Synchrophasor Implementations

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Topics of Discussion

- Description of Manitoba WAMS
- Introduction to Birchtree SVC Project
- Commissioning Results
- Lessons Learned and Future Road Map

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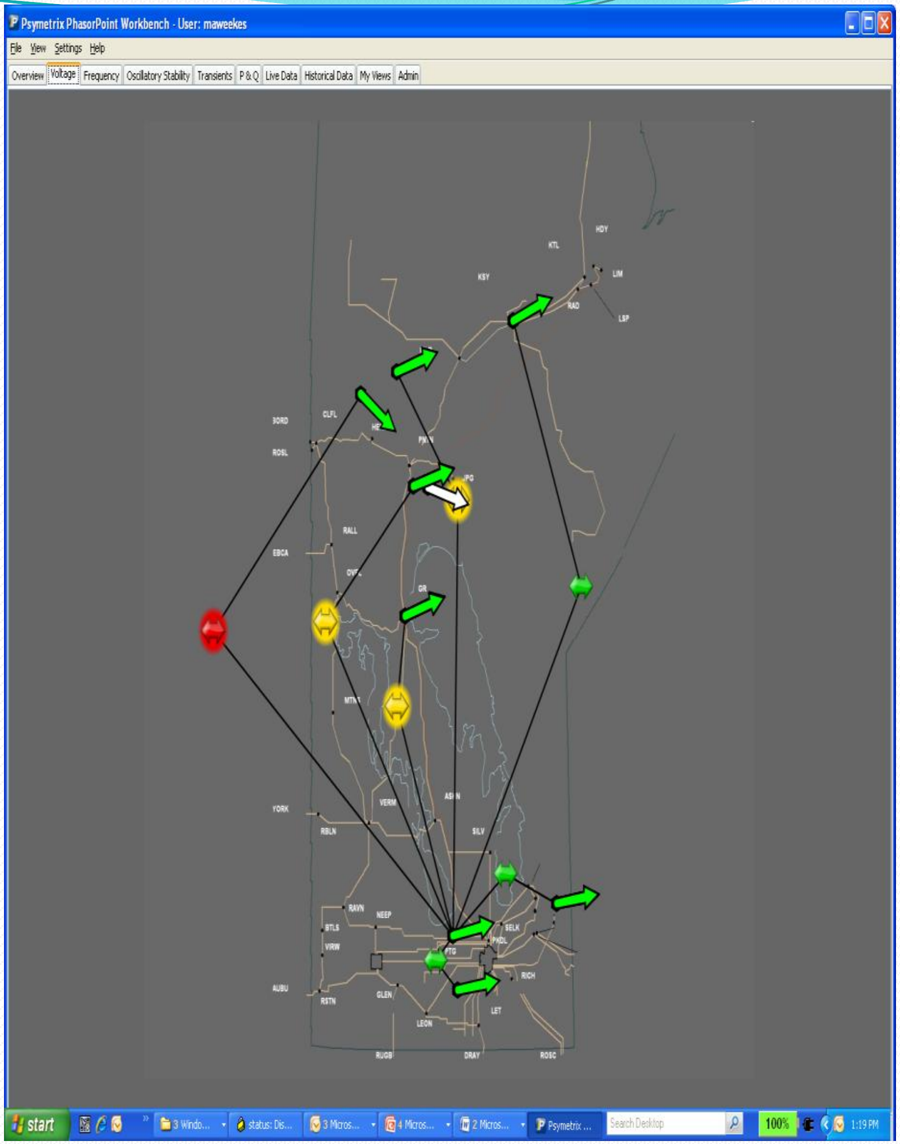
Organization	PDC Contracted	PDC Connected	PMU Confirmed Sites	PMU Connected Devices
Ameren	1	1	21	6
American Trans Co.	N/A	1	N/A	5
Duke Energy	1	1	16	4
Great Rivers Energy	1	1	8	2
Hoosier Energy	1	1	7	9
Indianapolis P&L	1	1	6	7
International Trans Co.	1	1	12	5
Manitoba Hydro	***2***	***1***	***22***	***6***
MidAmerican Energy	1	0	12	0
Minnesota Power	1	1	4	1
Montana Dakota Utilities	0	0	5	0
Northern Indiana Public Service	3	1	8	2
Ottertail Power	2	1	6	3
Vectren	1	0	3	0
WAPA	0	0	4	0
XCEL Energy	0	0	11	0
TOTAL	**16**	**11**	**145**	**50**

Need for wide Area Measurements

- Typical PSS tuning monitors local signals
- Problems can arise with fighting between controllers
- Advantage of monitoring a wide area can be addressed with synchrophasors

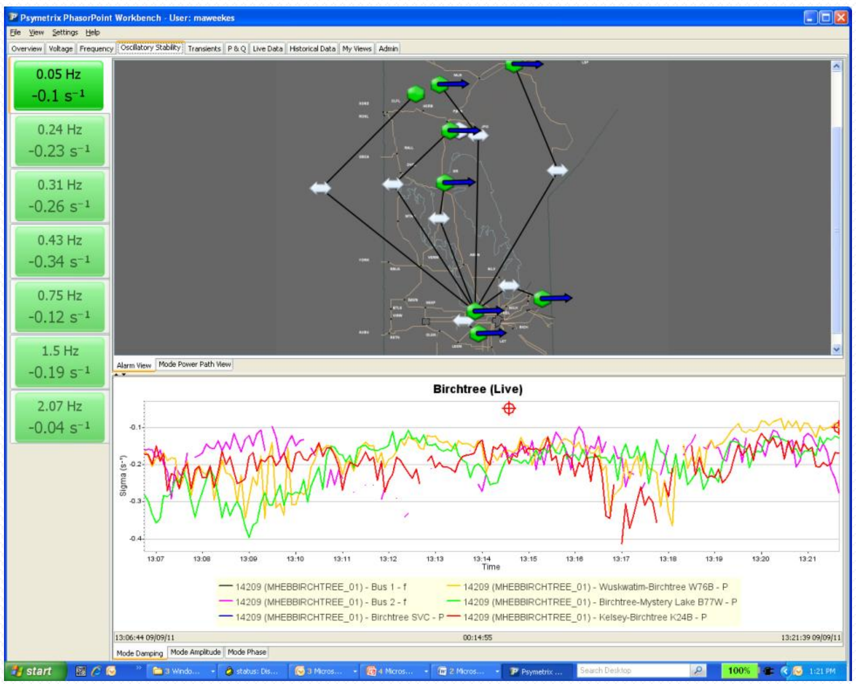
WAMS

- Phasorpoint tool used primarily to see the modes on the system

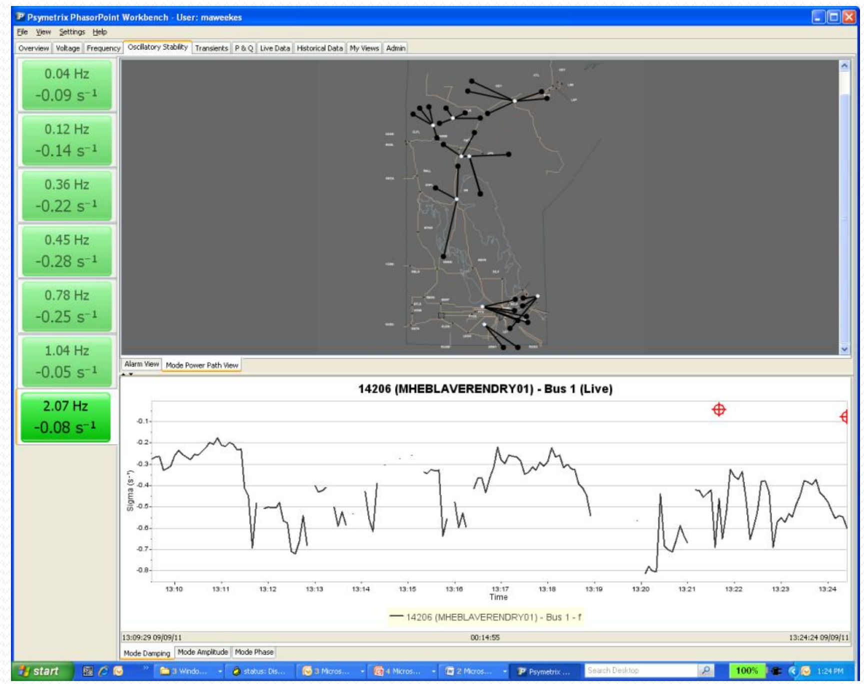


Phasor Point

Mode Charting



Mode Power Path



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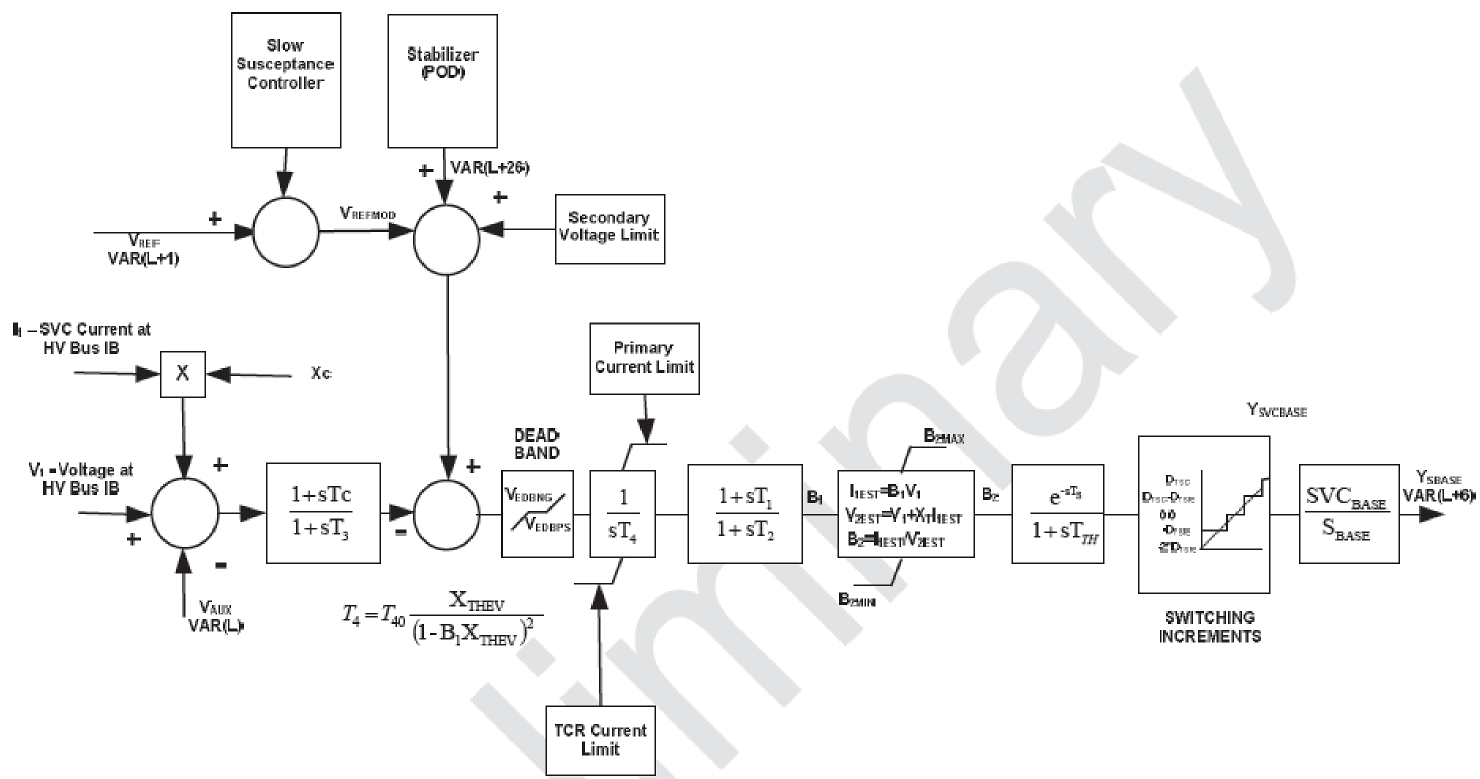
Sites Chosen

- known inter-area modes in our Northern ac.
- sensitivities of modes to various power flow conditions
- Upcoming projects in Northern ac
- Future sites will increase from 6 to 30 PMU locations
- Using existing TFR devices

Birchtree SVC Controller



BTSVC – Voltage Controller

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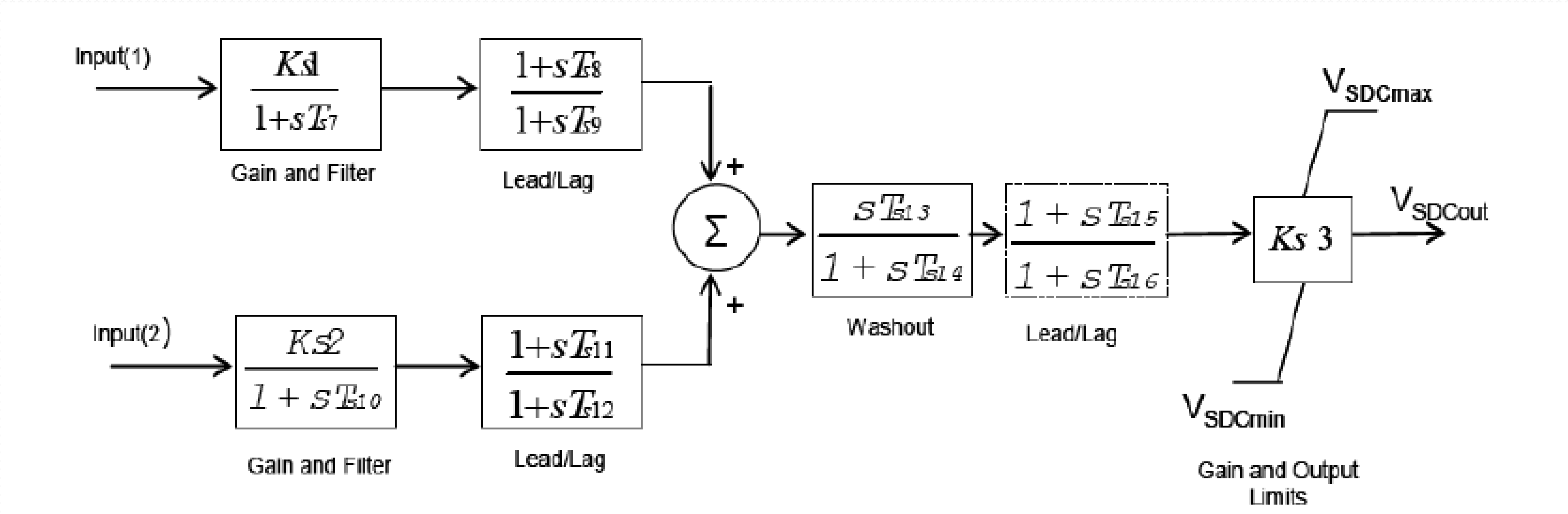
Power Oscillation Damper (POD)



Commissioning Objectives

- **Transfer function verification** of the SVC voltage and POD controllers
- **Tuning the POD** to provide good damping performance for the modes within the frequency range of interest 0.5 to 0.9 Hz
- **Minimize the interaction** between the Ponton SVC and Birchtree SVC
- **Optimize the Birchtree SVC POD and Ponton SVC SDC settings** for most northern ac system generation patterns and operating conditions

Risks and Mitigations

- Output is correctly controlled from input, as expected
- Check the degree of movement in the rest of the system in response to a step change
- Confirm consistency with time-domain measurements
- Decide criteria for "unacceptable" oscillations.
- Switch controllers off one-by-one or plant-by-plant, separated by a period of time.

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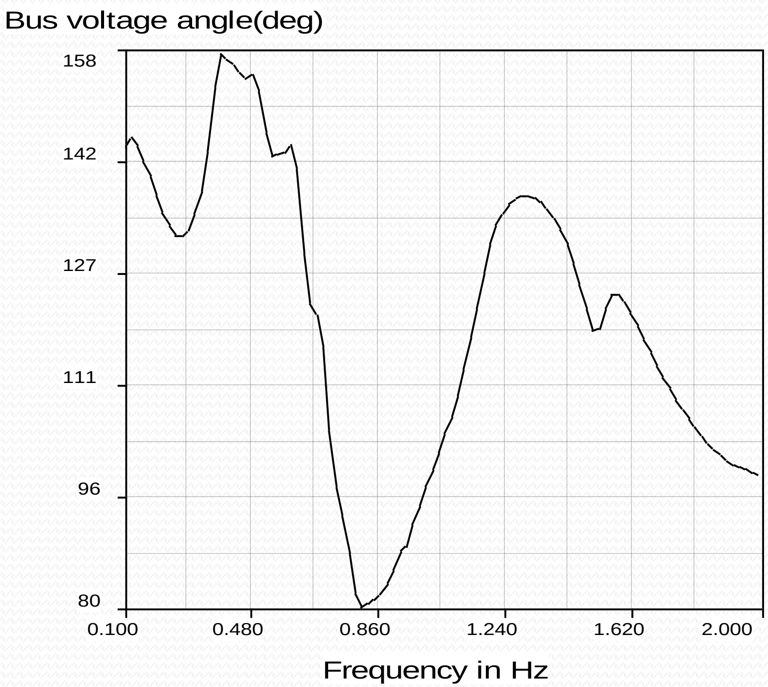
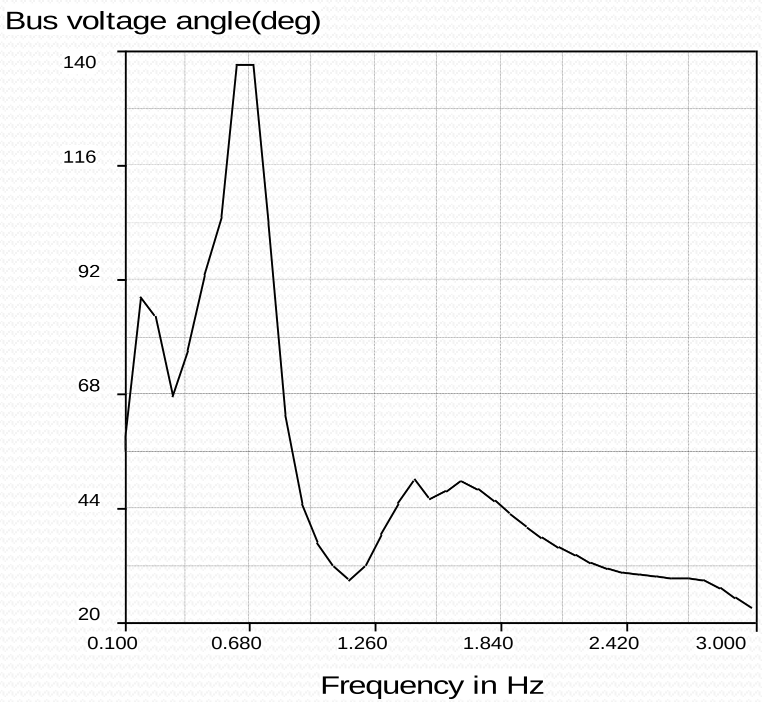
System Frequency Response

- Model verification (frequency response) of SVC POD design



Phase



Magnitude

The frequency response characteristic (magnitude and phase) of the transfer function between Birchtree SVC input and voltage angle (frequency

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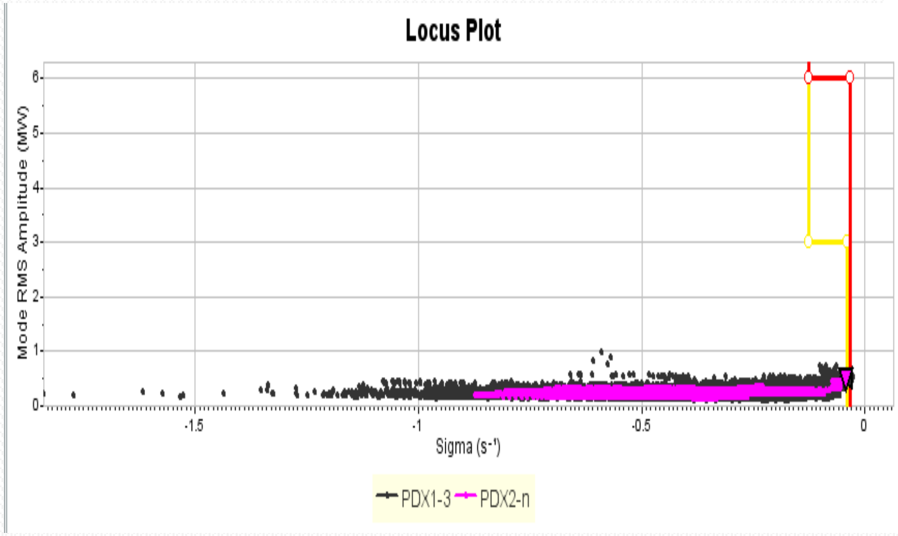
Voltage
Frequency
Active & Reactive Power
Oscillation Magnitude W76B
SAMSUNG

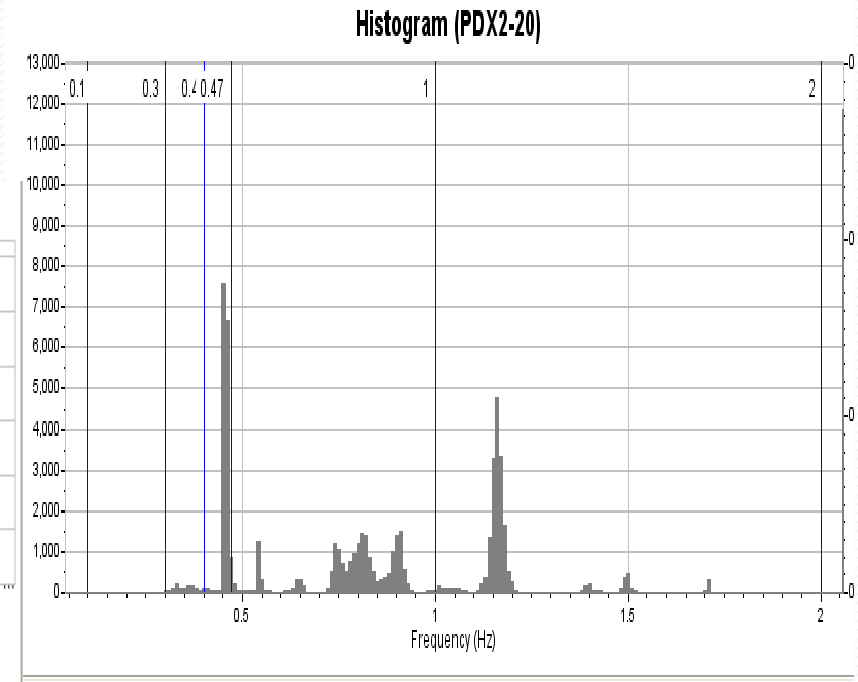
Mode Trending

Root locus of mode

- Trending and verification of damping controller performance



Observability of the mode over time



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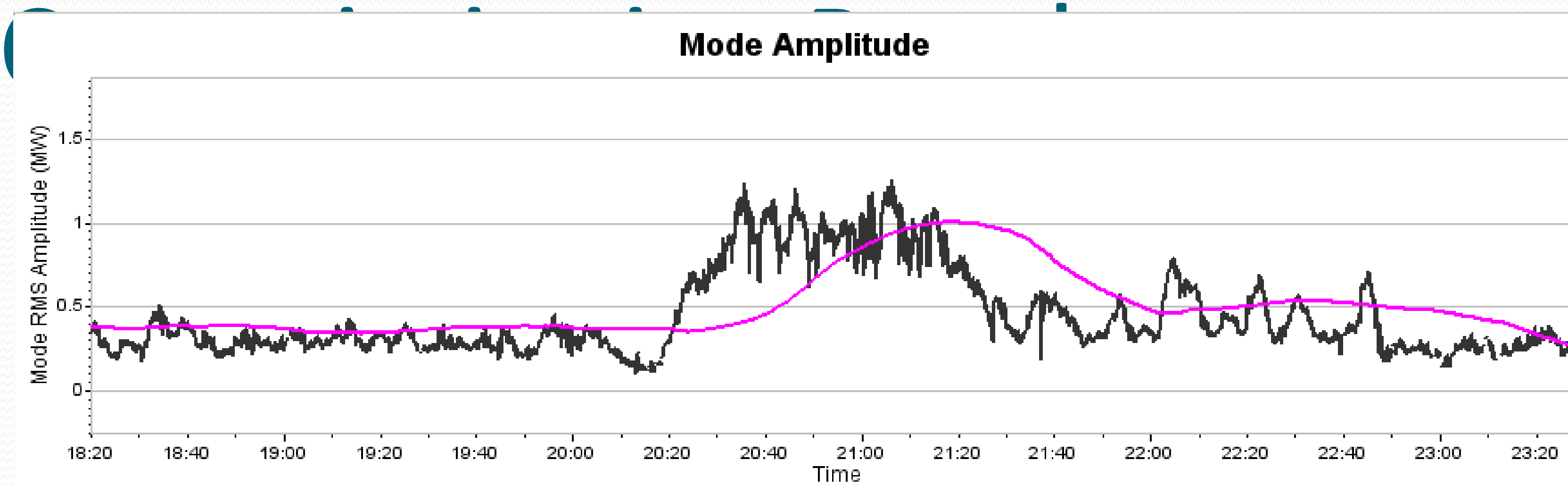
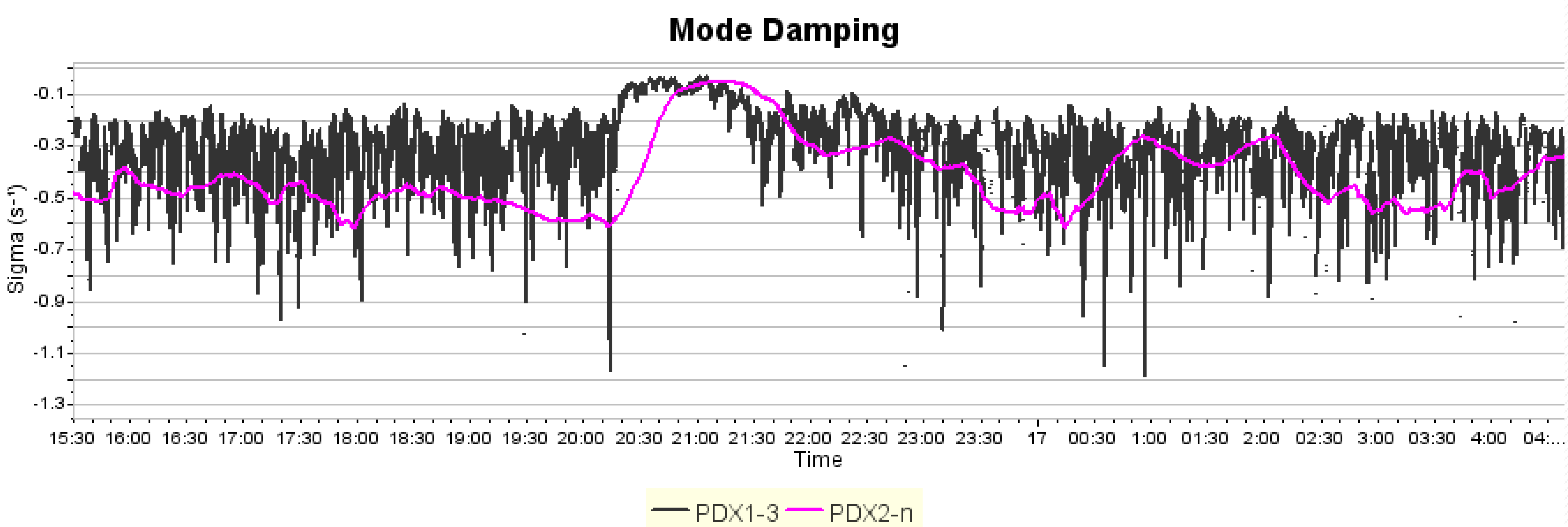

Mode Amplitude
Mode RMS Amplitude (MW)
1.5
1
0.5
0
18:20
18:40
19:00
19:20
19:40
20:00
20:20
20:40
21:00
21:20
21:40
22:00
22:20
22:40
23:00
23:20
Time


Mode Damping
Sigma (s⁻¹)
-0.1
-0.3
-0.5
-0.7
-0.9
-1.1
-1.3
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
20:00
20:30
21:00
21:30
22:00
22:30
23:00
23:30
17
00:30
1:00
01:30
2:00
02:30
3:00
03:30
4:00
04:...
Time
PDX1-3
PDX2-n

Unexpected Results Captured

- Mode increases with lower power
- Initial response of POD with other settings
- Clock error

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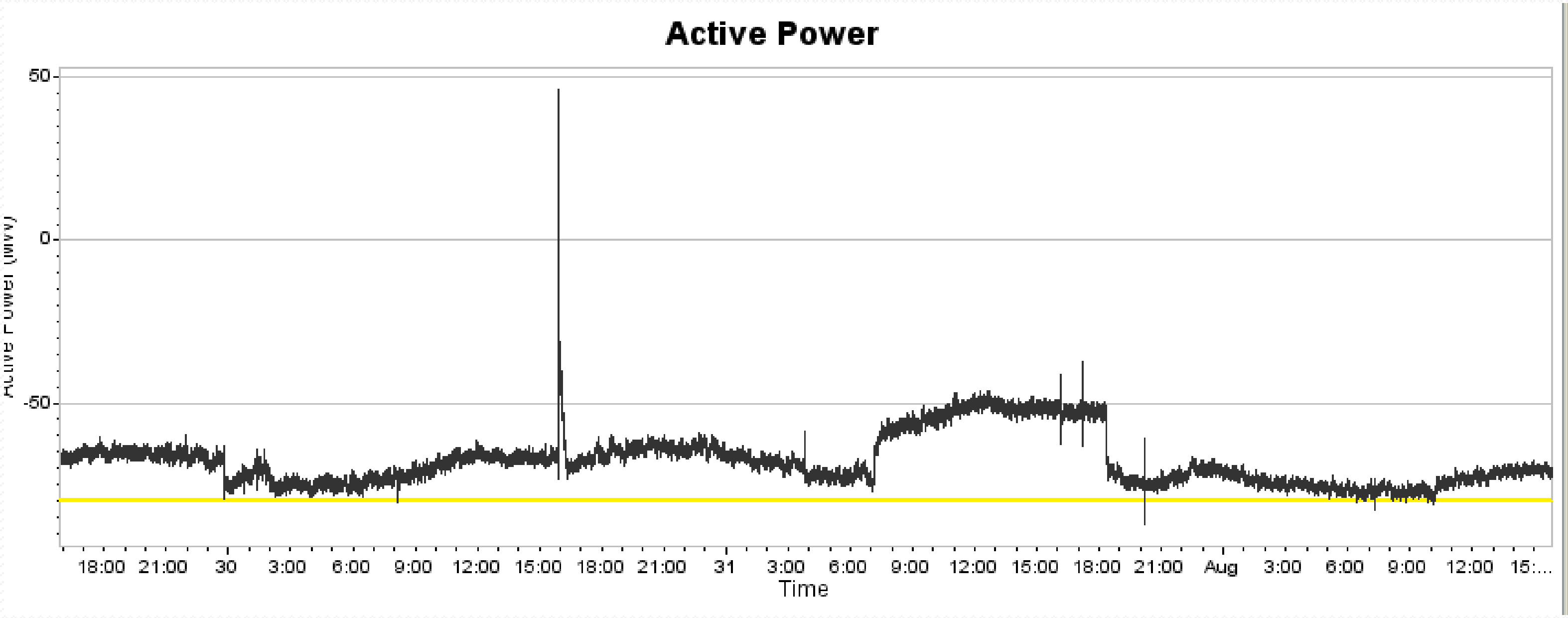
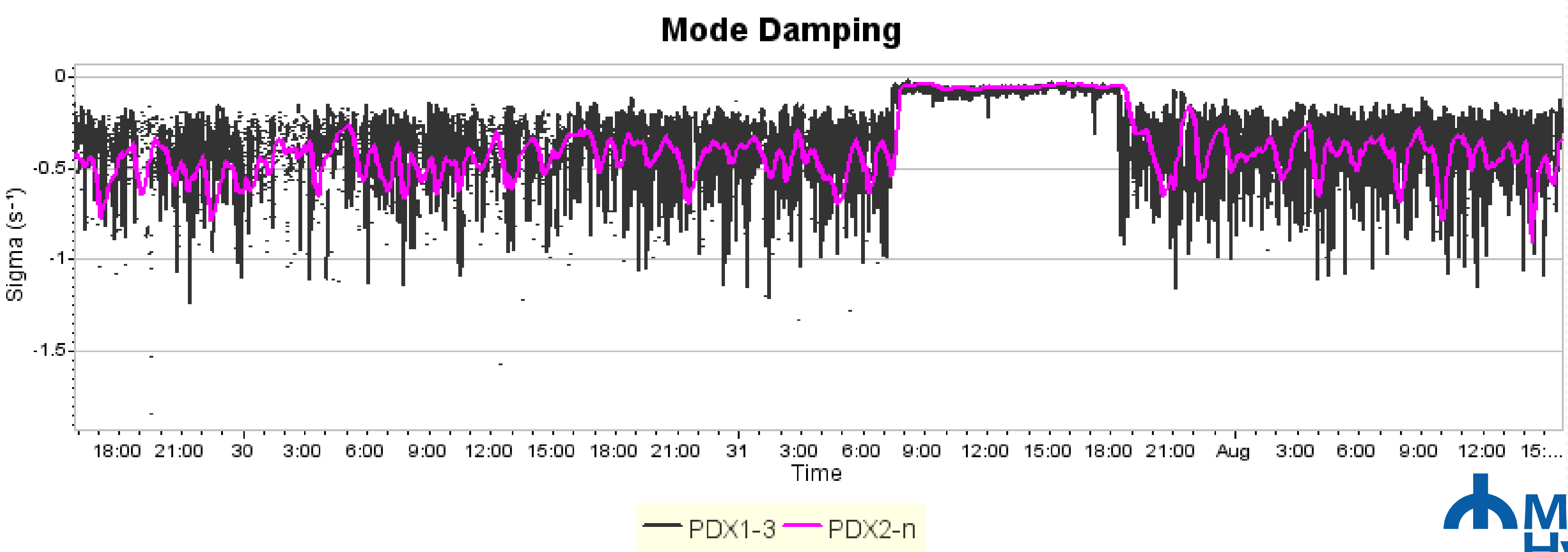
Cont…..System Baselining





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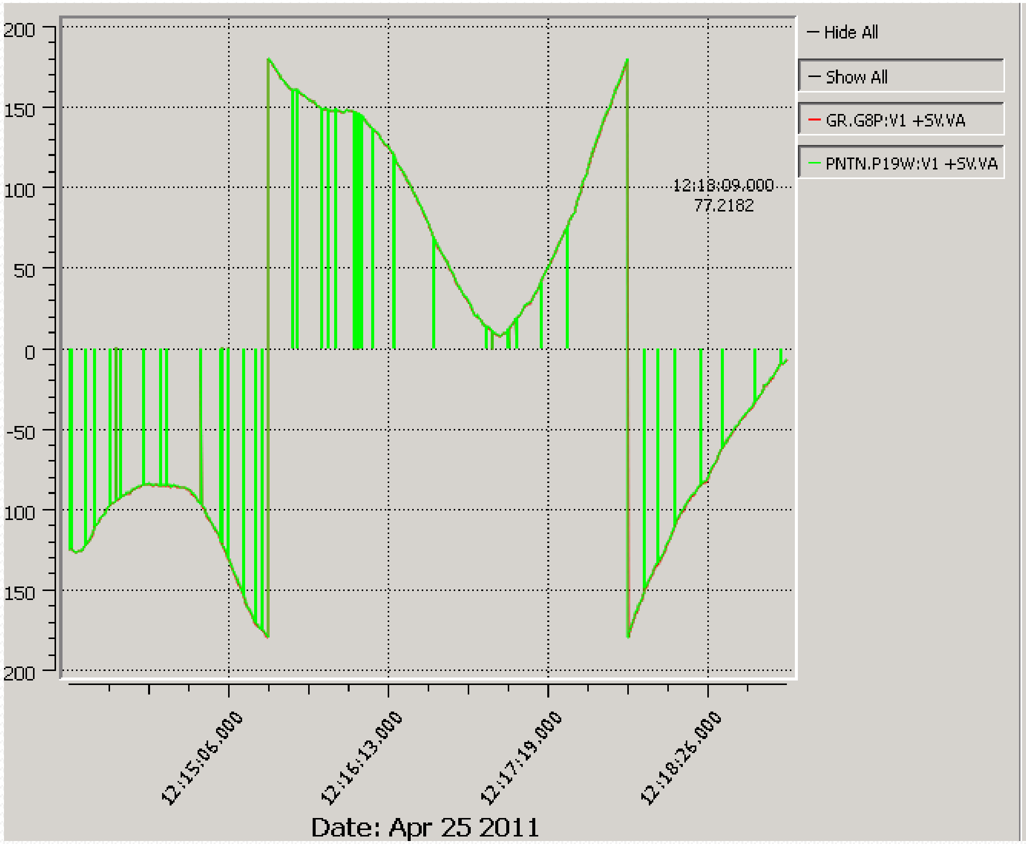
Cont…..System Baselining

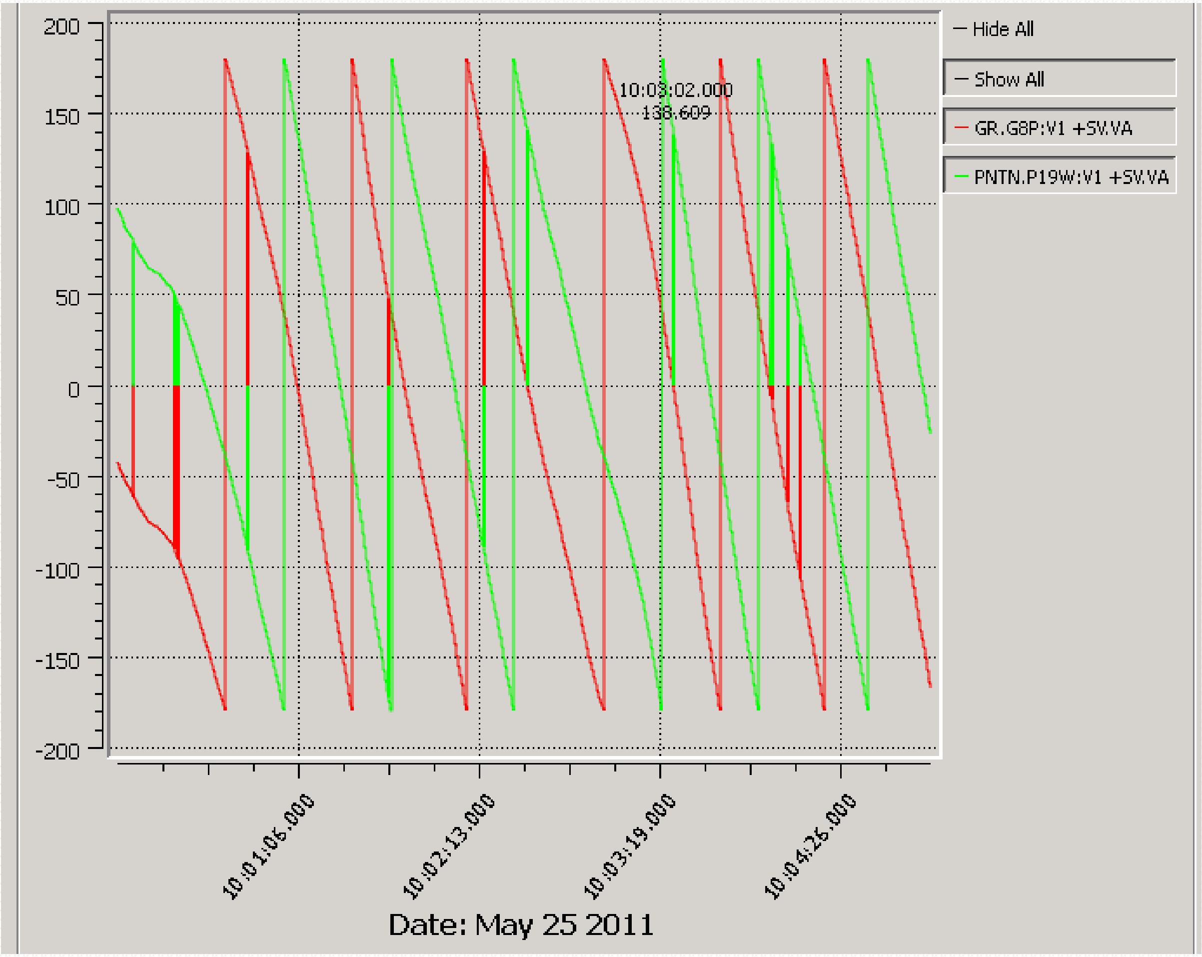
April 25, 2011 – 11:14:00 to 11:19:00 – Approx. 2 hours before event

Clock Errors

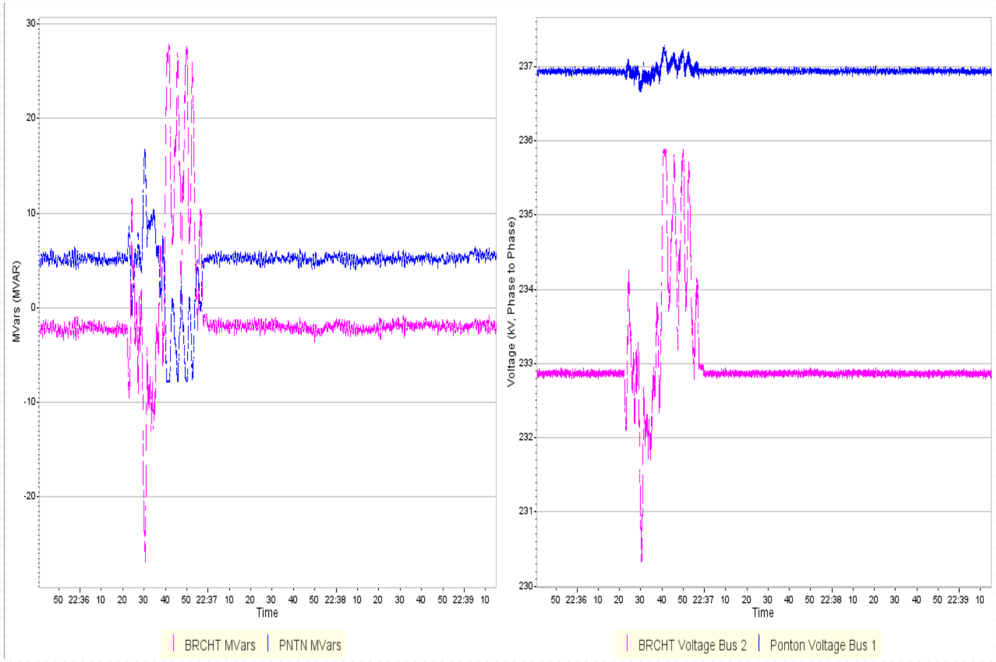


Cont.....System Baselining

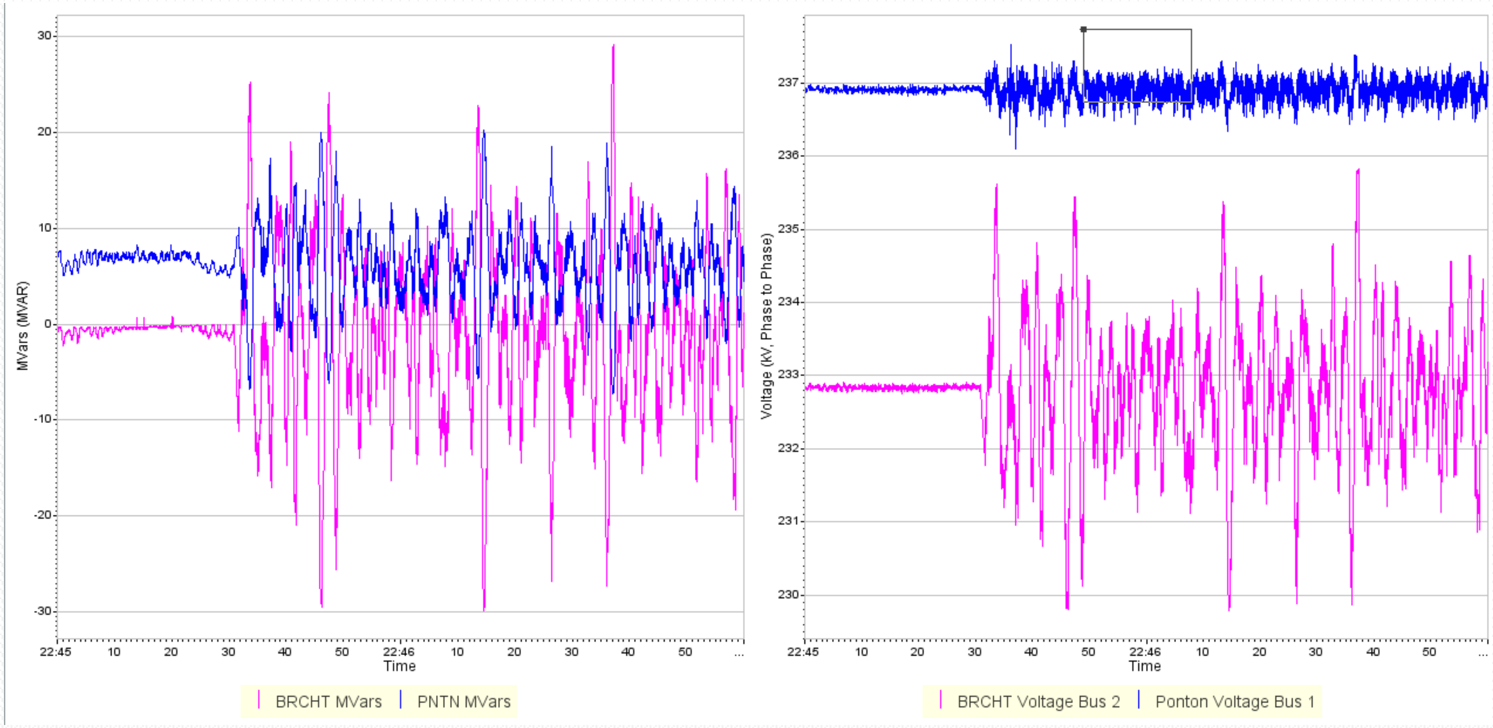
May 25, 2011



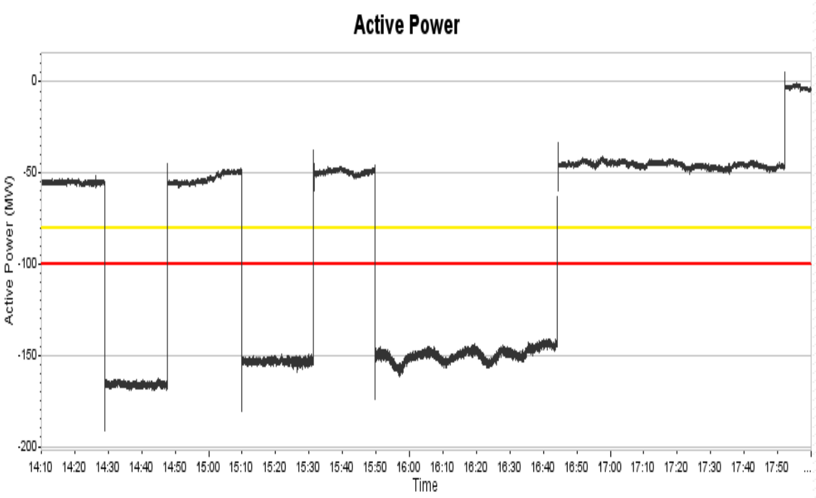
POD First Settings

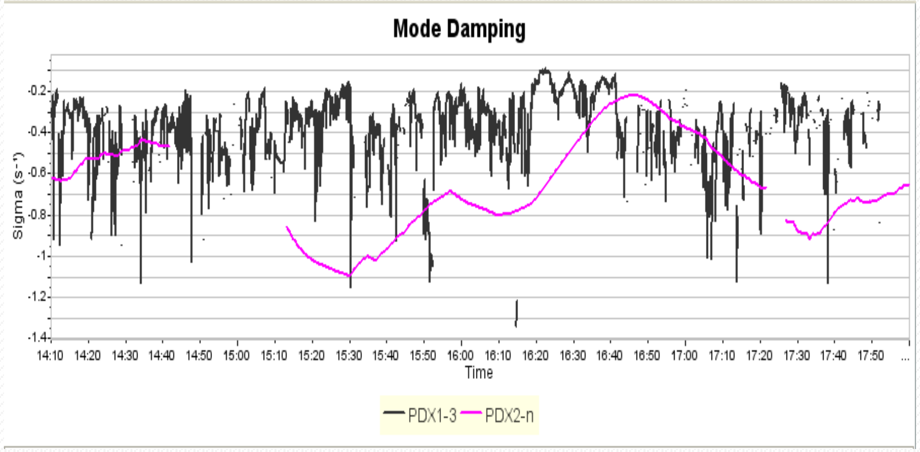


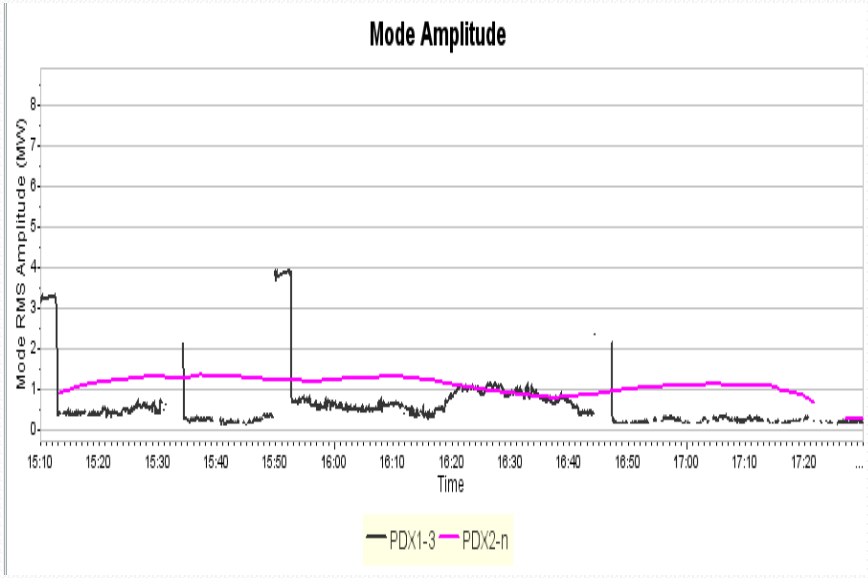
POD Second Settings



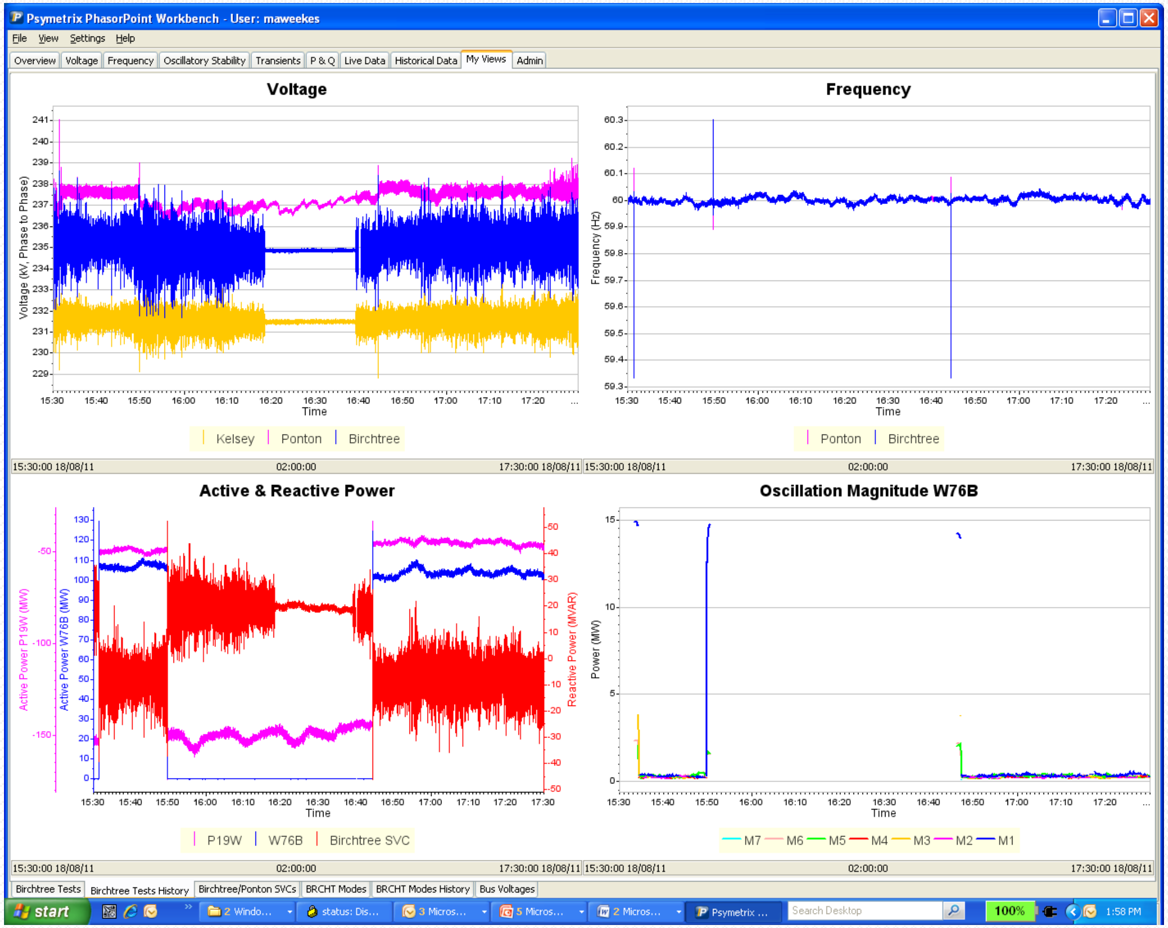
Open/Close line test







Open/Close Line Test



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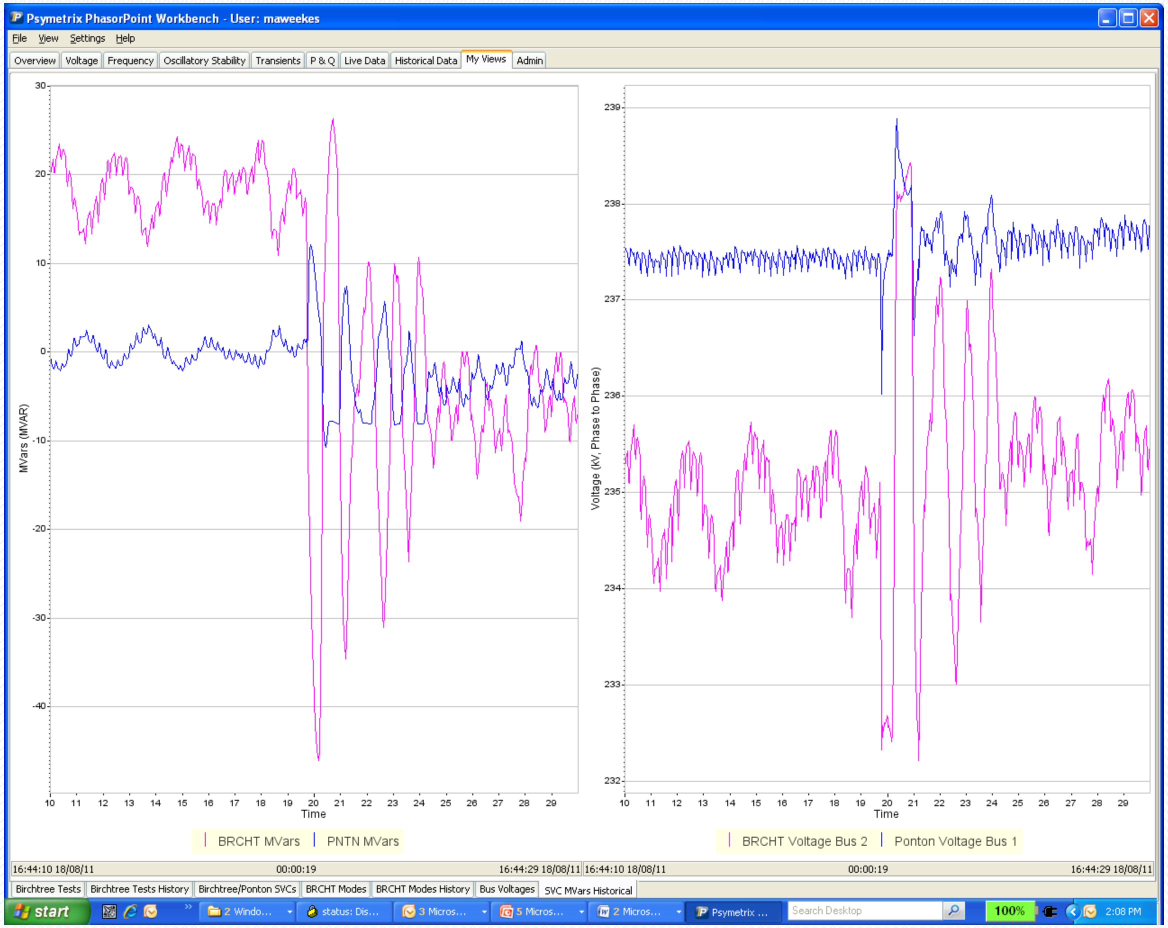
Open/Close Line Test



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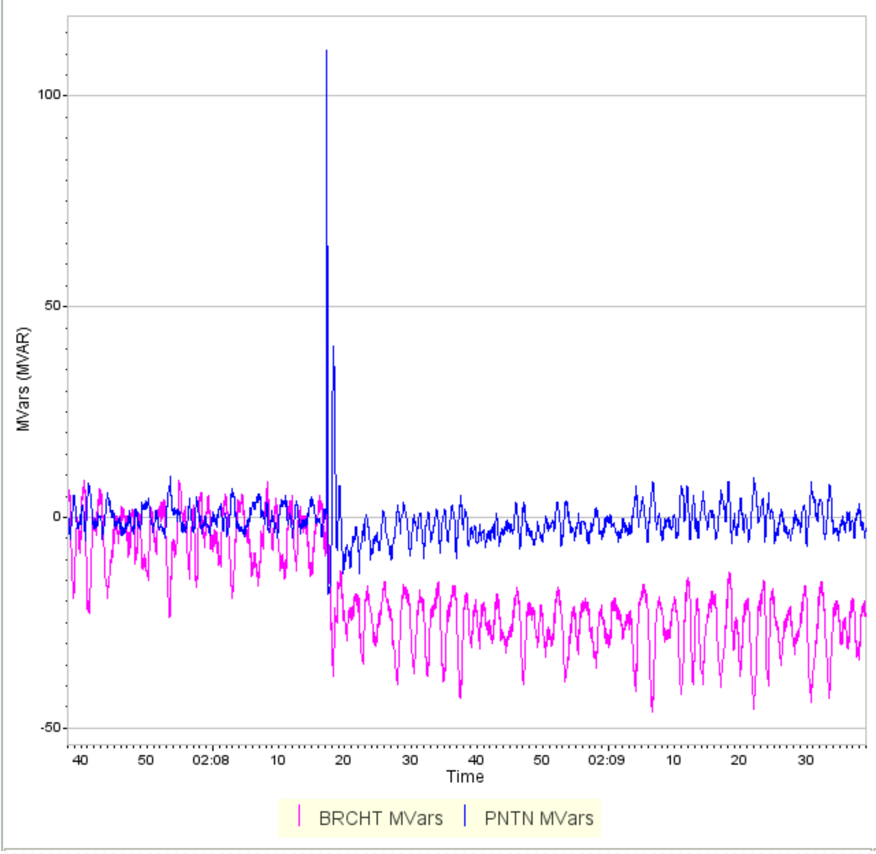
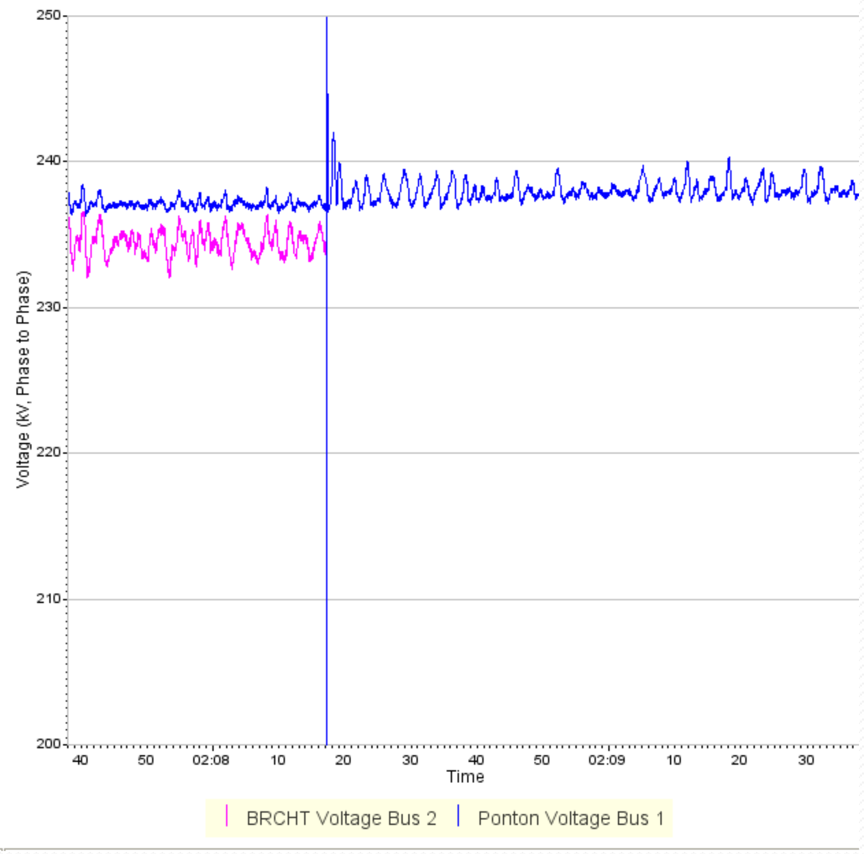
SLG Fault



MVars (MVAR)
100
50
0
-50
40
50
02:08
10
20
30
40
50
02:09
10
20
30
Time
BRCHT MVars
PNTN MVars



Voltage (KV, Phase to Phase)
250
240
230
220
210
200
40
50
02:08
10
20
30
40
50
02:09
10
20
30
Time
BRCHT Voltage Bus 2
Ponton Voltage Bus 1

Lessons Learned

- **Channel Selection** (problem with power calculation if switching occurs)
- Importance of doing a **frequency response** intially to confirm models
- **Real time feedback** to see if and how multiple power system controllers may fight with each other.
- **Clock errors can be significant** and need mitigation measures both in real time and regular maintenance
- **Integration of analog signals** in the future to PMU data (also significance of proper channel selection and sites)
- **Unusual Modes were identified** as consistently observed on the system but low in magnitude

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Future Road Map

- Model verification (complement NERC testing)
- Investigations to increase transfer limits through compound event analysis
- Investigation of islanding and coherency of generators
- Integration with real time tools that use power models (benchmarking)
- EMS state estimator improvement especially after the full complement of PMUs are on the system

Questions ??

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