Synchrophasor Activities in Manitoba

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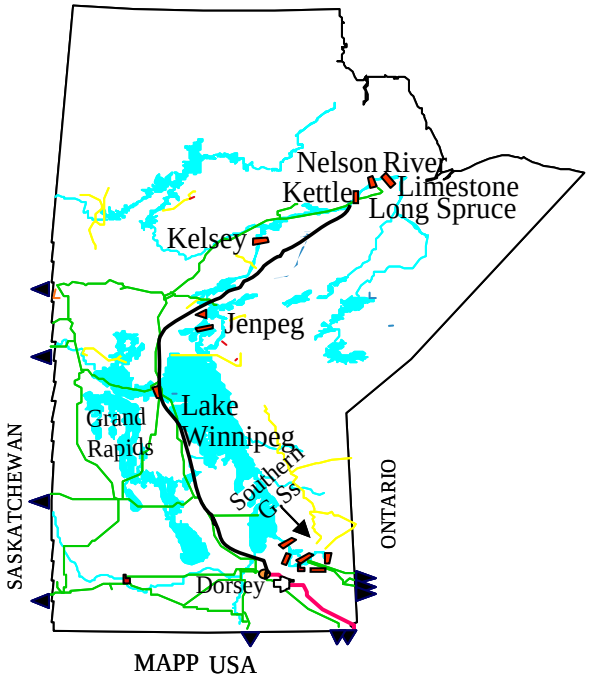
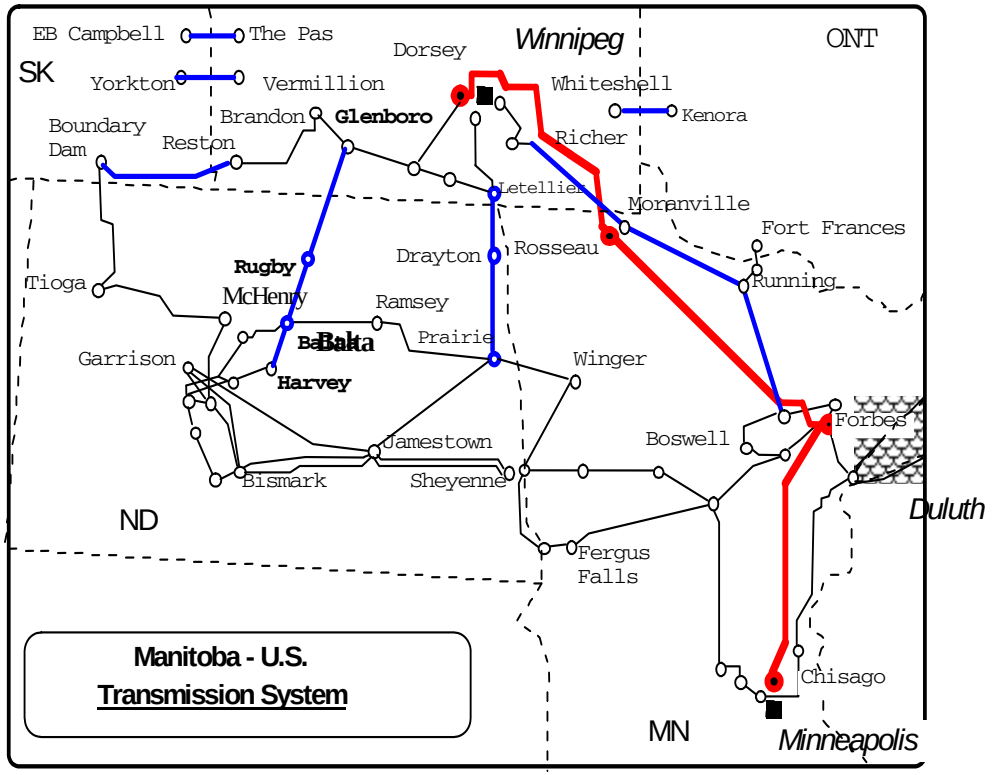
Background

- Geographic Layout of Manitoba Hydro System
- - Approx. 70% of generation in northern part of province
- - Ties to Ontario (East) ; Saskatchewan (West) ; MAPP(MRO) USA (South)
- - Power from 3 largest hydro plants transmitted south over 2 HVdc Bipoles for serving load centres in south and for export.



PMU Geographic Location

- MB-U.S. Transmission System
- 4 ties to US
- Most heavily loaded tie D602F was chosen
- 2 transformers at Dorsey with easily accessible 230 kV sides for PTs and CTs



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Groups Required

- Participation required from:
  - Project Manager
  - IT (Information Technology Services)
  - Plant Eng.
  - Protection Maintenance
  - Protection technicians on site
  - Communication Eng.
  - Commissioning
  - Transmission Services

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Risk

- Risk Assessment

  - power system conditions during the commissioning

- Cyber Security

  - MB Hydro chose a dedicated VPN connection with no possibility of connection to our local area network

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Location Within Station

- Location within the station

  - GPS mounting to be as high as possible and also a lightning arrestor design should be included. Cable length to antenna is also a factor.

  - for MB Hydro is was easy to access PTs and CTs in the relay trailer of the 230 kV side of the transformer

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Testing

- Bench Testing

  - Prior to installation the unit needs to be bench tested.

  The TVA Connection Tester posted on the NASPI (http://phasors.pnl.gov/resources_tools.html) web site is a simple way to check data coming from your PMU.

  - Removal of fixed errors in the PMU can be calibrated out of the calculation through offsets to minimize the total vector error (TVE)

- Commissioning

  - Standard commissioning of PTs and CTs needed.
  - GPS needs to be commissioned to see at least 4 satellites

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Performance Requirements

- Performance Requirements

  - An assessment of how the unit performs is needed after installation

  - Test guide currently being developed by NASPI contains many steady-state and dynamic tests that can be performed.

  - MB Hydro has performed: steady-state tests that can be used to calculate the TVE, steady-state tests that examine off nominal frequencies and a rate of phasor rotation in degrees per second, and dynamic tests to see the response to a frequency change. No modulation nor interference frequency tests have been attempted to date.

  - tests which compare the PMU output to SCADA (state estimator) results have also been performed and helped us in a correction of 150 degrees due to incorrect line to neutral translation and incorrect sequencing of phases A,B, and C.

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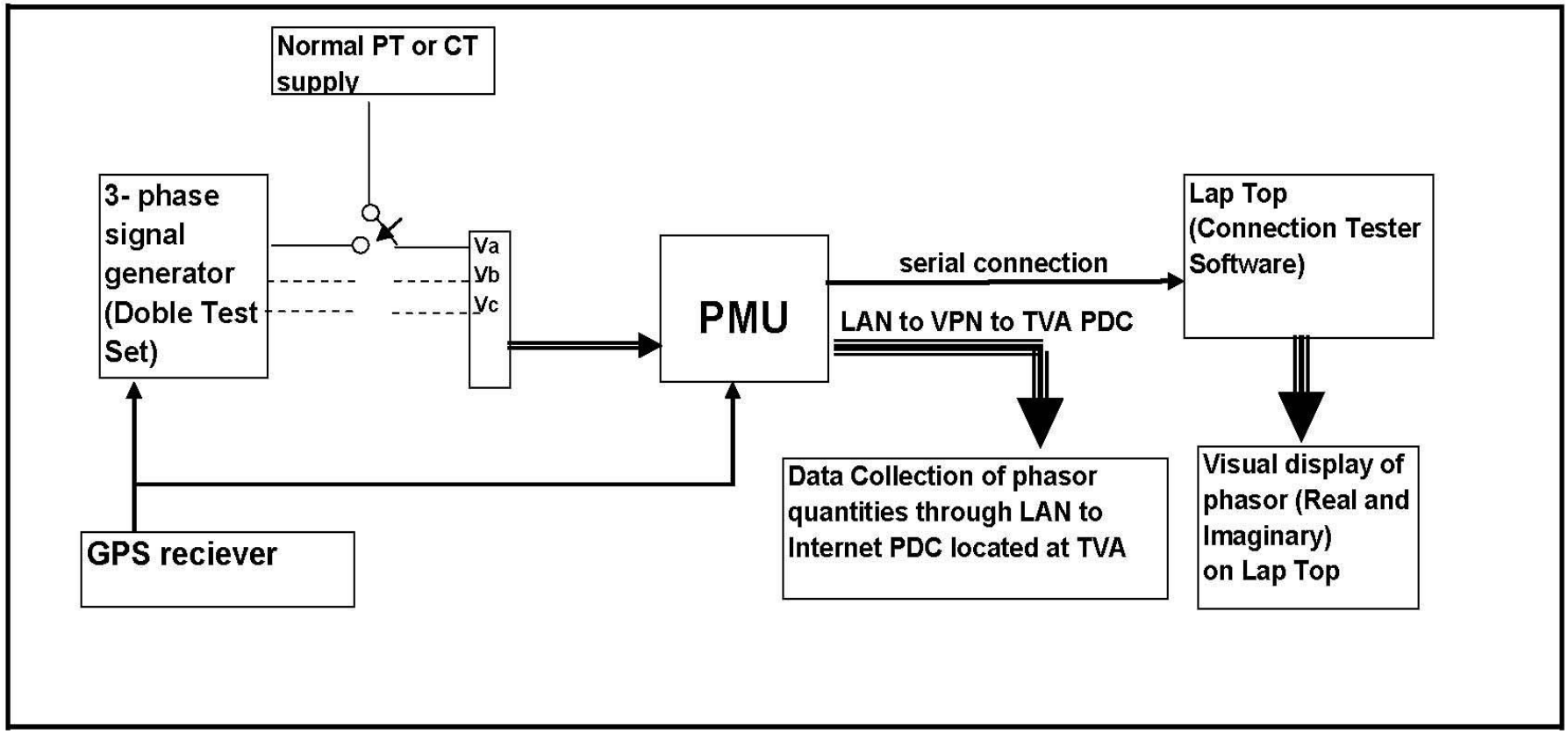
PMU Testing Set-Up



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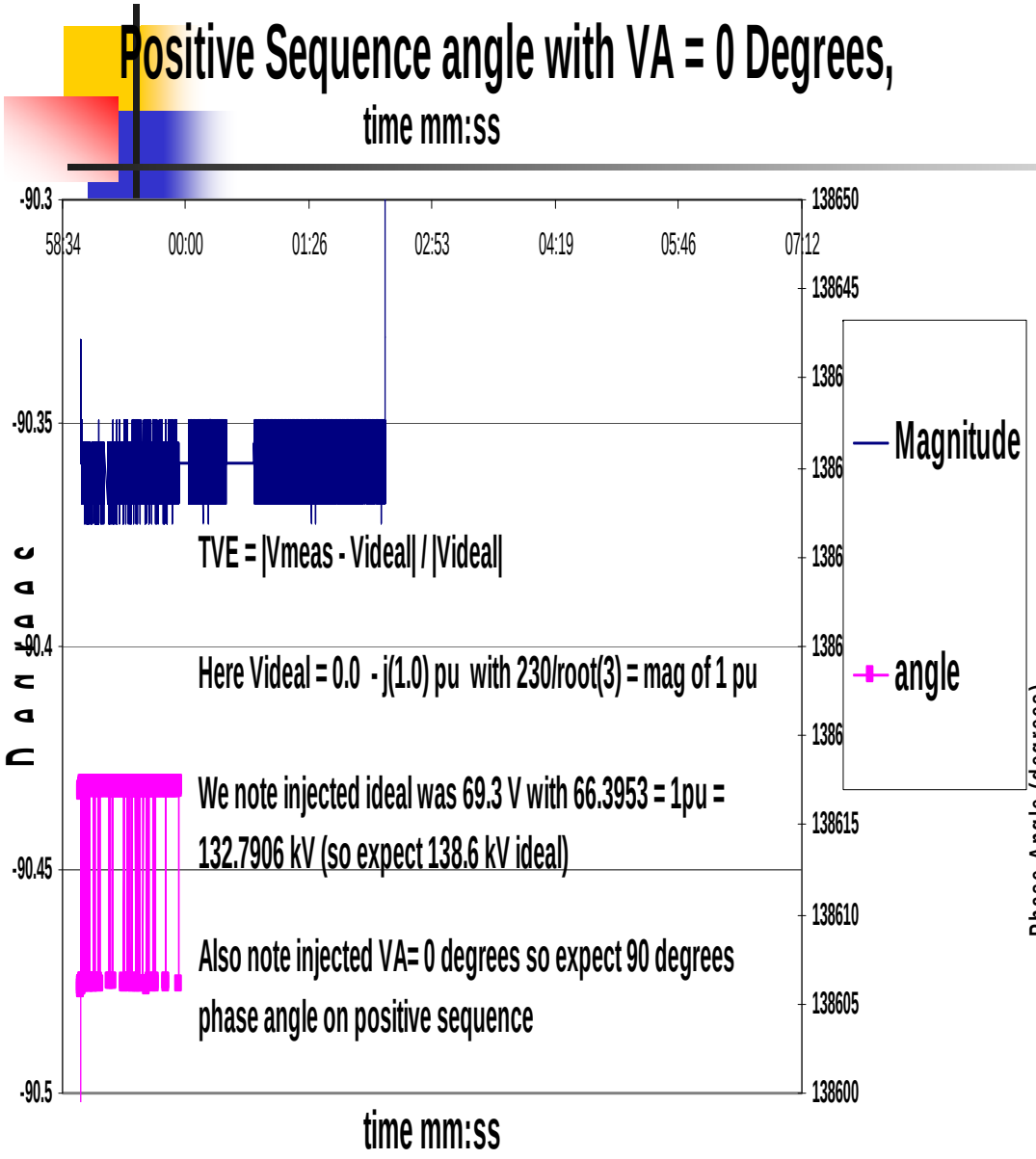
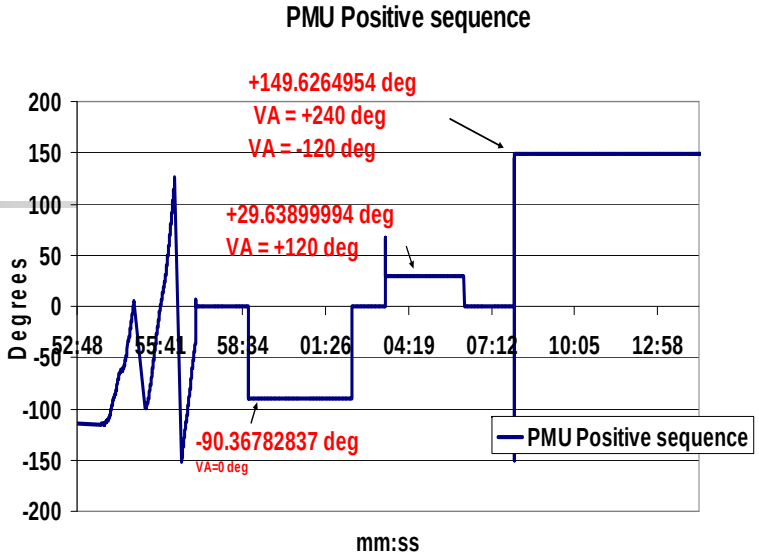
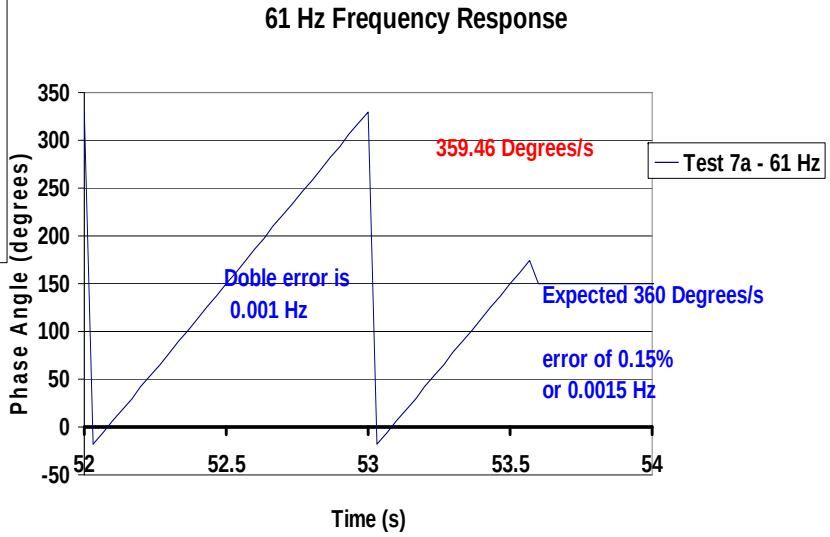
Steady-State Performance Test Results







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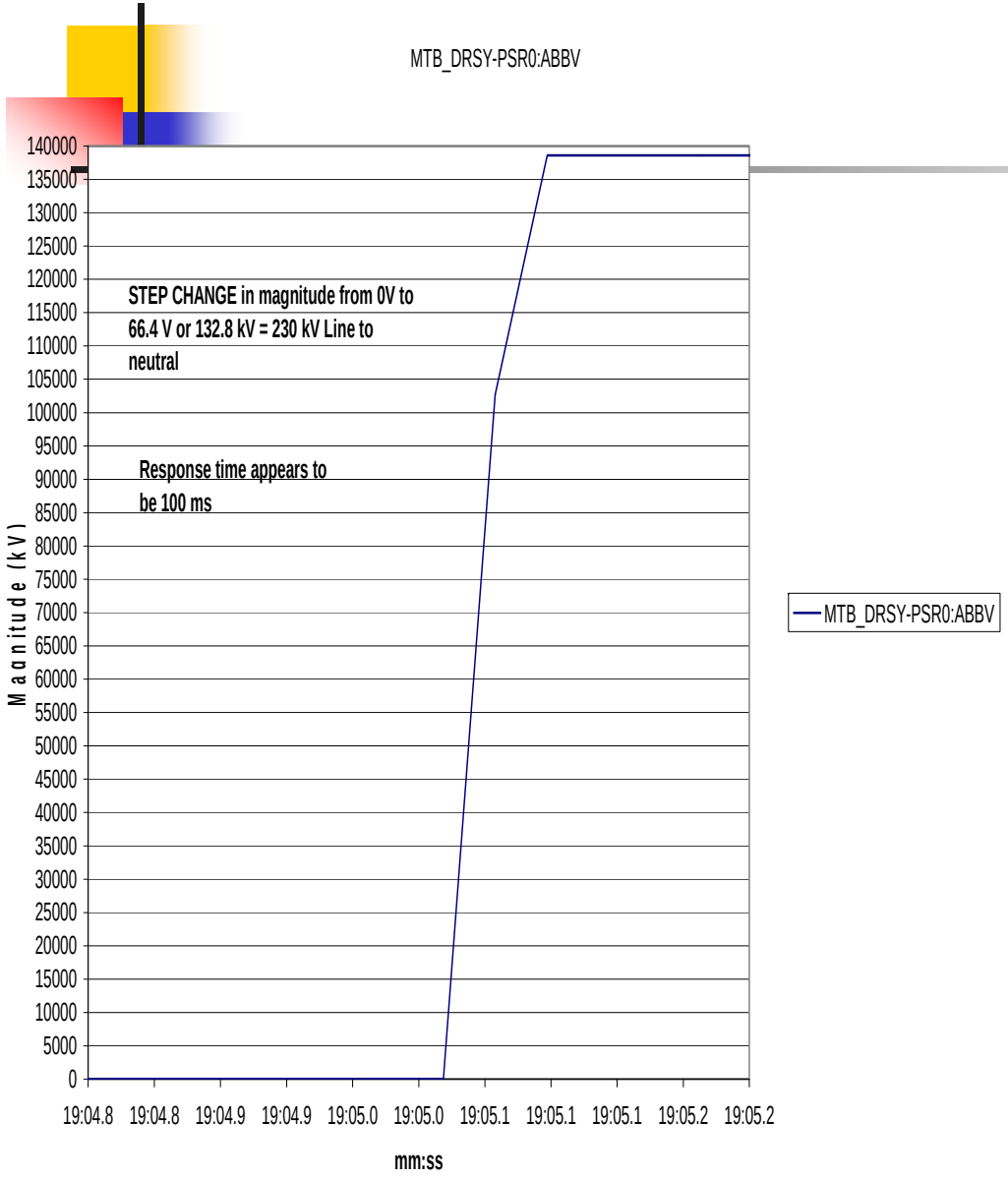
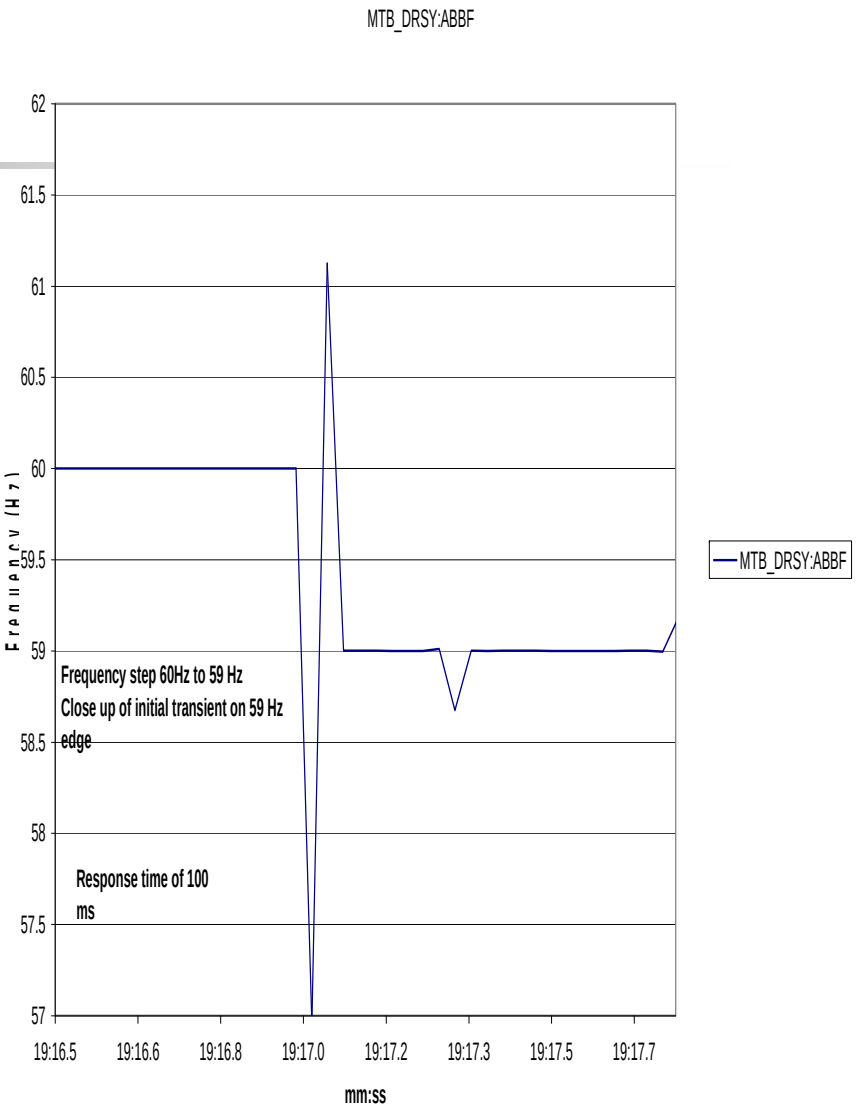
Dynamic Test Results





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Issues of Operation

- Operational Experience

  - 4 GB for one Day with only 9 phasors (6 current and 3 voltage)

  - filter programs needed.

  - RTDMS (Real Time Dynamic Monitoring System). Enhanced version now has modal analysis. Infrastructure not there yet too rely on the data shown.

  - choosing reference bus and resolving differences between PMUs is an issue

  - lack of reliability of data at certain times can be a problem in early stages of the infrastructure.

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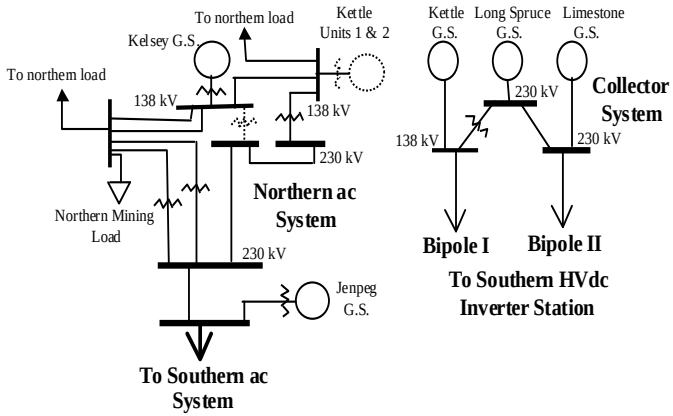
Local Area Network

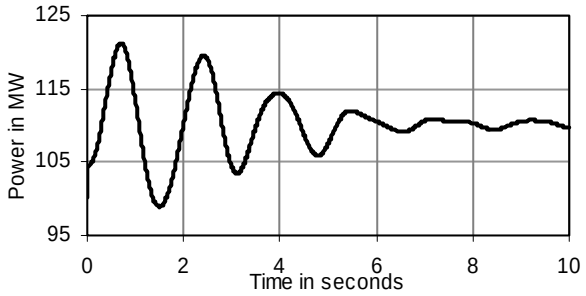
- Local northern modes (0.6-0.8 Hz) affect our operation and modal analysis is a benefit both for commissioning and increasing power transfers
- PMU technology has been chosen as a way to visualize these real time modes. Secondary benefits of our PMU technology within this network will be to improve models, improve damping, and to improve our existing state estimator.
- The network will begin with only 5 PMUs planned throughout Manitoba possibly using Tesla recorders and later expand to 20-25 PMUs using more recorders. Final stage would include relay technology and at that stage State estimator improvement would be expected.
- Technical specification has not been completed. Communication infrastructure is expected to use same network as other recorders on the system. Software applications which provide modal analysis are being reviewed
- Tesla recorder application has been tested with good results. Communication traffic increase was negligible at the site chosen. Offers an inexpensive way to incorporate PMUs without design needed only replacement of existing recorders with upgrade. Comfort level for using relays is not yet there.

Local Area Network Cont'd

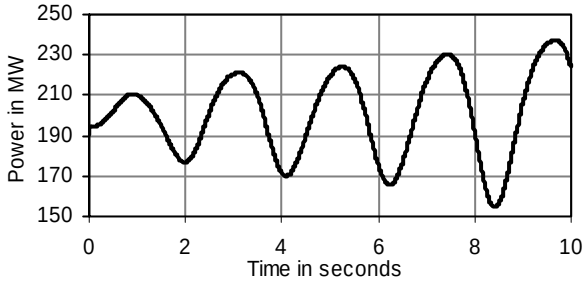
- Single line of Northern AC and Collector Systems
- - Northern AC and Collector systems operate asynchronously
- - Frequency in Northern AC system fairly constant (tied to Eastern Interconnect)
- - Inter-Area modes (0.6-0.8 Hz) a concern
- - Frequency in Collector system experience significant variations (no customer loads connected)
- - Inter-Plant and local modes (1.1-1.7 Hz) a concern



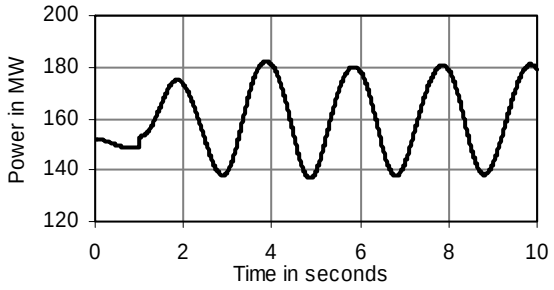
Simulated seasonal inter-area oscillation with PSSs out-of-service



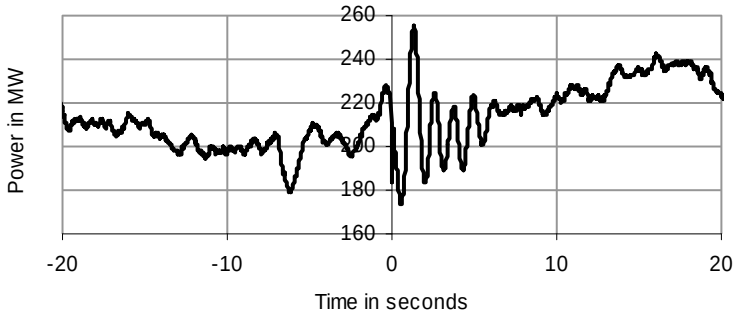
Winter Peak



Spring/Summer



Winter off-peak



DSR Data

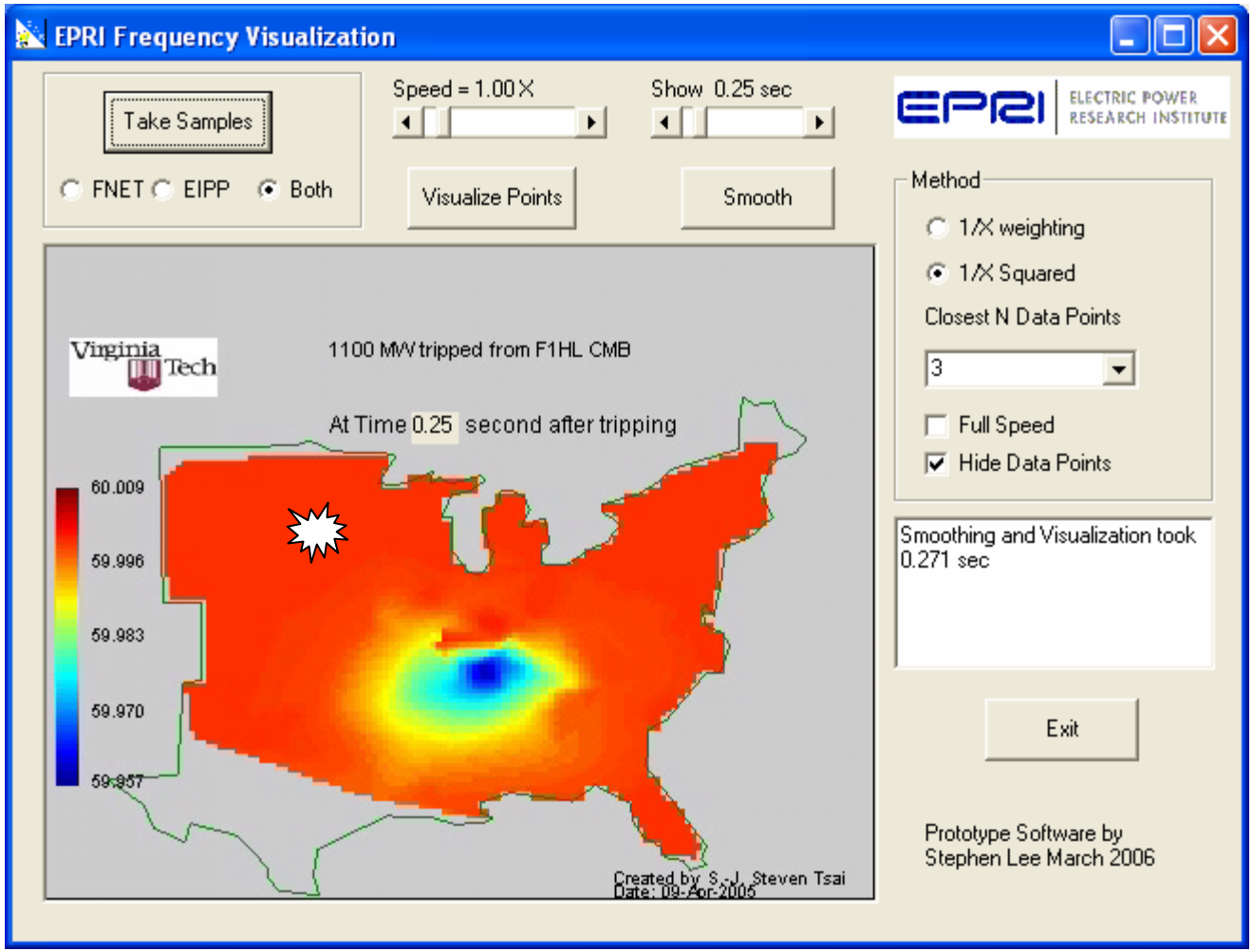
Tesla Application

- MB Hydro recently had experience testing a NXTphase recorder that was converted to a PMU. They plan on using these recorders to develop a local area network of PMUs within the MB Hydro system.
- The conversion process was simple and only required an update to the firmware used by the 3000 series. MB Hydro has 5 such existing 3000 series PMUs that could be converted on their system. In the future, it is expected that the 2000 series could also be converted in a similar manner and MB Hydro has approximately 20-30 of these 2000 series types that could be converted at that time.
- The PMU was installed on a temporary test basis at Laverendreye station and bench tests in the lab showed very good results (total vector error of 0.3% and the standard requires 1%).
- The bandwidth increase was negligible to the LAN connection where the PMU device was connected.
- The phasor data concentrator used in this temporary application was the TVA connection tester but it is expected that a commercial PDC would need to be purchased later.
- The future local area network of PMUs is expected to aid MB Hydro in the application of modal analysis for commissioning of northern generating stations where known modes are present and early detection for operators as well as maximizing power transfers is beneficial. MB Hydro is presently searching for different vendors that can supply this type of on-line modal analysis software to work with the PMU network.

Thompson Application

- Another NASPI PMU is expected to be installed at Thompson (Northern MB)
- Separate communications from our local area network to avoid cyber security issues.
- General applications for this would combine with the Dorsey PMU (on the edge of NASPI – gives wide area view). Voltage stability, transient stability, angle monitoring, modeling improvement, inter-area oscillation monitoring are all expected. We have known .25 Hz inter-area mode and we have known voltage stability issues in the midwest US which is dependent on our exports, DC loading, and voltage operation at Dorsey.

FNET


EPRI Frequency Visualization
Take Samples
FNET EIPP Both
Speed = 1.00 X
Show 0.25 sec
Visualize Points
Smooth
EPRI ELECTRIC POWER RESEARCH INSTITUTE
Method
1/X weighting
1/X Squared
Closest N Data Points
3
Full Speed
Hide Data Points
Virginia Tech
1100 MW tripped from F1HL CMB
At Time 0.25 second after tripping
60.009
59.996
59.983
59.970
59.957
Smoothing and Visualization took 0.271 sec
Exit
Prototype Software by Stephen Lee March 2006
Created by S.-J. Steven Tsai
Date: 09-Apr-2005

Control Room Training

- We have had seminars to explain phase angles and PMU applications to operators and engineers and also our plans at a division level.
- We do not expect to be in the control room in the next 2 years but we would like feedback beforehand. We do not want anything in the control room that will be viewed as a nuisance alarm.

Cost Benefit Analysis

- Business Case
  - Improvement to SCADA (state estimator) – on-going research
  - Reliability improvement
  - Increased transfers (angles, and modes)
  - Wide area PSS
  - Voltage stability
  - Transient stability
  - Commissioning of exciters and resolving interplant modes on a local area network of PMUs
  - Model verification – SCADA (state estimator) can be used to compare initial PMU accuracy and later PMUs can be used to verify existing models

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Vision

- Final Road Map

  - MB Hydro plans a local area network utilizing recorders and relays as well as stand-alone PMUs bought for new stations.

    Advantage of this local area network is that we are not limited by cyber security issues if we strictly use our local communication network.

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Conclusions

- Establish a project leader
- Assess the risks
- Find a suitable location (both geographically and within the station)
- Perform Tests to confirm proper operation both before and after installation
- Lastly, develop a business case and plan for future integration

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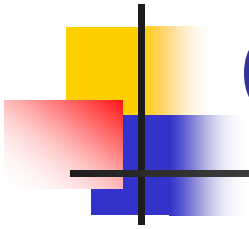

Questions?