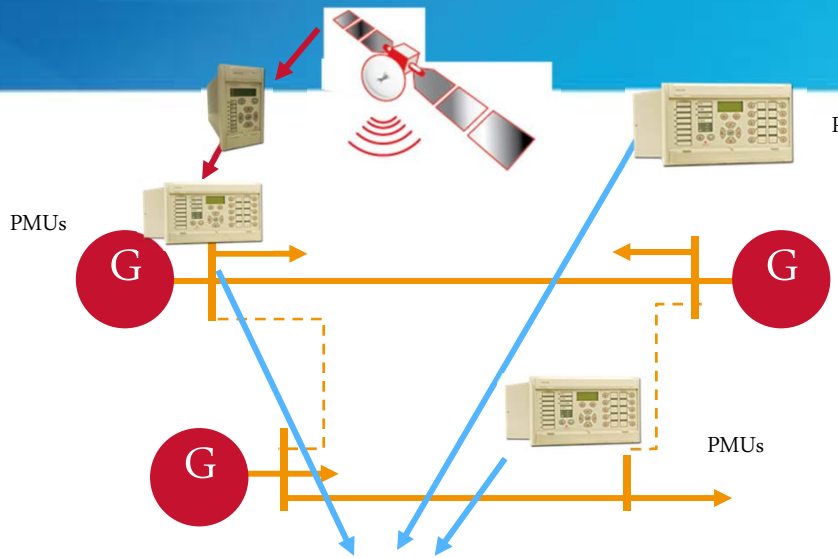
openPDC in the Control Center

August 22th, 2012

Barbara Motteler

ALSTOM

ALSTOM's Integrated SynchroPhasor Solution



EMS

Improved State Estimation using PMUs

e-terratransmission

Phasor Data Concentrator (openPDC)

1 per second

30-60 per second

Wide-Area Advanced Visualization

PMU Measurement-based information

(e.g. Oscillation Detection)

e-terravision

SynchroPhasor Applications

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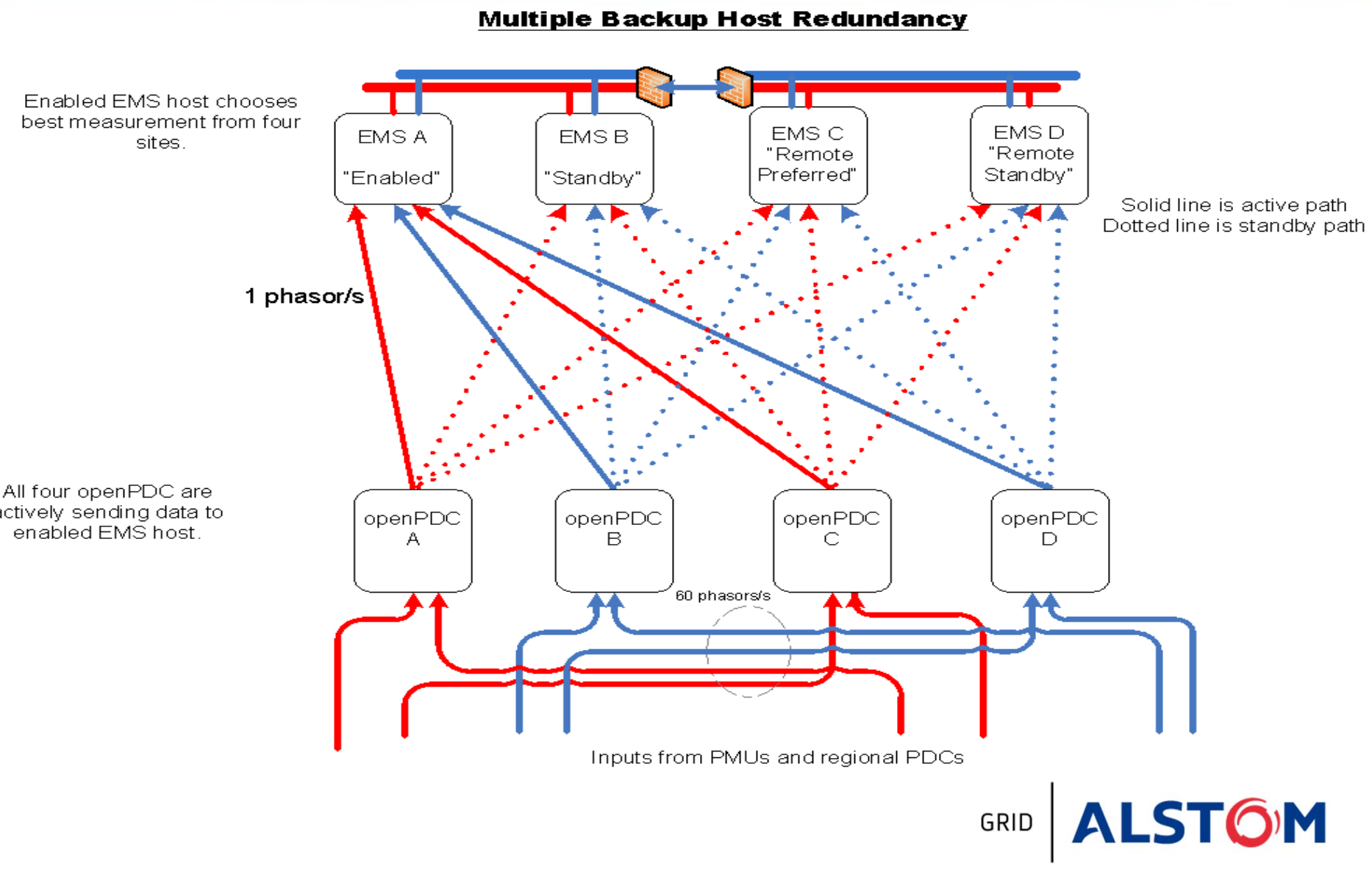
OpenPDC with Multi-Host Redundancy (ISD Link)



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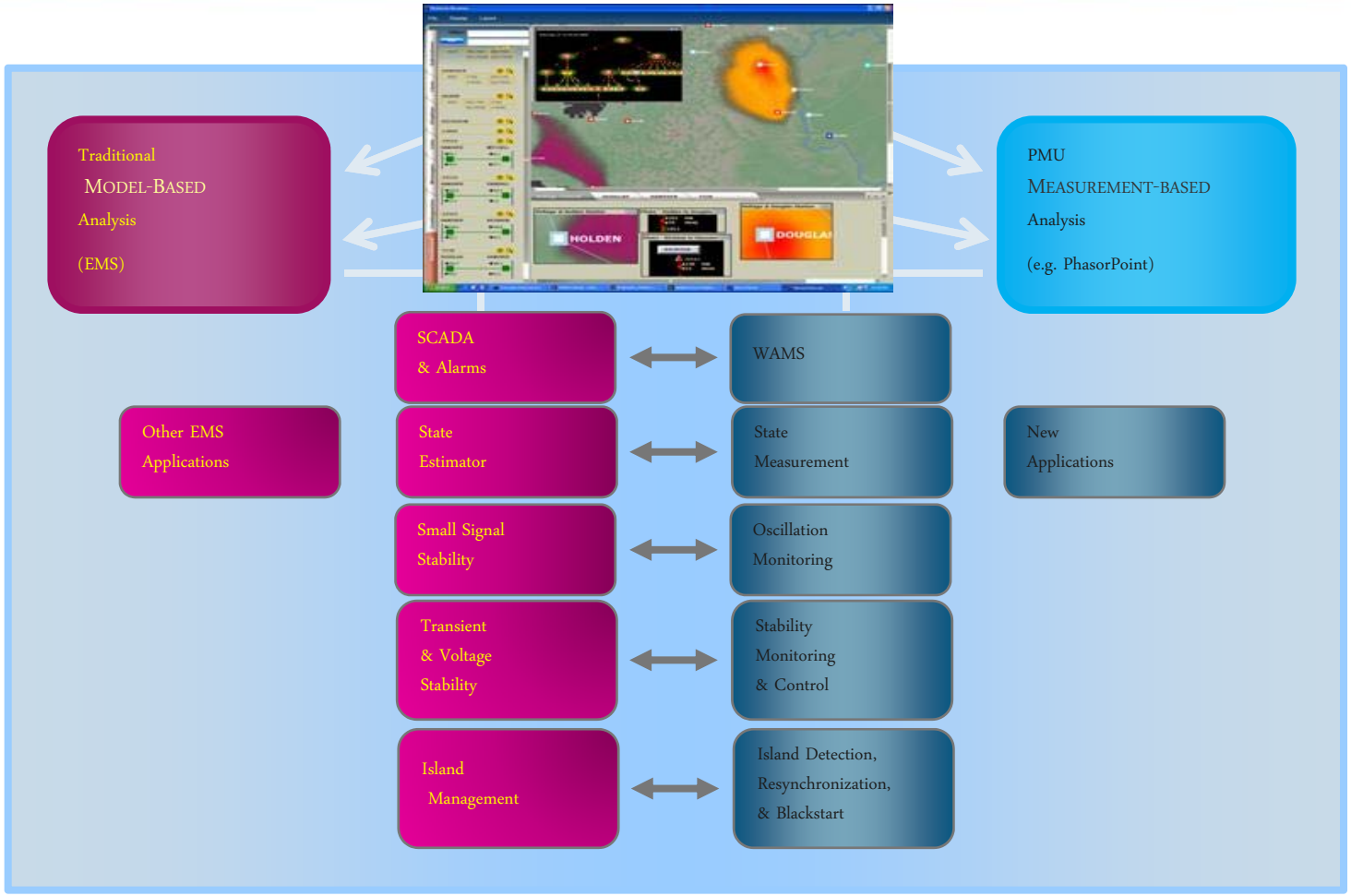
Our Vision for SynchroPhasors....

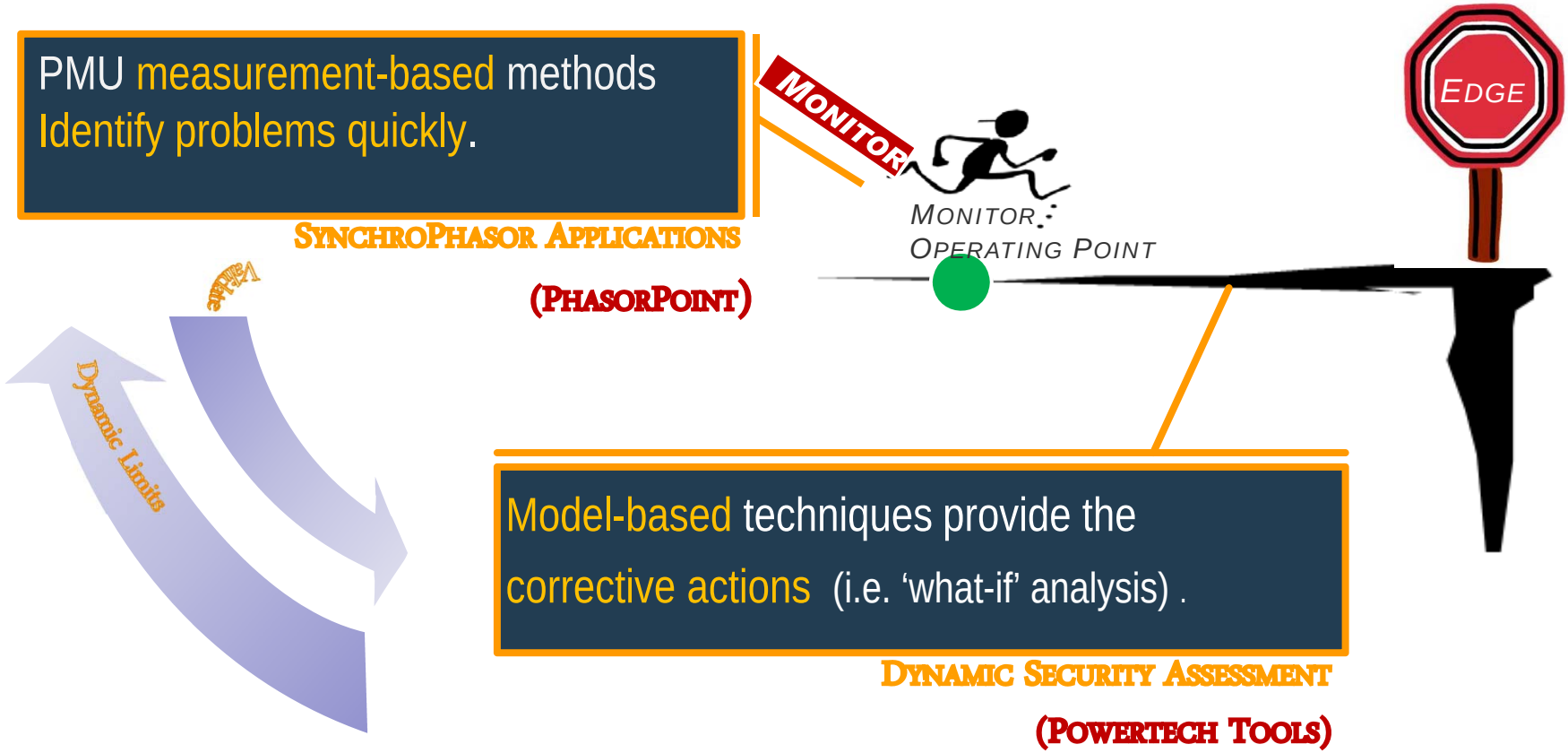


An Integrated *"measurement-based"* and *"model-based"* approach.....

PMU measurement-based methods Identify problems quickly.

SYNCHROPHASOR APPLICATIONS

(PHASORPOINT)



Model-based techniques provide the corrective actions (i.e. 'what-if' analysis) .

DYNAMIC SECURITY ASSESSMENT

(POWERTECH TOOLS)

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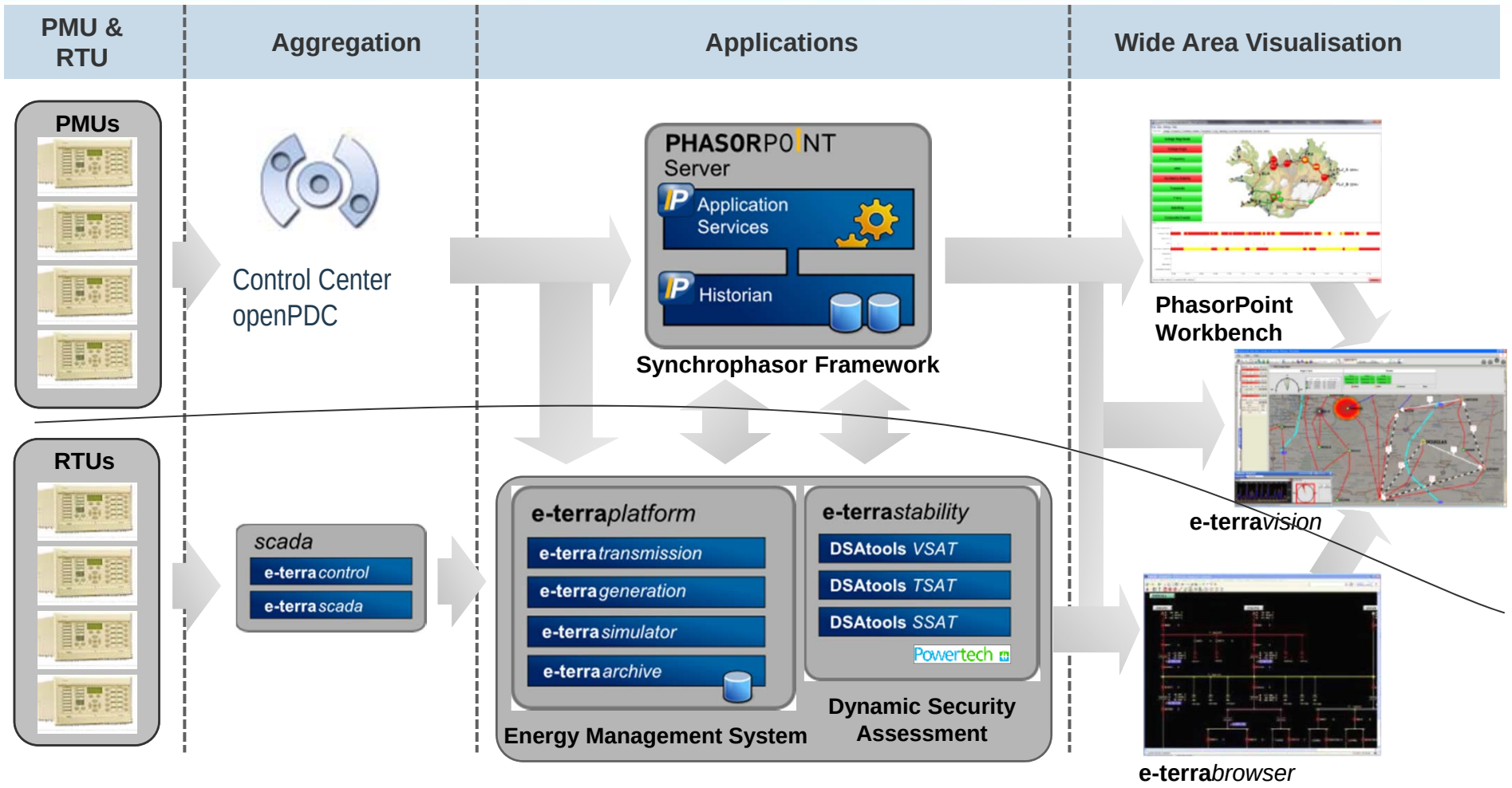
Our Solution



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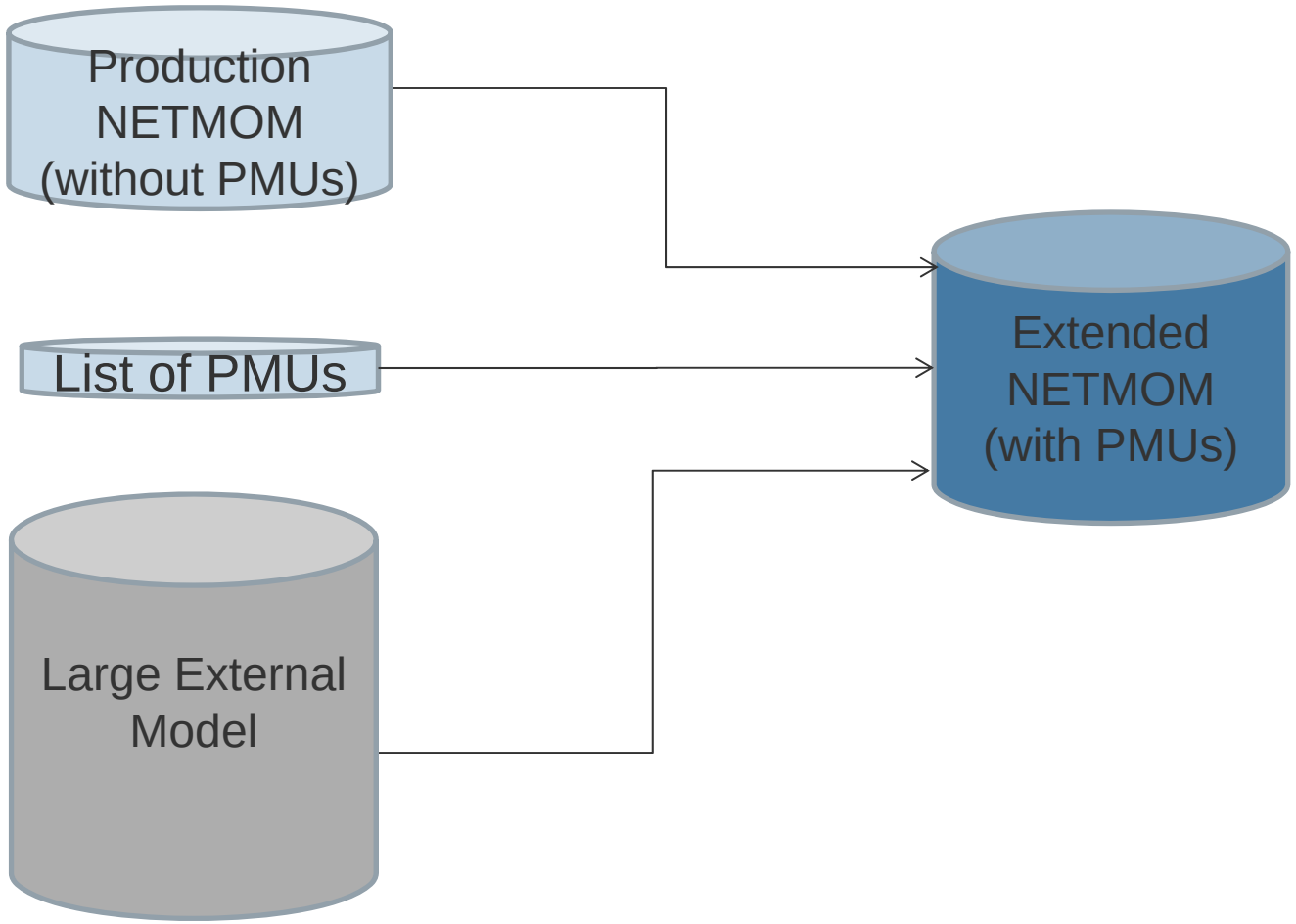
Integrating PMU based Applications

Philosophy: Complement Model based applications with Measurement based Applications

- **Linear State Estimator (LSE)**
- **Substation Super Calibrator (GeorgiaTech)**
- **Fault Indicator**
- **Future:**
  - **Voltage Stability Predictor**
    - **Based on Singular Value Decomposition**
    - **Based on Thevenin equivalents**

Extended Network Model



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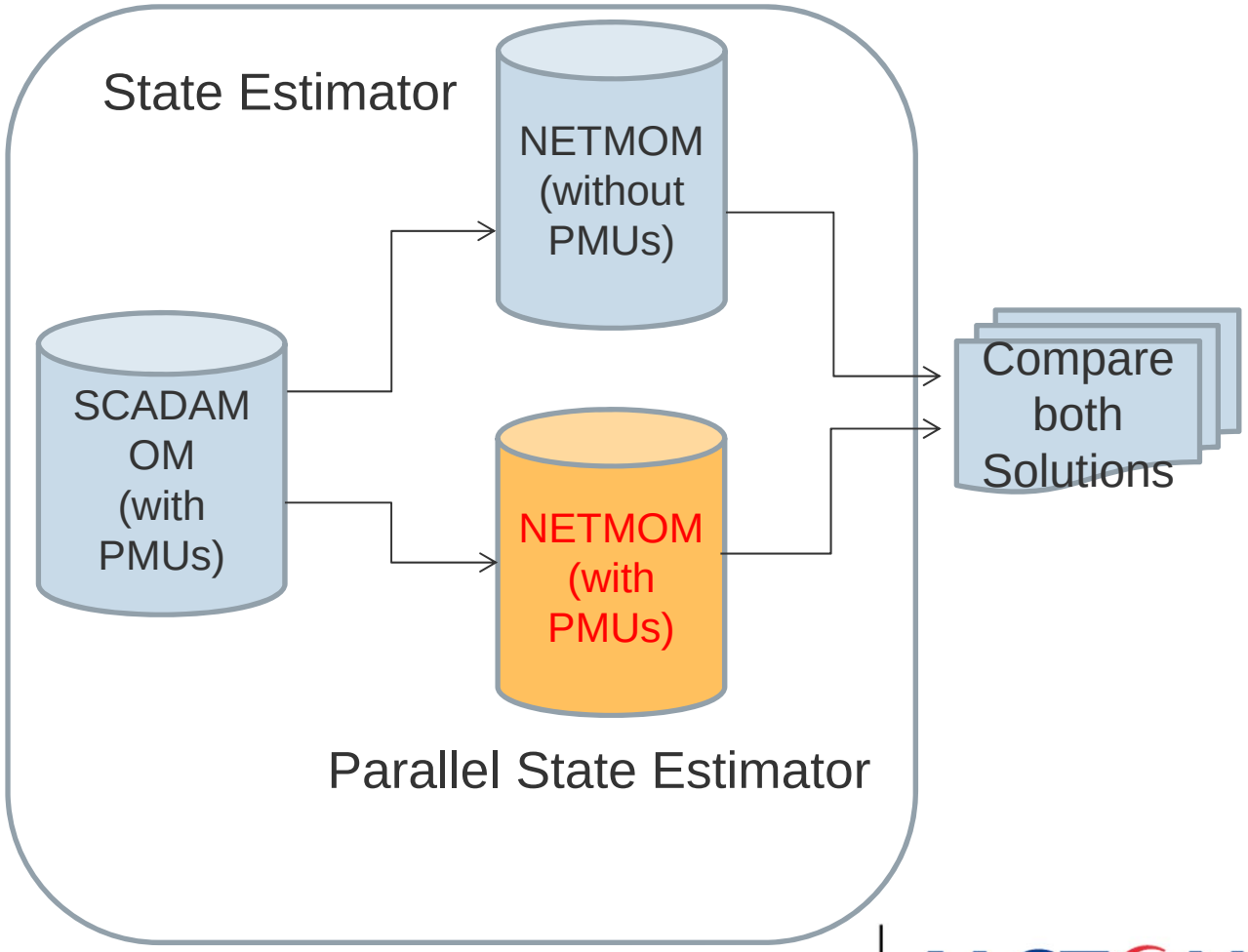
Framework – Parallel State Estimator



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Enhanced EMS State Estimator with PMUs

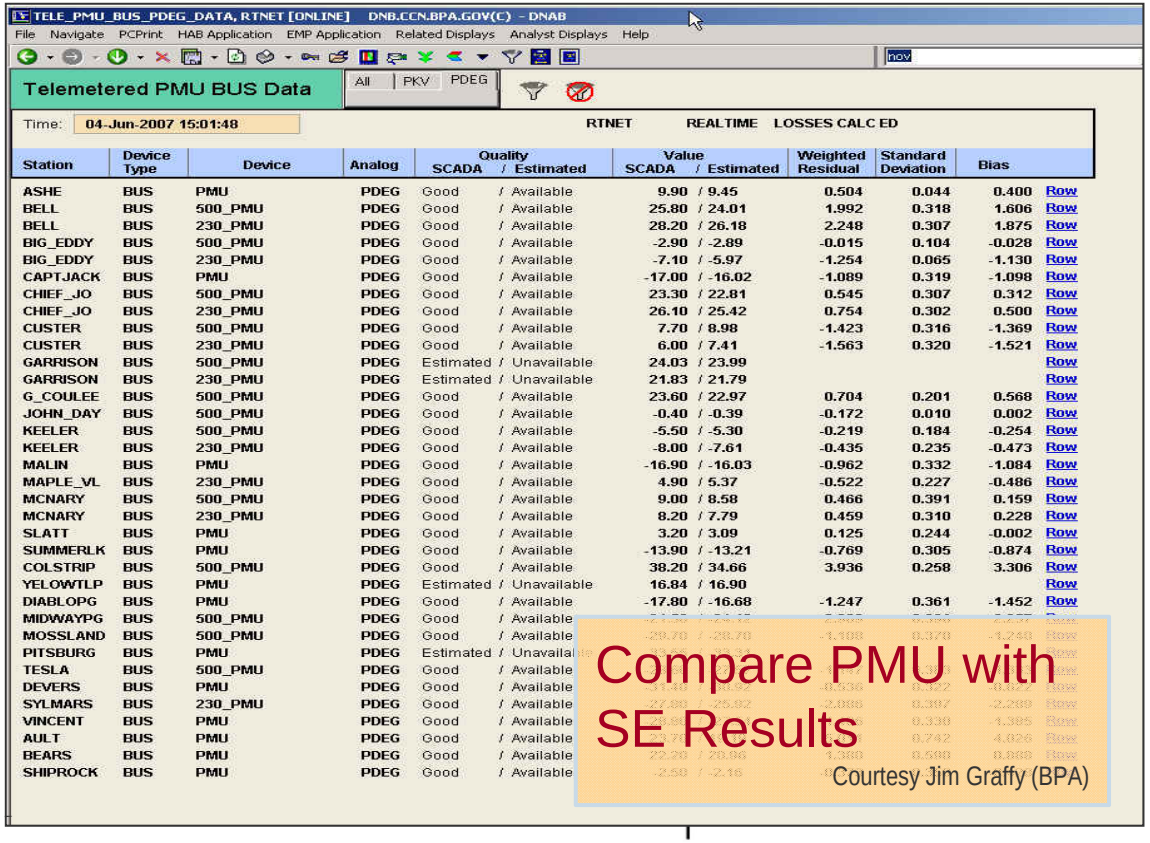
Uses PMU data at the 1 sample/sec rate

Utilization of PMU data (voltage & Current Phasors) in SE to improve round-the-clock reliability & robustness.

- Increase the number of 'Valid Solutions' ⇒ improved reliability
- Reduce dependency on 'Critical Measurements' ⇒ better observability
- Improved SE solution quality to minimize 'Variance of State'

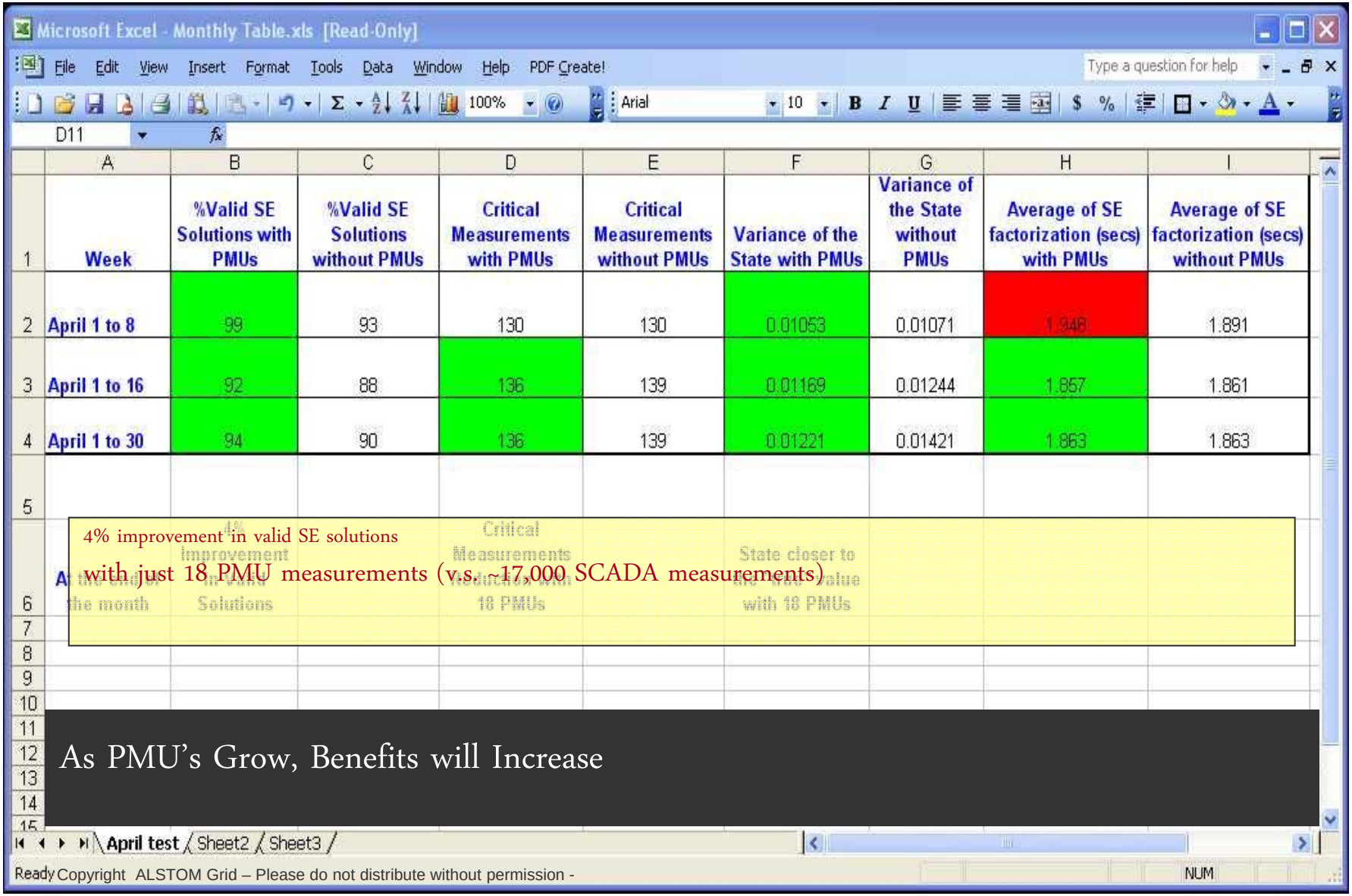
  ⇒ higher accuracy
- Fewer SE iterations

  ⇒ faster performance



Online SE with PMUs

Co-funded project (Phase 2 - Completed in 2008)



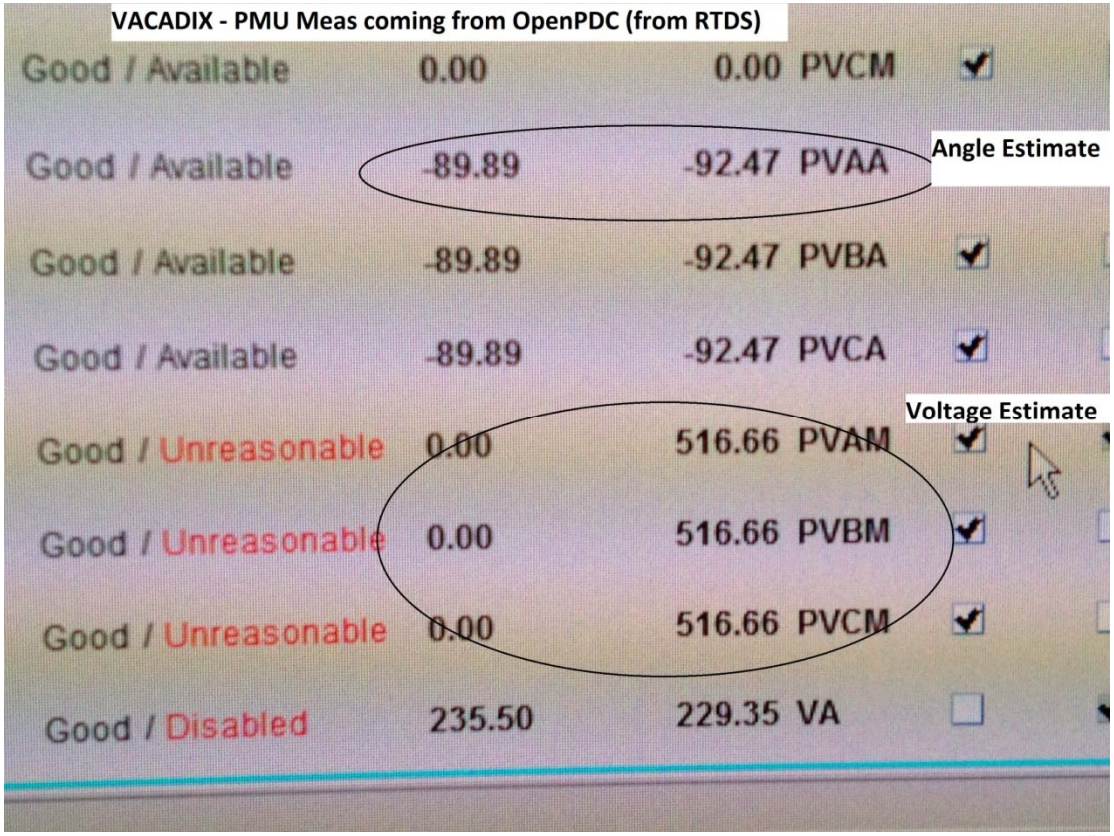
	A	B	C	D	E	F	G	H	I
1	Week	%Valid SE Solutions with PMUs	%Valid SE Solutions without PMUs	Critical Measurements with PMUs	Critical Measurements without PMUs	Variance of the State with PMUs	Variance of the State without PMUs	Average of SE factorization (secs) with PMUs	Average of SE factorization (secs) without PMUs
2	April 1 to 8	99	93	130	130	0.01053	0.01071	1.948	1.891
3	April 1 to 16	92	88	136	139	0.01169	0.01244	1.857	1.861
4	April 1 to 30	94	90	136	139	0.01221	0.01421	1.863	1.863

4% improvement in valid SE solutions

with just 18 PMU measurements (v.s. ~17,000 SCADA measurements)

As PMU's Grow, Benefits will Increase

- Preliminary Results – Only 2 PMU Voltage info is used for SE (NO field RTU meas is used)



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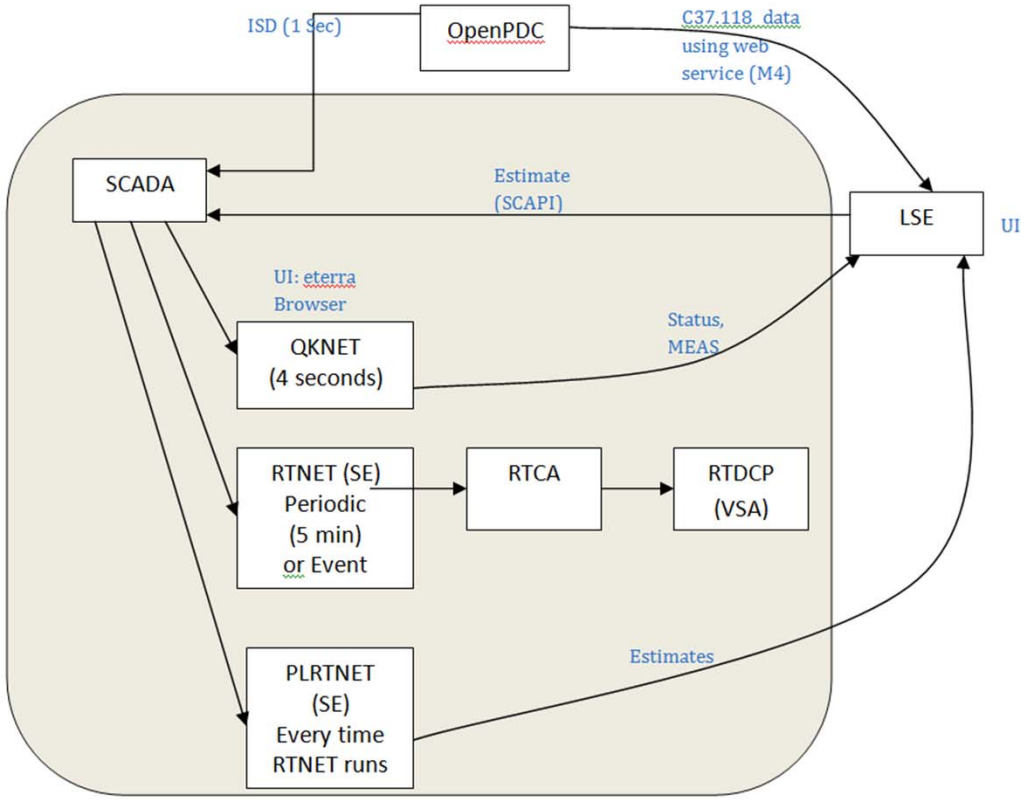
LSE Application Context



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Linear State Estimator – Benefits

The goal is to run SE at **subsecond** cycles using phasor measurements - Much faster than State Estimator

Validation of PMU data, including the possibility of topology error detection at substation level

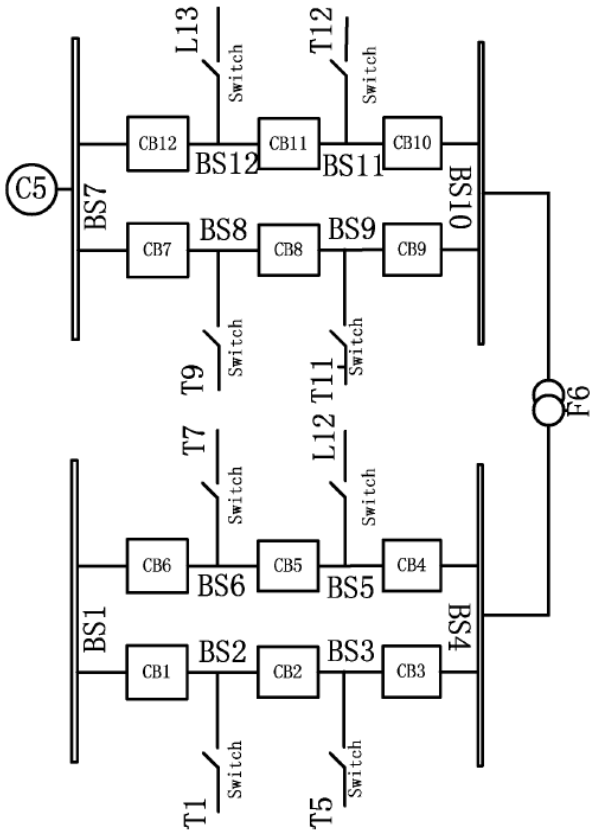
Output of LSE can be used for RAS, SE - Estimated values (as opposed to raw inputs)

Substation Level LSE

Analog State Estimation

- State:
  - Currents on Circuit Breakers
- Measurements:
  - Injection Currents to Nodes: Z_{inj}
  - Currents on Circuit Breakers: Z_{cb}
- Measurement Functions
  - Kirchhoff's Current Law
  - Identity Matrix
  - Formula:

$$z = \begin{pmatrix} z_{inj} \\ z_{cb} \end{pmatrix} = \begin{pmatrix} A_{KCL} \\ I \end{pmatrix} \mathrm{x} + \begin{pmatrix} r_{inj} \\ r_{cb} \end{pmatrix} = Hx + r$$



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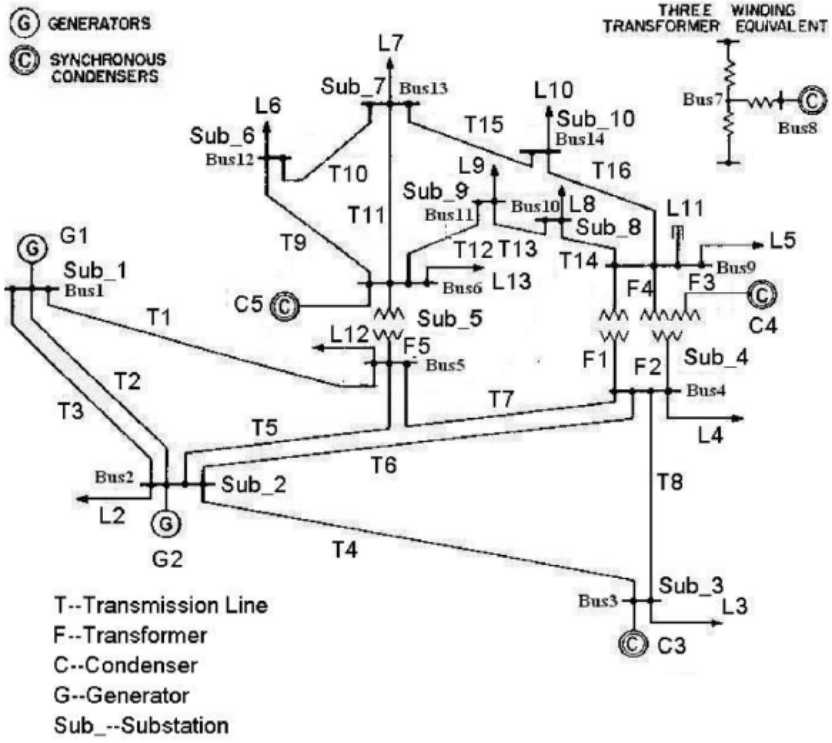
Control Center Level LSE

State Estimation

- States
  - Complex Bus Voltages
- Measurements (Phasor)
  - Bus Voltages: V_{bus}
  - Two Direction Branch Currents: I_{b1}, I_{b2}
  - Injection Currents: I_{inj}
- Measurement Functions

$$z = \begin{pmatrix} V_{bus} \\ I_{b1} \\ I_{b2} \\ I_{inj} \end{pmatrix} = Hx + r = \begin{pmatrix} I \\ Y_{b1} \\ Y_{b2} \\ Y \end{pmatrix} x + r$$



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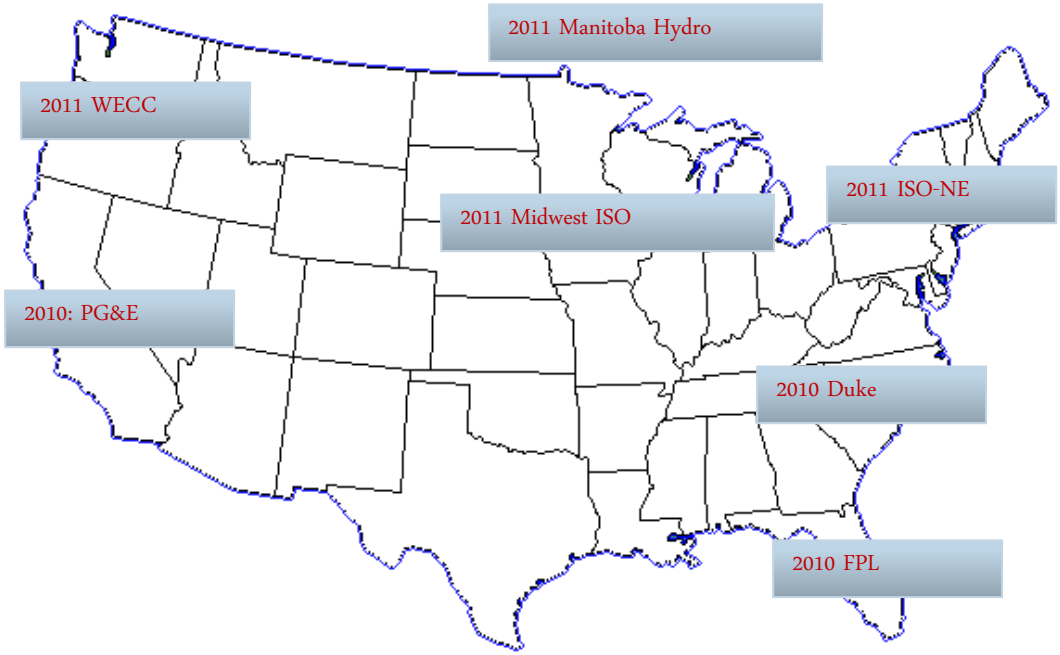
ALSTOM Involvement in SGIG Contracts

- Western Electricity Coordinating Council (WECC)
- Midwest ISO (MISO)
- Pacific Gas & Electric (PG&E)
- ISO New England (ISO-NE)
- Manitoba Hydro (MH)
- Florida Power & Light (FPL)
- Duke Energy
- Active proposals being submitted to others.....



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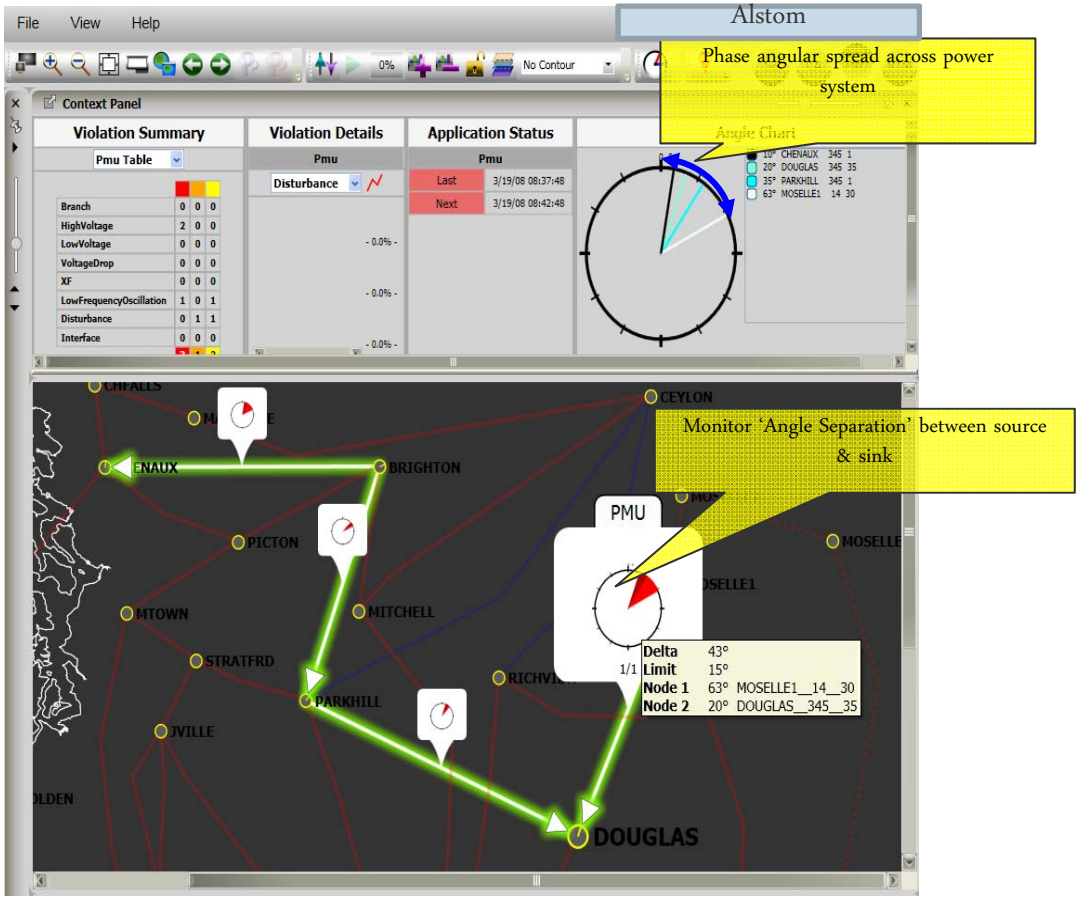
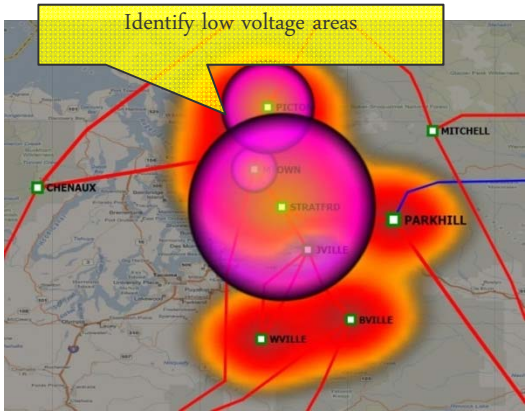
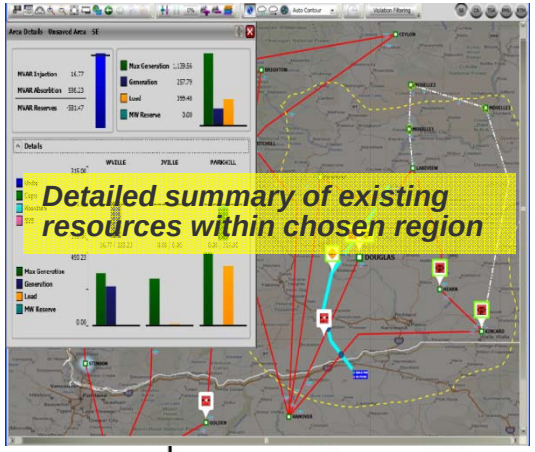
PMU Visualization within e-terra*vision*

Monitor 'angular separation' as an indicator of increased grid stress due to:

- *increased transmission path loading between 'Sources' & 'Sinks' of power*
- *sudden events such as line outages (i.e. weakening of the grid)*







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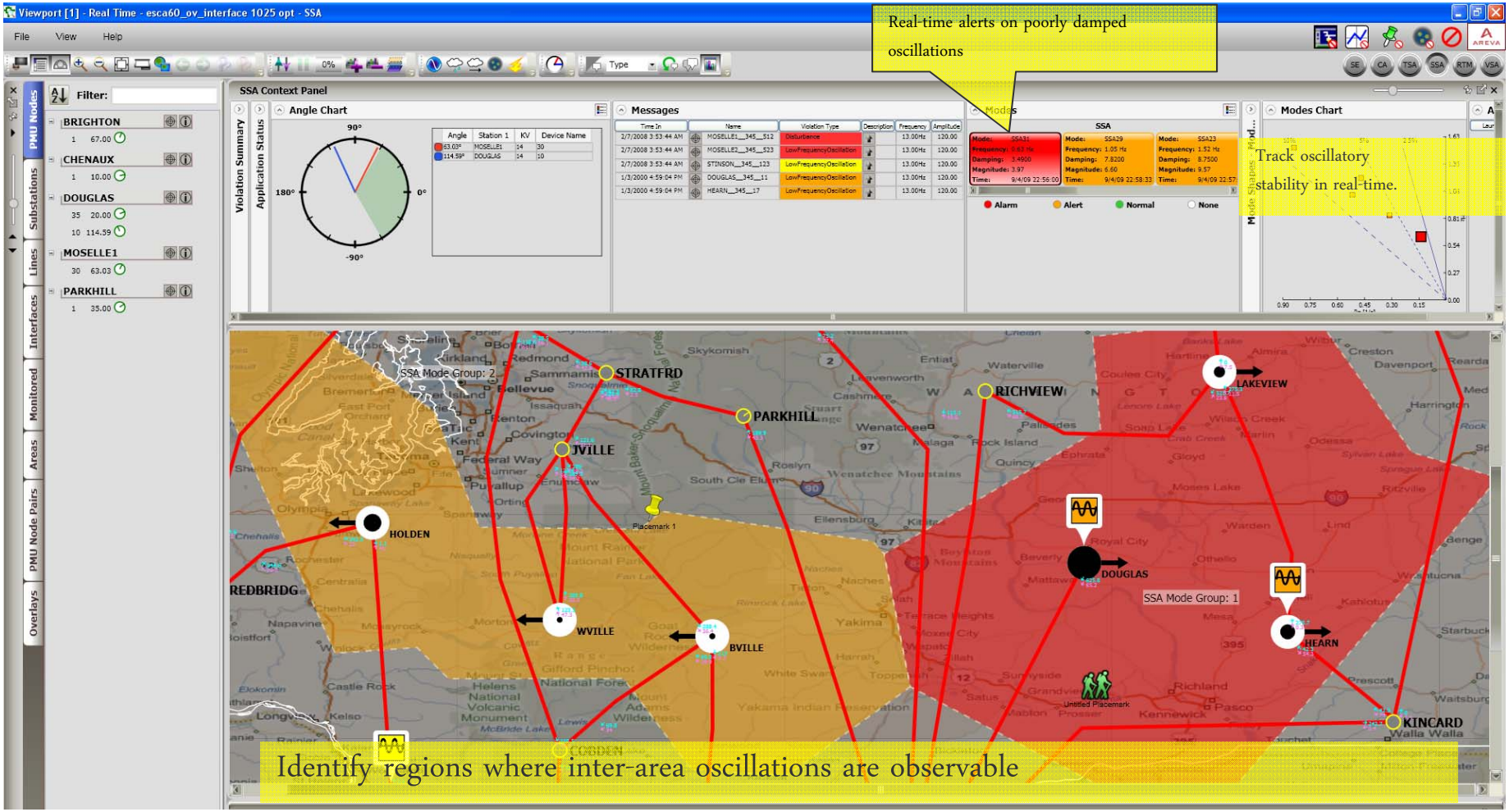
Small Signal Stability Visualization in e-terra*vision*

Modes shapes, amplitudes, damping, frequency, etc



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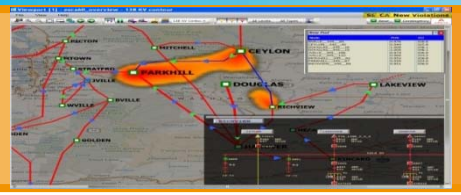
Our Implementation



Unified Wide-Area Visualization

e-terravision

VISUALIZATION

PhasorPoint Workbench

e-terrabrowser

DSA Tools UI

DATA MANAGEMENT & APPLICATIONS

Oscillatory Stability Management

Composite Event Alarms

Islanding Resync, & Blackstart

Line Parameter Estimation

SynchroPhasor Platform

Phasor Historian

Enhanced State Estimator

Contingency Analysis

Alarm Management

DTS

EMS e-terraplatform

Voltage Stability Assessment

Powertech Tools

High Speed PMU Data (30-60 per second)

Downsampled PMU Data (1 per second)

MEASUREMENT-BASED APPLICATIONS

MODEL-BASED APPLICATIONS

Control Center openPDC

DATA ACQUISITION & CONTROL

PMUs

G

G

PMUs

PMUs

Substation PDC

Damping control

FACTS