DOE/OE Transmission Reliability Program

Baselining Studies and Analyses

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Consortium for Electric Reliability Technology Solutions

Project Objectives

- **Investigate power grid data** (Eastern Interconnect State Estimator Data at this time), including phase angle differences between site pairs (both within an ISO and between ISOs), current, voltage, frequency, and possibly derived variables, like mode meter and oscillation.
- **Identify atypical events** and characterize **typical patterns**.
- Recommend **upper and lower limits** for **"normal" operation**.

Major Technical Accomplishments to be Completed this Year

- Receive a **new list of phase angle pairs from PJM** and implement them into the process / analysis.
- Run **updated analyses** including the new pairs, and other variables (Voltage, Current, Frequency).
  - Create a **list of atypicalities** discovered through the analyses.
  - Send list to PJM for review.
- **Document the procedures** necessary to run these analyses.
- Continue working with the **NASPI Planning Task Team** (including interacting at the NASPI meeting in October).

Deliverables and Schedule for Activities to be Completed under FY13 Funding

- Baseline Analysis Report, including the list of atypicalities to be reviewed by PJM – November 2013
- Baseline Procedure Report – November 2013

Risk Factors Affecting Timely Completion of Planned Activities and Movement Through the R&D Cycle

- New phase angle pairs need to be identified by PJM.
  - Analyses could be updated using old pairs if needed, however PJM felt that a newer set of pairs will be more informative.
- Interactions with domain experts (at PJM and any other interested parties) are needed to determine the effectiveness of our analyses.

Possible Follow-on Work to be Considered in FY14

- Add the ability to look at other data streams, including PMU data.
- Refine data quality filters using domain expertise, reducing the number of false-positives.
- Process more data, establish stable typical patterns, and move to a classification driven system, so that results may occur in near-real-time.

Analysis Methods for State Estimator Data

- Analyses on Phase Angle Differences and other variables between two sites.
- Method 1 – Situational Awareness (SitAAR) approach to study typical patterns and atypical events.
- Method 2 – Date / Time Model
  - Predict phase angle for each pair for each 3 hour period in 2011.
  - Calculate candidate limits for monitoring phase angle pairs.
- Methods could eventually lead to a near-real-time monitoring and alerting system.

Phase Angle Difference Between ISOs
The Fiduciary Method

In a meeting at PJM, NE-ISO brought up the need to **calculate phase angle differences between ISOs**.

- **The issue**: state estimator data time stamps are usually different for each ISO.
- **The solution**: Calculate Angle Differences between Angles from Different ISOs by Using Other Angles Both ISOs Have in Common.

	Angle1.ISO1	FidAngle1.ISO1	Difference
00:00:00	-35.385	-12.301	-23.085
00:00:30	-33.148	-10.247	-22.901
00:01:00	-32.478	-9.275	-23.202
00:01:30	-32.243	-9.170	-23.073
00:02:00	-32.119	-9.419	-22.699
00:02:30	-32.634	-9.964	-22.671
00:03:00	-33.080	-10.202	-22.879
00:03:30	-33.480	-10.462	-23.019

	Angle3.ISO2	FidAngle1.ISO2	Difference
00:00:07	-34.850	-27.168	-7.682
00:03:06	-34.850	-27.307	-7.543
00:06:06	-34.883	-27.738	-7.145

Angle 1 ISO1 – Angle 3 ISO 2

	Difference
00:00:30	-15.647
00:01:00	-15.779
00:01:30	-15.721
00:02:00	-15.587
00:02:30	-15.619
00:03:00	-15.754
00:03:30	-15.955

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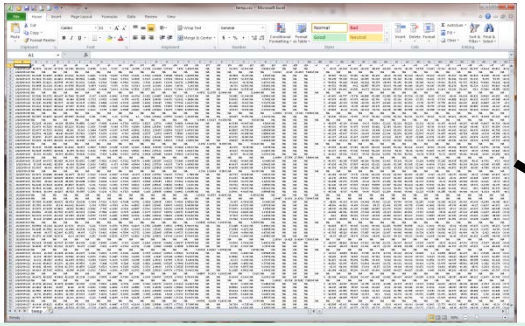
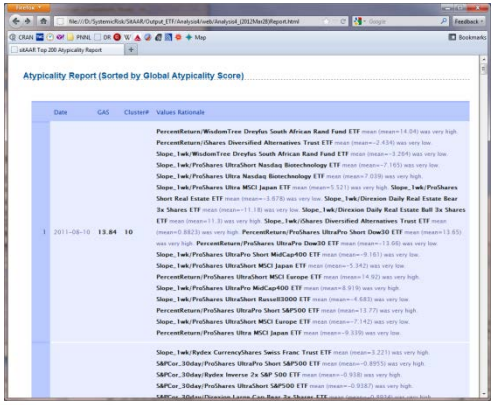
SitAAR
(Situational Awareness and Alert Report)

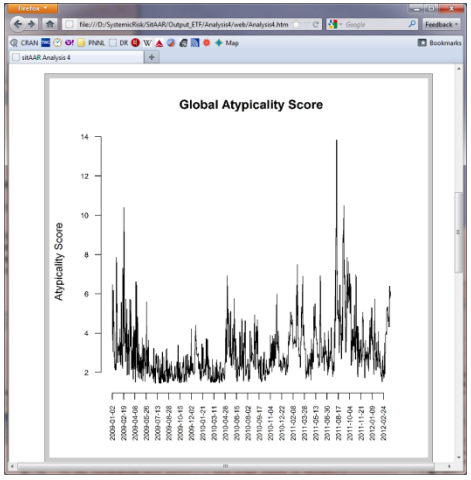


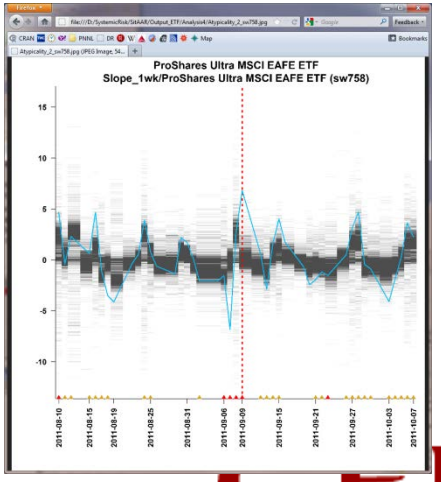
Time-based Data Stream

Subject Matter Expertise

SitAAR

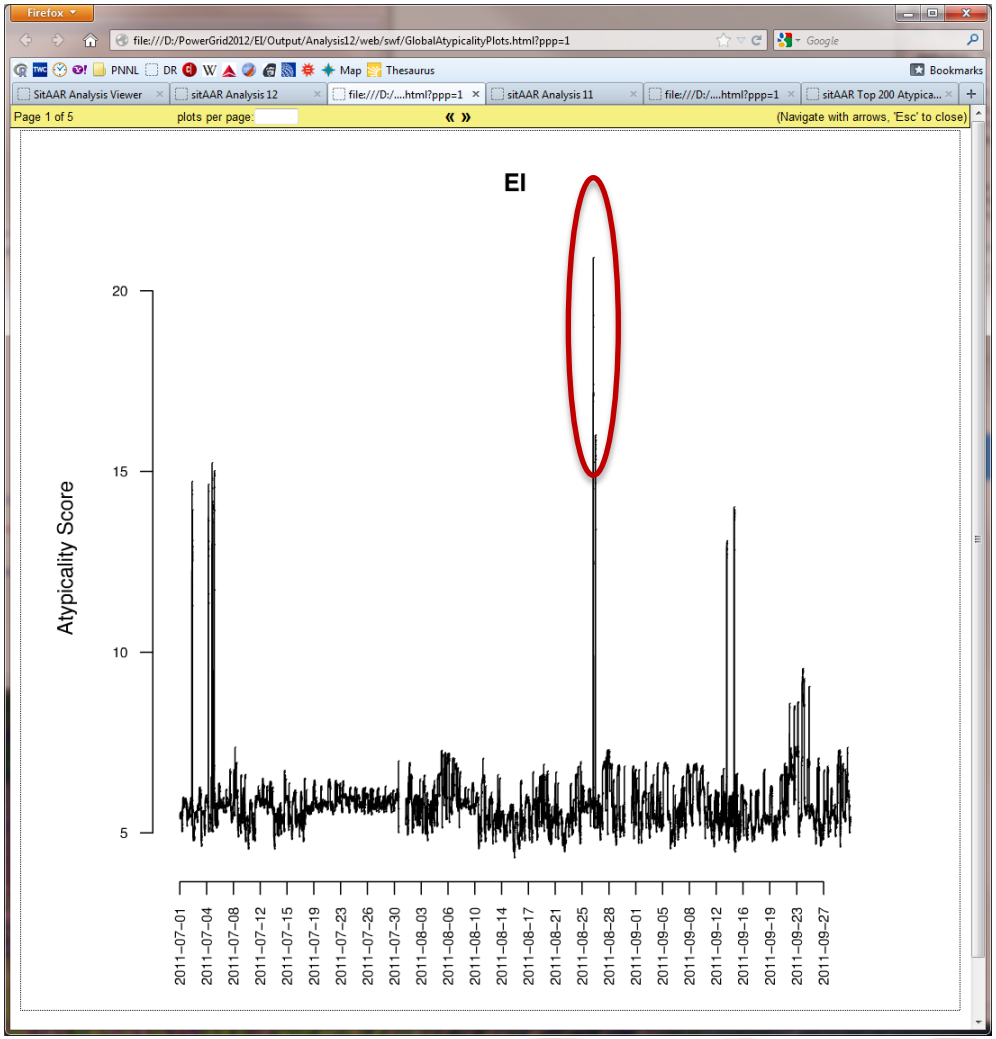






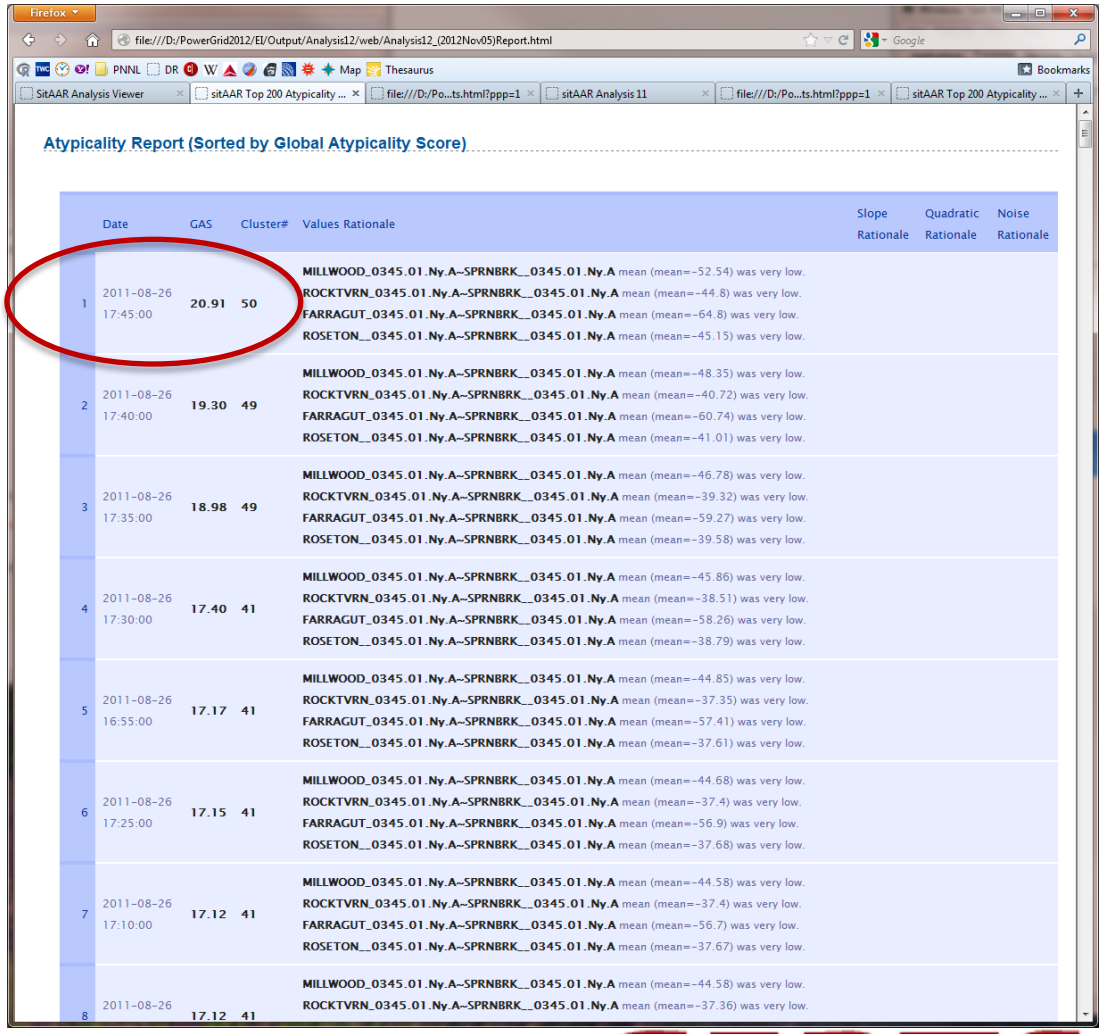
SitAAR Example: 3rd Quarter 2011

- Phase angle differences
- Atypicality Score measured every 5 minutes
- Larger scores indicate more atypical



SitAAR: Atypicality Report

- Atypicality Report shows most atypical time was **2011-08-26 17:45**.
- Phase angle differences contributing to the atypicality are listed and can be clicked to investigate.

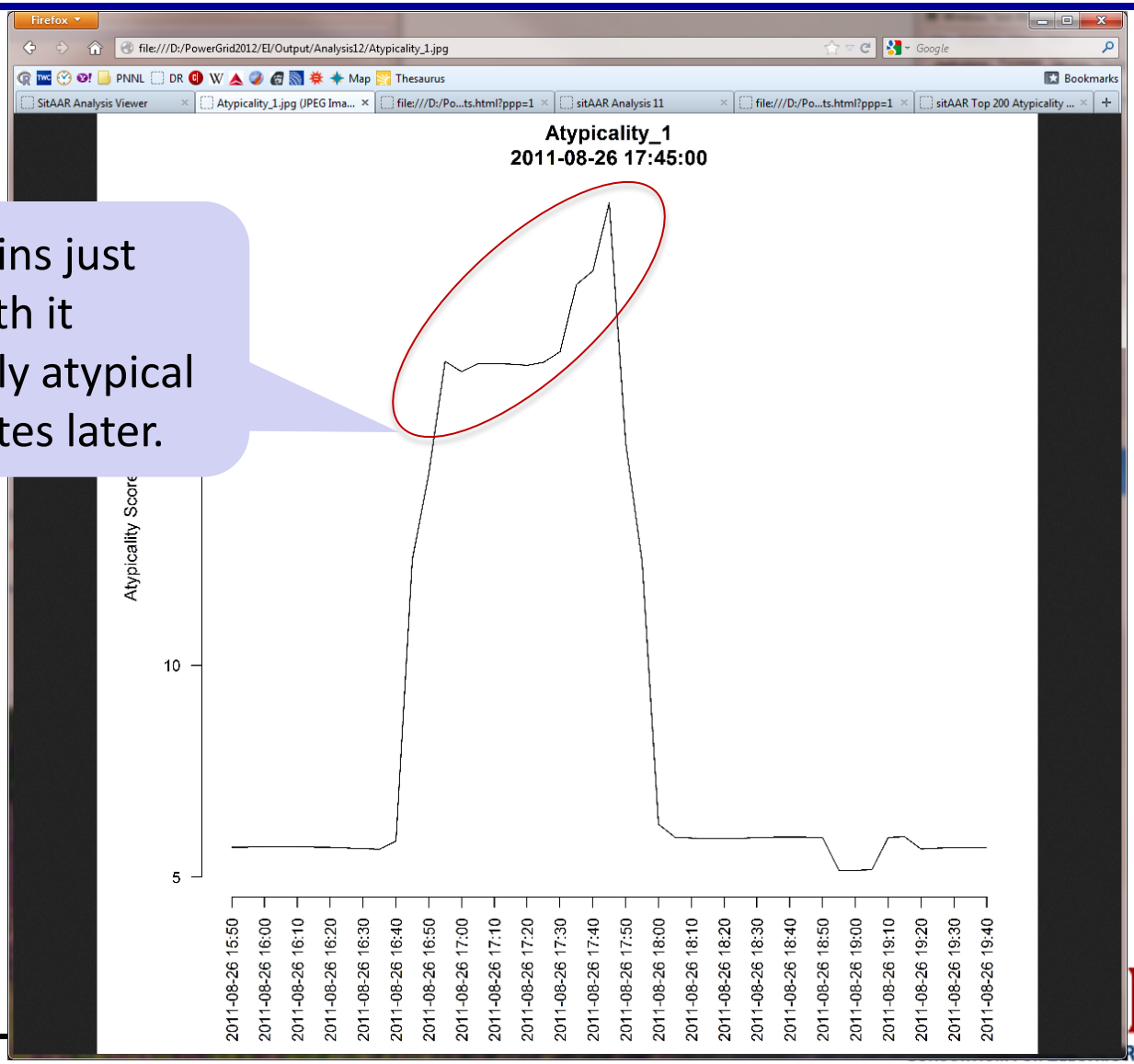


Atypicality Report (Sorted by Global Atypicality Score)

	Date	GAS	Cluster#	Values Rationale	Slope Rationale	Quadratic Rationale	Noise Rationale
1	2011-08-26 17:45:00	20.91	50	MILLWOOD_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-52.54) was very low. ROCKTVRN_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-44.8) was very low. FARRAGUT_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-64.8) was very low. ROSETON__0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-45.15) was very low.			
2	2011-08-26 17:40:00	19.30	49	MILLWOOD_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-48.35) was very low. ROCKTVRN_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-40.72) was very low. FARRAGUT_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-60.74) was very low. ROSETON__0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-41.01) was very low.			
3	2011-08-26 17:35:00	18.98	49	MILLWOOD_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-46.78) was very low. ROCKTVRN_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-39.32) was very low. FARRAGUT_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-59.27) was very low. ROSETON__0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-39.58) was very low.			
4	2011-08-26 17:30:00	17.40	41	MILLWOOD_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-45.86) was very low. ROCKTVRN_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-38.51) was very low. FARRAGUT_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-58.26) was very low. ROSETON__0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-38.79) was very low.			
5	2011-08-26 16:55:00	17.17	41	MILLWOOD_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-44.85) was very low. ROCKTVRN_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-37.35) was very low. FARRAGUT_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-57.41) was very low. ROSETON__0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-37.61) was very low.			
6	2011-08-26 17:25:00	17.15	41	MILLWOOD_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-44.68) was very low. ROCKTVRN_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-37.4) was very low. FARRAGUT_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-56.9) was very low. ROSETON__0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-37.68) was very low.			
7	2011-08-26 17:10:00	17.12	41	MILLWOOD_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-44.58) was very low. ROCKTVRN_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-37.4) was very low. FARRAGUT_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-56.7) was very low. ROSETON__0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-37.67) was very low.			
8	2011-08-26	17.12	41	MILLWOOD_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-44.58) was very low. ROCKTVRN_0345.01.Ny.A~SPRNBRK__0345.01.Ny.A mean (mean=-37.36) was very low.			

SitAAR: Atypicality Score Plot Zoom-in

Atypicality begins just after 16:40, with it becoming highly atypical about 10 minutes later.



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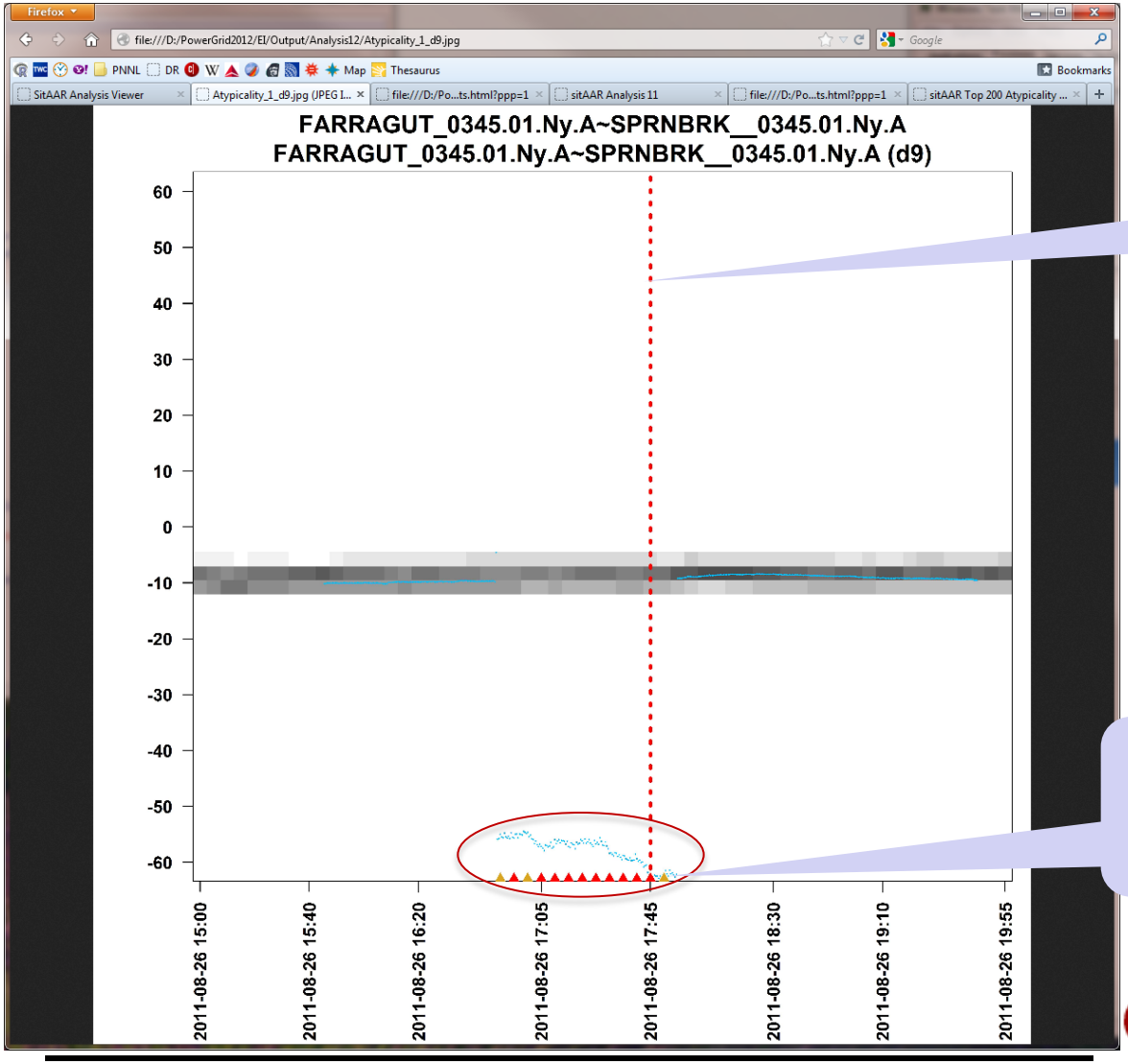
SitAAR: Drilldown Plot to Show Atypical Variables



Selected atypical moment

Each triangle represents a significantly atypical moment

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Date/Time Model: EI Phase Angle Prediction

Date/Time Model (based on a moving 4 week window)

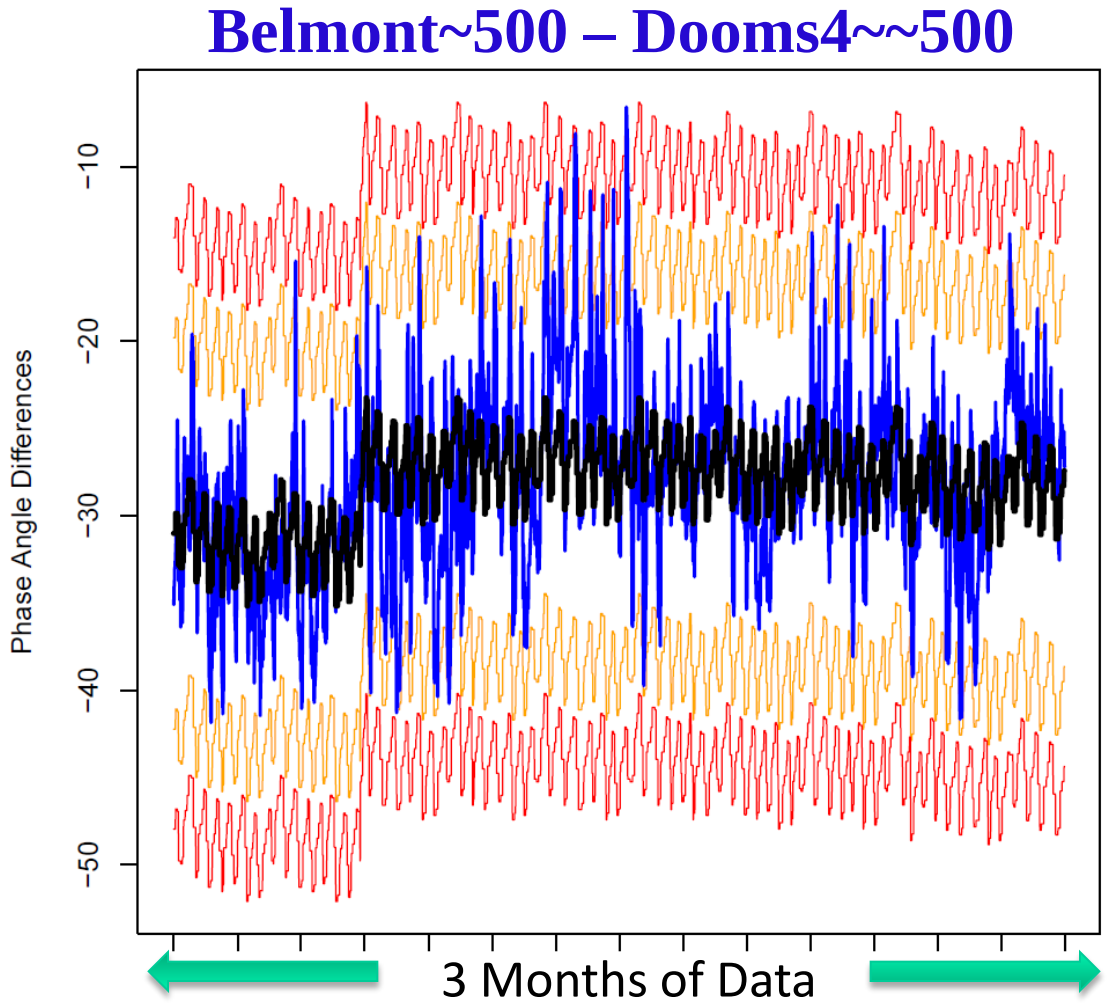
$$PredictedAngle = \mu + DayOfWeek_{(j)} + TimeOfDay_{(k)} + \varepsilon_{(j,k)}$$

where: $j = 1, 2, \ldots, 7$; $k = 1, 2, \ldots, 24$

- Looked at the 54 pairs recommended by PJM.
- Calculated angle differences for every State Estimator data point pair (every 5 minutes for ~10 months).
- Using a moving 4 week window proved to be a better fit than a seasonal model.

Date/Time Model Example

- Actual
- Predicted
- 99% C.I.
- 99.99% C.I.



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Conclusions

- Analysis **progress continues** and looks **encouraging**.
- **SitAAR** approach **finding ways to mitigate data quality issues** and allow the user to **focus more on actual grid phenomena** and **better monitor the grid**.
- **SitAAR** approach finds **interesting grid behavior** and provides **insight** to the domain experts.
- **Date/Time prediction model** showing promise in effective use of phase angle pair difference data.
- **Additional R&D is necessary** to mature the promising nature of the work to date.