## openPDC in the Control Center

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#### ALSTOM's Integrated SynchroPhasor Solution



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## OpenPDC with Multi-Host Redundancy (ISD Link)



## Our Vision for SynchroPhasors....



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





## **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

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## **Extended Network Model**



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### Framework – Parallel State Estimator



#### 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'  $\Rightarrow$  improved reliability
- Reduce dependency on 'Critical Measurements'  $\Rightarrow$  better observability
- Improved SE solution quality to minimize 'Variance of State'

 $\Rightarrow$  higher accuracy

- Fewer SE iterations

 $\Rightarrow$  faster performance

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BIG_EDDY	BUS	500_PMU	PDEG	Good	/ Available	-2.90	/ -2.89	-0.015	0.104	-0.028	Row
BIG_EDDY	BUS	230_PMU	PDEG	Good	/ Available	-7.10	/ -5.97	-1.254	0.065	-1.130	Row
CAPTJACK	BUS	PMU	PDEG	Good	/ Available	-17.00	/ -16.02	-1.089	0.319	-1.098	Row
CHIEF_JO	BUS	500_PMU	PDEG	Good	/ Available	23.30	/ 22.81	0.545	0.307	0.312	Row
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CUSTER	BUS	230_PMU	PDEG	Good	/ Available	6.00	/ 7.41	-1.563	0.320	-1.521	Row
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JOHN DAY	BUS	500 PMU	PDEG	Good	/ Available	-0.40	/ -0.39	-0.172	0.010	0.002	Row
KEELEB	BUS	500 PMU	PDEG	Good	/ Available	-5.50	/ -5.30	-0.219	0.184	-0.254	Row
KEELER	BUS	230 PMU	PDEG	Good	/ Available	-8.00	1-7.61	-0.435	0.235	-0.473	Row
MALIN	BUS	PMU	PDEG	Good	/ Available	-16.90	/ -16.03	-0.962	0.332	-1.084	Row
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### Online SE with PMUs Co-funded project (Phase 2 - Completed in 2008)

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# Model Validation – Early Results

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



#### LSE Application Context





#### 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<sub>inj</sub>
  - Currents on Circuit Breakers: Z<sub>cb</sub>
- Measurement Functions
  - Kirchhoff's Current Law
  - Identity Matrix
  - Formula:

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



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#### Control Center Level LSE

#### State Estimation

- States
  - Complex Bus Voltages
- Measurements (Phasor)
  - Bus Voltages: *V*<sub>bus</sub>
  - Two Direction Branch Currents: *I*<sub>b1</sub>, *I*<sub>b2</sub>
  - Injection Currents: *I*<sub>inj</sub>
- 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.....





## PMU Visualization within e-terravision

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-terravision

Modes shapes, amplitudes, damping, frequency, etc



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ALSTOM SynchroPhasor Solutions





#### **Our Implementation Unified Wide-Area Visualization** e-terravision VISUALIZATION asorPoint DSA Tools UI Workbench Oscillatory Composite Enhanced Contingency Stability State Event Alarms Analysis Voltage Stability Management tion DATA MANAGEMENT Estimator Assessment **& APPLICATIONS** Islanding Line Parameter Alarm Resync, & DTS Estimation Management Blackstart Powertech Tools SynchroPhasor Platform EMS e-terraplatform Phasor High Speed PMU Data Historian Downsampled PMU Data (30-60 per second) (1 per second) **MEASUREMENT-BASED APPLICATIONS MODEL-BASED APPLICATIONS** Control Center openPDC DATA ACOUISITION **PMUs** G PMUs G & CONTROL Damping Substation **FACTS**

**PMUs** 

PDC

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