# MB Hydro Experiences with Synchrophasor Implementations

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# Topics of Discussion

- NASPI and the MISO Project
- Description of Manitoba WAMS
- Introduction to Birchtree SVC Project
- Commissioning Results
- Lessons Learned and MH Future Road Map
- MISO Project Status
- NASPI Products & Future Challenges

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# NASPI and MISO Projects

- NASPI (North America Synchrophasor Initiative)
  - Overall goal to improve power system stability reliability through wide-area measurement and control in North America
  - First steps to create a synchronized data measurement infrastructure.
  - Second step to include analysis and monitoring tools for better planning and operation and improved reliability
- MISO Synchrophasor Project
  - To provide an infrastructure of synchronized data measurement in the MISO area presently funded by SGIG (smart grid initiative grants)
  - Work with NASPI for an overall North American effort.

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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** |

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# 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

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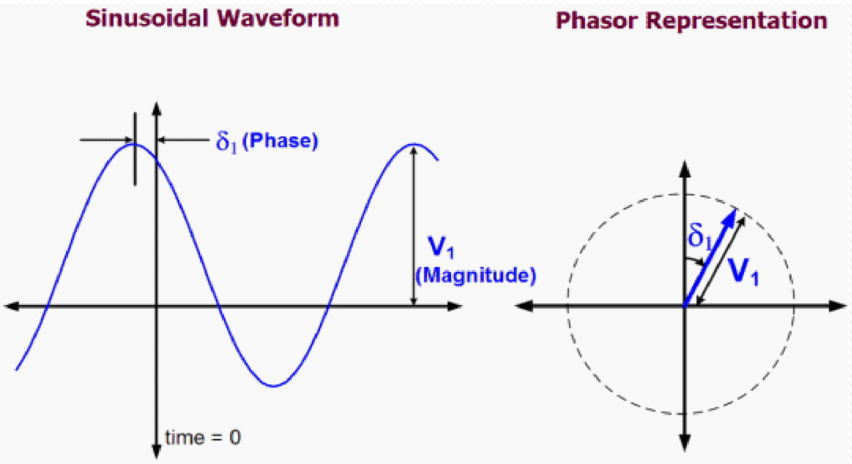
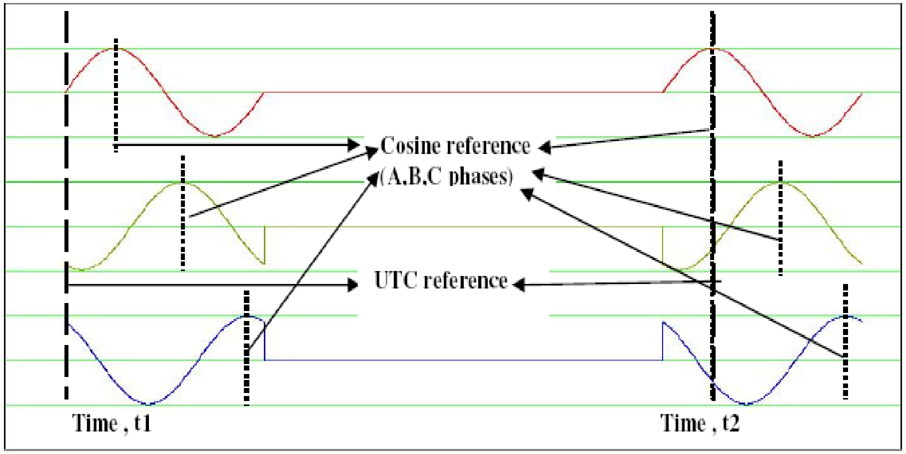
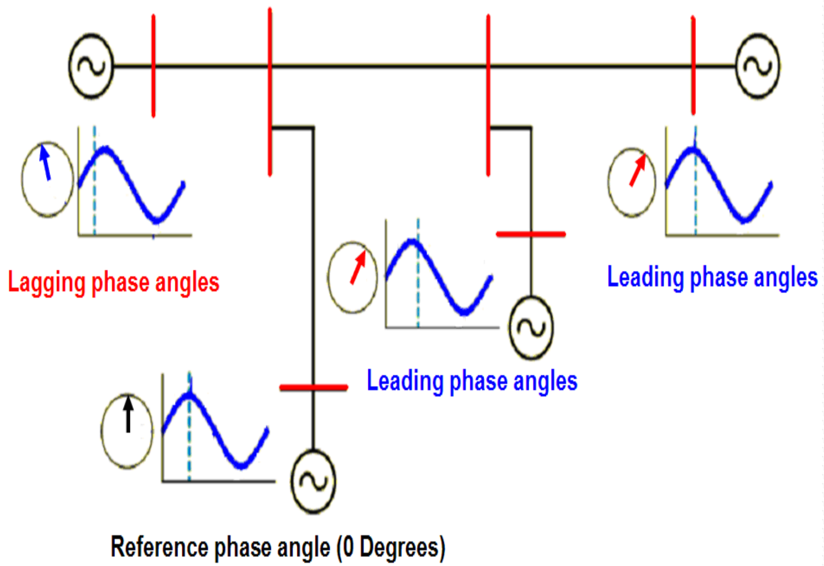
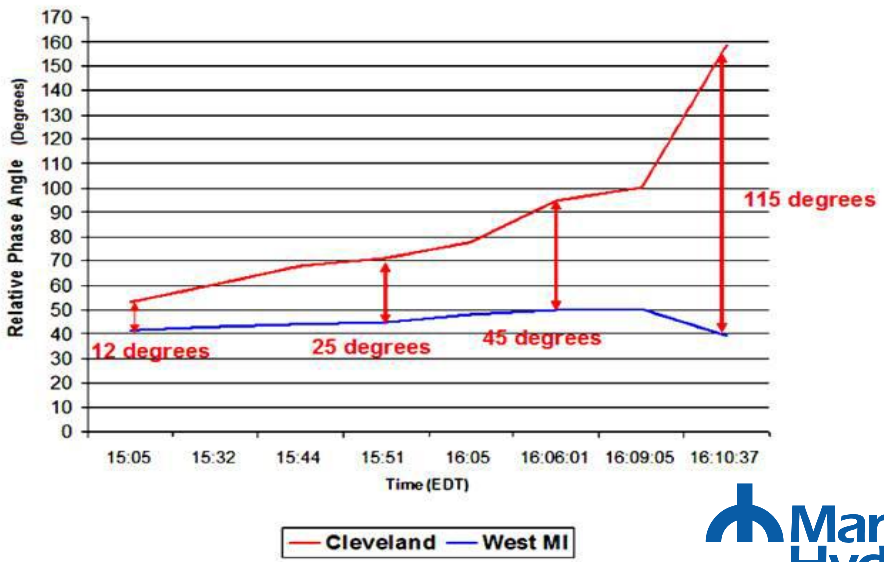
# Phasor Definition

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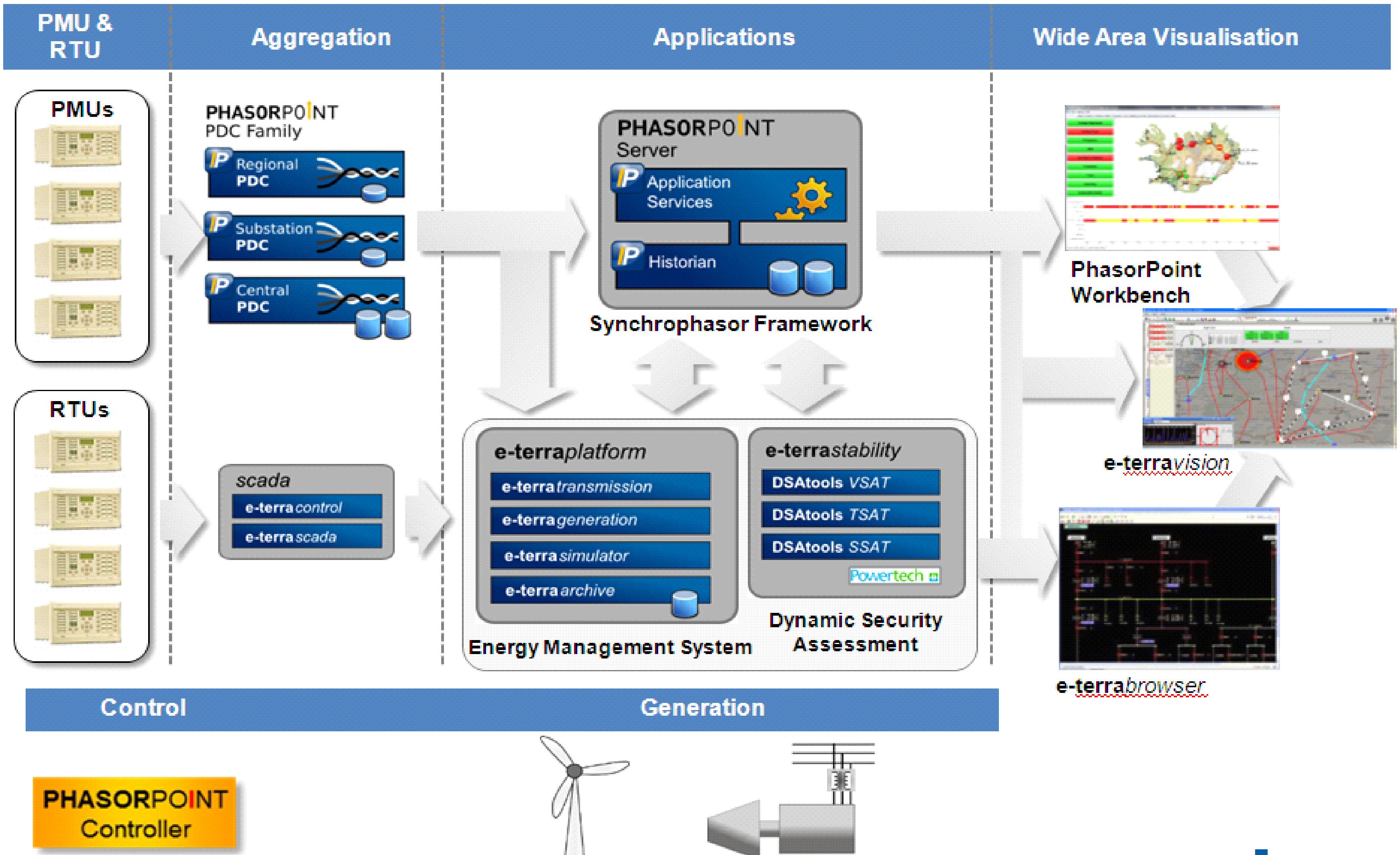
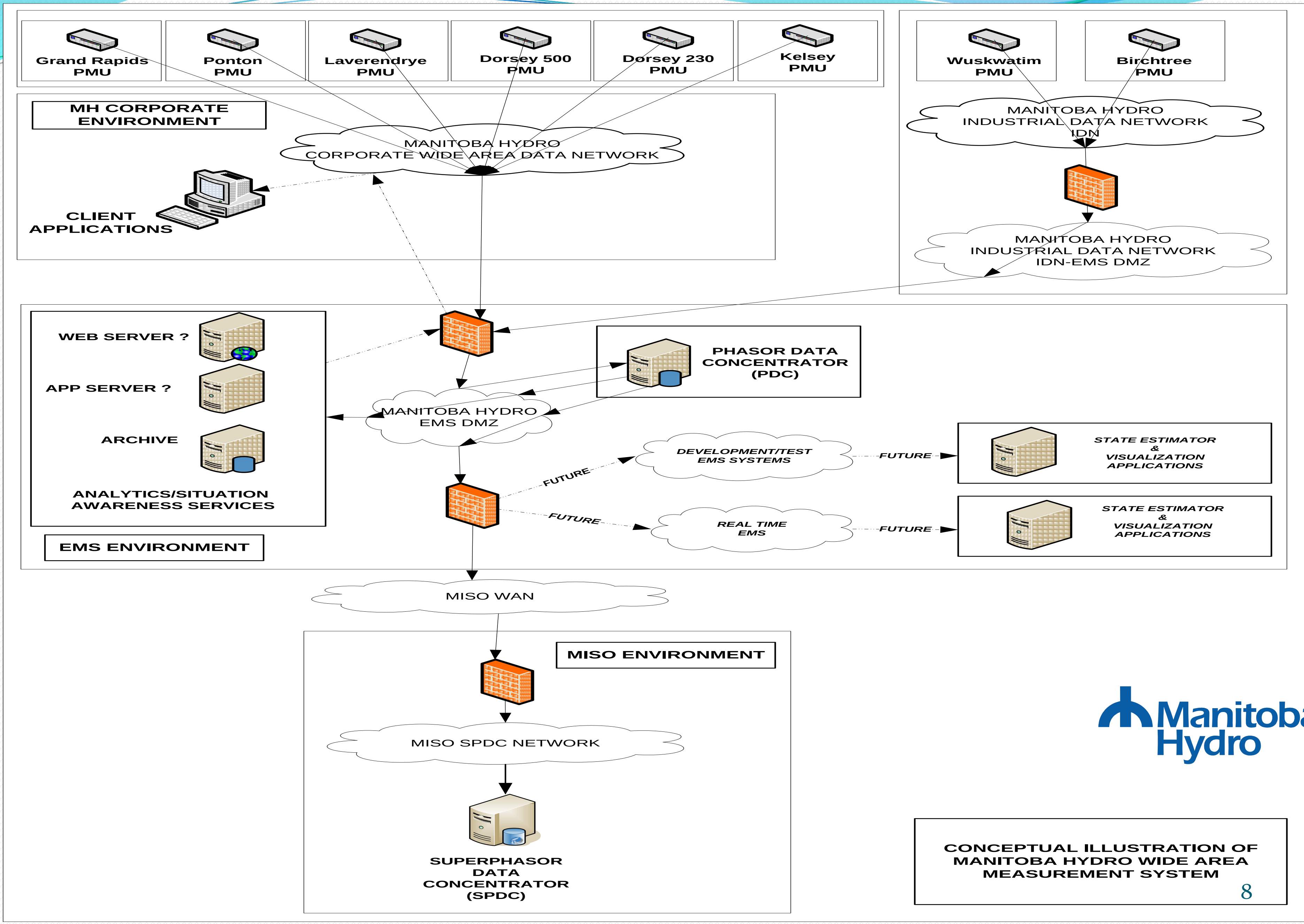
# Conceptual Integration into Technology Road Map



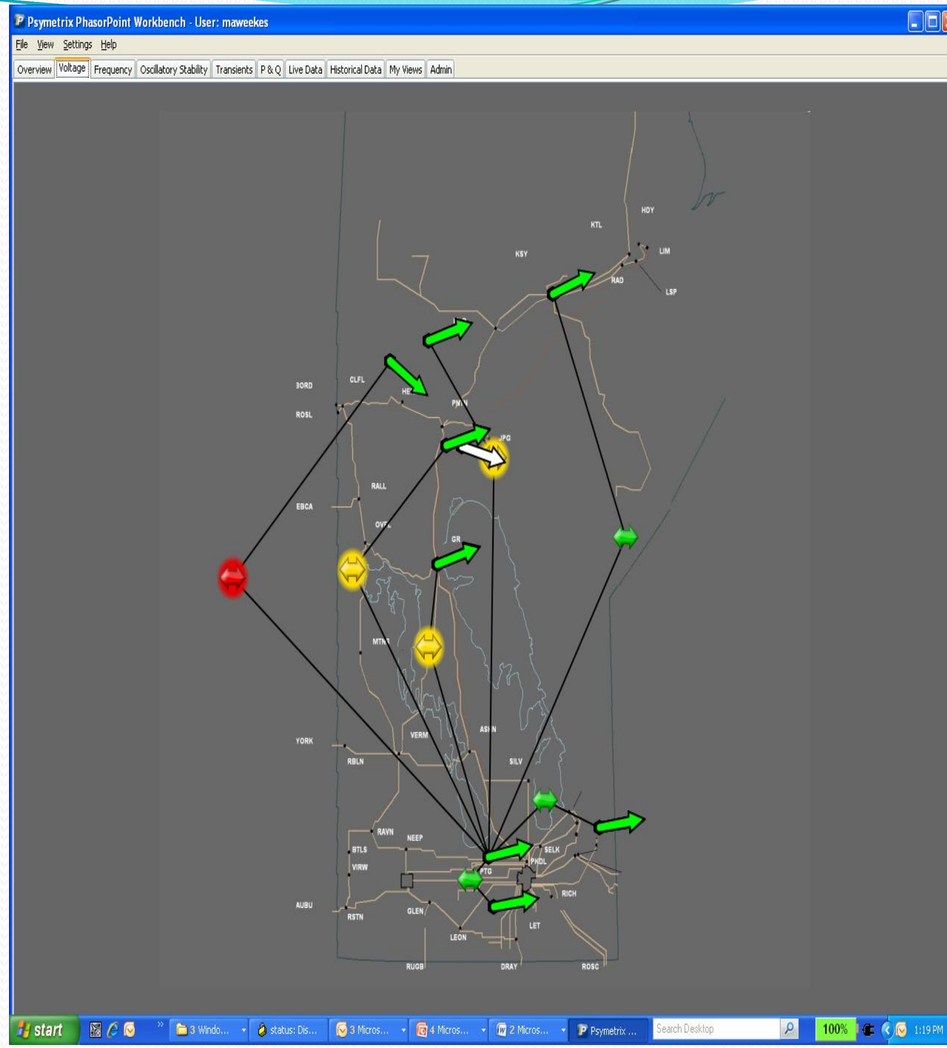

Reference: Psymetrix (Alstom) presentation "Overview of PhasorPoint and Applications in Damping Controller Tuning

# Conceptual illustration of MH WAMS



# WAMS

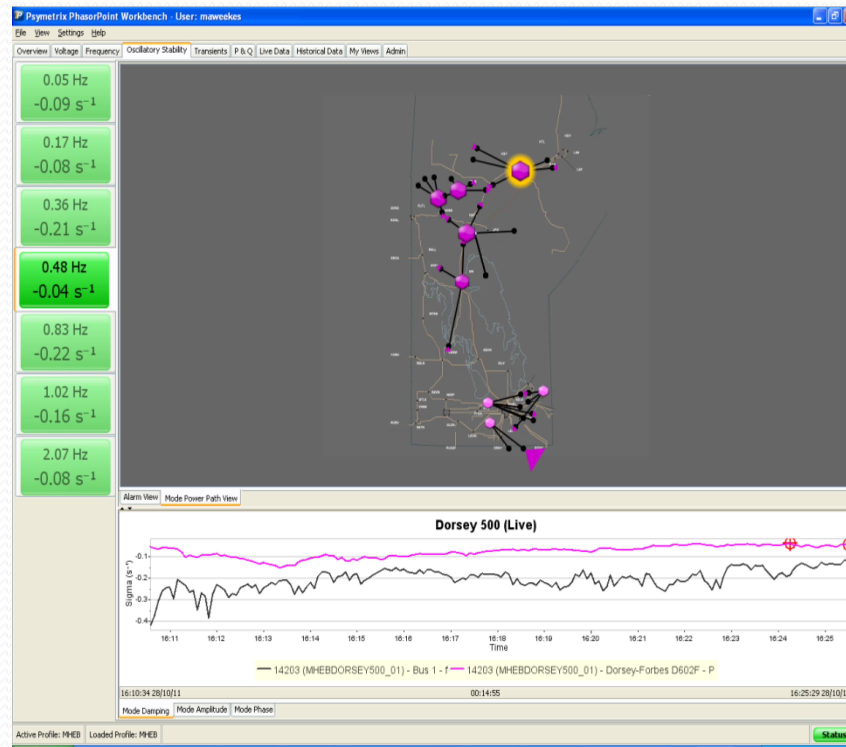
- Phasorpoint tool used primarily to see the modes on the system
- Initial R&D WAMS used in 1997 at MH (non-PMU based)



# 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:
  - Seven units at Kelsey G.S. refurbishment to include high initial response static exciters and modern PSS
  - New Birchtree SVC SDC (to be presented here)
  - Three unit proposed for Wuskwatim G.S. will include high initial response static exciters with modern PSS
  - Grand Rapids is being considered for PSS
  - Refinement of Ponton SVC SDC
  - Refinement of Kettle units 1 and 2 PSSs

- Future sites will increase from 6 to 30 PMU locations
- Using existing TFR devices

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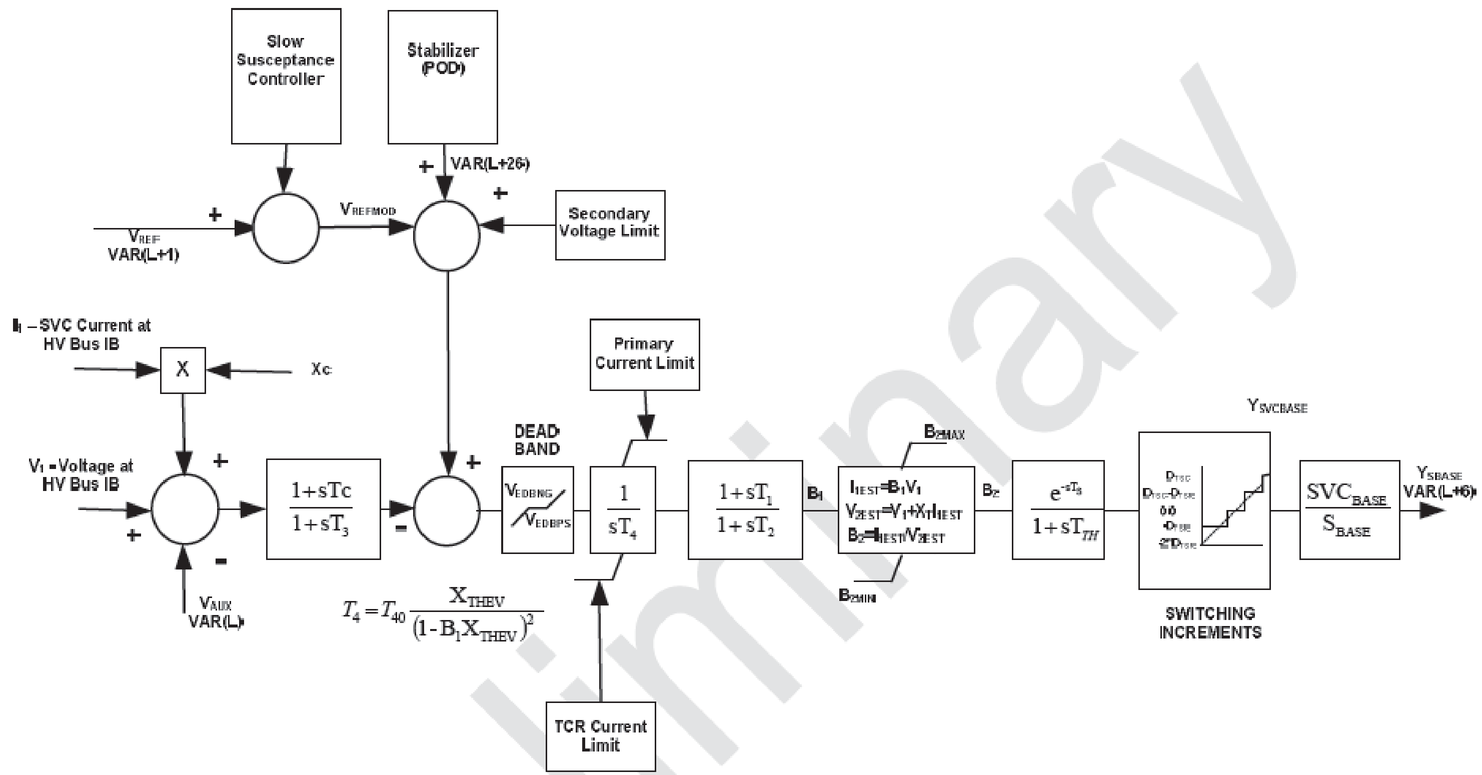
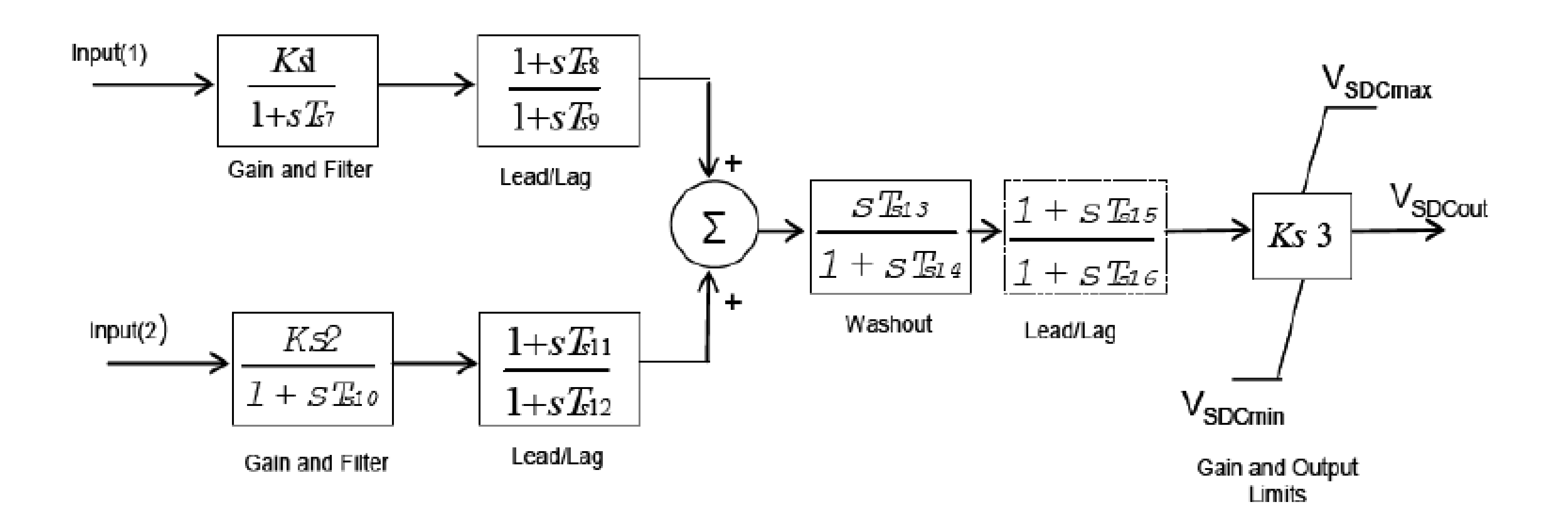
# Birchtree SVC Controller






BTSVC – Voltage Controller

# 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

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# 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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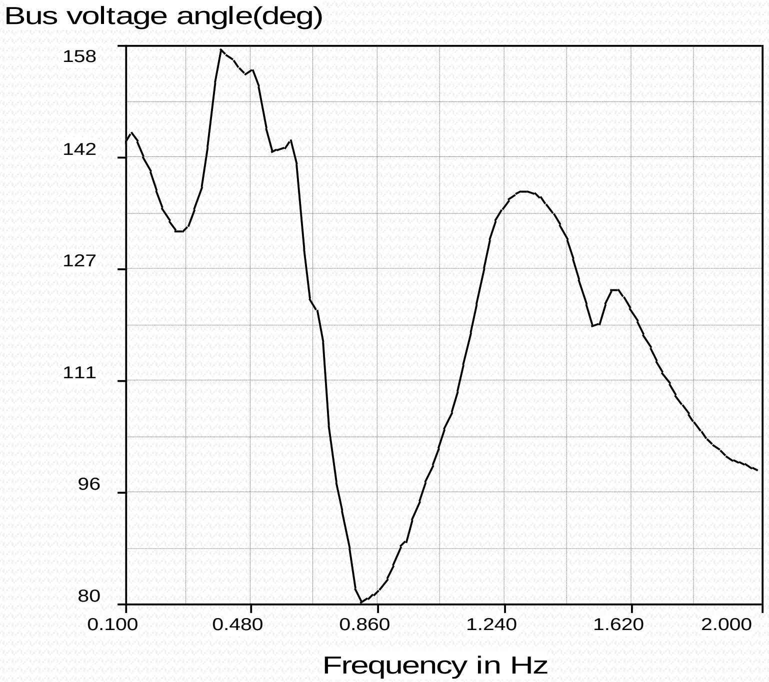
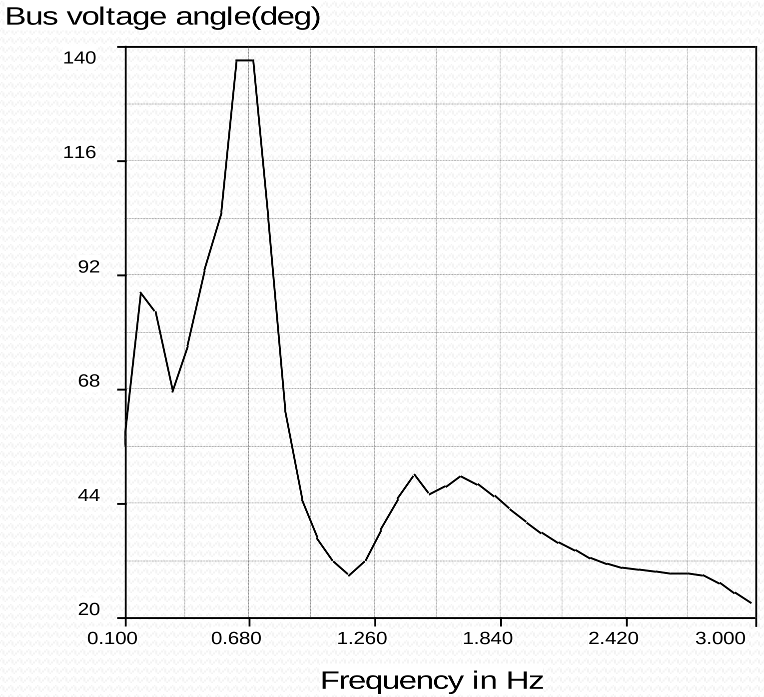
# System Frequency Response

- 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 output

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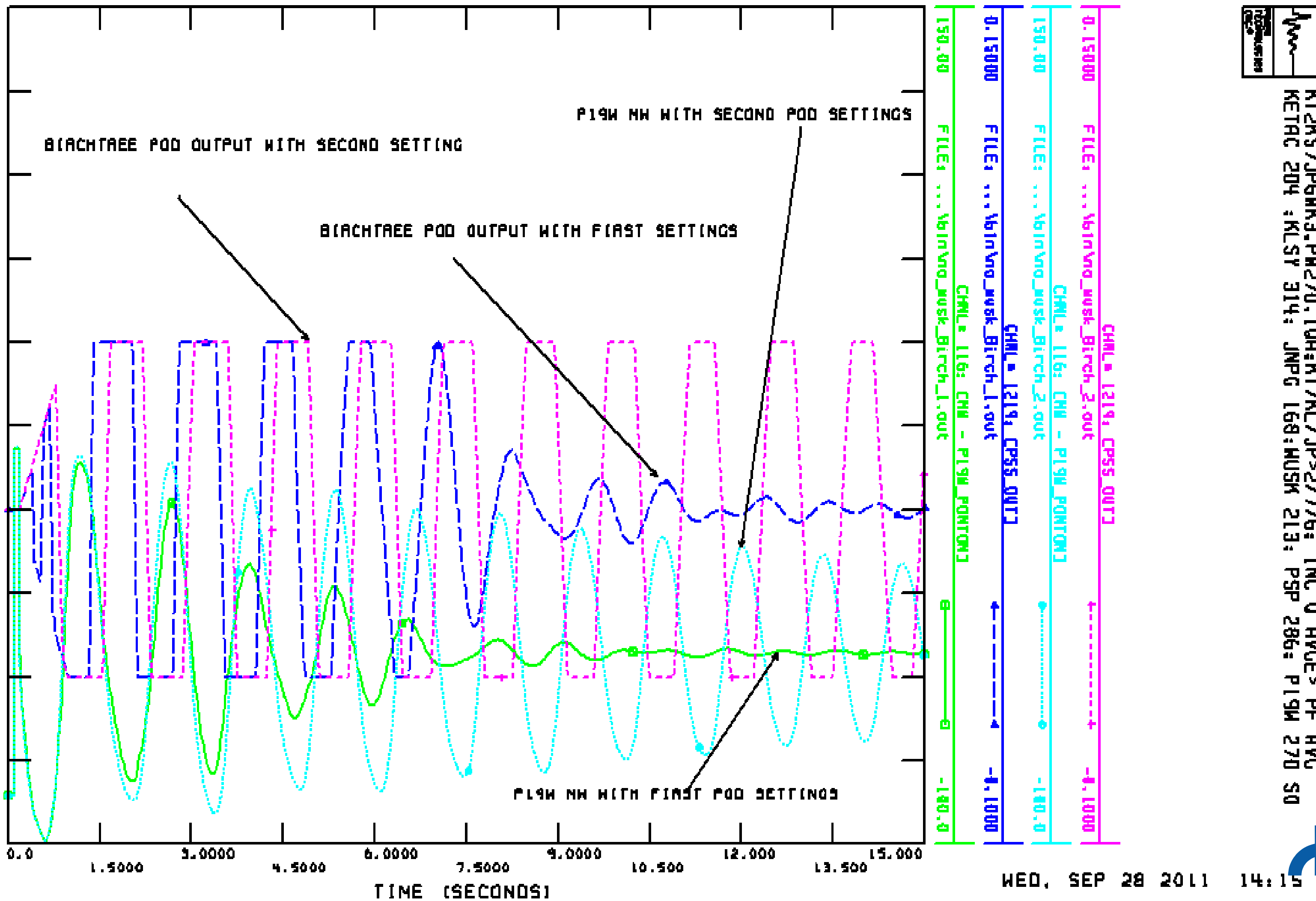
# Simulation Results



# Cont….Simulation Results

- Frequency Domain

MODAL COMPONENTS

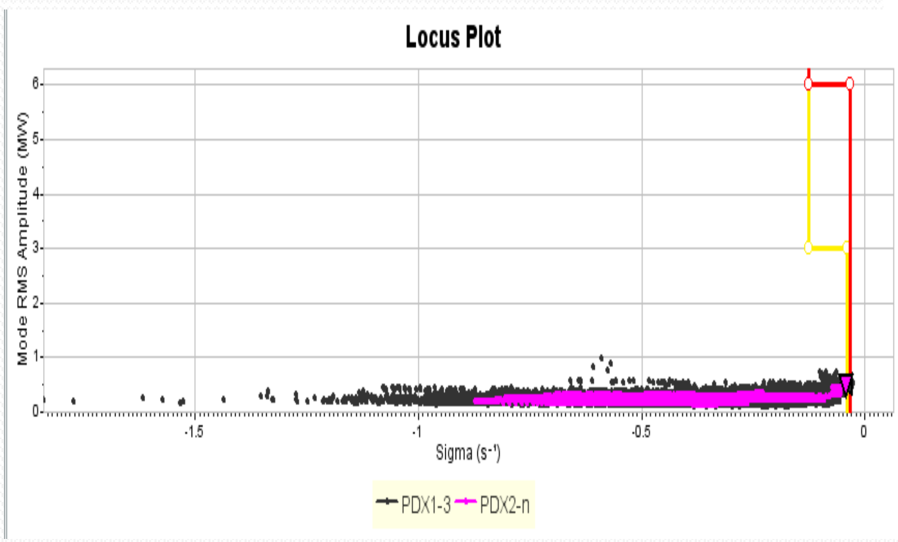
| COMP. NO | EIGENVALUE REAL | EIGENVALUE IMAGINARY | EIGENVECTOR MAGNITUDE | EIGENVECTOR ANGLE | REMARKS |
|---|---|---|---|---|---|
| 1 | 0.810635E-04 | -- | -104.72 | -- | |
| 2 | -0.149205 | 4.66803 | 16.997 | -43.39 | FREQ.: 0.743 HZ. |
| 3 | -9.23642 | 25.3357 | 2.1226 | -85.51 | FREQ.: 4.032 HZ. |
| 4 | -8.97202 | 42.6287 | 2.0465 | -47.19 | FREQ.: 6.785 HZ. |
| 5 | -0.212545 | 6.82925 | 1.4056 | 98.87 | FREQ.: 1.087 HZ. |
| 6 | -7.89161 | 57.9493 | 0.98096 | 71.41 | FREQ.: 9.223 HZ. |
| 7 | -5.64456 | 39.4219 | 0.66522 | 138.48 | FREQ.: 6.274 HZ. |
| 8 | -0.895488 | 10.2439 | 0.47889 | -124.57 | FREQ.: 1.630 HZ. |
| 9 | -4.86058 | 61.9287 | 0.20336 | -138.38 | FREQ.: 9.856 HZ. |
| 10 | -1.22760 | 17.8970 | 0.17606 | -20.57 | FREQ.: 2.848 HZ. |
| 11 | -3.04154 | 50.4016 | 0.13071 | 9.49 | FREQ.: 8.022 HZ. |


Voltage
Frequency
Active & Reactive Power
Oscillation Magnitude W76B
SAMSUNG

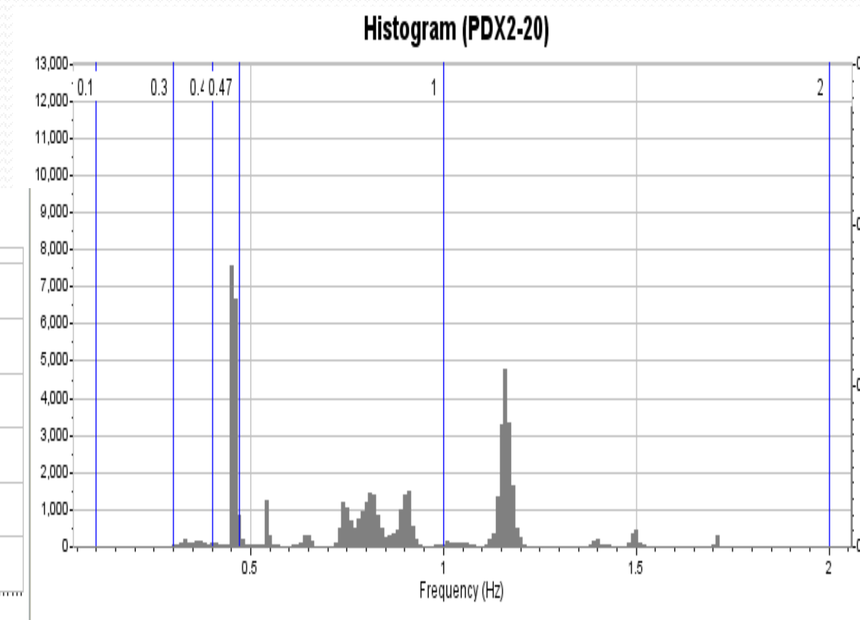
# Mode Trending

## Root locus of mode

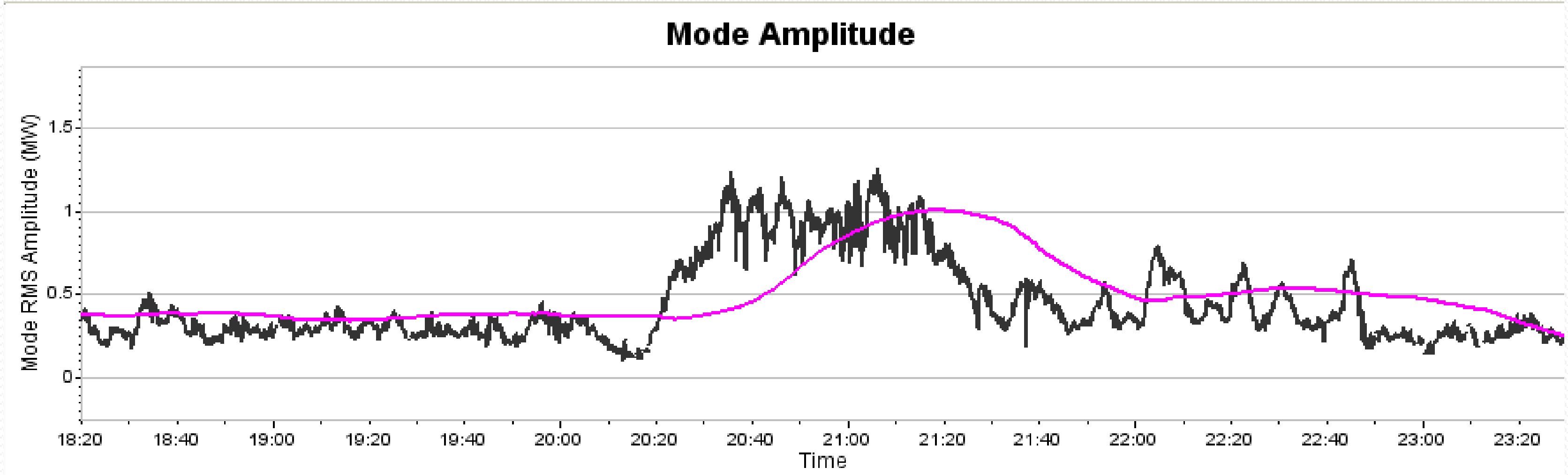
- Trending and verification of damping controller performance

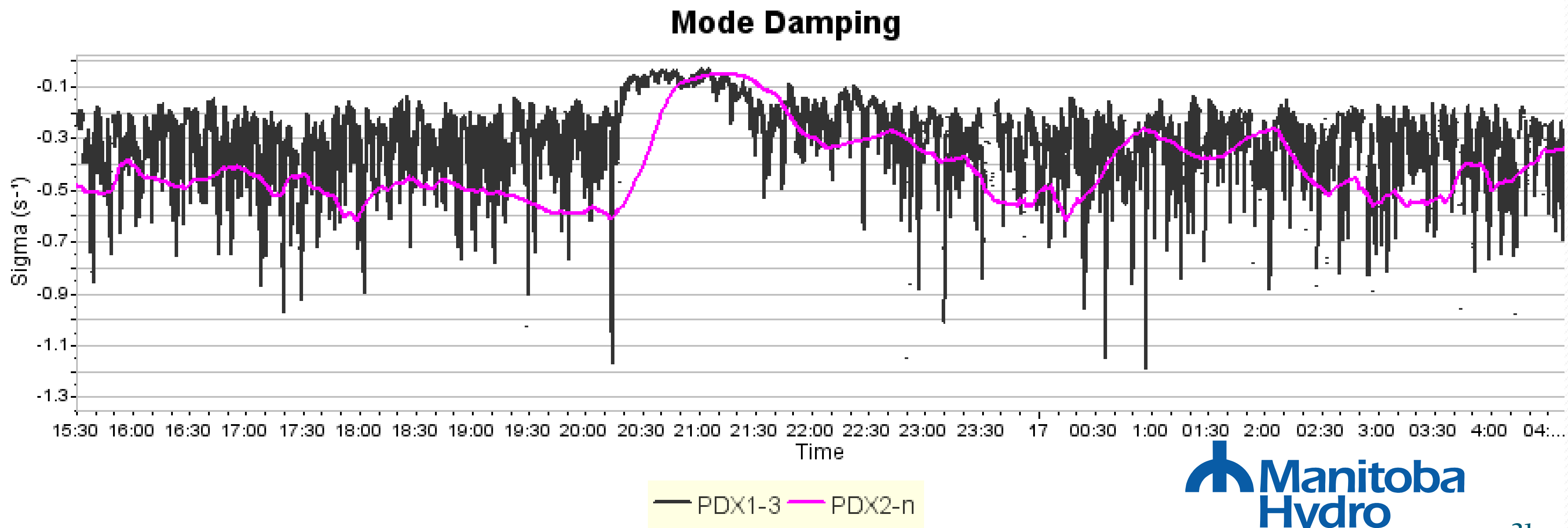



## Observability of the mode over time



# Commissioning Results

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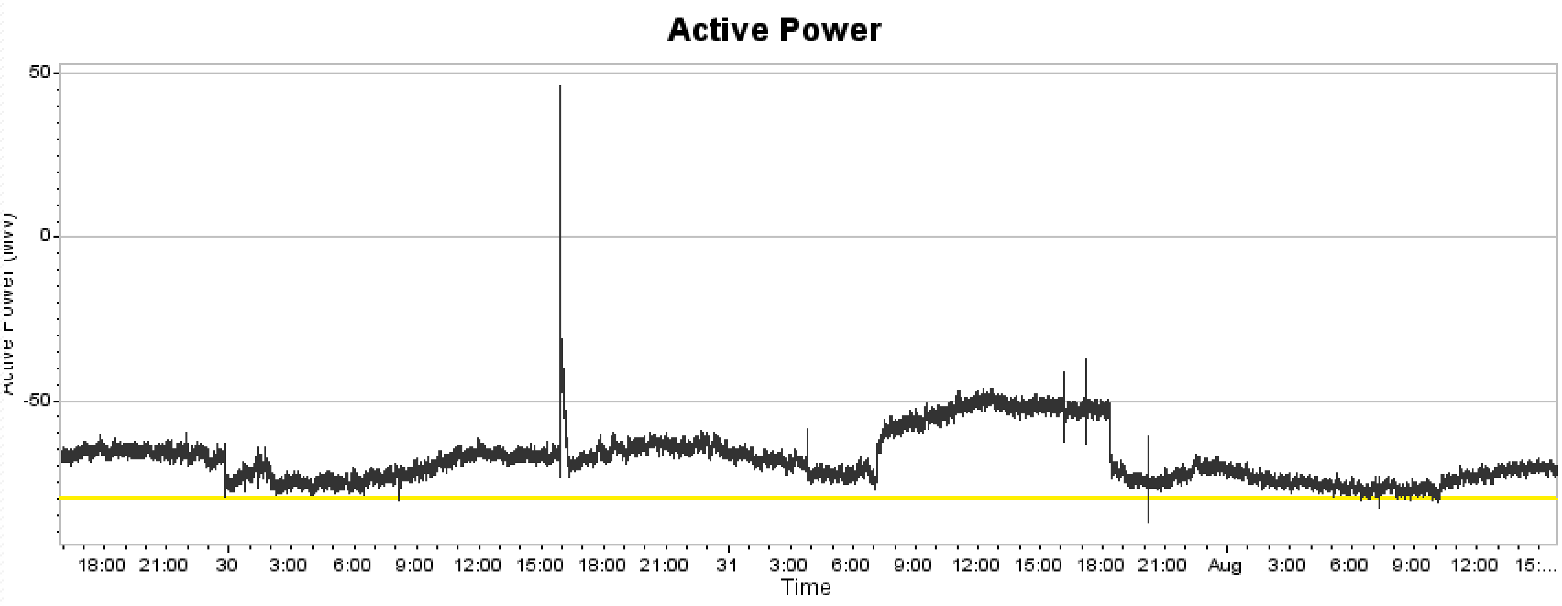
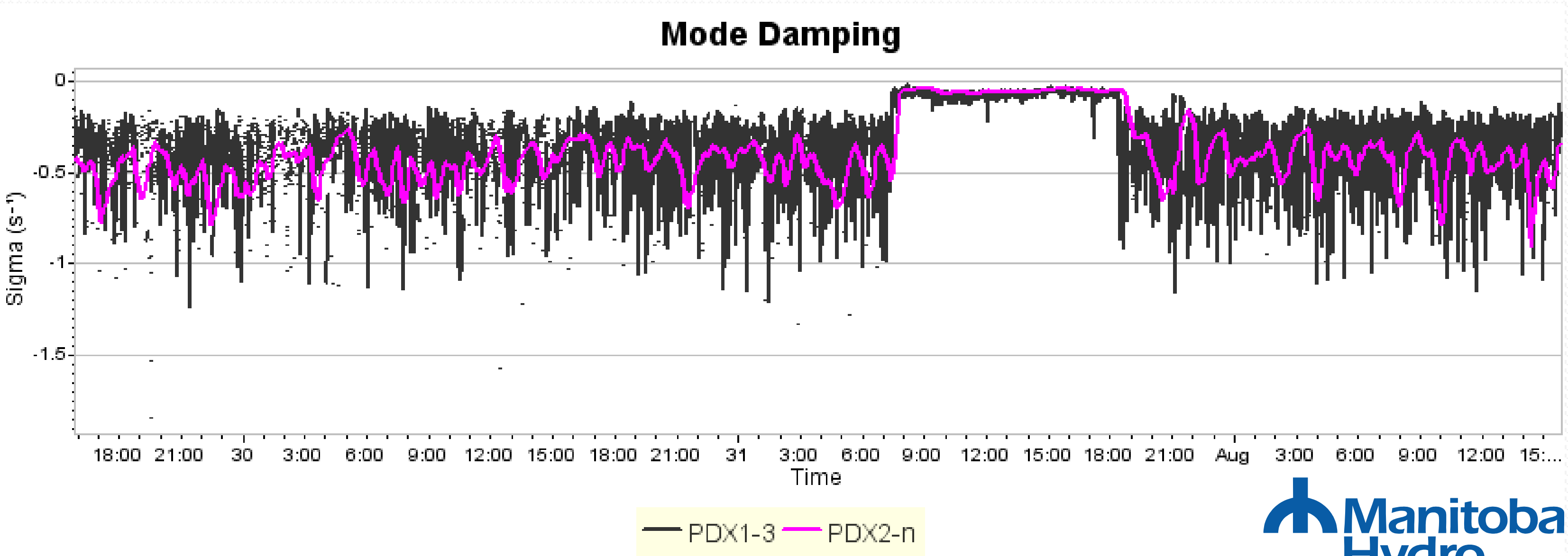
# Unexpected Results Captured

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

# Cont.....System Baselining

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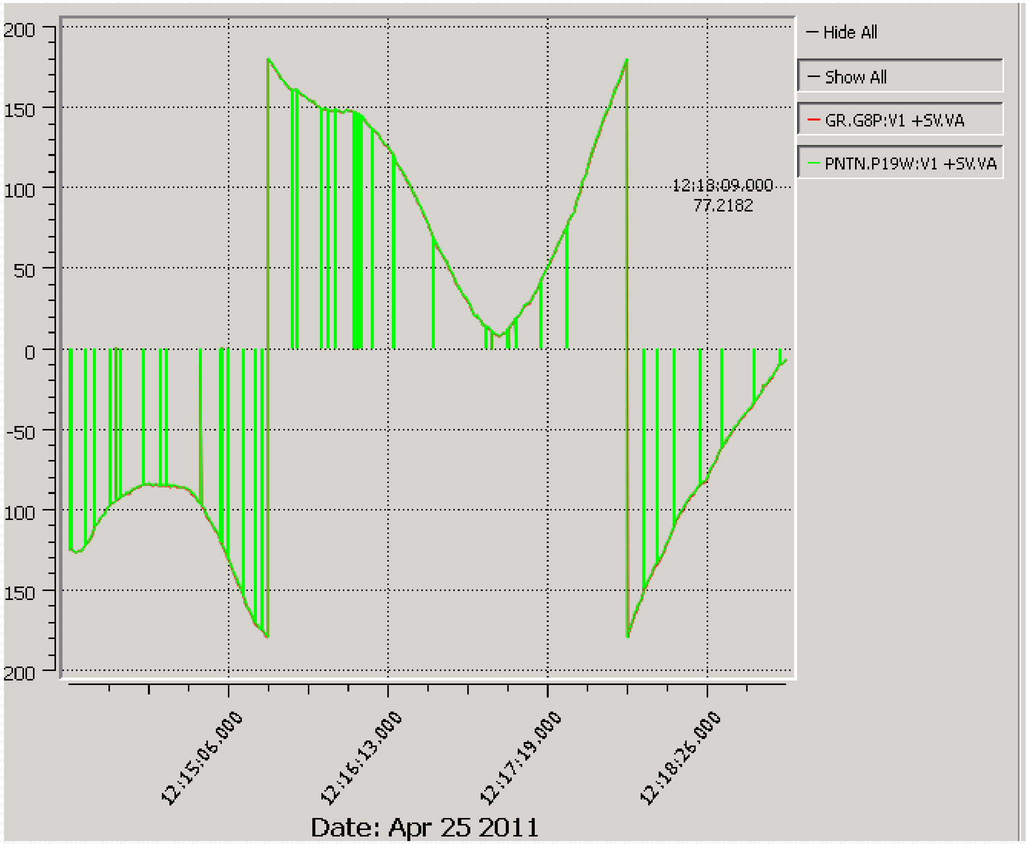
# Cont…..System Baselining

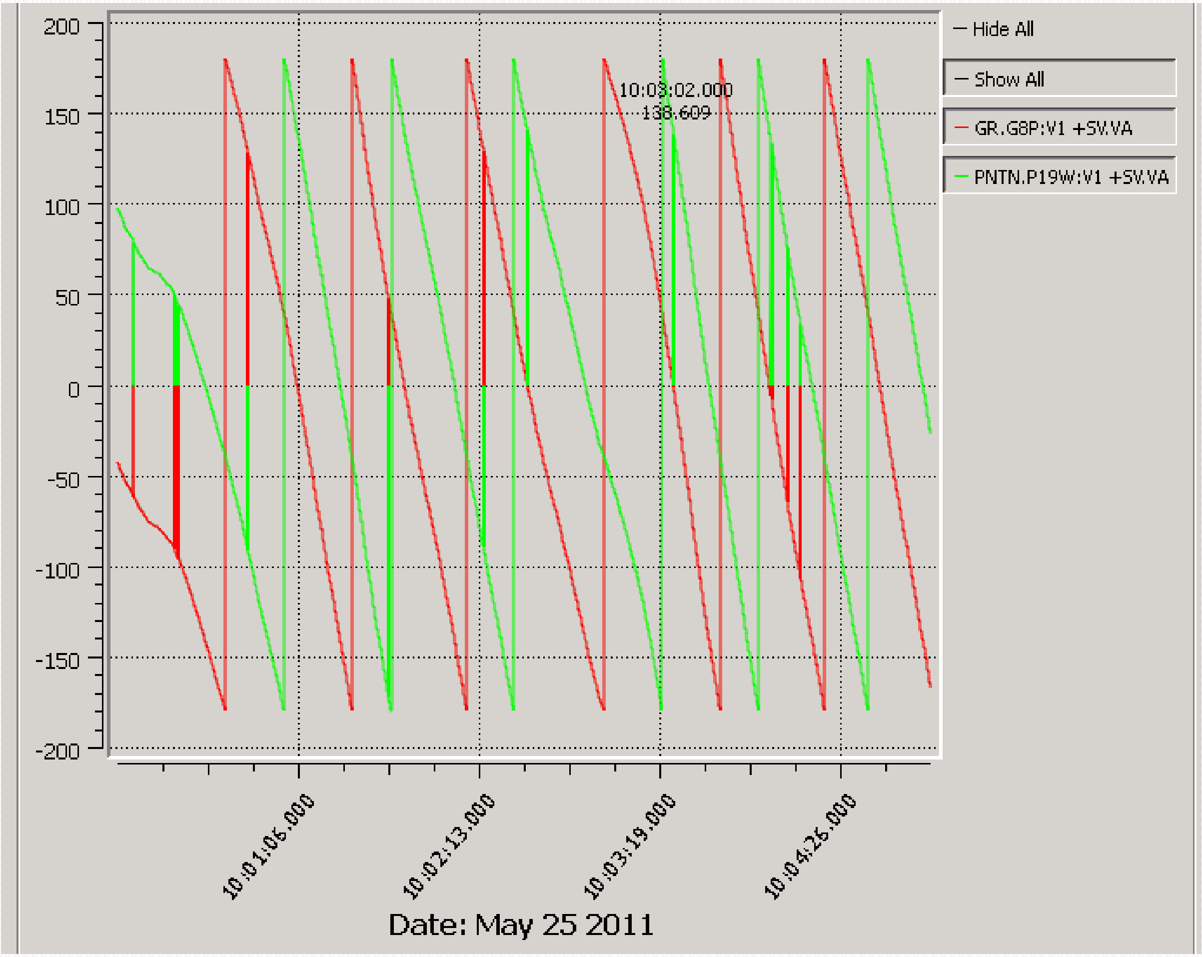
**April 25, 2011 – 11:14:00 to 11:19:00 – Approx. 2 hours before event**

## Clock Errors

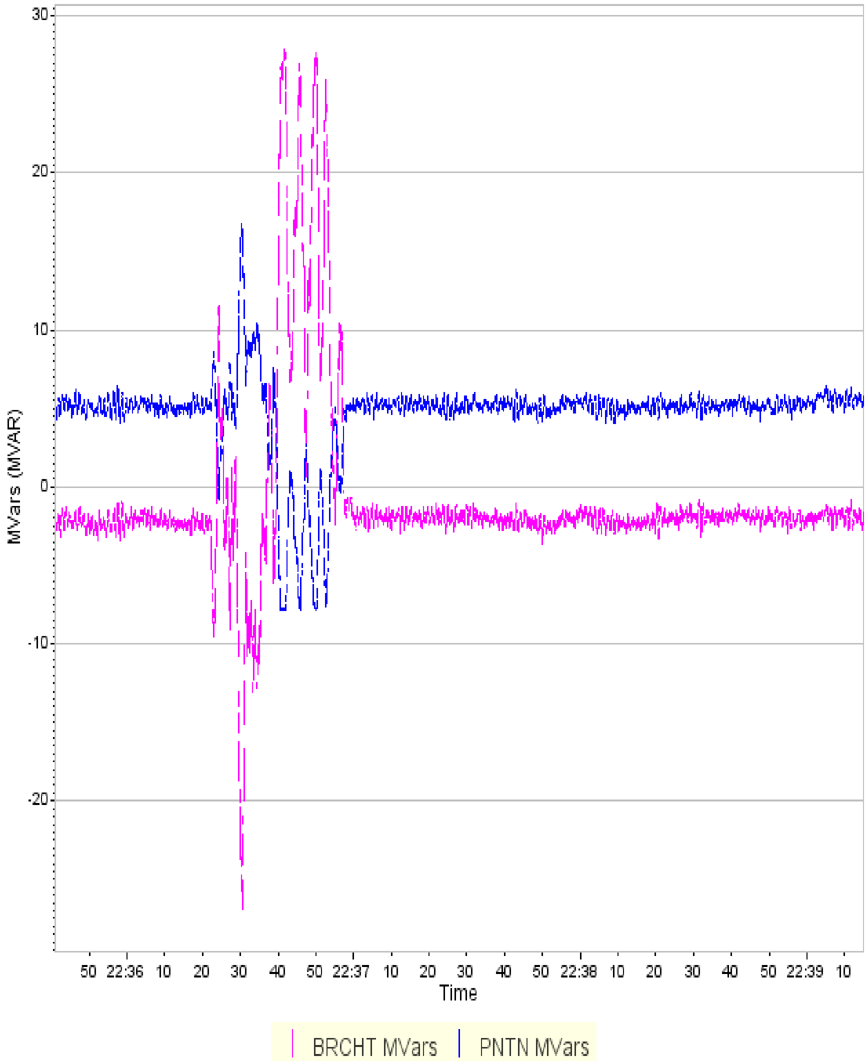


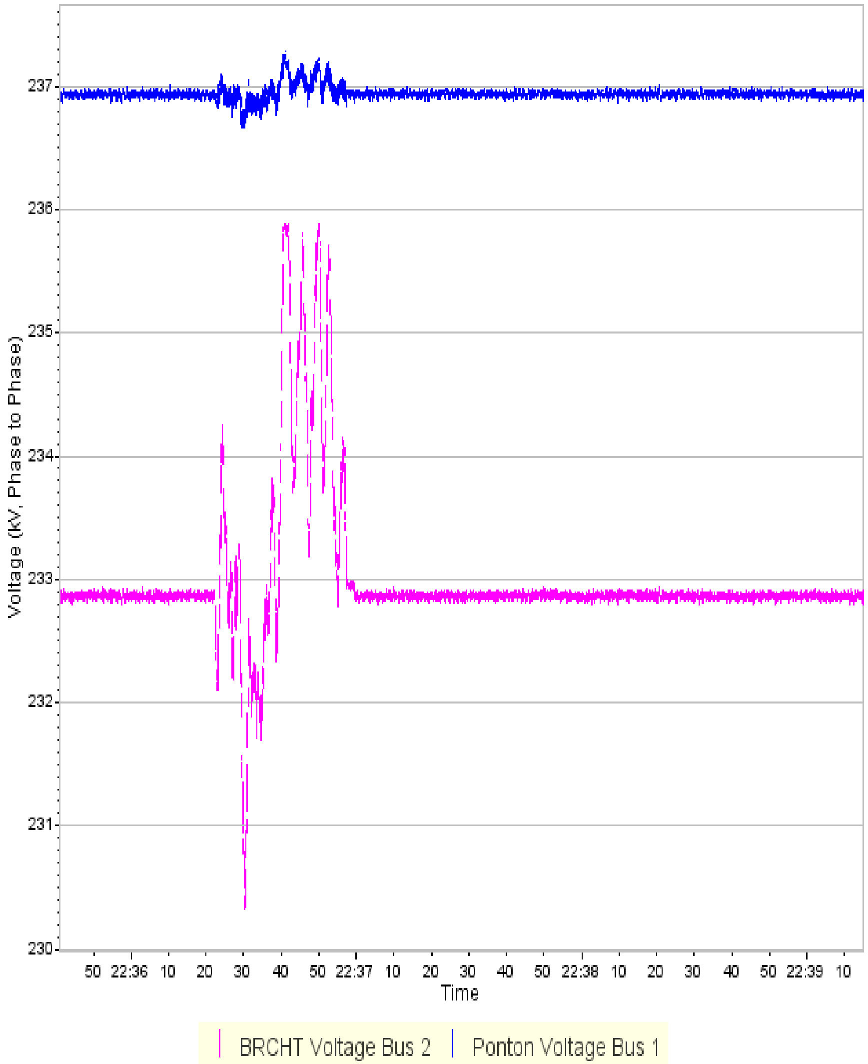
# Cont…..System Baselining

**May 25, 2011**

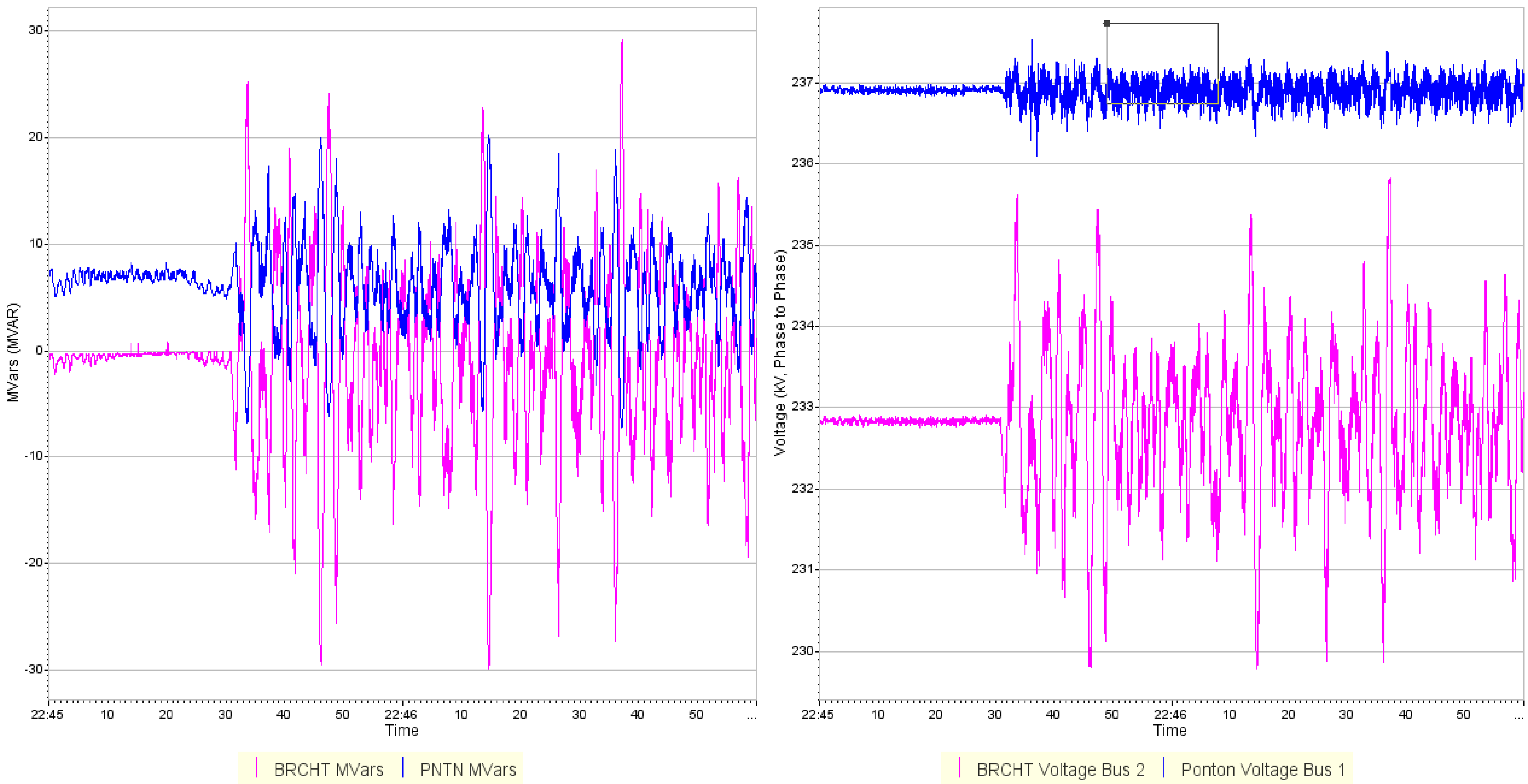


# POD First Settings



# POD Second Settings

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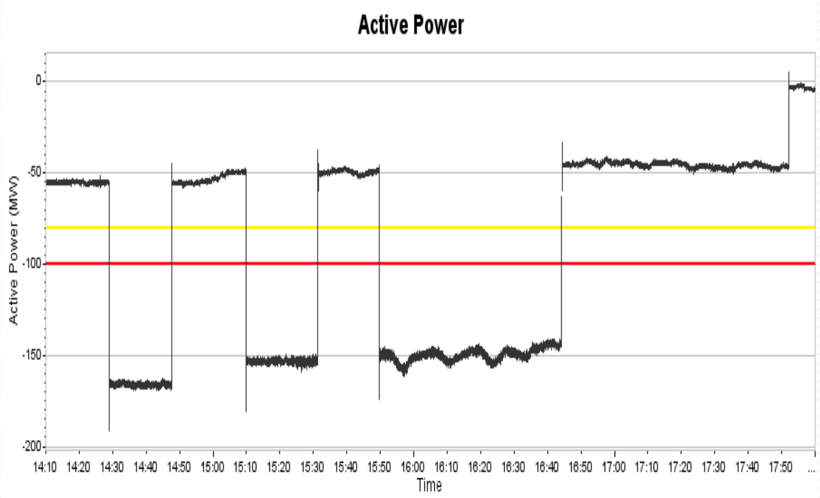
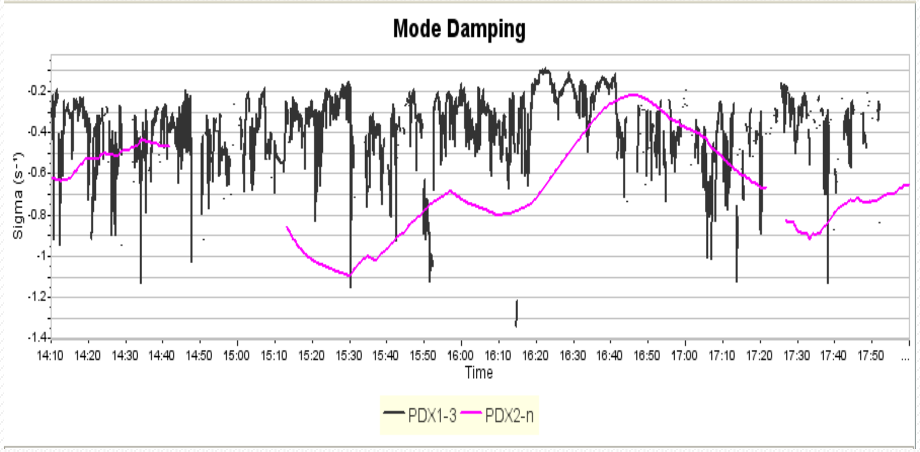
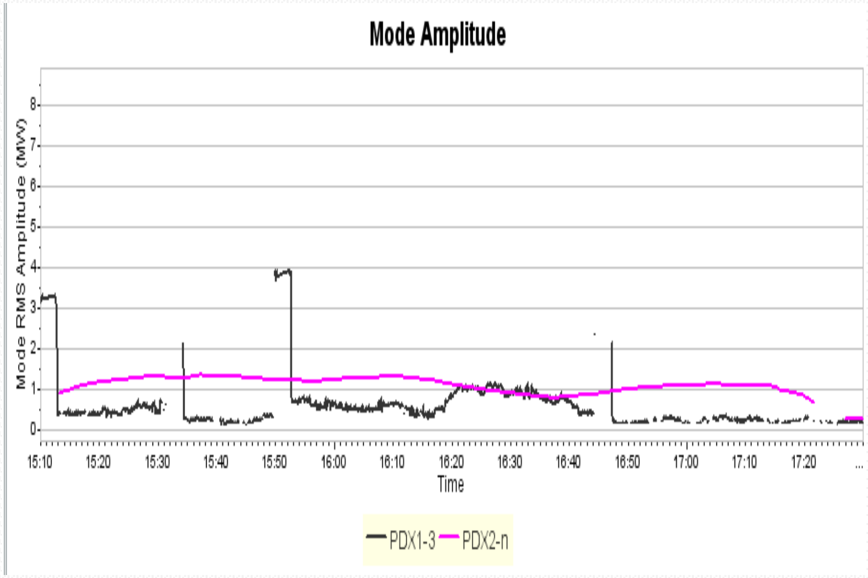
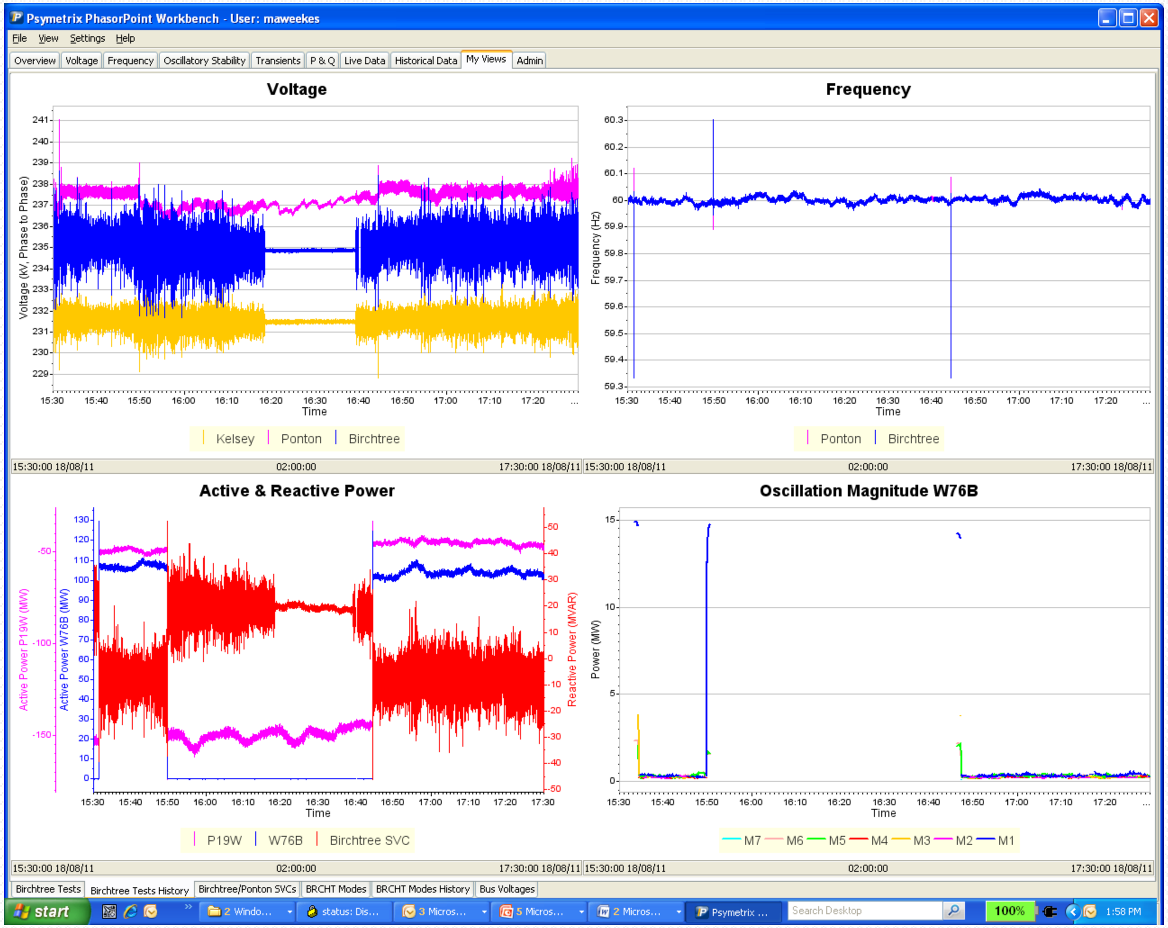
# Open/Close line test



# Open/Close Line Test



# Open/Close Line Test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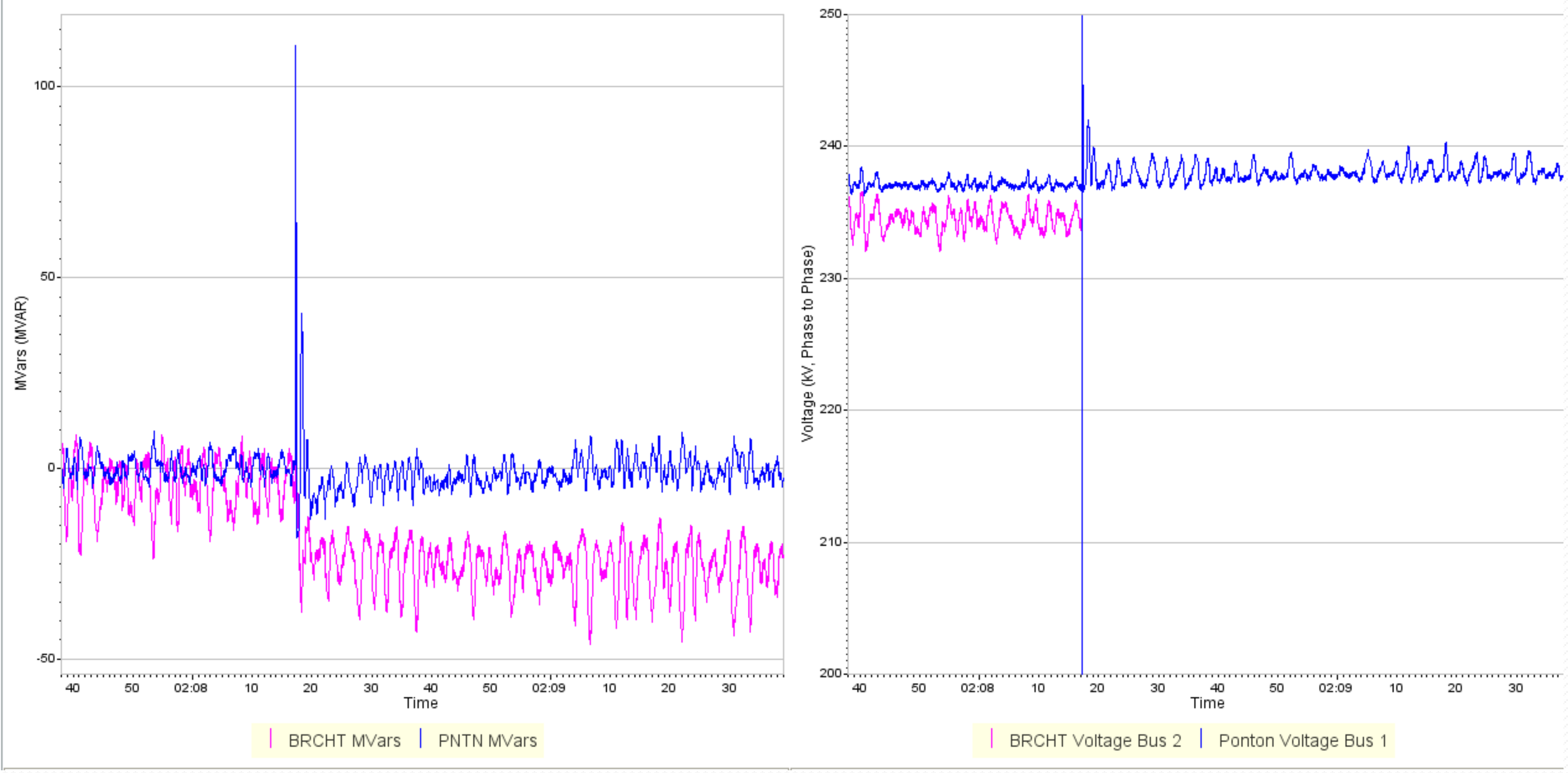
# SLG Fault

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# 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
  - Many current and future research projects which are required to facilitate our MH roadmap
  - R & D supported work (PhD) on generator cohesive cluster visibility- funded , identified future PMU locations
  - Additional R & D needed for wider MH and adjoining network
  - R & D needed in areas of transient stability visibility – 1 proposal to be presented today
  - R & D needed in areas of voltage stability visibility
- Refine/expand system alert and alarm levels
  - R & D needed to refine these levels
  - R & D needed for leading indicators
- Benchmark/develop analytical tools
  - R & D needed to help develop tools
    - R & D needed to develop real-time dynamic equivalent s of the external system using PMU measurementsR & D needed to help develop smart, realistic, accurate optimization techniques for model parameter validation
- More efficient/informative post-event analysis
- Wide Area Controls – 1 R & D project approved – additional research may be needed in this area
- Studying and understanding effects of communication delays, missing data, etc.
  - R & D needed to better model communications and communication delays – 1 proposal to be presented today
  - R & D needed to understand impact of communication delays , missing data and interpolation techniques
  - R & D needed to quantify required communication and measurement redundancies
- Integration with real time tools that use power models , such as DSA tools (benchmarking) – R & D needed
- Off-line studies and extensive (incl. statistical) analysis of on-line data to develop uncomplicated rules for operators – R & D needed
- Intelligent island formation in power system – R & D needed
- Integration into real time
  - Considerations - R & D, PMU dynamic performance standards, cyber security standards, industry pace, …

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# MISO Project Status

- Transmission Owner Synchrophasor Solutions
  - MISO will provide Transmission Owners with Phasor Grid Dynamics Analyzer (PGDA), Real-time Wide Area Displays and a down-sampled data stream.
  - The project will provide Transmission Owners with a subset of the data being collected by the MISO local and regional PDCs in C37.118 format, down-sampled to 1 sample per second
    - This is a change from the initial approach that called for the data to be provided via ICCP.
    - Providing data in C37.118 format will allow the timestamp to be preserved, which will protect the accuracy of phase angle measurements.
  - MISO will also host a subset of its wide-area visualization capabilities that TOs will be able to access via CITRIX.
  - Real-time Displays have not been finalized by are targeted to be deployed in 2012

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# MISO Project Status (continued)

- Transmission Owner Solutions (continued)
  - Host Phasor Grid Dynamics Analyzer (PGDA), an historical phasor-data event analysis tool, and provide TOs with access to the application and data to analyze.
  - Users will be able to analyze events and save them to the MISO Extranet for later access.
  - MISO will be hosting Synchrophasor training for members. PGDA training will occur early next year. The timeline for hosting PGDA includes:
    - Pilot selected events with first TO by Q2 2012, and have deployed to all TOs by the end of 2012.
    - Data archive available for analysis by Q3 2012
    - PGDA training for TOs to start in 2012
      - First session will be instructor-lead, later session will be hands-on

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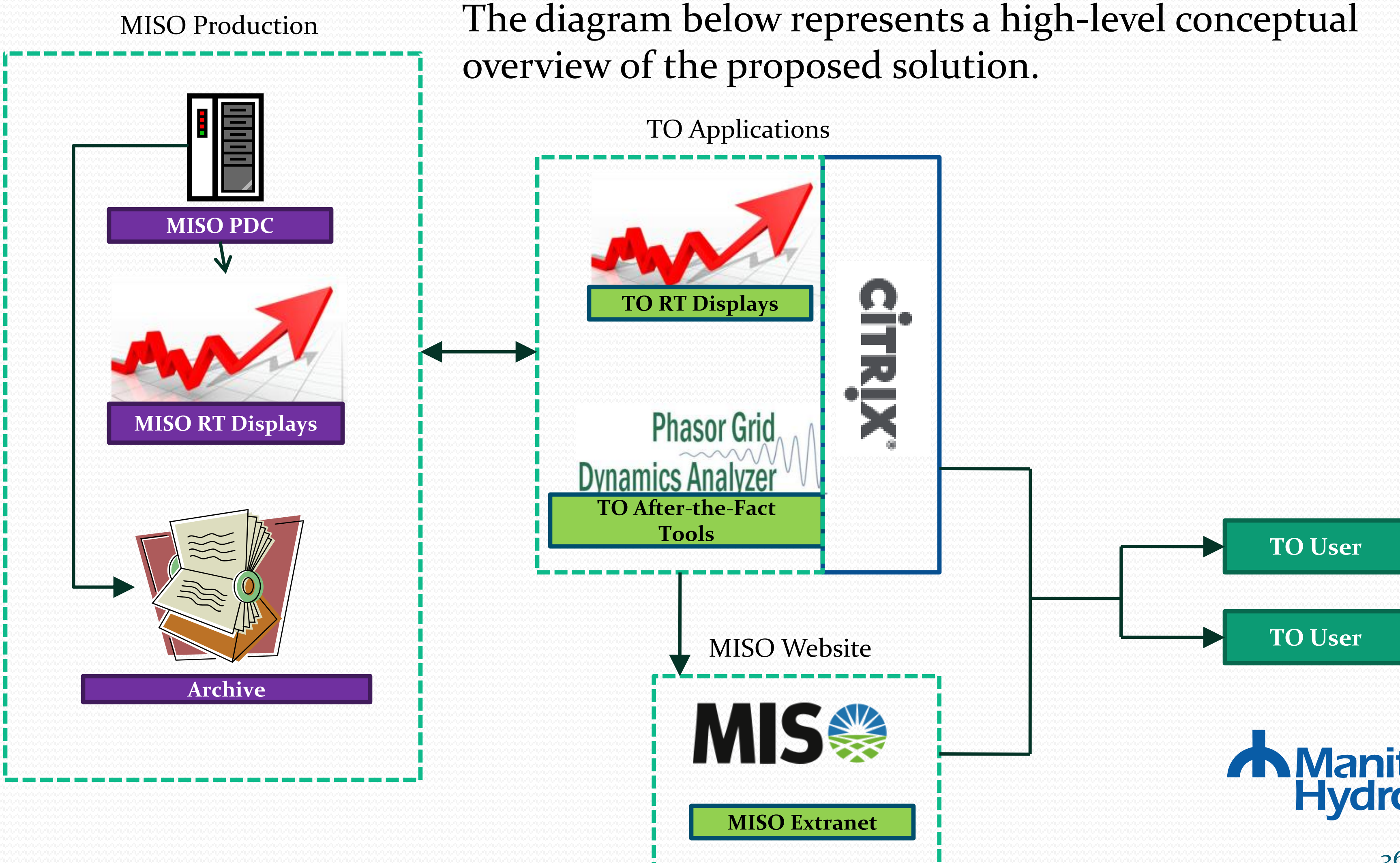
# MISO Project Status

- **Transmission Owner Solutions (continued)**

The diagram below represents a high-level conceptual overview of the proposed solution.



# NASPI Products (Performance and Standards Task Team)

- PSTT has rolled out several standards over the past 2 years:
- C237.118.1 – Class M
- C237.118.2 – Class P
- C37.244 – PDC Requirements
- C37.242 – Synchronization, testing, calibration, and installation
- C37.238 (Communication)
- 61850-90-5 (Station automation Protocol)
- Draft stages (PAR approved) – to be continued in IEEE

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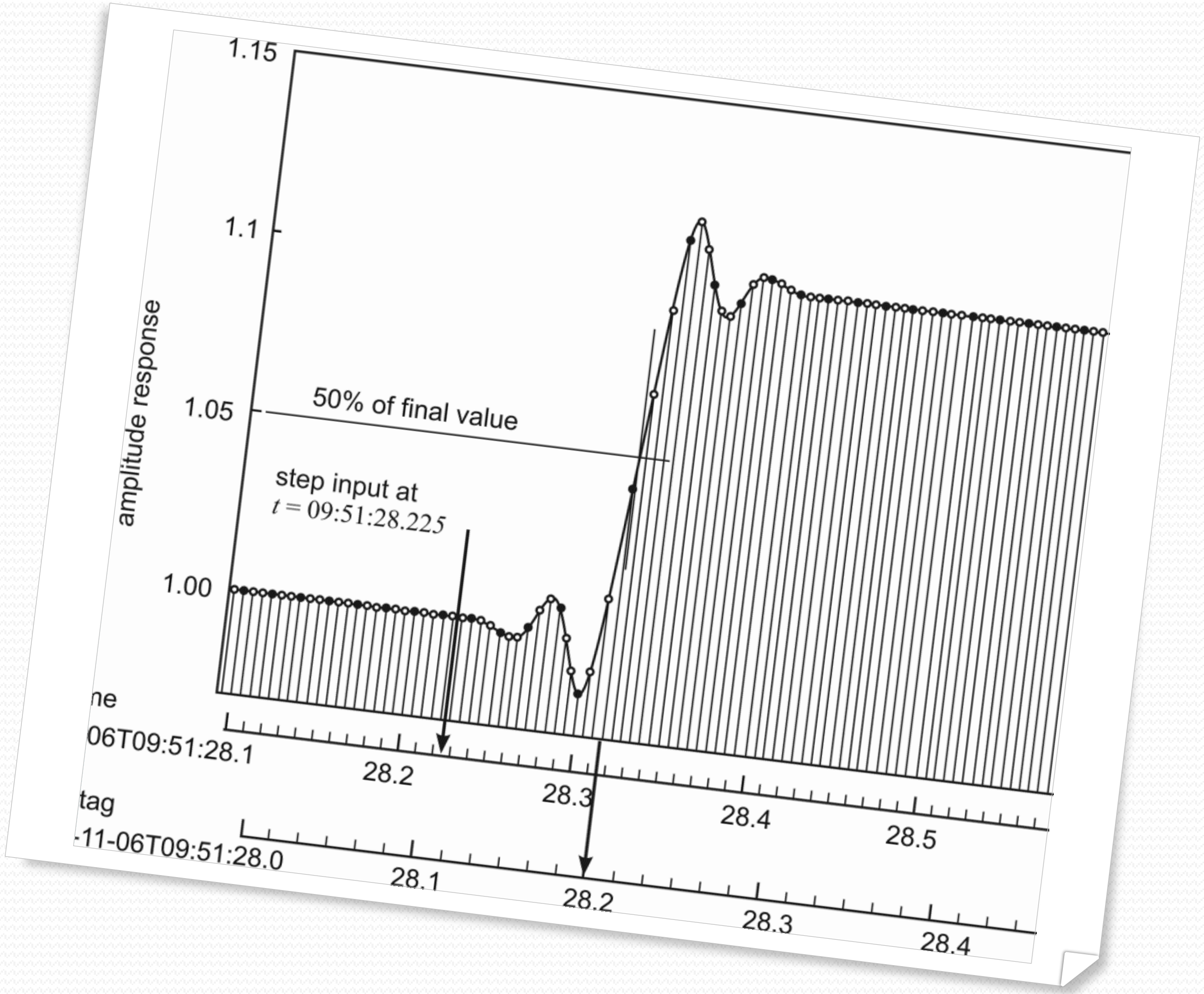
## Future Challenges for NASPI

Some of the challenges to NASPI have been to define dynamic requirements, define latency, issues with missing data, standardizing real time displays, standardizing testing, interoperability with for example 61850, central archiving (publish and subscribe gateways)

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