Practical PMU Applications for Utilities

University of Washington

EE Graduate Seminar

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SynchroPhasor Technology

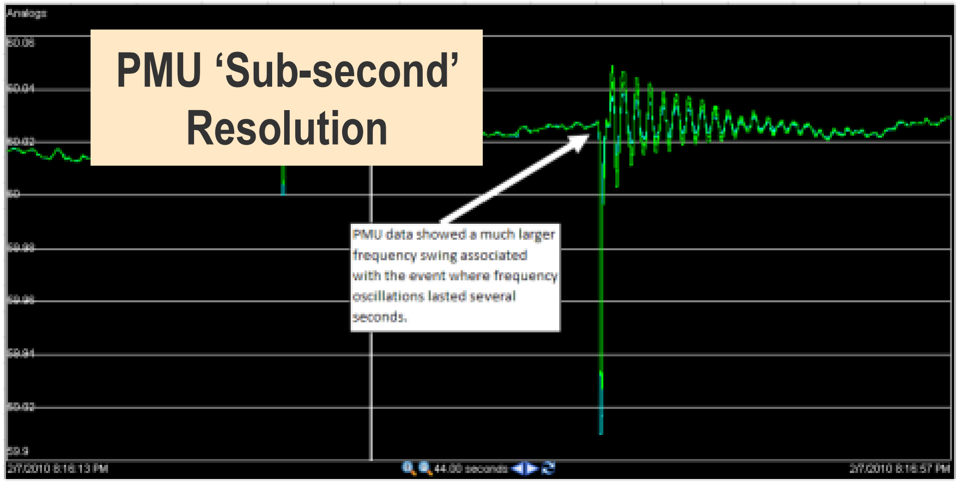
Phasor Measurement Units (PMUs)

- Next generation measurement technology. (voltages, currents, frequency, frequency rate-of-change, etc)

- Higher resolution scans (e.g. 30 samples/second).
  - *Improved visibility into dynamic grid conditions.*
  - *Early warning detection al...*

- Precis...
  - *...wareness.*
  - *...t Analysis.*

“PMUs: MRI quality , color 3-D visibility compared to X-ray quality , B&W 2-D visibility of SCADA”
– Terry Boston (CEO, PJM)



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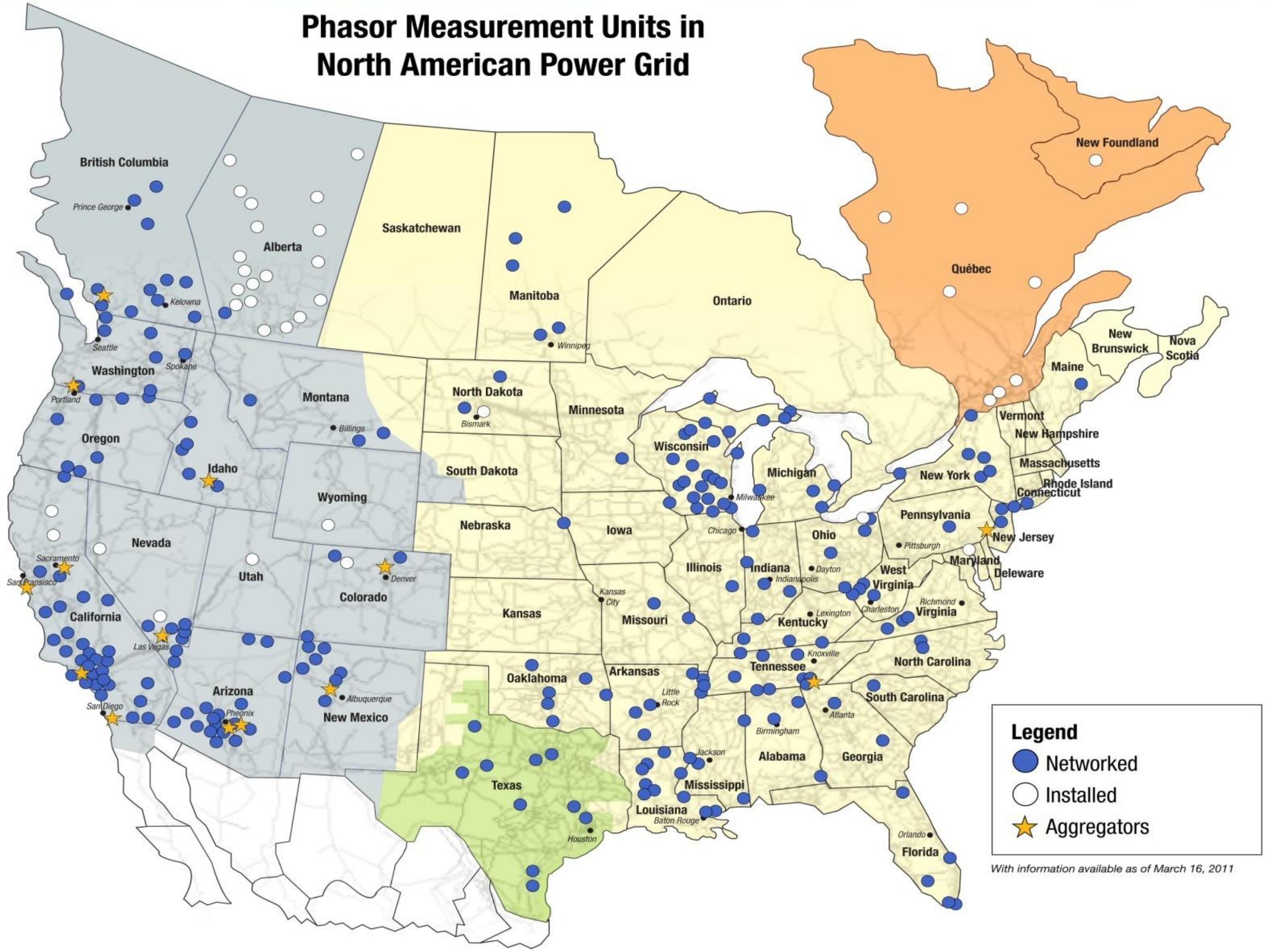
PMU Deployment within North America

Currently 200+ PMUs Installed.

Expected to exceed 800+ PMUs by 2013
(under SGIG Investments)



Source: NASPI Website (www.naspi.org)

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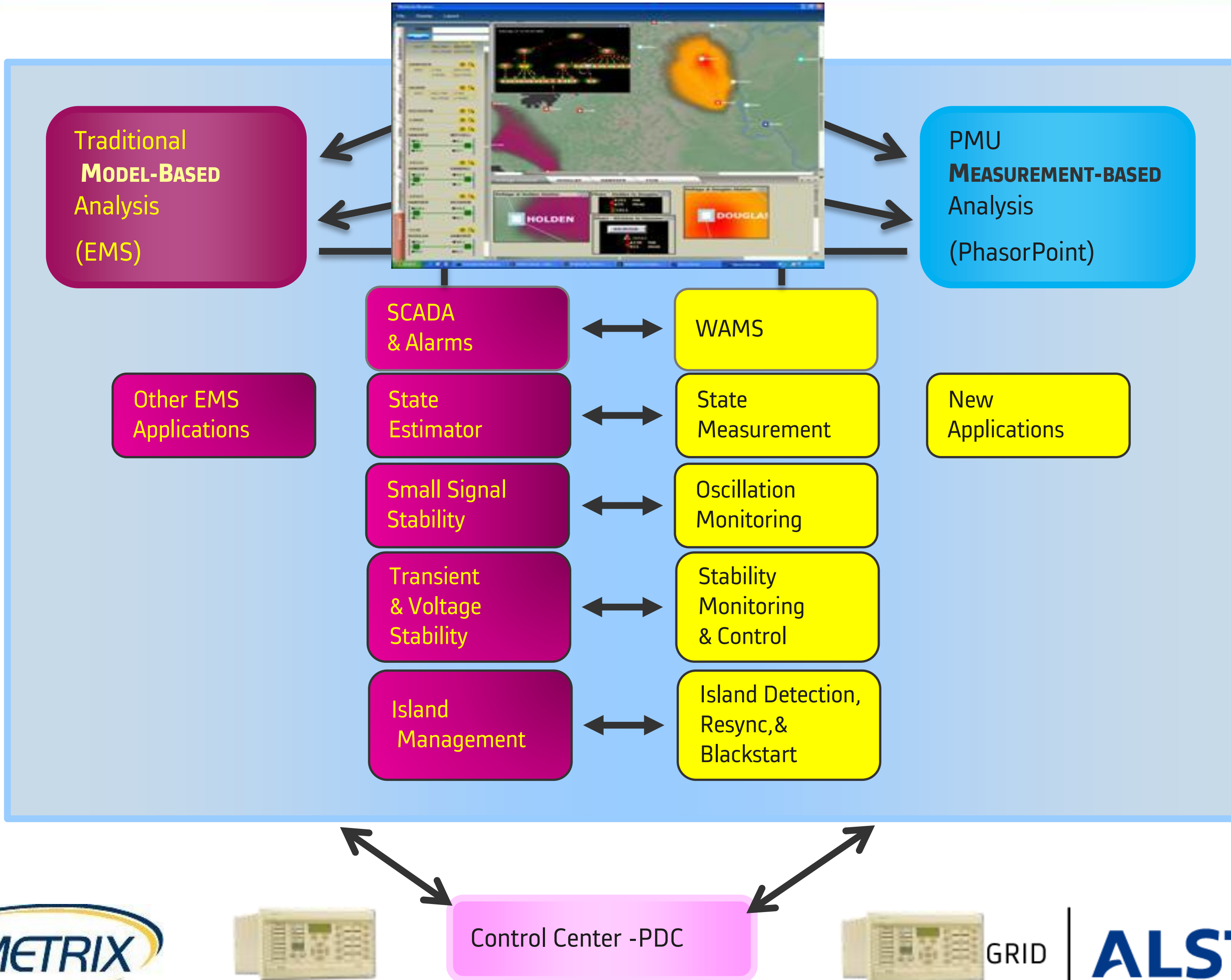
SynchroPhasors & Energy Management Systems



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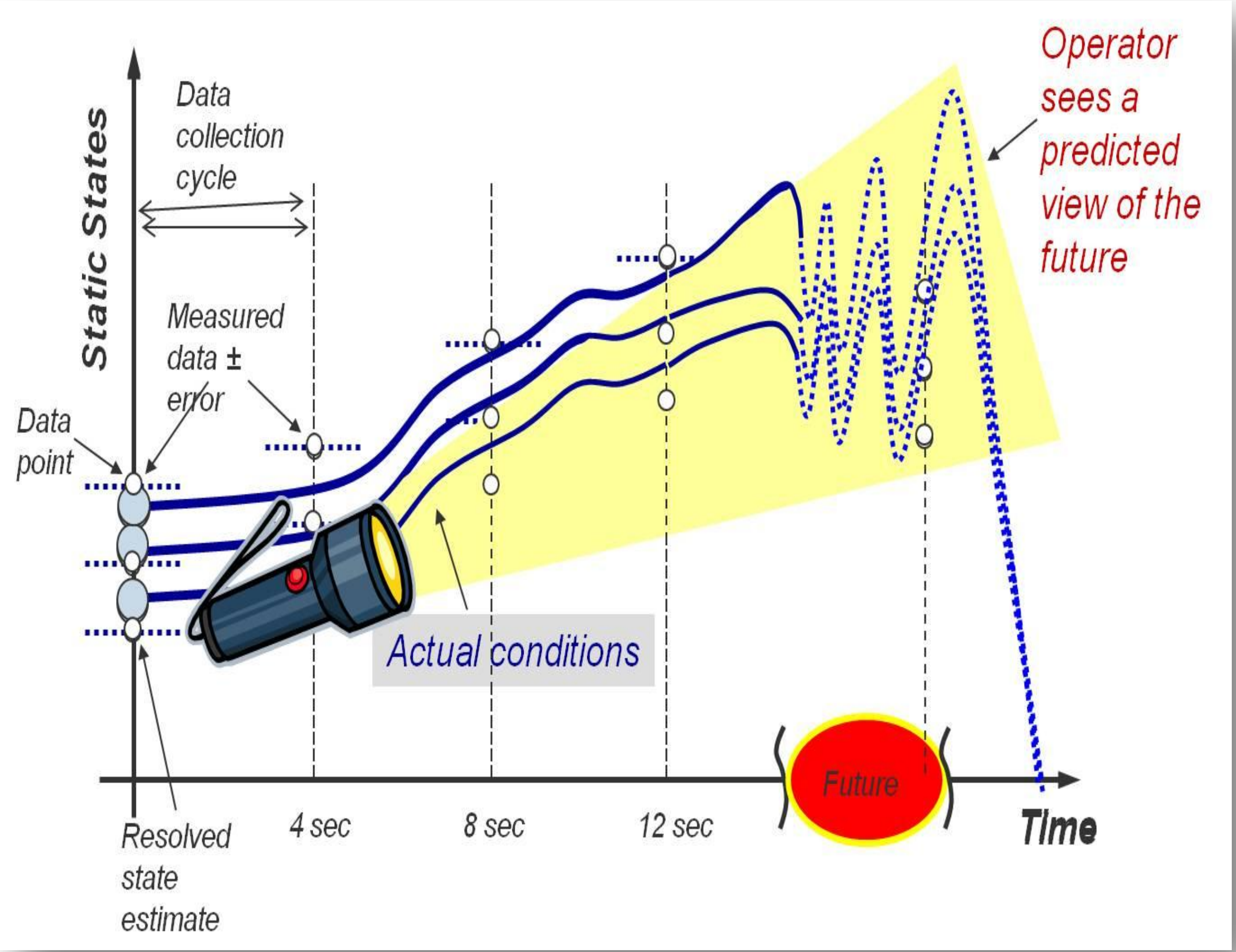
Look Ahead and Predictive Operations Capability in Control Rooms

- ***Reduces the impact of variability and uncertainty on real-time decision making in the control room***



SynchroPhasor Benefits

Reliability

- Situational Awareness
- Identifying sources of oscillations
- Vulnerability detection
- Automated wide area protection
- Identifying equivalent dynamic models
- Analysis tools e.g.
  - Post Mortem
  - Dynamic model validation
  - Baselining

Constraint Relief

- Stability (damping) constraints
- Angle constraints
- WAMS + DSA *(integration of "measurement-based" and "model-based" security assessment).*
- Angle based control

Sustainability

- Renewable connections
- Impact of renewables on stability
- Distribution management

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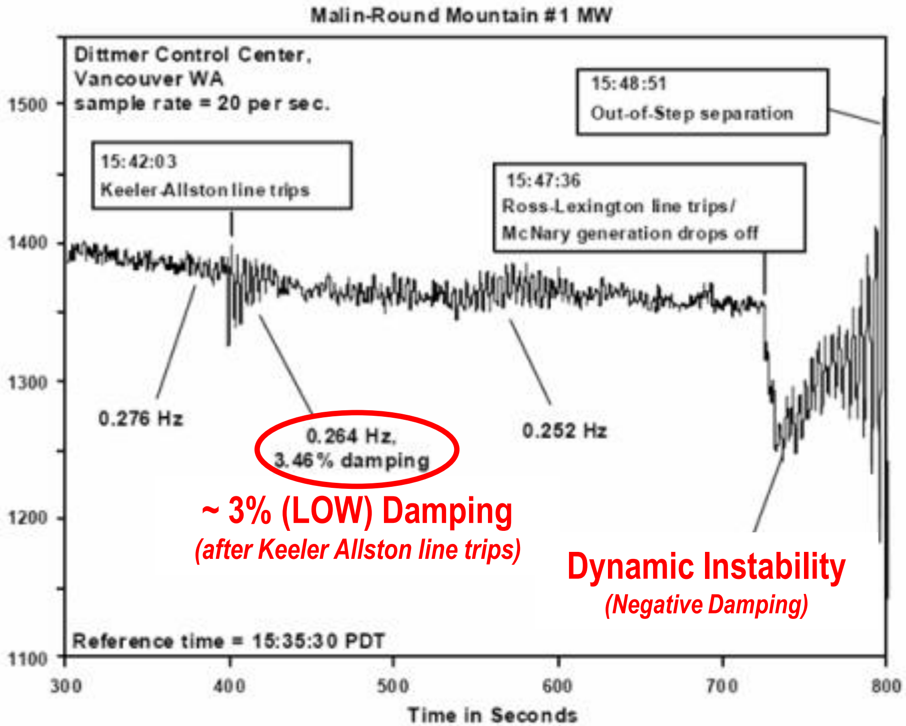
Operational Benefits

Improved Reliability

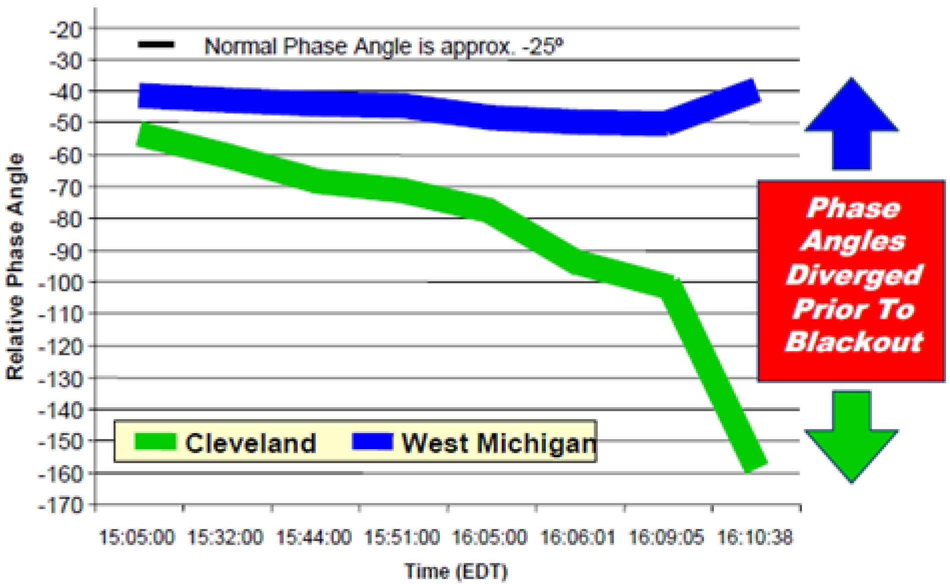
August 10, 1996 Blackout



Early detection of dynamic instability.

Monitor wide-area grid stress.

August 14, 2003 Blackout



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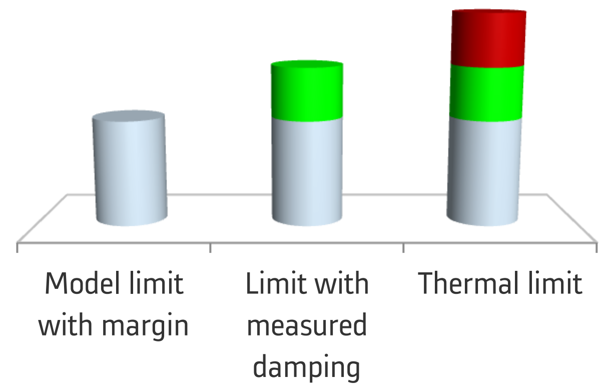
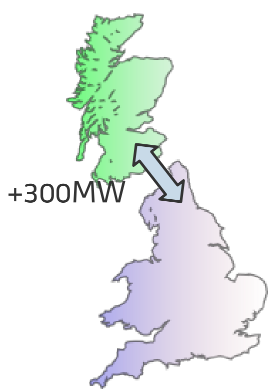
Asset Management

Congestion Relief

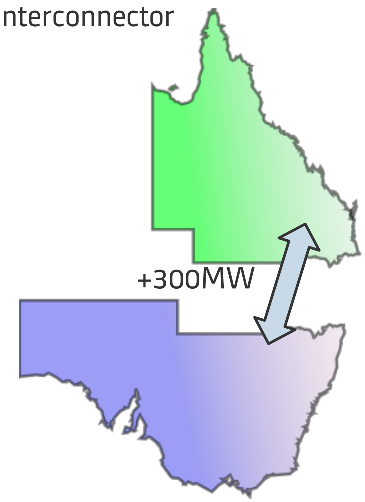
Transmission Corridor
Net Transfer Capacity

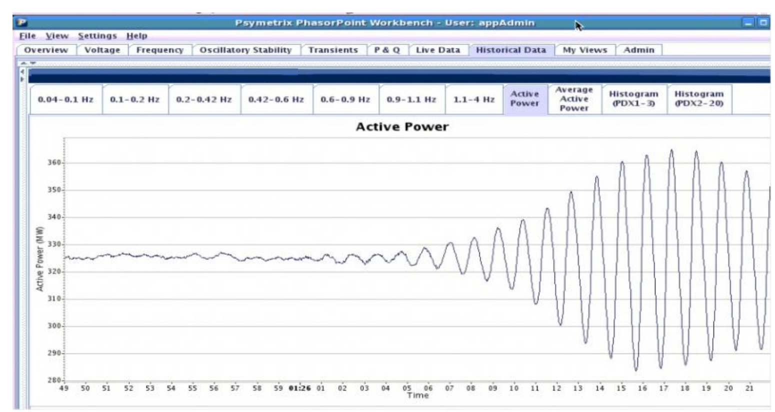


Great Britain
Scotland – England Interconnector



Australia
Queensland – NSW Interconnector





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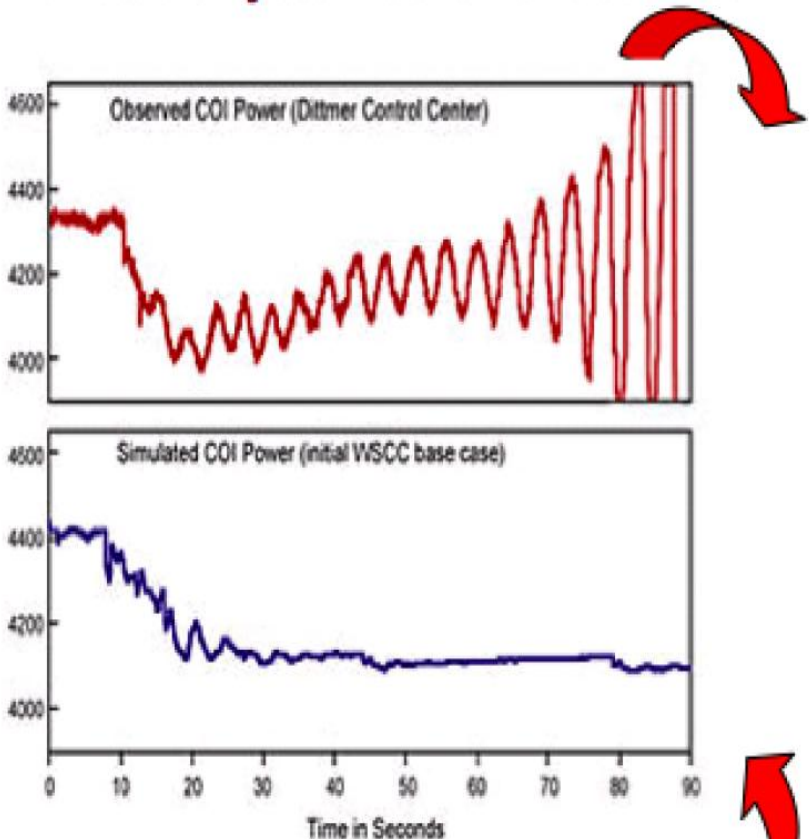
Planning Benefits
Dynamic Model Validation

Western Interconnection
August 10th, 1996 Blackout

Dynamic models predicted stable system when the system was in fact unstable.

PMU provide necessary dynamic data to calibrate dynamic power system models.

Actual System Performance
- unstable system behavior observed.



Model Simulation
- predicted stable system performance.

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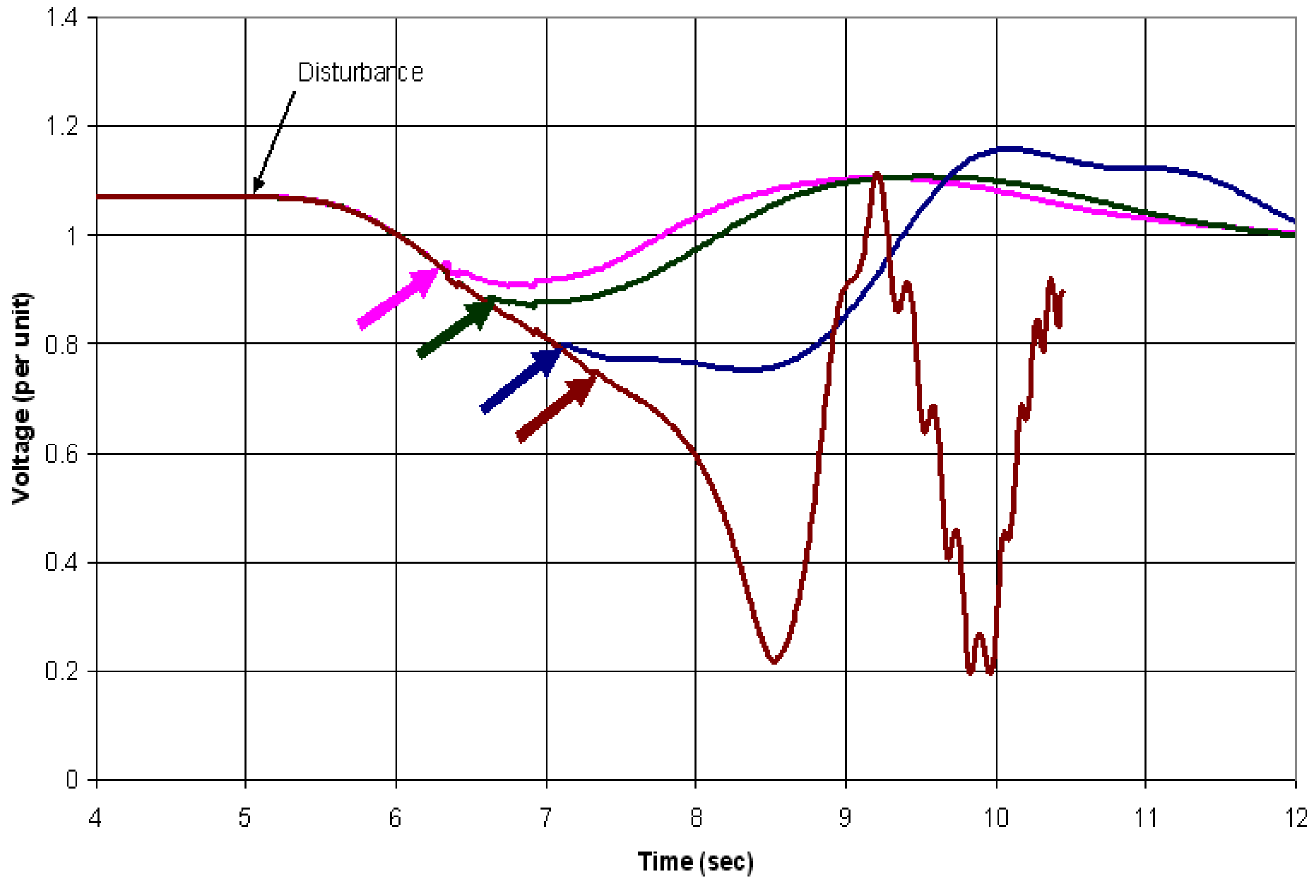
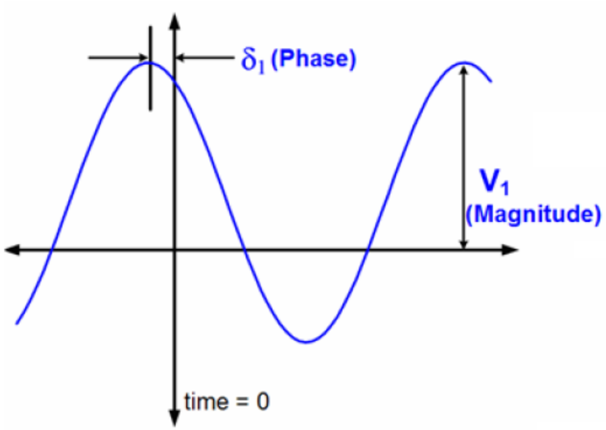
Protection & Control

Timely control actions necessary for them to be effective!

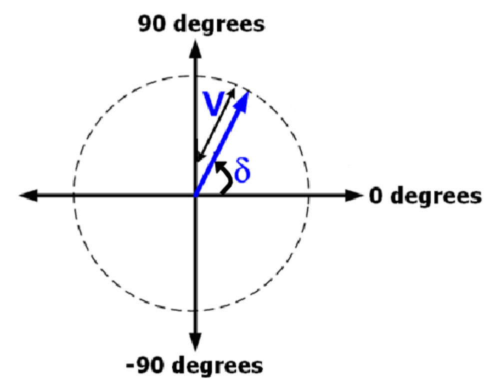


PMU Basics: *What is a PMU?*

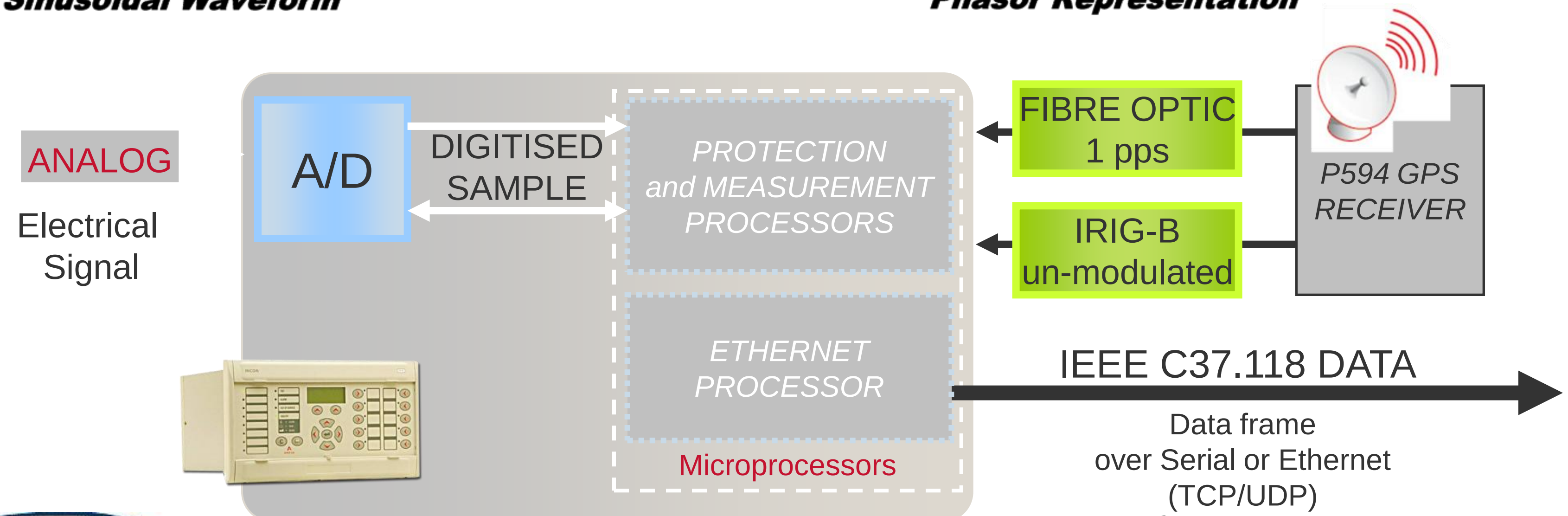


Sinusoidal Waveform

=



Phasor Representation



Areva P847 PMU

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Fundamental WAMS Components

Phasor Measurement Unit (PMU) *(MiCOM P847 Series)*

Analog Channels

- Va, Vb ,Vc,V1, V2,V0
- I1 , I2 , I0, Ia , Ib ,Ic
- Frequency & Rate of Change of Frequency

Digital Channels

- Any 8 status signals available

Phasor Data Concentrator (PDC) *(PhasorPoint PDC, OpenPDC)*

Time align measurements received from multiple PMU/PDC streams.

Perform data validation.

Provide time-aligned data at desired periodicity and formats to downstream applications.

Central PDC
PHASORPOINT

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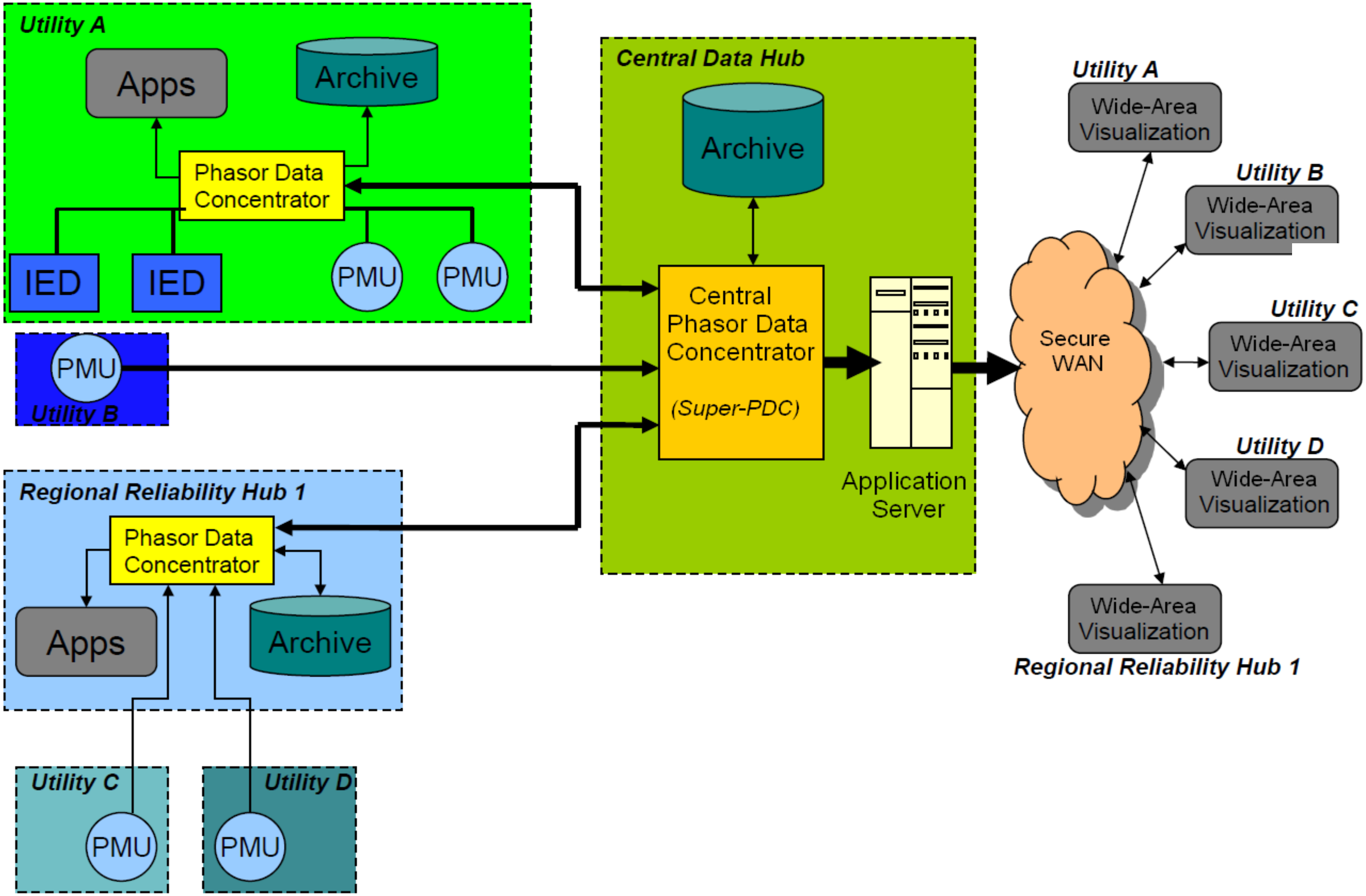
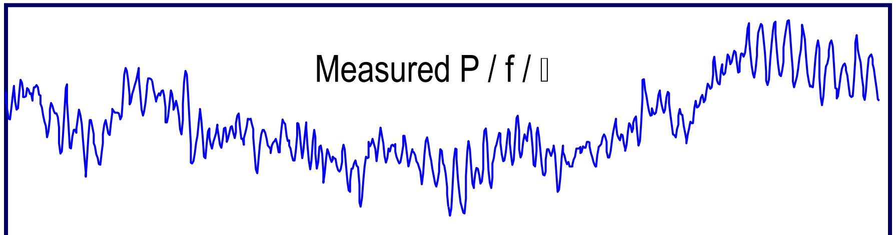
Typical WAMS Architecture

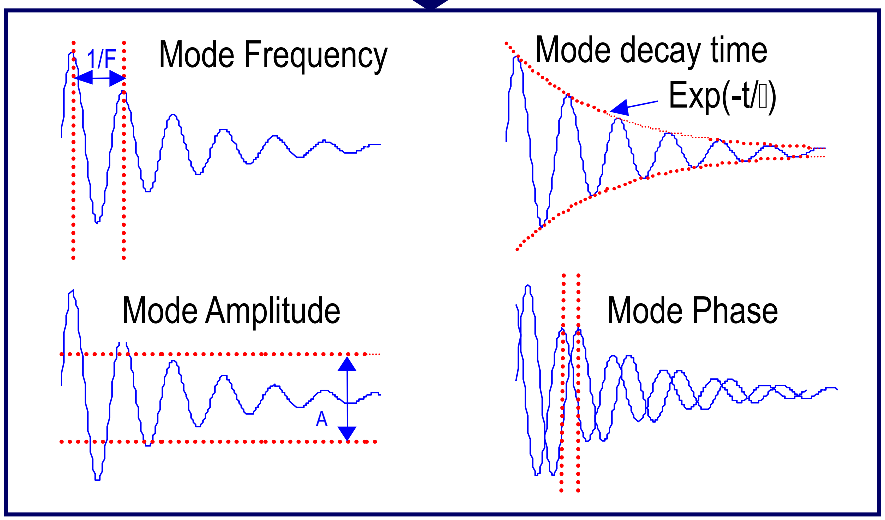


Source: NASPI Website (www.naspi.org)

Oscillatory Stability Management

Simultaneous multi-oscillation detection and characterisation direct from measurements





Fast Modal Analysis:	Alarms
Trend Modal Analysis:	Analysis

Does not use system model

In operational use since 1995

Operations

Early warning of poor damping (two level alarms)

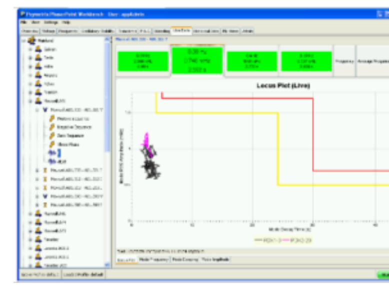
Unlimited oscillation frequency sub-bands

Individual alarm profiles for each sub-band

For each oscillation detected, alarm on:

- mode damping and/or
- mode amplitude for

Wide area mode alarms



Mode locus plot with alarm thresholds

Planning & Analysis, Plant Performance

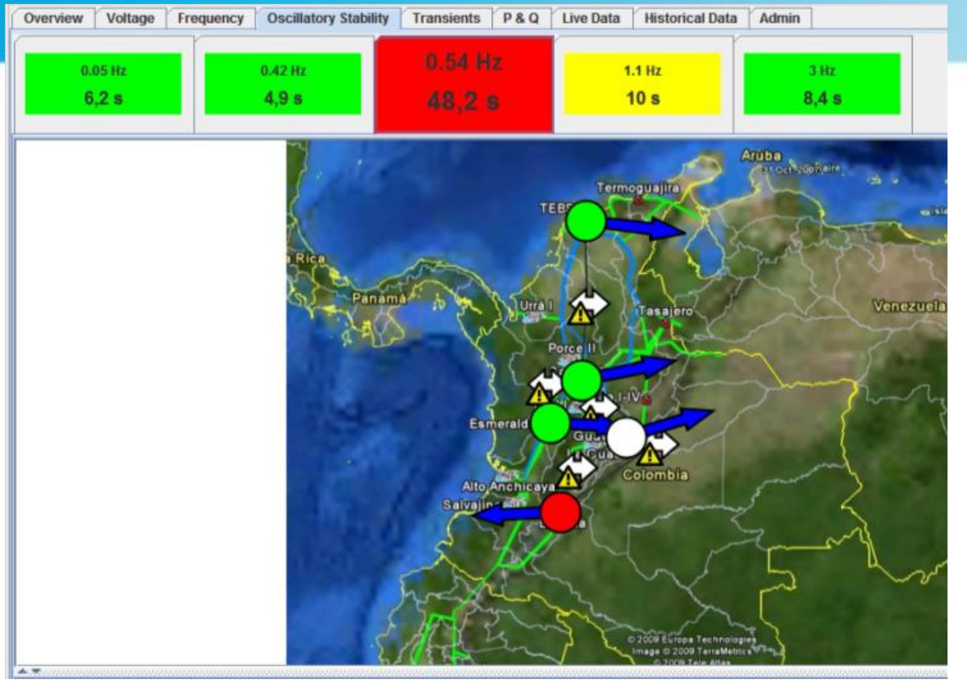
Post-event analysis

Dynamic performance baselining

Dynamic model validation

Damping controller performance assessment

Oscillatory Modes Observed in Colombia (2009)



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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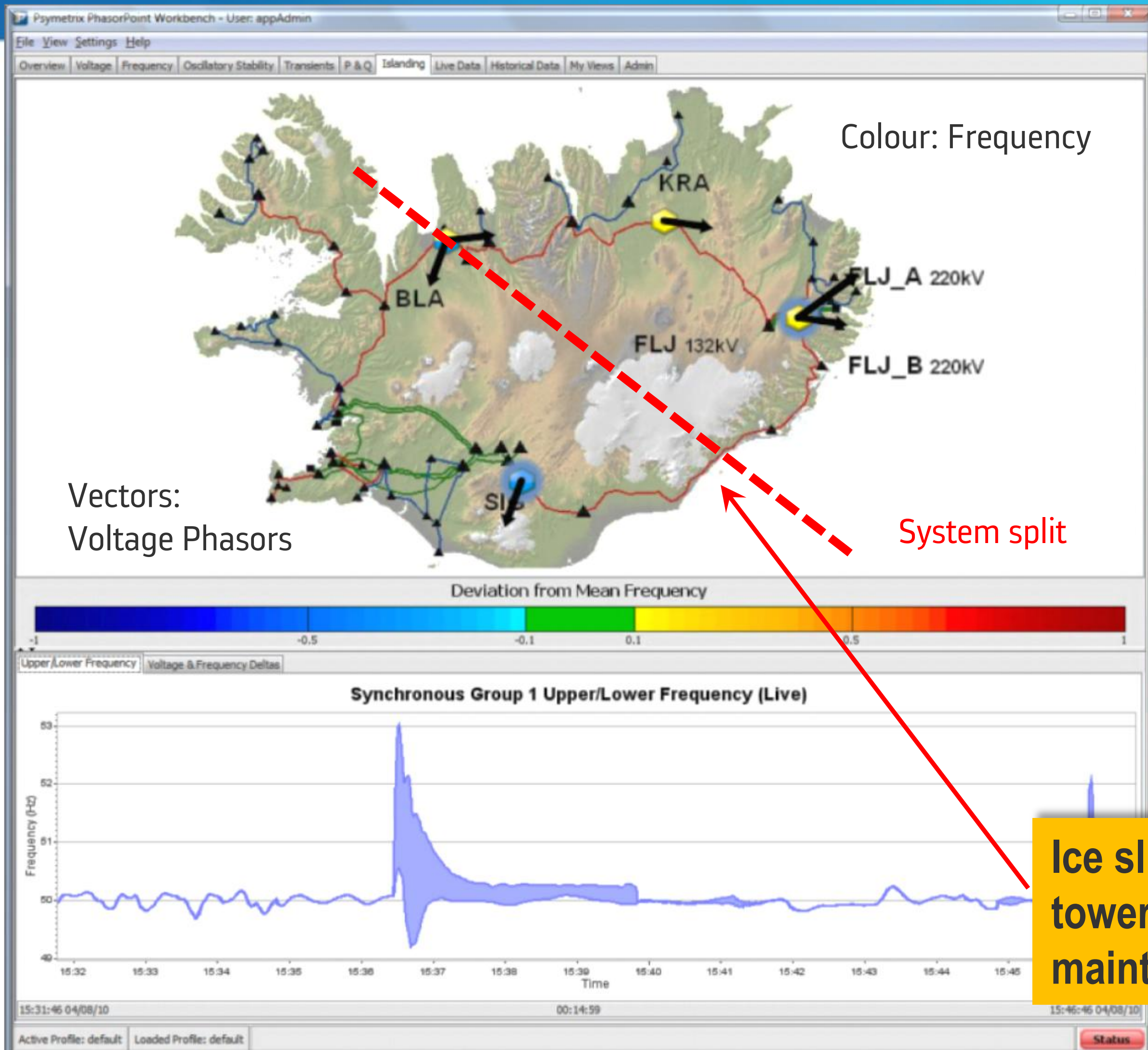
Islanding, Resynchronization and Blackstart



Identify islanding quickly

Alarm raised

Islands clearly visualized

Reduce time to resynchronize

Improve system visibility in blackstart

Ice slide destroys 2 transmission towers, IRB used to monitor system to maintain synchronisation for 2 weeks

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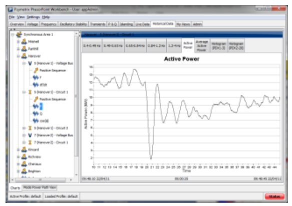
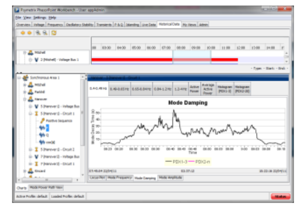
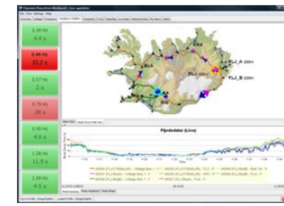
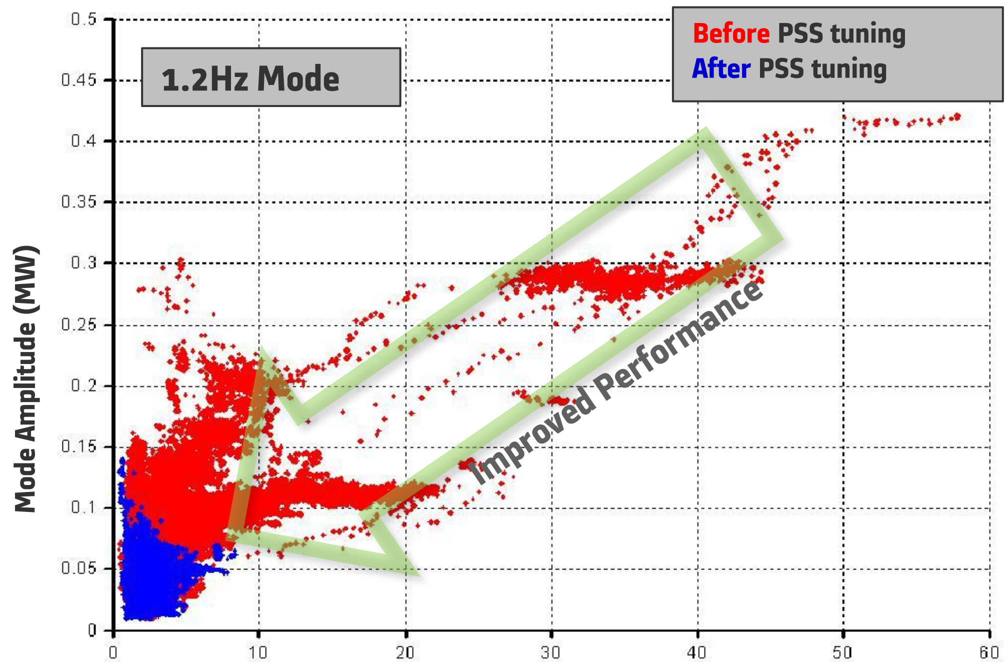
PSS Tuning & Generator Commissioning – Iceland (2006)

1 Observe → 2 Model → 3 PSS Design → 4 Testing & Commissioning → 5 Operation









PhasorPoint Oscillatory Stability Management:

- Wide area real-time damping visualization and alarms
- Dynamics baselining & trending
- Wide area event analysis

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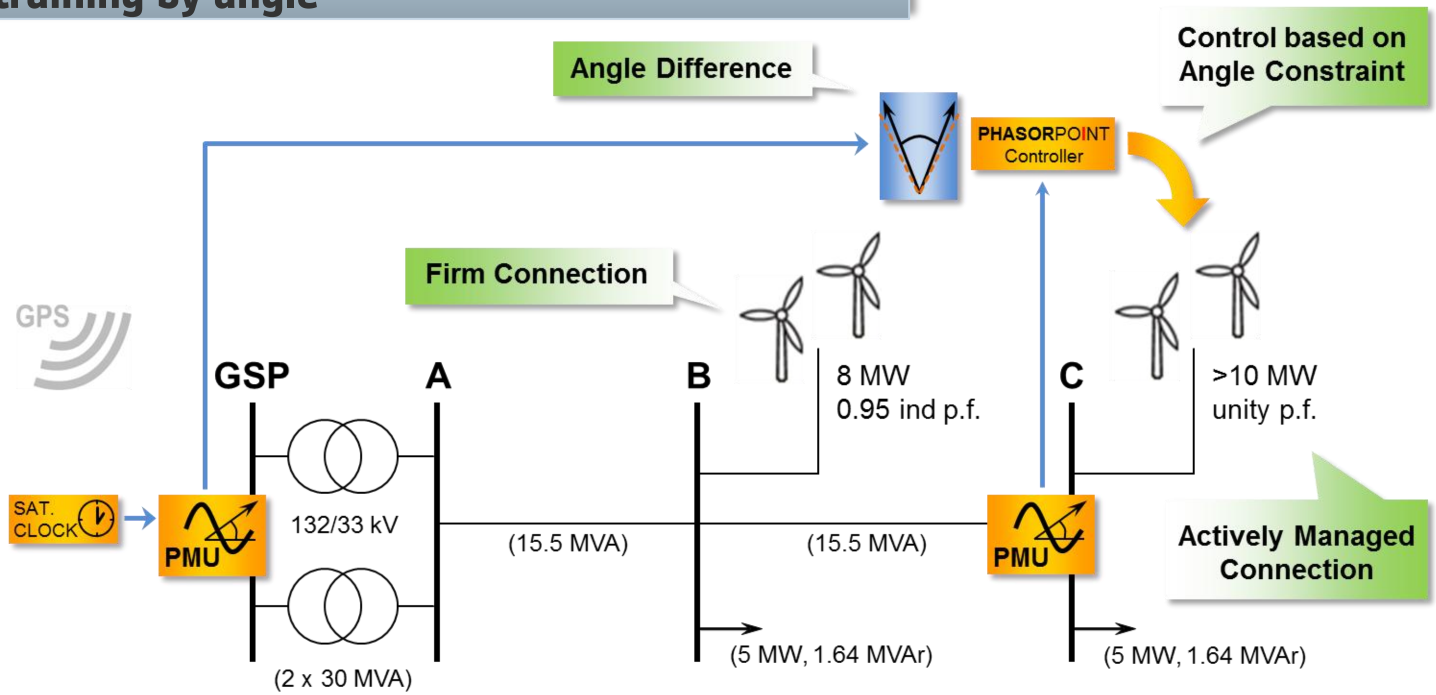
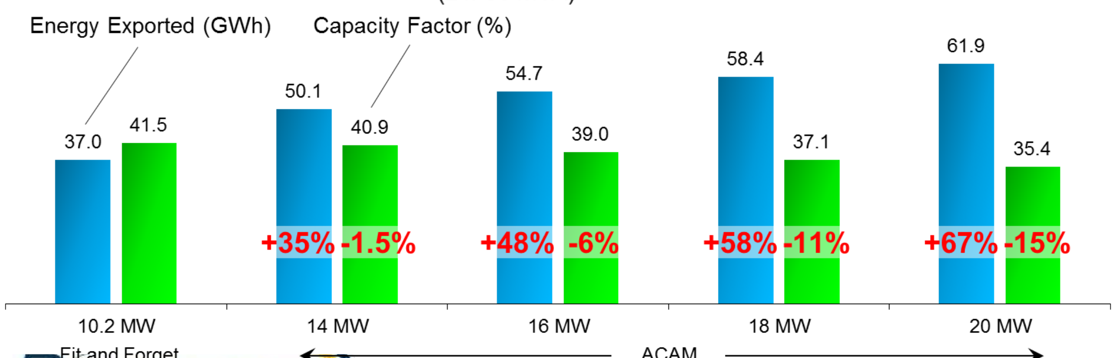
Renewables Integration – Scotland (2012)

In distribution network, increase connection capacity by constraining by angle





Marginal reduction of capacity factor

➔ *More capacity*

➔ *More energy*

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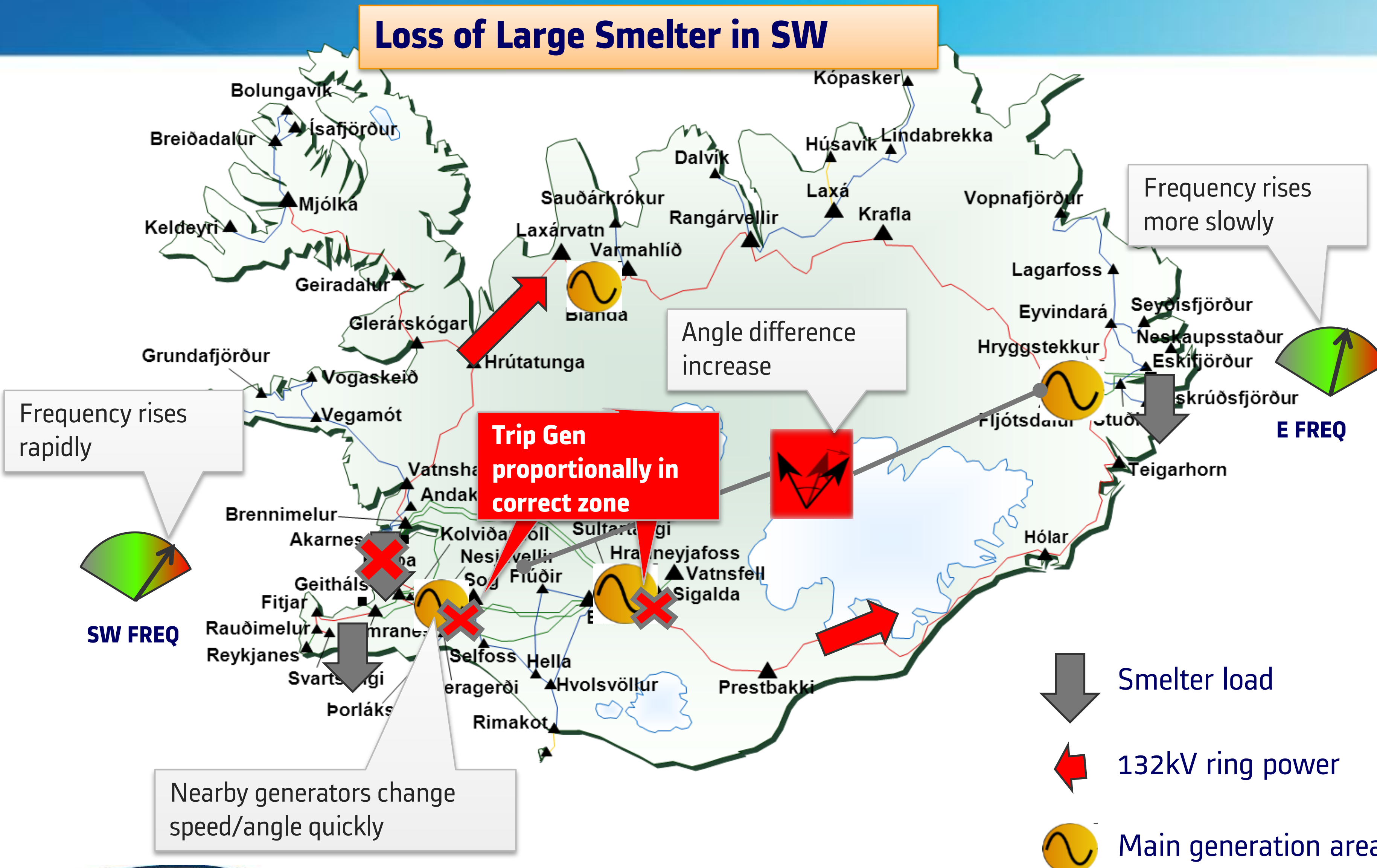
Wide Area Protection Scheme – Iceland (2012)



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