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Wide area monitoring, control and protection using synchrophasor measurements

Galina Antonova

November 12, 2013

Power and productivity for a better world™

Presenter

Galina Antonova

Galina Antonova is with ABB Substation Automation Products group, North America. She has over 15 years of experience in the area of electrical engineering, data communications and time synchronization, which she mainly applied to the power industry. In her current role with ABB, Galina is applying her expertise to substation automation and protective relaying applications. Galina received her M. Sc. degree (1993) and a Ph.D. (1997) in Electrical Engineering and Data Communications from the State University of Telecommunications, St. Petersburg, Russia, and spent one year at University of British Columbia (UBC) on a scholarship from the Russian President. She is actively involved with IEEE PSRC and is a Canadian member of the IEC TC57 WG10.

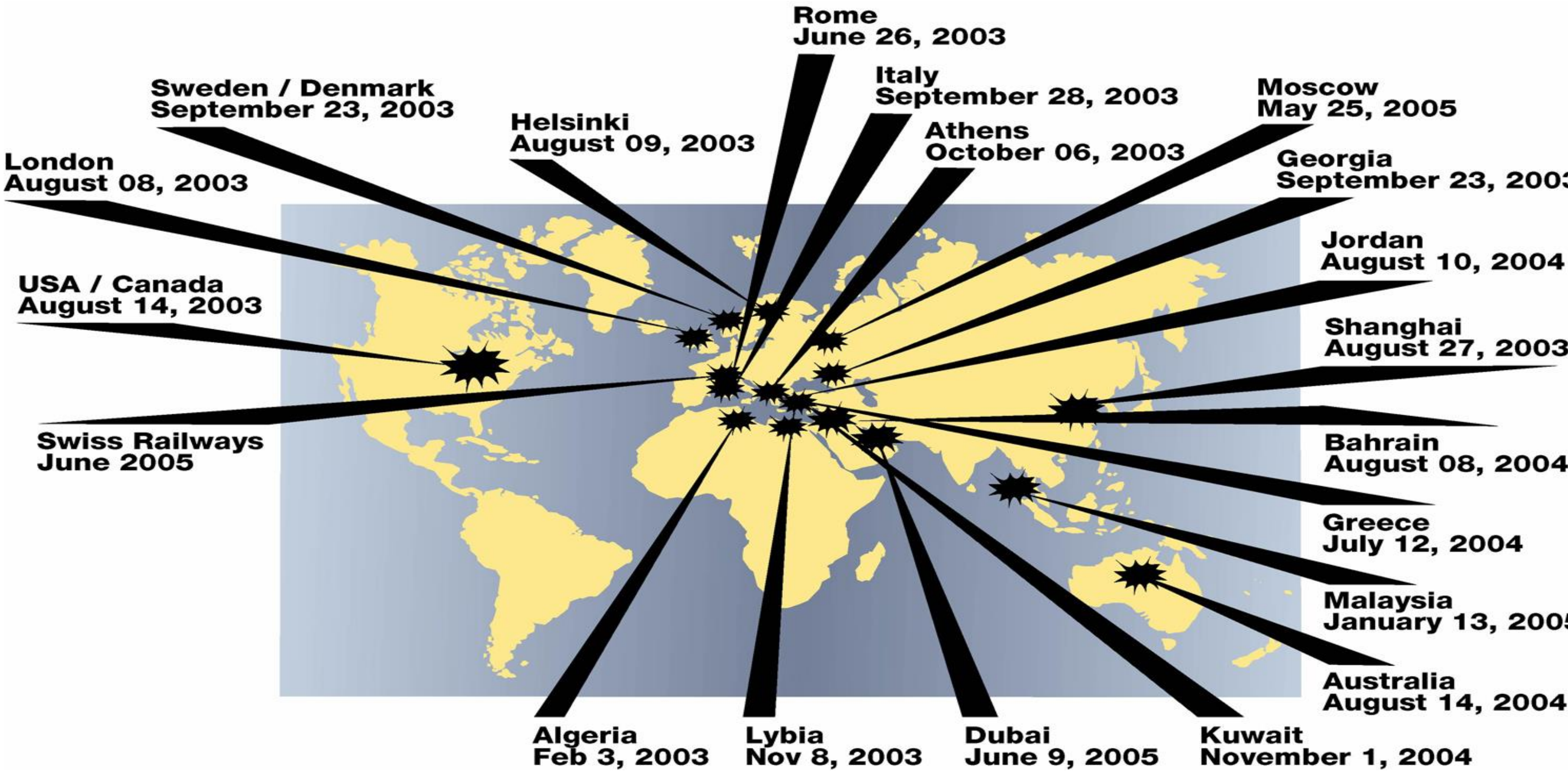
Learning objectives

- Understand the synchrophasor technology and its use in power systems
- Become aware of related industry standards and guides
- Learn about synchrophasor-based monitoring, control and protection applications
- Review examples of synchrophasor-based applications deployed in existing power systems world wide

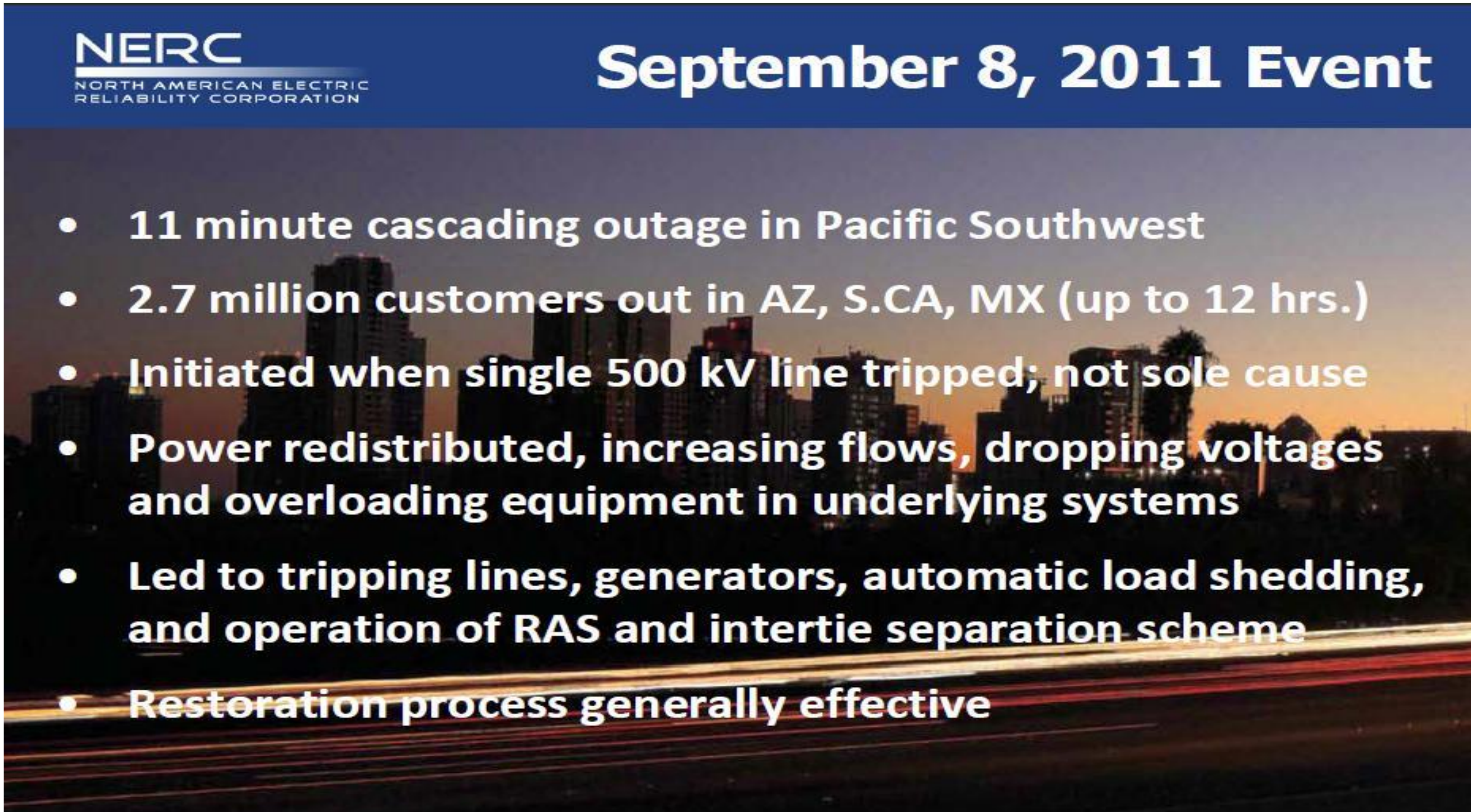
Outline

- Introduction
- Synchrophasor definitions
- Industry standards and guides on synchrophasors
- Synchrophasor-based applications for wide-area monitoring, control and protection
- Examples of deployed synchrophasor systems
- Conclusions

Hot summer blackouts

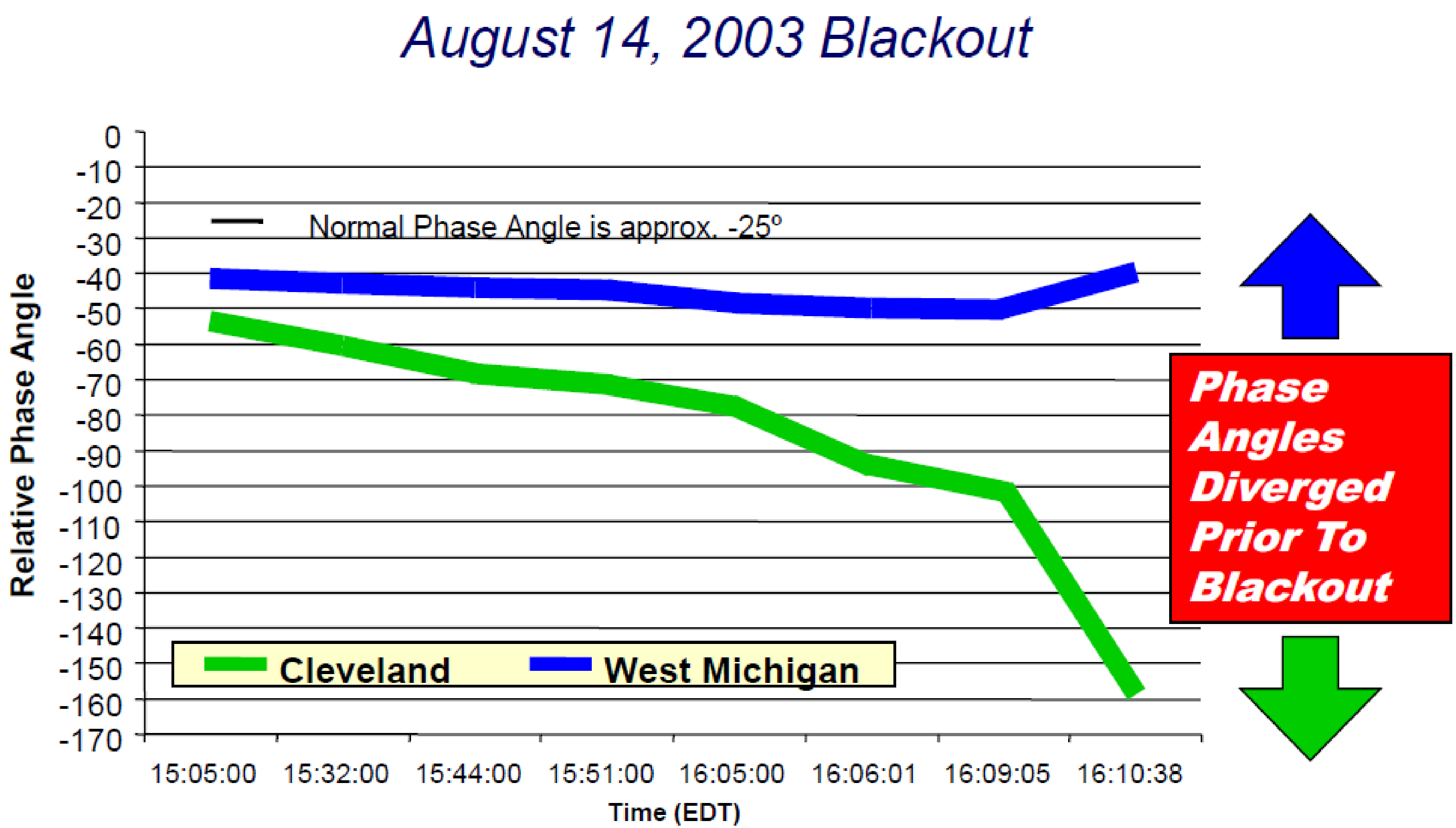


September 2011 Southwest US Outage



Source:NERC Recommendations from 2011 Southwest Outage May 8 2012

What can help ?



Power Systems Challenges and Solutions

Applications and technologies

Gateways with bi-directional communication for consumer interaction

Smart meters, Internet/mobile telecom, smart houses

Customer service systems including billing

Fault detection, isolation and restoration; voltage optimization

FACTS, HVDC,

WAMS → WAMPACS

1) Integration of renewables

Remote grid operation with distributed generation (wind/solar farms)

Increase grid capacity and stability

Balance load to supply

2) Integration of electric vehicles

Charging / billing

Energy storage

Load management

3) Demand response

Real time pricing / tariffs

Home automation / load management

Distributed generation / storage

4) Reliability and efficiency

cyber security

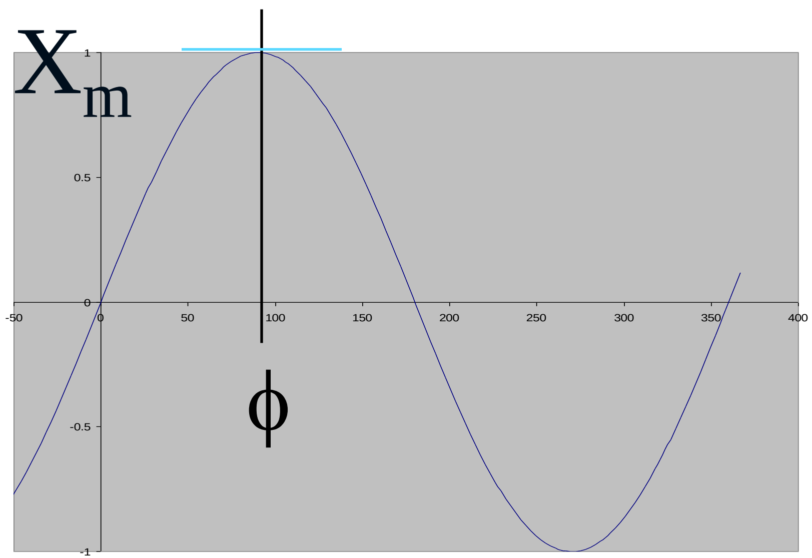
customer outage information

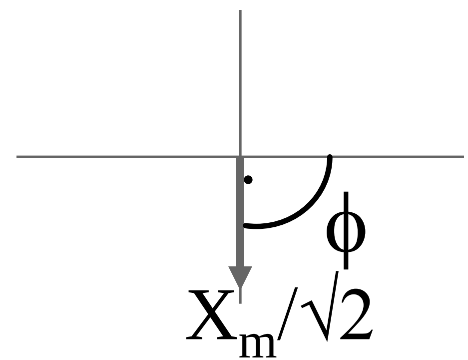
emergency / peak power

What is Phasor ?

A complex number that represents the phase and magnitude of an AC waveform

$$X_m \cos(2\pi 60 t + \phi) \qquad\qquad X_m/\sqrt{2}\, e^{j\phi}$$

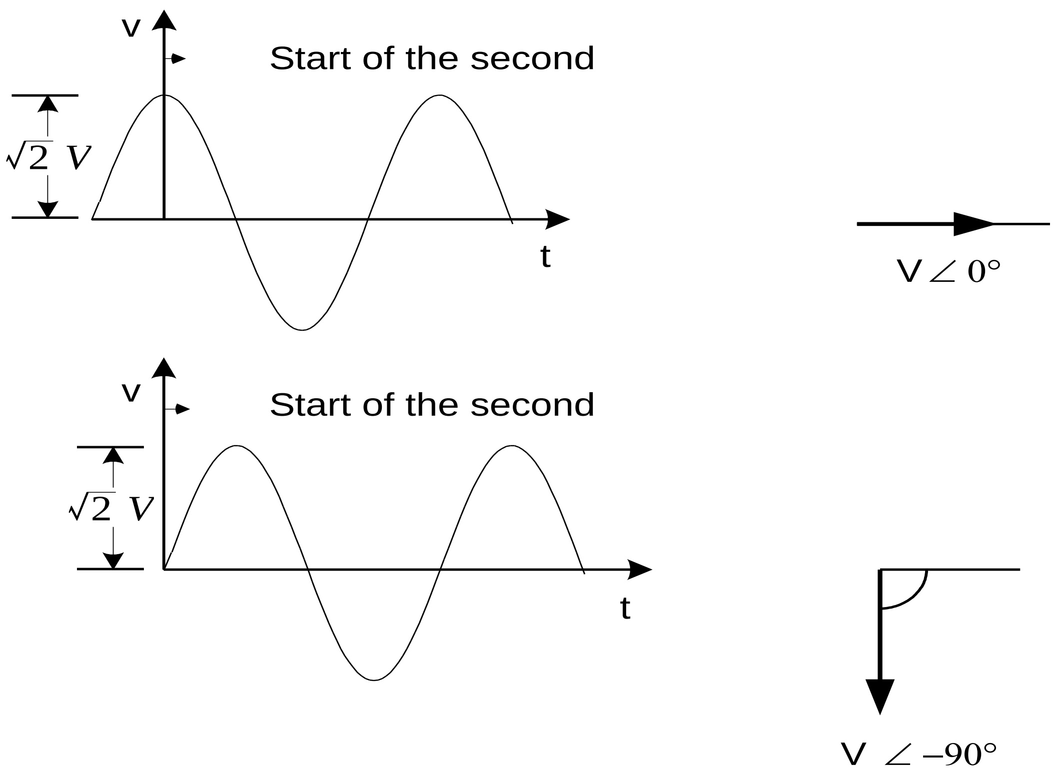




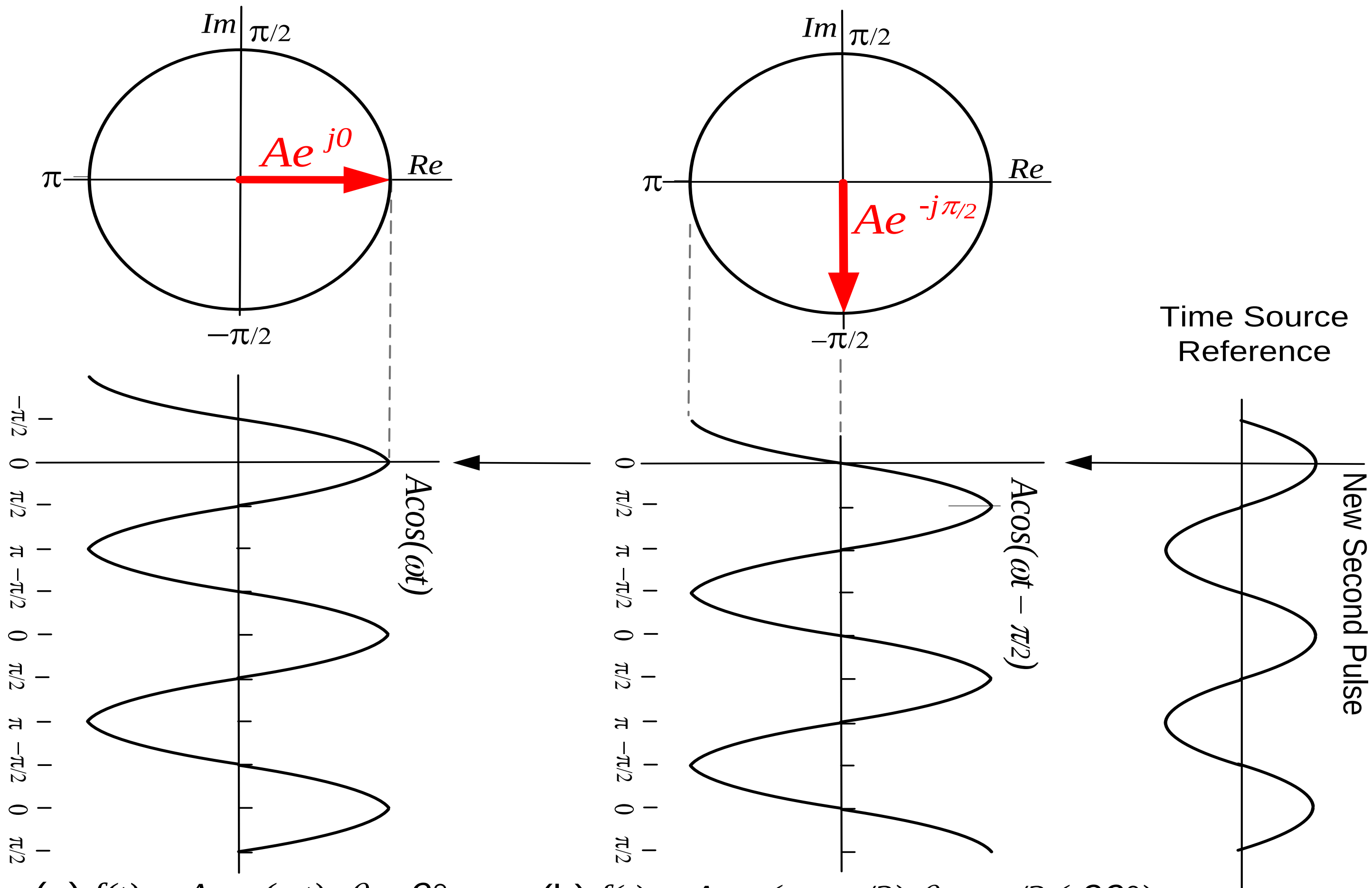
What is Synchrophasor ?

- Synchrophasor is a phasor with a **phase** determined by UTC time (start of the second)
- Reference waveform is cos(wt) at a nominal system frequency
  - Angle = 0° for positive maximum at the start of UTC second
  - Angle = -90° for positive zero crossing at the start of UTC second

$$v(t) = \sqrt{2}\, V \cos(\omega_0 t + \varphi)$$

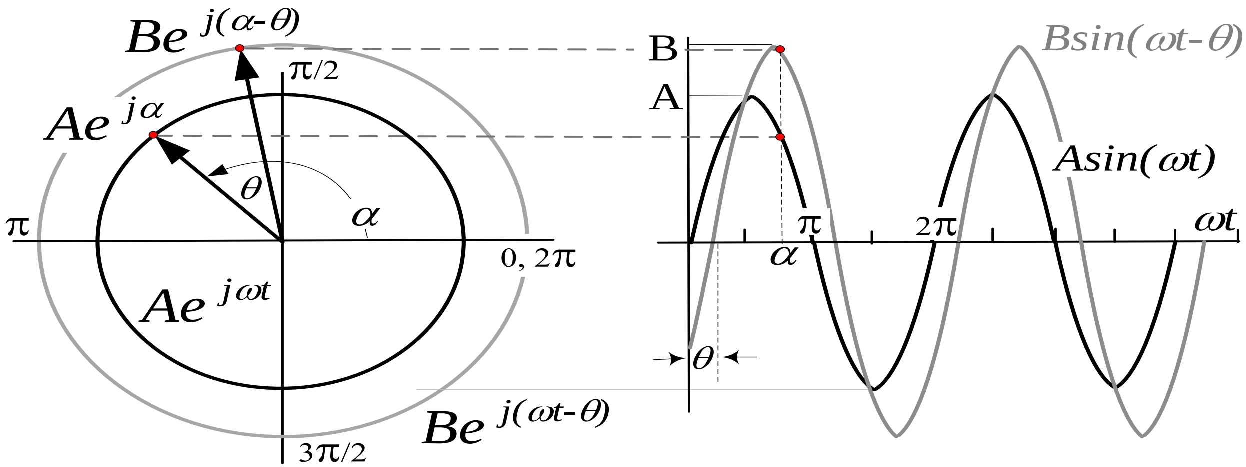


Synchrophasor definition



(a) $f(t) = A\cos(\omega t),\ \theta = 0°$ (b) $f(t) = A\cos(\omega t - \pi/2), \theta = -\pi/2\ (-90°)$

Why use Synchrophasors

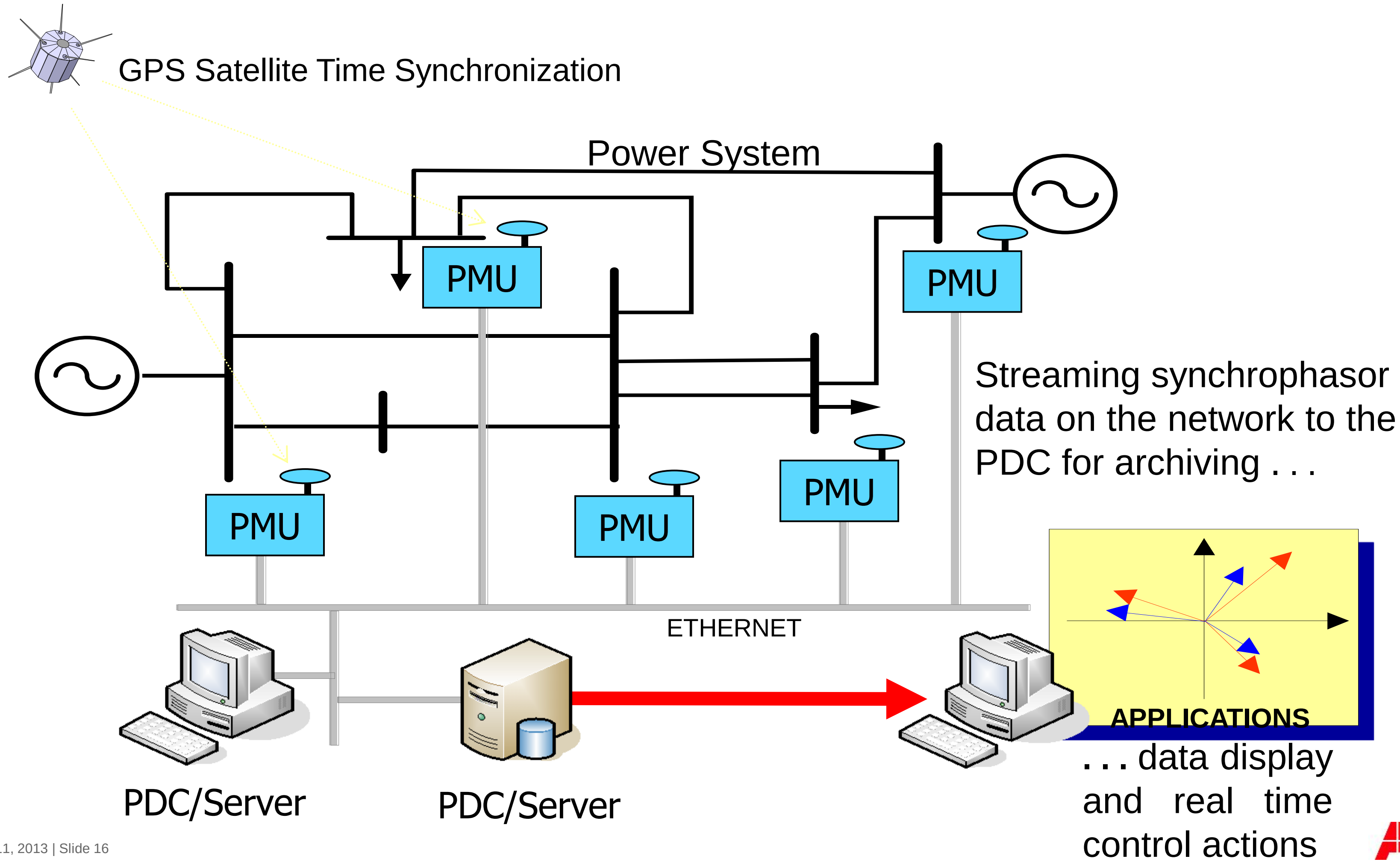


- Consider the ability to measure the voltage magnitude and phase angle at every system bus and current magnitude and phase angle at every branch (lines, transformers and other series elements) in the power system network simultaneously and continuously and having them instantly available where we need them when we need them

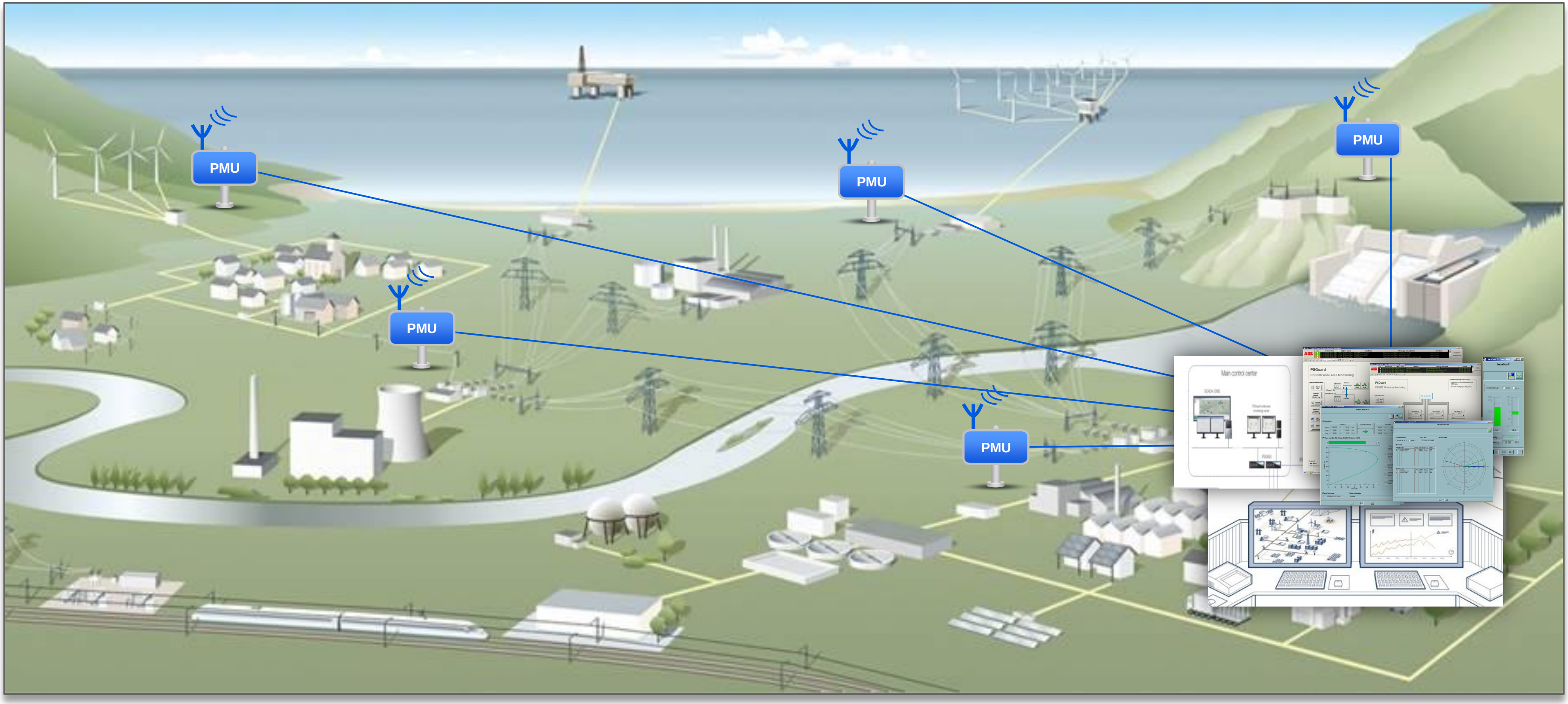
Synchrophasors Terminology

- UTC - Universal Time Coordinated
- GPS – Global Positioning System with time traceable to UTC
- PMU – Phasor Measurement Unit
  - Measures bus voltages and line currents
  - Estimates phasors
  - Synchronizes each phasor with UTC time – 1.0 μs accuracy
  - Sends synchrophasor data at 240, 120, 60, 30 frames/s to clients, PDC, etc
- PDC – Phasor Data Concentrator
  - Merges, synchronizes and archives synchrophasor data

Synchrophasor Measurement System

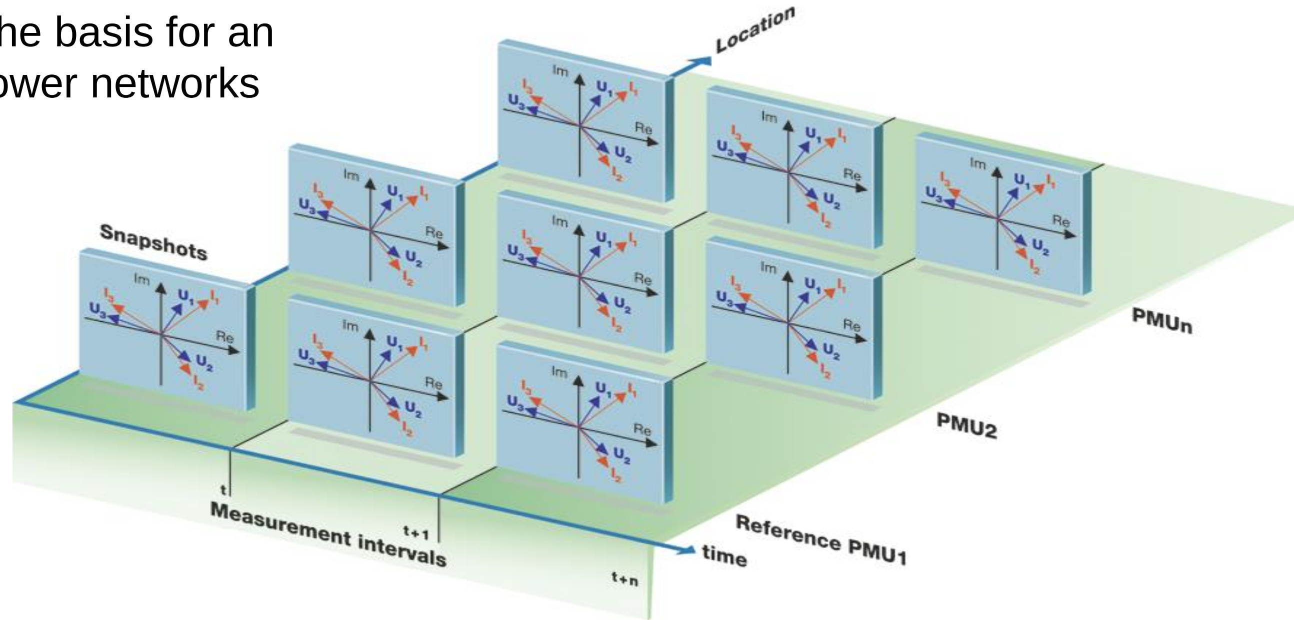


Wide Area Monitoring



Synchrophasor measurements

High accuracy provides the basis for an accurate monitoring of power networks



Timestamp accuracy:	1 microsecond
Absolute angle accuracy error:	< 0.1 degree
CT/VT:	0.2 …0.5%

Synchrophasor Measurement Unit: RES670

- Up to 8 Analog Phasors
  - Positive / Negative / Zero sequence
  - Polar or Rectangular phasors
- Transmission rates
  - 8/10-200/240 frames/s at 50/60 Hz
- TVE < 1%
- Configurable time stamp position
- 8 fully configurable binary signals
- 8 independent users / data recipients
- 2 optical Ethernet ports
- Embedded GPS, electrical / optical IRIG-B
- Built on protective relay platform

Time synchronization options

GPS time synchronization

- 1us time accuracy to UTC
- Embedded GPS receiver, or external clock
- GPS cable (20m, 40m)

Electrical IRIG-B interface

- BNC cable
- 1 kHz Amplitude Modulated or DC shift

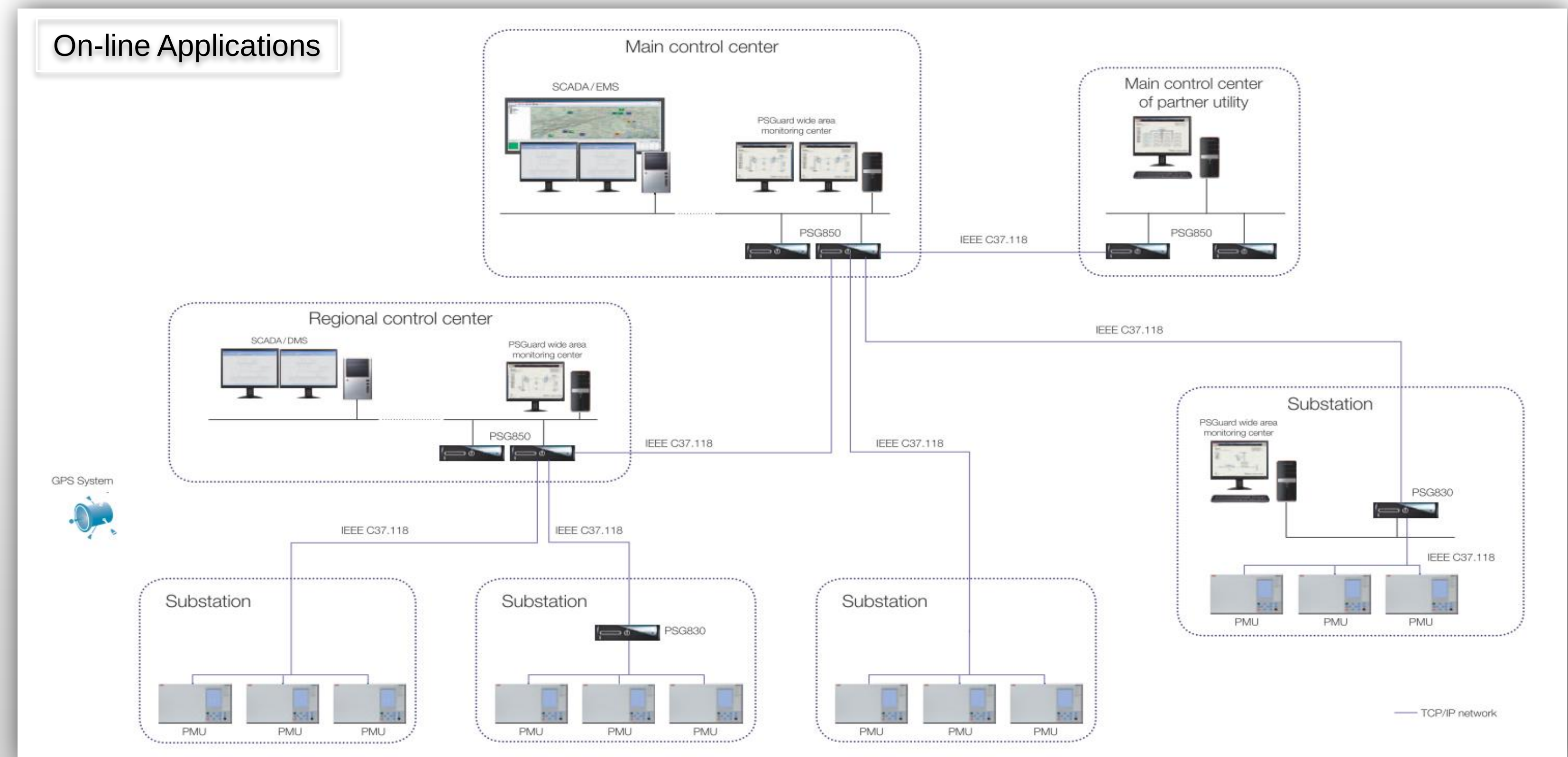
Optical IRIG-B interface

- Optical cable, with ST connector
- Immune to surrounding noises

Emerging Precision Time Protocol

- IEEE 1588 / C37.238 standards
- Ethernet, with 1us time accuracy to source

Typical Architecture



Synchrophasor Standardization

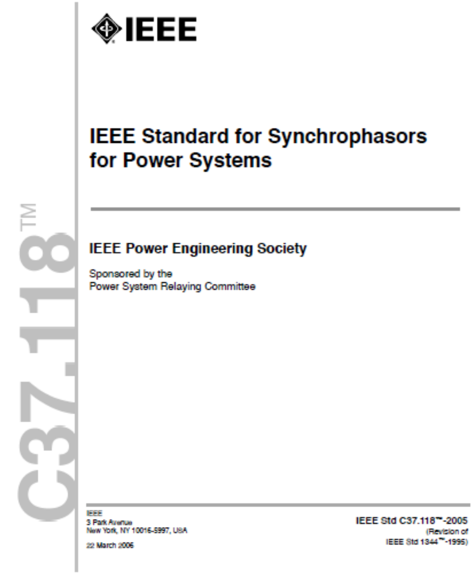
- IEEE 1344-1995 Synchrophasor standard superseded by IEEE C37.118-2005
- IEEE C37.118-2005 Synchrophasor standard superseded by
  - IEEE C37.118.1-2011 Standard for Synchrophasor Measurements
  - IEEE C37.118.2-2011 Standard for Synchrophasor Data Transfer
  - Amendment to IEEE C37.118.1-2011(under approval)
- IEC 61850-90-5 Technical Report for Synchrophasor Data Transfer over in IEC 61850
- Joint IEC / IEEE Standard on synchrophasor measurements (initiated)

First Synchrophasor Standard

- IEEE Std 1344-1995
- Measurement requirements
  - Time synchronization specified
    - Included specifications for IRIG-B
  - Data sampling requirements
  - No specification on phasor measurement
- Data transmission formats
  - Followed binary COMTRADE syntax
  - Adapted for single PMU only, serial communication
- Not widely implemented

IEEE C37.118-2005 Synchrophasor Standard

- IEEE Std C37.118-2005 - Replaced IEEE 1344
- Measurement requirements
  - Phasor estimation characteristics
  - 2 performance levels
- Data transmission formats
  - Similar to 1344
  - Many improvements
  - Includes single or multiple PMU data
  - Simple Communication protocol (serial, Ethernet, IP)


C37.118™

IEEE

IEEE Standard for Synchrophasors
for Power Systems

IEEE Power Engineering Society

Sponsored by the
Power System Relaying Committee

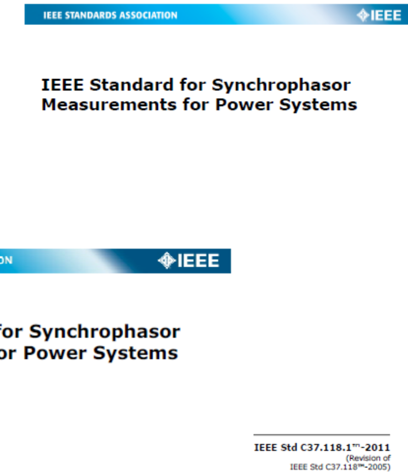
IEEE
3 Park Avenue
New York, NY 10016-5997, USA

22 March 2006

IEEE Std C37.118™-2005
(Revision of
IEEE Std 1344™-1995)

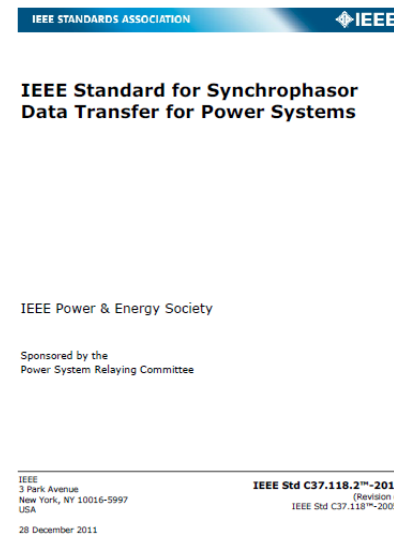
IEEE C37.118.1/2-2011 Standards

- IEEE Std C37.118.1/2 – 2011 Replaced IEEE C37.118-2005
  - C37.118.1 – Measurements
  - C37.118.2 – Communications (legacy)
  - Dynamic tests added
  - 2 classes – Measurement (M) and Protection (P)
  - Higher reporting rates recommended, new filtering
  - Dynamic tests, new configuration frame (CFG-3)
  - Continuous Time Quality
  - Locked definition


IEEE STANDARDS ASSOCIATION IEEE

IEEE Standard for Synchrophasor Measurements for Power Systems

IEEE Std C37.118.1™-2011
(Revision of IEEE Std C37.118™-2005)


IEEE STANDARDS ASSOCIATION IEEE

IEEE Standard for Synchrophasor Data Transfer for Power Systems

IEEE Power & Energy Society

Sponsored by the
Power System Relaying Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

28 December 2011

IEEE Std C37.118.2™-2011
(Revision of IEEE Std C37.118™-2005)

Amendment to IEEE C37.118.1-2011 is going through IEEE approvals

Other Synchrophasor Standards

- IEC TR 61850-90-5 Approved and published in May 2012
  - Transport of synchrophasor data
  - Integration with IEC 61850 systems
  - Routable transport (targeted to substation to substation)
  - UDP transport, unicast and multicast (preferred)
  - Security included
  - Multiple communications layers

Work on joint IEC / IEEE standard on synchrophasor measurements started

IEEE Guides and Reports on Synchrophasors

IEEE PES PSRC Working Groups generated the following documents

- IEEE Report Published in August 2013

  Use of Synchrophasor Measurements in Protective Relaying Applications

- IEEE C37.242-2013 Published in March 2013

  Guide for PMU Synchronization, Calibration, Testing and Installation

- IEEE C37.244-2013 Published in May 2013

  Guide for PDC Requirements for Power System Protection, Control and Monitoring

Report on use of Synchrophasors for Protection

- Present applications
  - Wide-area frequency monitoring
  - Power swing detection
  - Load shedding
  - Automatic generator shedding
  - Distributed generation anti-islanding
  - Line reclosing selectivity
  - Distance to fault
- Future applications
  - Bus differential relaying
  - Line differential relaying
  - Distance function
  - Line backup protection

USE OF SYNCHROPHASOR MEASUREMENTS IN PROTECTIVE RELAYING APPLICATIONS

Power System Relaying Committee
Report of Working Group C-14
of the
System Protection Subcommittee

Members of the Working Group

Jim O'Brien, Chair
Alla Deronja, Vice-Chair

Alex Apostolov
Andrew Arana
Miroslav Begovic
Sukumar Brahma
Gustavo Brunello
Fernando Calero
Herb Faulk
Yi Hu
Gary Kobet
Harold Kirkham
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Chih-Wen Liu
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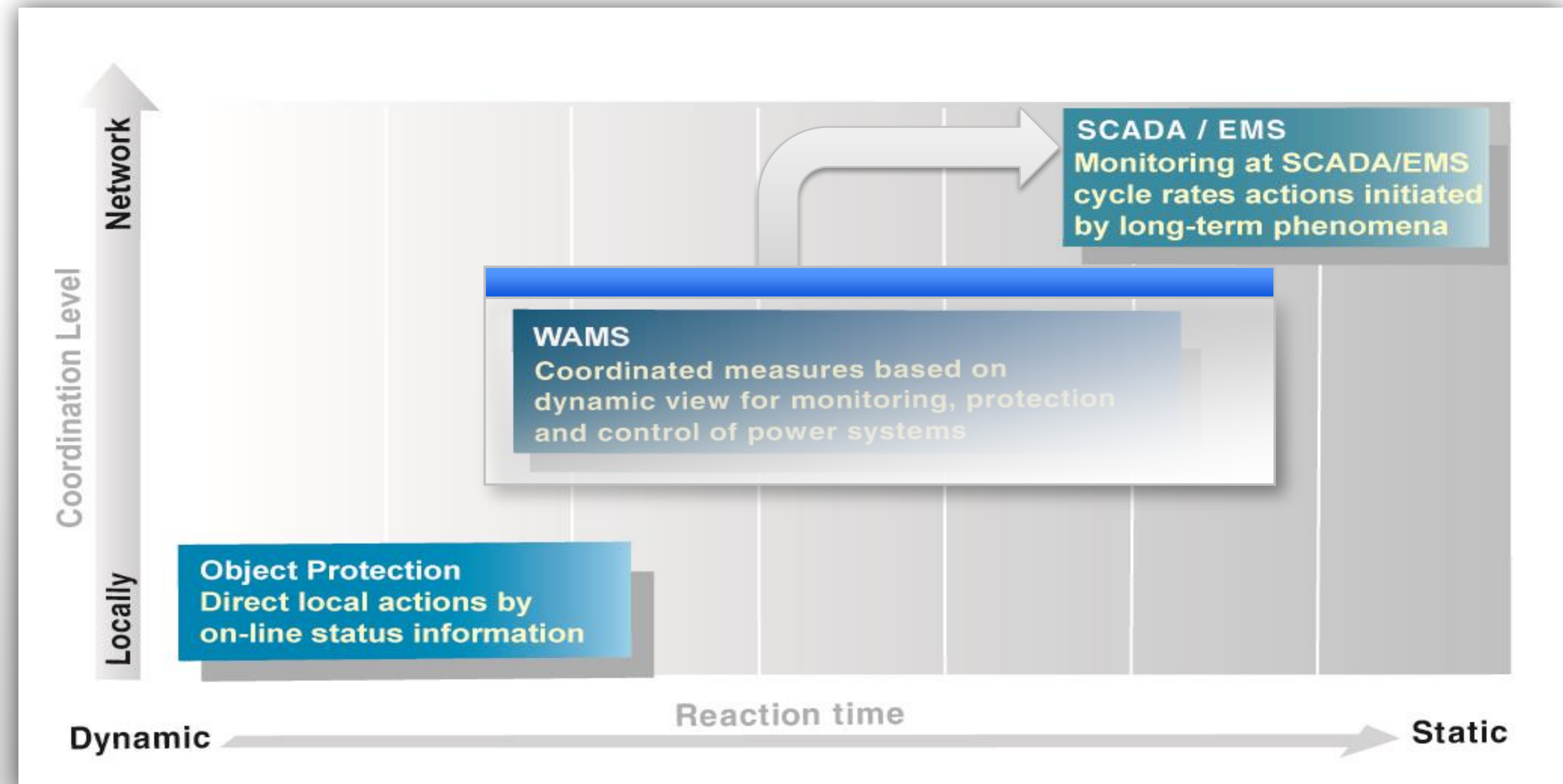
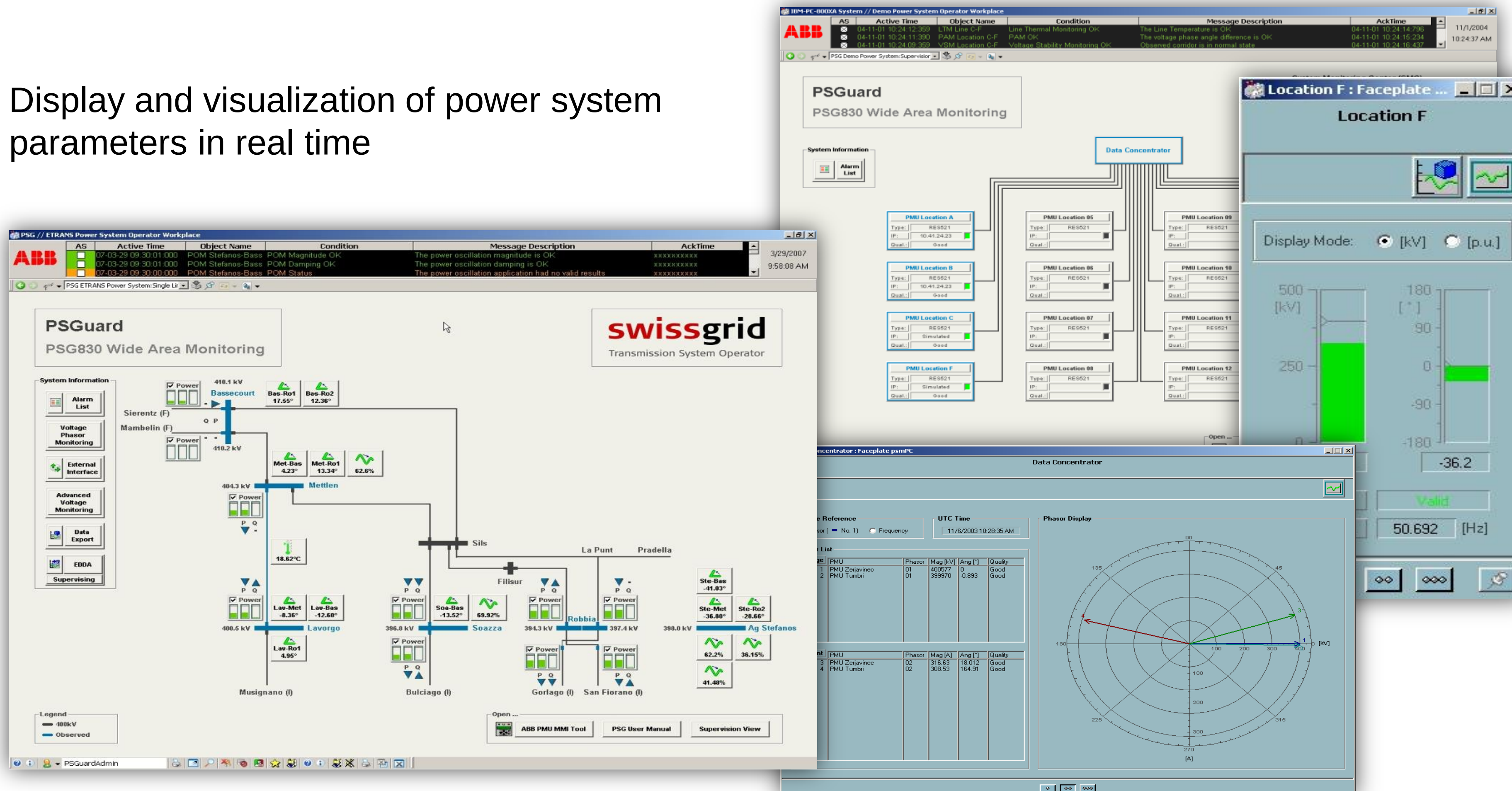
Don Lukach
Ken Martin
Joe Mooney
Jay Murphy
Krish Narendra
Damir Novosel
Mahendra Patel
Elmo Price
Sinan Saygin
Veselin Skendzic
Rick Taylor
Demetrios Tziouvaras
Solveig Ward

Synchrophasor-based applications



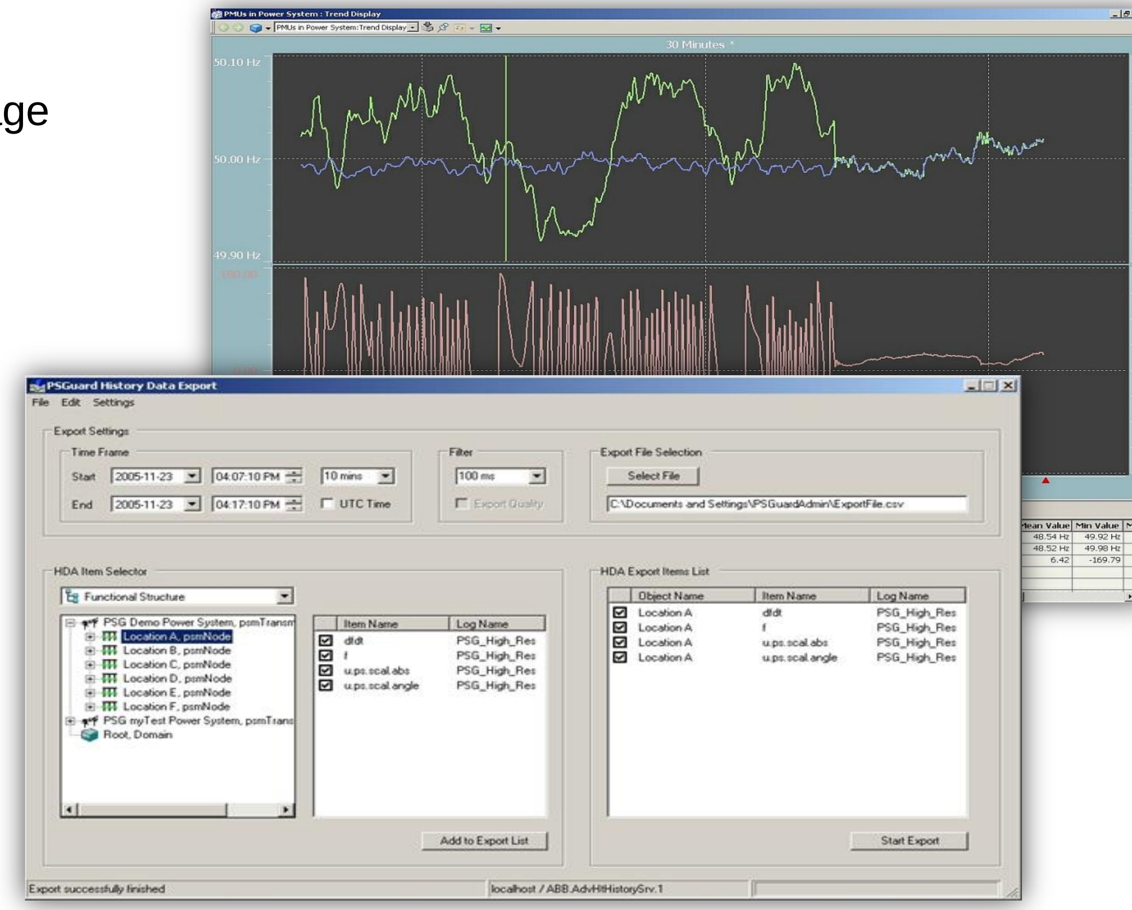
Power System Monitoring

Display and visualization of power system parameters in real time



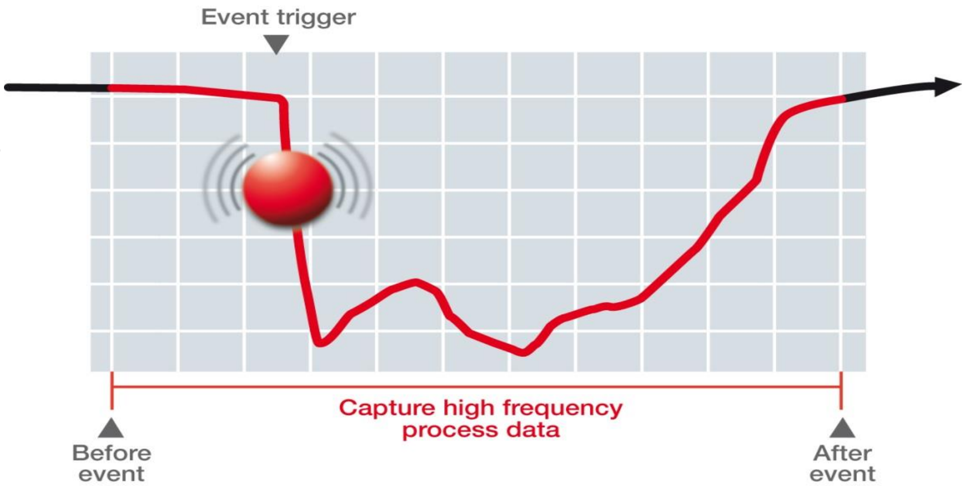
Data Storage and Export

- Configurable ring buffer data storage
  - PMU measurements
  - Application results
- Every data point stored with
  - Timestamp
  - Value
  - Quality
- Export application
  - Export to CSV files



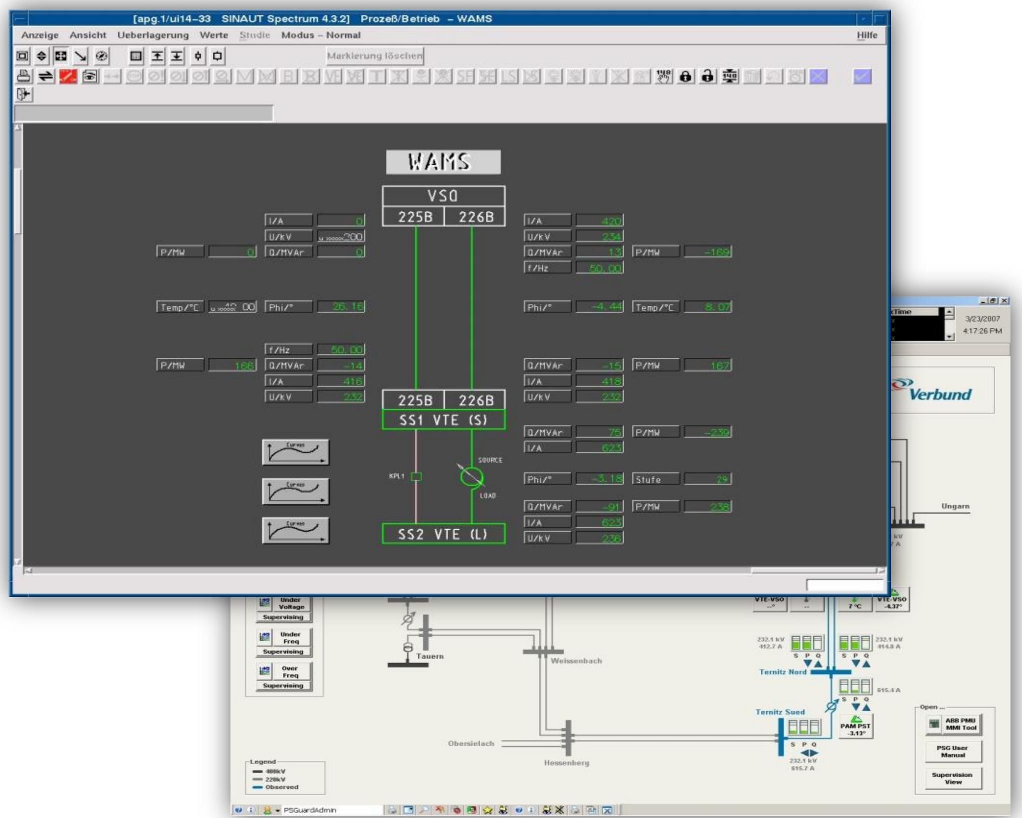
Event Driven Data Archiving

- Wide area disturbance recorder based on logical trigger conditions
- Central triggering by observing network-wide data
- Configurable archiving length and resolution
- Archives can be provided in CSV file format (MS Excel)
- Continuous archiving provides daily archives for long-term data storage

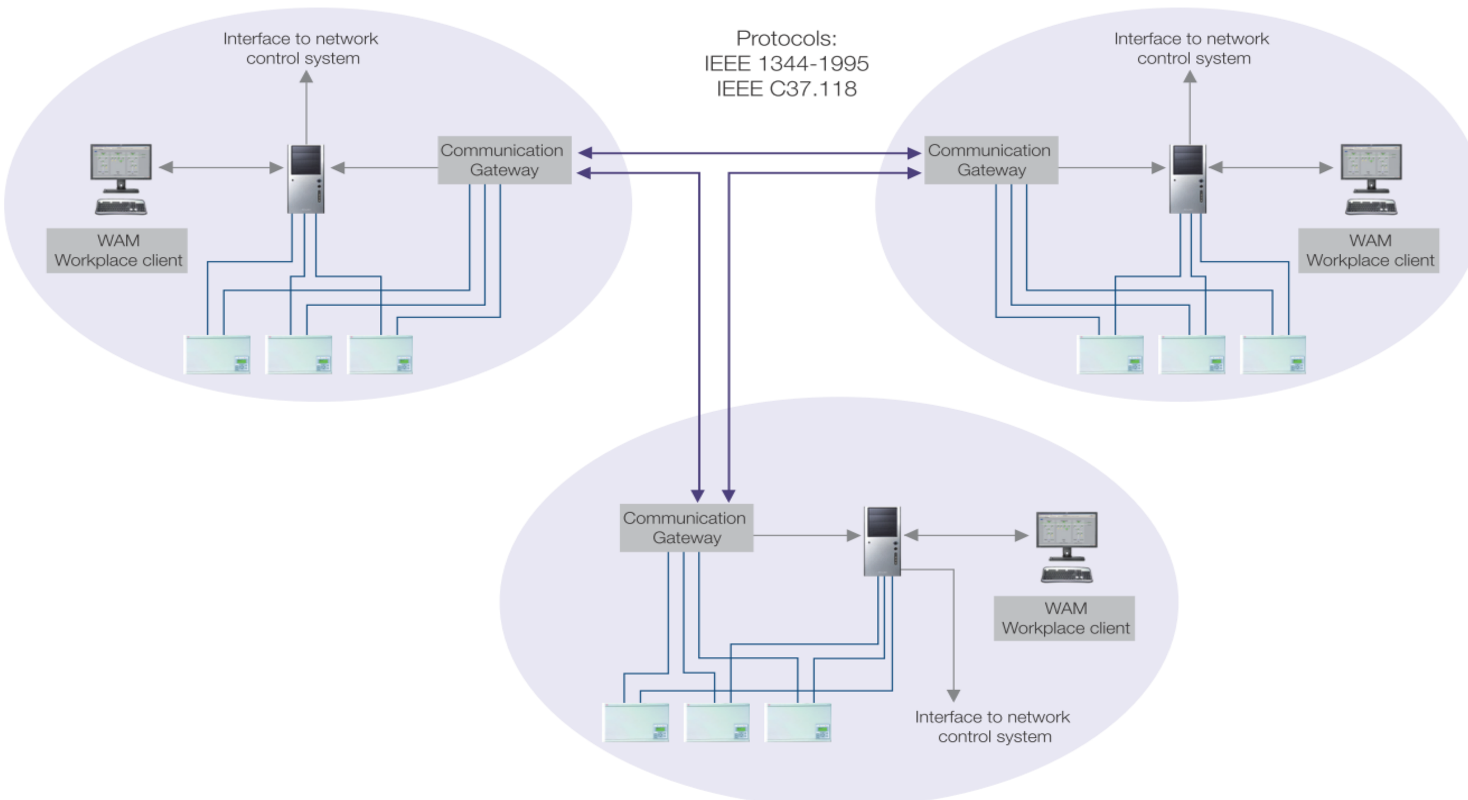


SCADA / EMS integration

- Provides SCADA/EMS operators with processed data and alarms
- RTU standard protocols and specific customer protocols could be supported

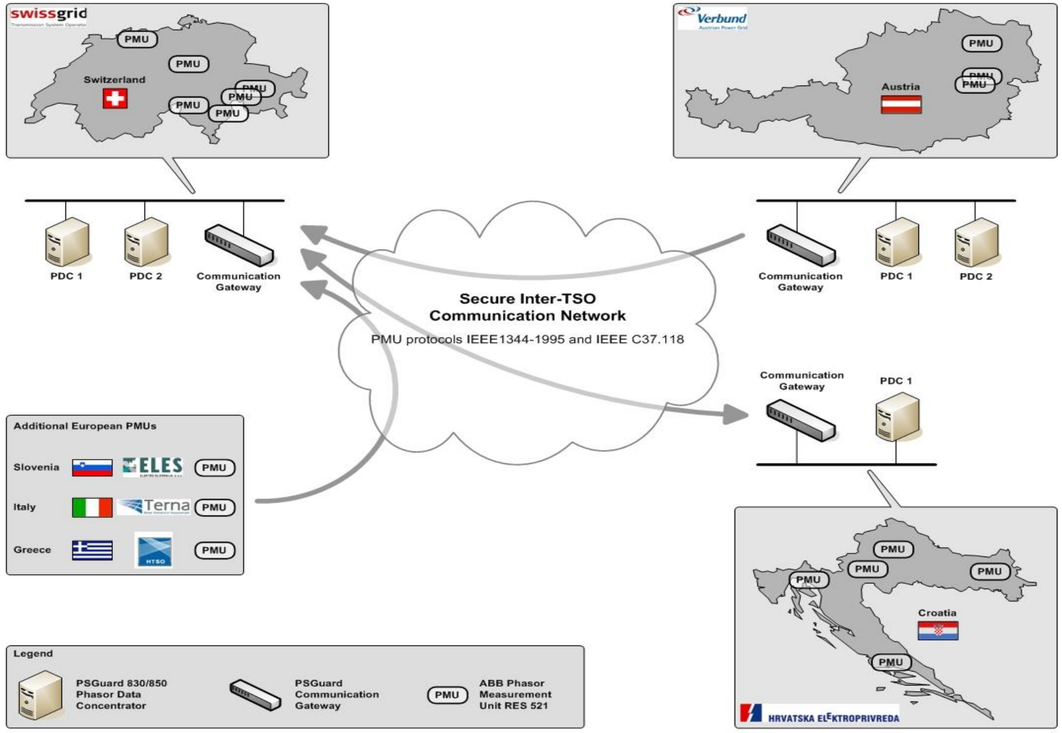


Communication Gateway

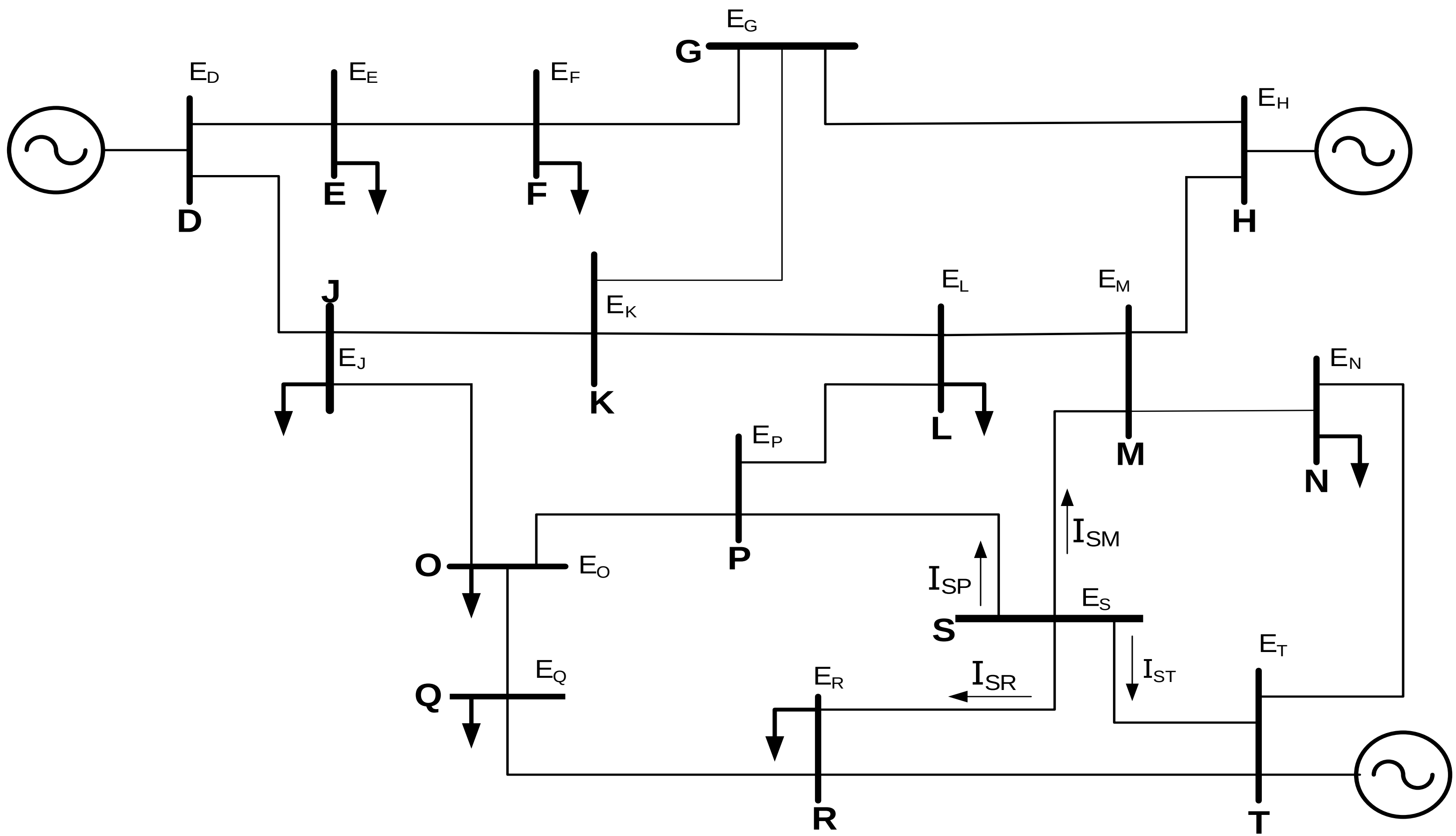


Communication Gateway

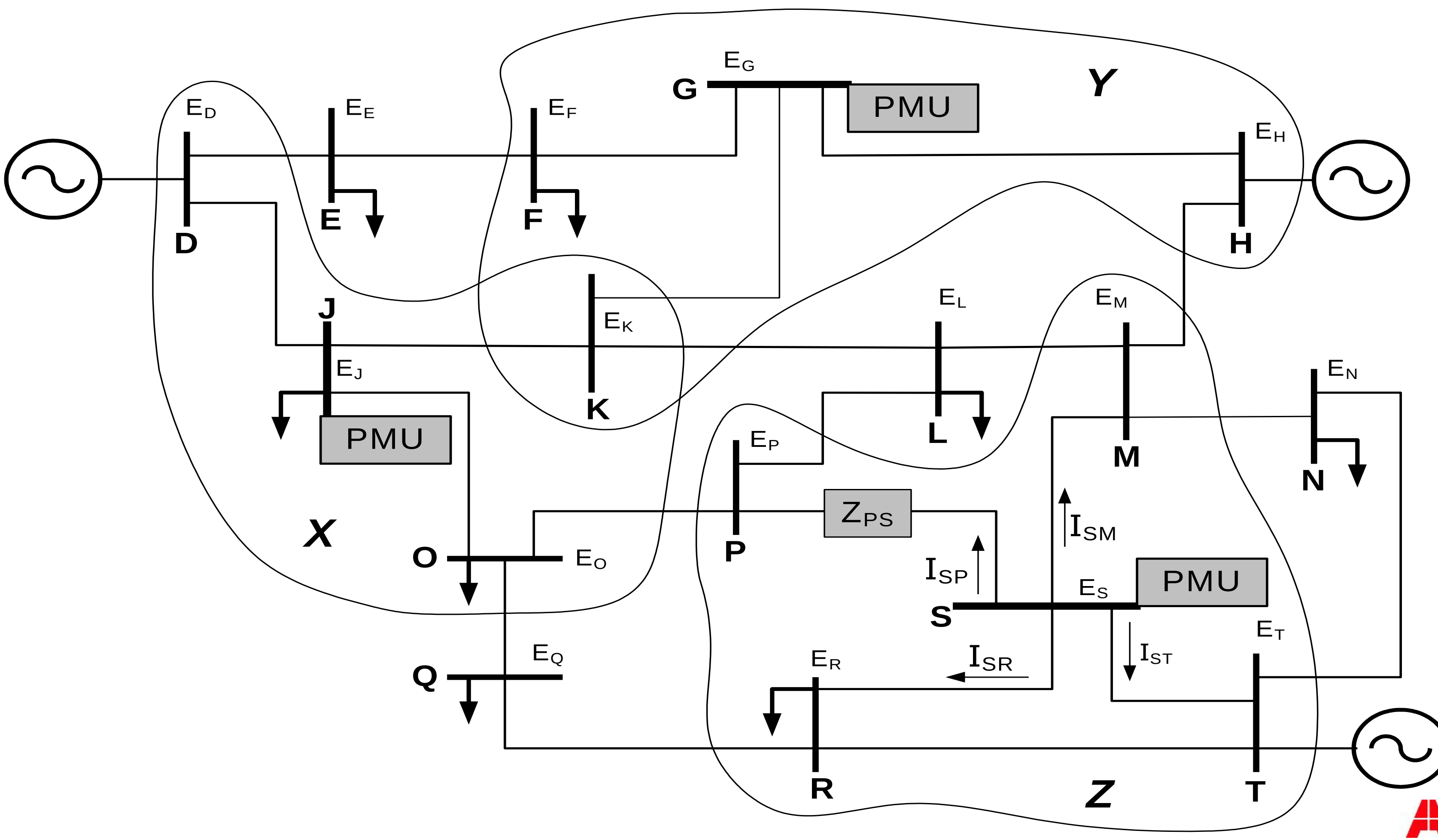
- PMU data exchange between utilities in real-time
- PMU standard protocols IEEE1344-1995 and IEEE C37.118 are supported
- The external WAM systems are able to communicate with the Gateway as with a physical PMU device
- Filter functionality allows selective data transmission (e.g. only voltages but no current measurements are provided)



State Estimator



Phasor-Enhanced State Estimator

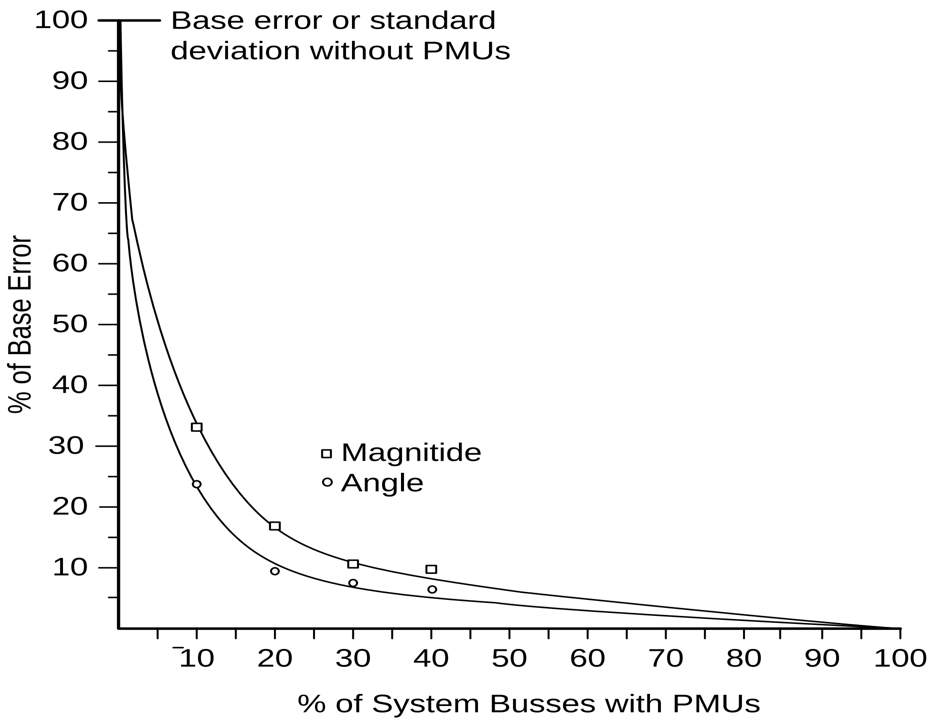


ABB

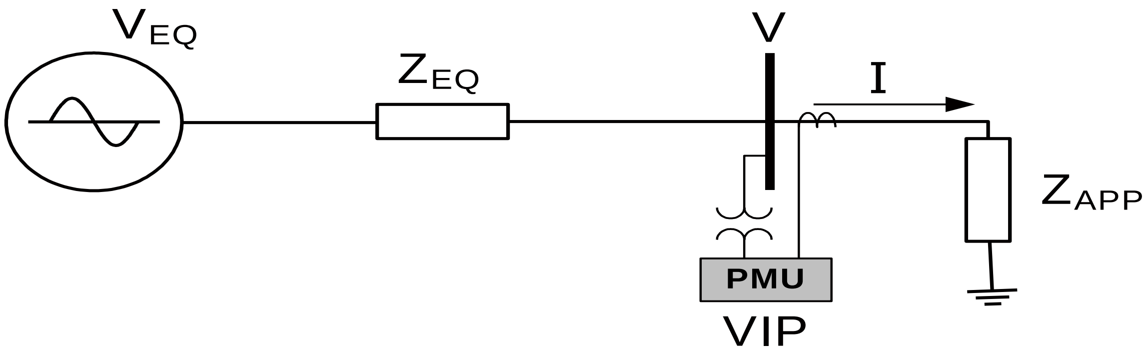
Phasor-Enhanced State Estimator

- Benefits are increased observability, redundancy, accuracy, and bad data detection capability

- The application of a sufficient number of PMUs across the system will improve the State Estimation solutions to the point they will be called state calculations.

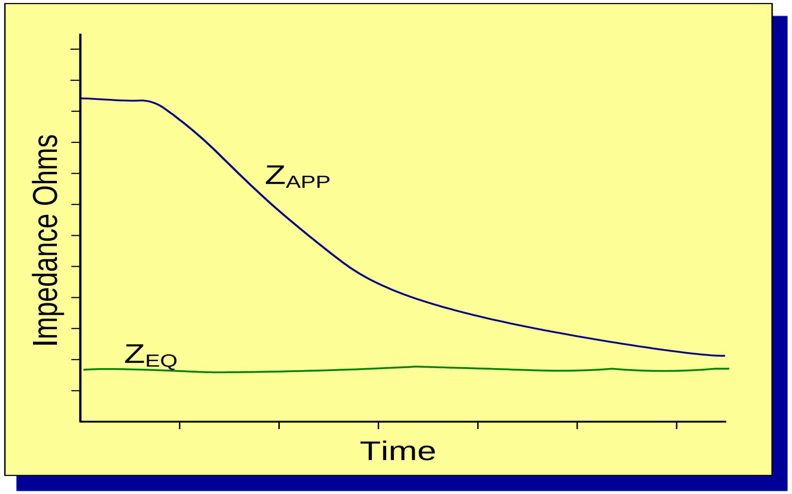


Voltage Instability Predictor

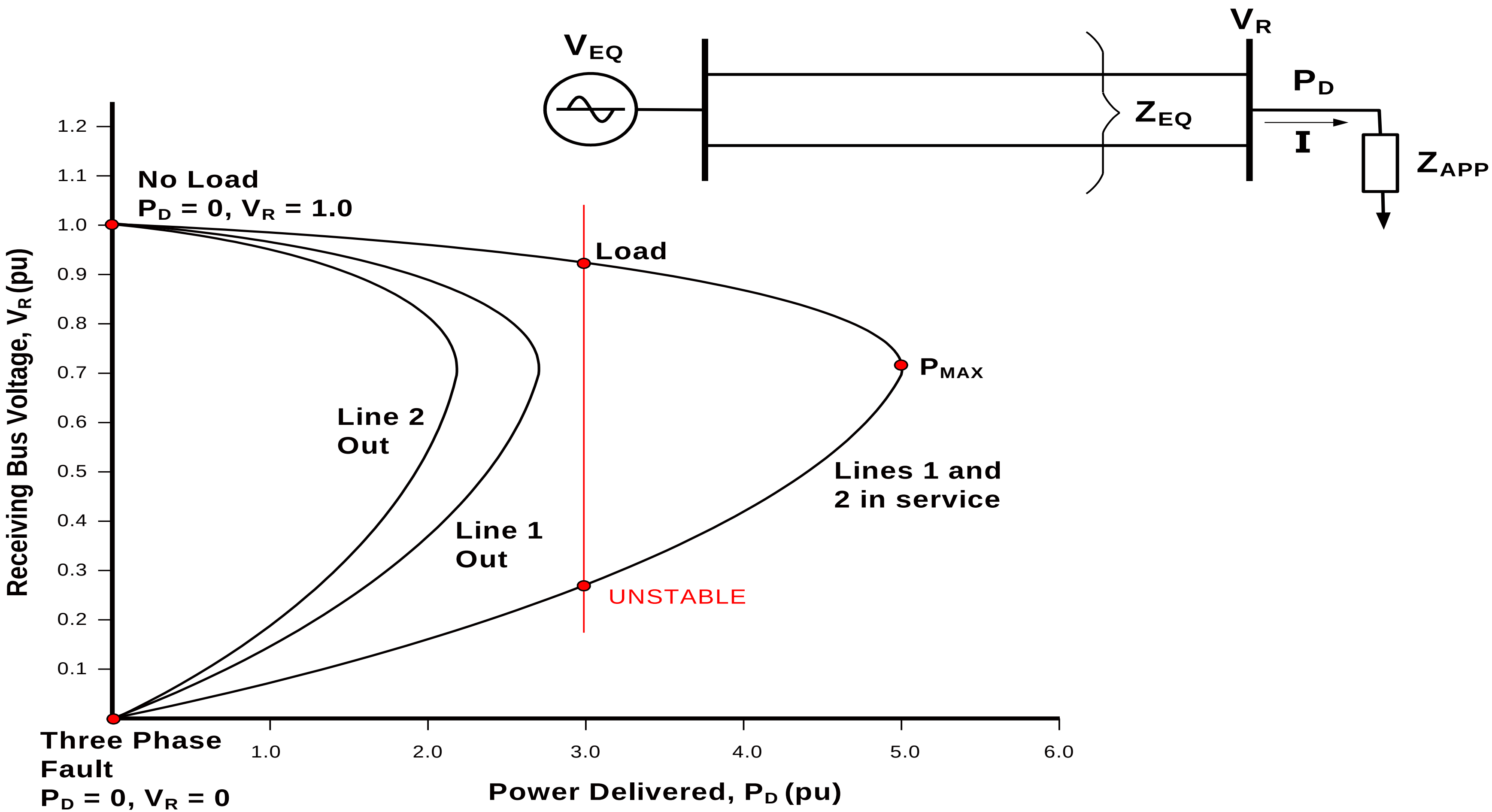


$$Z_{APP} = \frac{V}{I}$$

$$Z_{EQ} = \frac{V_{EQ} - V}{I}$$

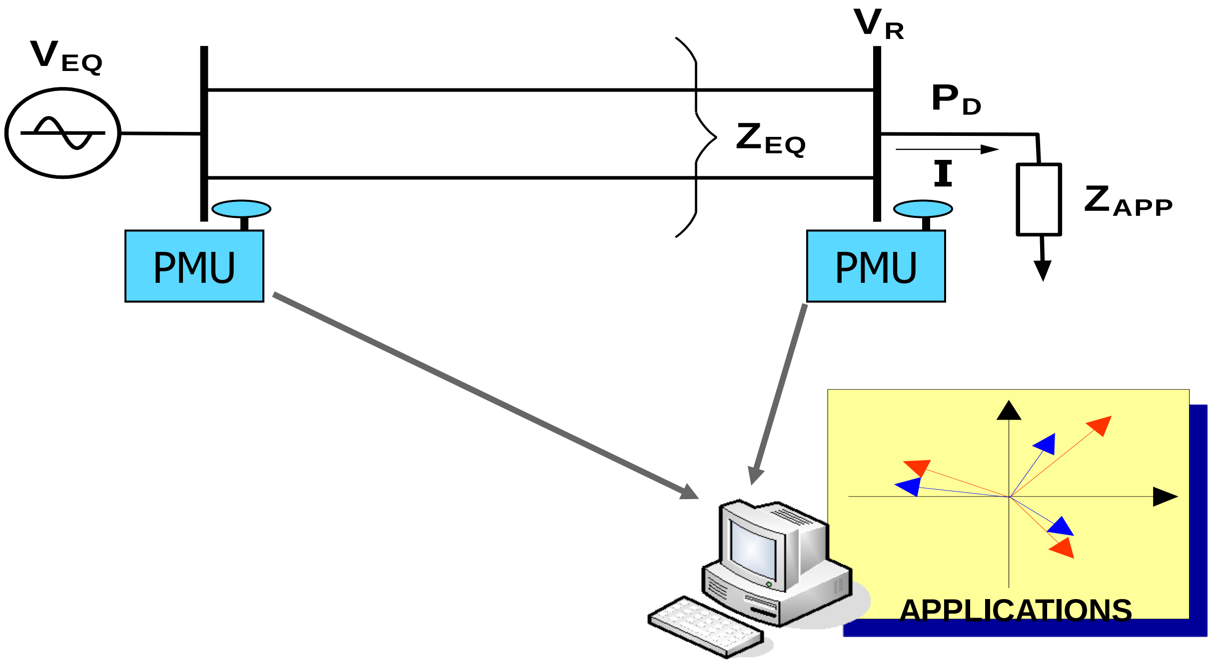


Voltage Instability

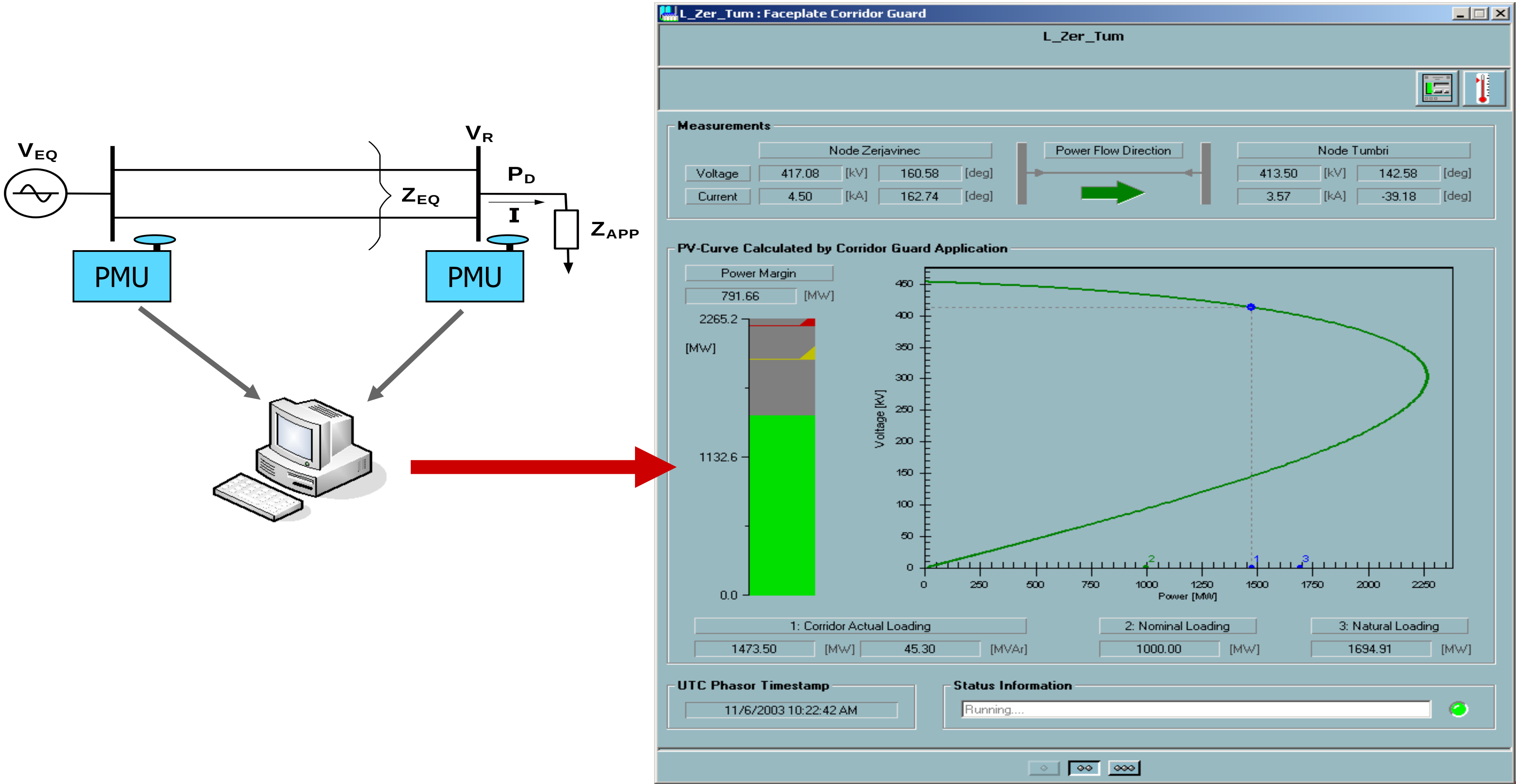


Voltage Stability Monitoring

Voltage Stability Monitoring, VSM

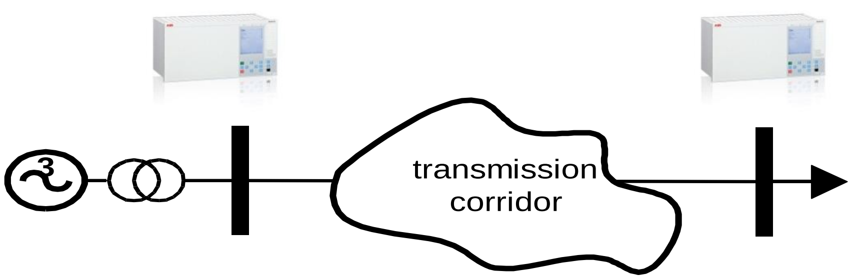


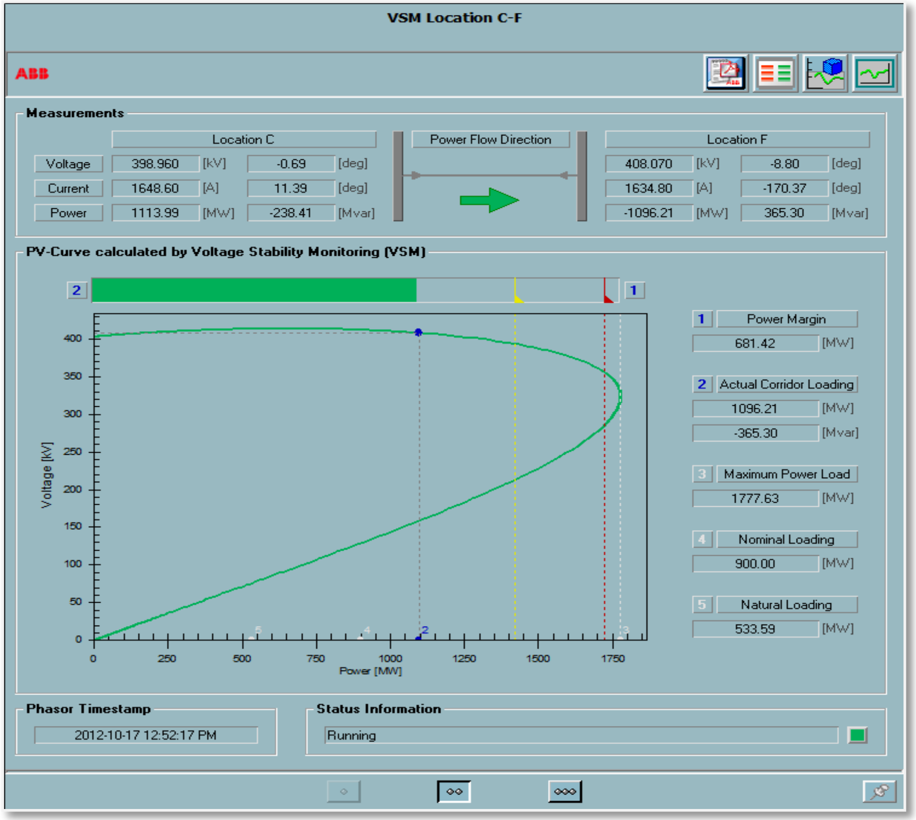
Voltage Stability Monitoring



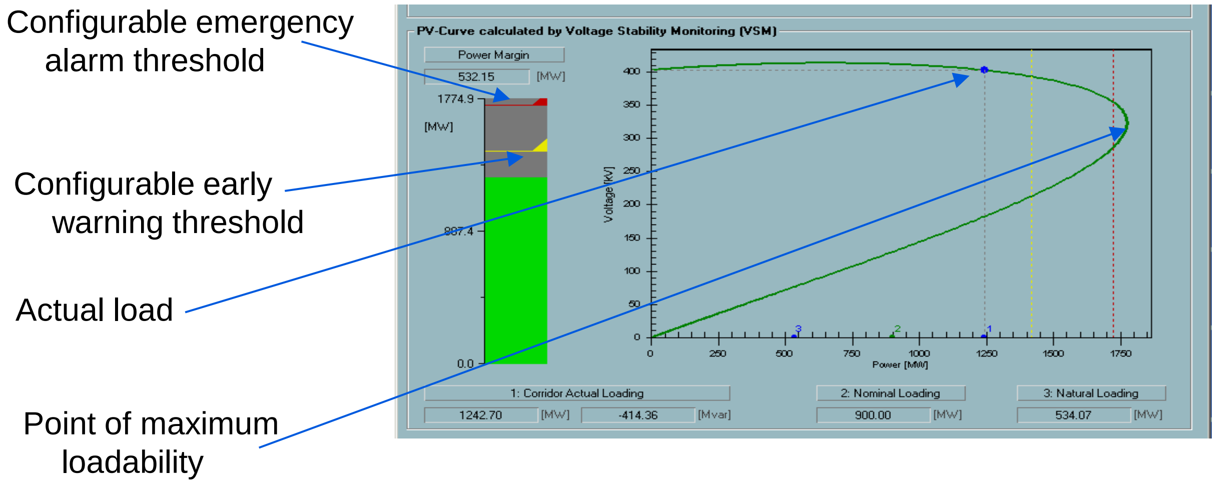
Voltage Stability Monitoring

- Provides power margin to the point of maximum loadability of transmission corridors regarding voltage stability
- High accuracy by using PMU data
- Fast reaction (uses real-time data)



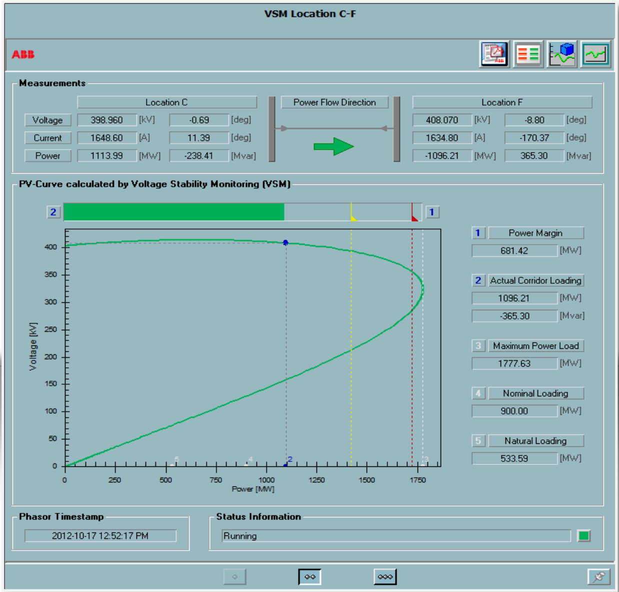


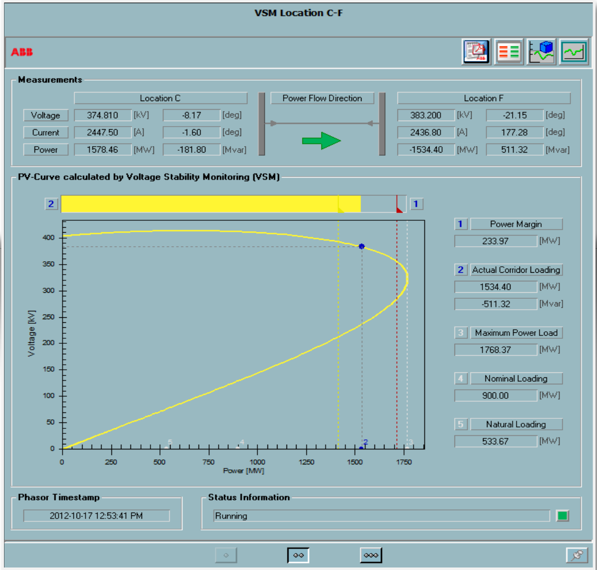
Voltage Stability Monitoring

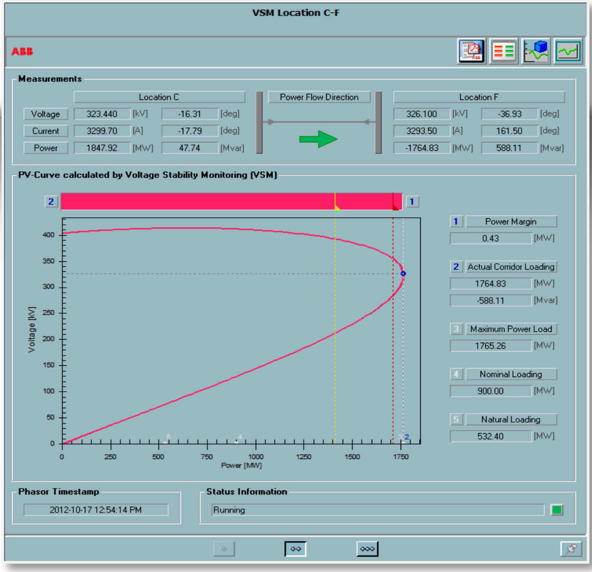


- Voltage Stability Monitoring provides power system operators with on-line information to perform a real-time assessment of the power margin on individual transmission corridors with respect to voltage stability
- The power margin is the amount of additional active power that can be transported on a transmission corridor without jeopardizing the voltage stability of the grid
- VSM computes the power margin by monitoring the actual loading point on the PV-Curve against the maximum deliverable power P_{MAX}

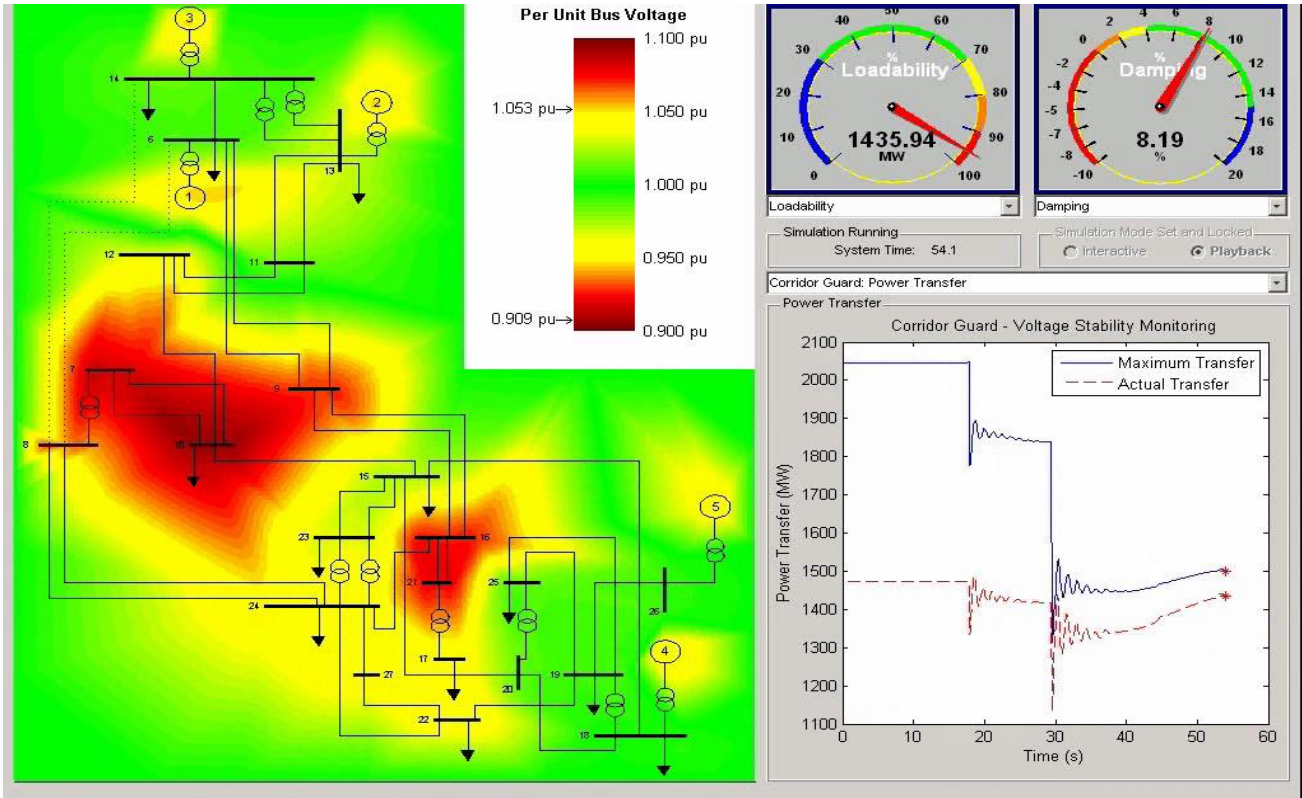
Voltage Stability Monitoring





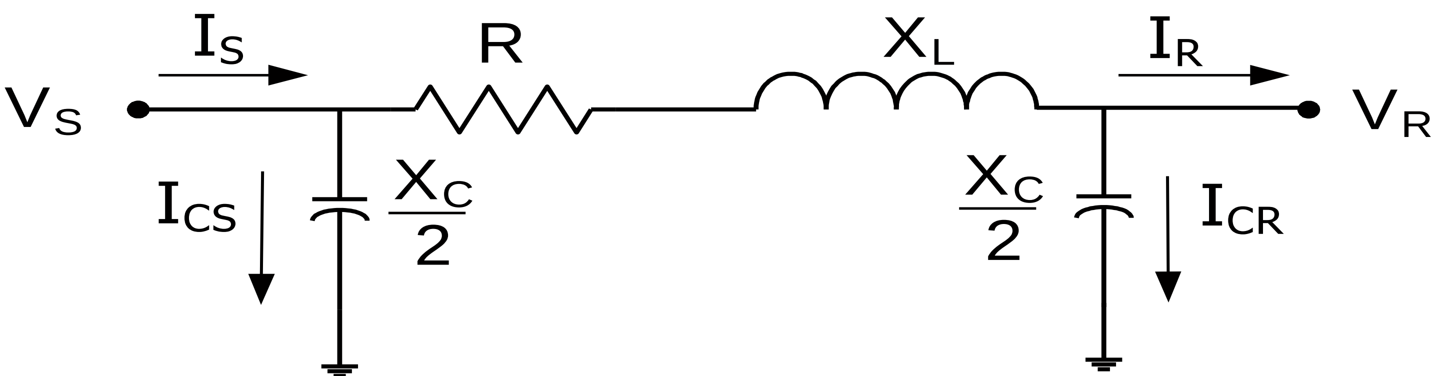


Voltage Stability Monitoring
Demonstration



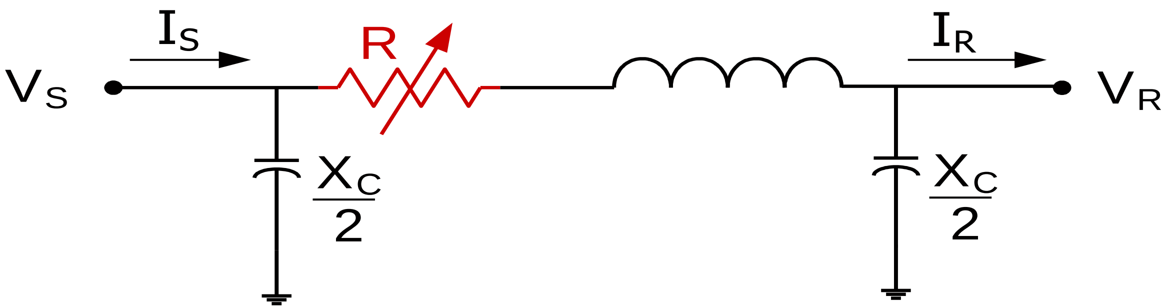
Movie - volcollapse.wmw

Line Parameter Calculations



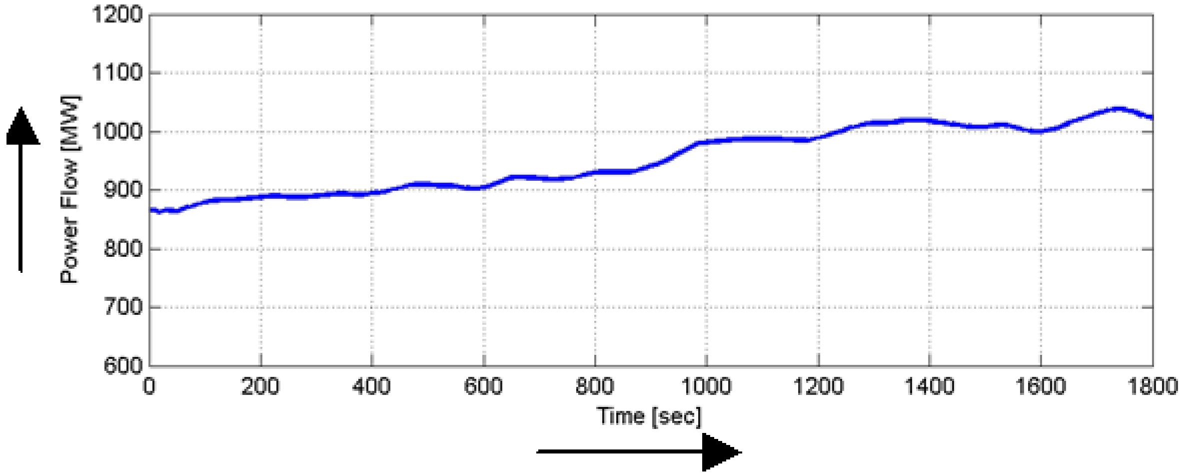
Line Thermal Monitoring

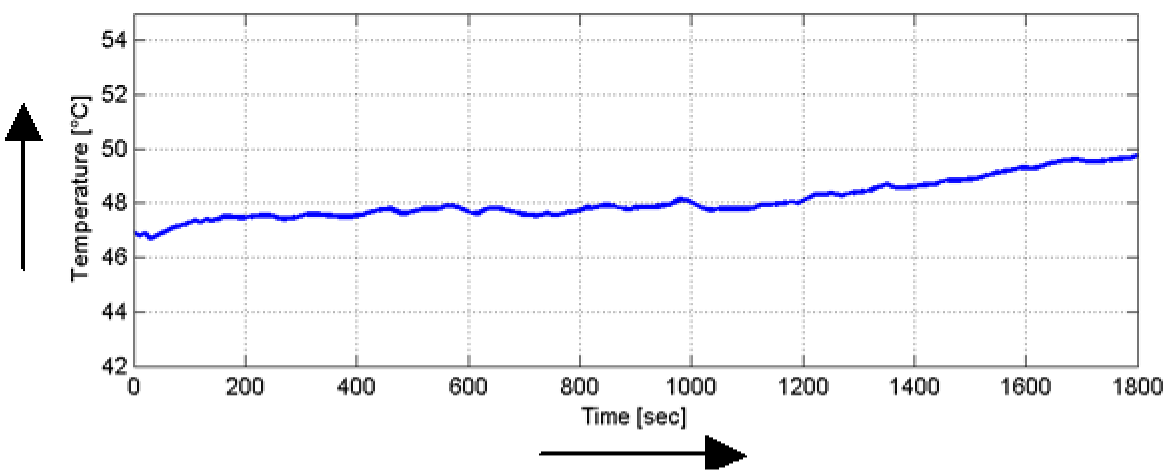
- Transmission Line Thermal Monitoring



- Compute average conductor temperature to provide
  - Real-time assessment of loadability
  - Early warnings in case of overload
  - Available line capacity
  - Indirect estimation of line sagging

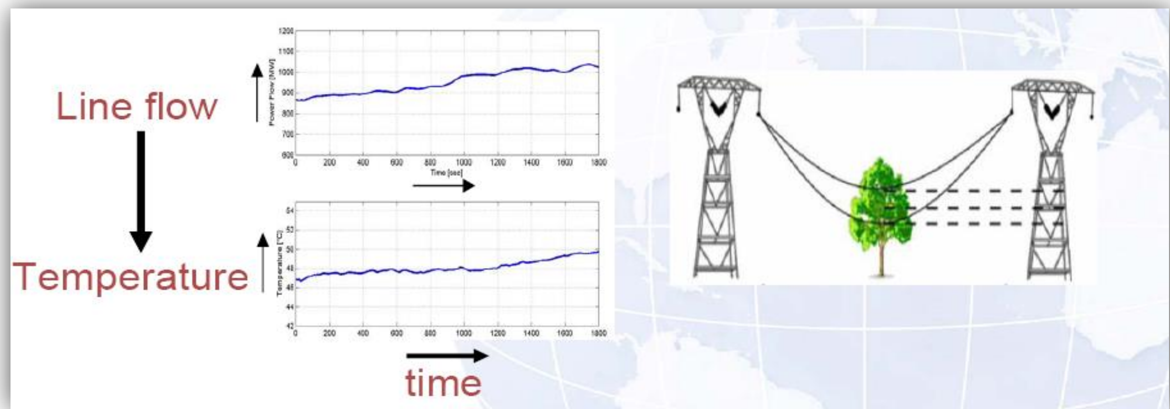
Line Thermal Monitoring





Line Thermal Monitoring

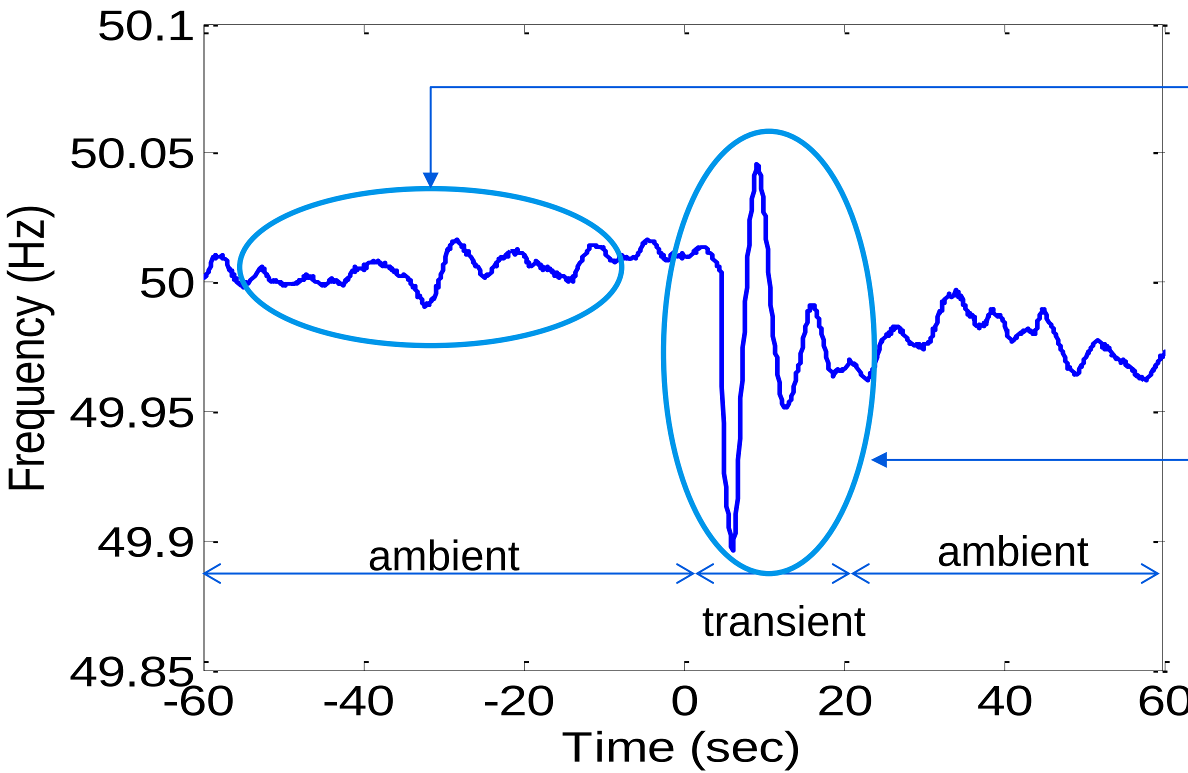
- Uses PMU measurements of voltage and current to calculate average line temperature of the monitored line
- On-line display of average temperature
- Field results correlate increased power transfer from 950 MW to 1150 MW leads to an average temperature increase from 46C to 49C over 30 min



Sample recordings from Swissgrid

Line Thermal Monitoring

Power Oscillation Monitoring
Ambient vs. Transient Oscillations

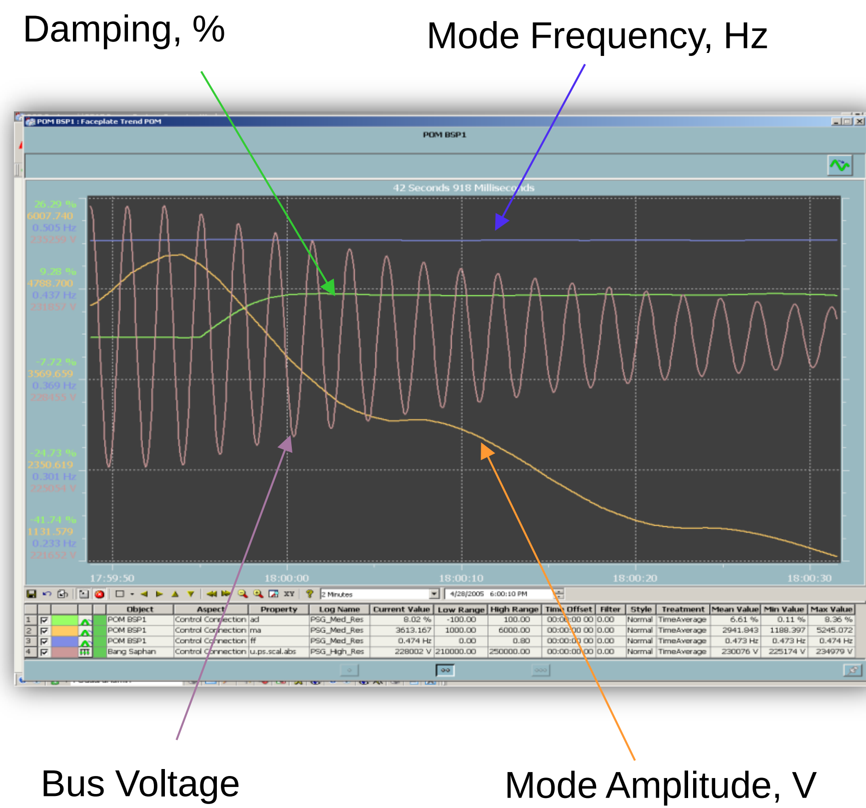


PDM
determining modes and characteristics based on ambient variations

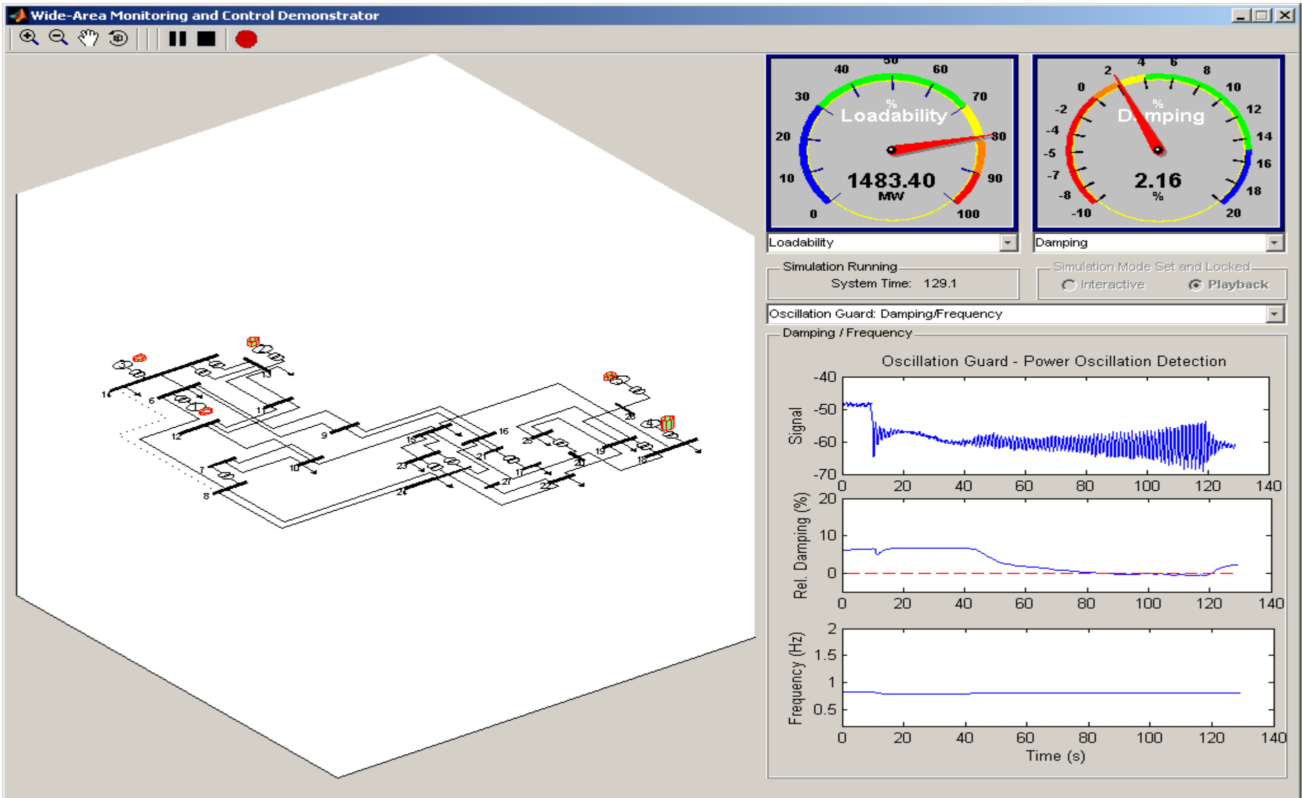
POM
detecting transient oscillations

Power Oscillations Monitoring

- Real-time detection of power swings
- Algorithm is fed with selected voltage and current phasors
- Detection of various swing (power oscillation) modes
- Quickly identifies amplitude and frequency of oscillations
- In service since 2005
- Field experience in Switzerland, Croatia, Mexico, Thailand, Finland, Norway, Austria



Power Oscillation Monitoring
Demonstration

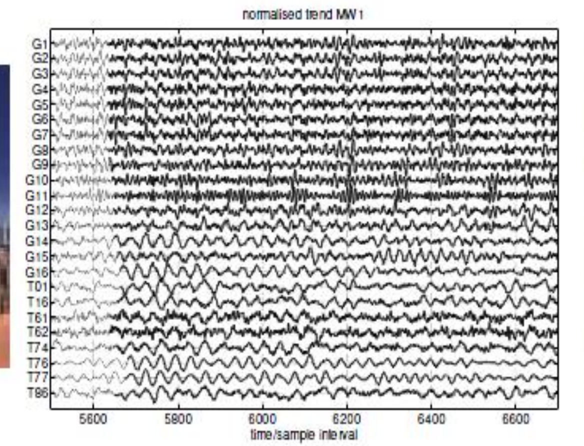


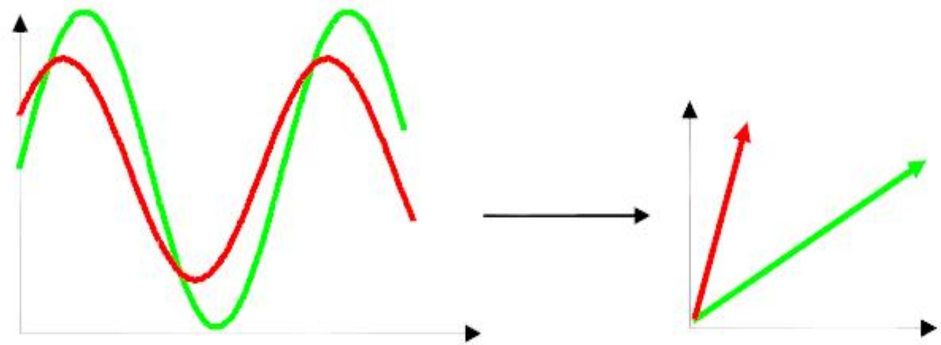
Movie – Oscmon.mat

Power Damping Monitoring

- Next generation of POM application
  - Accurate determination of damping levels under ambient conditions
  - Mode shape determination
  - Use of multiple input signals
  - Simultaneous detection of multiple modes

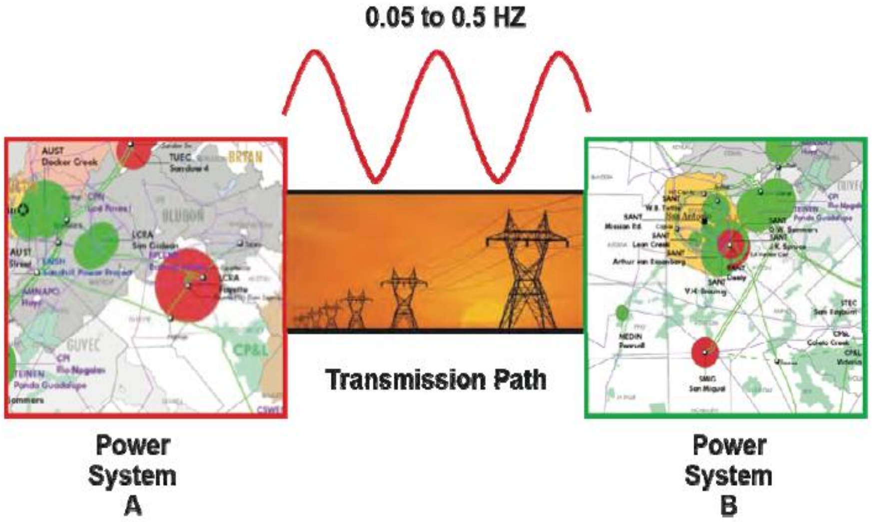
- Verified against simulated measurements and field measurements from the Fingrid WAMS





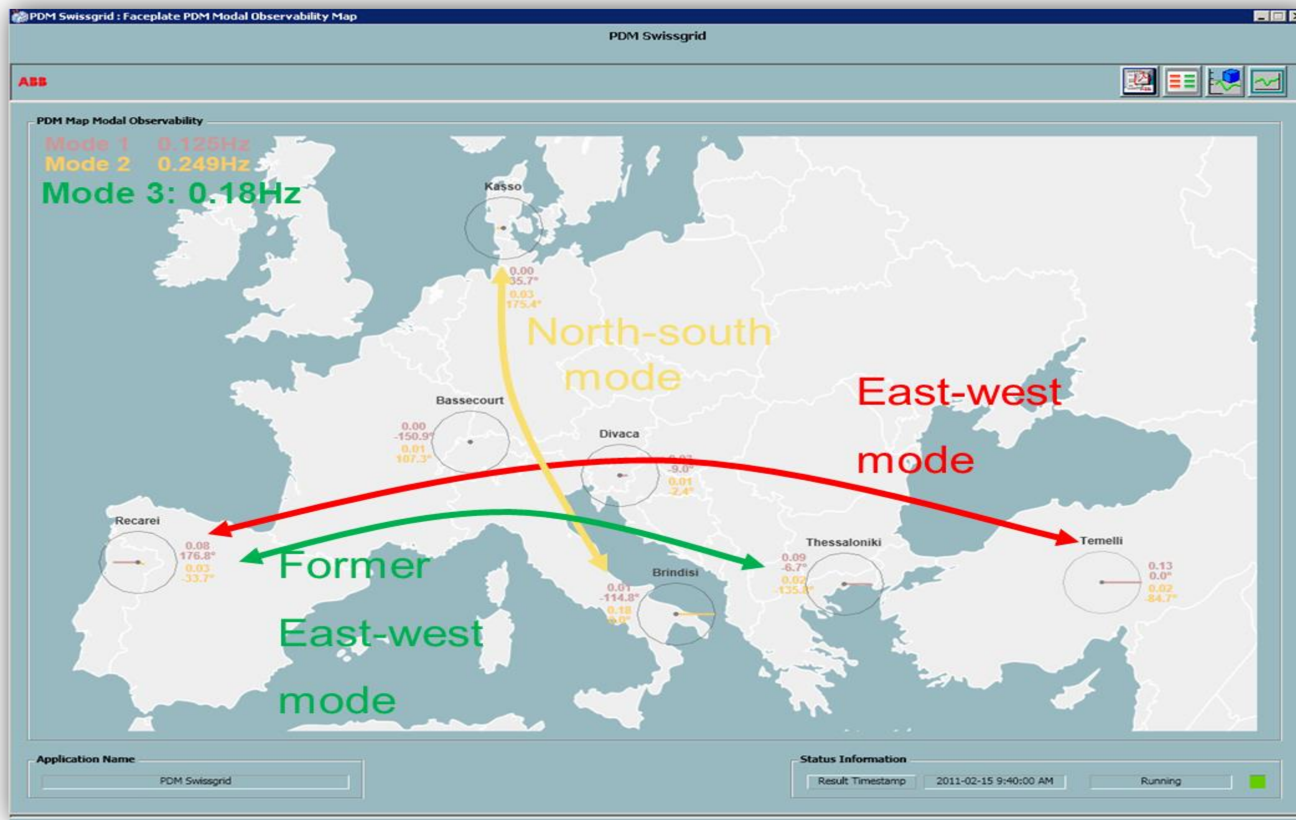
Power Damping Monitoring

- Real-time detection and visualization of multiple oscillation modes to truly understand the system behaviour
- Monitor damping and modal activity of most dangerous modes in the power system from ambient data (before large excitations happen)
- Quickly identify the participants and sources of inter-area oscillations using online visualization of modal shapes



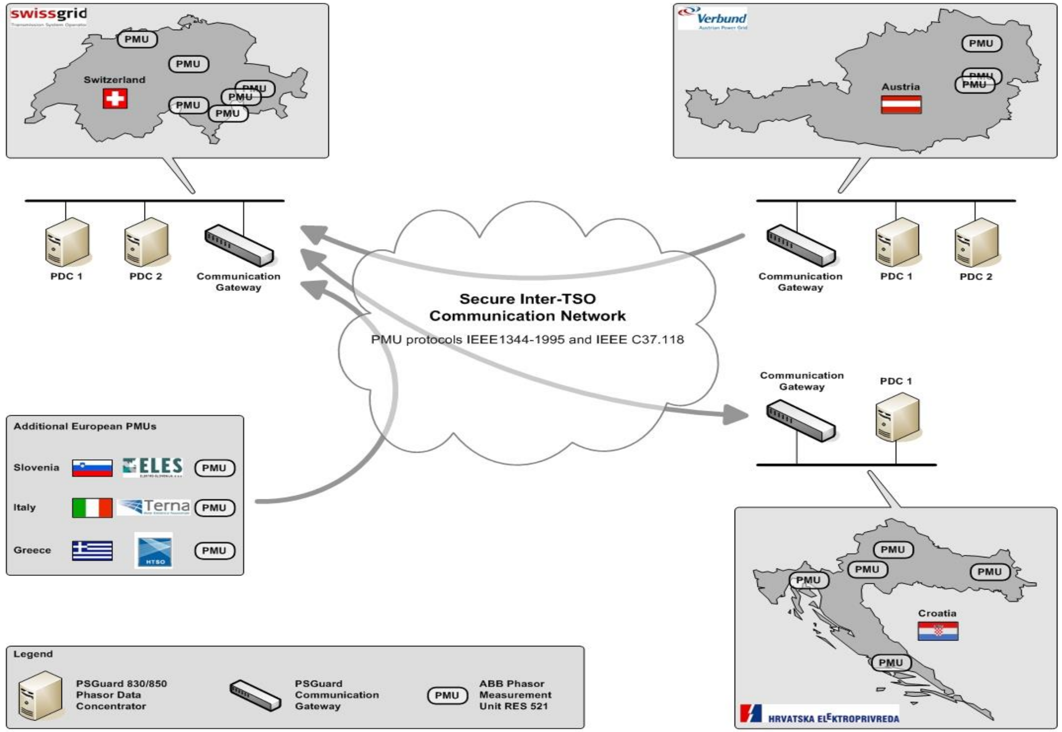
Early warning of poorly damped lines allows operators to react before an event triggers an inter-area oscillation

PDM Modal Observability Map
Participants in inter-area oscillations



European ENTSO-E System

- Consists of Nordic, UK and Continental European Systems, coordinated from Brussels
- 22 PMUs in 9 countries in Continental European System
- Communication over secure Inter-TSO Network, multi-vendor interoperability through IEEE C37.118
- 3 ABB PSGuard Systems: Switzerland, Austria and Croatia, super PDC in Switzerland
- PMU data exchange between utilities in real-time, using IEEE1344-1995 and IEEE C37.118 protocols
- PDM functionality implemented in Swissgrid in 2010. It was added to POM functionality in operation from 2005.



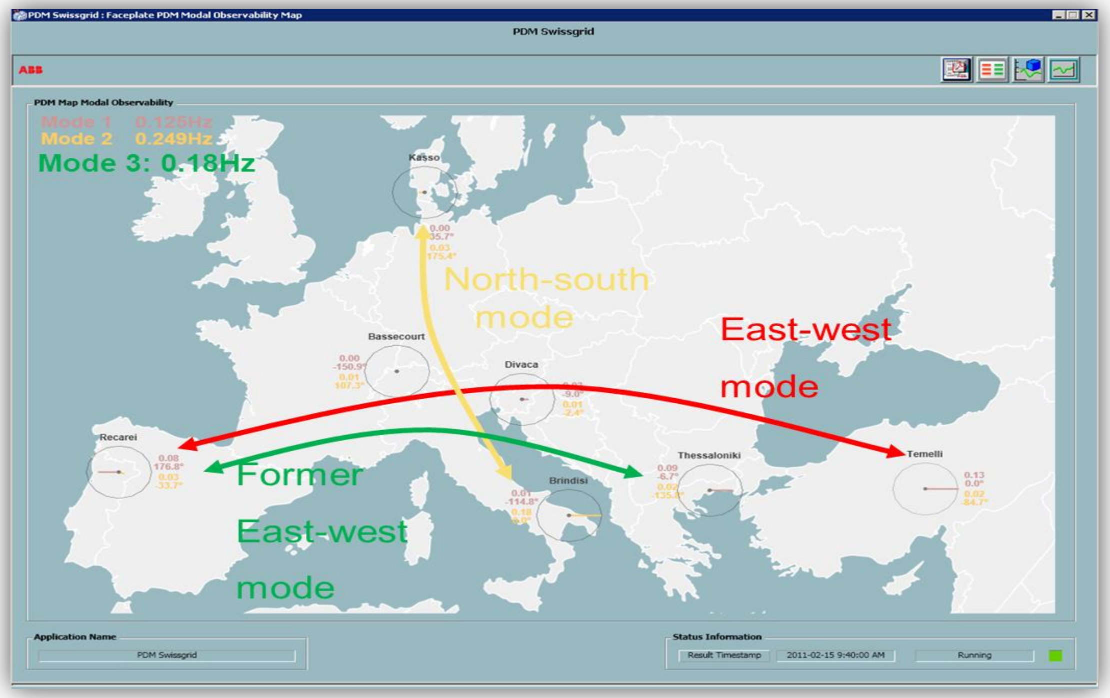
ABB

ENTSO-E Power Oscillations

- Real-time **ambient oscillations**
- Detects up to 2Hz oscillation, requires at least 10 frames/second
- Determines modal frequencies and damping
- Simultaneously monitors multiple modes
- Provides phase in each measurement
- In operation at Swissgrid since Dec 2010

3 dominated modes

- East-west mode - ~0.13 Hz
- North-south mode - ~0.25 Hz
- Former east-west mode - ~0.17 Hz

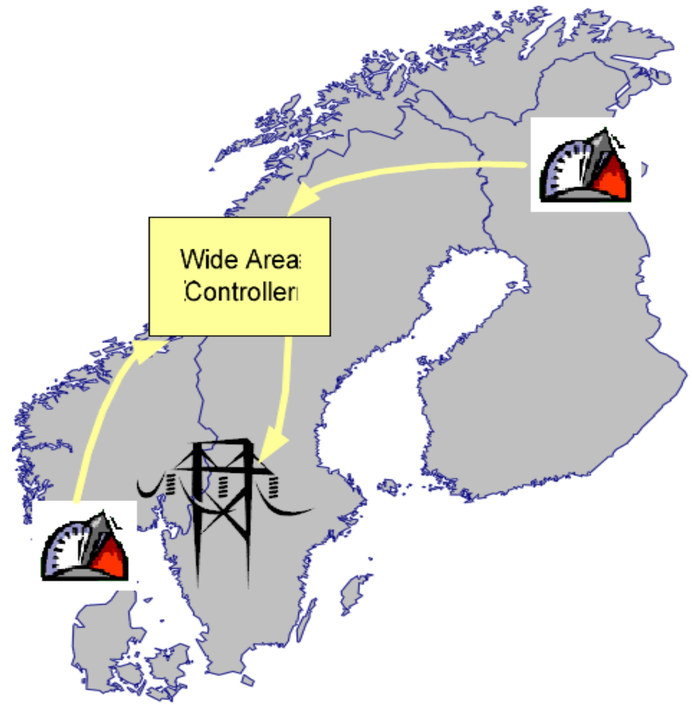


ABB

Wide Area Control of FACTS

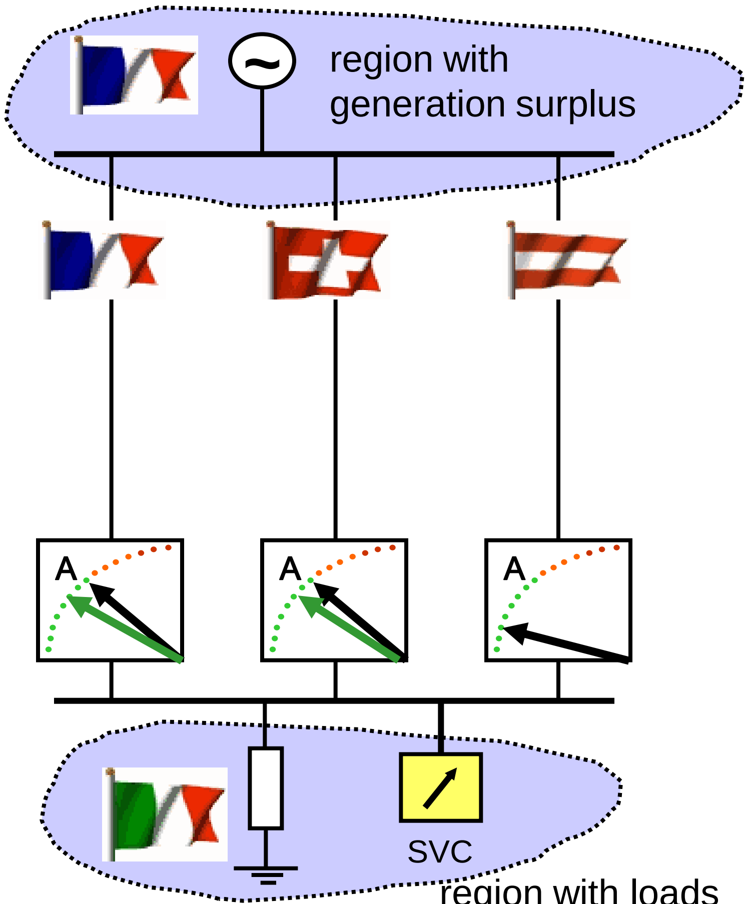
- Wide Area Power oscillation Damping control WA-POD
- Choose feedback signals from any PMU equipped substation
- Coordinated POD action from several actuators (SVC, FACTS, Generators)

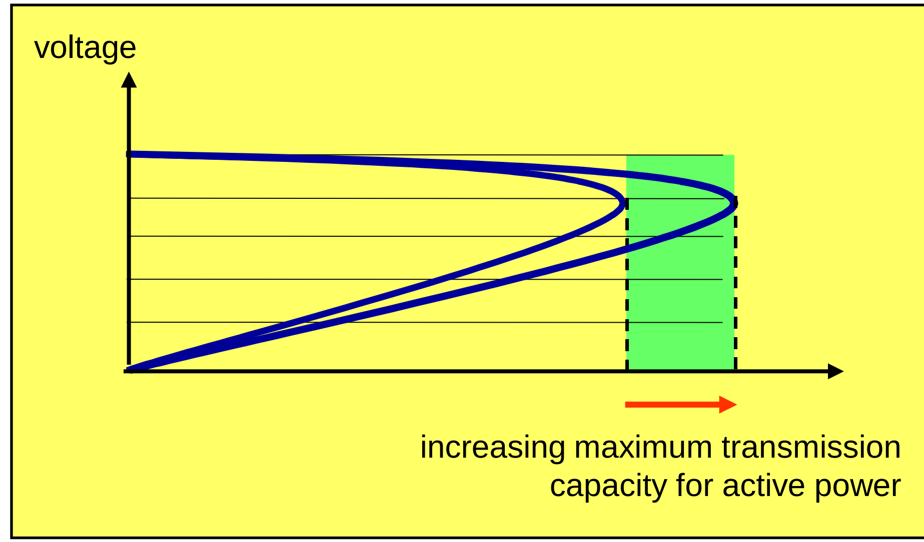
- Prototype WACS implemented and tested
  - PMU-PCU400 PDC-MACH2 control system
  - Wide Area Power Oscillation Damper (POD) with local signal based POD as backup
- Ready for deployment in 2010



ABB

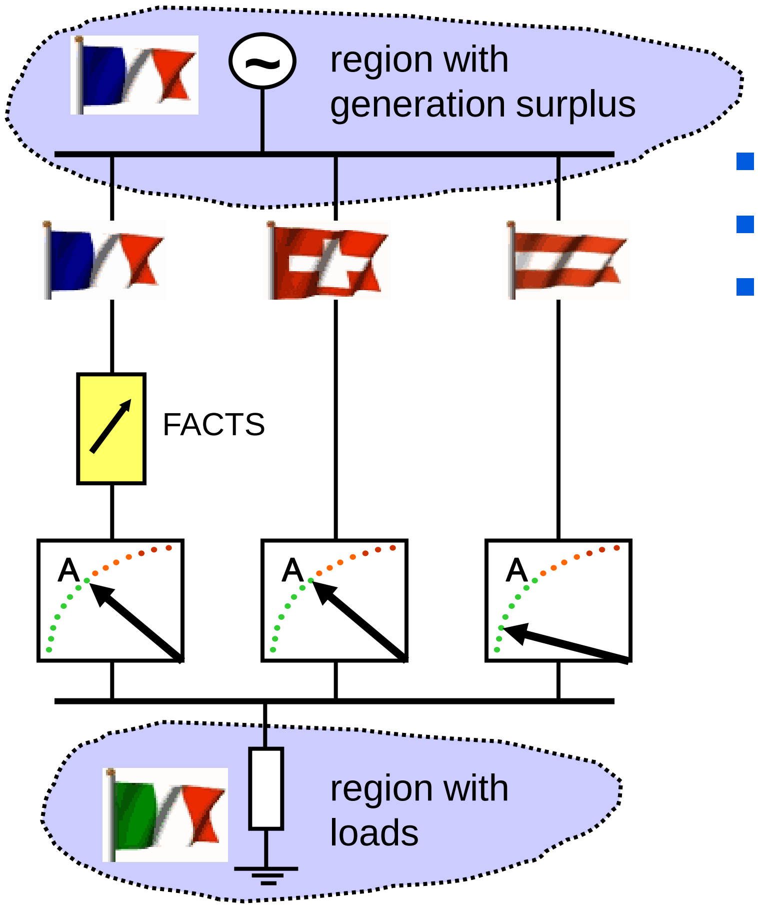
2004: Increasing capacity with SVC





SVC: static var compensation

2004: FACTs for Power Flow Control

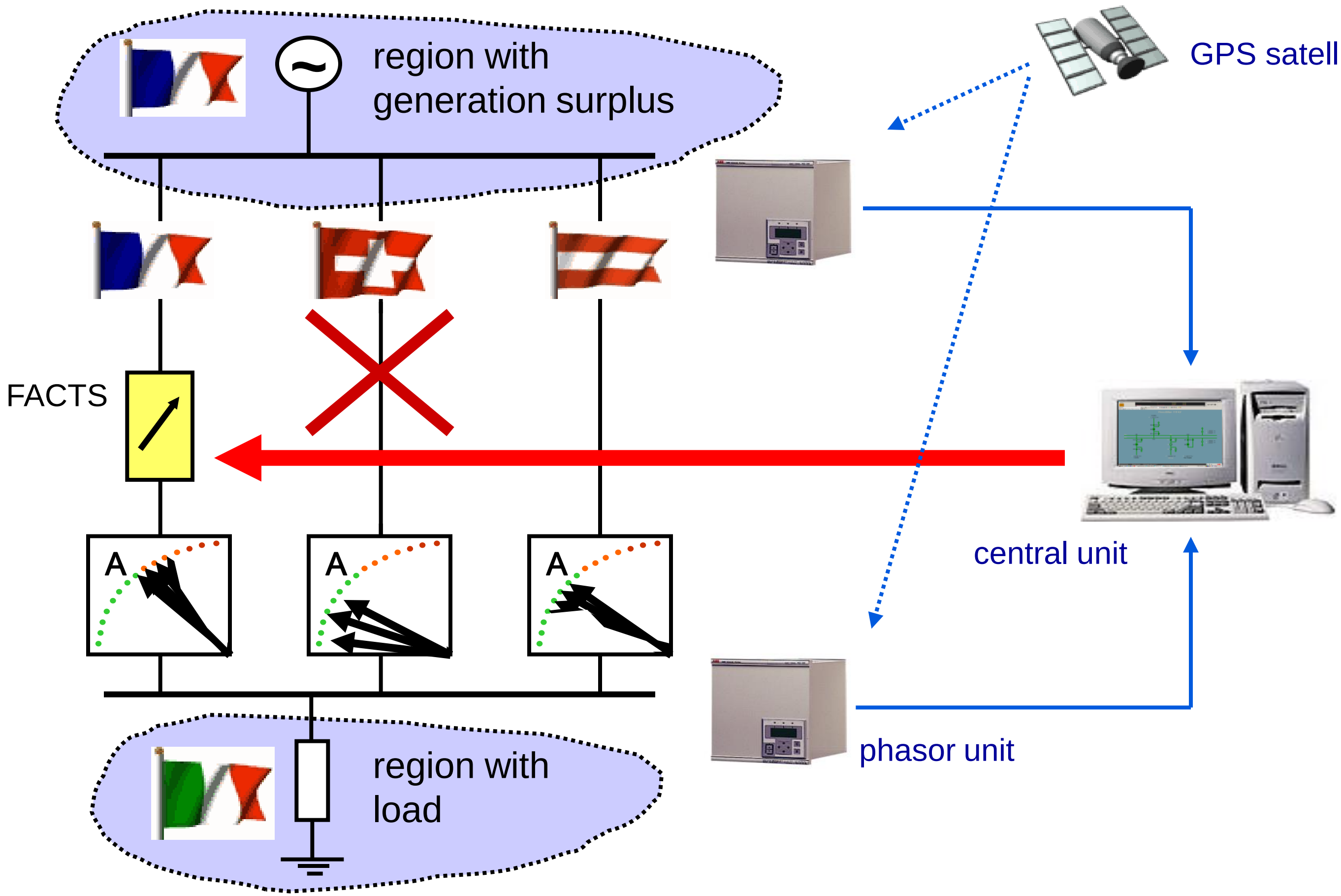


- switched series compensation (SC) *new 2004*
- thyristor controlled series compensation (TCSC)*
- dynamic flow control (DFC)* *vision*

* fast control

ABB

2004 vision: combining intelligent solutions



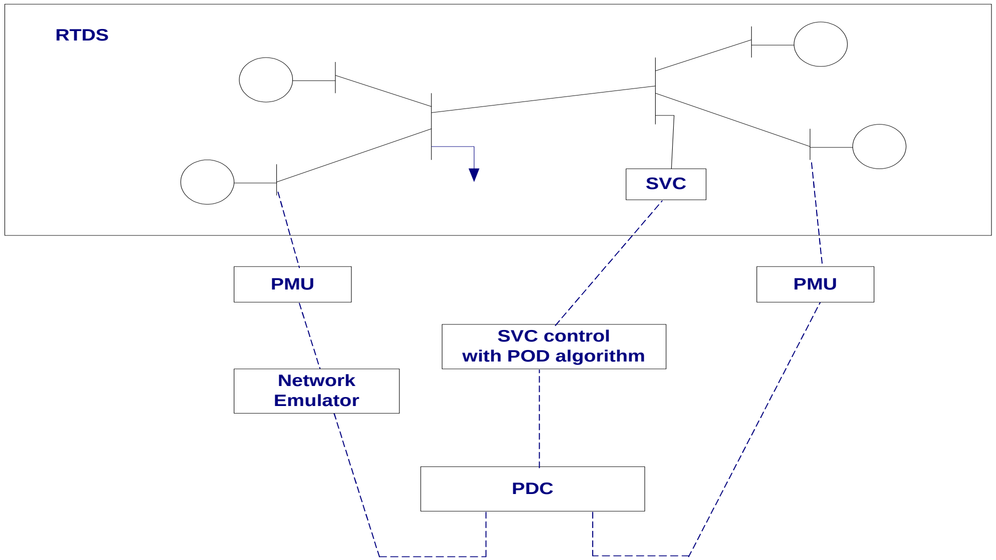
Step 1:

- system analysis
- free capacity available
- temporary overload acceptable

Step 2:

- increase reactance of overloaded line
- stable situation

Power Oscillation Detection

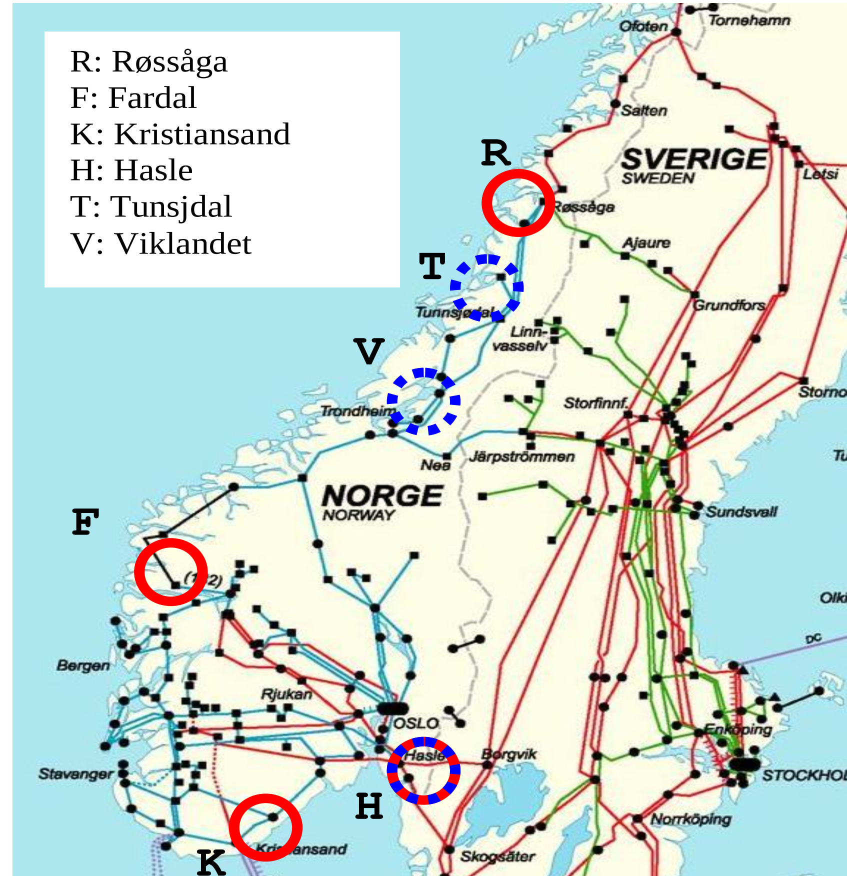


- Real-time detection of power swings based on selected voltage and current phasors
- The algorithm identifies the amplitude, frequency and damping for the dominant power swing modes
- Closed-loop control of Static Var Compensators

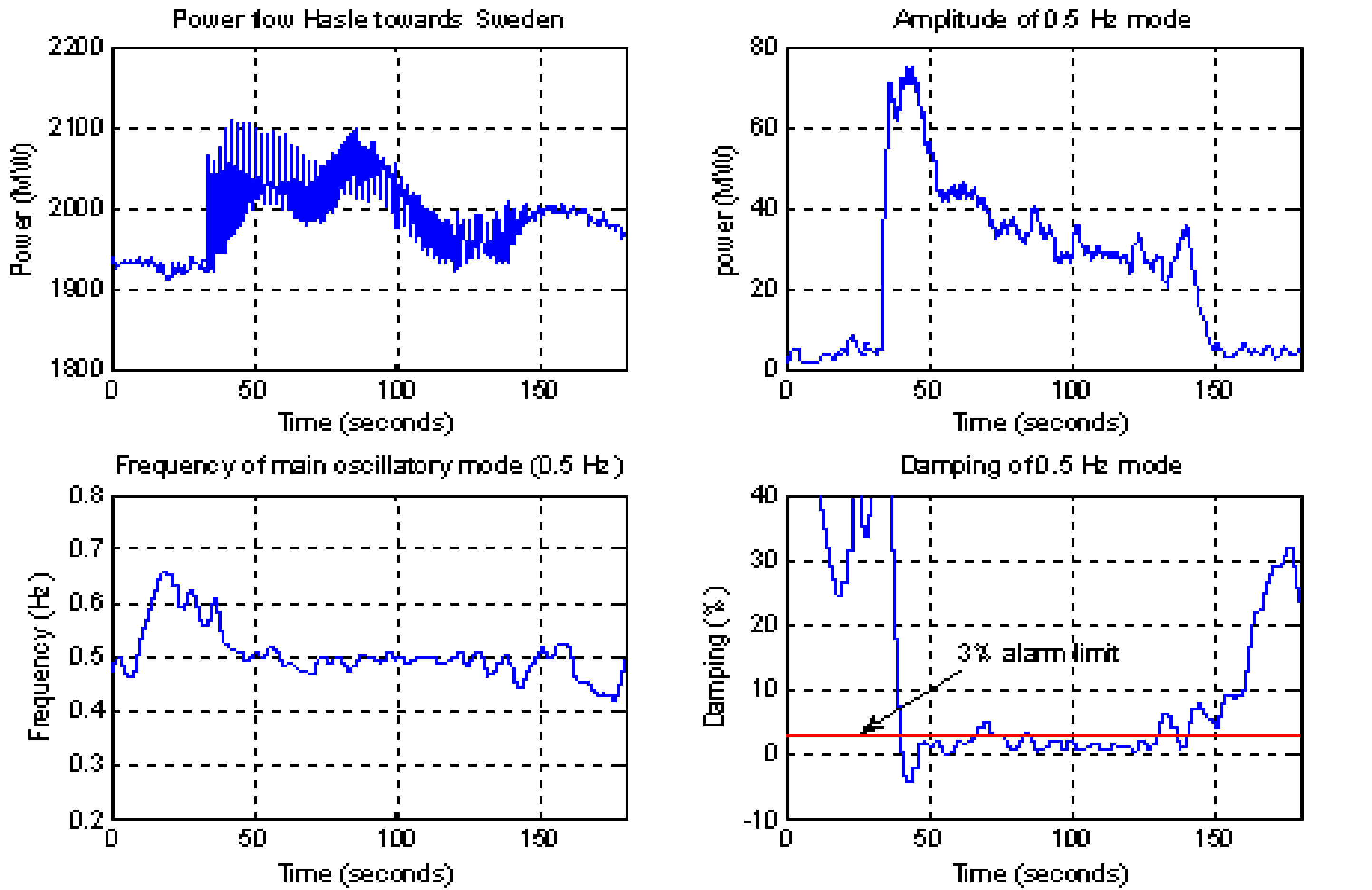
Nordic Power System

- Interconnected power systems
  - Finland
  - Sweden,
  - Norway,
  - East Denmark
  - West Denmark
  - Iceland (isolated)

- Recently installed in Norway
  - PMUs (locations R, F, K, H)
  - SVCs (locations H, T, V)

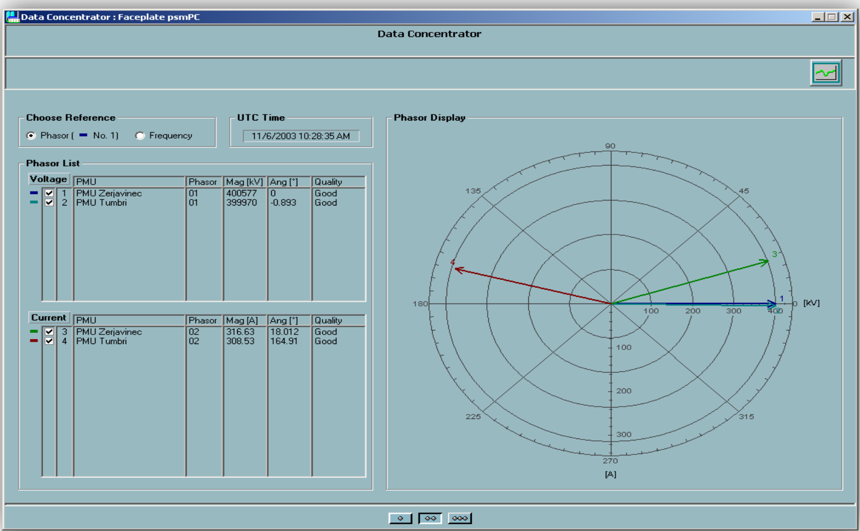


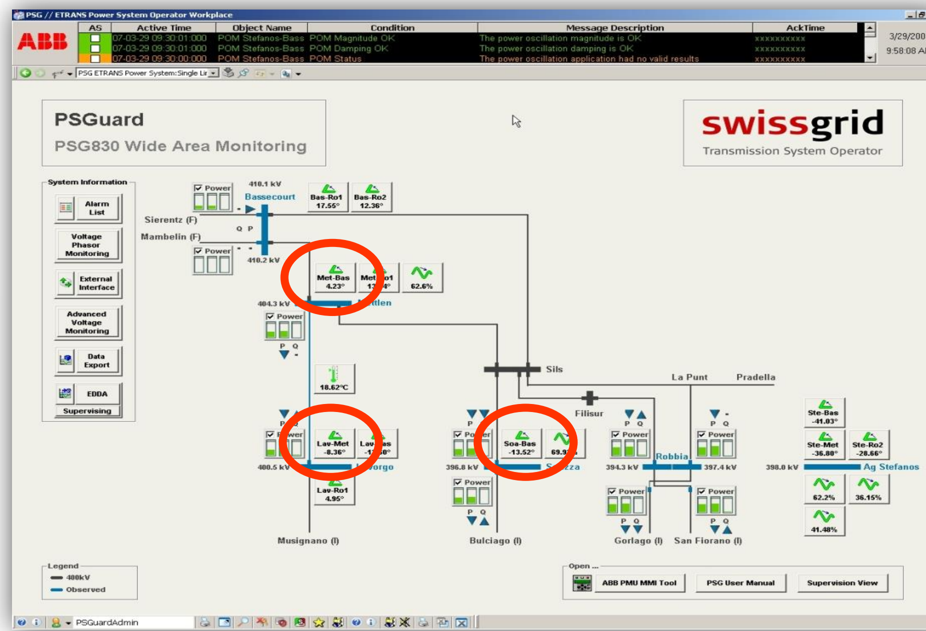
Nordic Power System Measurements



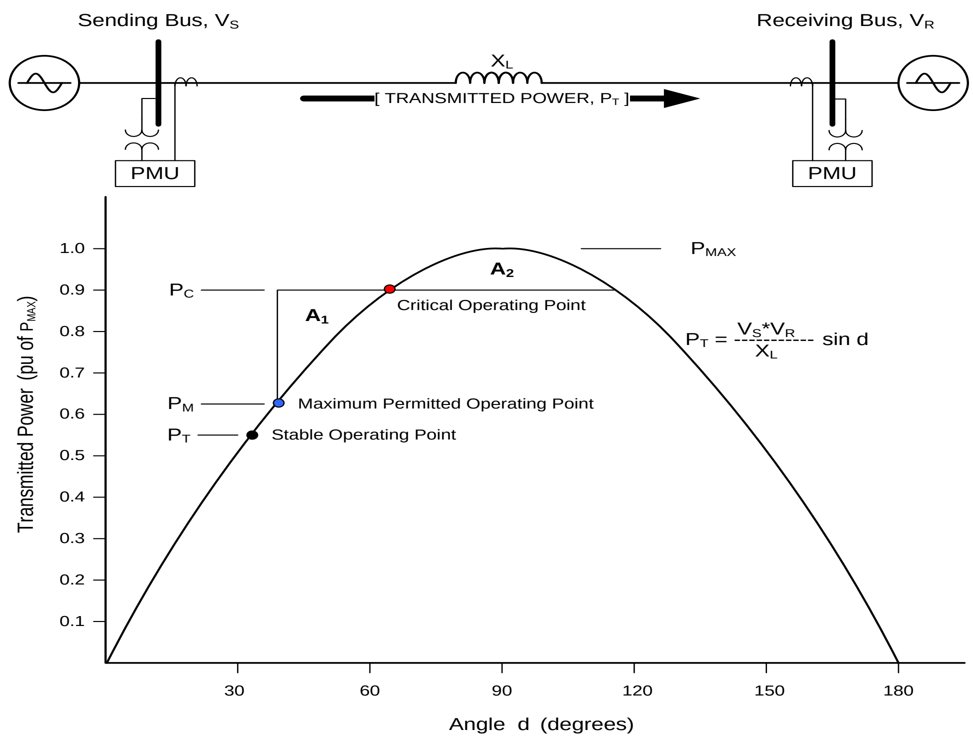
Phase Angle Monitoring

- Online calculation of voltage phase angle difference
- Configurable alarming and warning thresholds



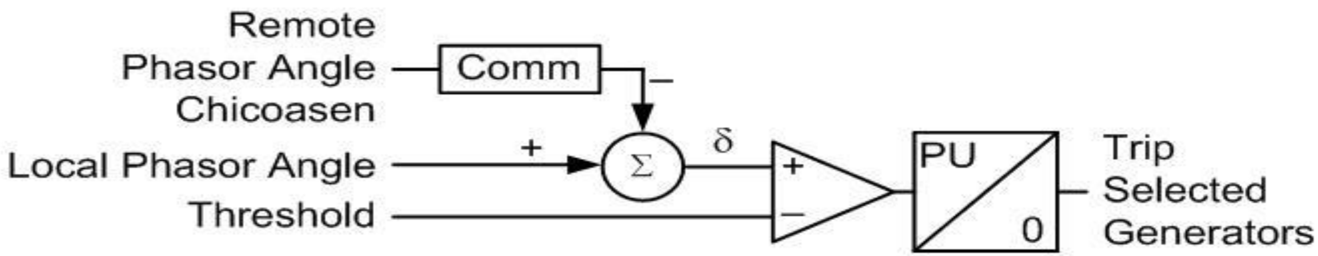


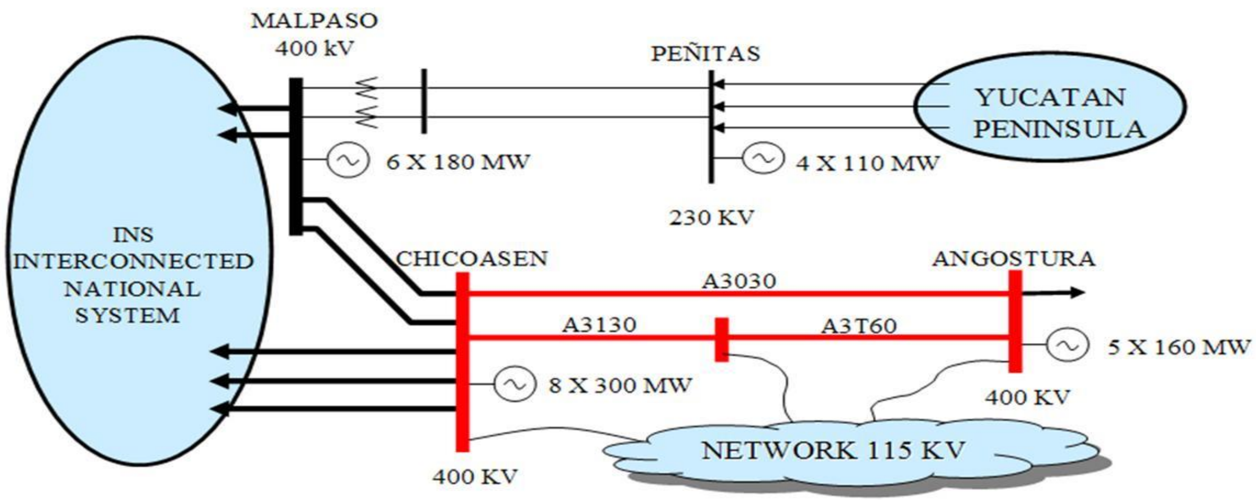
Power Transfer Stability



- Visual tracking of the operating power transfer point between two synchronous systems is achievable and might also be useful
- Voltage synchrophasor and line impedance model can be used to graphically display the power transfer curve and operating point P_T

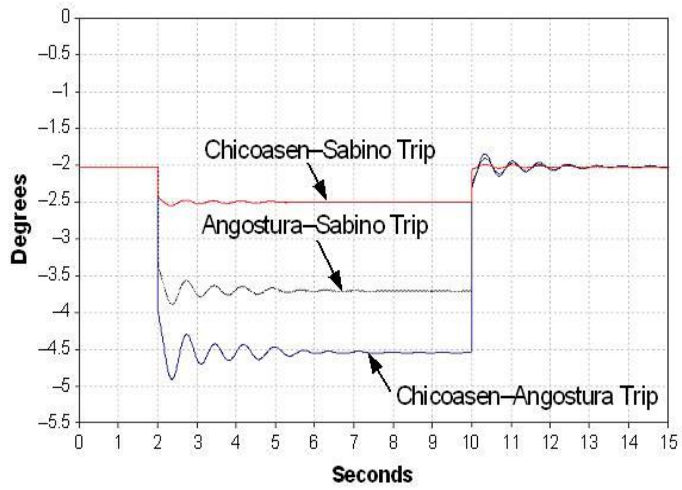
Angular Differential Protection

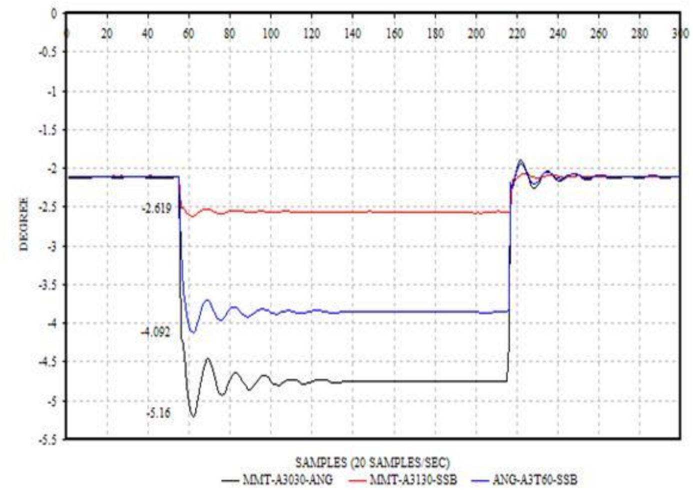




Source: E.Martinez Angular Difference Protection Scheme, Conference on Actual Trends in Development of Power System development and Automation, Sept 2009, Moscow, Russia

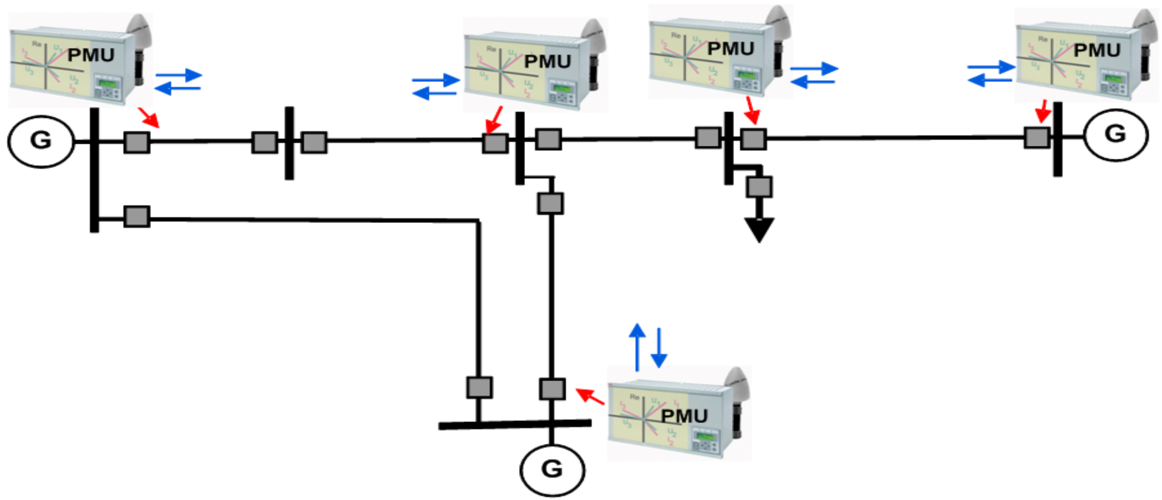
Angular Differential Protection





Source: E.Martinez Angular Difference Protection Scheme, Conference on Actual Trends in Development of Power System development and Automation, Sept 2009, Moscow, Russia

System Integrity Protection Schemes (SIPS)

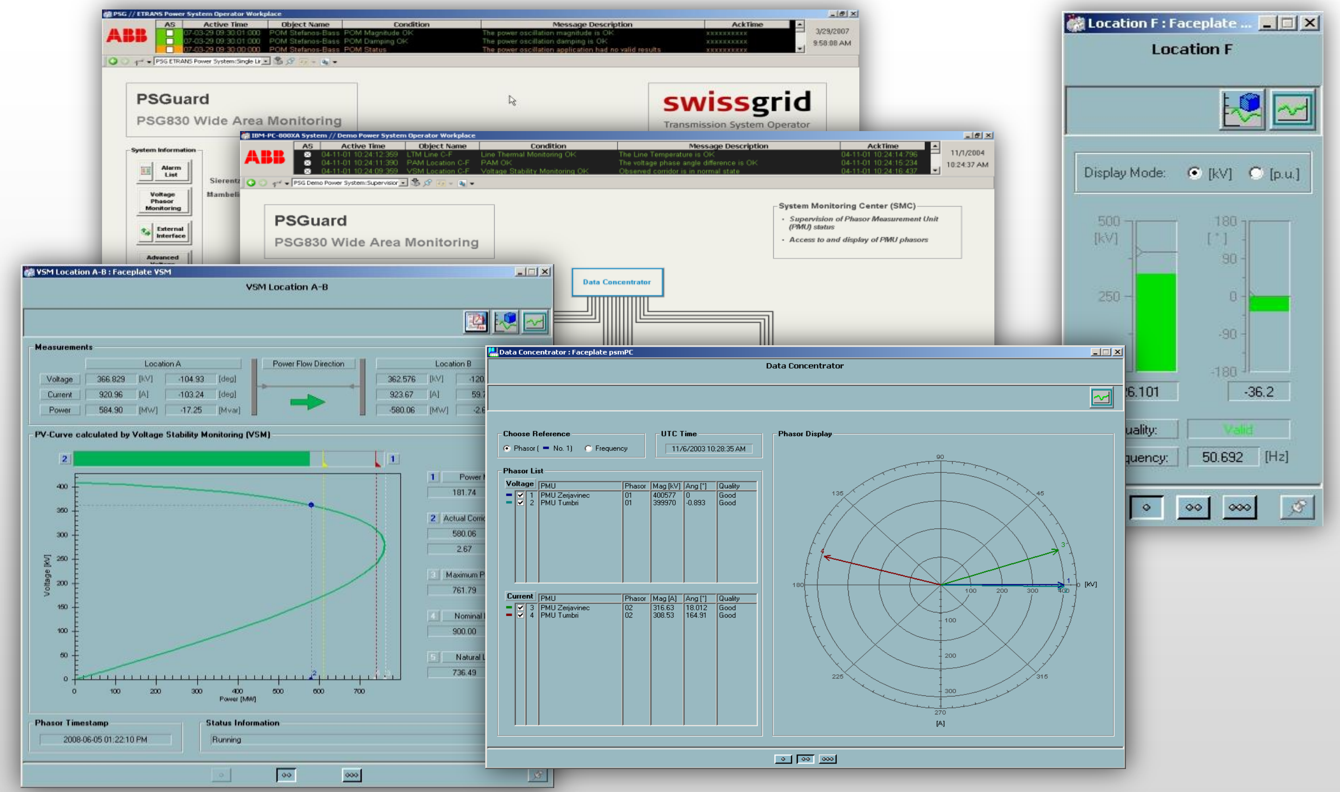


- SIPS based on synchrophasor measurements, line differential communications, and synchrophasor functions allow a limited number of PMUs (up to 5) to communicate with each other and share synchrophasor, analog values and topology (apparatus position) information, to make various decisions
- The decision algorithms can be concentrated in one PMU or distributed among the communicating PMUs
- The SIPS algorithms can detect **system islanding**, **out-of-step**, **voltage collapse** and **severe thermal overload**

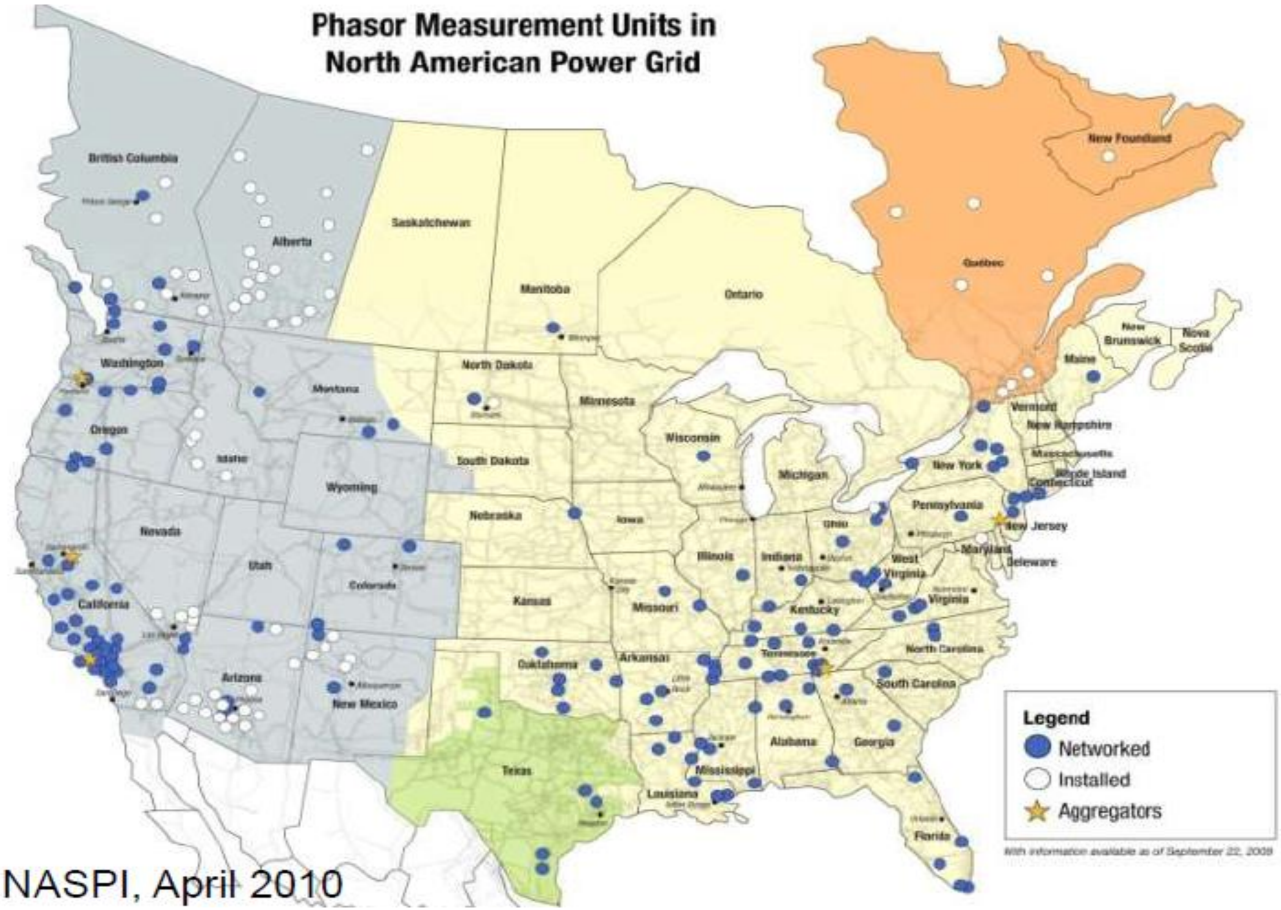
PSGuard
Wide Area Monitoring System

PSGuard Applications

- Phase Angle Monitoring
- Voltage Stability Monitoring
- Line Thermal Monitoring
- Event Driven Data Archiving
- Power Oscillation Monitoring
- Power Damping Monitoring
- SCADA/EMS integration
- Communication gateway



North American Synchrophasor Initiative



Source: NASPI, April 2010

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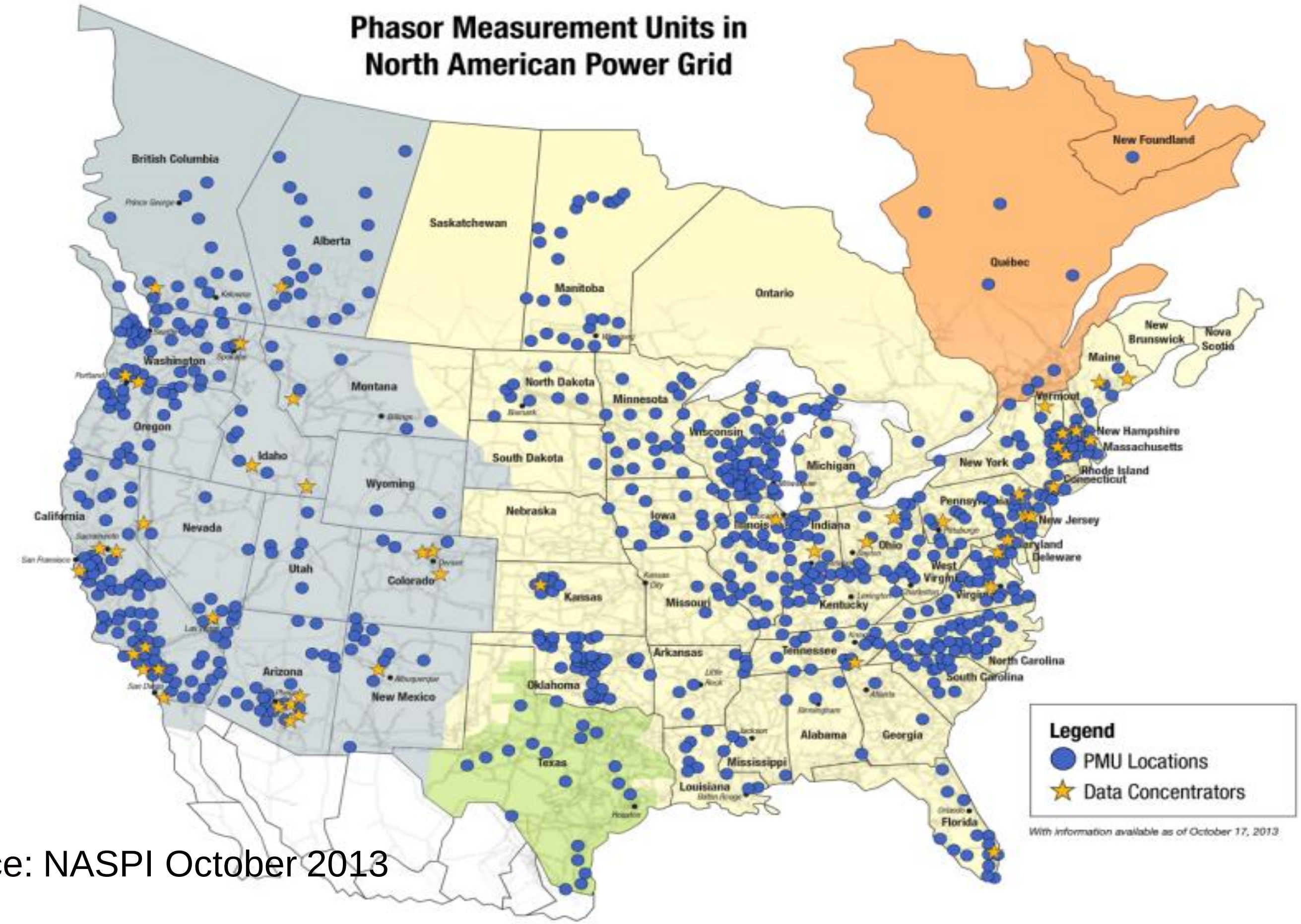
North American Synchrophasor Initiative



Source: NASPI October 2013

Western Interconnection Synchrophasor Program

PNM

SDGE connected

A Sempra Energy utility

BC hydro FOR GENERATIONS

CFE COMISIÓN FEDERAL DE ELECTRICIDAD

IDAHO POWER. An IDACORP Company

TEP

PACIFICORP A MIDAMERICAN ENERGY HOLDINGS COMPANY

SOUTHERN CALIFORNIA EDISON An EDISON INTERNATIONAL Company

Western AREA POWER ADMINISTRATION

Los Angeles LA DWP Department of Water & Power

California ISO Shaping a Renewed Future

PG&E

ROCKY MOUNTAIN POWER

BONNEVILLE POWER ADMINISTRATION

aeso ALBERTA ELECTRIC SYSTEM OPERATOR

aps

SRP Delivering More Than Power.

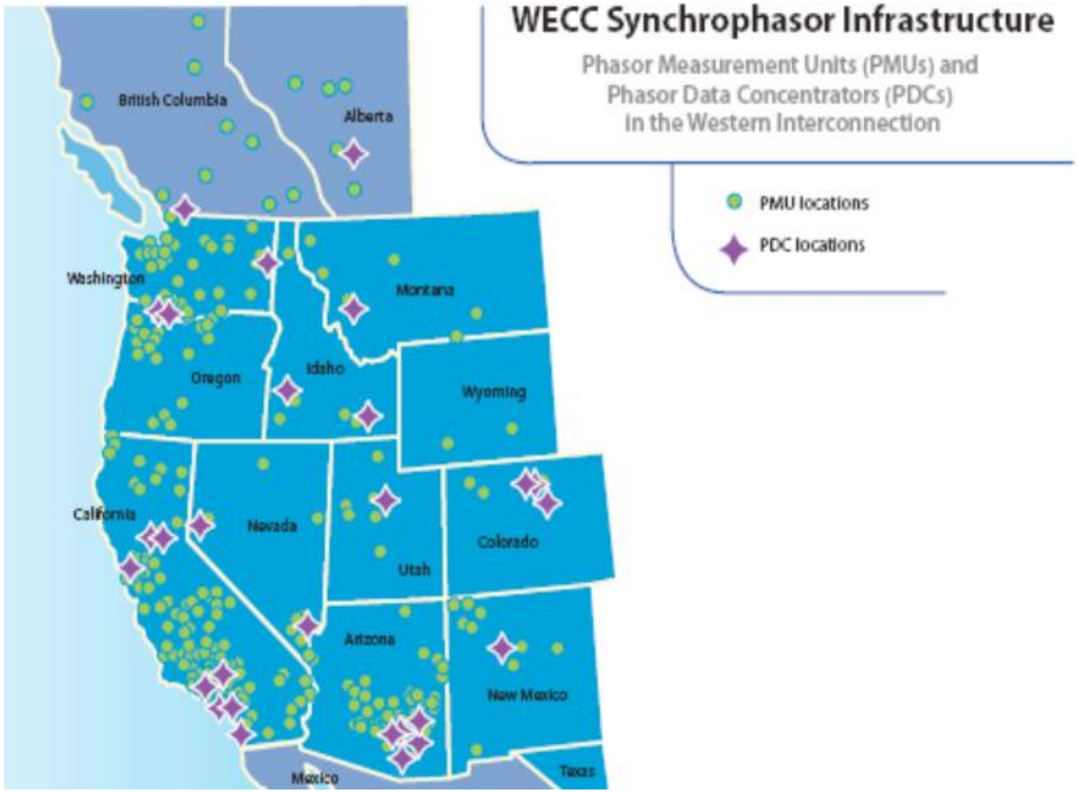
WECC Western Electricity Coordinating Council

NVEnergy

ABB

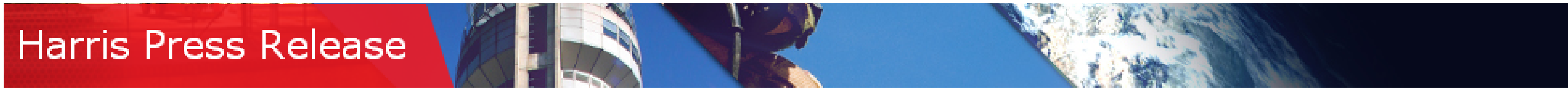
Western Interconnection Synchrophasor Program

- 244 Substations with PMUs
- Sampling Rate 30-120 sps
- Installation Rate:
  - 2011 Q3 22
  - 2011 EOY 38
  - 2012 EOY 267
  - 2013 Q1 362



Source: WECC WISP Western Interconnection Synchrophasor, Vickie VanZandt NASPI Work Group Meeting October 12-13, 2011

WISP Communications



Printer Friendly Version

Harris Corporation Network to Provide the Communication Infrastructure for Enhancement of Reliability in the Western Interconnected Electric Grid for Western U.S., Canada, and Northern Mexico

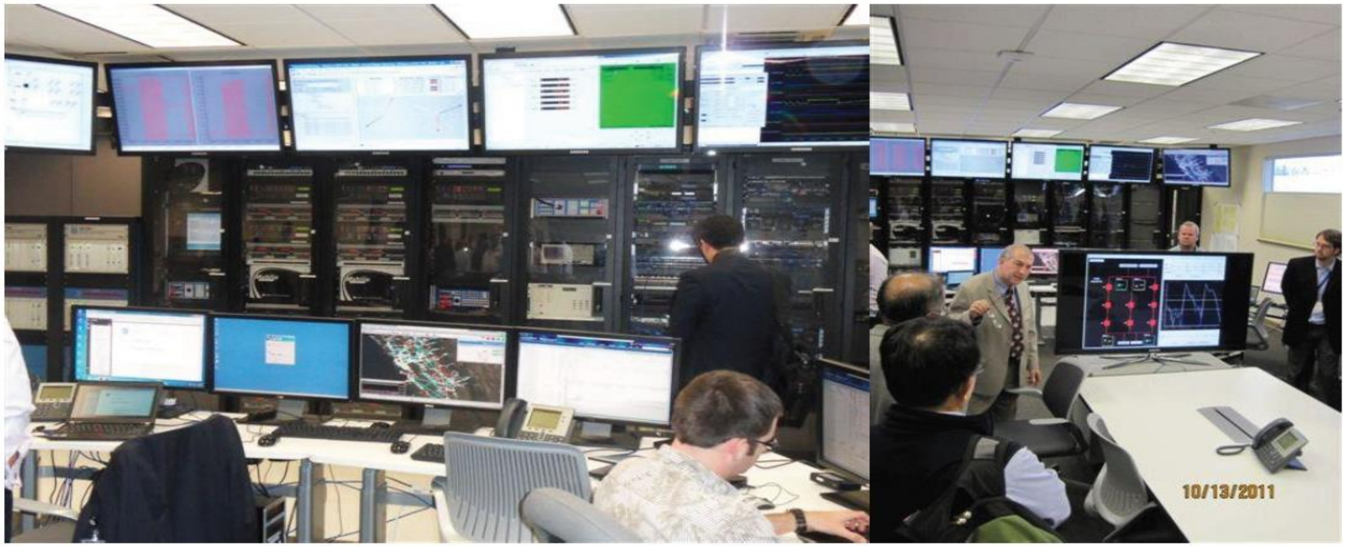
Highlights

- Wide area network to support the Western Electricity Coordinating Council and other participating electric utility organizations
- Key infrastructure component in implementing real-time vulnerability detection in western region's electric grid
- Enables utilities to have better visibility into the condition of the power system and take timely actions to mitigate widespread electrical outages

MELBOURNE, FL, July 14, 2011 — Harris Corporation (NYSE:HRS), an international communications and information technology company, has been awarded a five-year contract to provide a wide-area network that will help detect and assist in avoiding or mitigating regional electrical system disturbances in a service area that extends from Canada through 14 western U.S. states and northern Mexico.

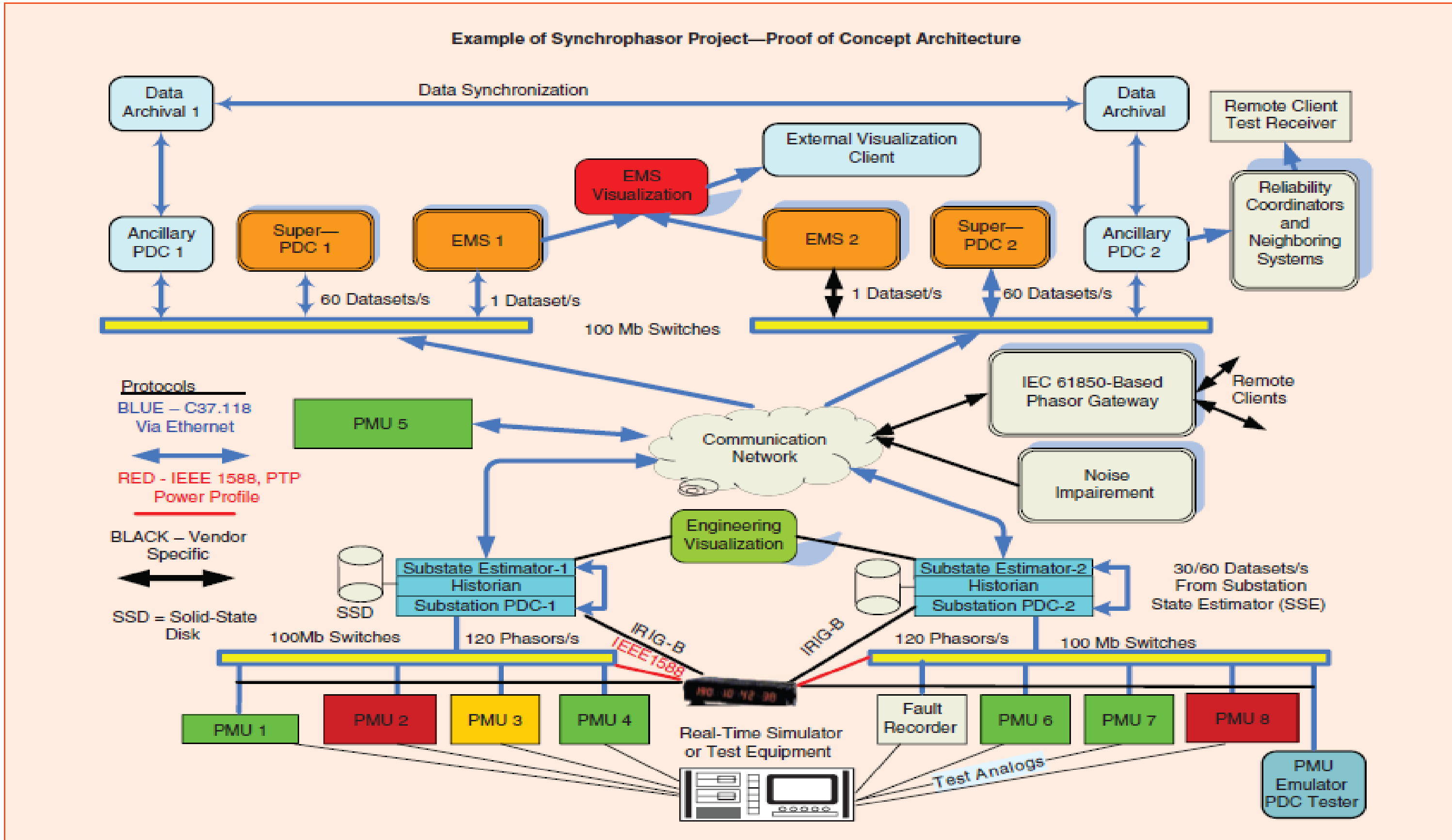
The private network will enable the Western Electricity Coordinating Council (WECC) Reliability Coordinator, and other participating entities, to detect and take timely actions to mitigate the risk of impacts such as oscillations, grid instability and ultimately, widespread system blackouts.

PG&E synchrophasor proof-of-concept facility



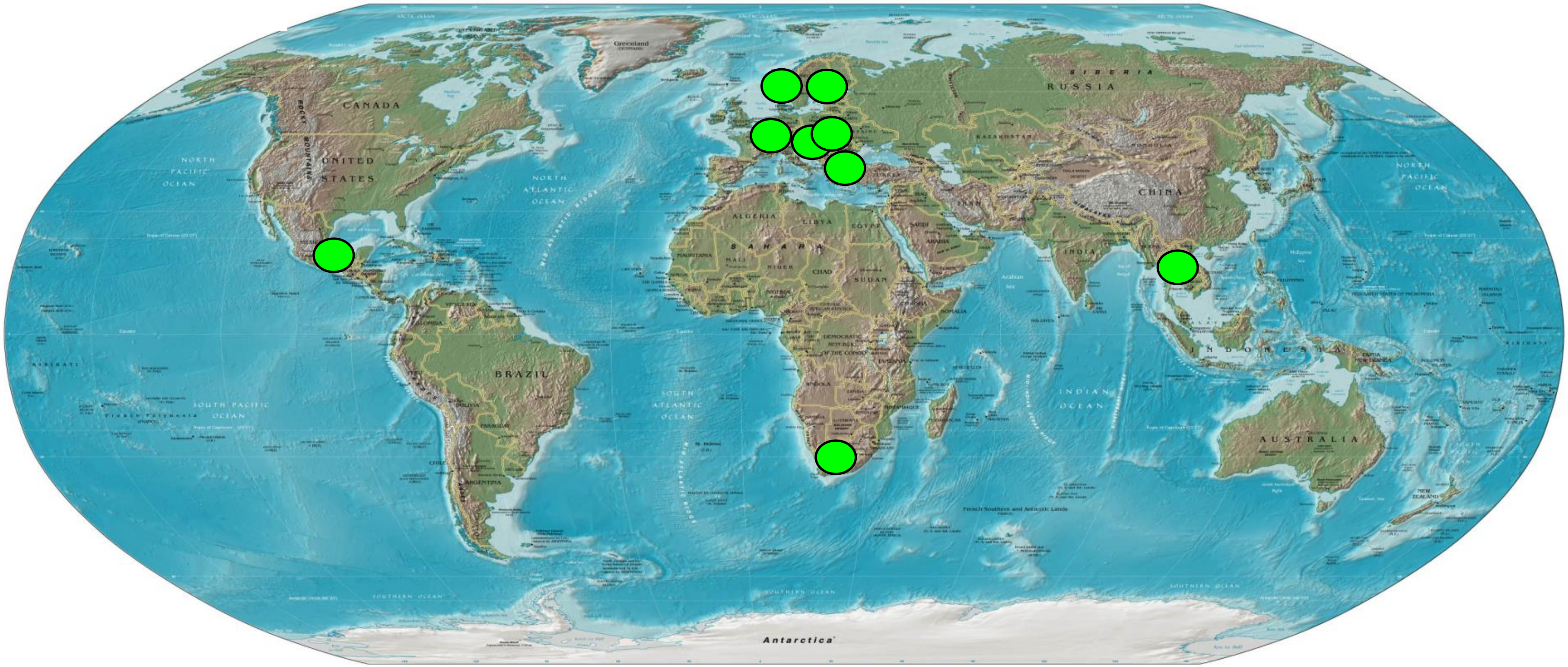
PG&E Synchrophasor Proof-of-Concept Facility (POC) is a smaller scale synchrophasor system used to **test**, **validate**, and **demonstrate** various functions and interoperability before field deployment

PG&E synchrophasor proof-of-concept architecture

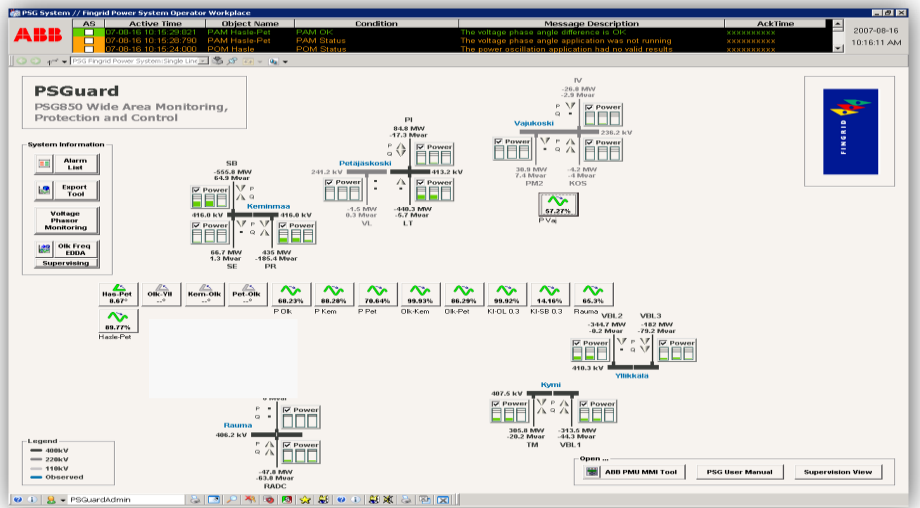


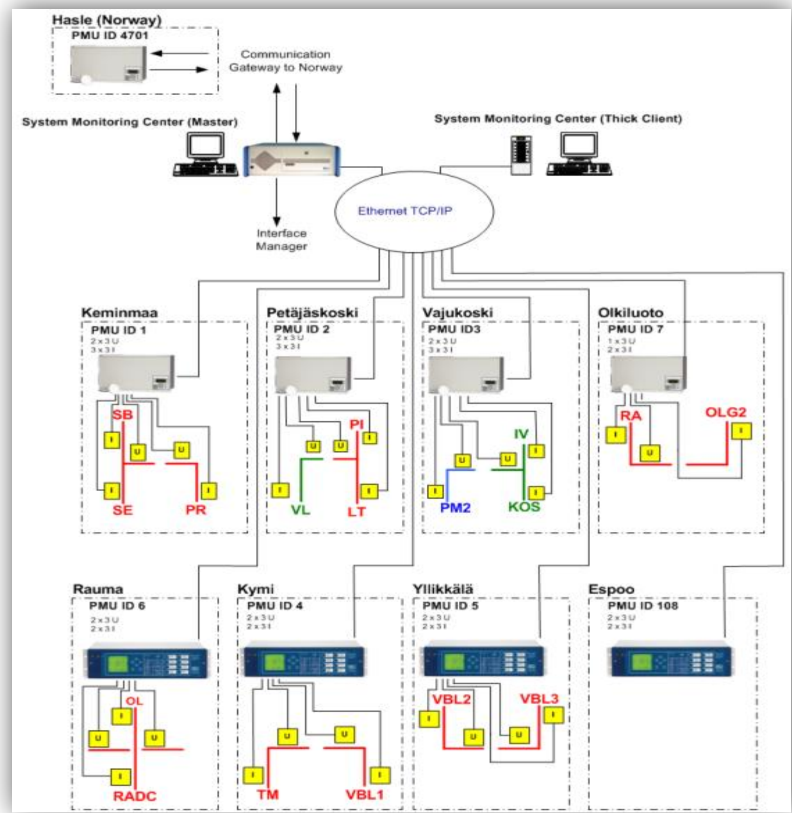
Source: Grid monitoring and situational awareness: PG&E synchrophasor proof-of-concept project presentation at ABB APW 2013

Synchrophasor Systems World Wide



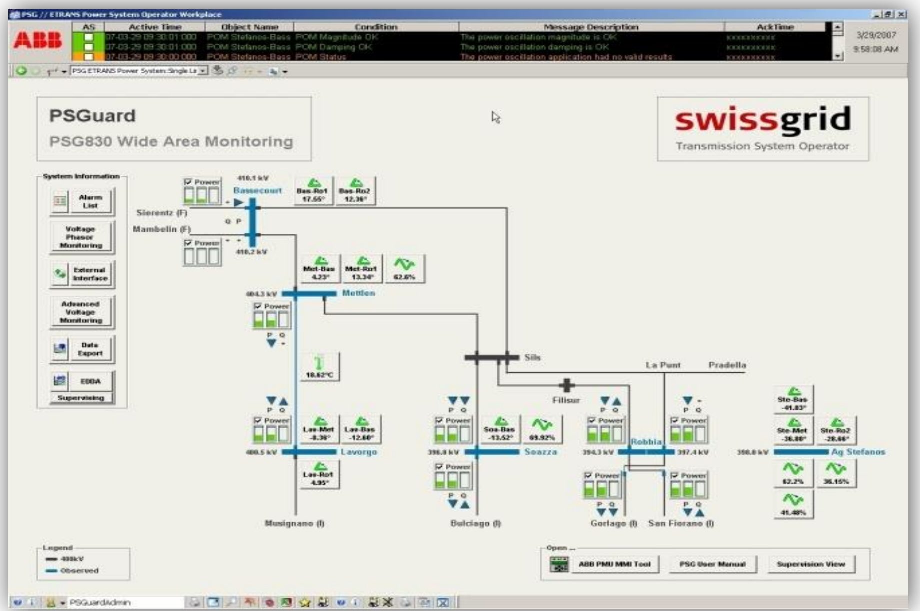
Wide Area Monitoring System
Fingrid (Finland)



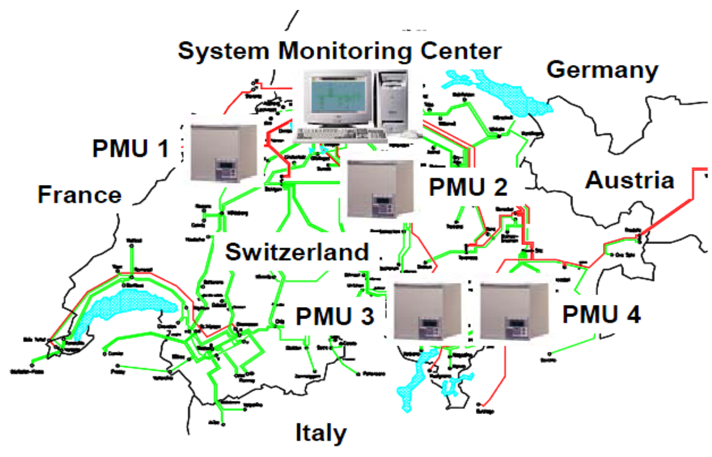


- Since 2006
- 10 PMUs in Finland
- Communication gateway to PMU in Norway
- SCADA integration
- Main application post-disturbance analysis of system performance
- Collaboration project on power oscillation monitoring

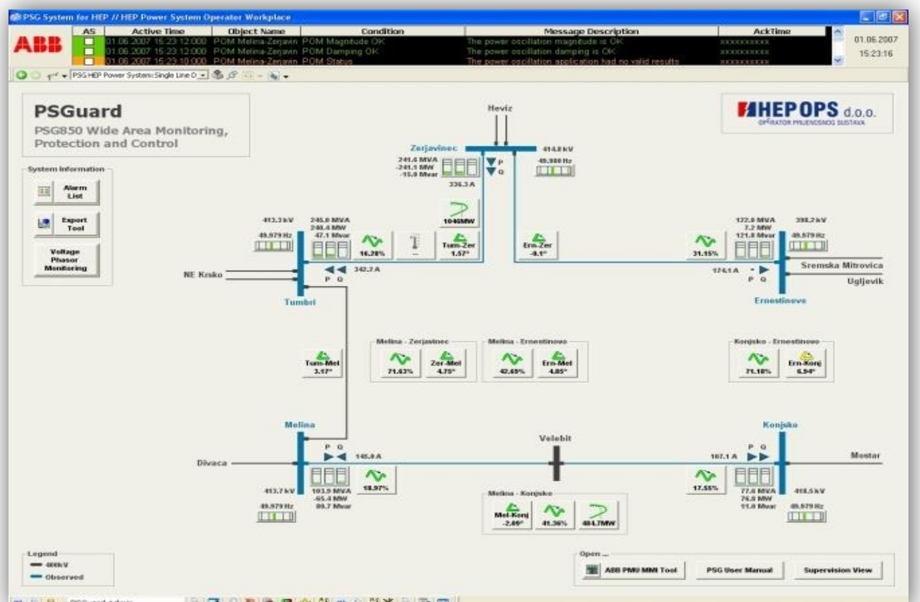
Wide Area Monitoring System
Swissgrid (Switzerland)



- Since 2004
- 7 PMUs – ABB RES521
- Connection to PDCs & PMUs from major European utilities allow monitoring of dynamics across Europe
- Monitoring and early warning system for the loading of the north-south corridor of the Swiss transmission grid
- SCADA integration
- Monitoring of reconnection of UCTE zones (2004)

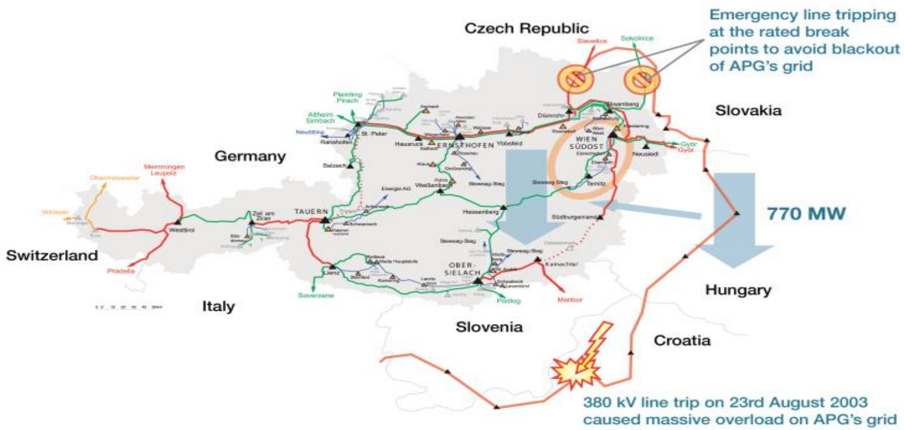


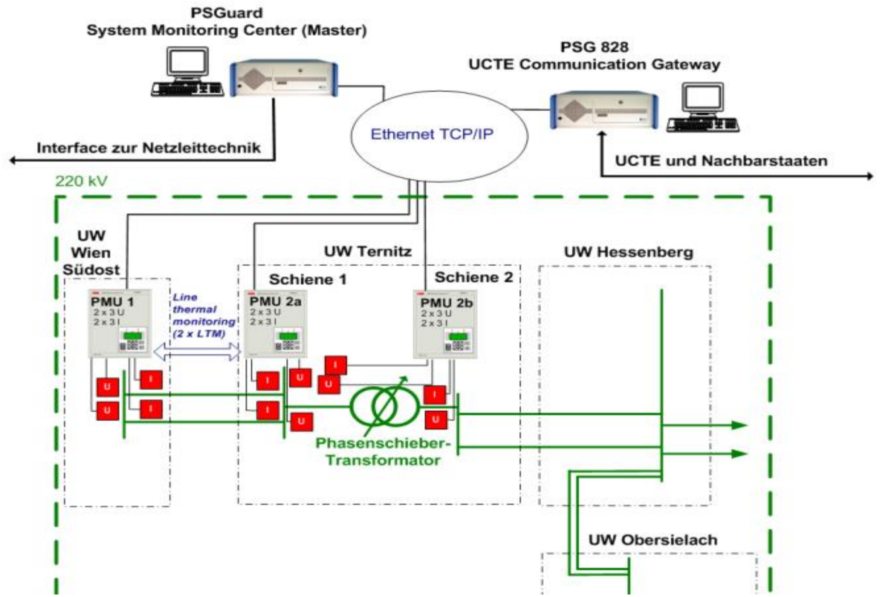
Wide Area Monitoring System
HEP (Croatia)



- Since 2003
- 14 PMUs – ABB RES521
- Enhance stability of transmission system and optimize utilization of transmission capacity
- Features:
  - 20 ms
  - Basic monitoring, storage and archive
  - Line thermal monitoring
  - Voltage stability monitoring
  - Data exchange with other PDCs

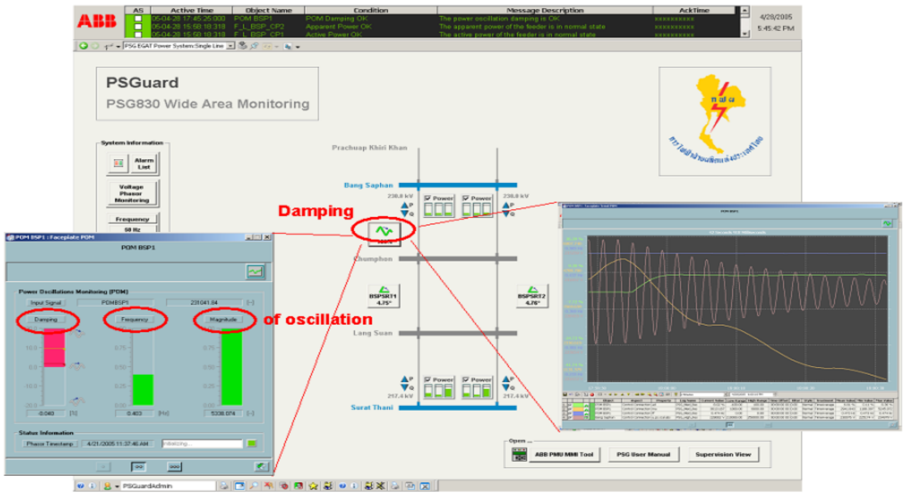
Wide Area Monitoring System
APG (Austria)



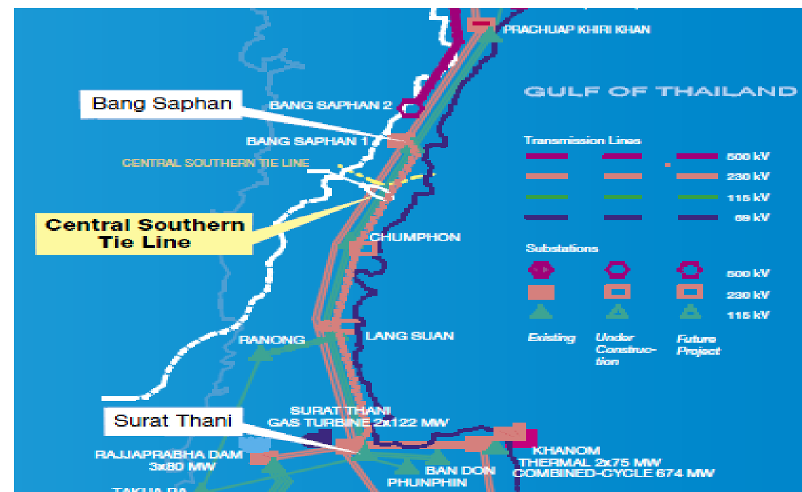


- Since 2005
- Monitoring of the vital 220 kV double lines between Vienna and Ternitz substations with phase angle monitoring and line thermal monitoring
- 3 PMUs – ABB RES521

Wide Area Monitoring System
EGAT (Thailand)



- Since 2005 (First WAMS in Asia)
- 4 PMUs – ABB RES521
- Monitor stability of heavily loaded 230 kV transmission lines between southern and central region of Thailand
- Application of Power Oscillation Monitoring to detect power swings



Conclusion

- Use of synchrophasor measurements can assist greatly in meeting strenuous reliability and power delivery requirements placed on power systems evolving today
- Synchrophasor measurements could be used for local and wide are monitoring, control and protective relaying applications
- Active standardization (supported by smart grid developments) enables interoperability and faster adoption of the synchrophasor technology by the power industry

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