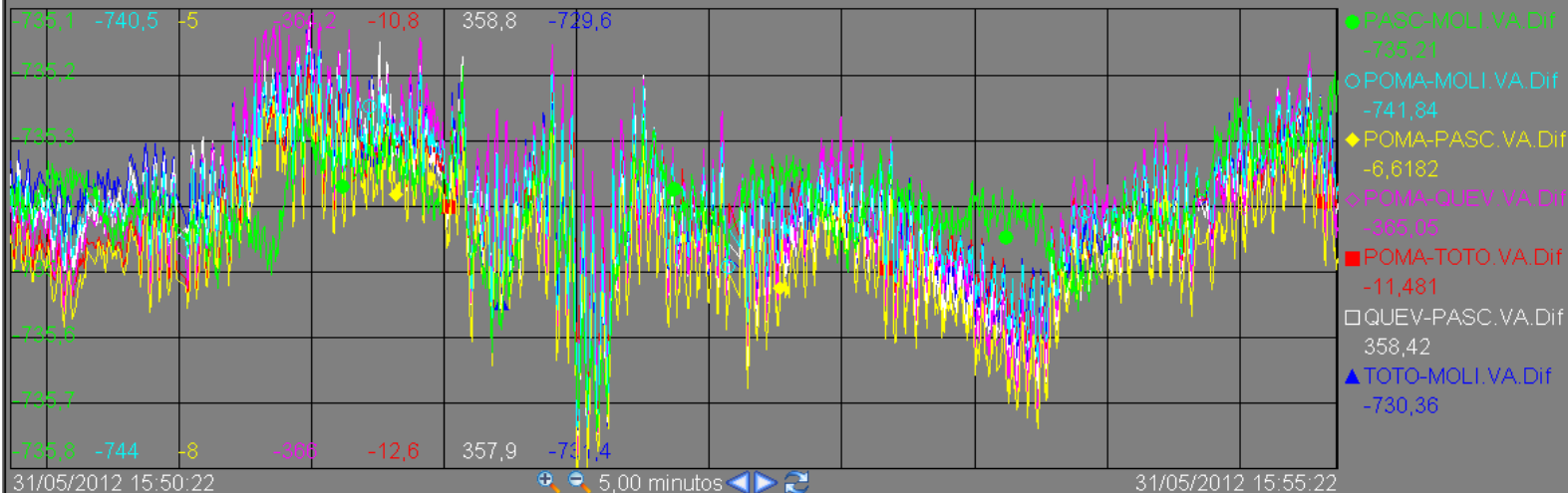
Critical Differences

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

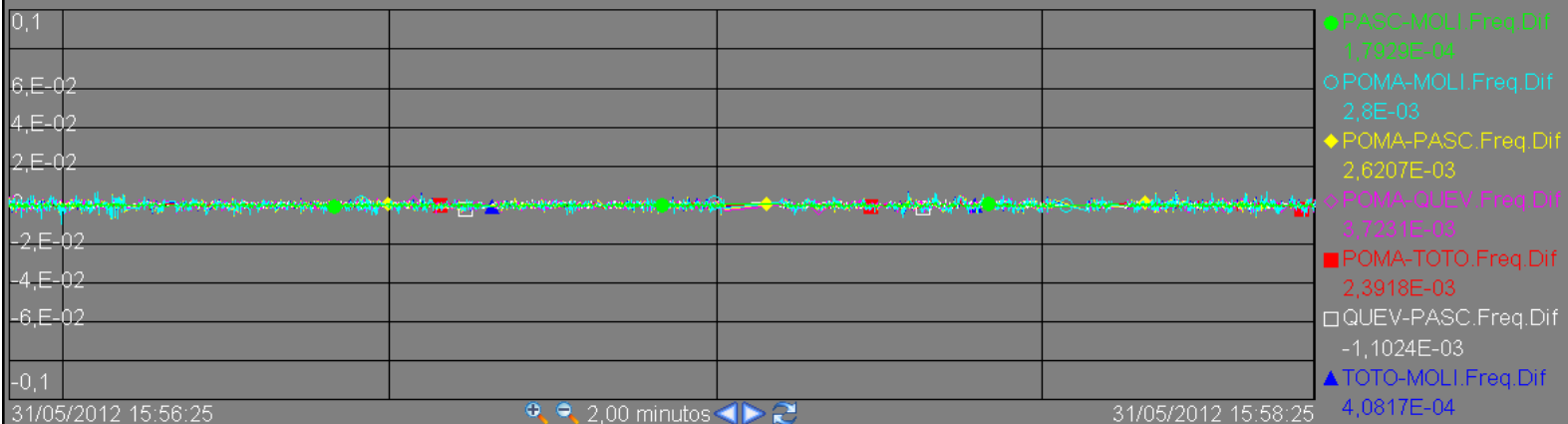


Frequency Differences Results

Phase A Voltage Differences



Frequency Differences



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)

Fast Fourier Transform of Differences

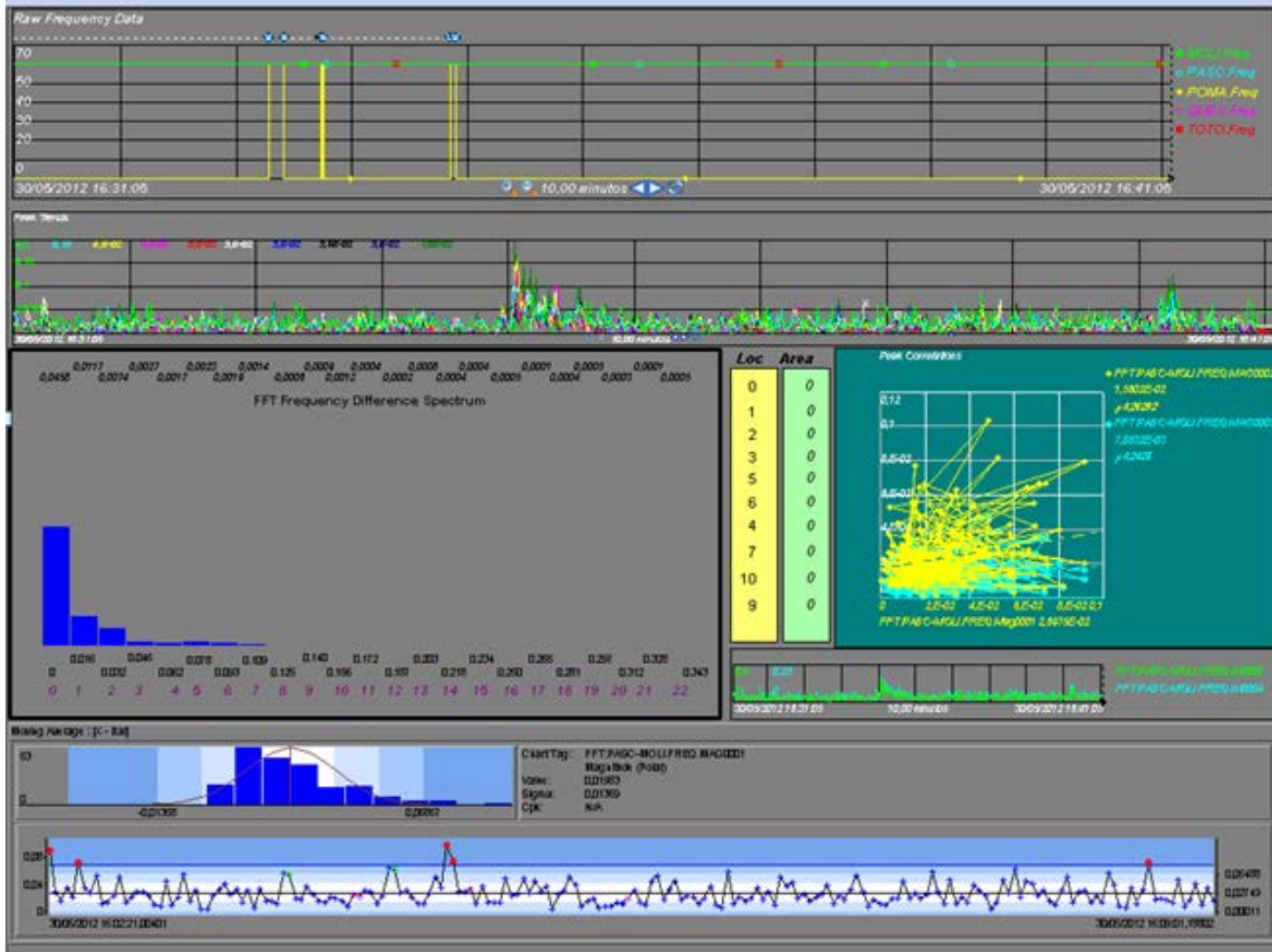
The screenshot displays the 'PI Interface Configuration Utility - PIFFTInt1' window. The interface is configured for 'PIFFTInt1 -> PI-SYSTEM-2010' with the type 'Fast Fourier Transform'. The description field is empty. The versions listed are 'PIFFTInt.exe version 1.1.4.20' and 'Unint version 4.5.2.0'. The 'PI Server Connection Status' is 'PI-SYSTEM-2010 Writeable' with a green checkmark.

The 'Fast Fourier Transform Interface-Specific Parameters (1.1.5.27)' section is active, showing the 'FFT Results' tab. The parameters are as follows:

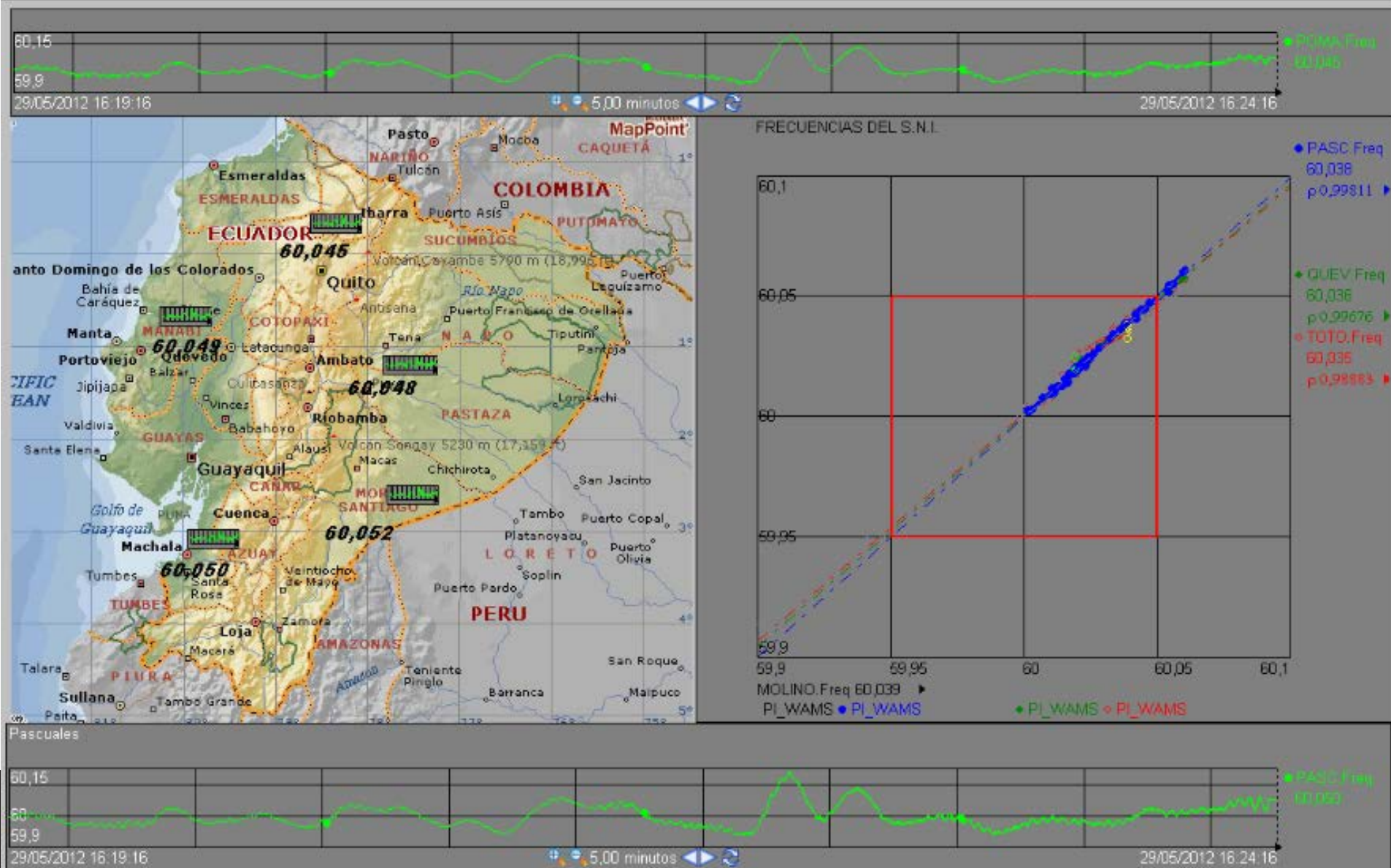
Parameter	Value
Scale angle outputs	<input type="checkbox"/>
Write "No Sample" to output tags	<input checked="" type="checkbox"/>
Sort magnitudes of FFT spectrum	<input checked="" type="checkbox"/>
Number of array indices for peak area calculation	5
Maximum output events	1000
Calculation Period	ms
Reset Time Period	60 Minutes

The 'Additional Parameters' field is empty. The status bar at the bottom shows 'Ready', 'Stopped', and 'PIFFTInt1 - Installed'.

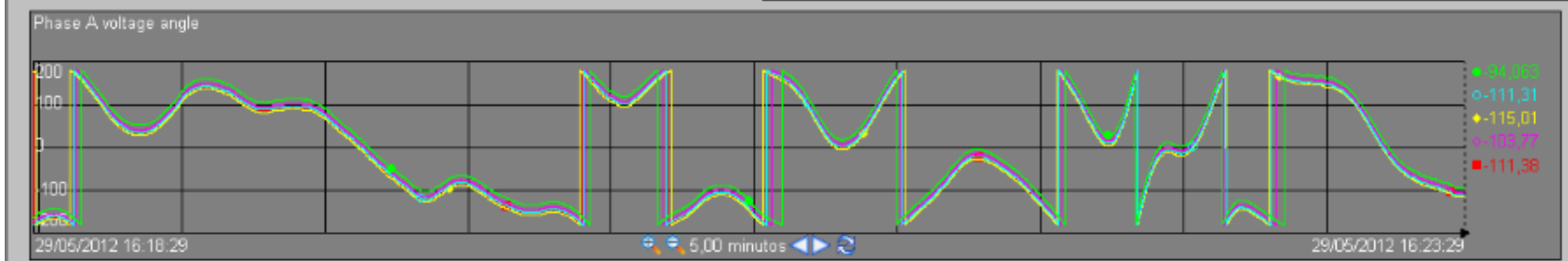
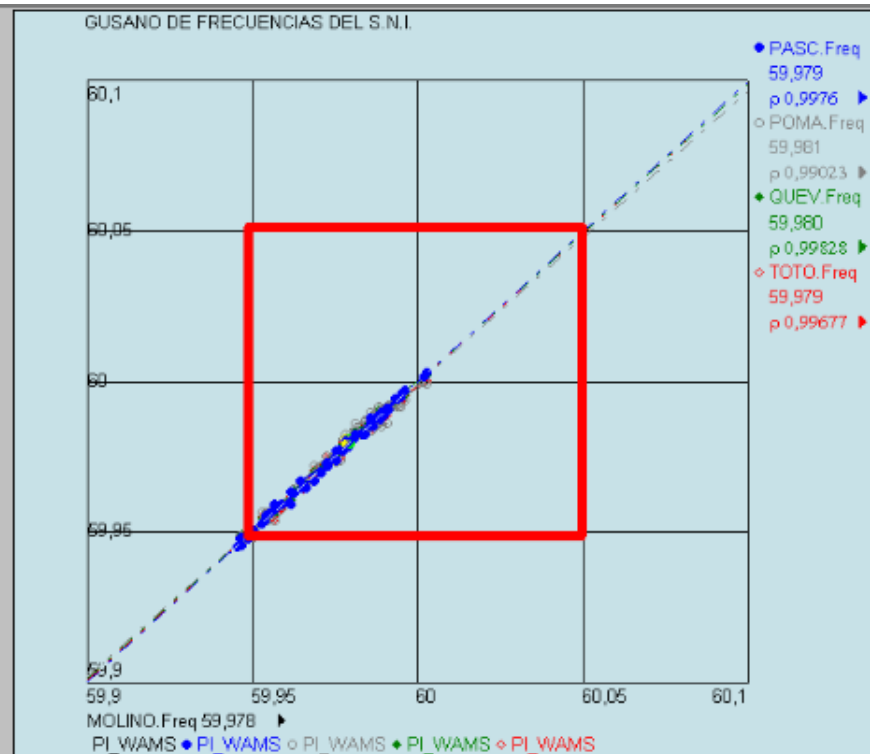
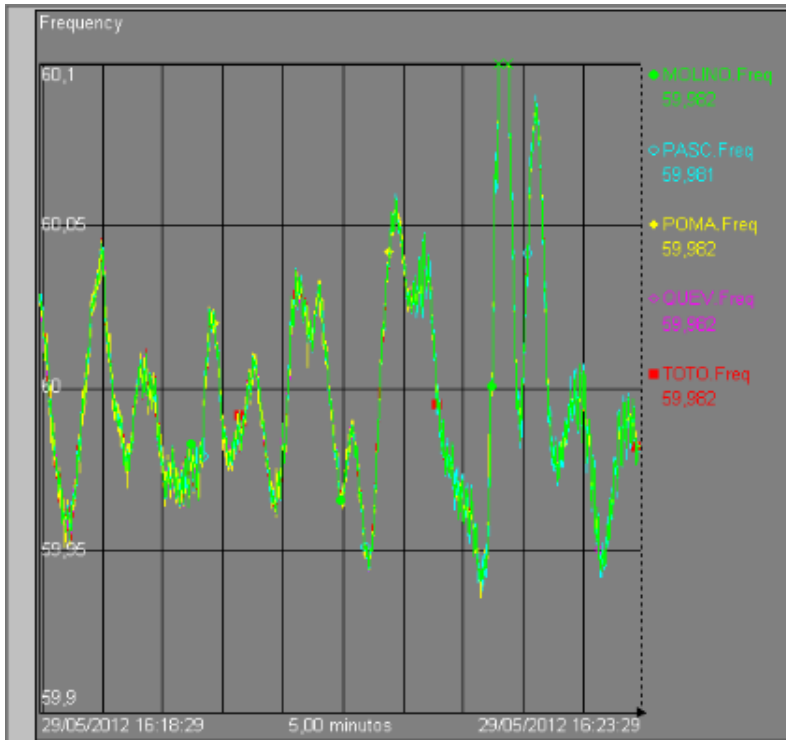
Fast Fourier Transform Spectrum



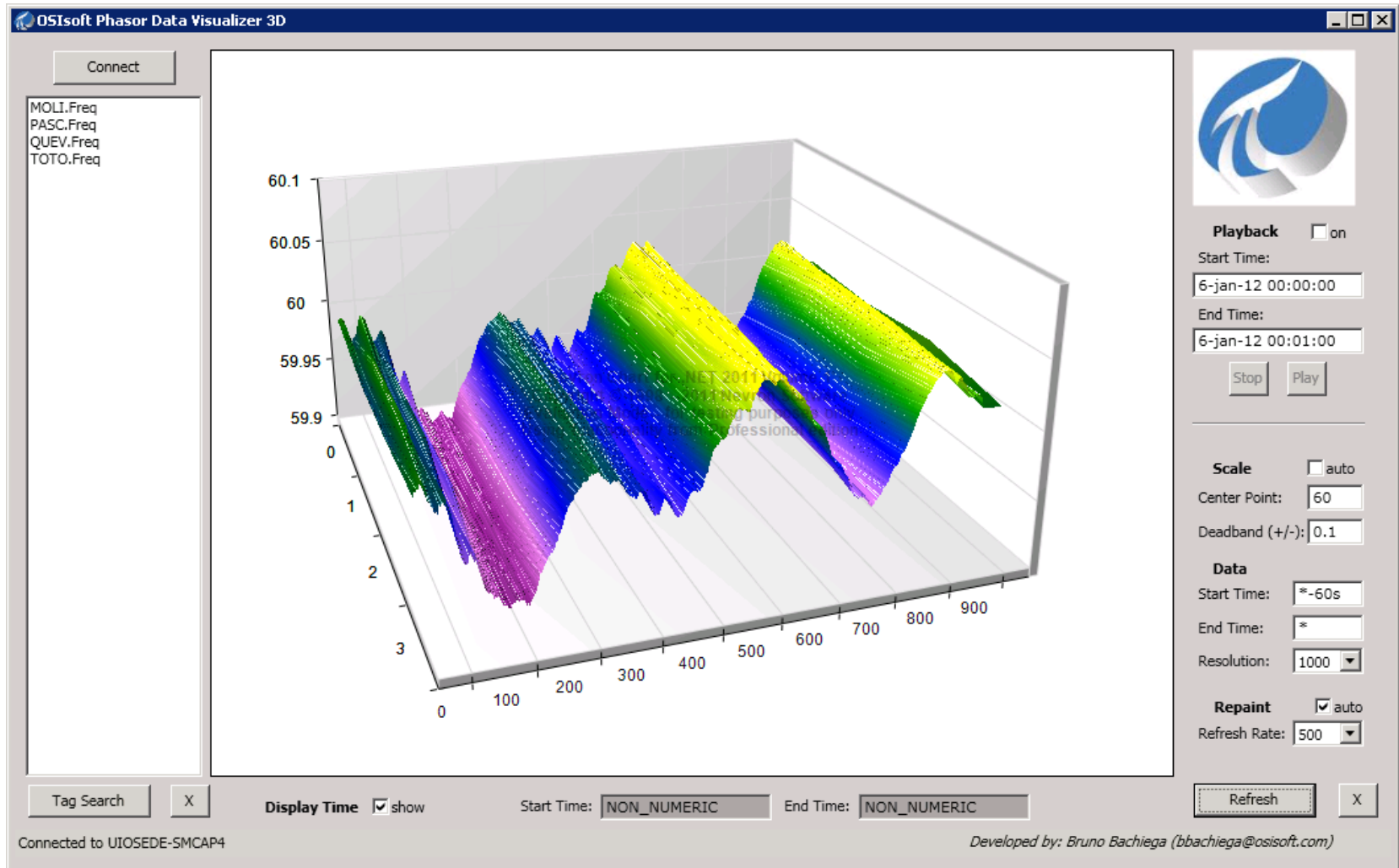
Synchrophasor Data Visualization



Synchrophasor Data Visualization

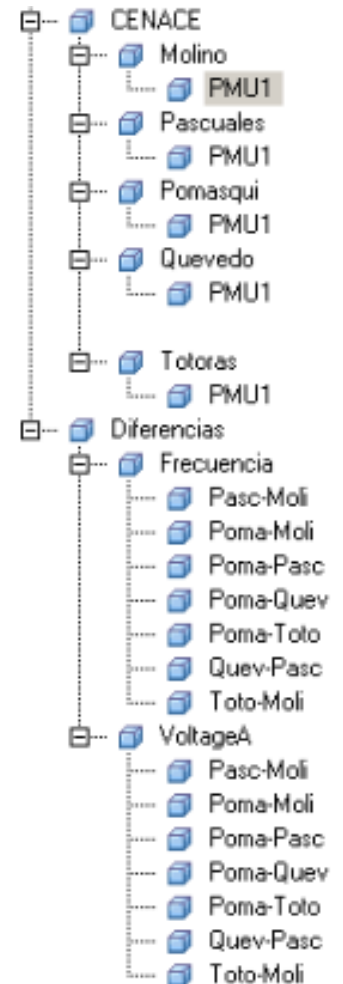


3D Synchrophasor Data Visualization



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



Name	Description	Default Value
FaseA		0
FaseB		0
FaseC		0
Frecuencia		0 Hz
Latitude		0
Longitude		0
Modelo PMU		11338
PMU ID		0
Proveedor		Aibler
ROCCDF		0 Hz



Similar Elements are based out of the same AF template

CENACE

- Molino
 - PMU1
 - Pascuales
 - PMU1
 - Pomasqui
 - PMU1
 - Quevedo
 - PMU1

PMU1

Name	Value
FaseA	0
Angulo de Corriente ...	-13,93392 °
Angulo de Voltagem ...	-123,9541 V
Maginitude de Corrie...	409,997589111328 A
Maginitude de Volta...	138924,234375 V
Parte Imaginaria de I...	-300,375335693359 A
Parte Imaginaria de ...	-115235,5625 V
Parte Real de Corrie...	-279,0568 °
Parte Real de Voltag...	-77593,23 V
FaseB	0
Angulo de Corriente ...	107,1743 °
Angulo de Voltagem ...	115,7504 V
Maginitude de Corrie...	410,063262939453 A
Maginitude de Volta...	138260,15625 V
Parte Imaginaria de I...	391,778961181641 A
Parte Imaginaria de ...	124530,3125 V
Parte Real de Corrie...	-121,0831 °
Parte Real de Voltag...	-60067,22 V
FaseC	0
Frecuencia	59,93267 Hz
Latitude	0
Longitude	0
Modelo PMU	1133B
PMU ID	1
Proveedor	Arbiter
ROCOF	-0,0112454099580646 Hz

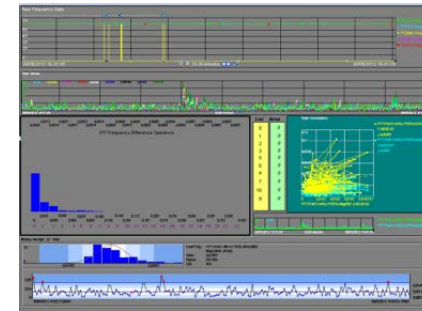
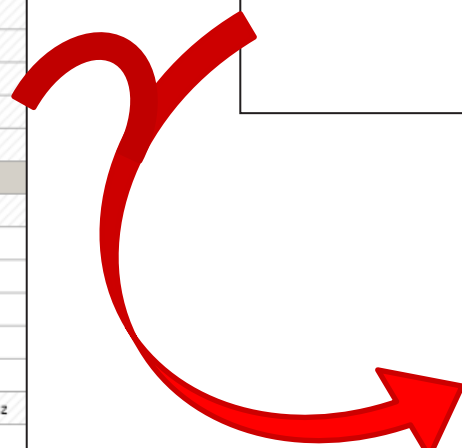
Frecuencia

- Pasc-Moli
- Poma-Moli
- Poma-Pasc
- Poma-Quev
- Poma-Toto
- Quev-Pasc
- Toto-Moli

VoltageA

- Pasc-Moli
- Poma-Moli
- Poma-Pasc
- Poma-Quev
- Poma-Toto
- Quev-Pasc
- Toto-Moli

Angles	0
Area	0
0000	0,057890602777004242
0001	0,053605470806360245
0002	0,033816829323768616
0003	0,008476943258523941
0004	0,0065457820892333984
0005	0,014334004372358322
0006	0,0058517483994364738
0007	0,0048373043537139893
0008	0,0036630176473408937
0009	0,0025130398571491241
Damping Coefficient	0
Harmonics	0
Integrals	0
Magnitude	0
Peak Locations	0
Station1	PASC
Station2	MOLI



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

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

Contacts

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