The Value of the PI System at PJM Interconnection

Presented by **Thomas Keyser**
Transmission System Operator

Agenda

- Who is PJM
- Background of PI System at PJM
- Control Room displays
- PMU data in PI System
- Wind generation and PI System
- PI System and GIS
- Performance Compliance uses for PI System

Regional Transmission Organizations

PJM Territory

About PJM

- Responsible for the reliable operation of the high-voltage electric grid in all or parts of 13 states and Washington DC.
- Balancing Authority – responsible for balancing supply and demand
- Operate world’s largest wholesale electricity market.
- Peak Demand - 163,000 MW
- Territory includes 6,000 substations
- 62,000 miles of transmission lines in PJM territory (69-765KV)
- Dispatch 1,300+ generators

Control room software vendors

- EMS
  - Siemens Spectrum EMS
    - Dual hot control centers at two different sites
- Market System
  - Alstom-Energy Market Systems
    - Day ahead and real-time market
- Visualization
  - OSIsoft
    - The PI System

Visualization Challenges

- Situation Awareness for large geographical area
- Tracking of 1300 generators- unit status, MW and MVAR output, unit reserves
- Tracking system voltages throughout 13 state territory
- Viewing transmission zone overviews for a large grid
- Keeping track of wind generation output and forecast
- Track MW transfers into PJM and across the transmission system
- Consistent displays in each control room

Visualization Solutions

- PI ProcessBook displays used throughout control room on video walls and desktop monitors.
- Use combination of bar charts, trends, and one-line overviews
- Use Multi-States with different colors to distinguish between normal/abnormal values

PI Client Overview

- PI ProcessBook displays for dispatcher real-time monitoring, training and during simulations and restoration drills
- PI ProcessBook displays for after event analysis
- PI DataLink for engineering analysis and reporting
- PI Coresight for ad-hoc analysis

Data Collected in PI System

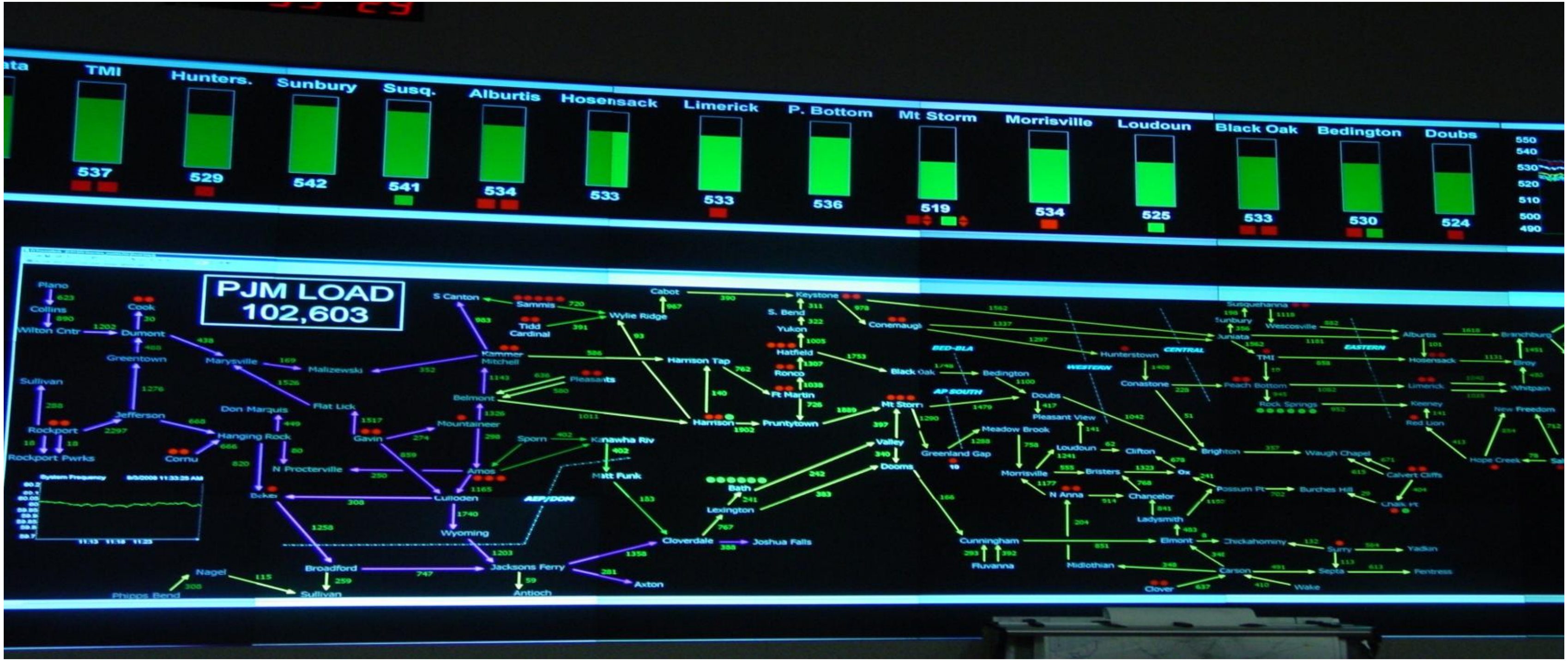
- Real-time SCADA data – voltages, MW, MVAR, loads, Circuit Breaker Status, MW reserves
- State Estimator data
- Market data – Generator bid information, Dispatch rates
- PMU data (synchrophasor)
- Line and transformer outage data
- All PI System data stored for 7 years except for phasor data which is stored for 90 days.

Control Room Displays

- Voltages
- Frequency
- Generation (steam units, CTs, wind and hydro)
- Transmission zonal loads
- Tie-lines between transmission companies
- One-line area overviews
- MW Reserves, MVAR reserves

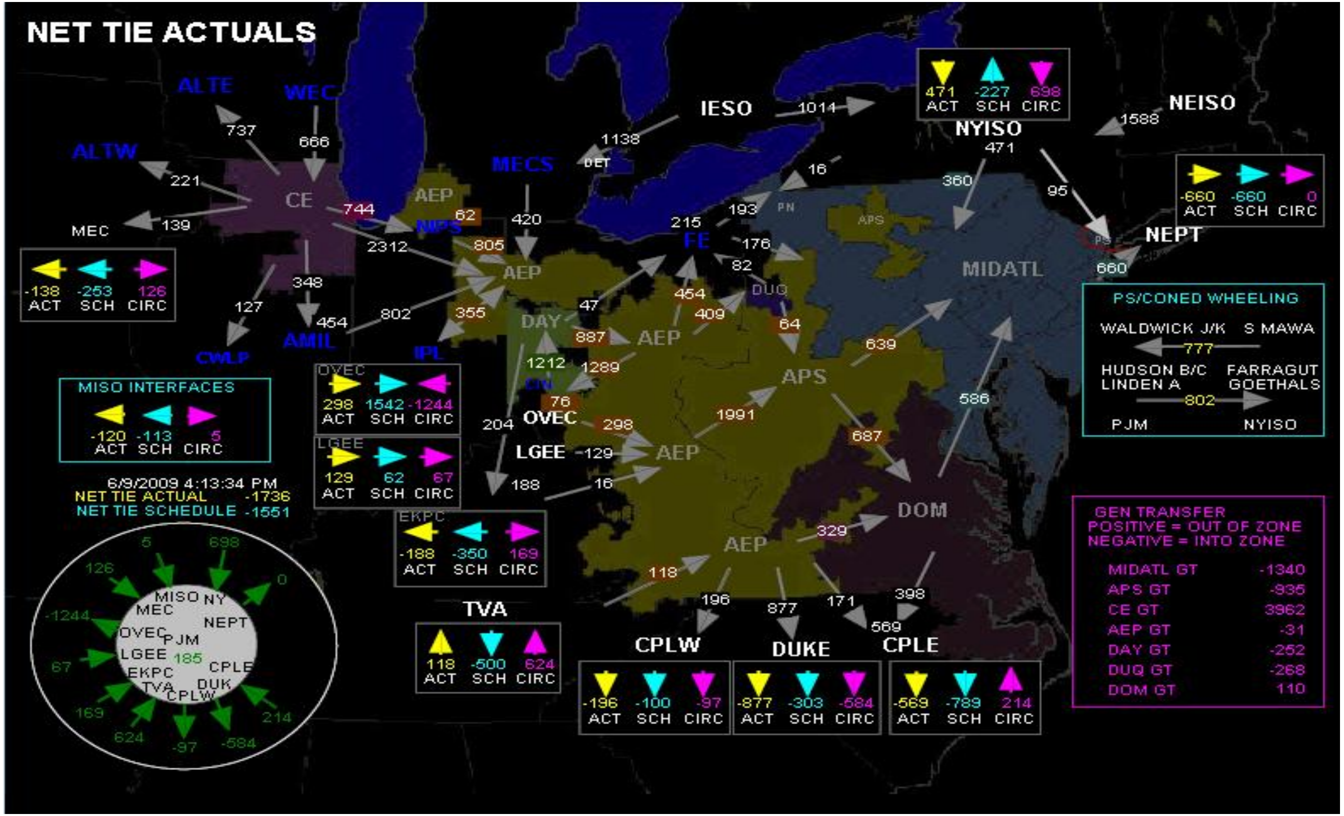
View of control room video walls

Situational awareness in control room



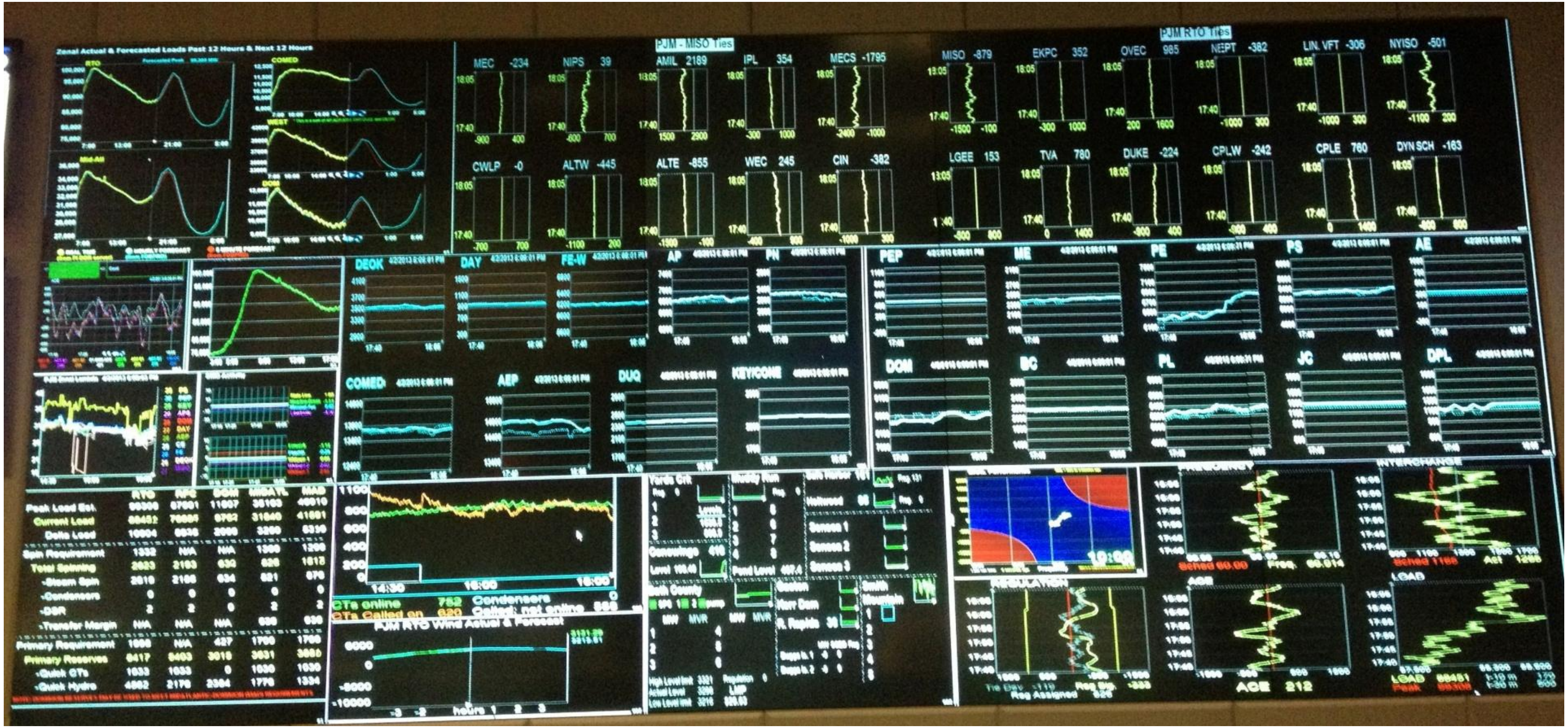
Transmission flows and voltages

Scheduled and Actual MW flows between PJM and neighbors



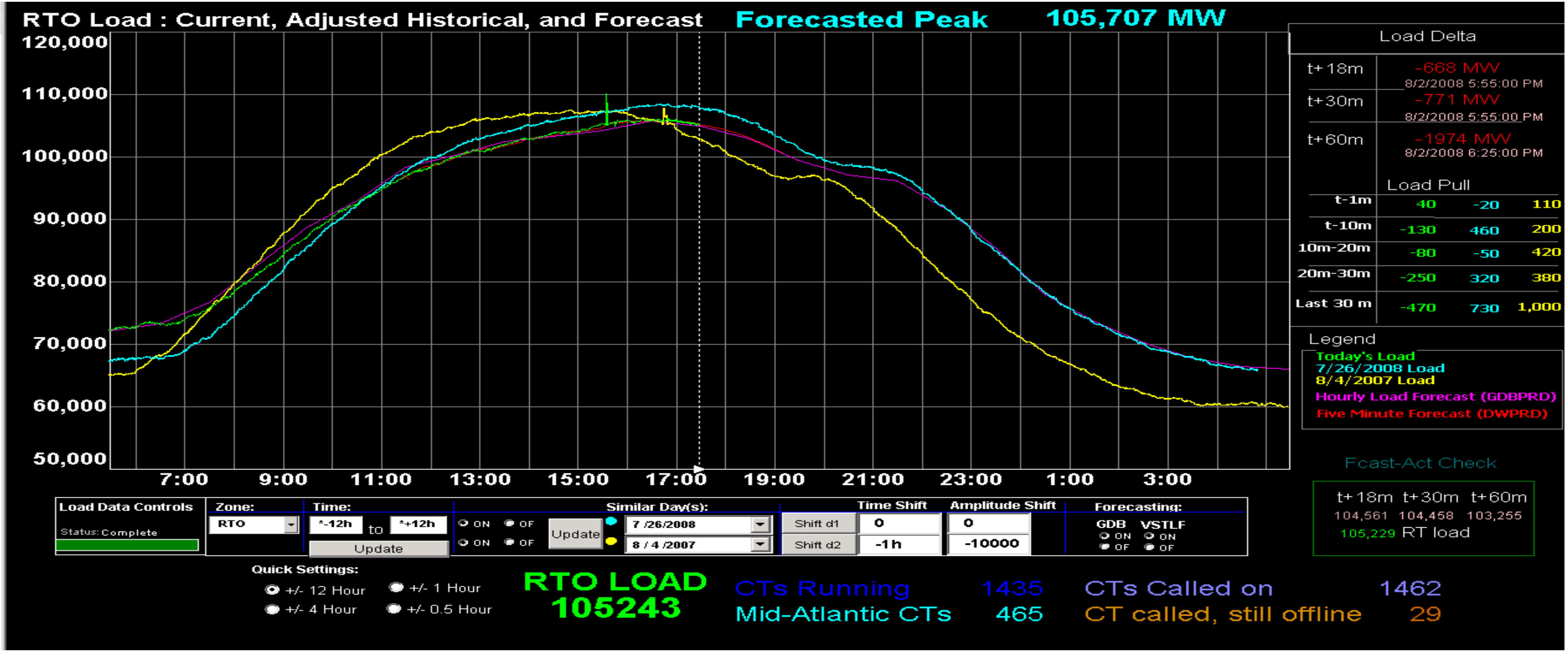
Generation outputs

Generation Video Wall

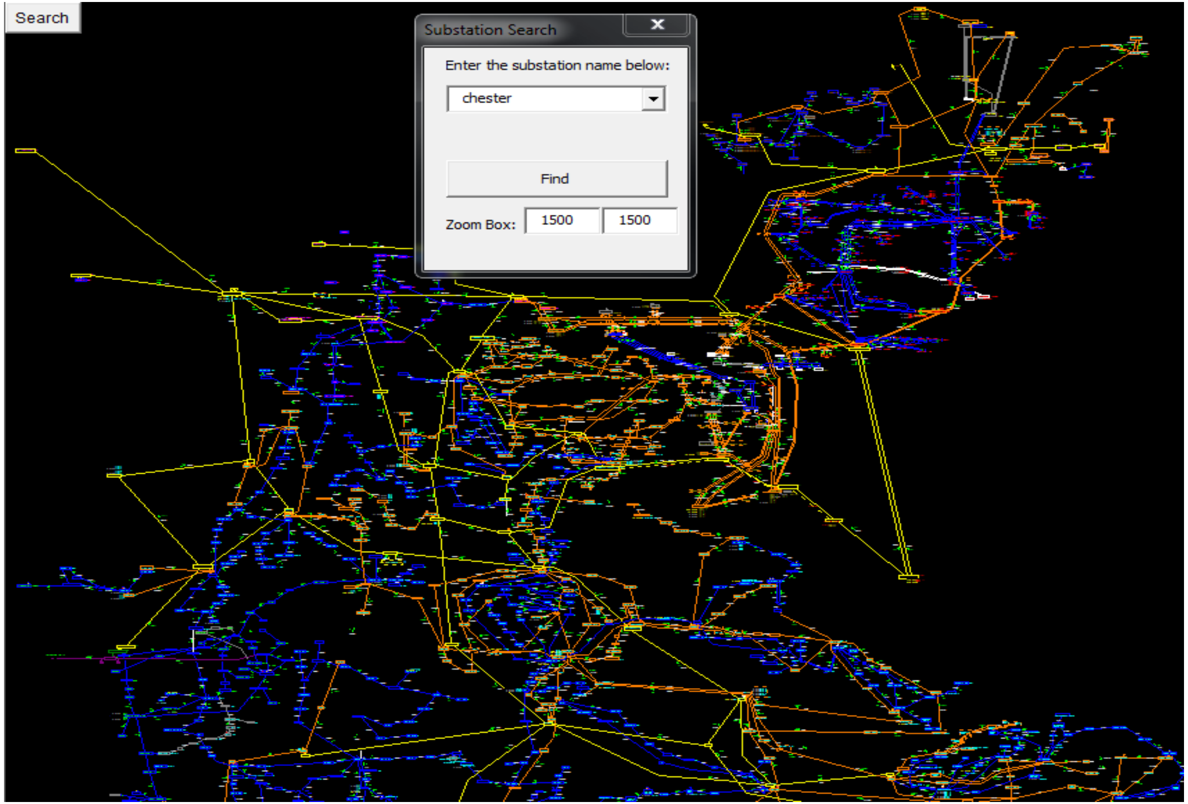


Desk Top Displays

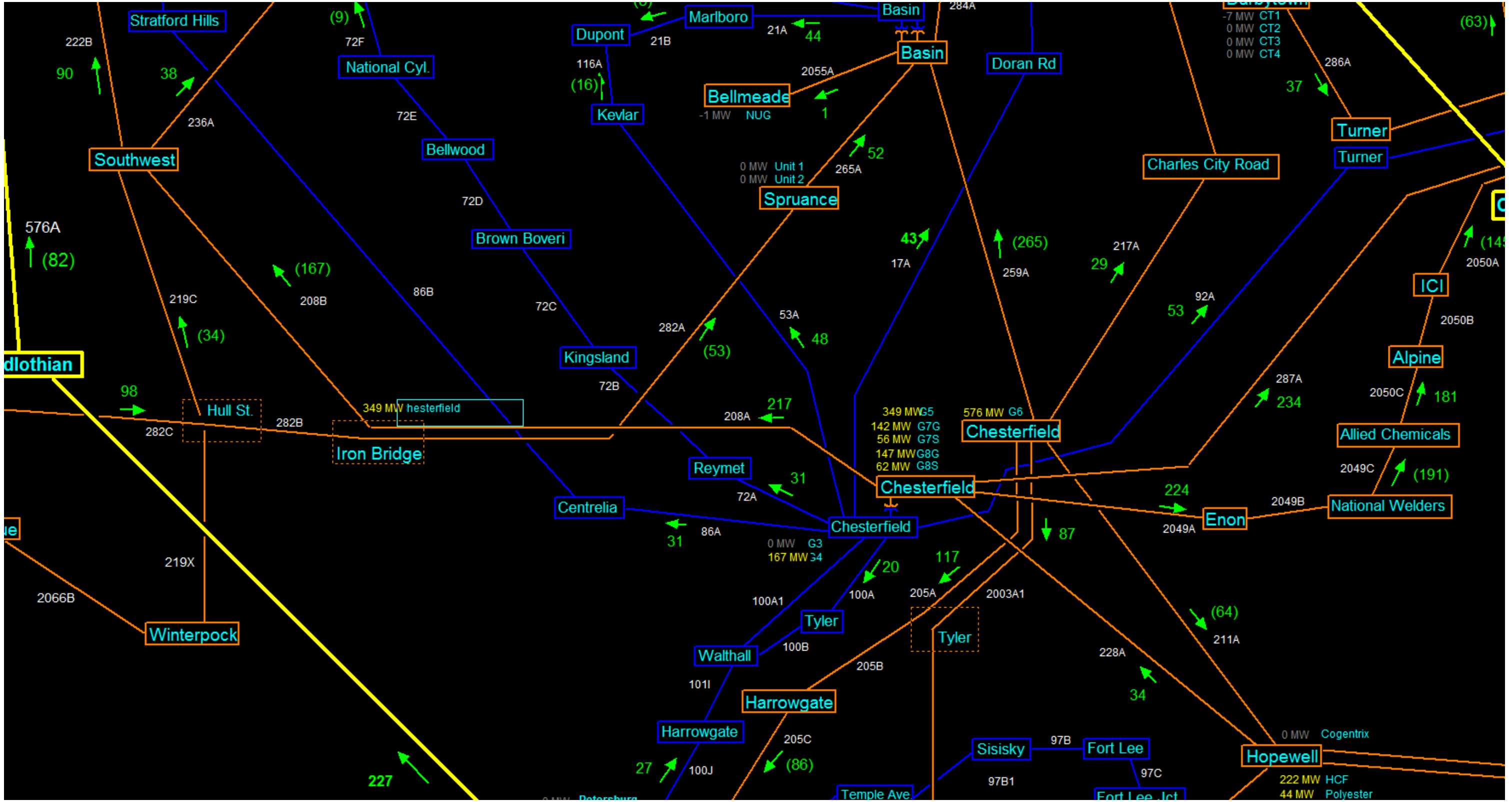
Load Picker Display



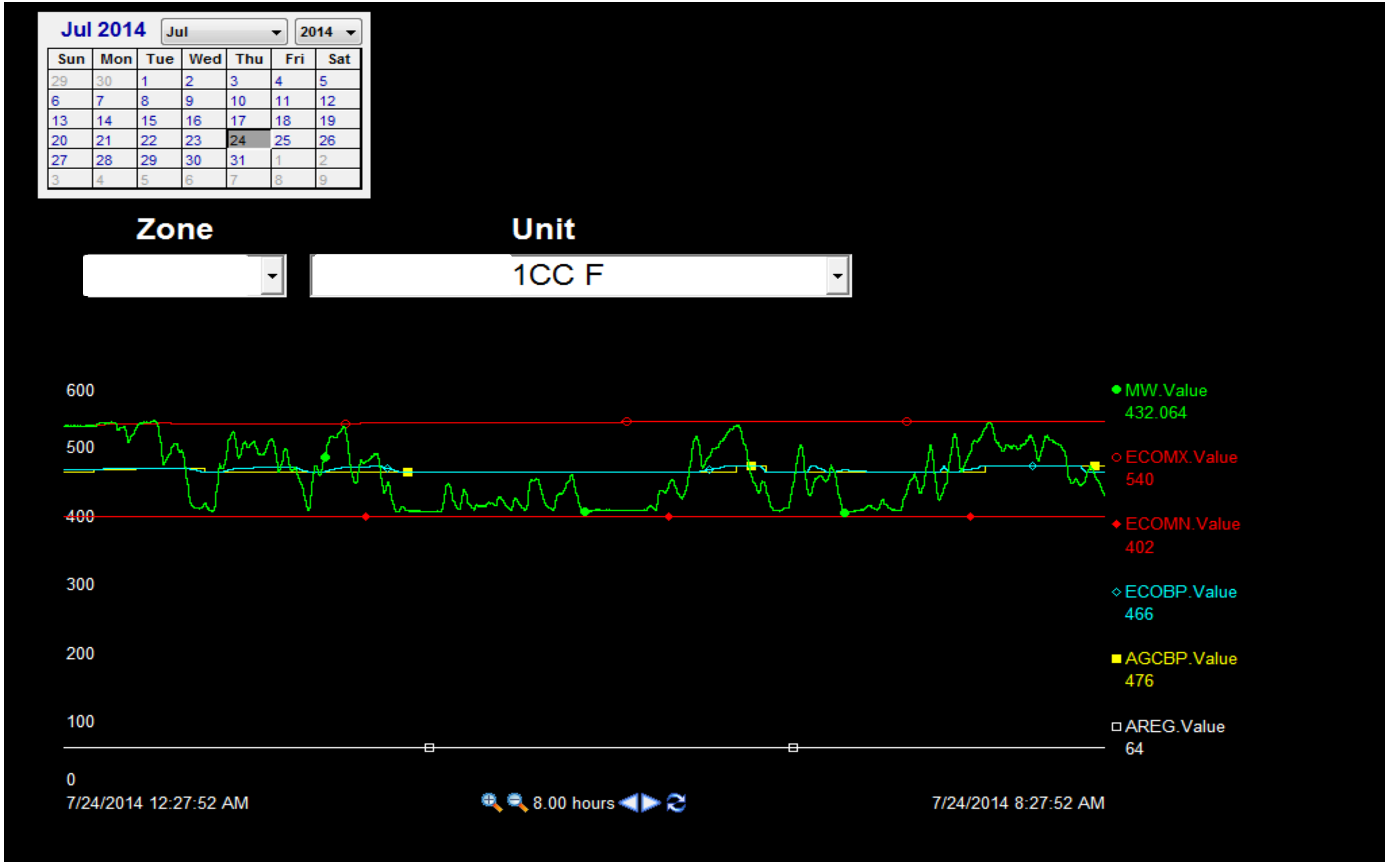
Transmission Zone Overview Example



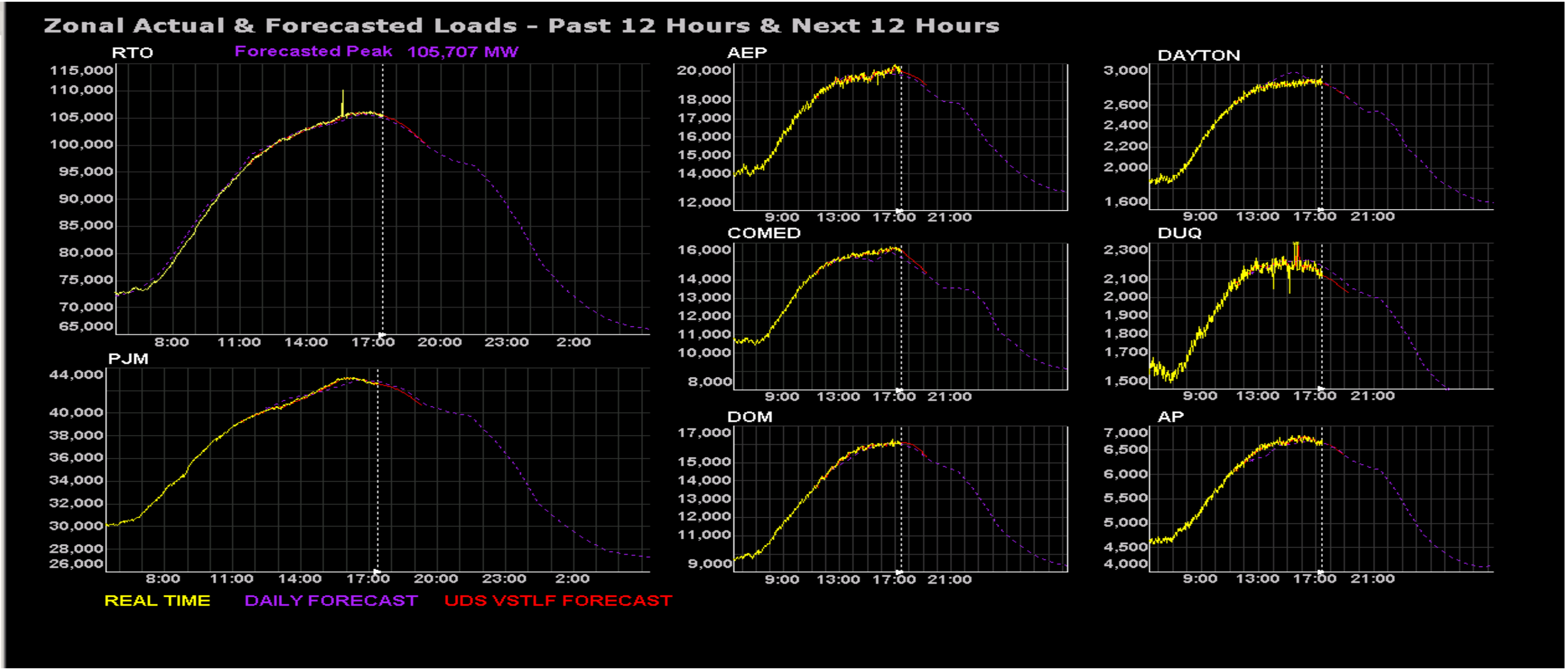
Zoomed in after search



Generator Unit details



Actual & Forecasted Loads



Situational Awareness Benefits with PI System

PJM is using PI ProcessBook displays on the large video walls and desktops in the control room for the operators to view generation outputs of over 1300 generators, and various transmission related displays.

Business Challenge

Being able to visualize large amounts of data is not possible with desktop PCs.

Desktop monitors too small for one-line overviews of large transmission systems.

Solution

Create PI ProcessBook displays for generation and transmission data that can be visible to all operators in the control room.

Results and Benefits

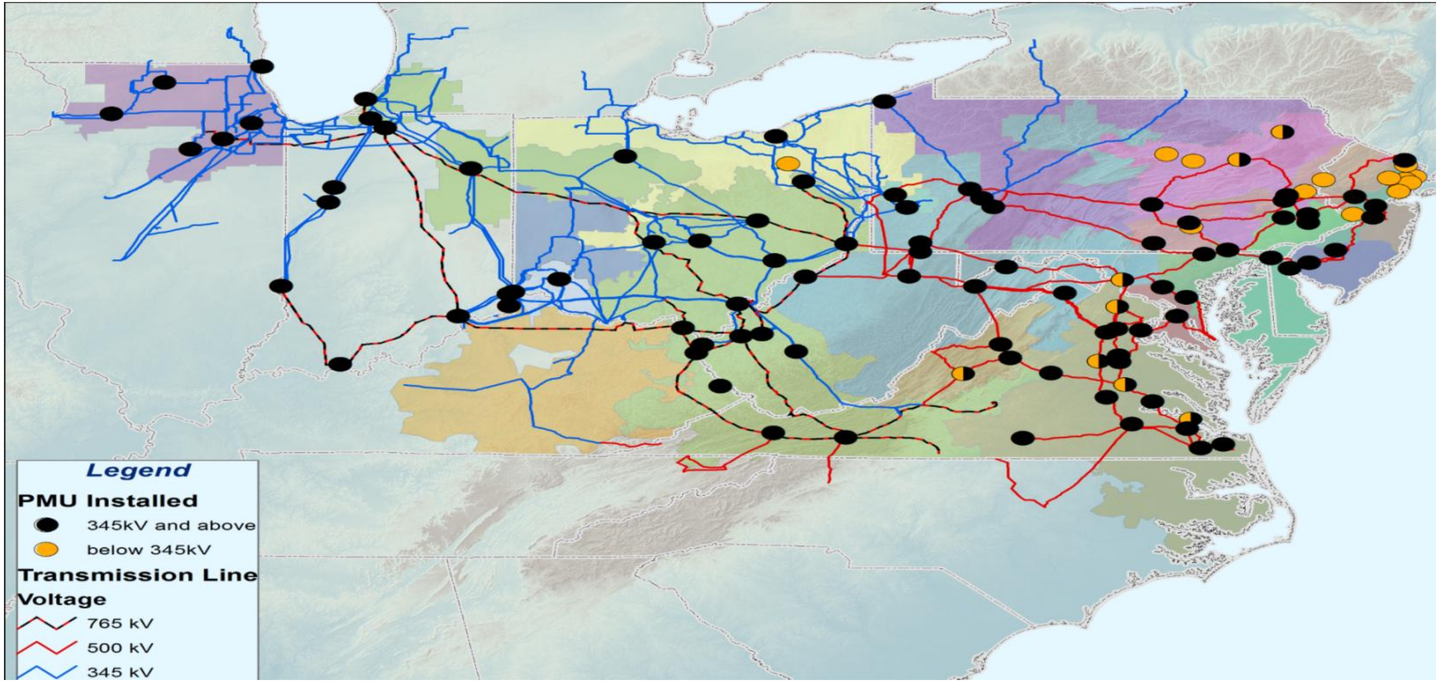
Situation awareness improved in control room.

Operators are all looking at same information

Synchrophasor Data at PJM

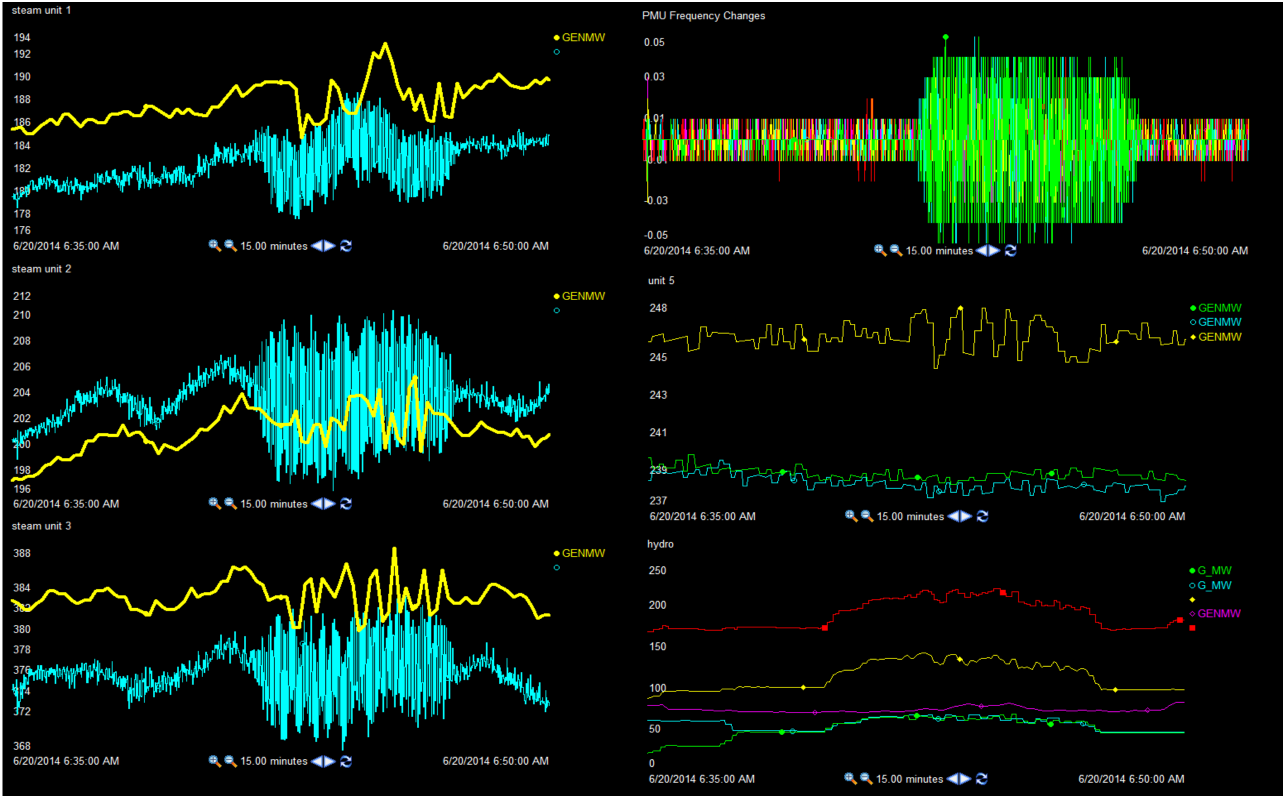
- 360 PMUs installed in 90 substations
- Approx 4500 PI Tags collecting data
- Estimated 1TB data per month collected
- Phasor PI Tags used for alarming in Intelligent Event Processor tool.
- Phasor data used for after event analysis

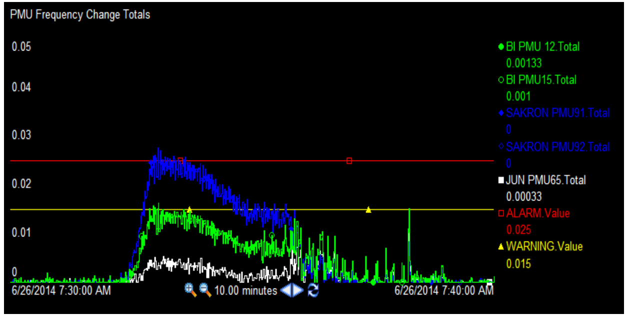
PMU Deployment



Phasor data example during switching event

SCADA MW / calculated MW using PMU data





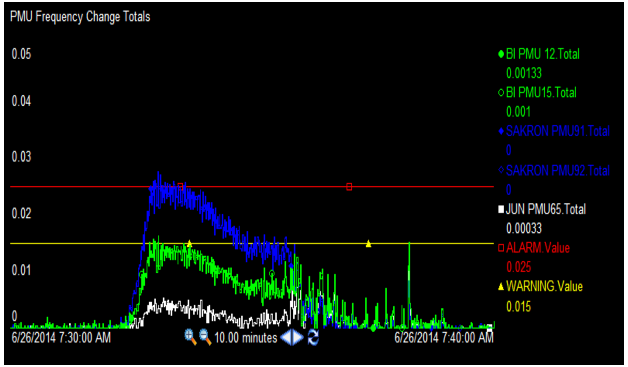
Frequency change

MW swinging on 1 unit but not the other 2 at same station

MW swings on hydro units

PMUs and The PI System

SCADA data is received every 2-4 seconds. PMU data is received at much faster scan rates and can pick up small changes in frequency and voltages that can be missed with SCADA data.



Business Challenge

Be able to capture instability on the transmission system that happens in cycles which normally wouldn't be picked up in SCADA data

Solution

Install PMU at all major substations and capture the data in PI System so displays can be built for real-time monitoring and post mortem analysis.

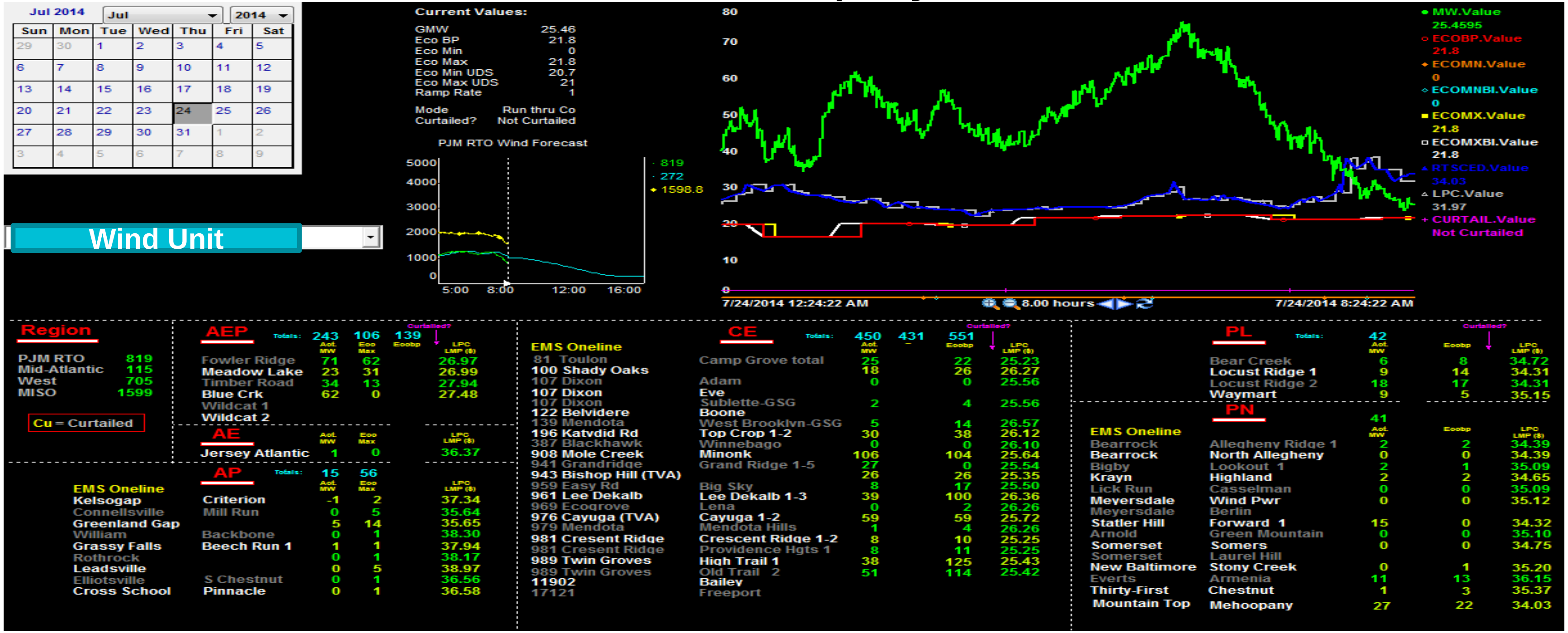
Results and Benefits

Performance Compliance department is currently using PMU data for analysis of system disturbances.

Engineers are using PMU data for stability analysis.

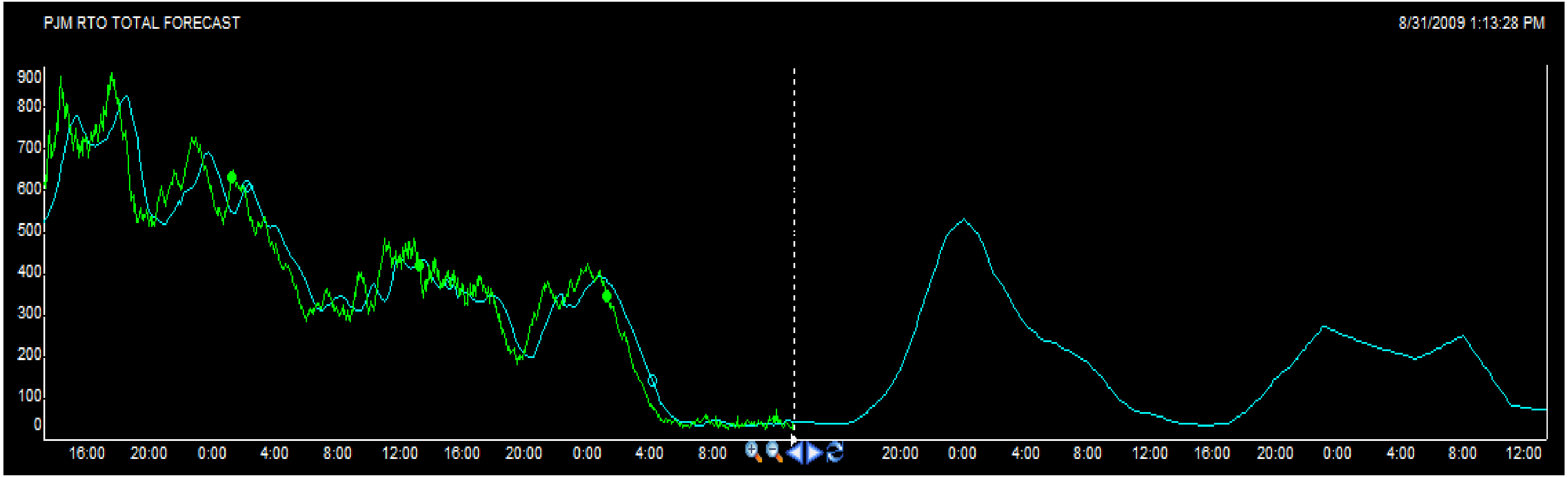
Renewable integration into Operations

Wind Display



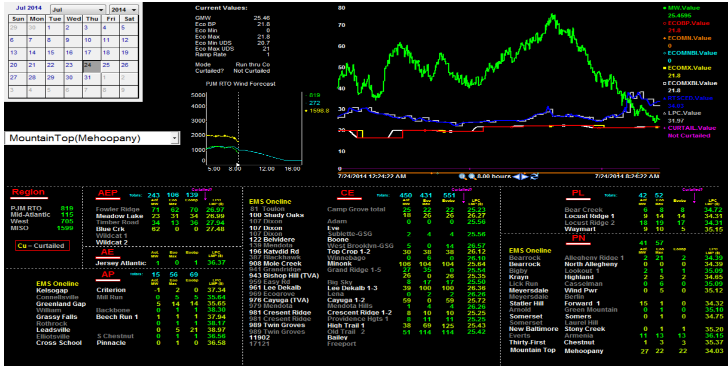
Wind Power Forecasting

Future data is combined with historical and real-time data



Renewable Integration into Operations

With the increasing amount of wind generation on the system, there is a need to display the output of each wind farm due to the volatility nature of wind generation.



Business Challenge

Balance generation supply with load can be challenging with wind outputs that can quickly increase or decrease

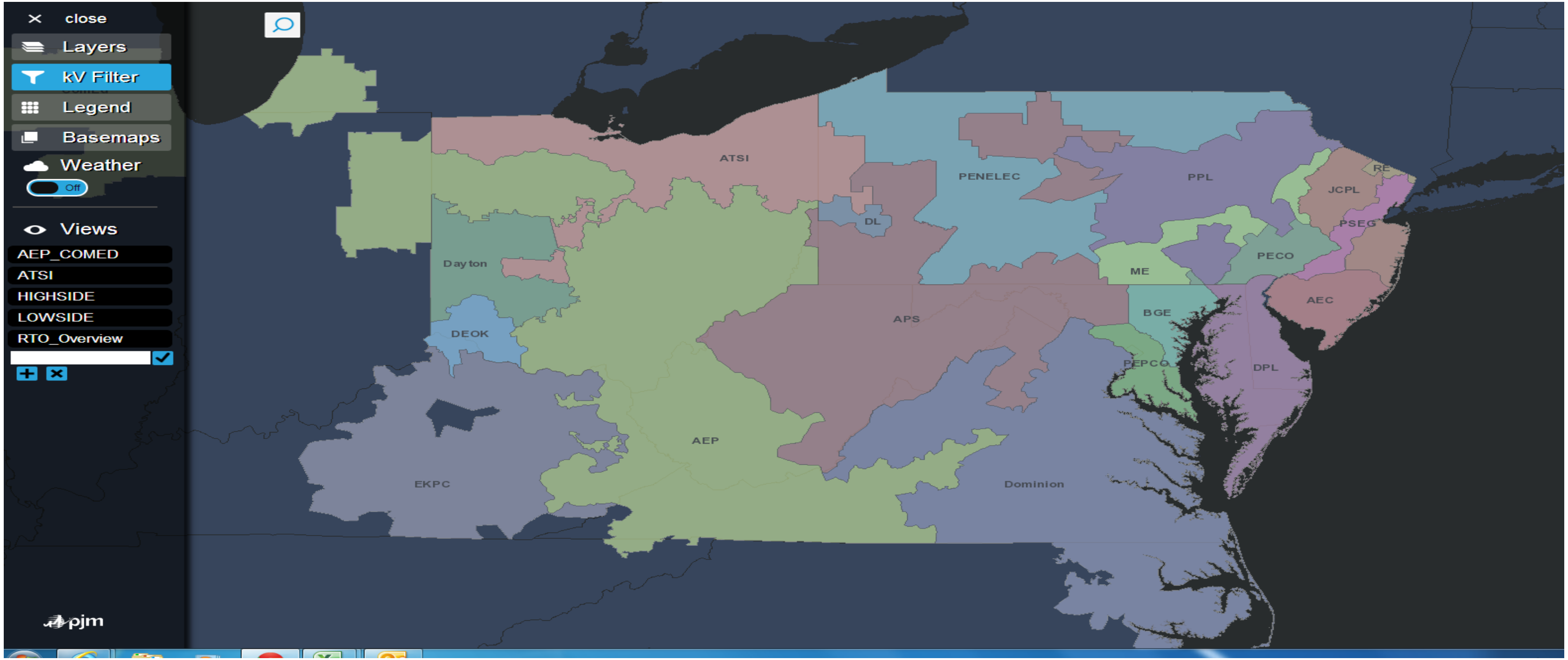
Solution

Build PI ProcessBook displays with Wind Farm outputs and trends with real-time MW and forecasted MW.

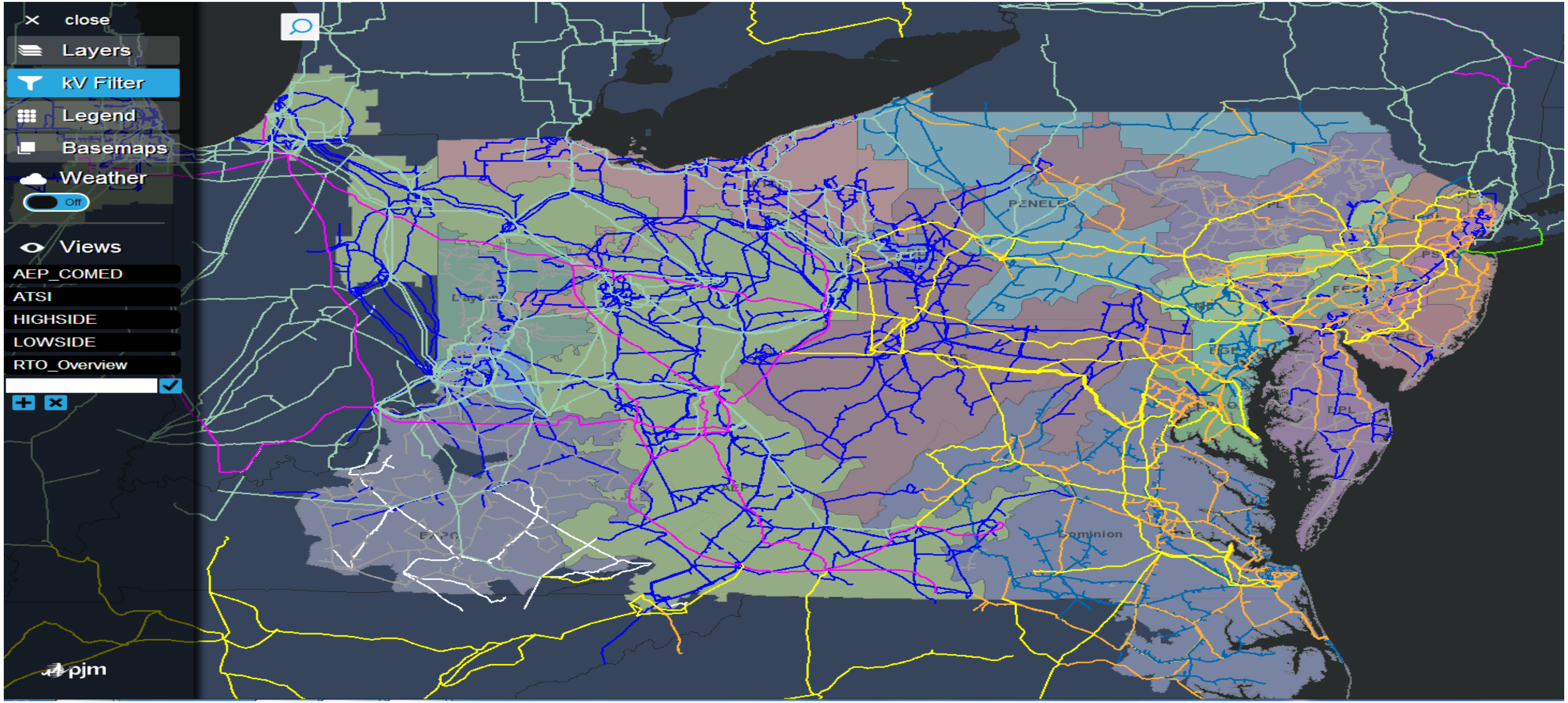
Results and Benefits

Dispatchers can view the real-time outputs of individual wind farms and view the forecast MW. Results in better situational awareness in the control room.

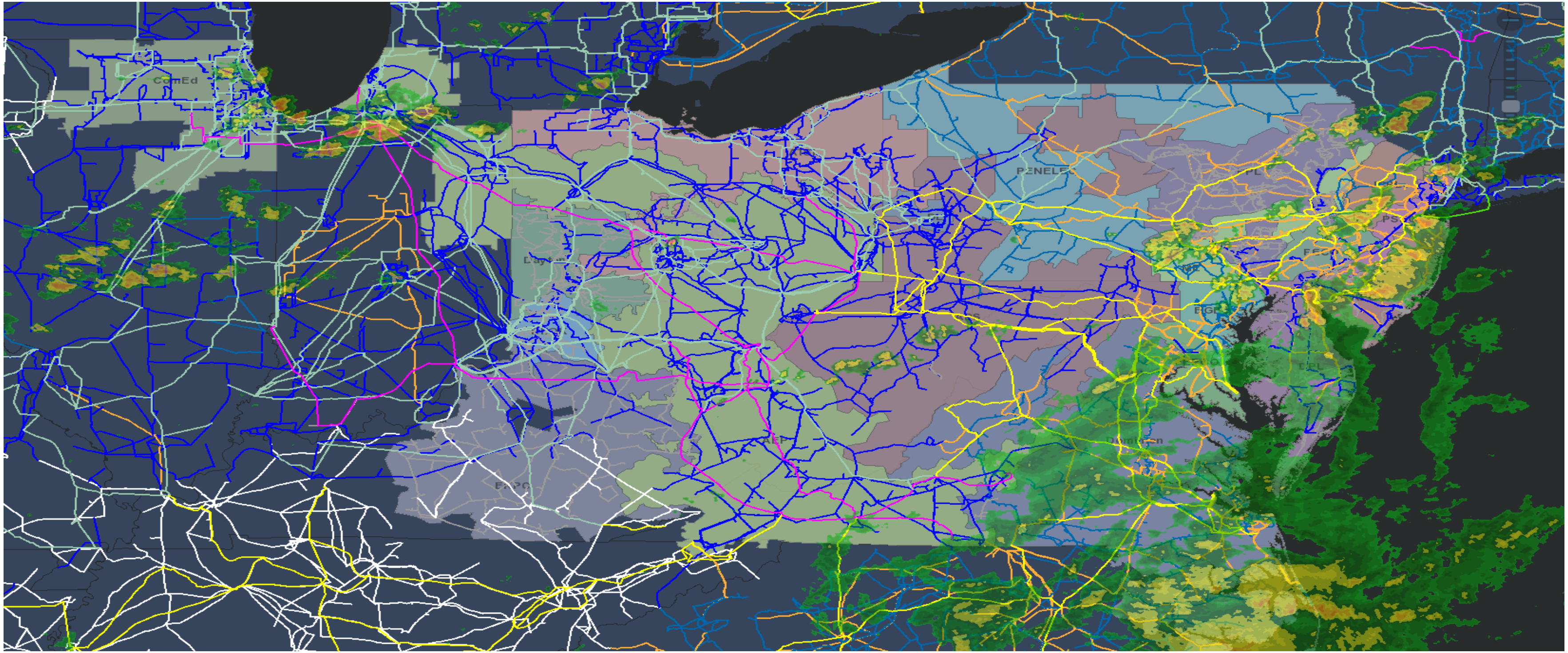
Future PI System data uses - ARC GIS



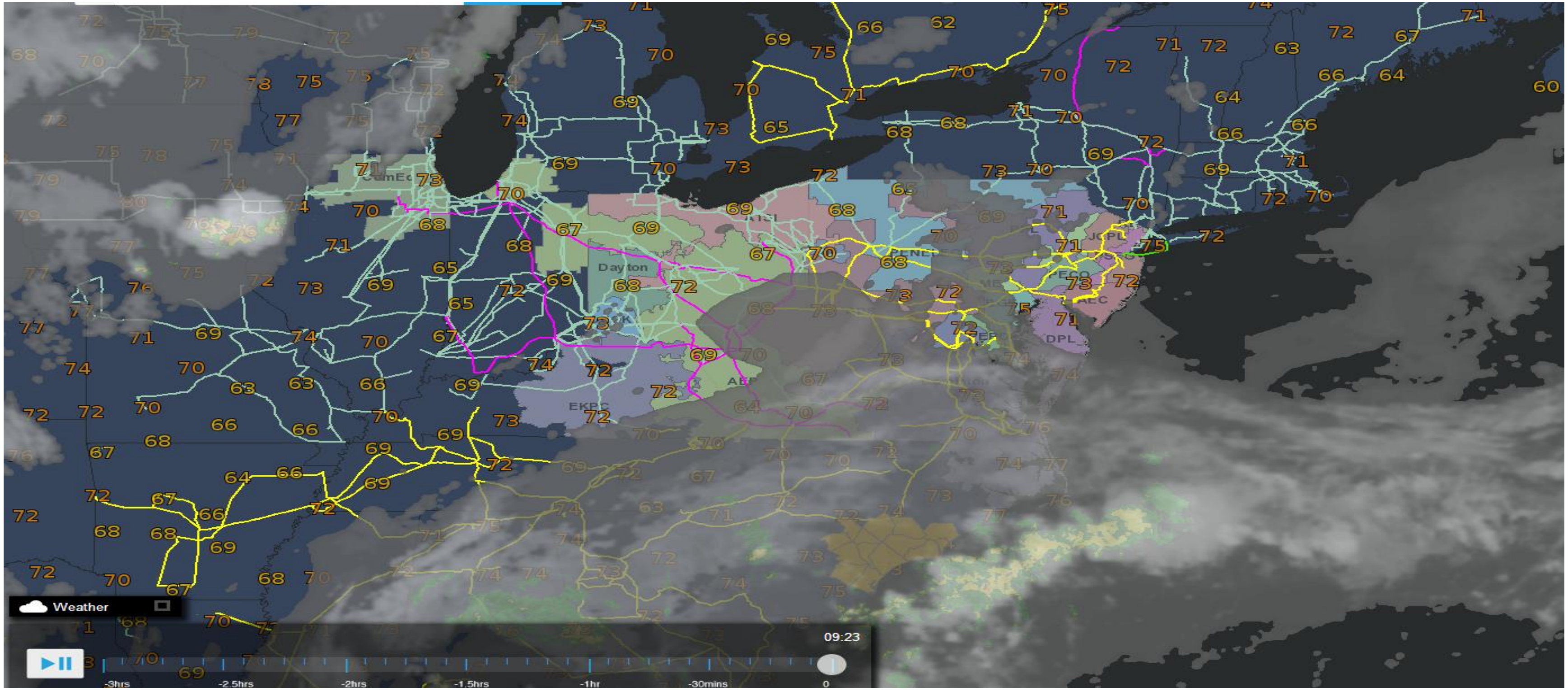
Transmission system overview



Radar data added

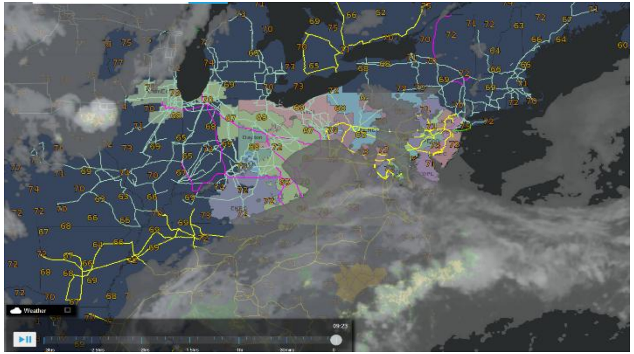


Temperatures and clouds added



GIS and PI System

With a control area spanning 13 states, PJM needs a tool to view a wide area picture of the transmission system.



Business Challenge

The need exists for a dynamic map that covers the PJM system and can display weather information along with transmission and generation data.

Solution

Combine Esri and OSIsoft products to visualize power flows on the PJM grid.

Results and Benefits

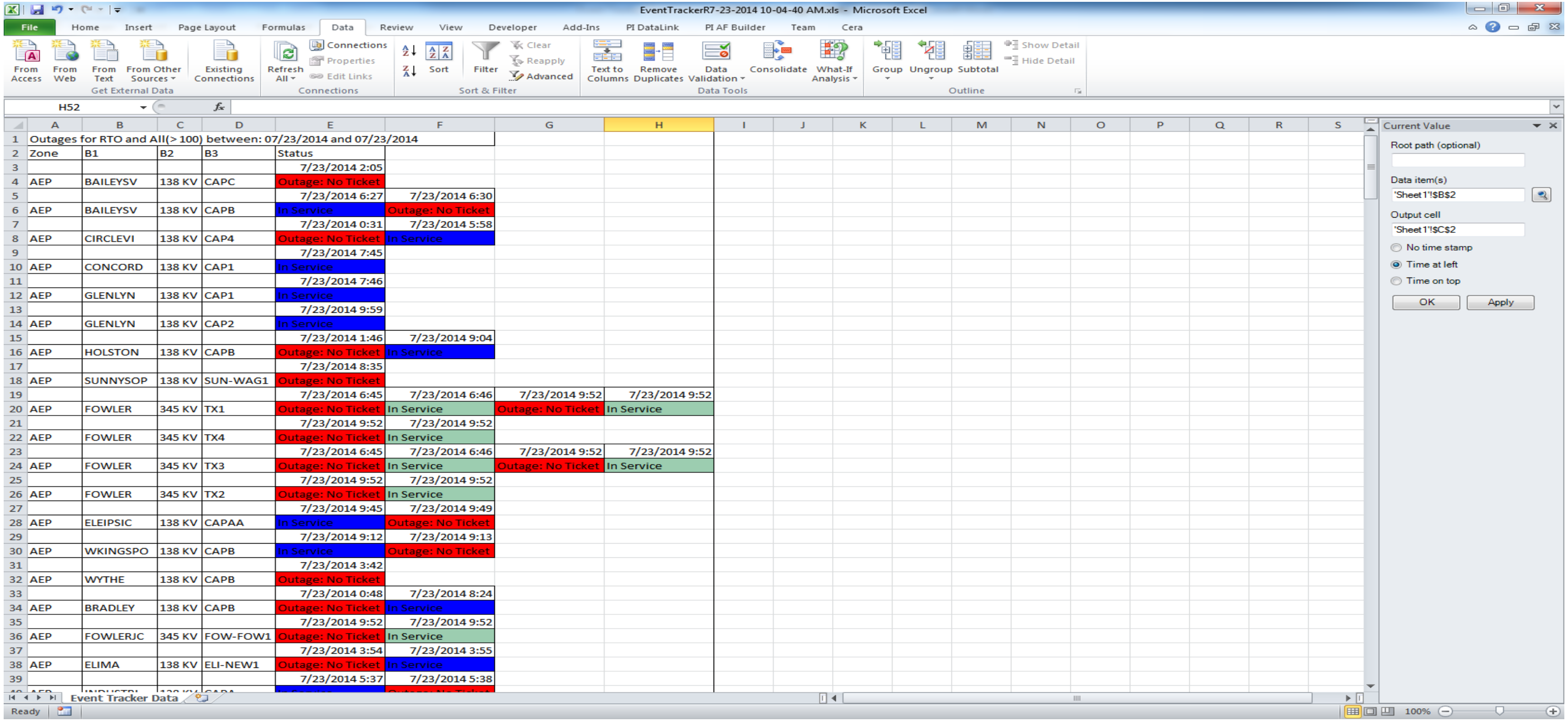
Ongoing project – PI System integration into dynamic map slated for 2015 timeframe.

PI System uses for Operations and Performance Compliance

Equipment Outage Tracker

HTML and ASP.net

Outage Tracker Report – PI AF SDK



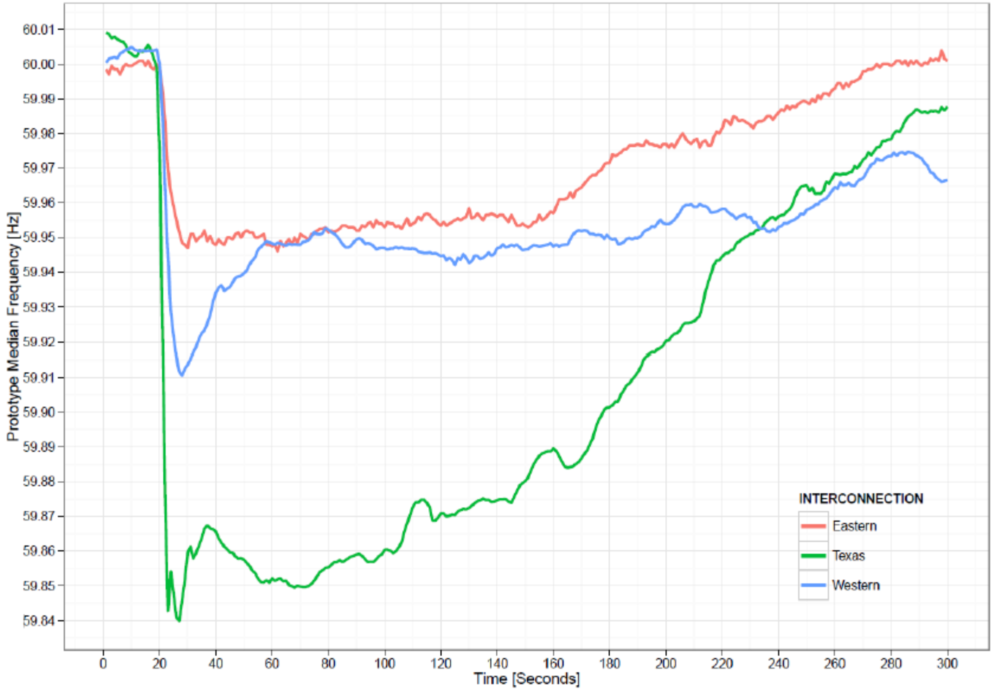
	A	B	C	D	E	F	G	H
1	Outages for RTO and All(> 100) between: 07/23/2014 and 07/23/2014							
2	Zone	B1	B2	B3	Status			
3					7/23/2014 2:05			
4	AEP	BAILEYSV	138 KV	CAPC	Outage: No Ticket			
5					7/23/2014 6:27	7/23/2014 6:30		
6	AEP	BAILEYSV	138 KV	CAPB	In Service	Outage: No Ticket		
7					7/23/2014 0:31	7/23/2014 5:58		
8	AEP	CIRCLEVI	138 KV	CAP4	Outage: No Ticket	In Service		
9					7/23/2014 7:45			
10	AEP	CONCORD	138 KV	CAP1	In Service			
11					7/23/2014 7:46			
12	AEP	GLENLYN	138 KV	CAP1	In Service			
13					7/23/2014 9:59			
14	AEP	GLENLYN	138 KV	CAP2	In Service			
15					7/23/2014 1:46	7/23/2014 9:04		
16	AEP	HOLSTON	138 KV	CAPB	Outage: No Ticket	In Service		
17					7/23/2014 8:35			
18	AEP	SUNNYSOP	138 KV	SUN-WAG1	Outage: No Ticket			
19					7/23/2014 6:45	7/23/2014 6:46	7/23/2014 9:52	7/23/2014 9:52
20	AEP	FOWLER	345 KV	TX1	Outage: No Ticket	In Service	Outage: No Ticket	In Service
21					7/23/2014 9:52	7/23/2014 9:52		
22	AEP	FOWLER	345 KV	TX4	Outage: No Ticket	In Service		
23					7/23/2014 6:45	7/23/2014 6:46	7/23/2014 9:52	7/23/2014 9:52
24	AEP	FOWLER	345 KV	TX3	Outage: No Ticket	In Service	Outage: No Ticket	In Service
25					7/23/2014 9:52	7/23/2014 9:52		
26	AEP	FOWLER	345 KV	TX2	Outage: No Ticket	In Service		
27					7/23/2014 9:45	7/23/2014 9:49		
28	AEP	ELEIPSIC	138 KV	CAPAA	In Service	Outage: No Ticket		
29					7/23/2014 9:12	7/23/2014 9:13		
30	AEP	WKINGSPO	138 KV	CAPB	In Service	Outage: No Ticket		
31					7/23/2014 3:42			
32	AEP	WYTHE	138 KV	CAPB	Outage: No Ticket			
33					7/23/2014 0:48	7/23/2014 8:24		
34	AEP	BRADLEY	138 KV	CAPB	Outage: No Ticket	In Service		
35					7/23/2014 9:52	7/23/2014 9:52		
36	AEP	FOWLERJC	345 KV	FOW-FOW1	Outage: No Ticket	In Service		
37					7/23/2014 3:54	7/23/2014 3:55		
38	AEP	ELIMA	138 KV	ELI-NEW1	Outage: No Ticket	In Service		
39					7/23/2014 5:37	7/23/2014 5:38		

Responding to new FERC orders

Order No. 794 approved by the FERC on January 16th, 2014
Applicable to Balancing Authorities

Effective April 1st, 2016
Each … Balancing Authority … shall achieve an annual Frequency Response that is equal to or more negative than its Frequency Response Obligation

Typical Interconnection Frequency Responses for 2011



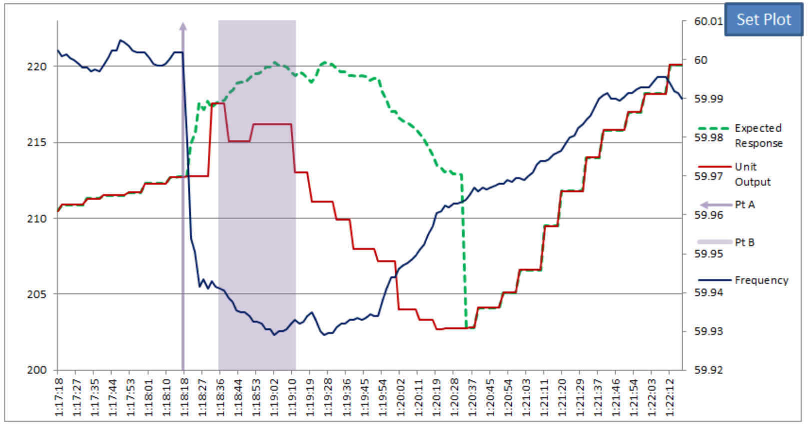
Frequency Response Unit Event Performance Tool

Governor Settings	
Droop (%):	*5%*
Deadband (Hz):	*0.036*

in MW	**Actual Resp.**	**Expected Resp.**
Point A =	**212.733**	**212.733**
Point B =	**215.894**	**219.370**

Plot Times	
Event Start:	12/29/2012 1:18:18
Plot Start:	12/29/2012 1:17:18
Plot End:	12/29/2012 1:22:18
Interval:	2s

Actual Response =	**3 MW**
Expected Response =	**7 MW**
Deficiency =	**3 MW**

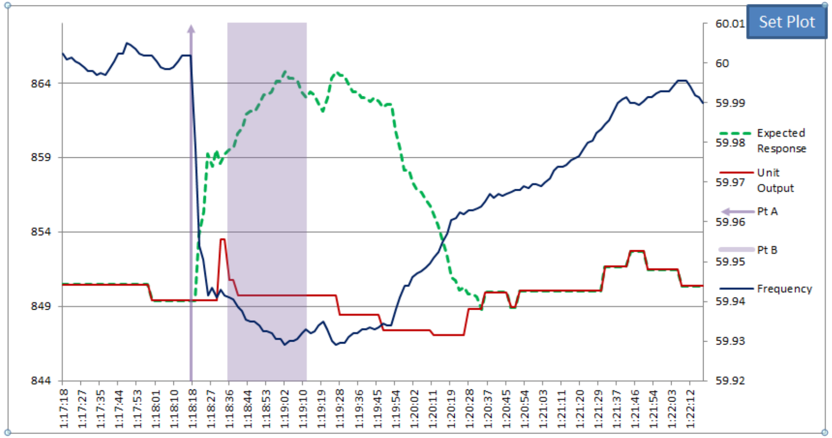


Governor Settings	
Droop (%):	*5%*
Deadband (Hz):	*0.036*

in MW	**Actual Resp.**	**Expected Resp.**
Point A =	**849.400**	**849.400**
Point B =	**849.814**	**862.880**

Plot Times	
Event Start:	12/29/2012 1:18:18
Plot Start:	12/29/2012 1:17:18
Plot End:	12/29/2012 1:22:18
Interval:	2s

Actual Response =	**0 MW**
Expected Response =	**13 MW**
Deficiency =	**13 MW**



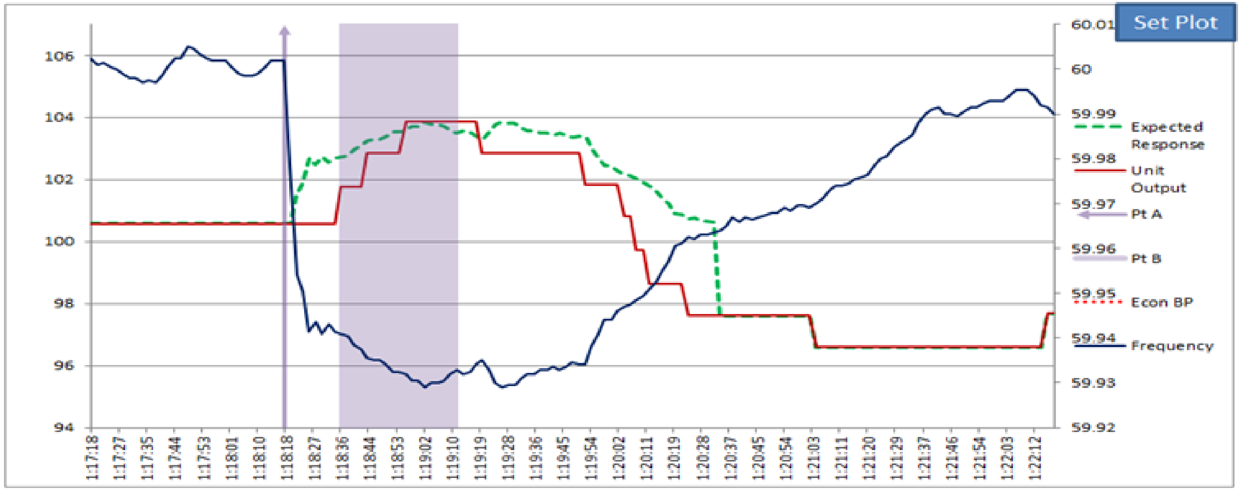
Unit responded as expected

Governor Settings	
Droop (%):	5%
Deadband (Hz):	0.036

in MW	Actual Resp.	Expected Resp.
Point A =	100.576	100.576
Point B =	103.127	103.459

Plot Times	
Event Start:	12/29/2012 1:18:18
Plot Start:	12/29/2012 1:17:18
Plot End:	12/29/2012 1:22:18
Interval:	2s

Actual Response =	3 MW
Expected Response =	3 MW
Deficiency =	0 MW



Response as Expected

Frequency Response Unit Summary Performance

Unit:
Frequency:
Unit MW:
Spin Max:

$$MW_{PrimaryControl} = \left[\frac{(HZ_{actual} - 60 + DB)}{(60 * Droop - DB)} \right] * (FrequencyResponsiveCapacity) * (-1)$$

Generator Output MW = Load Set-point MW + $MW_{PrimaryControl}$

Governor Settings

Droop (%):	5%
Deadband (Hz):	0.036
RPM Capacity (MW):	635
Unit Zone:	
Resource ID:	
Econ. Min	220
Spin Max	635
Compliance Year	2013

Unit Summary		
Median Response =	**0.8**	**MW**
Median Expected =	**3.8**	**MW**
Median Deficiency =	**1.2**	**MW**
% Wrong Direction =	**39%**	**%**
% w/ Headroom =	**100%**	**%**

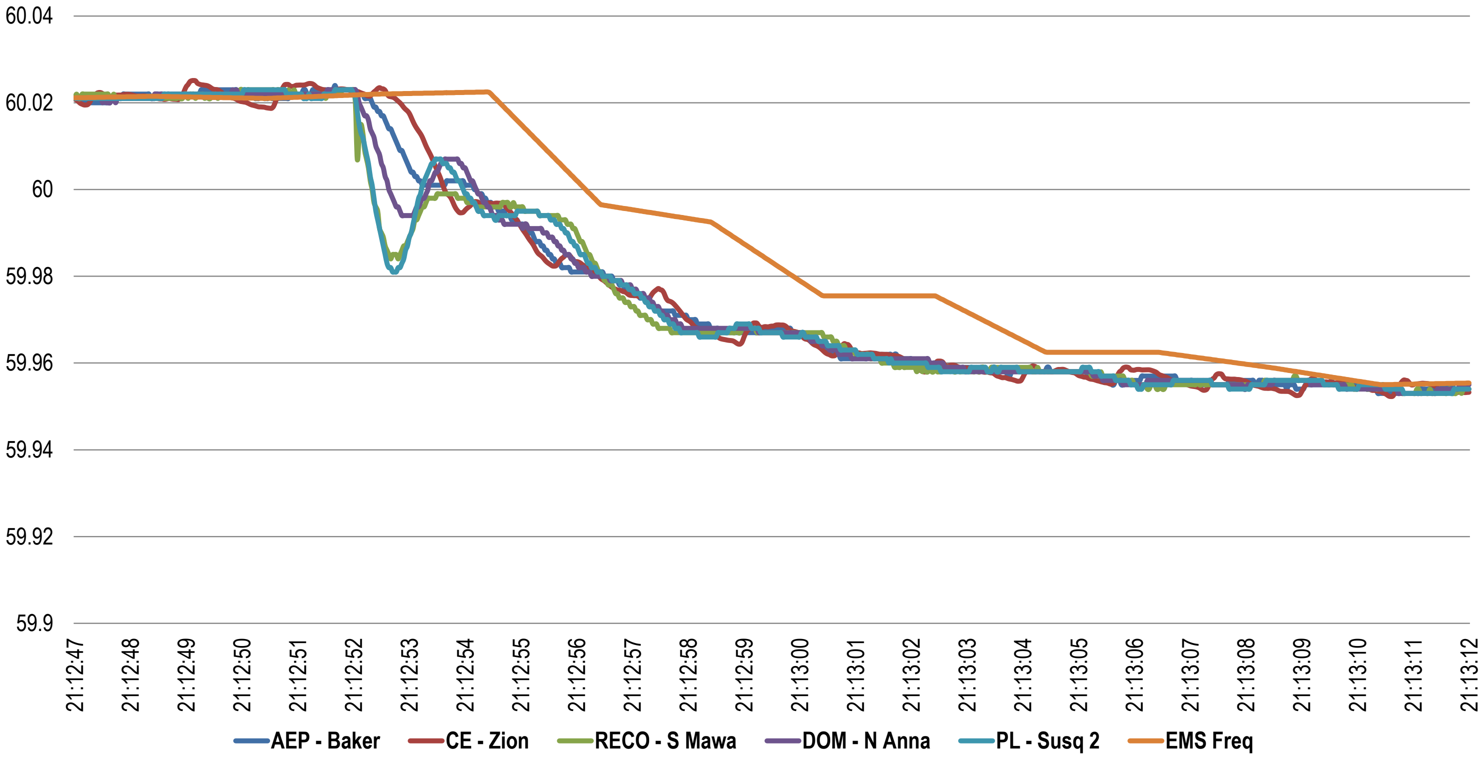
Set Plots

Copy Charts

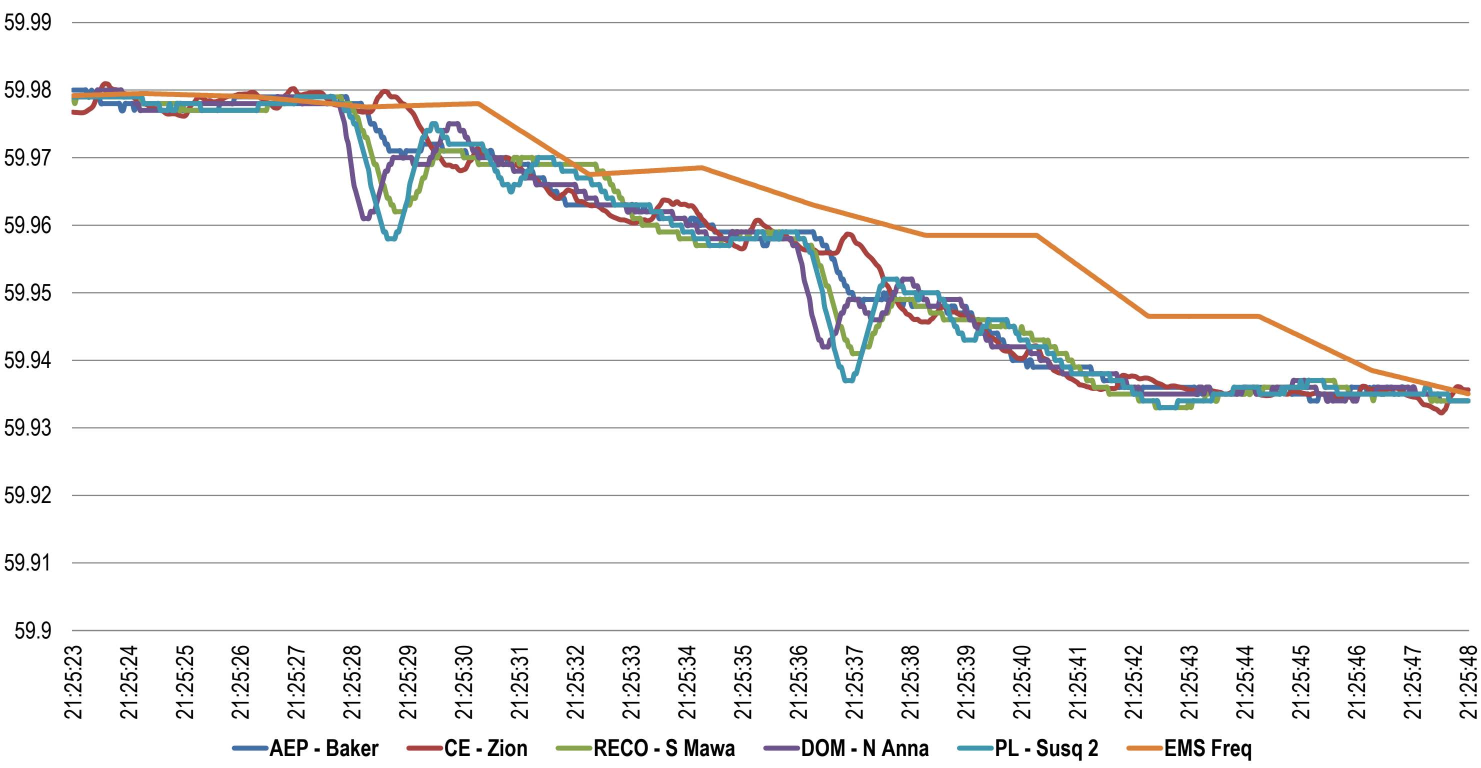
Summary Data

Event #	Event List	Actual Response (MW)	Expected Response (MW)	Response Deficiency (MW)	Headroom (MW)	Point A (MW)	Point B Expected (MW)	Point B Actual (MW)
1	12/29/2012 1:18:18	3.2	6.64	3.5	427.3	212.7333	219.3699	215.8941
2	1/5/2013 0:37:13	6.5	5.01	-1.5	432.4	207.6000	212.6106	214.1147
3	1/22/2013 3:32:59	4.6	4.75	0.1	404.3	235.7000	240.4503	240.3382
4	2/23/2013 21:04:13	4.2	3.16	-1.0	420.4	219.6000	222.7594	223.7677
5	2/25/2013 14:12:31	4.7	3.94	-0.8	294.6	345.3500	349.2874	350.0647
6	3/12/2013 14:51:53	3.2	2.52	-0.7	236.8	403.2000	405.7243	406.4294
7	4/4/2013 15:59:00	0.0	Off-line	Off-line	Off-Line	-8.3525	0.0000	-8.3414
8	4/17/2013 15:59:40	0.0	Off-line	Off-line	Off-Line	-1.4545	0.0000	-1.4870
9	4/18/2013 9:27:06	0.0	Off-line	Off-line	Off-Line	-1.5375	0.0000	-1.5138
10	5/16/2013 10:15:46	2.8	9.58	6.8	10.8	629.2000	638.7809	632.0172
11	5/27/2013 14:41:09	-0.1	Off-line	Off-line	Off-Line	-9.6984	0.0000	-9.7770
12	6/5/2013 10:54:14	0.0	Off-line	Off-line	Off-Line	-8.2334	0.0000	-8.2556
13	6/5/2013 14:52:44	0.0	Off-line	Off-line	Off-Line	-8.0299	0.0000	-8.0356
14	6/17/2013 11:49:48	1.9	3.87	1.9	281.3	358.7000	362.5702	360.6494
15	6/28/2013 13:20:46	0.8	4.75	3.9	11.2	628.8000	633.5528	629.6143

Unit loss – SCADA data vs Phasor data



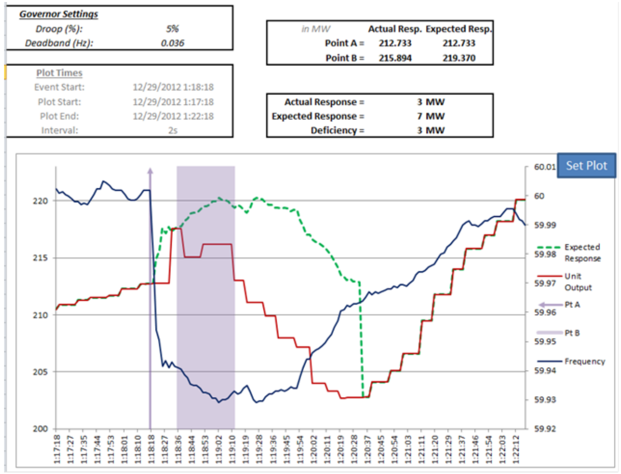
Two unit loss - 9 seconds apart



Meeting new requirements

Effective April 1st, 2016

Each … Balancing Authority … shall achieve an annual Frequency Response that is equal to or more negative than its Frequency Response Obligation



Business Challenge

Being able to develop displays in a timely manner without disruption to EMS.

Solution

PI ProcessBook and PI DataLink have been utilized to create new displays.

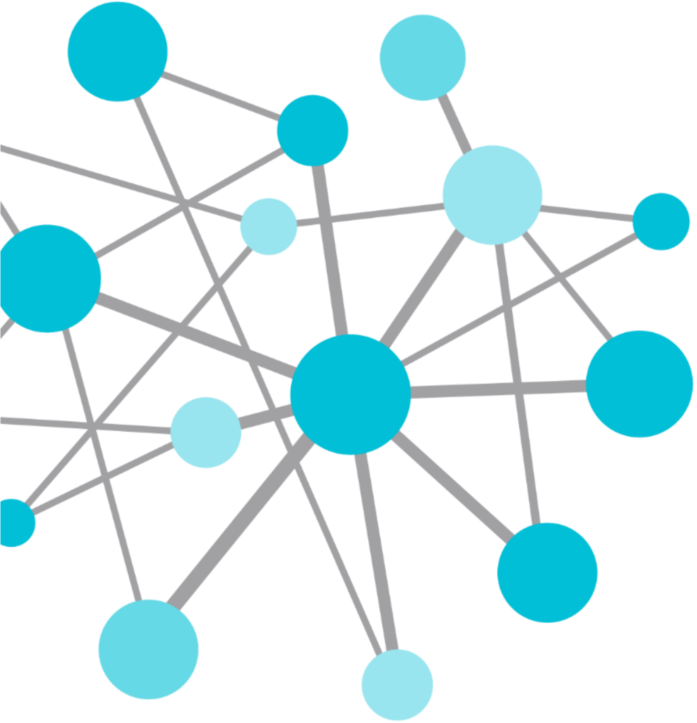
Results and Benefits

Displays built without the need of vendors.

Displays built without requiring code changes in the EMS.

Thomas Keyser

- Thomas.keyser@pjm.com
- Transmission Dispatcher
- PJM Interconnection



Questions

Please wait for the **microphone** before asking your questions

State your **name & company**

THANK YOU

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