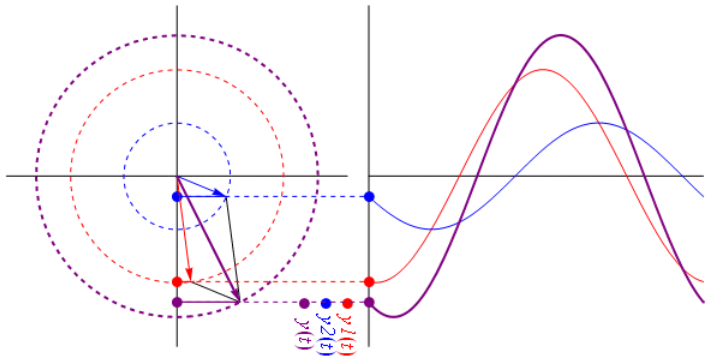
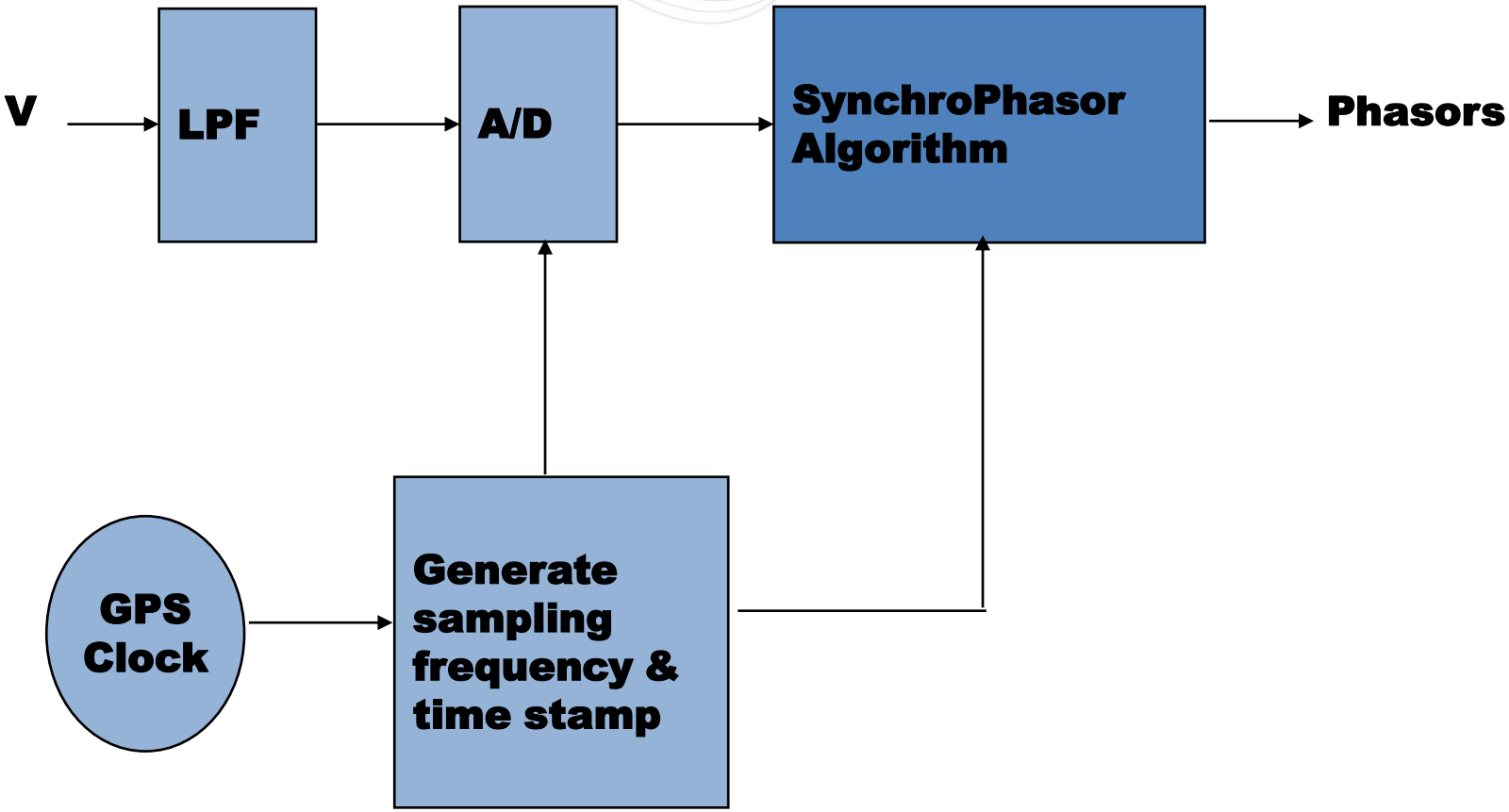
PJM SynchroPhasor Technology Deployment Under DOE ARRA Grant



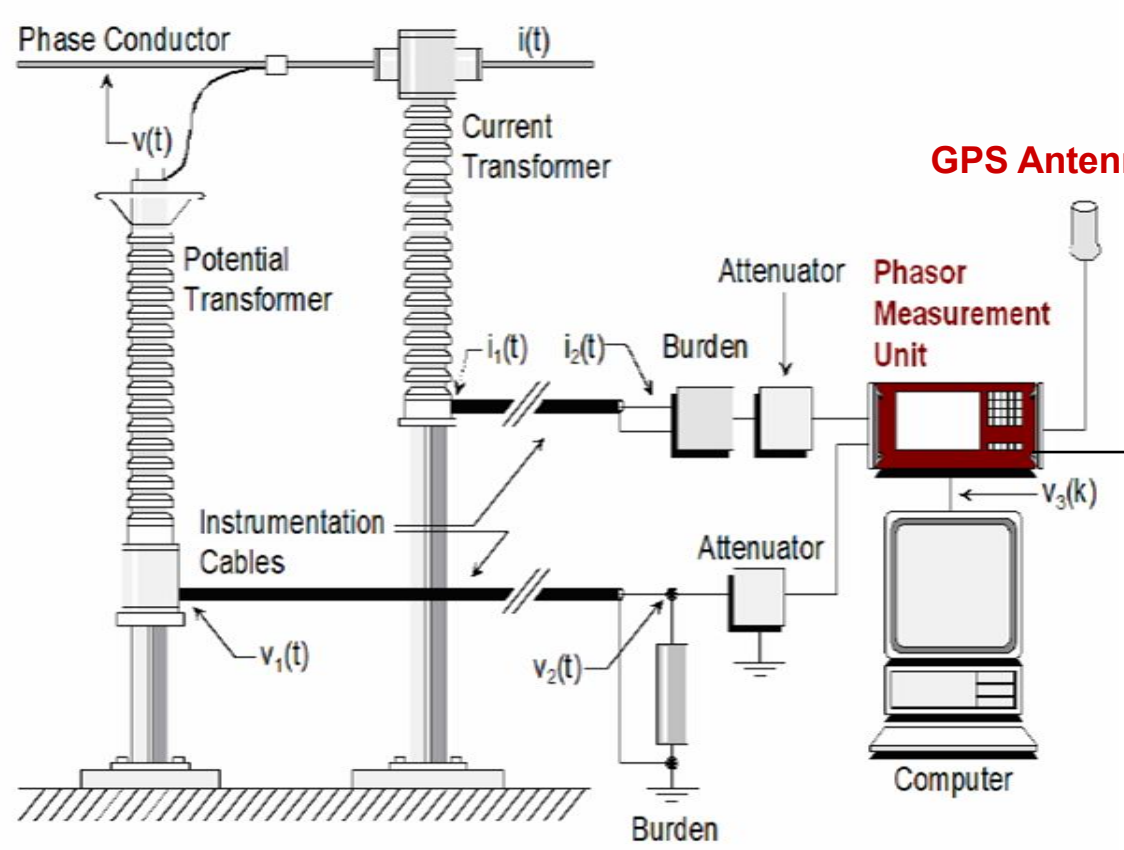
Planning Committee Meeting
February 3, 2011

Mahendra Patel
Applied Solutions PJM

Typical PMU building blocks



Phasor Measurement Units (PMUs)



Typical PMU Installation

Arbiter 1133A

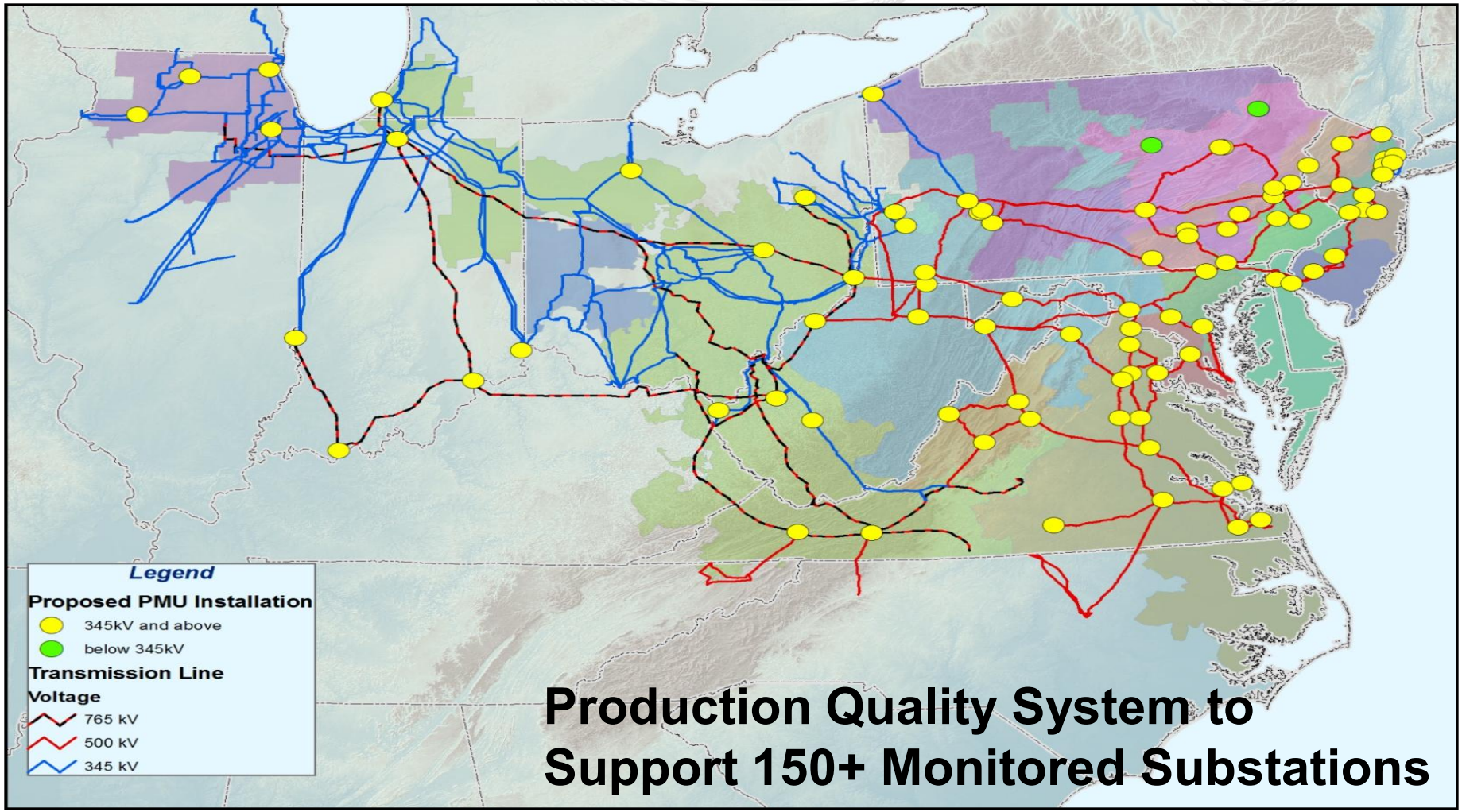
SEL 421

ABB RES 521

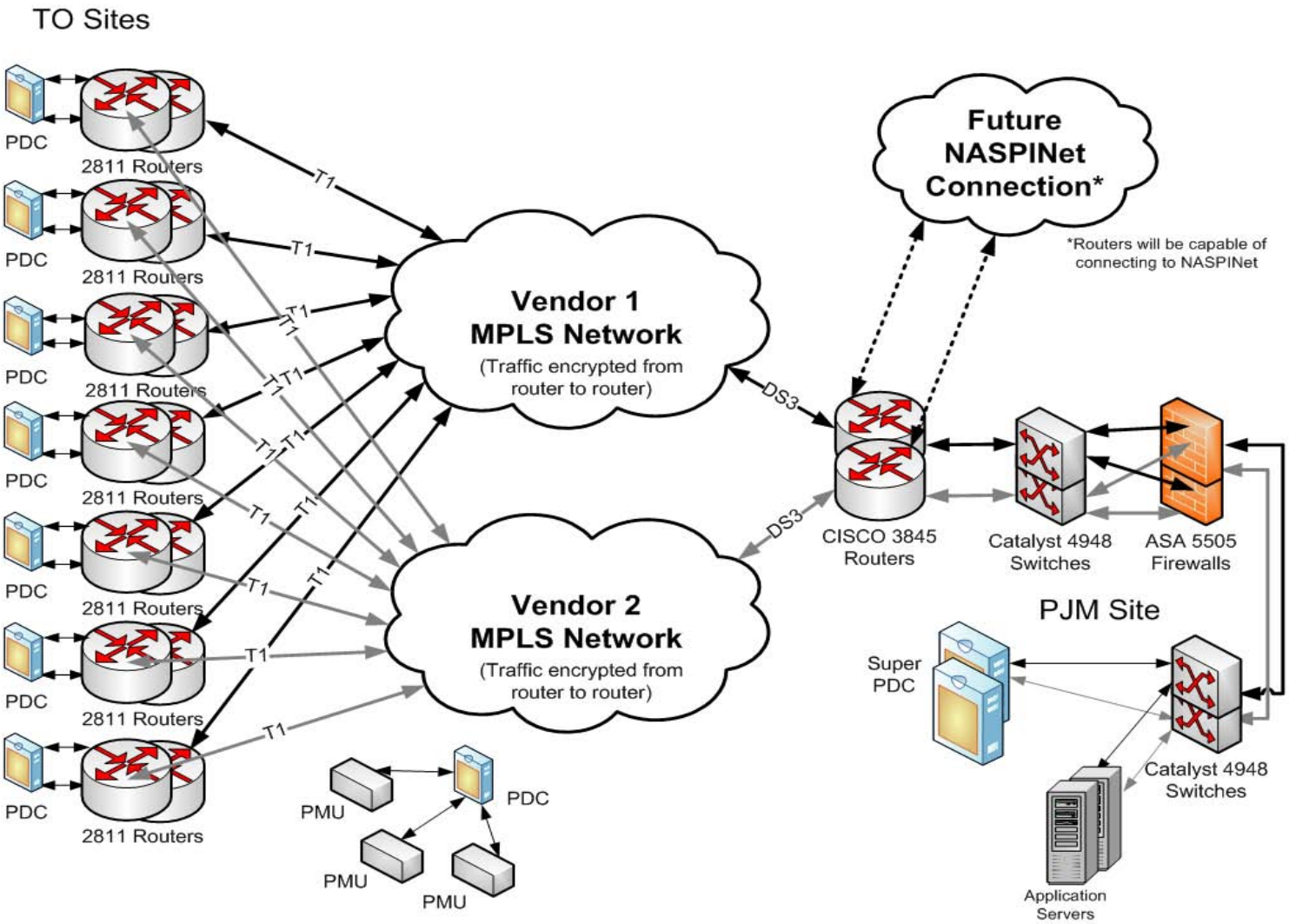
Macrodyne 1620

A few commercially available PMUs

PJM SynchroPhasor Deployment Project

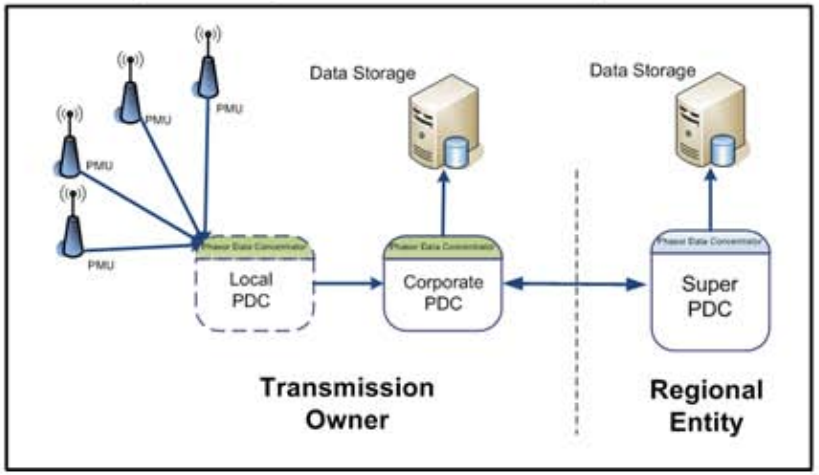


SynchroPhasor Redundant Network



Synchrophasor Data System & Applications

Synchrophasor Data System



Applications

- Situational Awareness
- Decision Support
- Real-Time Analysis (SE/CA)
- Planning
- Automated Control

Applications can be connected to a PDC at any level in the Synchrophasor Data System

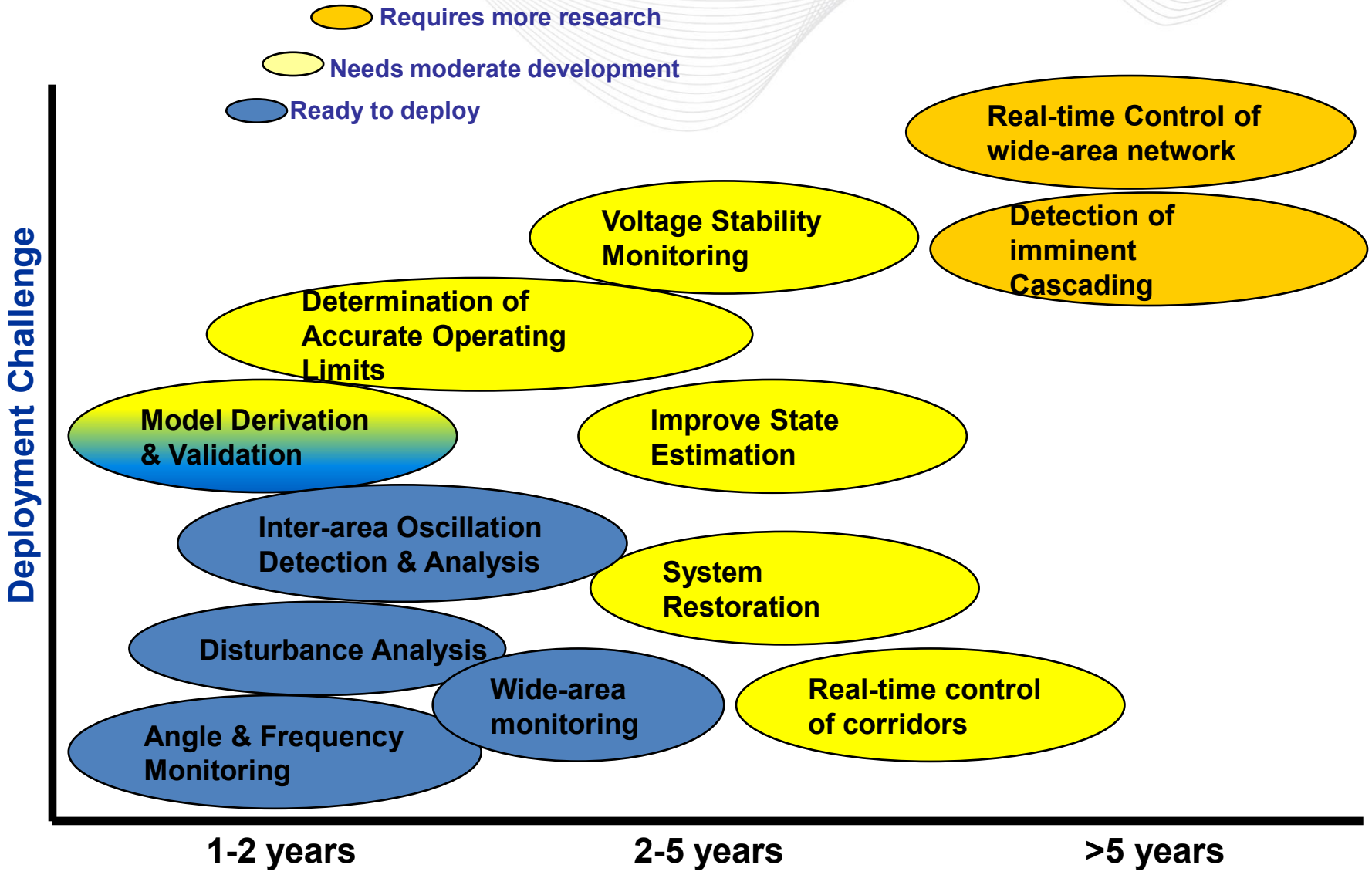
Off-line Applications

- **Synchrophasor Uses for Planning**
  (Off-line applications for Operations and Planning)
  - **Forensic Event Analysis**
  - **Oscillation and stability analysis**
  - **Static system model calibration and validation**
  - **Dynamic system model calibration and validation**
  - **Generator & Load model calibration and validation**
  - **System operating limits evaluation and design**
  - **SPS design**

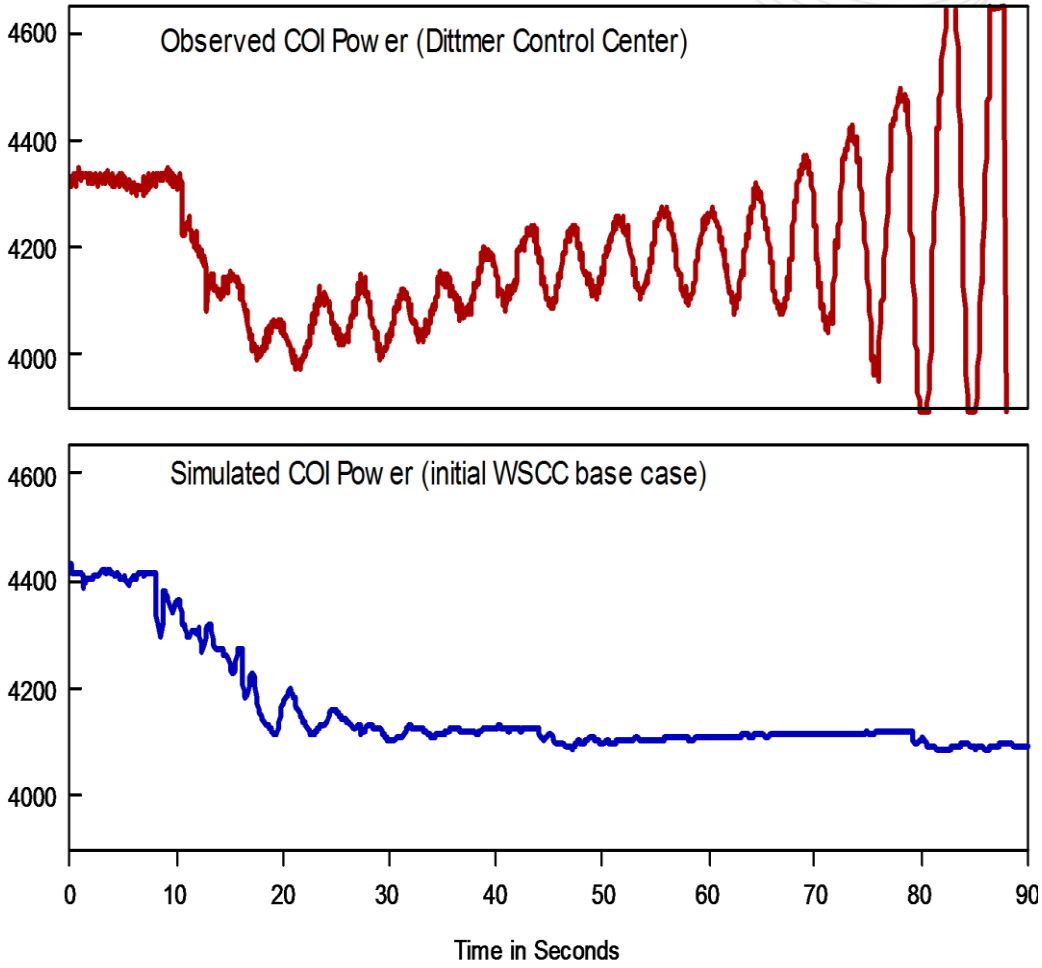
On-line Applications

- **Real-Time Operations**
  (On-line & near real-time operations applications)
  - **Wide-area situational awareness**
  - **Stability, oscillations and voltage monitoring**
  - **Alarming and setting SOLs**
  - **Resource integration (intermittent generation, demand response)**
  - **State estimation**
  - **Dynamic line ratings and congestion management**
  - **System Restoration**

SynchroPhasor Applications



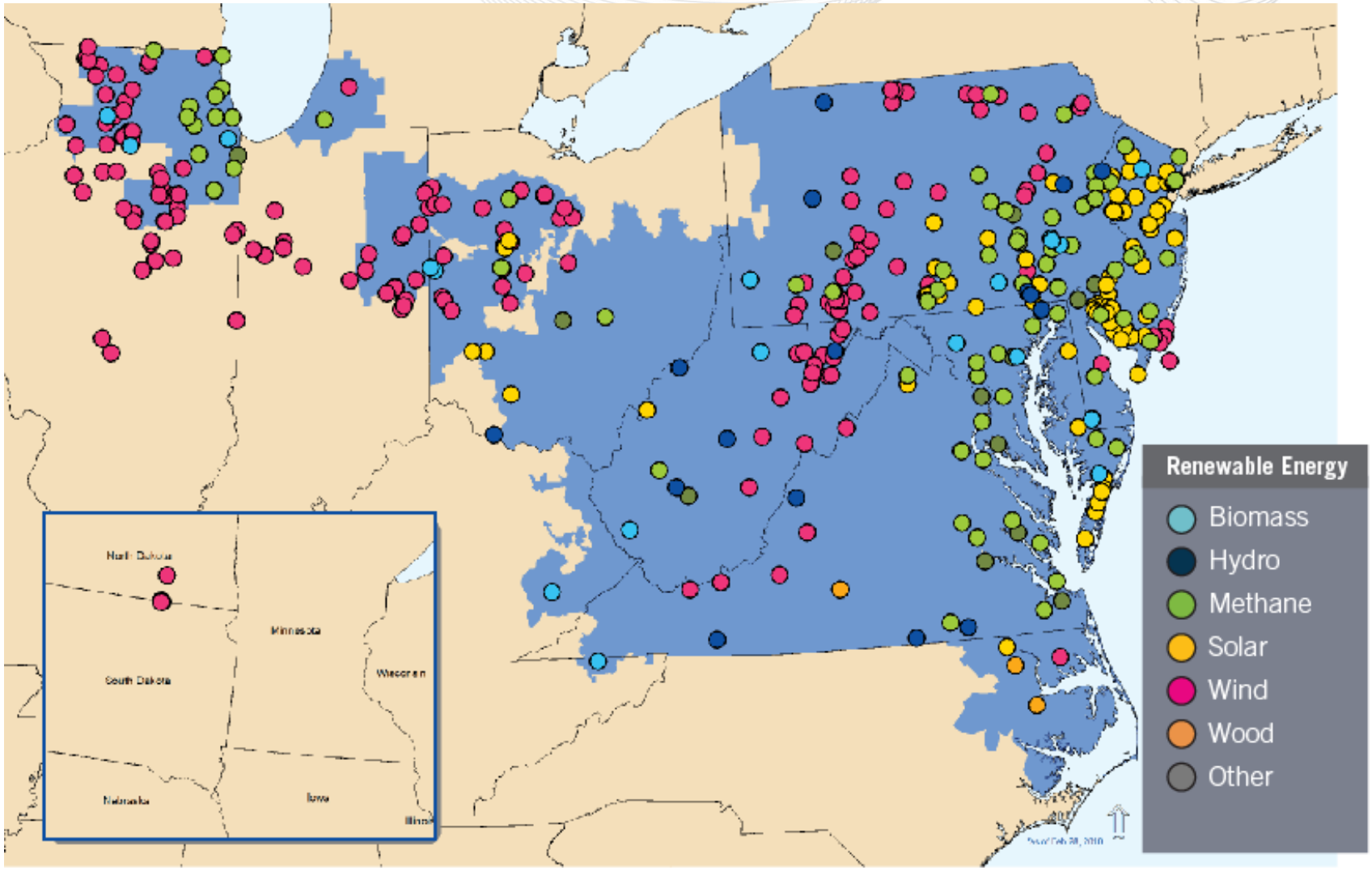
Off-line Applications



Phasor data measures system dynamic behavior during disturbances that simulations can't yet accurately predict

Generator Model Validation

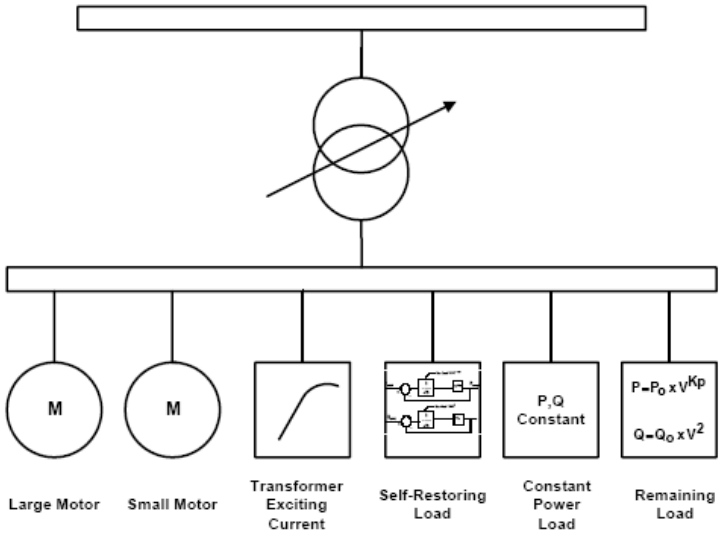
Proposed Renewable Generation in PJM



As of March 31, 2010

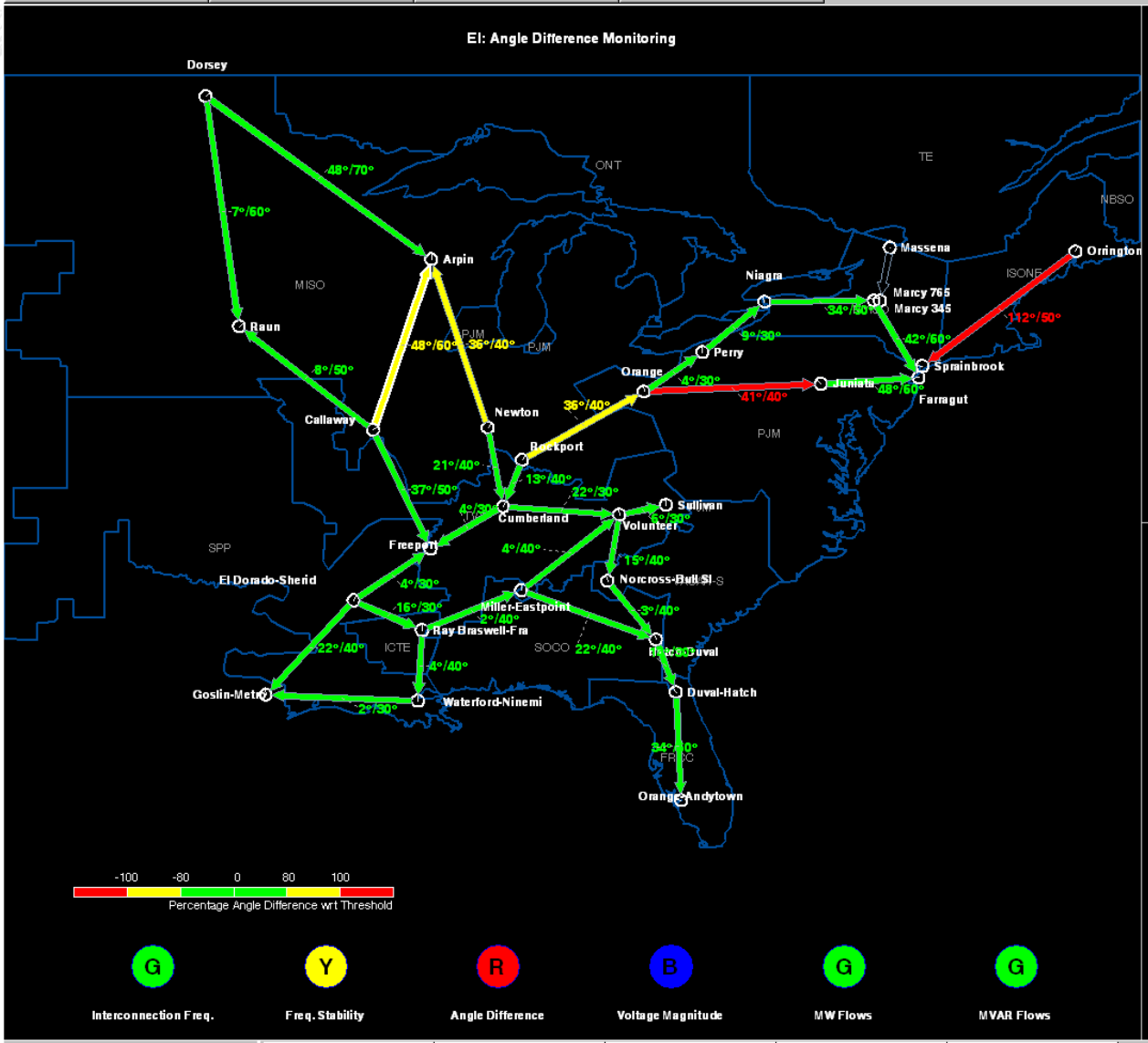
Load Characterization

- Load models are the least accurate component of the power system model.
- Having synchrophasor data will help better characterize and represent loads in system studies



Phasor Real Time Dynamics Monitoring System (Phasor-RTDMS™) – Visualization and Event Alarms Client v5.1.1

Dashboard | Interconnection | Reliability Coordinator | Local Area | Reports | Event Files | Alarms | Configuration | Help



Deselect All
Select All
Waterford-Ninemi
Volunteer-Sulliv
Volunteer-Norcro
Volunteer-Miller
Rockport-Cumberl
Ray Braswell-Fra
Raun-Callaway
Perry-Niagra
Orrington-Sprain
Orange-Rockport
Orange-Perry
Orange-Juniata
Norcross-Bull SI
Niagra-Marcy 345
Newton-Cumberlan
Newton-Arpin
Miller-Eastpoint
Massena-Marcy 76
Marcy 345-Farrag
Juniata-Farragut
Hatch-Duval
Goslin-Metro-Wat
Goslin-Metro-El
Freeport-Cumberl
El Dorado-Sherid
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Duval-Hatch-Oran
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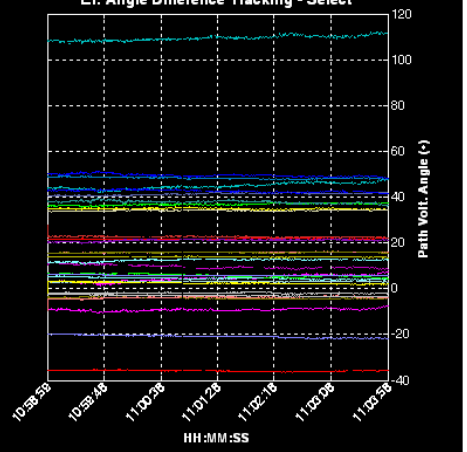
Dorsey-Arpin
Cumberland-Volun
Callaway-Freepor
Callaway-Arpin



Deselect All
Select All
Waterford-Ninemi
Volunteer-Sulliv
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Volunteer-Miller
Rockport-Cumberl
Ray Braswell-Fra
Raun-Callaway
Perry-Niagra
Orrington-Sprain
Orange-Rockport
Orange-Perry
Orange-Juniata
Norcross-Bull SI
Niagra-Marcy 345
Newton-Cumberlan
Newton-Arpin
Miller-Eastpoint
Massena-Marcy 76
Marcy 345-Farrag
Juniata-Farragut
Hatch-Duval
Goslin-Metro-Wat
Goslin-Metro-El
Freeport-Cumberl
El Dorado-Sherid
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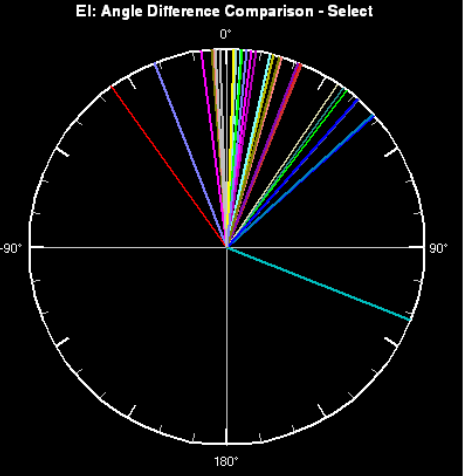
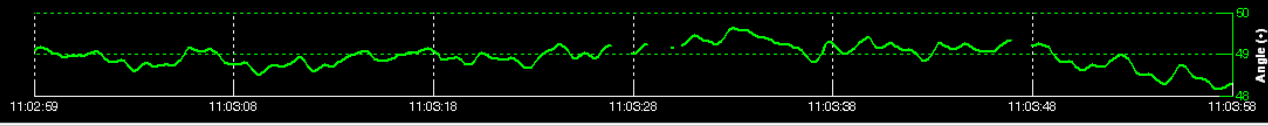
Duval-Hatch-Oran
Dorsey-Raun
Dorsey-Arpin
Cumberland-Volun
Callaway-Freepor
Callaway-Arpin



Date/Time: 03-Oct-2008 11:03:58 EDT
Auto Refresh
Callaway-Arpin
Angle Difference Across Path
Connected (Refresh Rate: 10 Second)
EPG GRID-3P®, U.S. Patent 7,233,843

Scrolling Chart | Panel 1 Data | Panel 2 Data | Panel 3 Data | Panel 4 Data



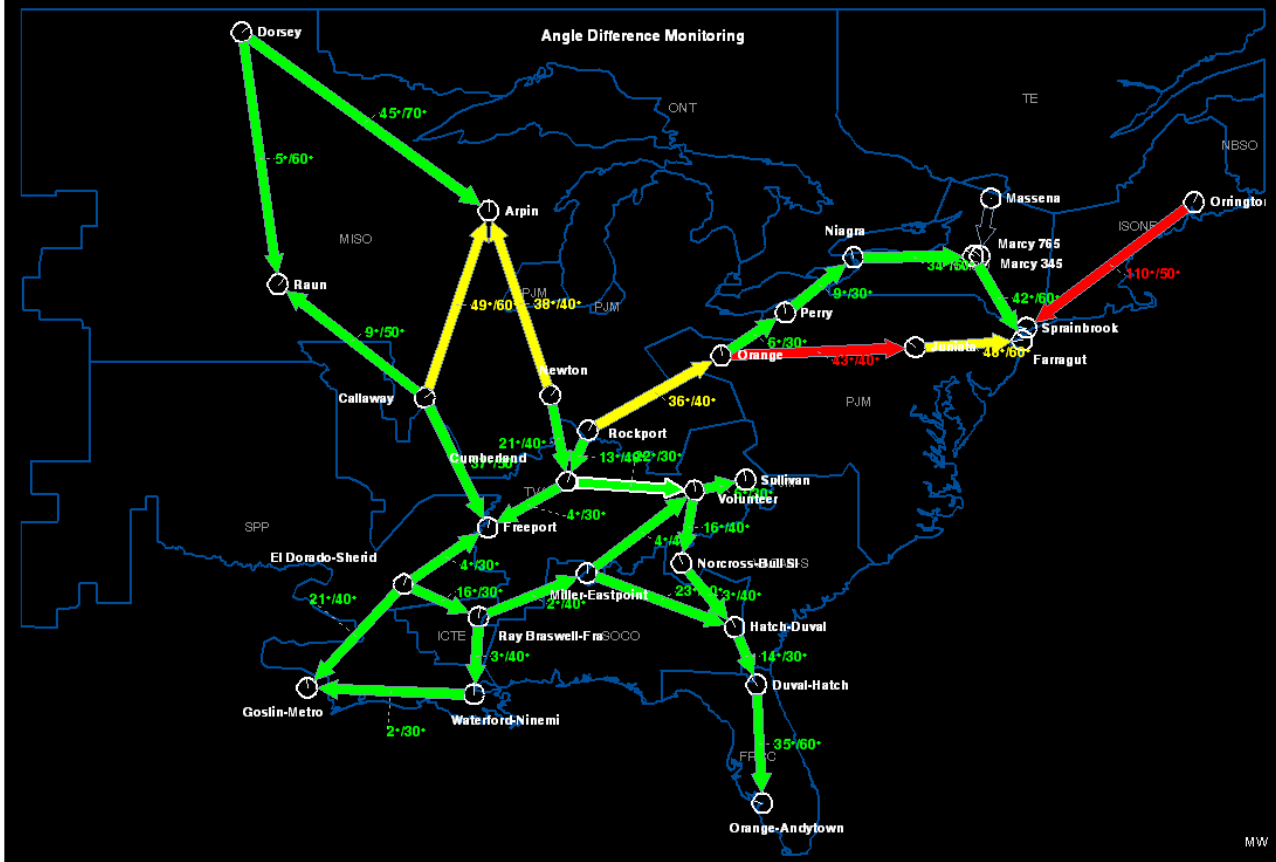
Replay
Frame:
Normal

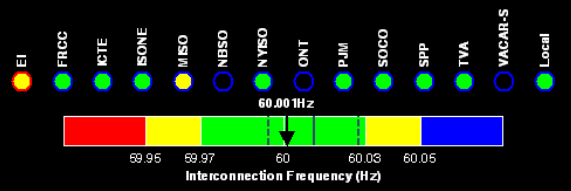
Start | RTDMS Remot... | Phasor Real ... | Microsoft Power... | 11:04 AM

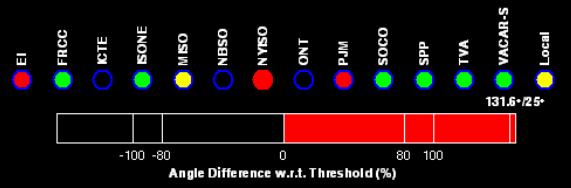
Phasor Real Time Dynamics Monitoring System (Phasor-RTDMS™) – Visualization and Event Alarms Client v5.1.1

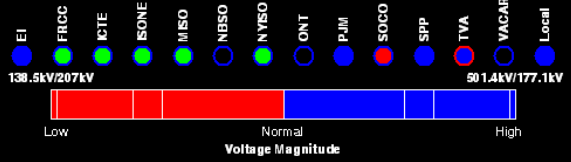
Dashboard | Interconnection | Reliability Coordinator | Local Area | Reports | Event Files | Alarms | Configuration | Help

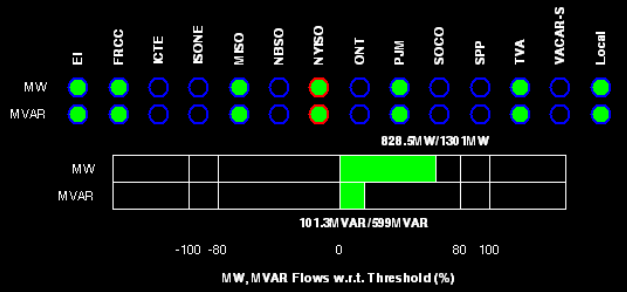
Situational Awareness Dashboard











G	Y	R	B	G	G
Interconnection Freq.	Freq. Stability	Angle Difference	Voltage Magnitude	MW Flows	MVAR Flows

Date/Time: 03-Oct-2008 11:01:18 EDT

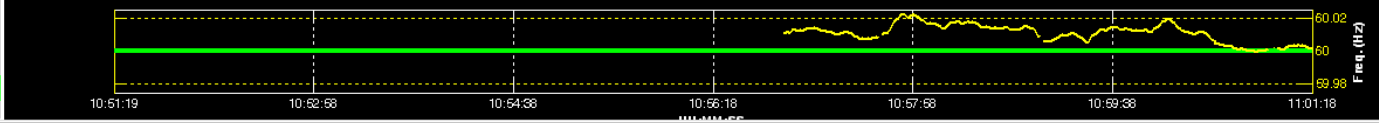
Auto Refresh

Interconnection Frequency
Frequency

Connected (Refresh Rate: 10 Second)

EPG GRID-3P®, U.S. Patent 7,233,843

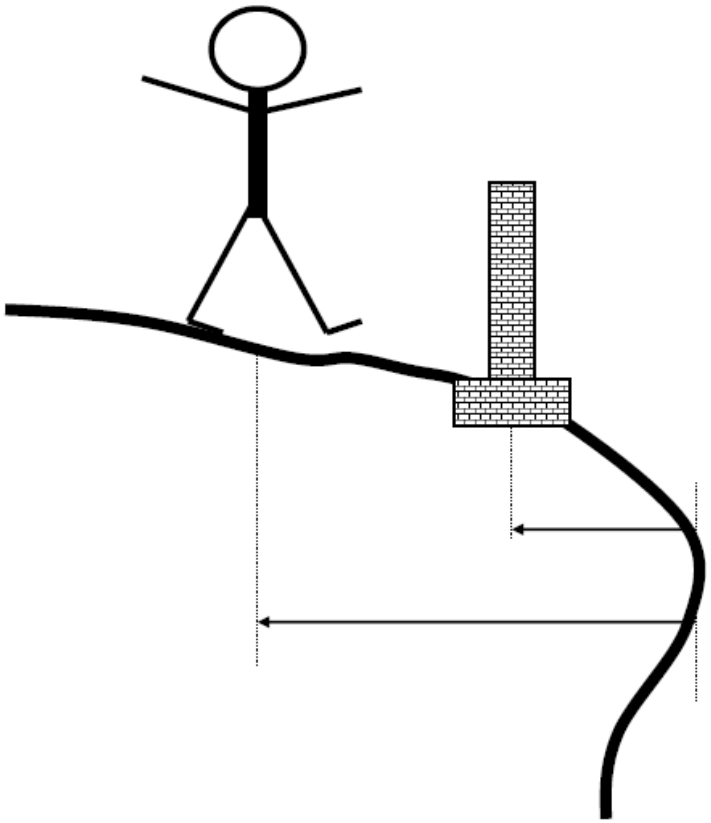
Scrolling Chart | Panel 1 Data | Panel 4 Data



Replay

Start | RTDMS Remot... | Phasor Real ... | 11:01 AM

Wide-area situational awareness



Measurements give us current system states:

For true situation awareness we need to know;

- **Where the edge is**
- **How close to the edge we can safely (reliably) operate**

Baselining studies of phasor angles are required for understanding system behavior

Additional Requirements for Improved Utilization

The project will provide a highly reliable data collection network.

However, at the conclusion of the project we will still be handicapped with severe scarcity of Measurement Points.

The system will provide data from;

- **Approximately 70 EHV buses with PMUs out of about 400 EHV buses in PJM**
- **Approximately 82 buses out of more than 7475 PJM buses in EMS (about 13500 total buses in EMS)**
- **Only a few Generator and Load Buses with PMUs**

Additional Requirements for Improved Utilization

Challenges resulting from sparse observability of the system:

- **Data validation (e.g. detection and elimination or correction of bad data) will be difficult**
- **When data is sparse, developing reliable applications that can sustain loss of a few data points is difficult**
- **For generator and load model development and verifications, we need high resolution data (SynchroPhasor data) at generator and load buses.**