Online Stability Solutions
Recent Advances

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we are shaping the future | ALSTOM

Emerging Smarter Grid Technologies & Solutions

- Advanced Sensing & Measurement
- Smart Meters
- Phasor Measurement Units (PMUs)
- Integrated Communications
- Advanced Components and Controls
- Improved Decision Support systems
- Advanced Visualization technologies
- Low Carbon emission technologies

And….Computing power:
"..the smartphones we use today
have more computing power than all of NASA did in 1969."
Prof Michio Kaku, City University of New York.

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Today's Grid Monitoring is changing

- Synchrophasor measurement devices are being deployed aggressively worldwide (PMUs, DFRs, etc)
  - Each PMU provides 10-12 separate sub-second measurements
    - voltages, currents (3 phases, positive/negative/zero sequence)
    - frequencies, rate of change of frequencies
    - Precise time-tags, minimal latency
- <u>Real-time grid measurements will be 60 to 120 times faster!</u>
  - Today 2-4 measurements/sec rate, without time tags
  - Tomorrow 30-60 samples/second rate, with time-tags
- A <u>time-synchronized snapshot</u> of grid conditions, at a sub-second rate

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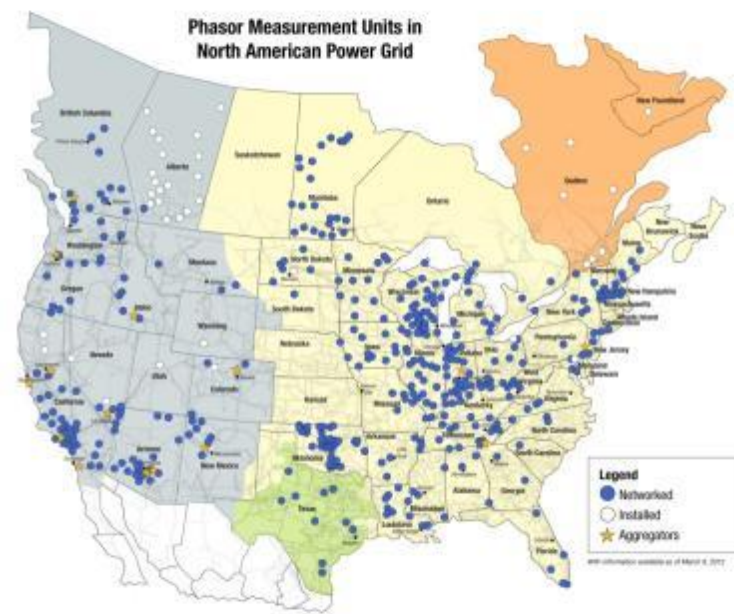
North American SynchroPhasor Initiative (NASPI)
DOE SGIG projects

DOE and NERC are working together closely with industry to enable wide area time-synchronized measurements that will enhance the reliability of the electric power grid through improved situational awareness and other applications

April 2007

March 2012



"Better information supports better - and faster - decisions."

NASPI North American SynchroPhasor Initiative

NERC NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

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Evolution of EMS Capabilities

EMS			PhasorPoint
Traditional MODEL-BASED Analysis			PMU MEASUREMENT-BASED Analysis
	SCADA & Alarms	WAMS Alarms	
Other EMS Applications	State Estimator	State Measurement	New Applications
	Small Signal Stability	Oscillation Monitoring	Grid Stability Analysis
	Transient & Voltage Stability	Stability Monitoring & Control	
	Island Management	Island Detection, Resync, & Blackstart	
	Control Center - PDC		

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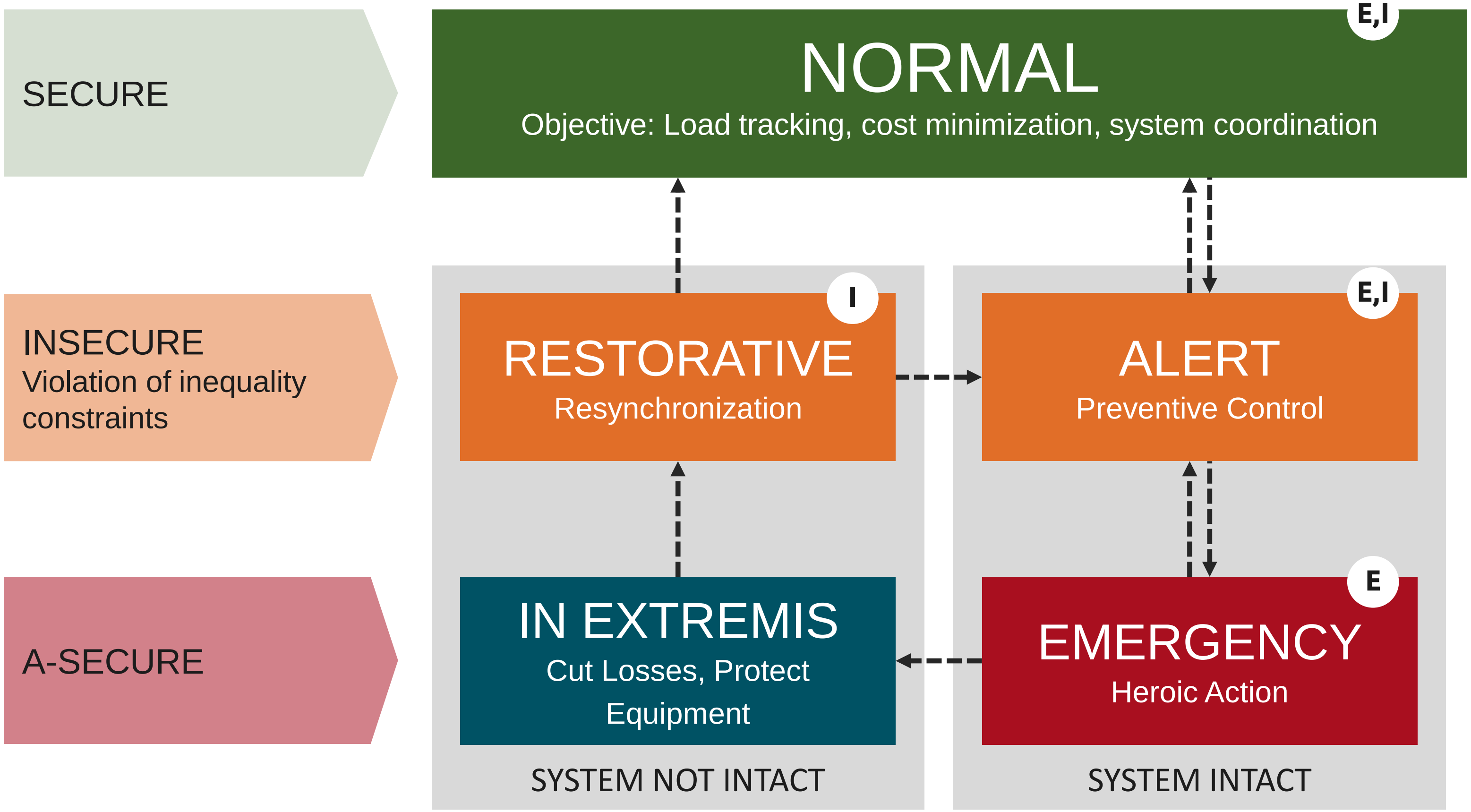
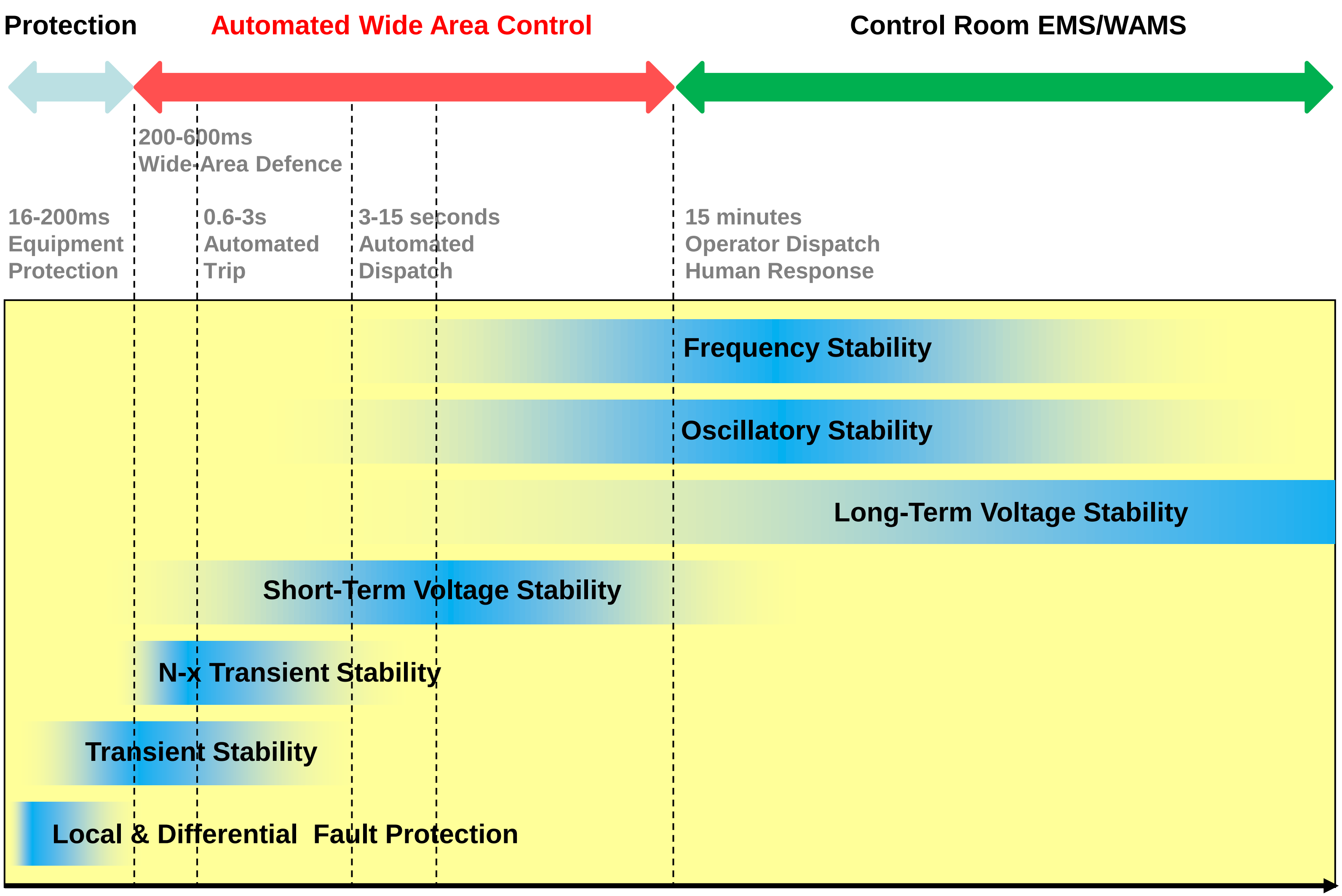
Today the focus is on
is on grid dynamic security as well!

E = Demand is met, I = Constraints are met



Timeframe for Stability Actions

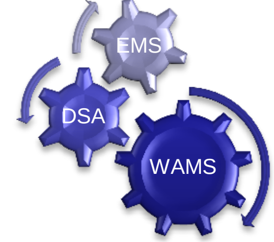
The next step - Bridging the grid dynamics gap!



Types of Grid Oscillations

- Inter-area oscillations = 0.1 –0.7 Hz
- Local generator oscillations = 0.5 –2.0 Hz
- Wind turbine-generator torsional = 1.5 –2.0 Hz
- HVDC control modes ~ 5 Hz, 30Hz ?
- Exciter control modes ~ 5 Hz
- Steam turbine torsional ~5Hz, 10Hz, 15Hz, 30 Hz, 50 Hz
- Harmonics

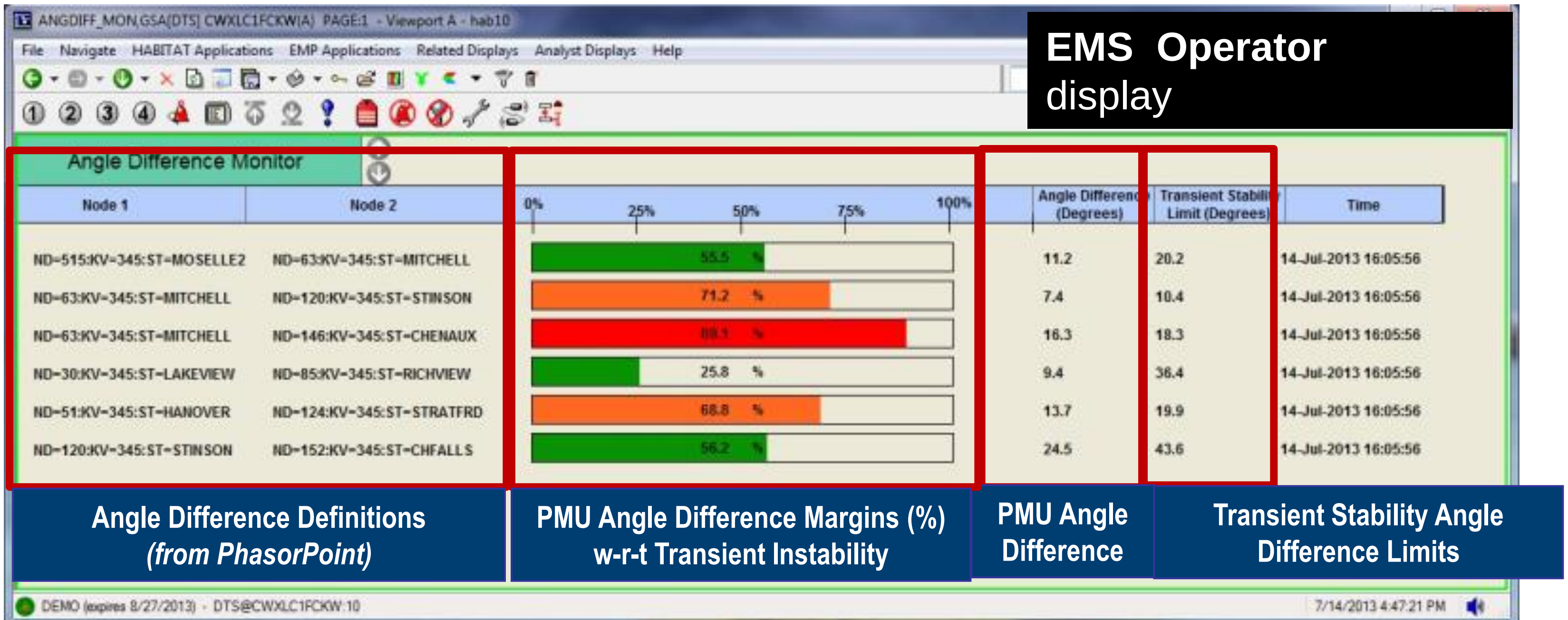
Real-Time Dynamic Limits



Combining ***measurement-based*** (PhasorPoint) and

model-based (Powertech's DSA tools) technologies.

Releasing latent capacity across PG&E's stability limited transfer paths.



PHASORPOINT

Powertech

Alstom/Psymetrix experience with dynamics studies

Description	Reference
Systems Studies using high speed (most recently synchrophasor) measurements to validate dynamic models and to ensure system stability (inter-area oscillations) following the deployment and testing of Power System Stabilisers/Power Oscillation Damper and Static VAR Compensators	Manitoba Hydro, Canada 1999*, 2012
Tuning Power System Stabilisers/Power Oscillation Dampers	Landsnet, Iceland, 2007*,2008,2011,2012,2013 (Multiple projects)
Studies to identify causes of very low frequency oscillations (governor controller) issues in the region of 0.05Hz	Energinet, Denmark, 2011 XM, Colombia, 2010*
System studies using synchrophasor measurements to identify inter-area oscillations issues in transmission systems	ESKOM, South Africa, 2011*
Studies using phasor measurements to increase the capacity of medium voltage networks in order to support connection of additional wind turbines	Scottish Power, UK, 2012
Design of synchrophasor based automated response systems to manage load balancing within transmission networks	Landsnet, Iceland, 2012

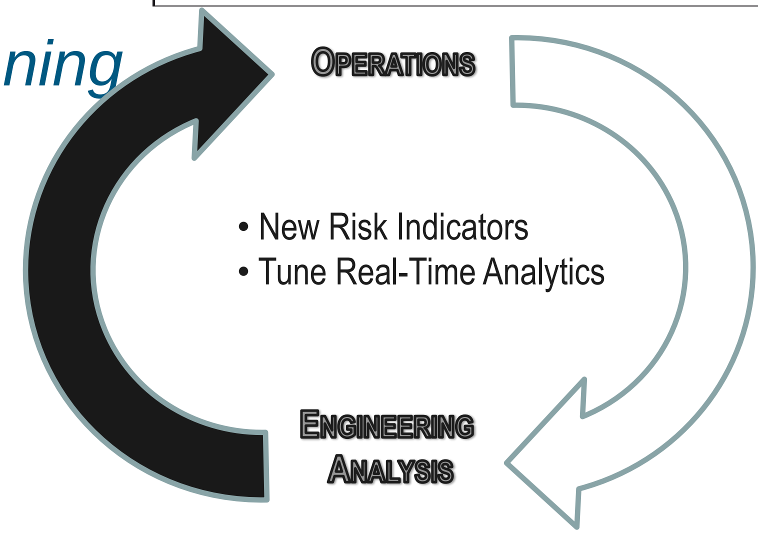
Synchrophasor Solutions Worldwide

Operationally Proven

1. 2011 Manitoba Hydro
2. 2011 WECC
3. 2011 ISO-NE
4. 2011 Midwest ISO
5. 2011 Svenska Krafnat
6. 2011 Eskom
7. 2011 China
8. 2010 PG&E
9. 2010 Mexico
10. 2009 Colombia
11. 2009 Energinet
12. 2007 UK Consortium
13. 2006 Iceland
14. 2000 Powerlink
15. 1995 Scottish Power

e-terra *Phasor Analytics*

Leveraging WAMS in Operations Planning



- New Risk Indicators
- Tune Real-Time Analytics

Post Event Analysis

- Quicker post-mortem analysis.
- Sequence of events & root cause analysis.

Dynamic Model Validation

- Dynamic model verification.
- Generator model calibration.
- Load characterization.

Baselining

- Assess dynamic performance of the grid.
- Steady-state angular separation.
- System disturbance impact measures.

Compliance Monitoring

- Primary frequency (governing) response.
- Power System Stabilizer (PSS) tuning

Synchrophasor benefits for Post-Event Analysis

In the case of the 2007 Florida blackout, NERC investigators used phasor data to create the sequence of events and determine the cause of the blackout in only two days; in contrast, lacking high-speed, time-synchronized disturbance data it took many engineer years of labor to compile a correct sequence of events for the 2003 blackout in the Northeast U.S. and Ontario.

NERC RAPIR Report, 2010.

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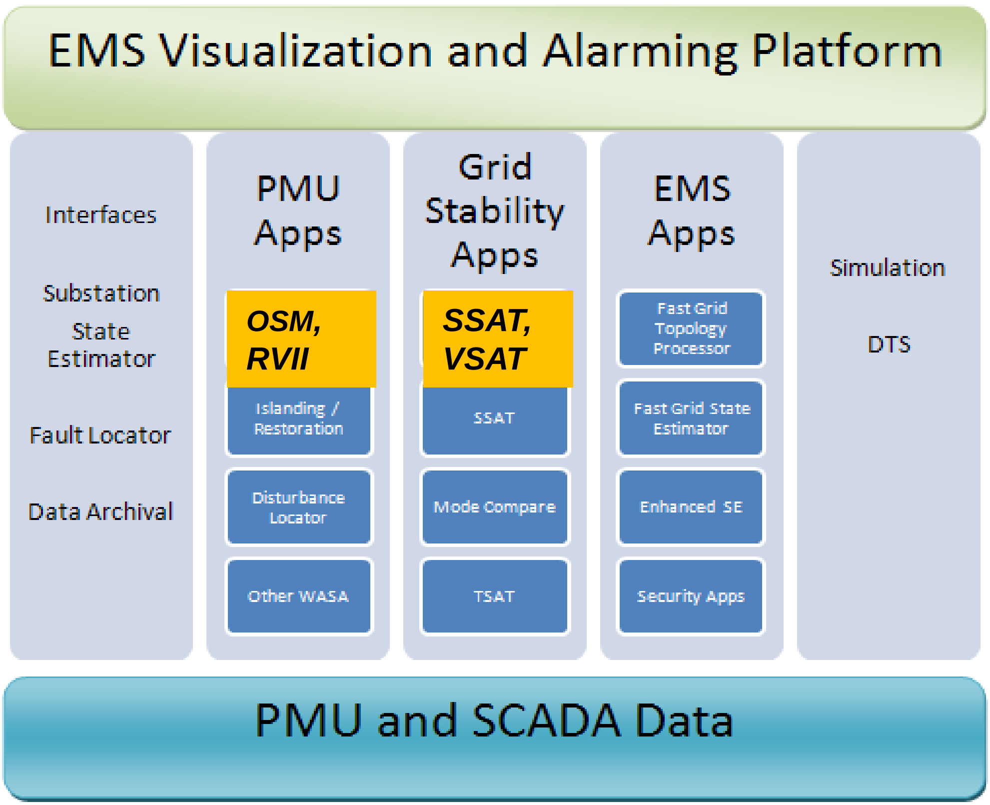
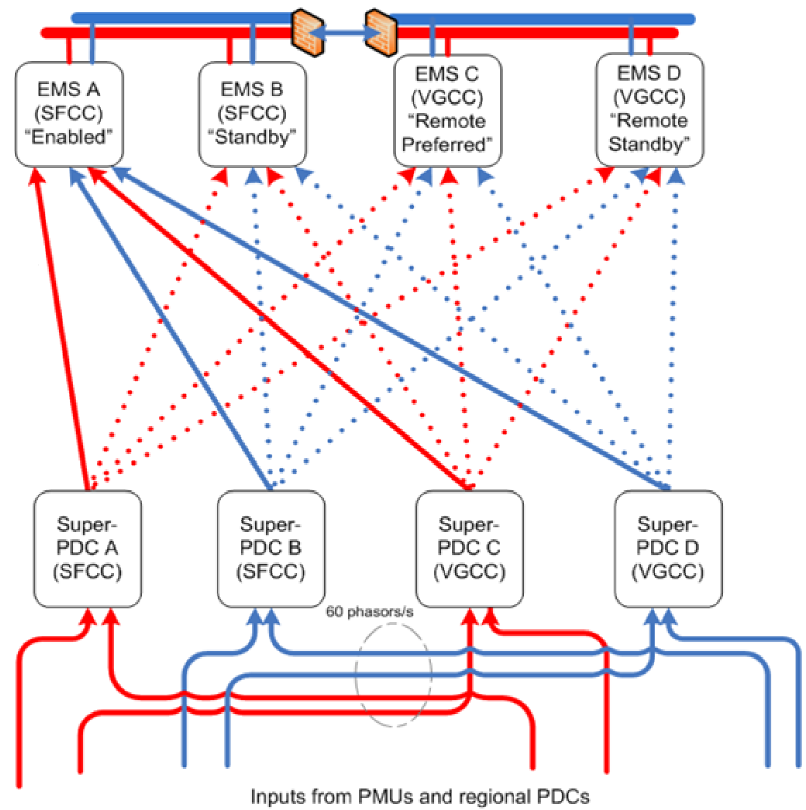
PG&E- Proof of Concept Facility

Strategic Team: ***PG&E, ALSTOM, GE, Mississippi State University, Quanta***

Academic & Testing ***Georgia Tech, OMICRON / RTDS / Virginia Tech., Washington State Univ.***





SynchroPhasor Applications for the Control Center ***Multi-host Redundancy (ISD Link)***

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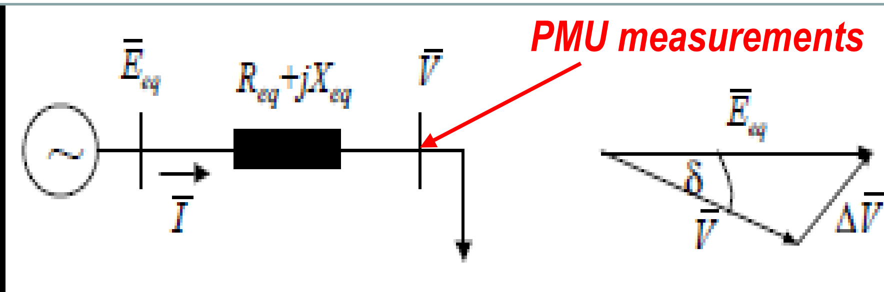
Voltage Stability Monitoring & Mitigation

An integrated "measurement-based" and "model-based " approach

MEASUREMENT-BASED

PMUs

Real-Time Voltage Instability Indicator (RVII)



Estimate equivalent parameters in real-time

QUANTA TECHNOLOGY

Detect WHEN in danger!

- *Bus Voltage (V)*
- *Equivalent Impedance (Z_{eq})*
- *Reactive Margin (Q_{margin})*

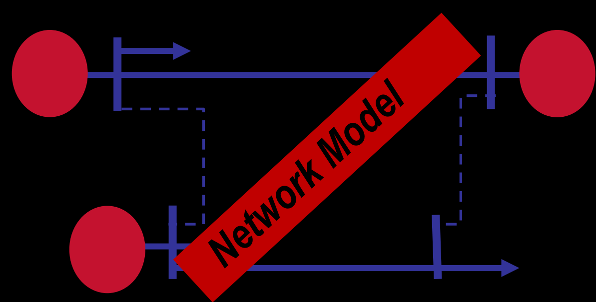
MODEL-BASDED

EMS & Online-DSA Applications

CA

VSAT

RAS



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Determine HOW to respond!

- *Predict Q_{margin} changes under "worst case" contingency.*
- *Provide recommendations on corrective actions.*

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Online Stability Solutions overview

	MONITOR	ASSESS/PREDICT	MITIGATE
Frequency Instability	▪ Detect islanding conditions. ▪ Monitor resynchronization process.	▪ Identify island boundaries ▪ Resource-generation mismatch	De-dispatch recommendations (to balance resources).
Voltage Instability	▪ Detect voltage stability problems (CE, RVII). ▪ Reactive reserve monitoring.	▪ VSAT based MW margins, critical contingencies, weak-elements, etc.	▪ VSAT based corrective controls.
Transient Instability	▪ Angle difference monitoring. ▪ Energy based indices.	▪ TSAT based MW margins, angle-difference limits, etc.	▪ TSAT recommendations for corrective actions. ▪ Arm PMU-based SPS..
Small-Signal Instability	▪ Monitor Damping level. ▪ Monitor Oscillation amplitudes.	▪ SSAT based MW margins, critical contingencies.	▪ SSAT recommendations on corrective actions. ▪ Mode Power Path
Complex Events	▪ Composite Events. ▪ Integrated with RAS capabilities.	▪ Trigger online-network sequence. ▪ Multi time point prediction.	• Linkages to Operator Guides. • Arm RAS.
Grid Optimization	Angle difference monitoring *(extend to voltage, risk indicators etc).*	Angular constraints in OPF.	▪ Re-dispatch recommendations (sensitivity-based).

“Model, Measure, Monitor, Mitigate!”

adapted – original credit to ‘3Ms’ by Jeff Fleeman, AEP

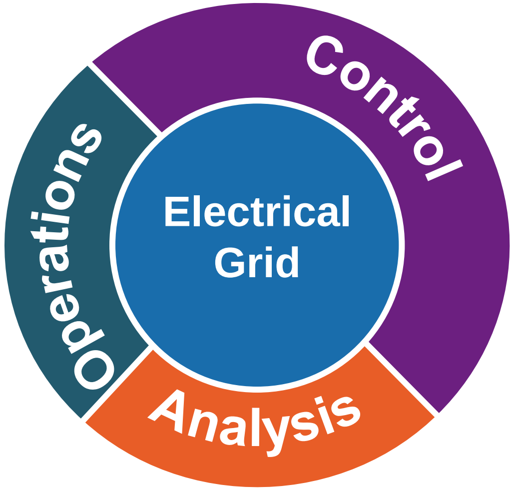
Control Room Operations

Wide-Area situational awareness and coordination across seams.

Create and manage robust real-time variable stability limits.

Add Operational Response Guidance to

Situational Awareness for Critical Conditions



Wide Area Control

Co-ordinated control hierarchy, centralized (via EMS/DMS), or decentralized as appropriate.

Engineering Analysis

Big Data Analytics

Risk assessment, data mining, baselining for grid vulnerability.

Analysis tools for condition monitoring, model validation, control tuning, post-event analysis, compliance monitoring.

Next steps - Transition to Wide Area Grid Control

Think Globally

&

Act Locally!

Thank you!

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