The Value of the PI System at PJM Interconnection

Presented by **Thomas Keyser**

Transmission System Operator

Agenda

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

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/Situational Awareness
  - 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

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
- Nodal Prices

PI assists Operators in the control room

- Allows unifying data from multiple sources into one screen easily to assist operators.
- Ability to quickly build displays for problem areas during extreme weather events.
- Build displays in real time by the operators to view current events.
- Operators need more data then what is in the EMS and PI allows for this. Example: PI is now monitoring the generators connected to the major gas pipelines.

Situational Awareness Benefits with PI

PJM is using 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 Processbook displays for generation and transmission data that can be visible to all operators in the control room.

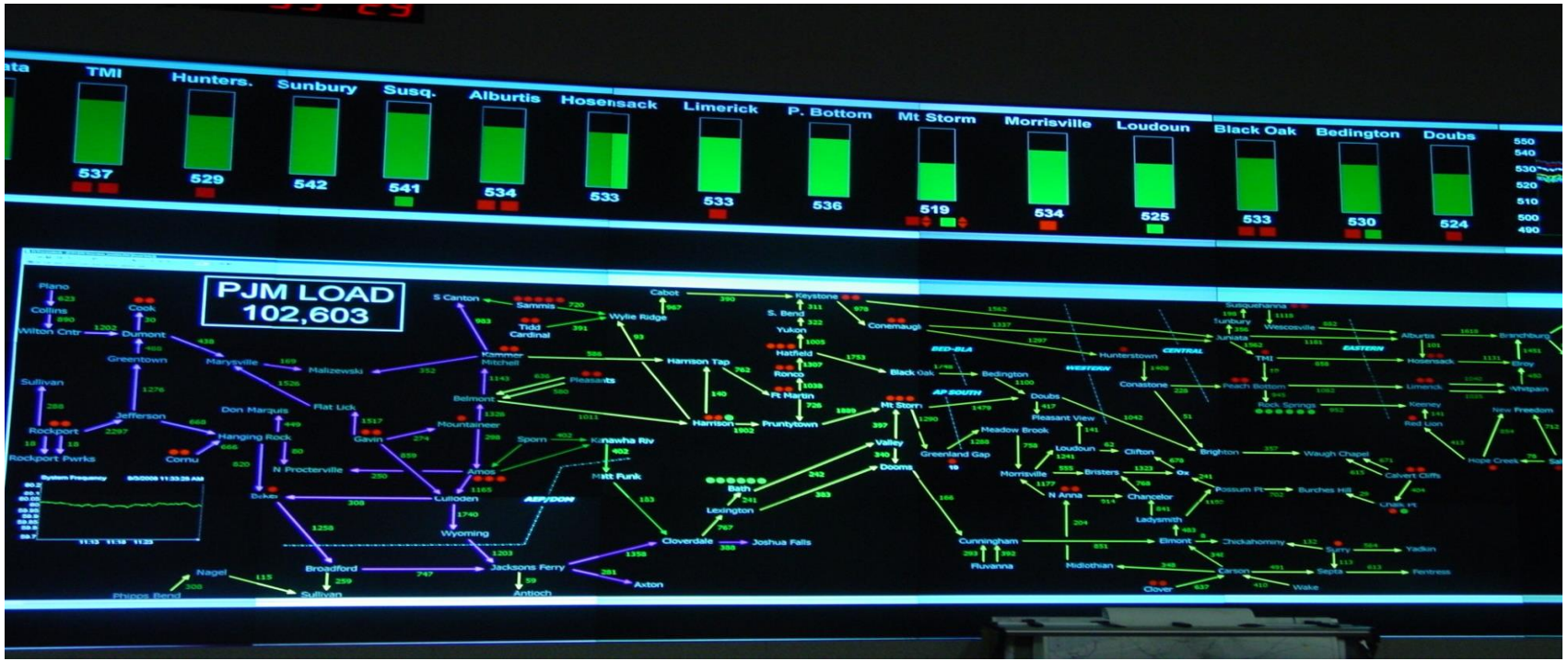
Results and Benefits

Situation awareness improved in control room.

Operators are all looking at same information

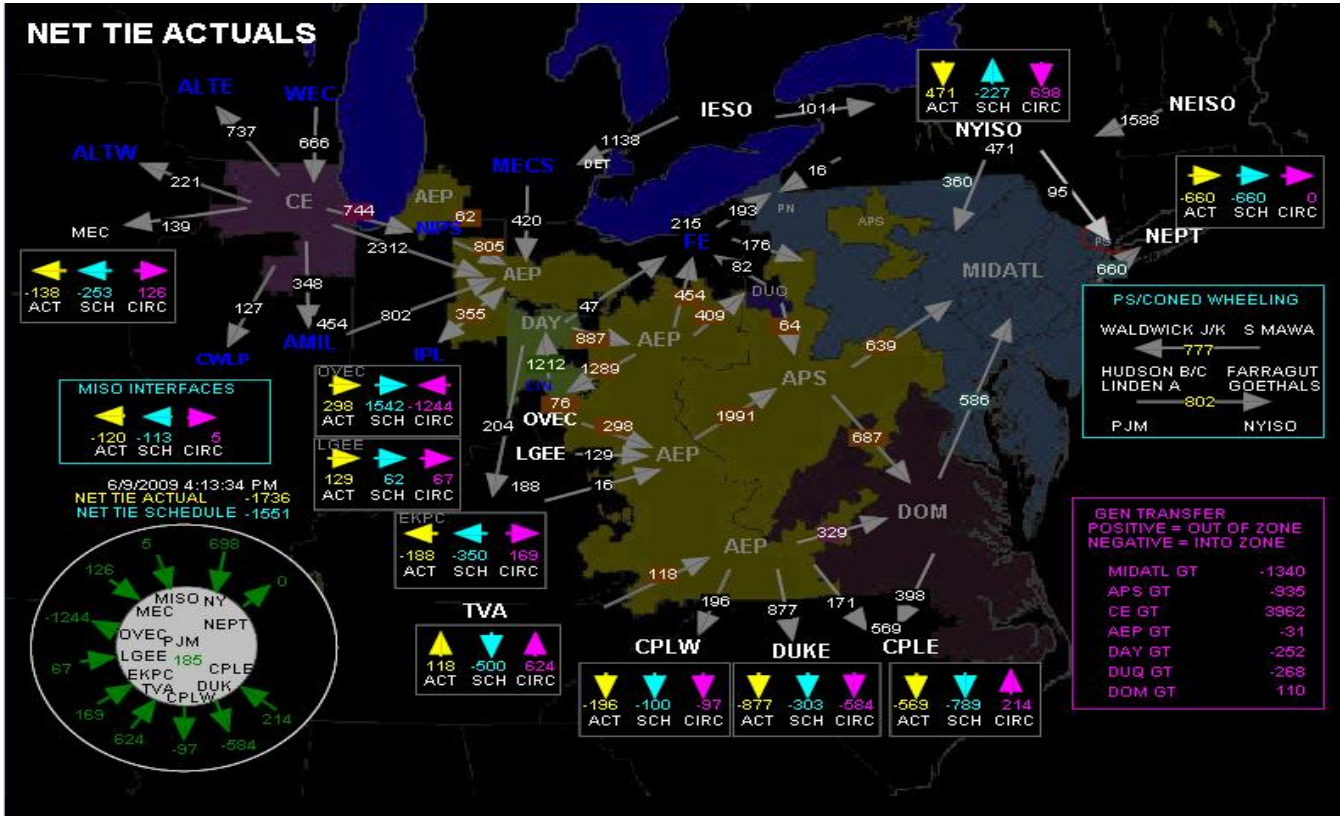
View of control room video walls

765kv and 500kv overview



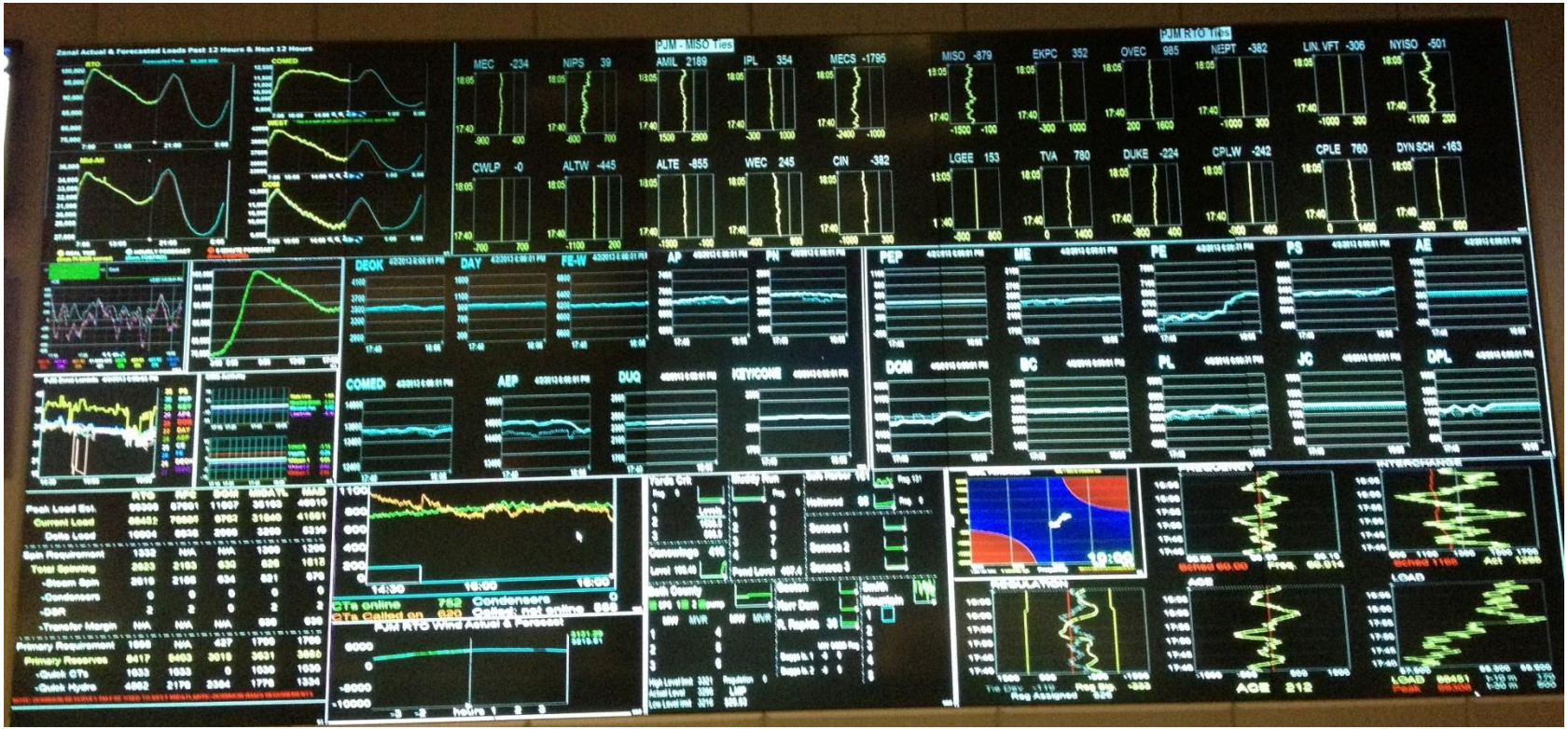
Transmission flows and voltages

Scheduled and Actual MW flows between PJM and neighbors

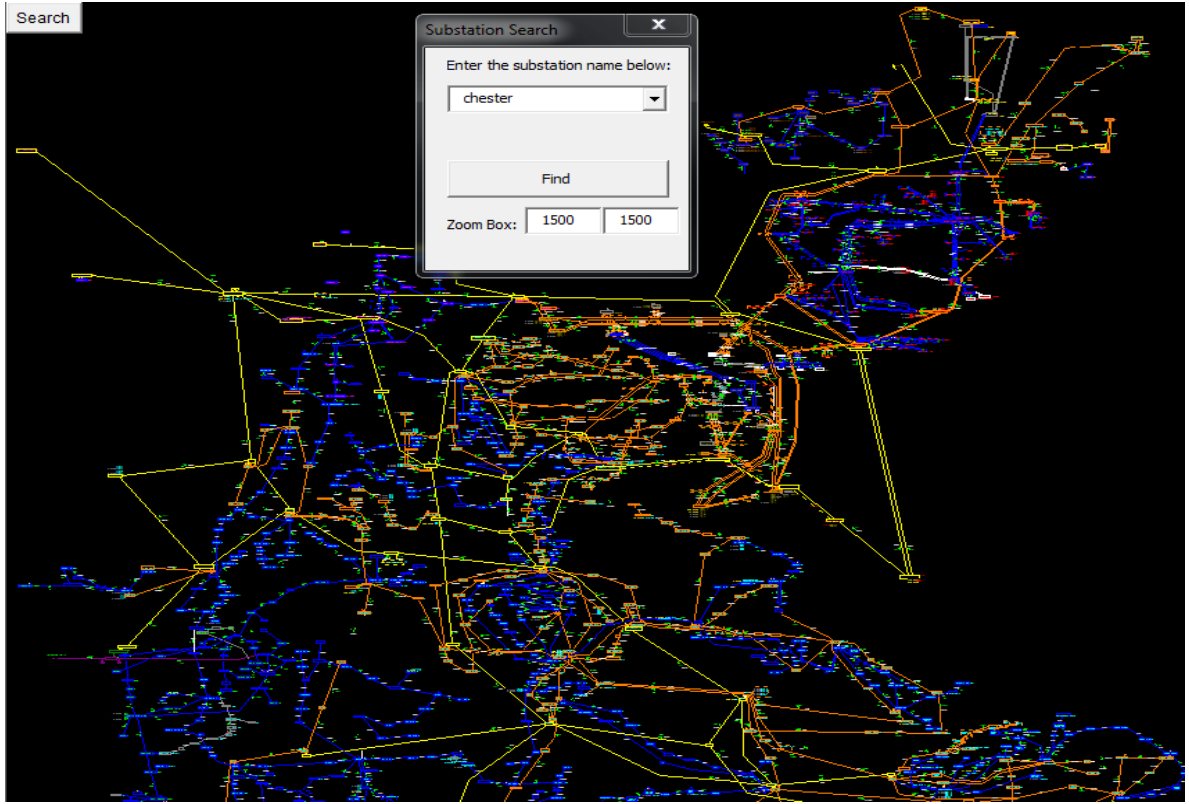


Generation outputs

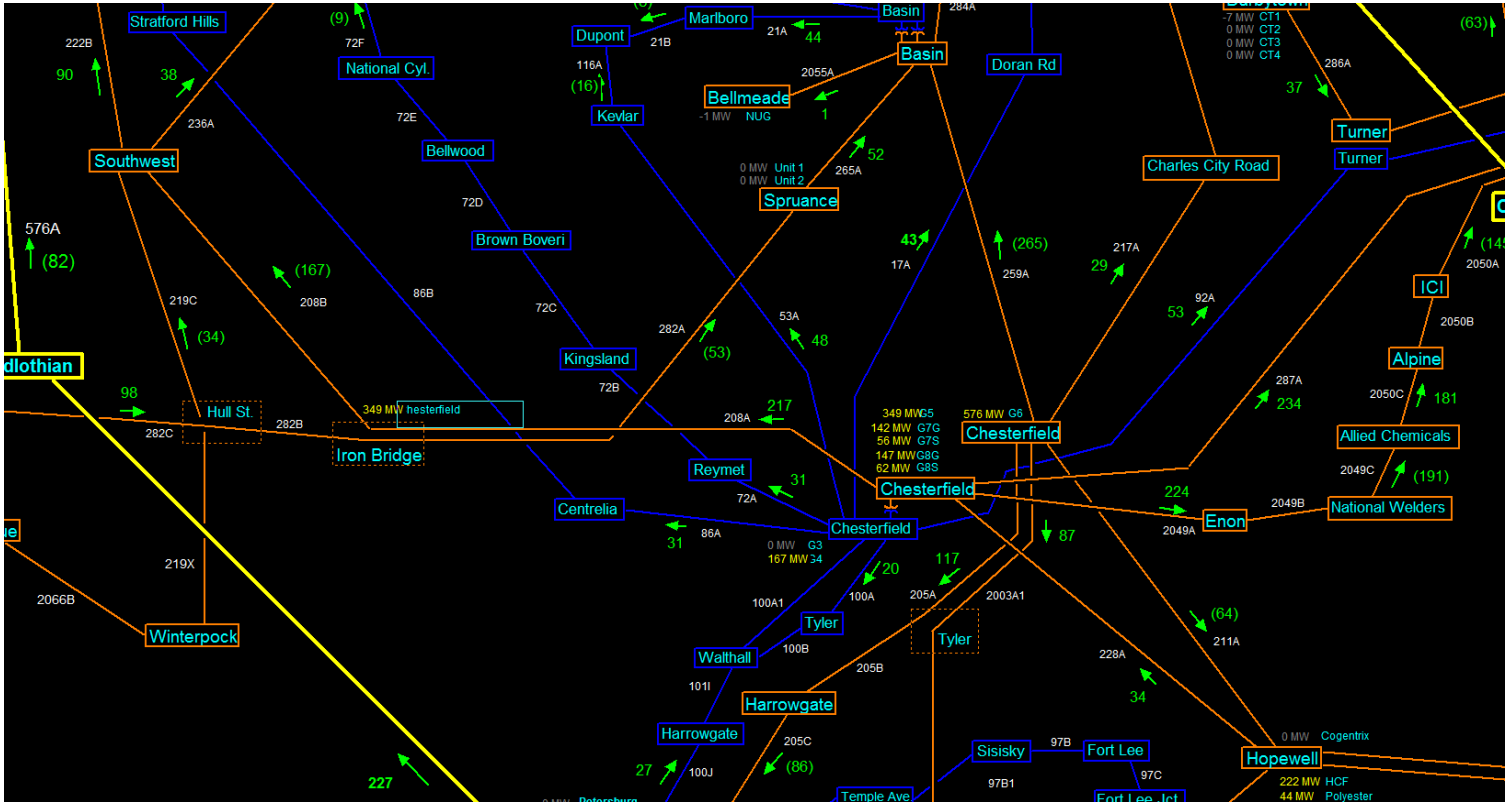
Generation Video Wall



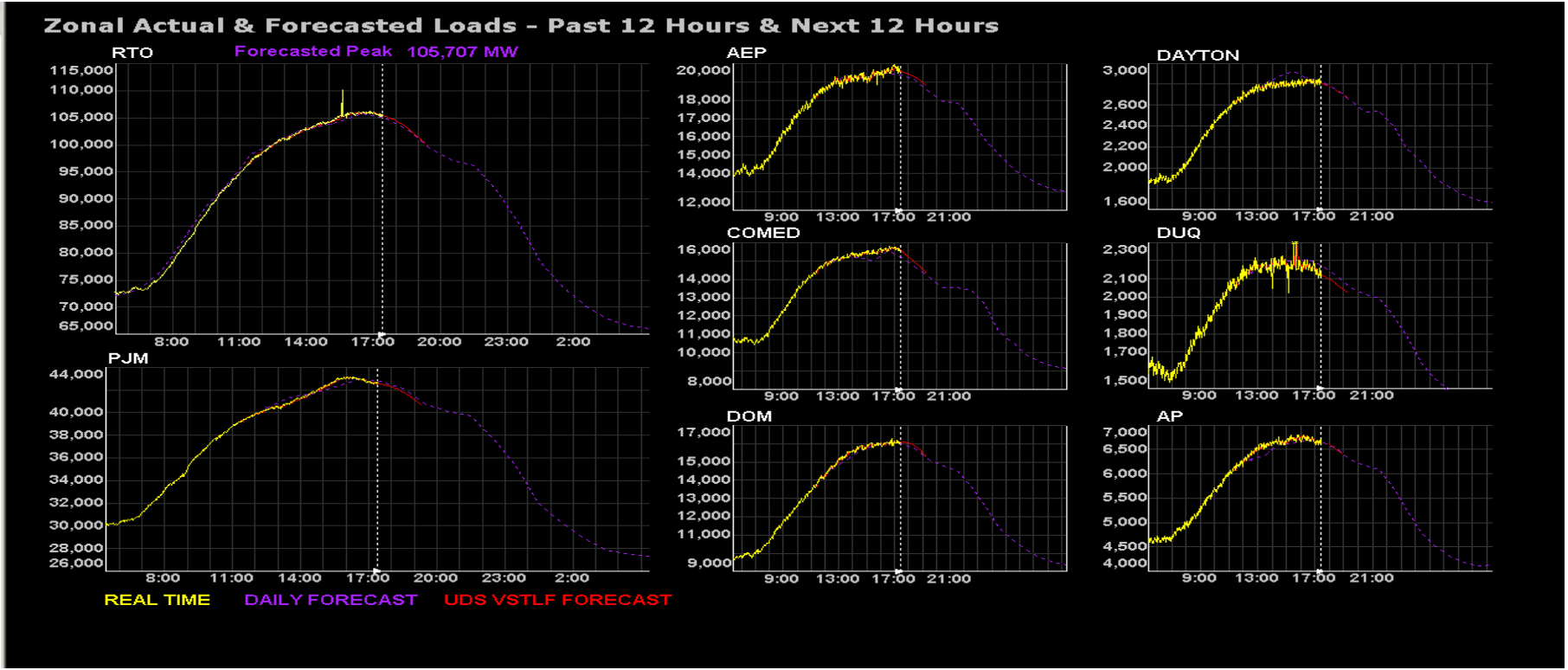
Transmission Zone Overview Example



Zoomed in after search

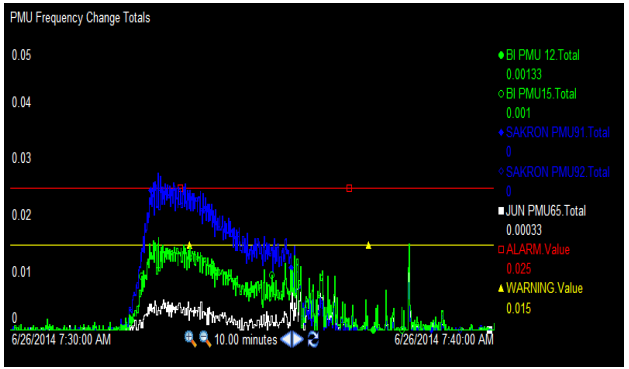


Actual & Forecasted Loads



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 so displays can be built for real-time monitoring and post mortem analysis.

Results and Benefits

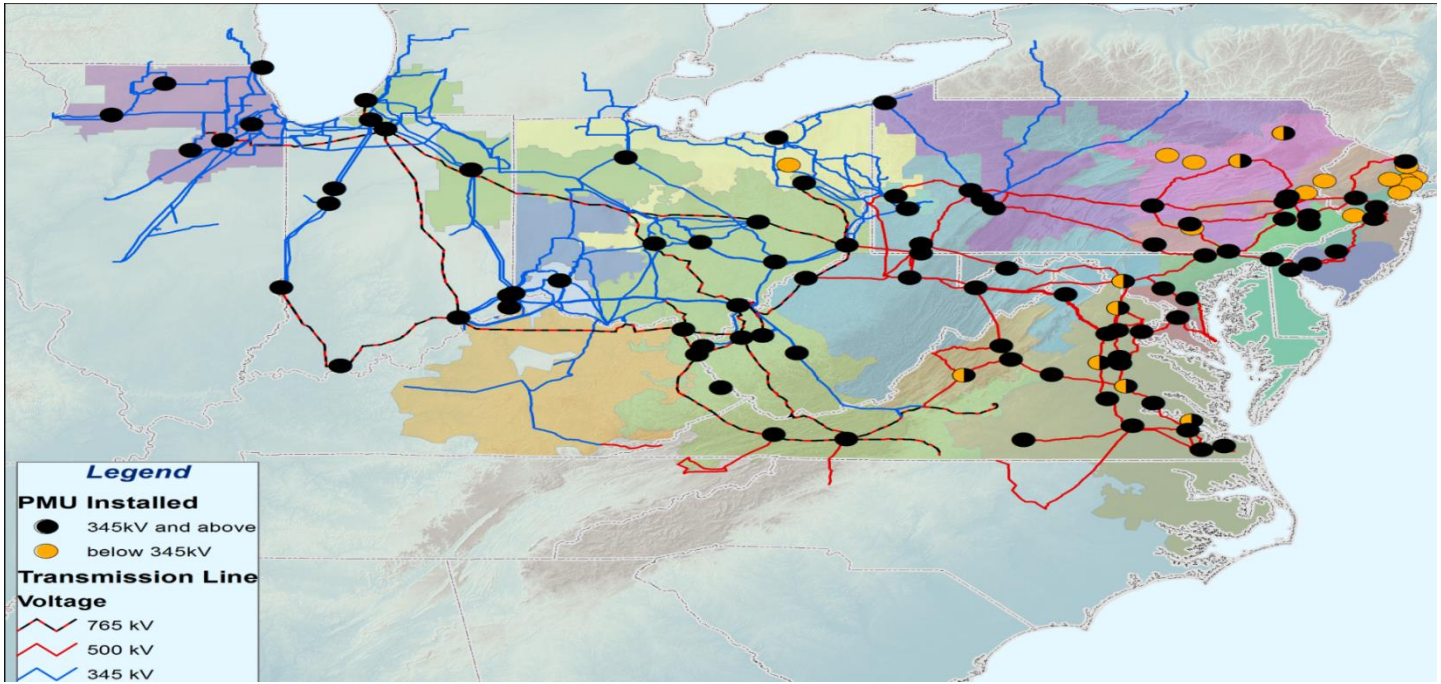
Performance Compliance department is currently using PMU data for analysis of system disturbances.

Engineers are using PMU data for stability analysis.

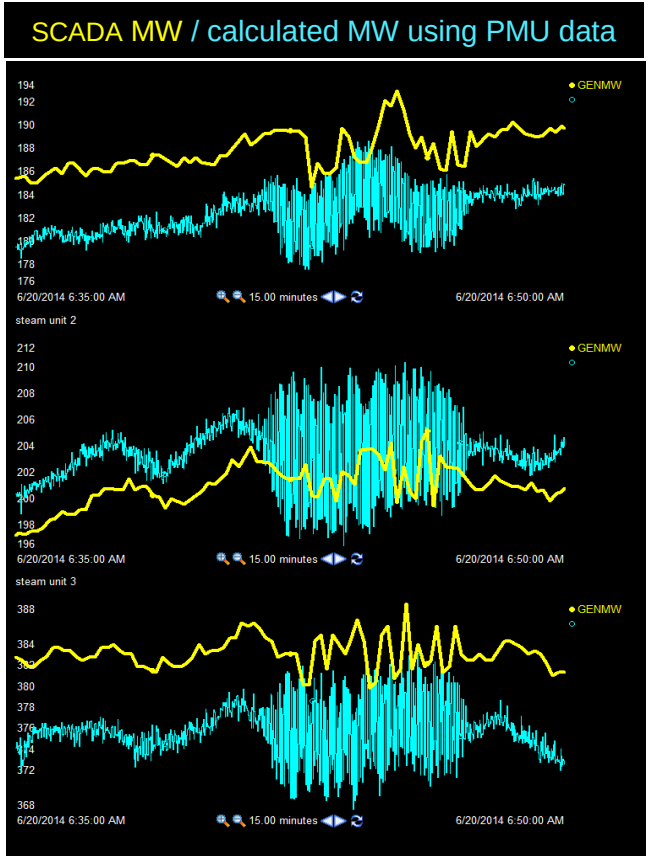
Synchrophasor Data at PJM

- 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



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

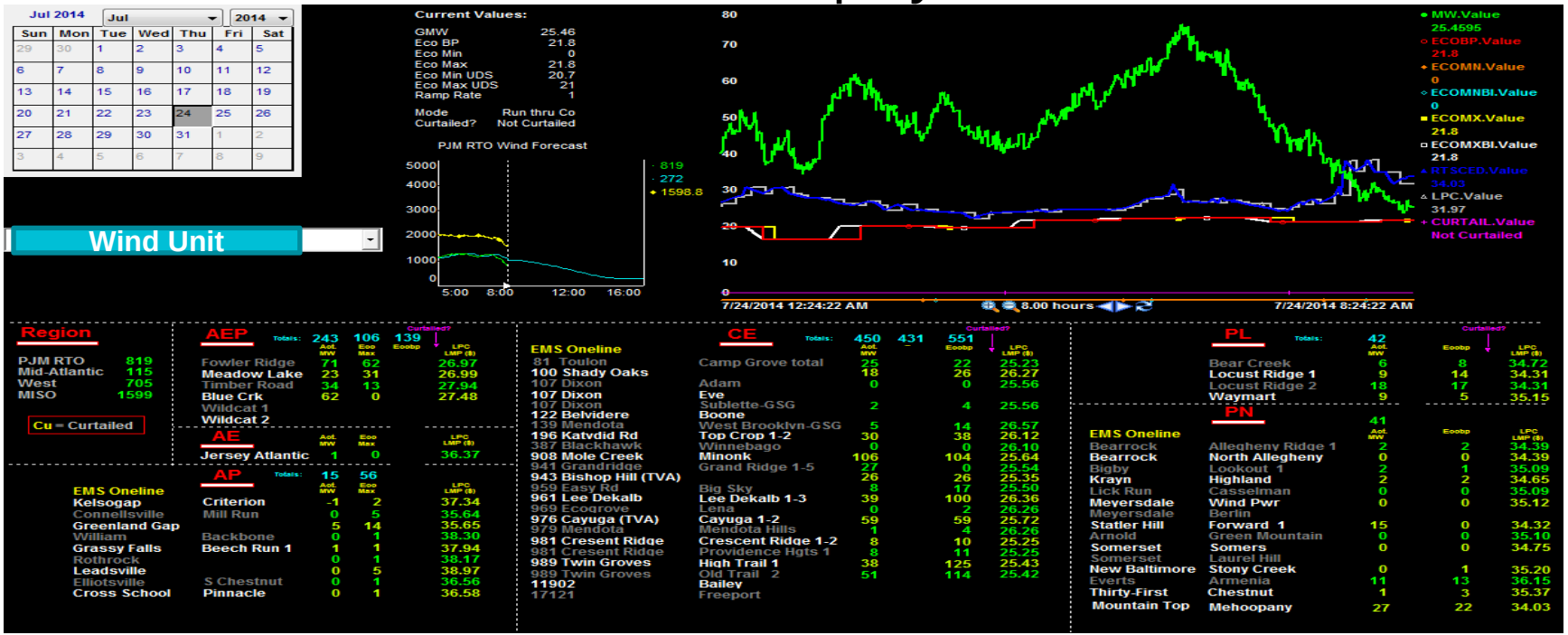
Build Processbook displays with Wind Farm outputs and trends with real-time MW and forecasted MW.

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.

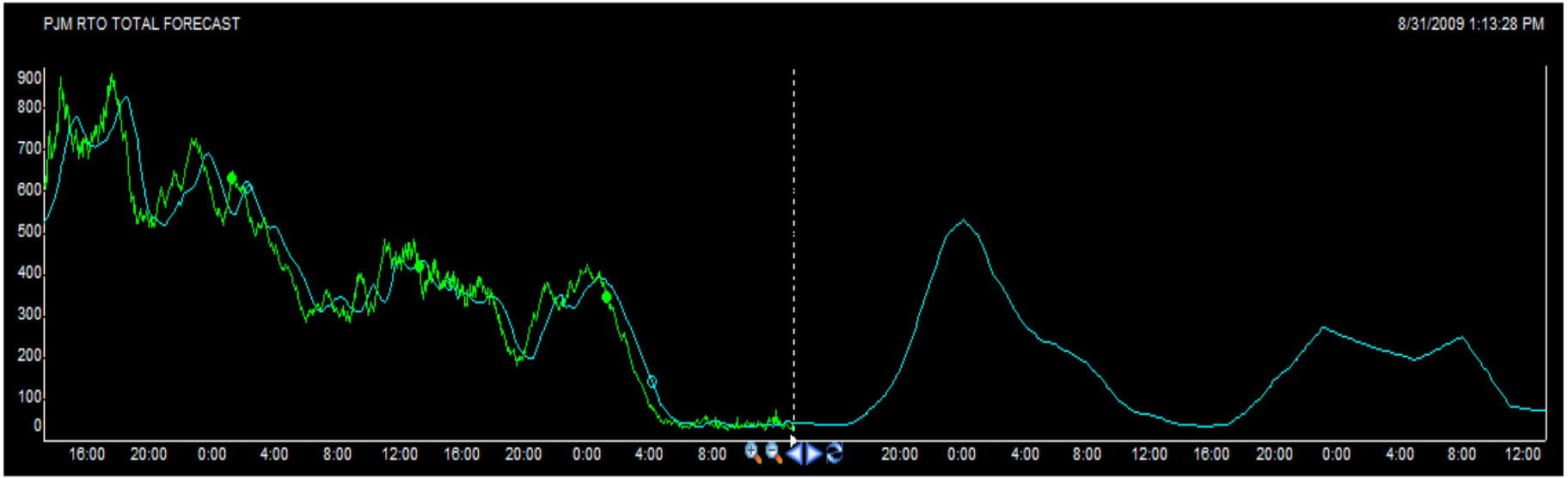
Renewable integration into Operations

Wind Display



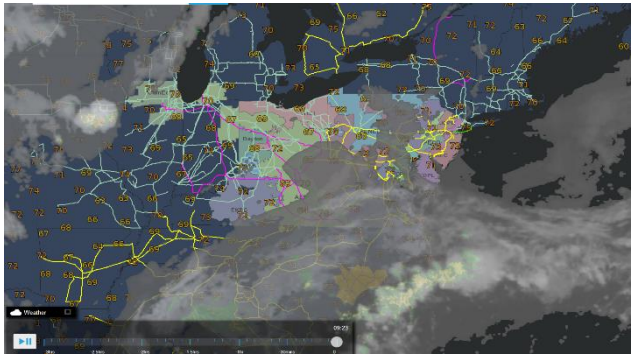
Wind Power Forecasting

Future data is combined with historical and real-time data



ARCGIS and PI

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

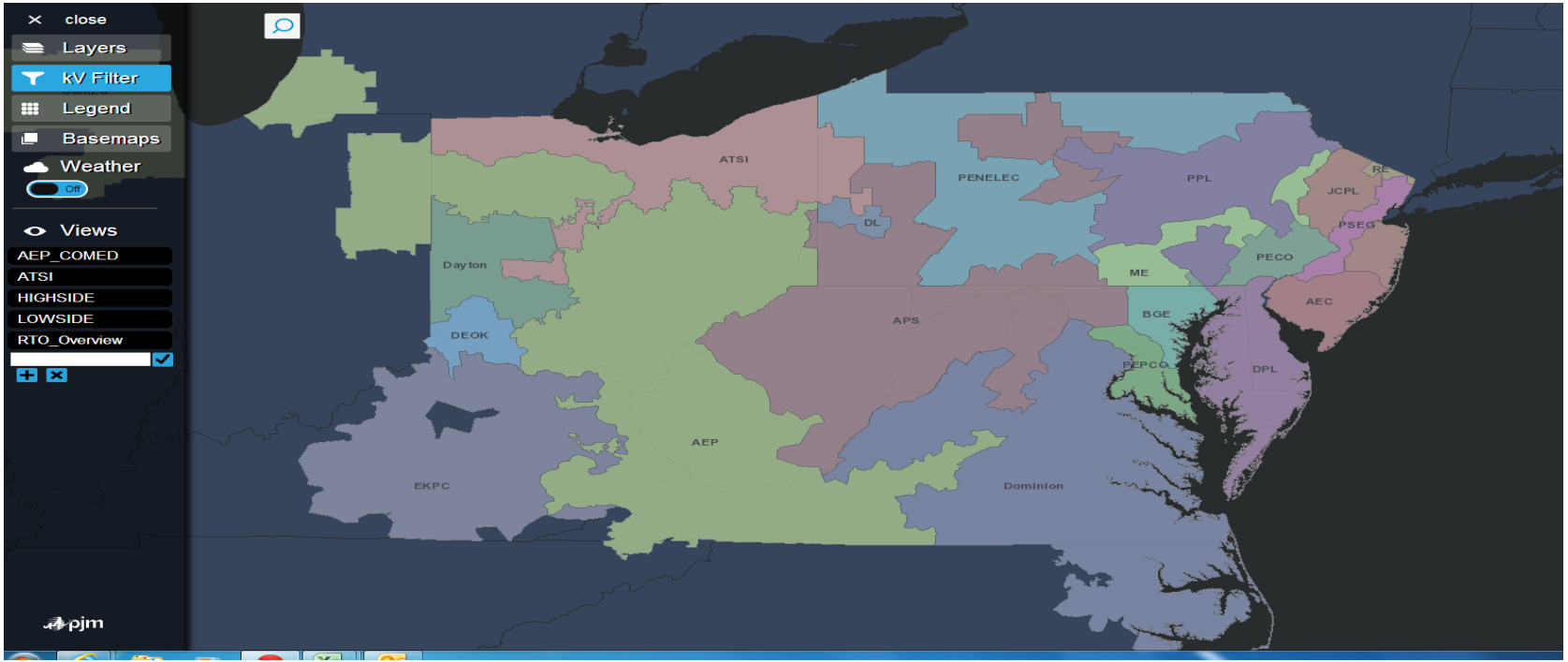
Combine ESRI and OSIsoft products to visualize power flows on the PJM grid.

Results and Benefits

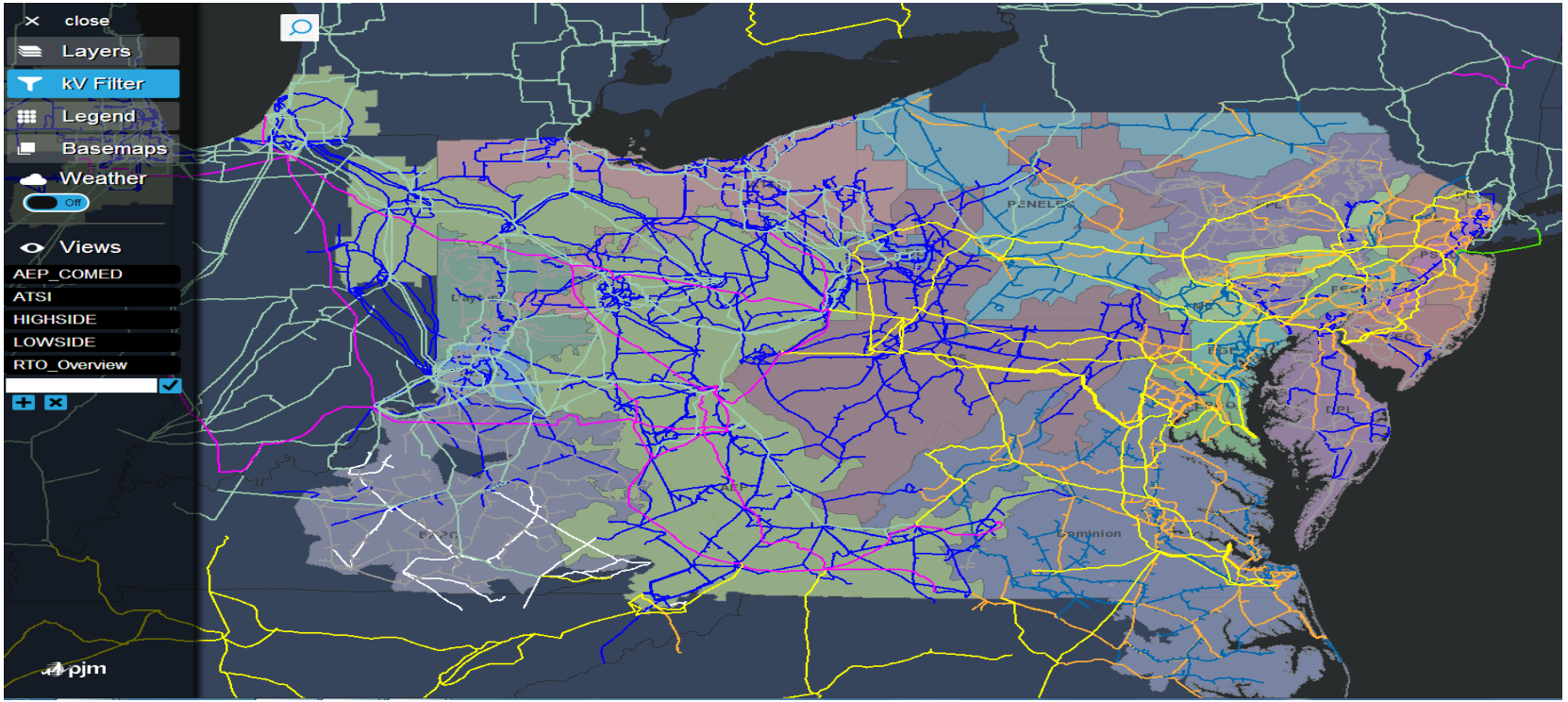
Improved situational awareness by combining data from multiple sources into a geographic view of the power grid

Dispatch Interactive Map Application (DIMA)

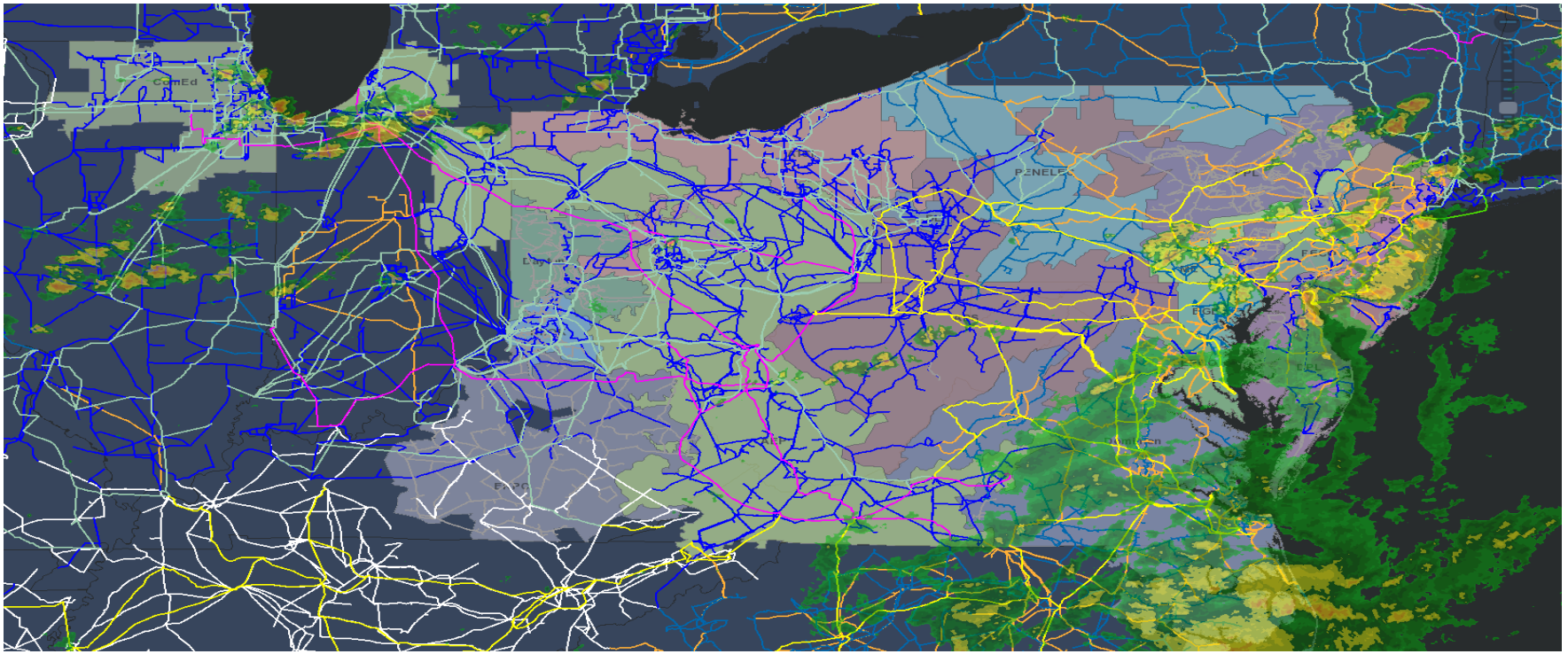
OSI PI System and ESRI ARCGIS integration



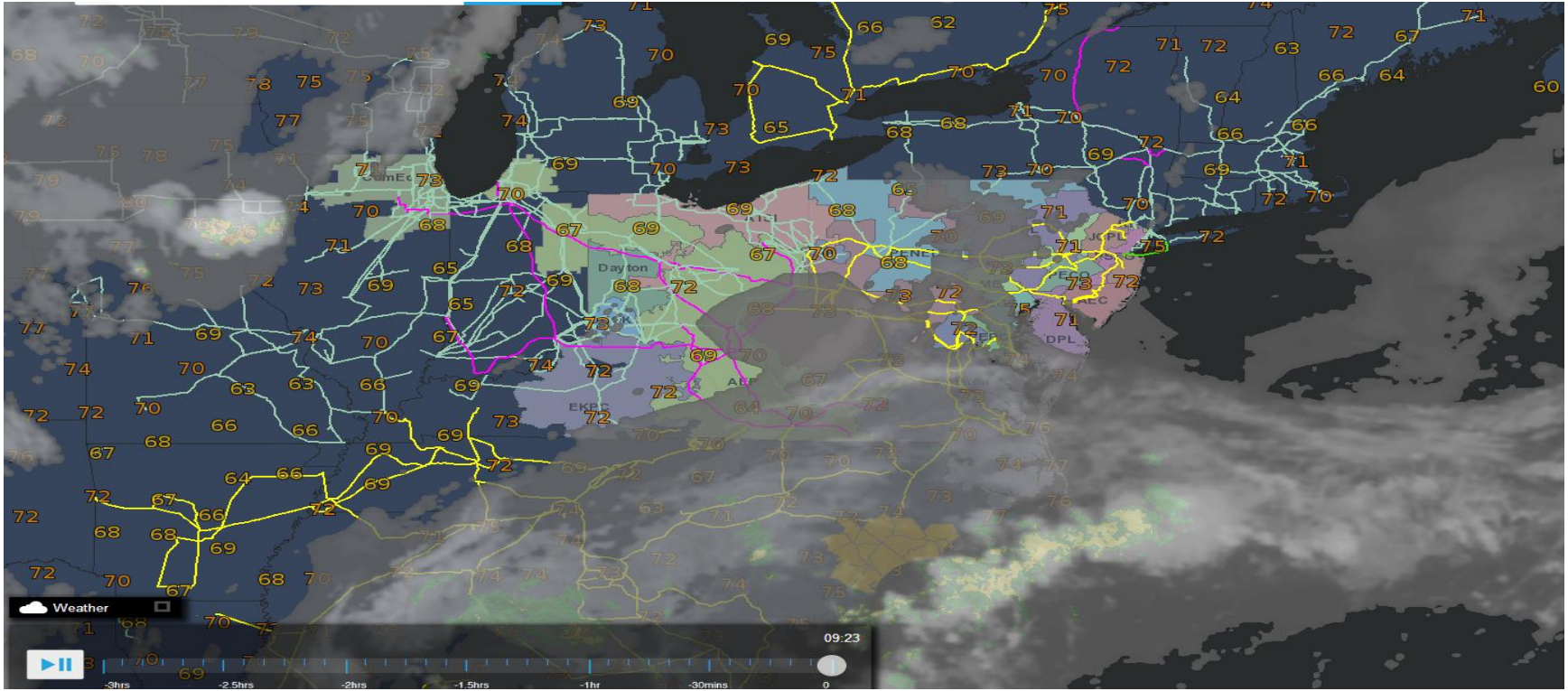
Transmission system overview



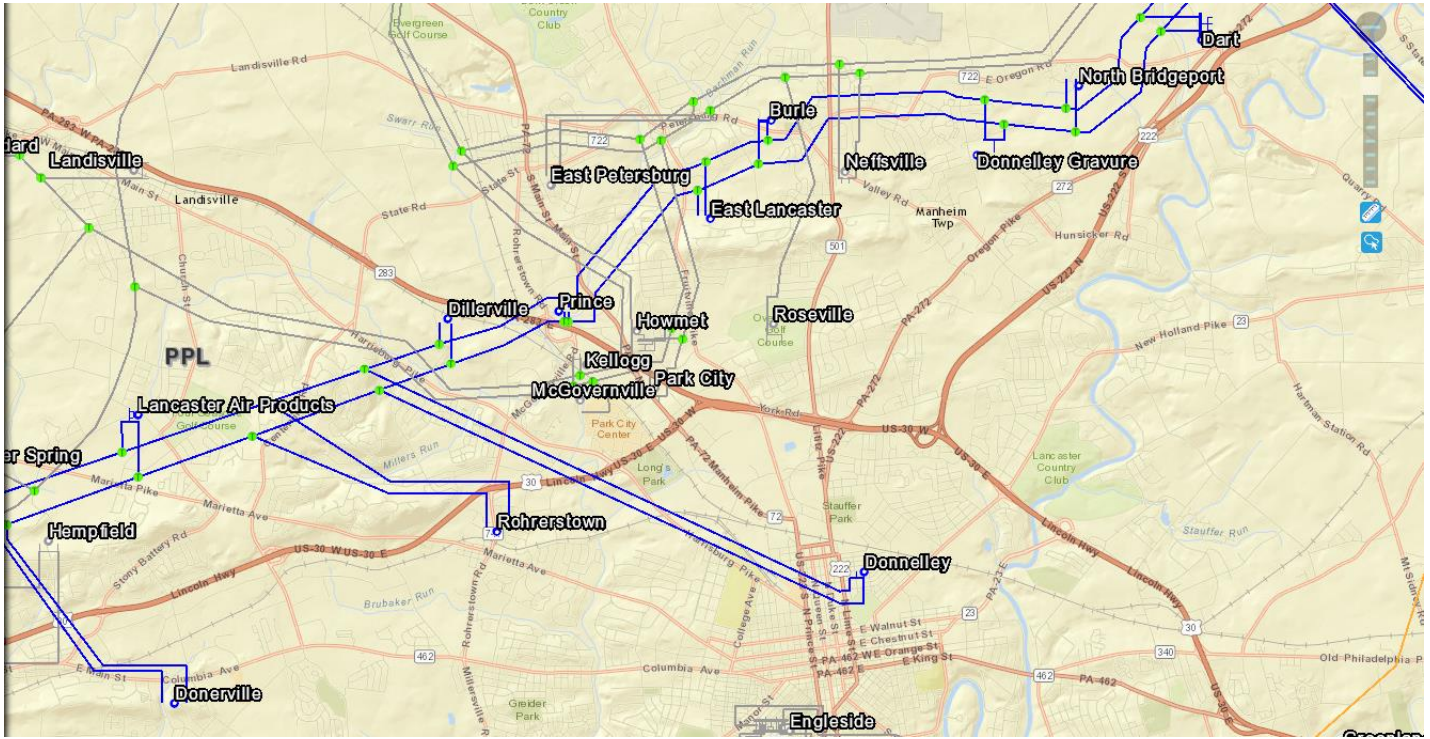
Radar data added



Temperatures and clouds added



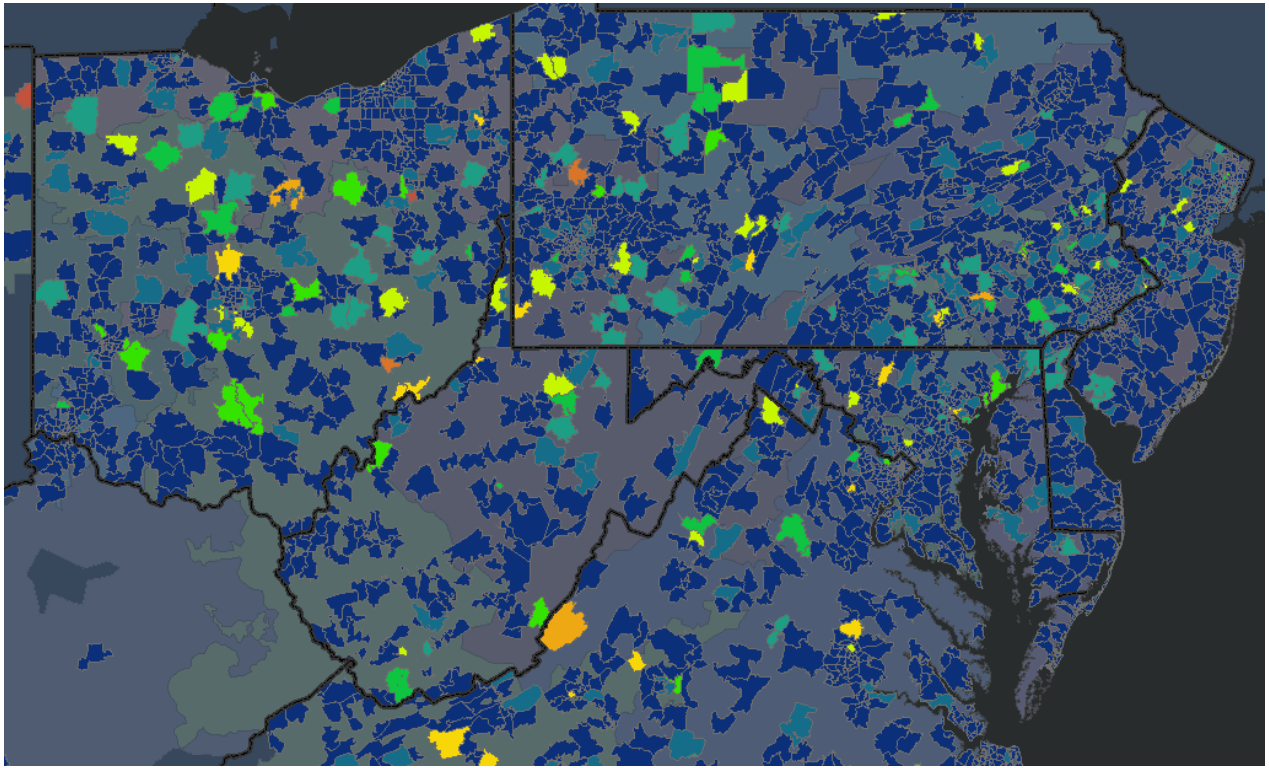
Zoomed in view of transmission lines



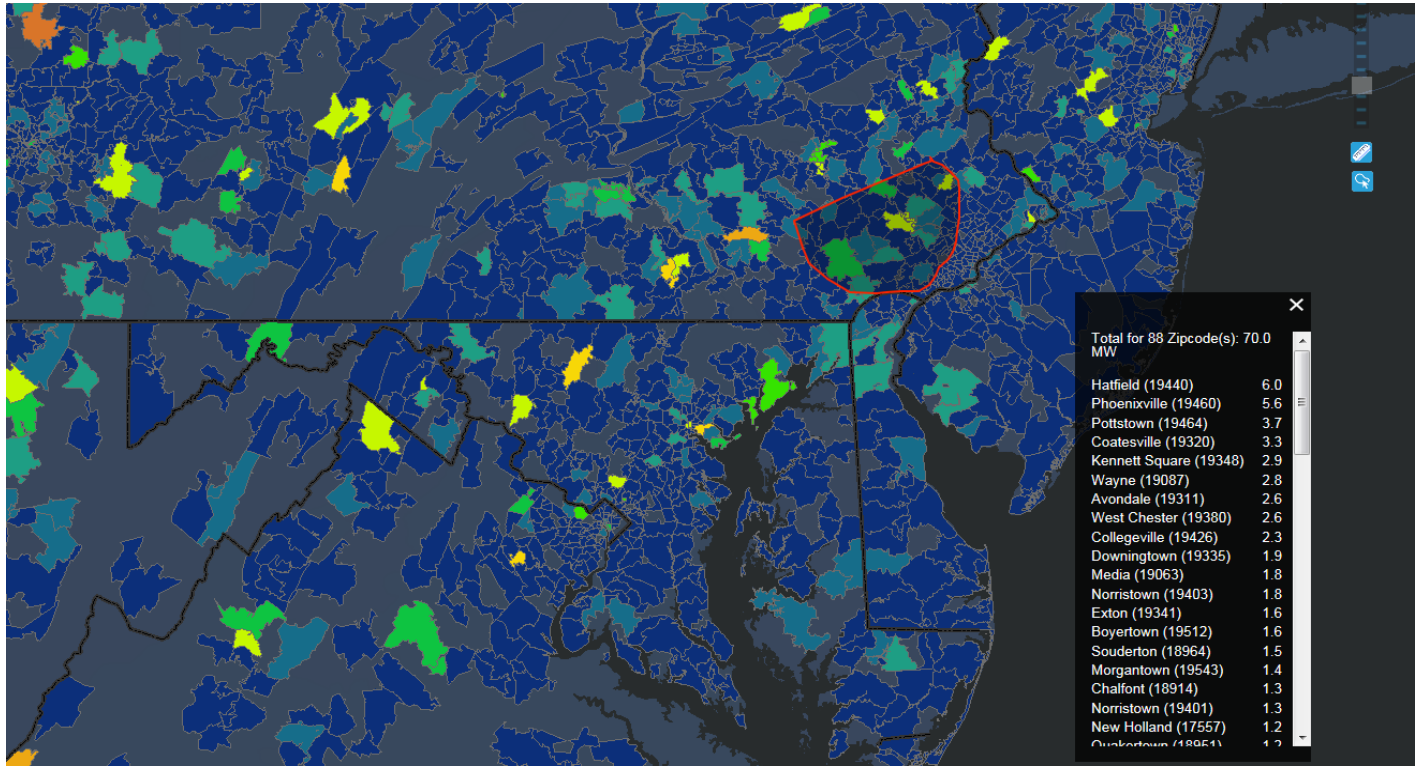
Line Outages

Line flows, Generator status, Station one-line configuration

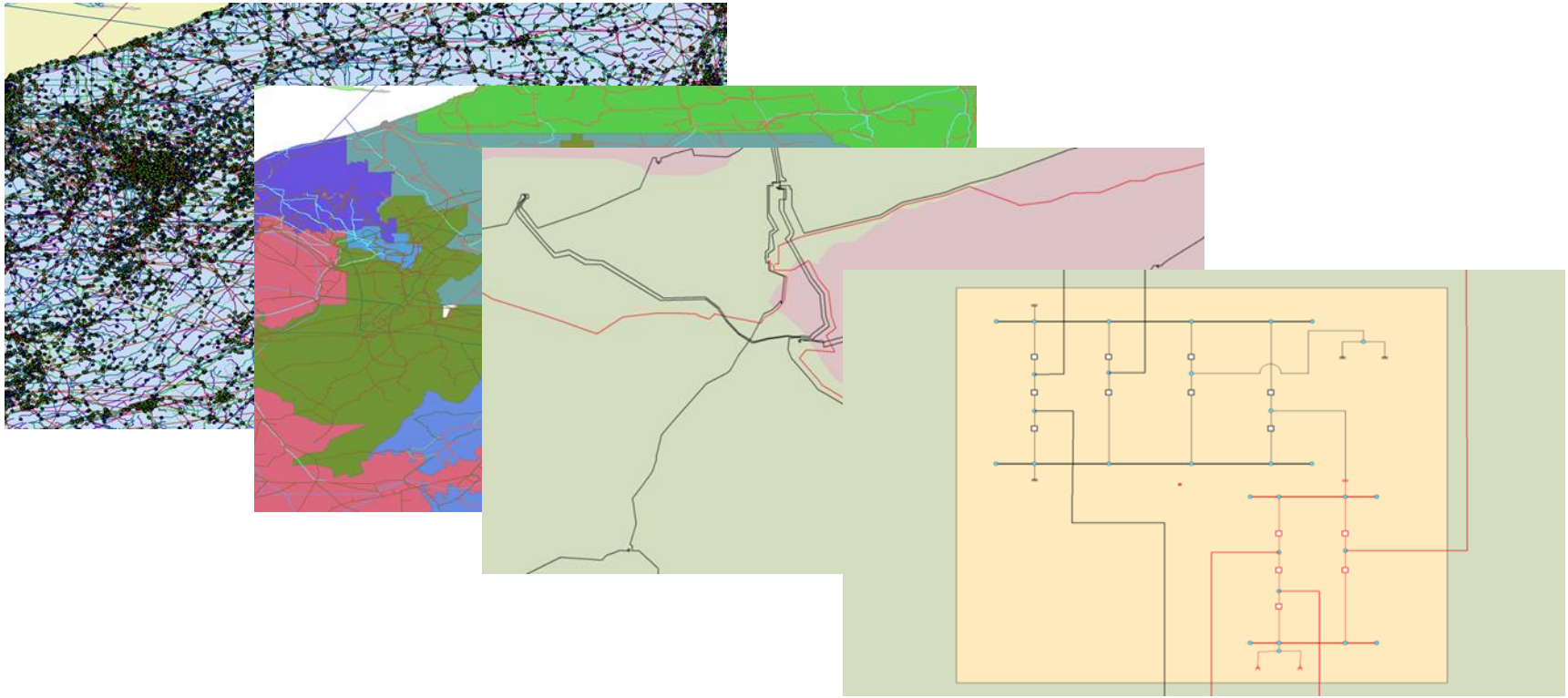
Demand Response



Demand response-zoomed in on area



Evolution of GIS at PJM

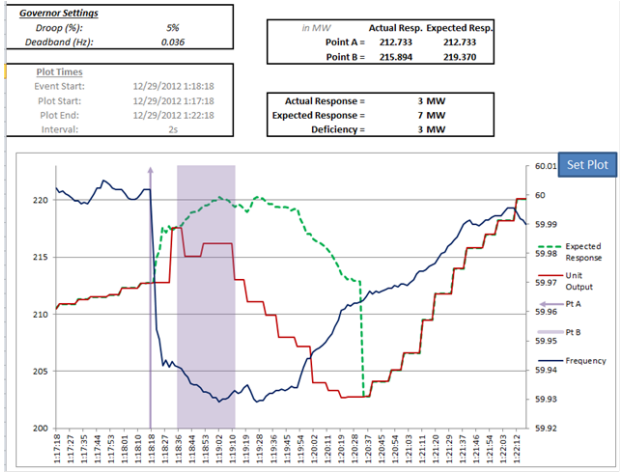


Responding to new FERC requirements

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.

Governor dead band and droop settings.



Business Challenge

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

Solution

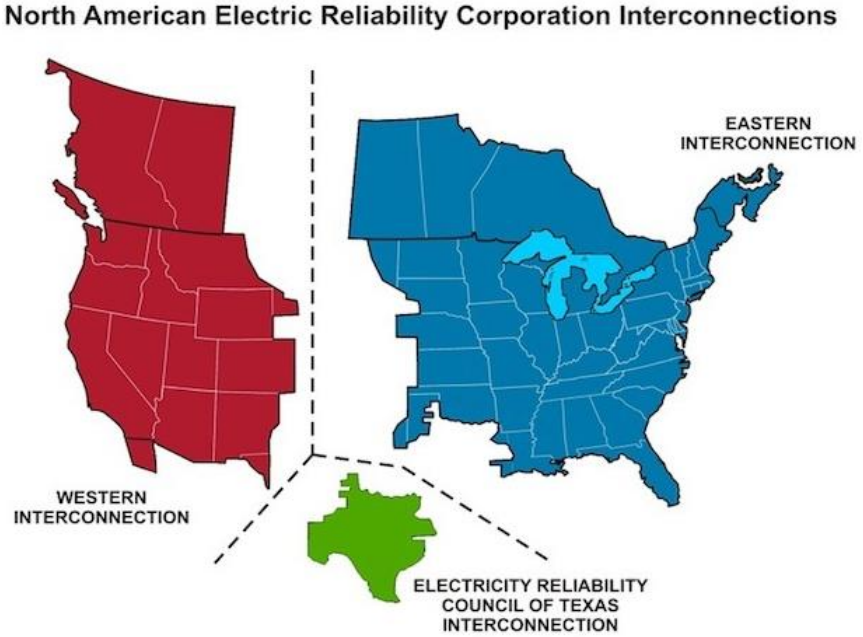
Processbook and Data Link have been utilized to create new displays.

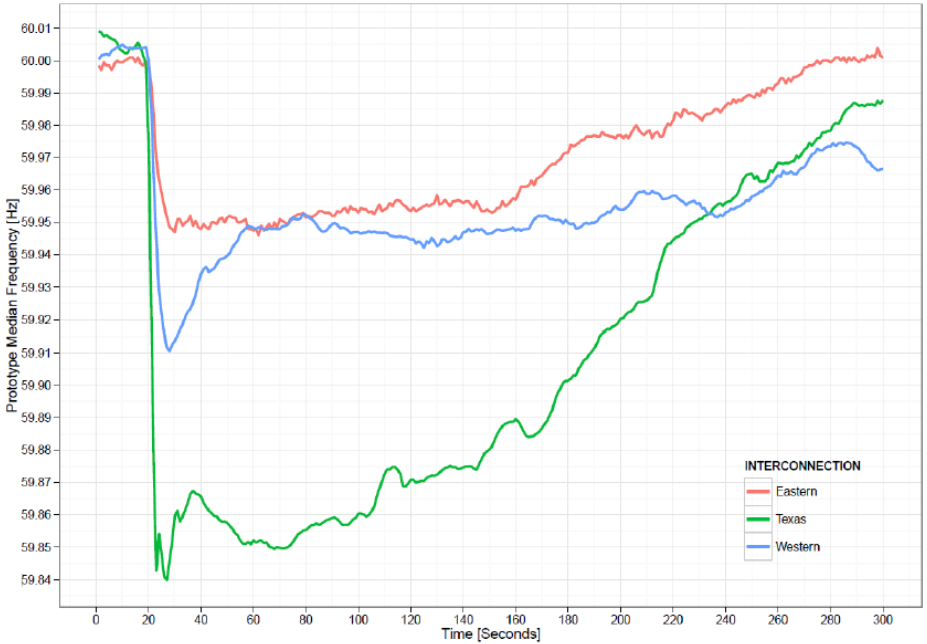
Results and Benefits

Displays built without the need of vendors.

Displays built without requiring code changes in the EMS.

Typical Interconnection Frequency Responses for 2011





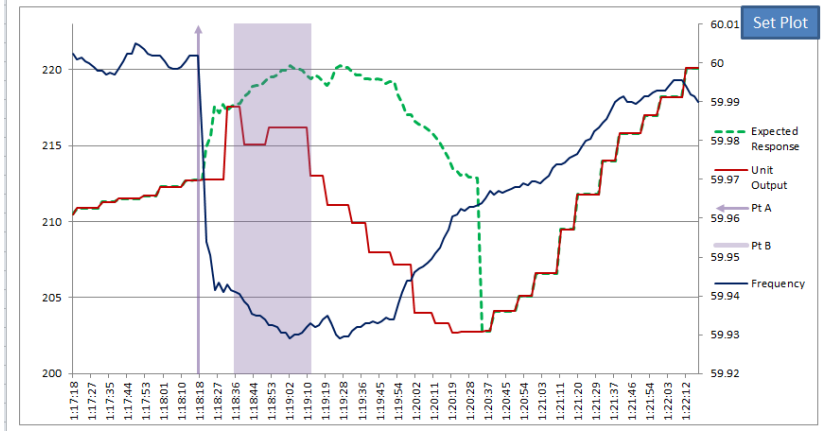
Frequency Response Unit Event Performance Tool

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

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

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

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

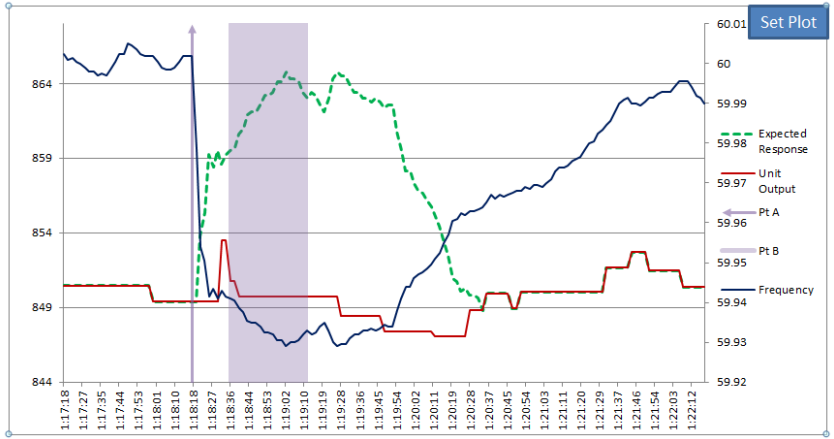


Governor Settings	
Droop (%):	5%
Deadband (Hz):	0.036

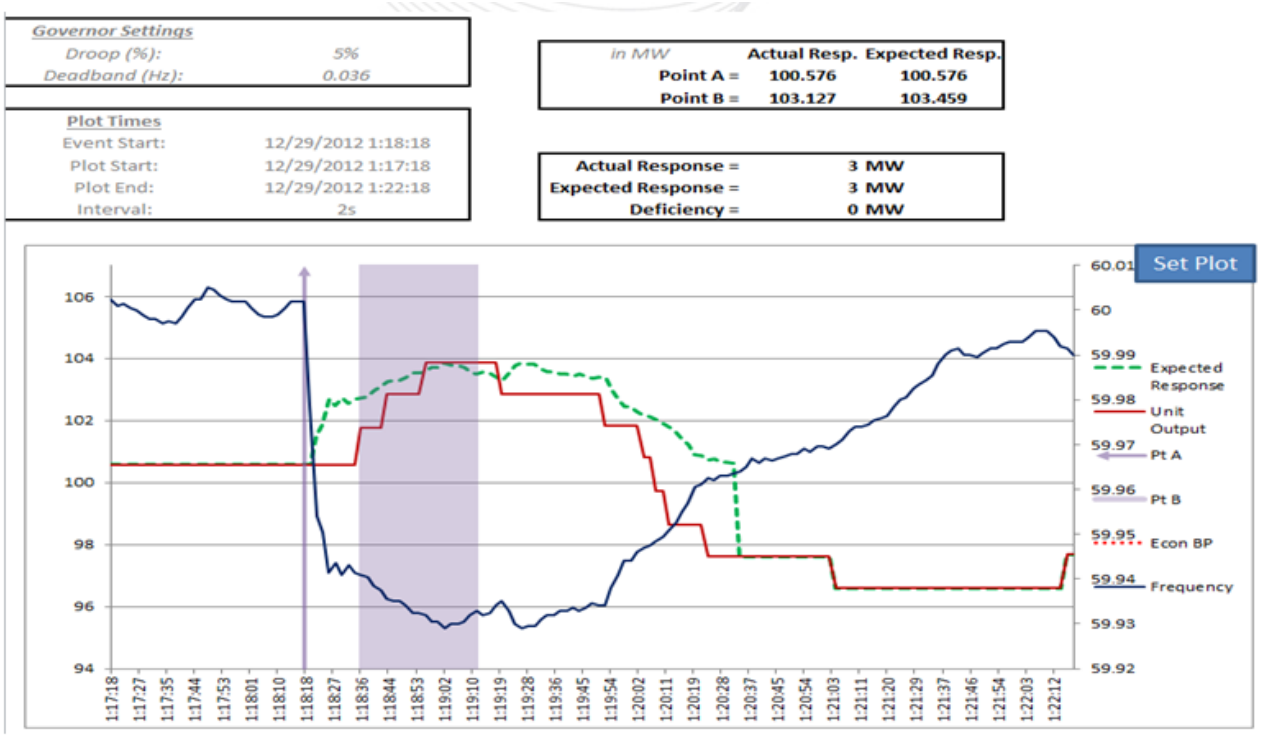
Plot Times	
Event Start:	12/29/2012 1:18:18
Plot Start:	12/29/2012 1:17:18
Plot End:	12/29/2012 1:22:18
Interval:	2s

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

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



Unit responded as expected



Response as Expected

Frequency Response Unit Summary Performance

Unit:
Frequency:
Unit MW:
Spin Max:

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

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 13:39:46	0.8	4.75	3.9	11.2	628.8000	633.5538	630.6143

Thomas Keyser

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

Questions

THANK YOU

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