
Lizard Lake Wind Farm Interconnection Evaluation Study

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Executive Summary

An Interconnection Evaluation Study (IES) has been performed to determine the Manitoba Hydro Interconnection Facilities necessary to connect a 50 MW or 100 MW wind farm near St. Leon, Manitoba. As stated in the Manitoba Hydro Open Access Interconnection Tariff (OAIT), there are two types of Interconnection Services available: Energy Resource Interconnection Service (ERIS) - “ERIS allows the Generator to connect the Facility to the System and be eligible to deliver the Facility’s output using the existing firm or non-firm capacity of the Transmission System on an “as available” basis”; and Network Resource Interconnection Service (NRIS) - “NRIS allows the Generator’s Facility to be designated as a Network Resource, up to the Facility’s full output, on the same basis as existing Network Resources interconnected to Manitoba Hydro’s System. NRIS in and of itself does not convey any right to deliver electricity to any specific customer or Point of Delivery.” The Generator has requested that the 100 MW wind farm be considered a Manitoba Hydro Network Resource. As a Network Resource, the impacts of scheduling to generation within Manitoba were evaluated. MH’s generation is located entirely within the Province of Manitoba, therefore the wind generation will not require the need to increase transfer levels on the Manitoba to Ontario, Saskatchewan or U.S. boundaries. This IES determined the impact of the wind generation on the existing MH transmission system by means of steady-state ac power flow analysis and stability analysis.

One option was studied for connecting the wind farm, which involved a direct connection to the St. Leon 230 kV station bus via a 32 km 230 kV transmission line. Analysis was performed at wind generation levels of 50 MW and 100 MW, for two different types of turbines: Turbine A – a directly grid-coupled induction generation, Turbine B – a doubly-fed induction generator.

AC contingency analysis was performed for N-1 and N-2 contingencies during system intact conditions. All analysis assumed the base cases included St. Leon and Pembina Hills wind farms. One thermal overload was identified that will require further investigation. A CT at Brandon on 110 kV Brandon-Neepawa line (BN5) would require replacement.

Similar to the St. Leon Interconnection Facilities Study (IFS) [3], if the St. Leon 230 kV ring bus is open in certain positions, there would be a possibility to isolate the wind generation onto the 66 kV load. Protection logic was installed with the St. Leon Wind Energy LP 99 MW wind farm at St. Leon to trip the wind generation if the St. Leon ring bus becomes open in breaker positions 2&3, 2&5 and 6&3. The existing logic would need to be modified to include breaker positions 5&3 as well.

The Manitoba Hydro Transmission System Interconnection Requirements (TSIR) [1] state that the Generator must provide reactive supply that is able to control the voltage level at the St. Leon 230 kV bus by adjusting the machine’s power factor between a minimum of 0.95 overexcited and 0.95 underexcited at the generator intermediate 25 kV bus with a minimum response time of 15 seconds. The Turbine A wind turbines would

need to install additional capacitive VAR support to meet the 0.95 leading power factor requirement. Some portion of this VAR support will need to be dynamic, such as an SVC or STATCOM, in order to meet the 0.7 pu transient undervoltage criteria for several local normal clearing three-phase faults, specifically on lines D14S and S60L. This would be evaluated further in an IFS study. The Turbine B wind turbines have a reactive supply range from 0.9 lagging to 0.95 leading and do not require any additional reactive supply equipment.

In order for the wind turbines to remain connected during transient undervoltages, a wind turbine with fault ride-through capability must be installed. Both the Turbine A turbine and Turbine B (with Turbine B Low Voltage Ride-through option II) turbine have adequate fault ride-through capability.

In order to remain connected during the worst-case transient overvoltages, the Turbine A 230-25 kV transformers may need to be equipped with an on-load tap changer. Whether or not the OLTC is needed depends on how much reactive power support will be dynamic and whether or not it is enough to keep the turbines from tripping on overvoltage. Additional details will follow in the IFS. The Turbine B turbines are able to ride through the worst-case transient overvoltages without any extra equipment.

During system intact conditions, there are two local breaker failure cases (St. Leon breakers R4 or R1), which can result in voltage collapse and/or undamped voltage oscillations because it leaves all of the wind generation at St. Leon radially feeding into line S60L or line D14S. A generator crosstrip scheme has been implemented with the first 99 MW St. Leon wind farm that will result in a trip of the St. Leon and Pembina Hills wind farms for breaker R4 failure. This crosstrip may need to include the Lizard Lake wind farm as well if Turbine A turbines are chosen, depending on the amount of dynamic reactive power support that would be installed with the wind farm. The breaker R1 failure does not require a crosstripping scheme until Lizard Lake is on-line. This scenario will require further investigation to determine if the dynamic reactive power support that would be installed with a Turbine A wind farm is sufficient to prevent voltage collapse or whether the Lizard Lake wind farm would require generator crosstripping. The Turbine B turbines just meet the undervoltage criteria and do not require crosstripping.

The overfrequency and underfrequency capabilities of the Turbine A and Turbine B wind turbines meet the Manitoba Hydro connection standards.

The results as summarized above generally hold true for both a 50 MW or 100 MW wind farm. The 50 MW wind farm has a slightly lesser impact, however the 0.7 pu voltage violations as described for the Turbine A wind farm still apply.

A planning cost estimate of the Manitoba Hydro Interconnection Facilities necessary to connect a 100 MW wind farm at Lizard Lake to the St. Leon 230 kV station bus was calculated. These total costs, not including Network Upgrades or any additional reactive power support requirements, were estimated to be \$13,000,000 ($\pm 50\%$).

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1.0 Introduction

1.1 Background Information

This report documents the results of an Interconnection Evaluation Study for a 50 MW or 100 MW wind farm near the town of St. Leon, Manitoba. The proposed in-service date is October 31, 2009.

The Generator has indicated that the wind turbines could be installed in Section 25, Township-Range 3-8W. For the purposes of this study, the Generator's distribution station is assumed to be 32 km away from the St. Leon station.

The plan for the distribution station is 25 kV. One 50/60/70 MVA 230-25 kV transformer will be installed for a 50 MW wind farm, two parallel 50/60/70 MVA 230-25 kV transformers will be installed for a 100 MW wind farm.

A 230 kV to 66 kV switching station is located at St. Leon. Three 230 kV lines terminate in this station. A 129 km line extends to Dorsey (D14S), a 52 km line terminates at Glenboro (S53G) and a 100 km line terminates at Letellier (S60L). The summer rating of each line is 372 MVA (D14S), 309 MVA (S60L) and 279 MVA (S53G). Three radial 66 kV lines are used to supply loads in the area. Line 51 is 106 km, line 52 is 82 km long and line 79 is 81 km. The summer rating of each line is approximately 64 MVA. Two 230-66 kV 93-MVA transformer banks supply the load. Fig. 1 is a single line diagram showing the existing facilities connected to the St. Leon station.

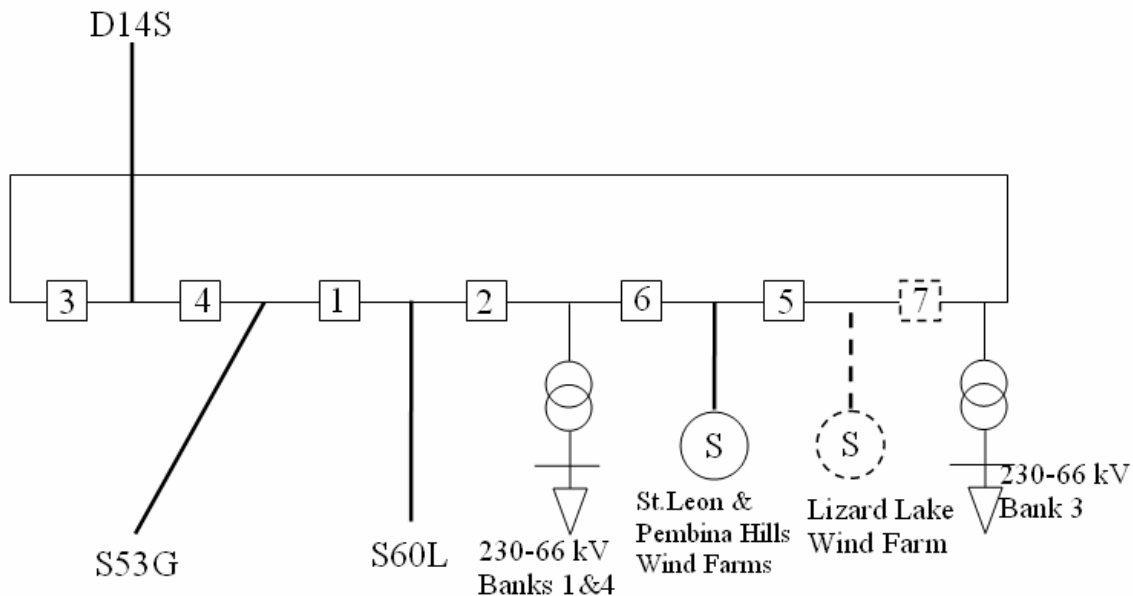


Fig. 1: Existing St. Leon station single line diagram.

The major interconnection facilities required to connect the wind farm into the 230 kV station bus include one 230 kV circuit breaker within the St. Leon station (and associated equipment) plus a 32 km line. The line is assumed to have a 954 MCM ACSR conductor,

100 deg C thermal rating (393 MVA summer, 515 MVA winter rating). A minimum of one motor-operating disconnect is required at the point of interconnection (i.e. high side of Generator's step-up transformer). MH requires visual isolation as well as the ability to automatically isolate the Generation Facility. The Generator must provide a circuit breaker near the point of interconnection. It is not MH's practice to provide primary protection for Generator's equipment due to liability concerns.

1.2 Objectives

The Interconnection Evaluation Study objectives are to determine:

- the voltage level at point of interconnection,
- facilities required to electrically connect the generator to the MH electrical system,
- adequacy of reactive power facilities,
- system reliability limitations (i.e. equipment overloads, voltage violations)
- planning level cost estimates of transmission facilities

If the Generator chooses to proceed, the Interconnection Facilities Study phase will:

- address the system reliability limitations
- short circuit impacts (e.g. circuit breaker replacement)
- perform steady state analysis with critical prior outages (prior outages referring to a certain line being out-of-service pre-contingency, therefore the steady state operating point is already in an n-1 condition, and applying further single contingencies during the steady state analysis would put the system in an n-2 condition)
- perform transient stability analysis with critical prior outages
- determine a good faith cost estimate of all the interconnection facilities
- determine a good faith construction schedule estimate
- determine special protection requirements (e.g. breaker fail, generator cross trip)
- determine communication requirements
- satisfy any requirements of the Regional Reliability Organization

2.0 Steady State AC Power Flow Analysis (ACCC)

The Generator has requested that the 100 MW wind farm be considered a Manitoba Hydro network resource. As a network resource, the impacts of scheduling to generation within Manitoba were evaluated.

2.1 Introduction

Steady state post-disturbance analysis in the IES study phase is used to apply all Manitoba Hydro single and select double contingencies (please refer to section 2.1.2) to several system intact power flow cases (please refer to section 2.1.1). The analysis monitors bus voltages and branch loading during the n-1 and n-2 contingencies to determine if any voltage or loading criteria is violated (please refer to section 2.1.3). If criteria is violated, the IES flags this reliability limitation (please refer to section 2.2) for further evaluation during the IFS phase.

2.1.1 Study Power Flow Models

Steady state post-disturbance analysis was performed using the following 2004 series MAPP base case loadflows:

- A. 2009 summer peak – Existing firm generation plus queued generation at Pine Falls (5 MW), Great Falls (4 MW), Kelsey (33 MW), St. Leon (99 MW) and Pembina Hills (99 MW).
- B. 2014 summer peak – Existing firm generation plus queued generation noted above plus Wuskwatim (200 MW) and associated transmission (Birchtree-Wuskwatim, Wuskwatim-Herblet Lake, Herblet Lake-Ralls Is., Dauphin-Neepawa).

Sensitivity analysis to Manitoba Hydro Export (MHEX) and North Dakota Export (NDEX) was performed. Four combinations of MHEX and NDEX were studied for both of the above 2009 and 2014 base cases:

- a. MHEX = 2175, NDEX = 1950
- b. MHEX = 2175, NDEX = 300
- c. MHEX = -700, NDEX = 1950
- d. MHEX = -700, NDEX = 300

The generation level in the MHEX 2175 MW summer peak cases were adjusted to the maximum accredited level less 55 MW to meet Manitoba's regulating reserve requirements. MH is delivering firm and non-firm power sales on the tie lines as well as the MAPP reserve obligation. According to the position of Lizard Lake in the MH generator interconnection queue, the following future generation was included in the analysis;

- Pine Falls – 6 MW
- Kelsey – 33 MW
- St. Leon Wind – 99 MW

- Pembina Hills Wind – 99 MW

Table 1 summarizes the output from each generator in the Manitoba transmission region in a maximum generation case at maximum Manitoba-US export of 2175 MW, and also at the maximum firm Manitoba-US import of 700 MW. The associated transmission upgrades for the queued generation are included in the analysis. Lena (99 MW), Elie (99 MW), Waskada (50 MW), Alexander (50 MW) and Letellier (100 MW) generation sites are ahead of Lizard Lake in the Manitoba Hydro generation queue. The Generator requested these sites not be included in the analysis.

Table 1: Maximum Accredited Capability of MH Generation

Generation Plant	Accredited Value (MW)	PSS/E summer peak (MW) – 2175 export
Limestone	1348.7	1296
Long Spruce	1030.6	994
Kettle	1233.1	1155
Jenpeg	168	139.8
Kelsey	237.6	237.6 + 33
Grand Rapids	480.0	480.0
Pine Falls	89.6	89.6 + 6
McArthur Falls	56.5	56.5
Great Falls	131.6	131.6
Seven Sisters	165.4	165.4
Slave Falls	68.0	68.0
Pointe du Bois	78.8	78.8
Brandon	386.5	386.5
Selkirk	145	128.0
St. Leon Wind	To be determined	99
Pembina Hills	To be determined	99
Total	5644.4	5643.8

2.1.2 Contingencies

The following contingencies were studied using PSS/E activity ACCC (AC contingency analysis):

System Intact:

- N-1 contingencies for all transmission lines and transformers 110 kV and above within Manitoba including tie lines.
- N-2 contingencies for all 110 kV and above double-circuit outages in Manitoba and breaker fail outages approximately two buses back from the St. Leon 230 kV station (i.e. at St. Leon, Glenboro and Letellier)

System intact analysis was assessed with Lizard Lake wind generation scheduled to each of the following sinks, such that the addition of the wind generation did not impact transfer levels:

1. Grand Rapids generation (AGC plant)
2. Dorsey DC generation (AGC plant)

Facilities identified in the post-disturbance analysis were flagged if loading exceeded 100% and the system intact power flow or contingency power flow resulted in a power transfer distribution factor (PTDF) or an outage transfer distribution factor (OTDF) greater than 2%, respectively. Branch loadings were monitored using Rate A for normal conditions and Rate C following a contingency. Bus voltages lower than 0.90 pu were flagged. Mitigation is required for overloads in which the wind generation has a PTDF greater than or equal to 5% or an OTDF greater than or equal to 3% [8]-[12].

2.1.3 Planning Criteria – Transmission Line Overloads

Manitoba Hydro thermal loading criteria does not allow short-term overload for single contingency (category B) events. A short-term overload of up to 115% may be allowed for multiple contingency events (Category C such as double circuit common tower outages) on a case-by-case basis. If a short-term overload rating is applied, it is necessary to be able to reduce the loading to within the steady state thermal rating within 30 minutes of the overload occurrence.

If the overloaded segment of a transmission line is station equipment rather than the line conductor, the overload capability for that piece of equipment will be individually assessed. Transformers are considered to have a 30-minute 119% Rate A summer overload rating.

2.2 Reliability Limitations

Several thermal overloads were identified through AC contingency analysis that required detailed investigation. N-1 and N-2 contingencies were studied for system intact conditions.

The following sections provide details on the worst-case overloads for which the wind generator OTDF is 3% or greater or PTDF is 5% or greater. These overloads require mitigation. For information purposes, please refer to Appendix F for a list of all thermal overloads with OTDFs greater than or equal to 2%.

Voltage violation impacts of 1% or greater are also listed.

2.2.1 System Intact: N-1 Contingencies

2.2.1.1 Brandon to Neepawa 110 kV line BN5

Contingency	Loading (%Rate C)		OTDF (%)	Wind (MW)	Year	MHEX	NDEX	Sink
	No Wind	With Wind						
MR11	none	100.7	new	50	2009 sp	-700	1913	Grd Rpds
MR11	none	none	n/a	50	2014 sp	-700	1913	Grd Rpds
MR11	none	102.3	new	100	2009 sp	-700	1913	Grd Rpds
MR11	none	none	n/a	100	2014 sp	-700	1913	Grd Rpds

The thermal rating of line BN5 is 38.1 MVA in summer and 45.7 MVA in winter. A CT at the Brandon end of the line is the limiting element.

2.2.1.2 Cornwallis 230-110 kV transformer Bank 1

Contingency	Loading (%Rate C)		OTDF (%)	Wind (MW)	Year	MHEX	NDEX	Sink
	No Wind	With Wind						
Cornw. Bk2	109.0	110.1	3.9	50	2009 sp	-700	1913	Grd Rpds
Cornw. Bk2	106.1	106.8	2.5	50	2014 sp	-700	1913	Grd Rpds
Cornw. Bk2	109.0	110.9	3.4	100	2009 sp	-700	1913	Grd Rpds
Cornw. Bk2	106.1	107.5	2.5	100	2014 sp	-700	1913	Grd Rpds

The thermal rating of Cornwallis transformer bank 1 is 176 MVA. Short-term transformer overload ratings (up to 119%) can be applied, with an operating guideline in place to curtail the wind generation to mitigate the overload within 30 minutes.

2.2.1.3 Cornwallis 230-110 kV transformer Bank 2

Contingency	Loading (%Rate C)		OTDF (%)	Wind (MW)	Year	MHEX	NDEX	Sink
	No Wind	With Wind						
Cornw. Bk1	108.3	109.4	3.9	50	2009 sp	-700	1913	Grd Rpds
Cornw. Bk1	105.5	106.2	2.1	50	2014 sp	-700	1913	Grd Rpds
Cornw. Bk1	108.3	110.3	3.6	100	2009 sp	-700	1913	Grd Rpds
Cornw. Bk1	105.5	106.7	2.5	100	2014 sp	-700	1913	Grd Rpds

The thermal rating of Cornwallis transformer bank 2 is 176 MVA. Short-term transformer overload ratings (up to 119%) can be applied, with an operating guideline in place to curtail the wind generation to mitigate the overload within 30 minutes.

2.2.2 System Intact: N-2 Contingencies

2.2.2.1 Brandon to Victoria 110 kV line BE3

Contingency	Loading (%Rate C)		OTDF (%)	Wind (MW)	Year	MHEX	NDEX	Sink
	No Wind	With Wind						
BE1+BE2	103.8	106.2	3.9	50	2009 sp	-700	1913	Grd Rpds
BE1+BE2	None	100.7	new	50	2014 sp	-700	1913	Grd Rpds
BE1+BE2	103.8	108.7	4.0	100	2009 sp	-700	1913	Grd Rpds
BE1+BE2	None	102.2	New	100	2014 sp	-700	1913	Grd Rpds

The thermal rating of line BE3 is 81.2 MVA in summer and 124.8 MVA in winter. The rating is limited by the line conductor. The conductor type is 336.4 MCM ACSR 26/7 and it is sagged to 75 deg C. Line BE3 will need to be re-sagged to 100 deg C, which will increase the line conductor thermal rating by 35.6% to 110.1 MVA in summer and by 13.7% to 141.9 MVA in winter. In addition, a CT at Victoria with a summer rating of 600 A (114.3 MVA) and a winter rating of 744 A (141.8 MVA) will require replacement due to high winter loading. The required CT ratings for summer and winter are 477 A and 795 A respectively.

Without the wind generation, the BE3 overload would be acceptable after the line re-sagging and CT replacement. However, with wind generation the winter overloads will still be 105.3% on the line conductor. Pre- and post-contingency loading on line BE3 was analyzed in more detail and it was determined that the temperature rise on the line would cause sag violations after the wind farm is in-service. Therefore, line BE3 will require re-conductoring.

There is currently a ground survey planned for summer 2006 to assess the thermal rating of line BE3. Appropriate mitigation action will be taken once the assessment is complete. For now, the BE3 overloads are being accepted.

2.2.3 Steady State Voltage Violations

There were no steady state voltage violation impacts greater than 1% during system intact conditions.

3.0 Wind Turbine Models

Two types of wind turbine models were tested during transient stability analysis:

- 1) Turbine A 1.65 MW, 60 Hz, additional reactive power support in the form of
 - a. 2x10 MVAR, 25 kV switched capacitors for a 50 MW wind farm
 - b. 4x10 MVAR, 25 kV switched capacitors for a 100 MW wind farm
- 2) Turbine B, 1.5 MW, 60 HZ, doubly-fed induction generator

3.1 Turbine A

The Turbine A wind turbines are the fixed-speed type consisting of a directly grid-coupled single cage induction generator. They come equipped with 24 MVAR or 49 MVAR of power factor correction capacitors located at the 600 V generator bus and the generator absorbs 21.6 MVAR or 42.1 MVAR at rated output for a 50 MW or 100 MW wind farm, respectively.

In PSS/E, the wind farm is represented as one aggregate generator, operating at 600 V. The aggregate generator is stepped up to 25 kV via a 54 MVA or 108 MVA transformer of 6.0% impedance for a 50 MW or 100 MW wind farm, respectively. The extra VAR support in the form of switched capacitors are modeled at the 25 kV bus. The 25 kV collector system is stepped up to the 230 kV connection voltage via one single or two parallel 50/60/70 MVA transformers of 7.0% impedance for a 50 MW or 100 MW wind farm, respectively. A 32 km 230 kV transmission line connects the Lizard Lake wind farm to the existing St. Leon wind farm 230 kV bus.

An IPLAN is used to add the wind farm to the PSS/E large system model. Detailed PSS/E user models representing Turbine A are used to perform the stability analysis.

3.2 Turbine B

The Turbine B wind turbines are the variable-speed type consisting of a doubly-fed wound rotor induction generator. They are capable of fast voltage control over a power factor operation range of 0.95 overexcited to 0.9 underexcited.

In PSS/E, the wind farm is represented as one aggregate generator, operating at 575 V. The aggregate generator is stepped up to 25 kV via a 57.8 MVA or 115.5 MVA transformer of 5.0% impedance for a 50 MW or 100 MW wind farm, respectively. The 25 kV collector system is stepped up to the 230 kV connection voltage via one single or two parallel 50/60/70 MVA transformers of 7.0% impedance for a 50 MW or 100 MW wind farm, respectively. A 32 km 230 kV transmission line connects the Lizard Lake wind farm to the existing St. Leon wind farm 230 kV bus.

An IPLAN is used to add the wind farm to the PSS/E large system model. Detailed PSS/E user models representing Turbine B are used to perform the stability analysis.

4.0 Frequency, Voltage and Reactive Power Requirements

This section describes the turbine capabilities in comparison with the MH interconnection requirements. The next Section 6 will demonstrate these capabilities through transient stability simulations.

4.1 Turbine Overfrequency / Underfrequency Ride-Through Capability

A typical generator connected to the MH network should stay connected if the frequency remains within the limits given in Table 5.

Table 5. MH Frequency Ride-Through Requirements.

Time	Underfrequency	Overfrequency
Continuous	60.0-59.0 Hz	60.0-61.5 Hz
10 minutes	59.0-58.7 Hz	61.5-62.0 Hz
30 seconds	58.7-57.5 Hz	62.0-63.5 Hz

4.1.1 Turbine A

The wind turbine has the capability to operate between 57 Hz and 62 Hz continuously.

The wind turbine has adequate underfrequency ride-through capability. The MH Transmission System Interconnection Requirements document [1] states that the Generation Facility is to remain connected if the frequency is in the range of 62.0-63.5 Hz for 30 seconds. MH has agreed that the overfrequency capability of 62 Hz continuous will be adequate for connecting to the MH transmission grid.

4.1.2 Turbine B

The Turbine B frequency ride-through capability is summarized in Table 6.

Table 6. Turbine B Frequency Ride-Through Capability

Time	Underfrequency	Overfrequency
Continuous	60.0-57.5 Hz	60.0-61.5 Hz
30 seconds		61.5-62.5 Hz
10 seconds	56.5-57.5 Hz	

The wind turbine has adequate underfrequency ride-through capability. The MH Transmission System Interconnection Requirements document [1] states that the Generation Facility is to remain connected if the frequency is in the range of 62.0-63.5 Hz for 30 seconds. MH has agreed that the overfrequency capability of up to 62.5 Hz for 30 seconds will be adequate for connecting to the MH transmission grid.

4.2 Turbine Overvoltage / Undervoltage Ride-Through Capability

Table 7 summarizes the overvoltage and undervoltage requirements at the St. Leon 230 kV bus during local and remote disturbances. The worst undervoltage cases occur during 230 kV faults near the St. Leon station. The worst system overvoltage cases typically occur when large amounts of power from the HVdc system are lost (e.g. trip of Manitoba-USA 500 kV line followed by an HVdc reduction, or a permanent or temporary block of a bipole).

Table 7. MH Over- and Undervoltage Requirements at the POI.

Overvoltage (pu)		Undervoltage (pu)	
Continuous	1.10	Continuous	0.90
2 sec	1.10-1.21	2 sec	0.70-0.90
200 ms	1.21	0.5 sec	0.70
		267 ms	0.0-0.50
		100 ms	0.0

Figure 1 below graphically represents the MH voltage criteria.

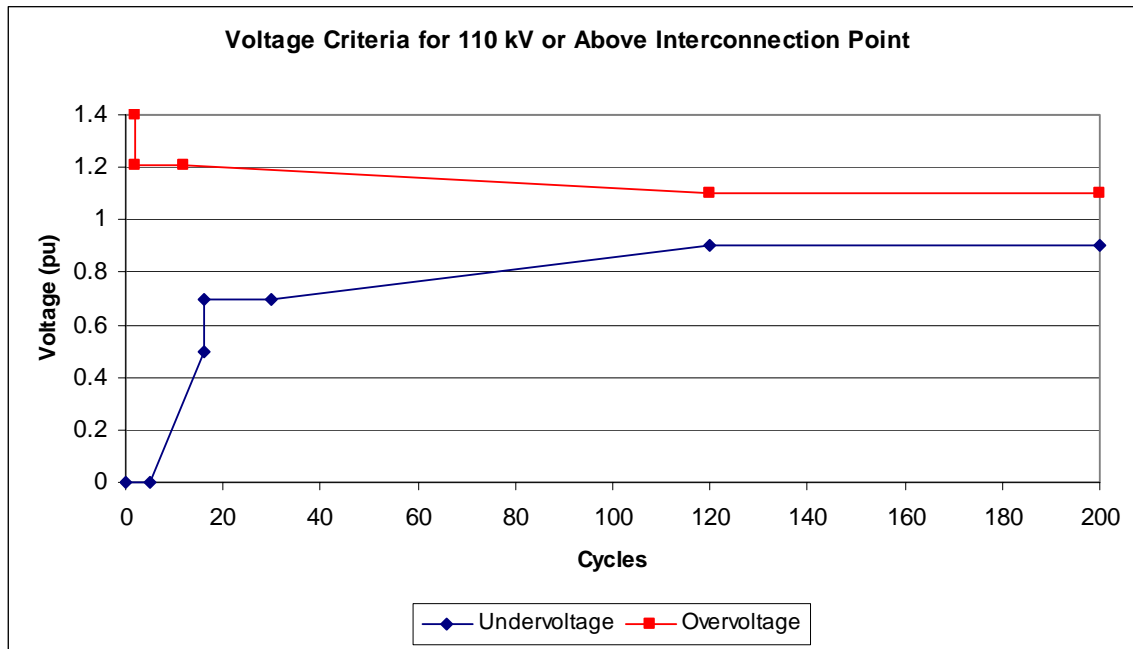


Fig. 1. Voltage Requirements for Interconnection to St. Leon 230 kV bus.

4.2.1 Turbine A

The Turbine A wind turbine can operate continuously between 90% and 110% voltage [2]. It has the capability to operate up to 115% voltage for 5 seconds. The wind turbine will trip off within 100 ms if the voltage at the wind turbine 600 V bus exceeds 115% [2]. The wind turbine will remain connected as long as the voltage does not drop below 70%

for more than 2.5 seconds or 15% for more than 0.7 seconds. Within 5 seconds the voltage should recover to a minimum of 90%.

The overvoltage ride-through capability of the wind turbine does not meet Manitoba Hydro's overvoltage criteria. A voltage control scheme would be required to ensure the voltage on the wind turbine's 600 V bus does not exceed 1.14 pu allowing a 0.01 pu voltage trip margin. This voltage control scheme will be described in section 7.0 of the report.

The undervoltage ride-through capability of the turbine meets Manitoba Hydro's undervoltage criteria.

4.2.2 Turbine B

The Turbine B wind turbine can operate continuously between 90% and 110% voltage. It has the capability to operate up to 115% for 1.0 second, and between 115% and 130% for 100 ms. With the Turbine B Low Voltage Ride Through (LVRT) option II, for line-to-ground or three-phase-to-ground faults, the wind turbine will remain connected as long as the voltage does not drop below 70% for more than 1.0 second or 15% for more than 0.625 seconds. Within 3 seconds the voltage should recover to a minimum of 90%. For line-to-line faults, the wind turbine will remain connected as long as the voltage does not drop below 70% for more than 1.0 second or 15% for more than 0.2 seconds. Within 0.2 seconds the voltage should recover to a minimum of 70%, and within 3 seconds to a minimum of 90%.

The overvoltage ride-through capability of the wind turbine does not appear to meet Manitoba Hydro's overvoltage criteria. However, due to the fast voltage control capability of the doubly-fed induction generator, the Turbine B wind turbine controls actually aid in reducing the worst-case overvoltage at St. Leon 230 kV bus and at the Turbine B 600 V generator bus, thus the Turbine B wind turbine is able to ride through the worst-case overvoltage. This voltage control capability will be demonstrated in section 6.0 of the report.

For line-to-ground and three-phase-to-ground faults, the undervoltage ride-through capability of the turbine (LVRT option II) meets Manitoba Hydro's undervoltage criteria. For line-to-line faults, the undervoltage ride-through capability is acceptable when considering normal clearing times, however the turbine will trip out for slow-clearing stuck breaker (NERC Category C) faults. MH has agreed to accept the reduced line-to-line fault ride-through capability for this particular case because the wind farm would only trip due to a low-probability NERC Category C fault. Transient stability simulations indicated no adverse system impacts due to a wind farm trip in this scenario.

4.3 Reactive Power Requirements

The Manitoba Hydro Transmission System Interconnection Requirements document [1] states that any Generation Facility greater than 10 MW comprised of induction type generators (such as may be connected to wind turbines) provide reactive supply that is able to control the voltage level by adjusting the machine's power factor between a minimum of 0.95 overexcited and 0.95 underexcited as measured at the Generator intermediate bus. The power factor requirements could be larger depending on transient stability analysis.

4.3.1 Turbine A

The Turbine A wind turbines come equipped with 24 MVAR or 49 MVAR of power factor correction capacitors located at the 600 V generator bus and the generator absorbs 21.6 MVAR or 42.1 MVAR at rated output for a 50 MW or 100 MW wind farm, respectively. Additional VAR support will need to be installed to provide the leading power factor requirement.

4.3.2 Turbine B

The Turbine B wind turbines consist of doubly-fed induction generators, which have inherent fast reactive power control capability ranging from 0.95 overexcited to 0.9 underexcited. The Turbine B turbines meet the Manitoba Hydro reactive power requirements.

5.0 Stability Investigation

Relevant stability plots are included in Appendix E.

5.1 Study Stability Models

The two base case system models used in the transient stability analysis were based on updated 2004 series MAPP stability models, and included:

- A. 2009 summer off-peak system intact with maximum MH-US transfer:
MHEX=2175, NDEX=1950
- B. 2009 summer peak system intact with maximum generation in Manitoba

MH load was the sink for the 100 MW Lizard Lake wind farm.

5.2 Disturbances

The following NERC category B (single component) and C (multiple components) disturbances were tested to determine the impact of the Lizard Lake generator on the Manitoba-US transfer capability, using the 2009 summer off-peak stability model:

- I. ag1 fault – 4-cycle SLF 345 kV fault at Leland Olds on Ft. Thompson line. Stuck breaker. Clear faulted line at 11 cycles.
- II. ei2 fault – permanent bipole fault on the CU DC line. Both Coal Creek units tripped at 0.28 seconds.
- III. mqs fault – SLG fault at Sherco unit #3 with breaker fail 8N28. Trip Sherco unit #3.
- IV. nbz fault – 4-cycle 3-phase 500 kV fault on at Chisago on Forbes line 601. Cross-trip D602F. **This is the Overvoltage Ride-Through test discussed in section 5.3.**
- V. mat fault – Loss of D602F with DC reduction.

The following NERC category B (single component) and C (multiple components) disturbances were tested to determine the impact of the Lizard Lake generator on the transfer capability within Manitoba, using the 2009 summer peak stability model:

- I. System intact, 3-phase normal clearing faults at St. Leon 230 kV on lines D14S, S53G, S60L, Y51L, G37C, D12C and D54C.
- II. System intact, single line-to-ground stuck breaker (slow clearing) faults (determined from ACCC analysis as candidate for stability analysis). **Breaker fail R4 is the voltage collapse case discussed in section 6.5.1.**
- III. mbs fault – Loss of Manitoba HVDC bipole loaded at 1882 MW at Dorsey. No cross-trip of Manitoba-Ontario tie lines.

5.3 Overvoltage Ride-Through Test

The 'nbz' fault (4-cycle 3-phase 500 kV fault at Chisago on Forbes line 601, cross-trip D602F) is the disturbance used to test the overvoltage ride-through capability of the wind turbines. To test for the worst-case scenario, the pre-disturbance intermediate bus voltages were set to as high as was reasonable for the particular cases. Please refer to figures in Appendix E-1.

5.3.1 Turbine A

The Turbine A Pembina Hills and St. Leon Wind Energy LP wind farms were each set to have all 2x10 MVAR capacitors and all 49 MVAR PFCs in-service as a worst-case scenario, with the pre-disturbance St. Leon 230 kV voltage operating near 1.06 pu.

The Turbine A wind farm tripped out during the disturbance as voltage at the generator 600 V bus exceeded 115%. The Turbine A turbines do not meet the MH transient overvoltage criteria. Mitigation, such as an on-load tap changer voltage control scheme on the 25-230 kV transformers, or fast inductive VAR capability (such as an SVC), would be required to keep the Turbine A wind farm on-line during this disturbance.

5.3.2 Turbine B

The Turbine B wind farm voltage control scheme was set to control the 230 kV POI voltage to 1.06 pu as a worst-case scenario. The existing St. Leon and Pembina Hills wind farms were set to a pessimistic operating point of 0.95 overexcited, each with 2x10 MVAR 25 kV capacitors as well as all 49 MVAR PFC capacitors in-service.

The Turbine B wind farm remained connected throughout the disturbance. The fast voltage controls of the doubly-fed induction generator aided in reducing the overvoltage seen at the St. Leon 230 kV bus when compared to the case without the wind farm. The Turbine B turbines meet the MH transient overvoltage criteria.

5.4 Undervoltage Ride-Through Test

All of the close-in three-phase and single line-to-ground faults can be regarded as undervoltage ride-through tests.

5.4.1 Turbine A

The Turbine A wind farm was observed to ride through all close-in faults. A three-phase fault on the St. Leon 230 kV bus resulted in a voltage of 0.189 pu for 83 ms at the 600 V generator bus, which is within the turbine's capability. The Turbine A turbines meet the MH undervoltage ride-through criteria.

5.4.2 Turbine B

The Turbine B wind farm was observed to ride through all close-in three-phase and single line-to-ground faults. A three-phase fault on the St. Leon 230 kV bus resulted in a voltage of 0.148 pu for 83 ms at the 575 V generator bus, which is just below the turbine's capability. This could be mitigated by choosing 230-25 kV transformers with a slightly higher impedance than 7%, which could be determined in the Interconnection Facilities Study phase.

5.5 System Intact with Local N-1 Contingencies

The MH transient undervoltage criteria requires that all system transient voltages remain above 0.7 pu after fault clearing. Please refer to figures in Appendix E-2.

5.5.1 Turbine A

The Turbine A generators violate the transient undervoltage criteria for two local three-phase faults (N-1). A normal clearing three-phase fault on Dorsey-St. Leon line D14S or on Glenboro-St. Leon line S53G violates the 0.7 pu transient voltage criteria and results in undamped voltage oscillations.

The switched capacitors alone would therefore not be an acceptable VAR support option. The Turbine A turbines would require some amount of dynamic VAR support, such as a STATCOM or an SVC, which could possibly be combined with some amount of switched capacitors to form sufficient VAR support so as to not violate the transient undervoltage criteria. The sizing of the switched capacitors and dynamic VAR support would be determined in the Interconnection Facilities Study phase.

5.5.2 Turbine B

The Turbine B doubly-fed induction generators do not violate the transient undervoltage criteria for any local three-phase fault (N-1).

The existing St. Leon and Pembina Hills wind farms were set to have 0x10 MVAR 34.5 kV capacitors in-service.

The worst –case three-phase fault is that on Dorsey-St. Leon line D14S. The voltage response just meets the 0.7 pu criteria.

The Turbine B wind farm remained connected throughout the disturbance. The fast voltage controls of the doubly-fed induction provided sufficient VAR support such that the St. Leon 230 kV transient voltage remained above 0.7 pu immediately following fault clearing. The Turbine B turbine meets MH transient undervoltage criteria.

5.6 System Intact with Local N-2 Contingencies

5.6.1 Breaker Failure R4 at St. Leon: Potential Voltage Collapse Scenario

At St. Leon, any disturbance that results in the simultaneous outages of Dorsey-St. Leon 230 kV line D14S and St. Leon-Glenboro 230 kV line S53G has the potential to result in voltage collapse or undamped voltage oscillations or a violation of the transient undervoltage criteria. These two line outages leave the wind generation from the St. Leon Wind Energy LP and Pembina Hills wind farms radially feeding into heavily loaded St. Leon-Letellier 230 kV line S60L. There are two system intact NERC Category C contingencies that result in this scenario:

Breaker failure R4 at St. Leon:

1. Stuck breaker (16-cycle) SLGF on Dorsey-St. Leon 230 kV line cleared by tripping St. Leon-Glenboro 230 kV line S53G, or
2. Stuck breaker (16-cycle) SLGF on Glenboro-St. Leon 230 kV line cleared by tripping St. Leon-Dorsey 230 kV line D14S

There is an existing cross-tripping scheme that is designed to trip the St. Leon Wind Energy LP and Pembina Hills wind farms should a breaker R4 failure occur.

Please refer to figures in Appendix E-3.

5.6.1.1 Turbine A

Assuming that the existing breaker R4 failure cross-tripping scheme remains in place (i.e. the St. Leon Wind Energy LP and Pembina Hills wind farm cross-trip), the Lizard Lake Turbine A wind farm may not require crosstripping, depending on the size of dynamic VAR support that is installed with the Lizard Lake wind farm. The Interconnection Facilities Study phase would need to investigate further.

5.6.1.2 Turbine B

Assuming that the existing breaker R4 failure cross-tripping scheme remains in place (i.e. the St. Leon Wind Energy LP and Pembina Hills wind farm cross-trip), the Lizard Lake Turbine B wind farm would not require crosstripping due to the inherent fast voltage control capability.

A simulation was run to see if the Turbine B type generators at Lizard Lake would provide sufficient reactive power support during this disturbance such that the existing cross-trip scheme could be disabled. This was not the case, therefore the St. Leon Wind Energy LP and Pembina Hills generator crosstripping scheme could not be disabled.

5.6.2 Breaker Failure R1 at St. Leon: Potential Overvoltage Trip

At St. Leon, any disturbance that results in the simultaneous outages of Letellier-St. Leon 230 kV line S60L and St. Leon-Glenboro 230 kV line S53G has the potential to result in voltage collapse or undamped voltage oscillations or a violation of the transient undervoltage criteria. These two line outages leave the wind generation from the St. Leon Wind Energy LP, Pembina Hills and Lizard Lake wind farms radially feeding into St. Leon-Dorsey 230 kV line D14S. There are two system intact NERC Category C contingencies that result in this scenario:

Breaker failure R1 at St. Leon:

1. Stuck breaker (16-cycle) SLGF on Letellier-St. Leon 230 kV line cleared by tripping St. Leon-Glenboro 230 kV line S53G, or
2. Stuck breaker (16-cycle) SLGF on Glenboro-St. Leon 230 kV line cleared by tripping St. Leon-Letellier 230 kV line S60L

Unlike the breaker R4 failure scenario, there is no existing special protection or crosstrip scheme in place for the breaker R1 failure. The Lizard Lake wind farm, depending on the turbine type, puts this contingency over the edge of criteria violation.

Please refer to figures in Appendix E-4.

5.6.2.1 Turbine A

The Lizard Lake Turbine A wind farm may or may not require crosstripping under this scenario, depending on the size of dynamic VAr support that is installed with the Lizard Lake wind farm. The Interconnection Facilities Study phase would need to investigate further.

5.6.2.2 Turbine B

The Turbine B generators provide a voltage response that just meets the 0.7 pu criteria. No special protection or cross-tripping schemes would be required.

5.7 Summary of Stability Results

Addition of generation in southwest Manitoba at the proposed wind site changes this Manitoba-US tie line sharing, resulting in increased south flow on the western ties (G82R and L20D) and reduced south flow on the remaining ties, primarily D602F. This change produces slightly different steady state and transient relay margins for the out-of-step impedance relays on the MH-US ties. The worst impact is to G82R transient relay margin during the high south flow summer peak cases with local N-1 and N-2 contingencies. Before Lizard Lake, a three-phase fault (N-1) on line S60L produces a G82R transient relay margin of 193%, and with wind it reduces to 138%. A single line-to-ground breaker

R1 failure reduces the G82R transient relay margin from 69% to 49%. Both cases do not exceed the 25% criteria.

The St. Leon IFS [3] identified the need to prevent the wind generation from becoming isolated onto the 66 kV St. Leon system by installing protection logic to trip off the wind farm if the ring bus becomes open in positions 2&5 (by tripping R6), 3&6 (by tripping R5), or 2&3 (by tripping R5 and R6). The Lizard Lake wind farm will require

5.7.1 Turbine A

The Turbine A wind turbines would need to install additional capacitive VAR support to meet the 0.95 leading power factor requirement. At least some portion of this VAR support will need to be dynamic, such as an SVC or STATCOM, in order to meet the 0.7 pu transient undervoltage criteria.

To meet the overvoltage ride-through criteria, the 230-25 kV transformer may need to be equipped with an on-load tap changer. The OLTC would be required to control the 25 kV bus voltage. Whether or not the OLTC is needed depends on how much reactive power support will be dynamic and whether or not it is enough to keep the turbines from tripping on overvoltage.

Because of potential voltage swings due to wind farm power oscillations combined with the voltage-squared effect of the 25 kV capacitors, a special generator crosstripping scheme that exists for the St. Leon Wind Energy LP and Pembina Hills wind farms may also be used for the Lizard Lake wind farm to avoid voltage collapse and ensure the MH transient undervoltage criteria are met, again depending on the dynamic VAR device's capability to keep the voltage from collapsing.

If the Turbine A generators are selected, the Interconnection Facilities Study would need to determine an appropriate reactive power support solution, including how many switched capacitors (if any) are required, the sizing of the dynamic reactive support, as well as whether or not an OLTC would be necessary.

5.7.2 Turbine B

The Turbine B wind turbines do not require any additional equipment or special protection schemes. They must be equipped with the Turbine B Low Voltage Ride Through (LVRT) option II in order to meet fault ride-through requirements.

5.8 Specific Issues to be Resolved during an Interconnection Facilities Study

5.8.1 Turbine A

If the Turbine A wind turbines are chosen, the following issues need to be resolved in an Interconnection Facilities Study:

- Extra reactive power support. Some amount of dynamic VAr support will be necessary. The IFS would need to define how much, if any, reactive power support could be provided by switched capacitors and how much must be supplied by a dynamic VAr device. A normal-clearing three-phase fault on line D14S or line S53G (n-1) both violate the 0.7 pu transient undervoltage criteria.
- Depending on the reactive power support solution, determine if the breaker R4 or breaker R1 failure scenarios will still require the Lizard Lake wind farm to be cross-tripped. The IES studied only switched capacitors, which showed to be insufficient to avoid generator cross-tripping under these two n-2 disturbances.
- Depending on the reactive power support solution, determine if an OLTC is needed on the 230-25 kV transformer.

5.8.2 Turbine B

If the Turbine B wind turbines are chosen, the following issues need to be resolved in an Interconnection Facilities Study:

- Determine an appropriate impedance for the 230-25 kV transformer. The 7% impedance studied in the IES found that the 0.15 pu fault ride-through voltage criteria was slightly violated during a solid three-phase fault at the St. Leon 230 kV bus. The impedance should therefore be higher than 7% to ensure the wind farm will ride through the fault.

6.0 Level 1 Cost Estimate

The Level 1 cost estimate for Lizard Lake IFS was taken directly from the Elie IFS report [2]. It is basically the same in terms of facility requirements:

Transmission Station Projects

- St. Leon termination - one 230 kV breaker and associated equipment
- Protection & Control
- Communication

\$6,000,000

Transmission Line Facilities

- 32 km new T/L

\$7,000,000

Total Cost Estimate: \$13,000,000 ($\pm 50\%$)

7.0 References

- [1] Manitoba Hydro Transmission System Interconnection Requirements, Revision 0, December 2003, http://www.hydro.mb.ca/business_customer/tariffsummary.shtml.
- [2] “Elie Wind Farm Interconnection Facilities Study”, Manitoba Hydro, System Planning Department, May 2006.
- [3] “St. Leon Wind Farm Interconnection Facilities Study”, Manitoba Hydro, System Planning Department, March 2004.
- [4] “St. Leon Wind Farm Interconnection Evaluation Study”, Manitoba Hydro, System Planning Department, August 2003.
- [5] "St. Leon Wind Generation - Addendum for MAPP DRS Constrained Interface Analysis", May 7, 2004.
- [6] “The Manitoba Hydro Horizon Fault Levels Anticipated at the Proposed Pembina Hills, New Haven, Elie and Lena Wind Farm Points of Delivery”, Manitoba Hydro, System Planning Department, M.R. Wonsiak, June 14, 2005.
- [7] “The Impact of Increased Short Circuit Fault Levels on Local Circuit Breakers with the Addition of Wind Farm Generation – Supplement to the Pembina Hills, New Haven, Elie and Lena IFS Study”, Manitoba Hydro, System Planning Department, M.R. Wonsiak, June 14, 2005.
- [8] ABB Coordinated Group Study of Group 1 Generator Projects, submitted to MISO and WAPA on April 5, 2004.
http://www.midwestiso.org/plan_inter/documents/CGS-Group1%20Draft-R2.pdf
- [9] Attachment A and B, MISO Generator Interconnection Manual, Volume 6.2, Version 2, May 5, 2004.
http://www.midwestiso.org/plan_inter/documents/generation_inter/Generator%20Interconnection%20Manual_day1_050504_cln.pdf
- [10] MISO Generation Deliverability Study Method, “Deliverability Study White Paper”
http://www.midwestiso.org/plan_inter/documents/gen_deliver_test/MISO_Generator_Deliverability_Draft_2-10-05.pdf
- [11] MAPP DRS document, “Steady-State Facility & Constrained Path Impact Determination Requirements & Screening Guidelines for Study Submissions” approved October 23, 2003. (on MAPP Member web site)
- [12] MAPP Members Reliability Criteria and Study Procedures Manual, Nov. 9, 2004

Appendix A:

Stability Plots

All Turbine A responses are shown with the 230-25 kV OLTC, 2x10 MVar or 4x10 MVar switched capacitors for a 50 MW or 100 MW wind farm respectively, and no dynamic VAR device.

Overvoltage Ride-Through Test (Section 5.3): nbz fault

Figure A-1a Base case & 100 MW Turbine A

Figure A-1b Base case & 100 MW Turbine B

Undervoltage Ride-Through Test (Section 5.4): 3PF S53G, System intact

Figure A-2a Base case & 50 MW Turbine A

Figure A-2b Base case & 100 MW Turbine A

Figure A-2c Base case & 50 MW Turbine B

Figure A-2d Base case & 100 MW Turbine B

Breaker Fail R4 (Section 5.6.1): Voltage Collapse/Transient Undervoltage

Figure A-3a Base case with St.Leon & Pemb Hills cross-trip & 50 MW Turbine A

Figure A-3b Base case with St.Leon & Pemb Hills cross-trip & 100 MW Turbine A

Figure A-3c Base case with St.Leon & Pemb Hills cross-trip & 50 MW Turbine B

Figure A-3d Base case with St.Leon & Pemb Hills cross-trip & 100 MW Turbine B

Breaker Fail R1 (Section 5.6.2): Voltage Collapse/Transient Undervoltage

Figure A-4a Base case with St.Leon & Pemb Hills cross-trip & 50 MW Turbine A

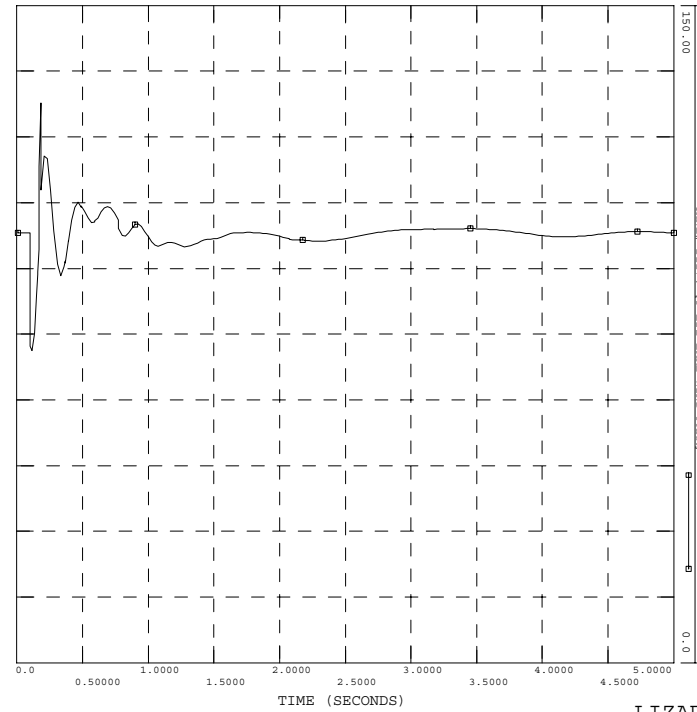
Figure A-4b Base case with St.Leon & Pemb Hills cross-trip & 100 MW Turbine A

Figure A-4c Base case with St.Leon & Pemb Hills cross-trip & 50 MW Turbine B

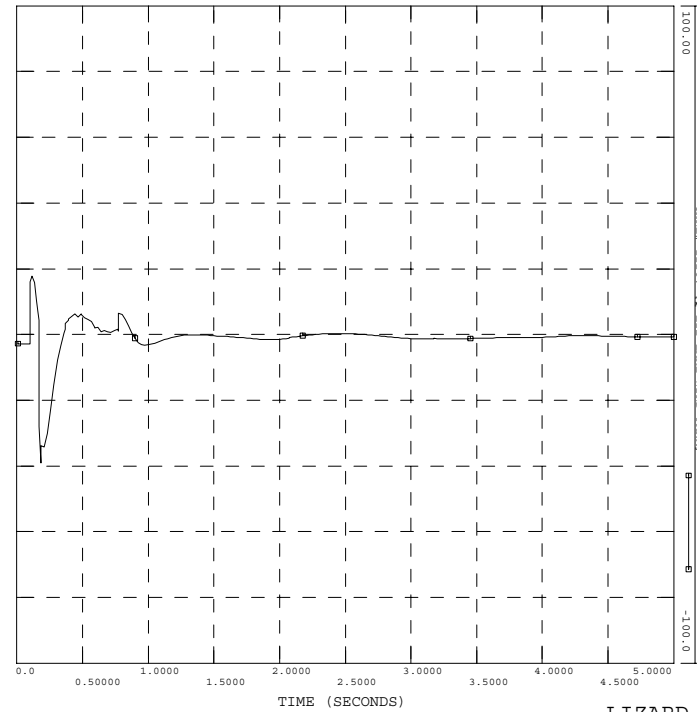
Figure A-4d Base case with St.Leon & Pemb Hills cross-trip & 100 MW Turbine B



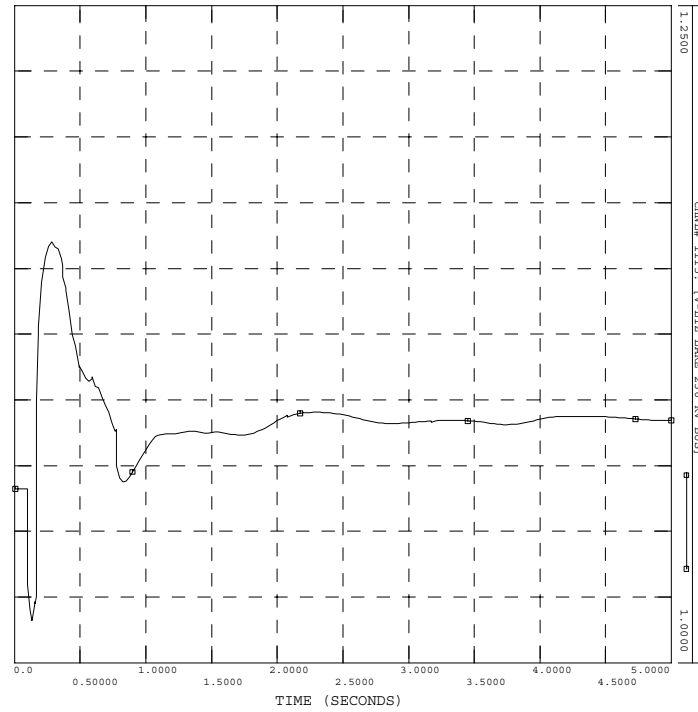
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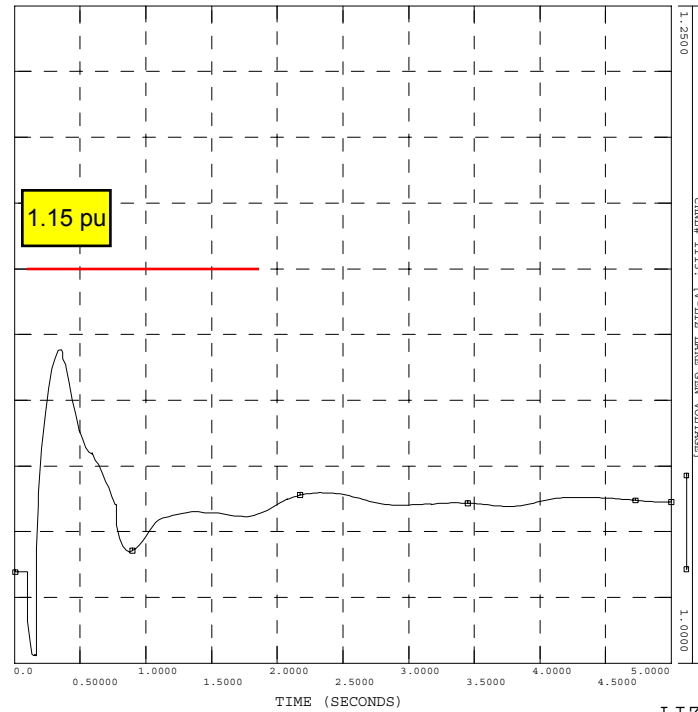
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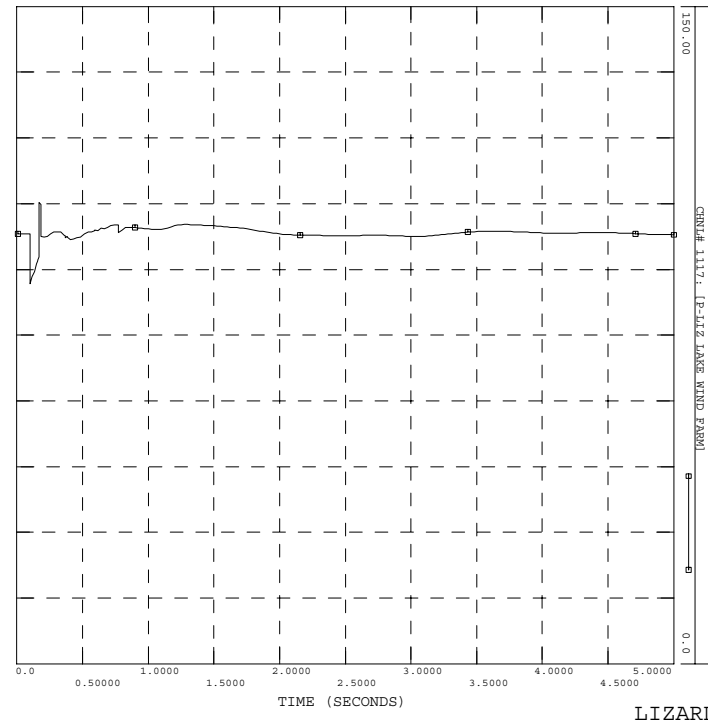
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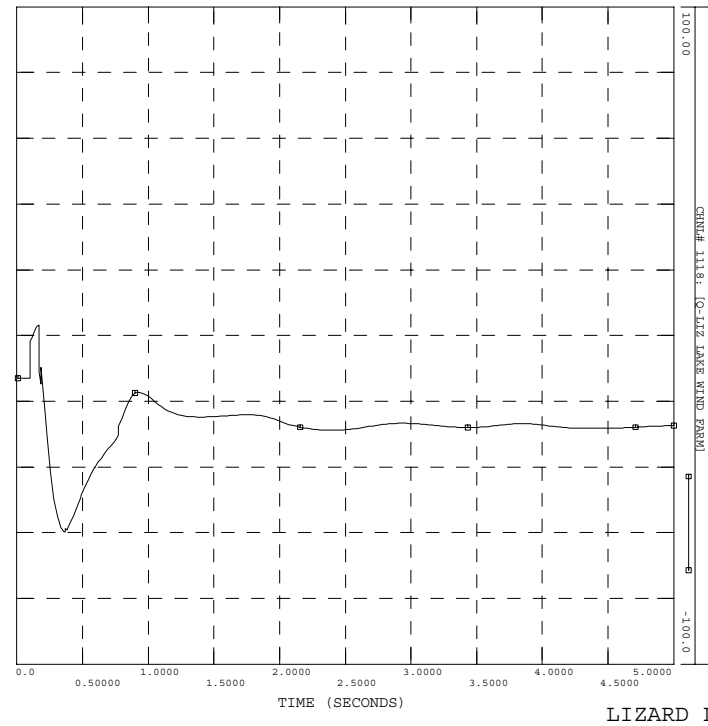
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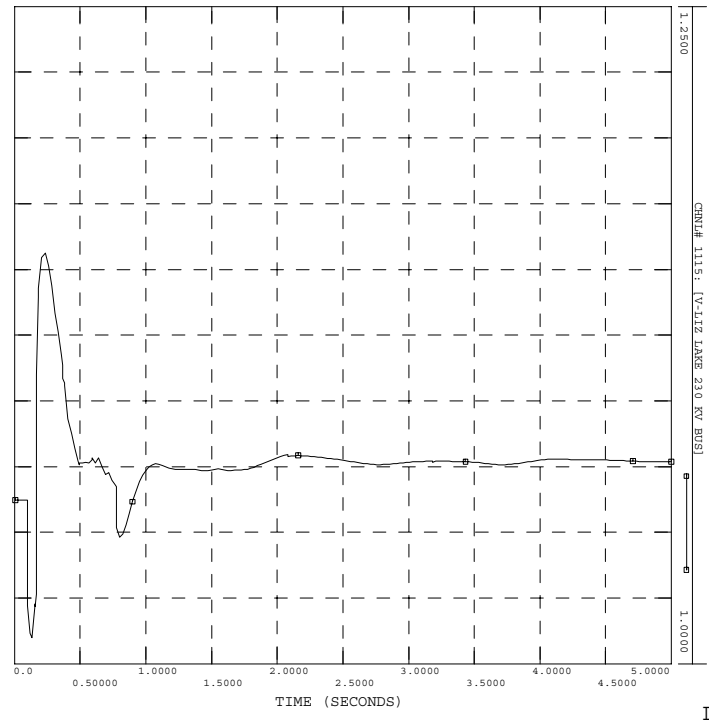
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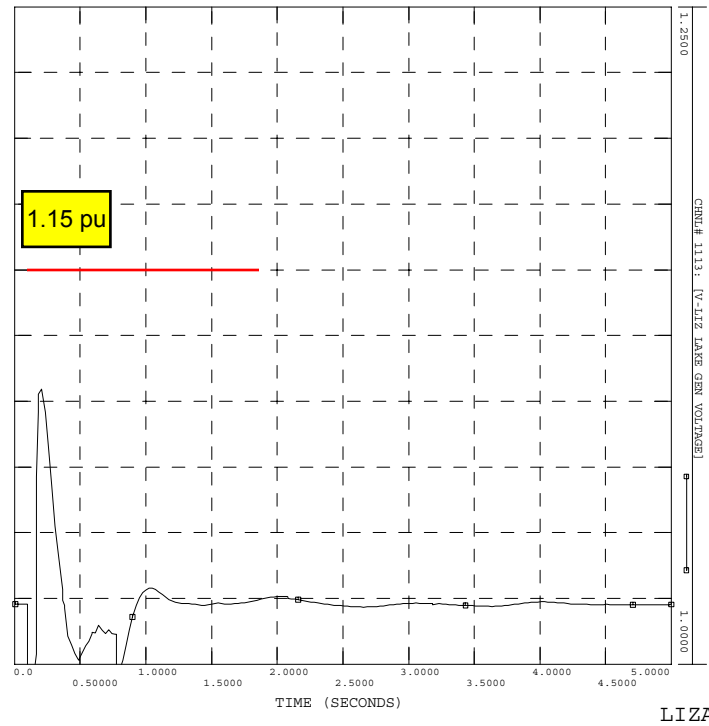
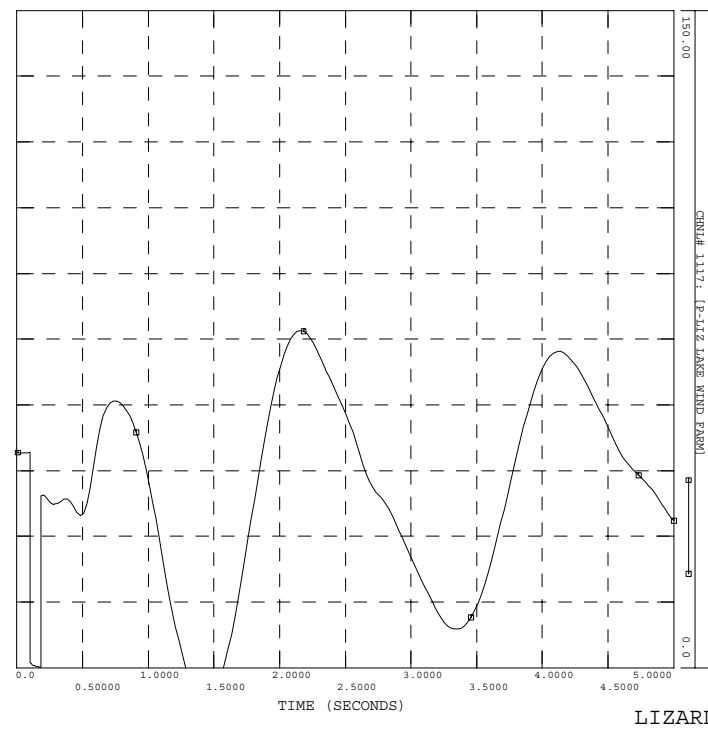


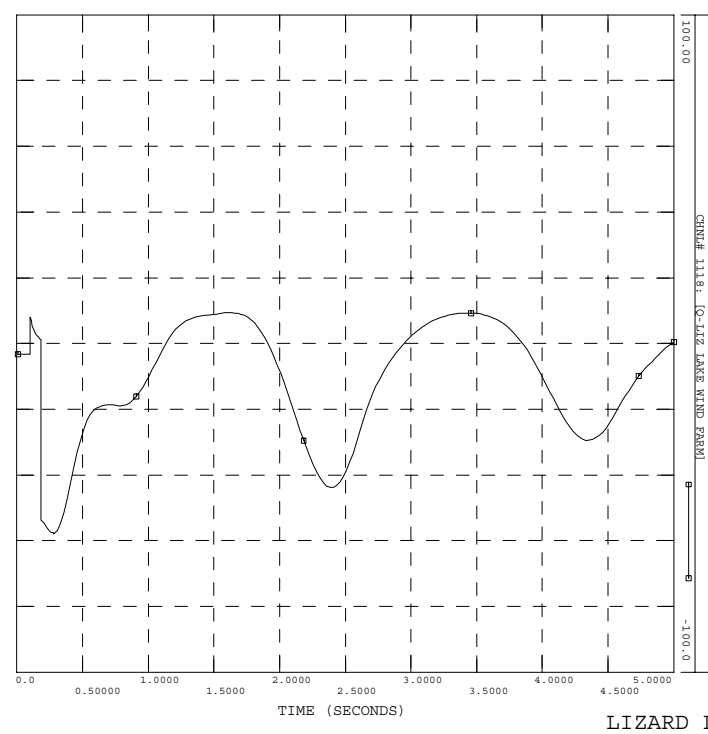
Fig A-1b

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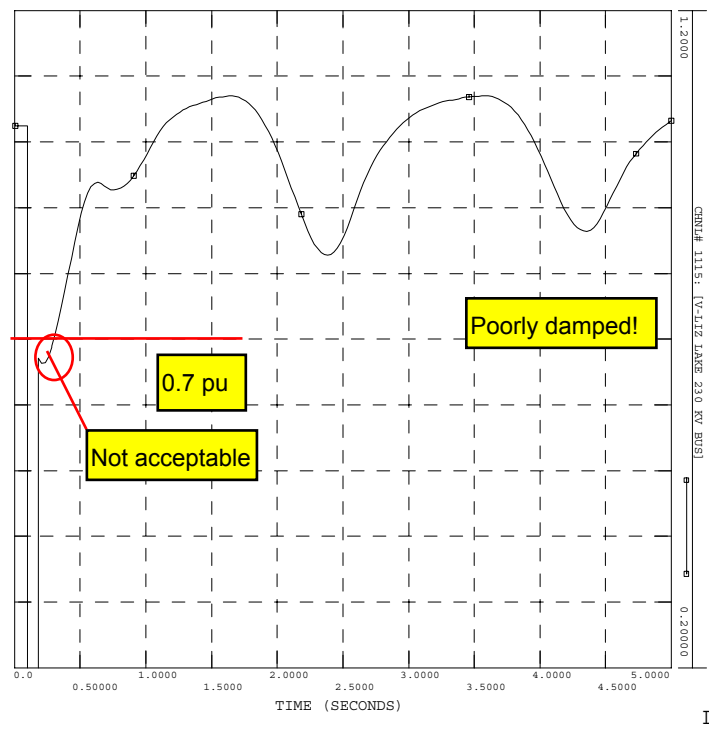
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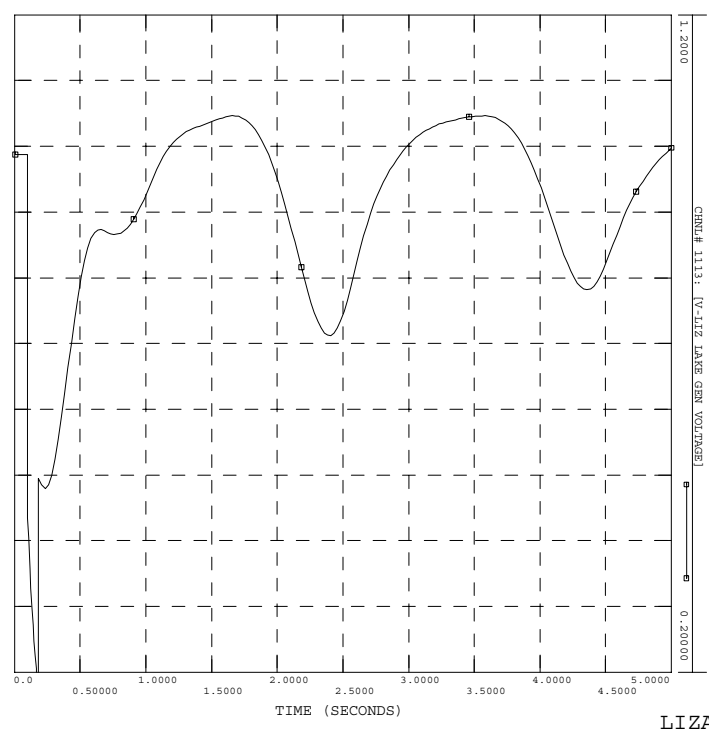
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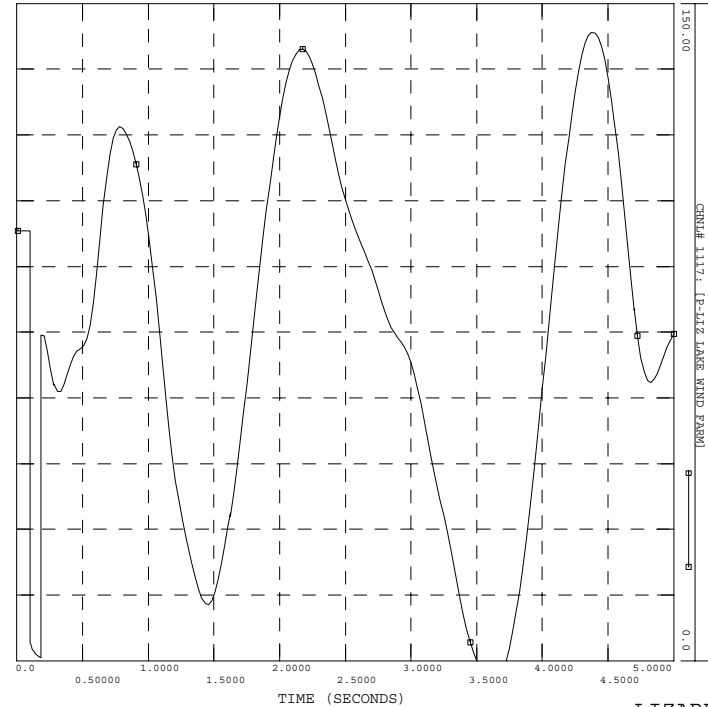


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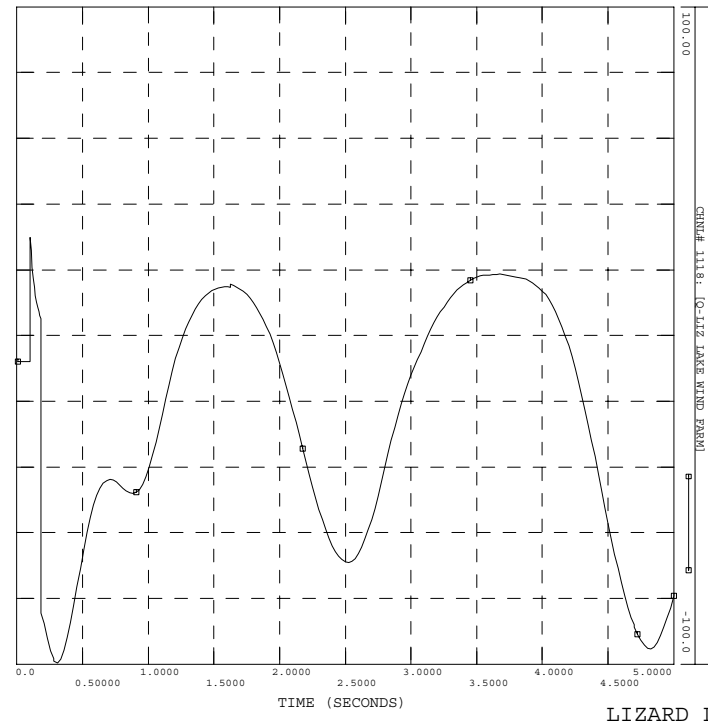
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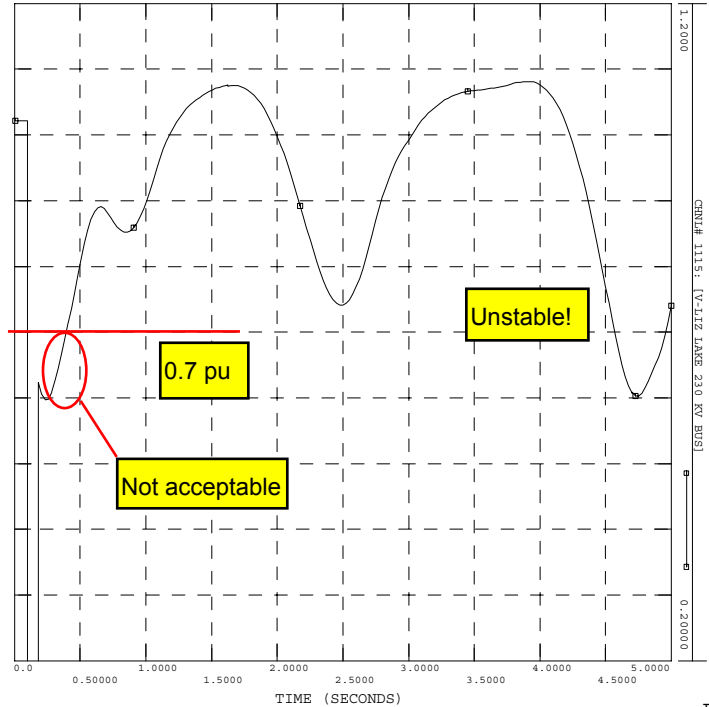
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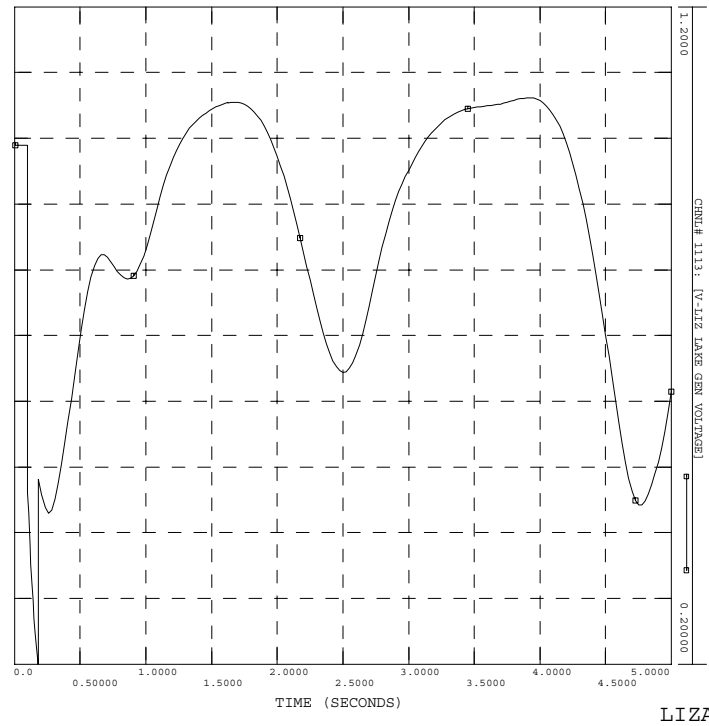
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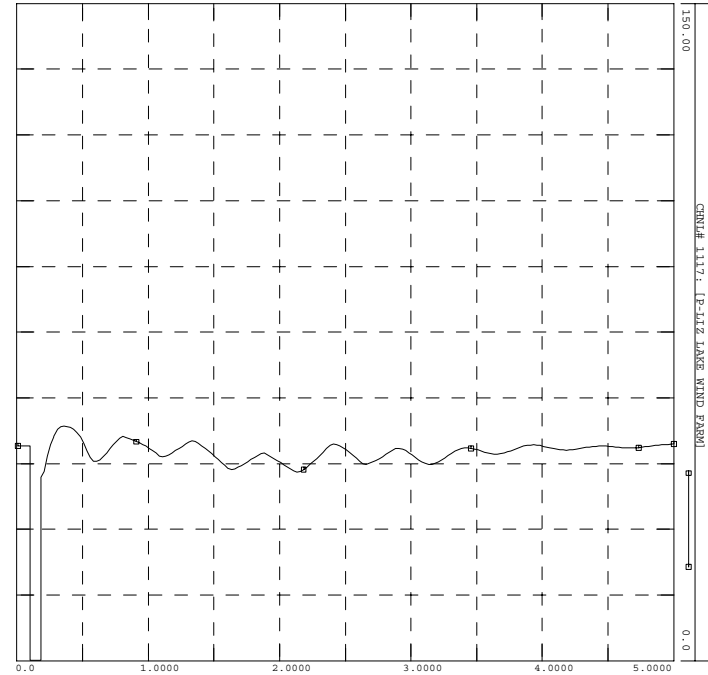
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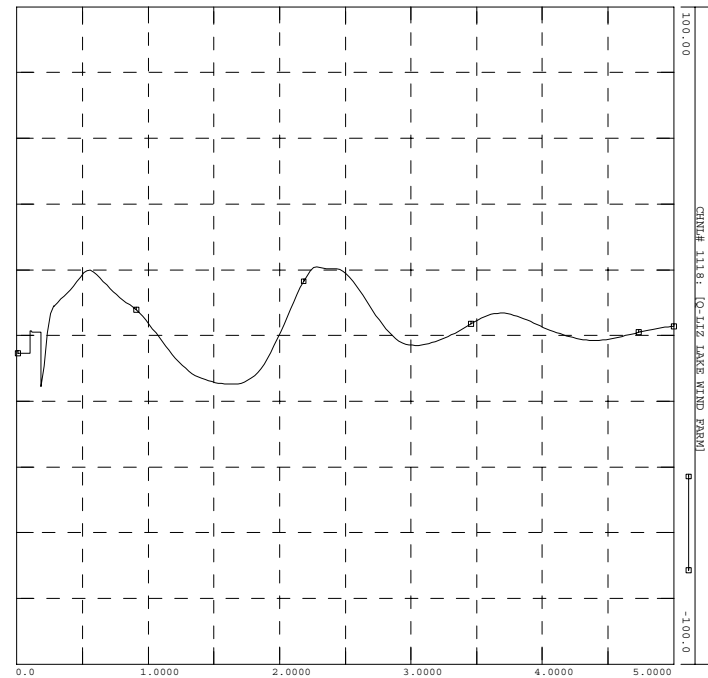
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MON, AUG 28 2006 10:33
 LIZARD LAKE WIND ERROR



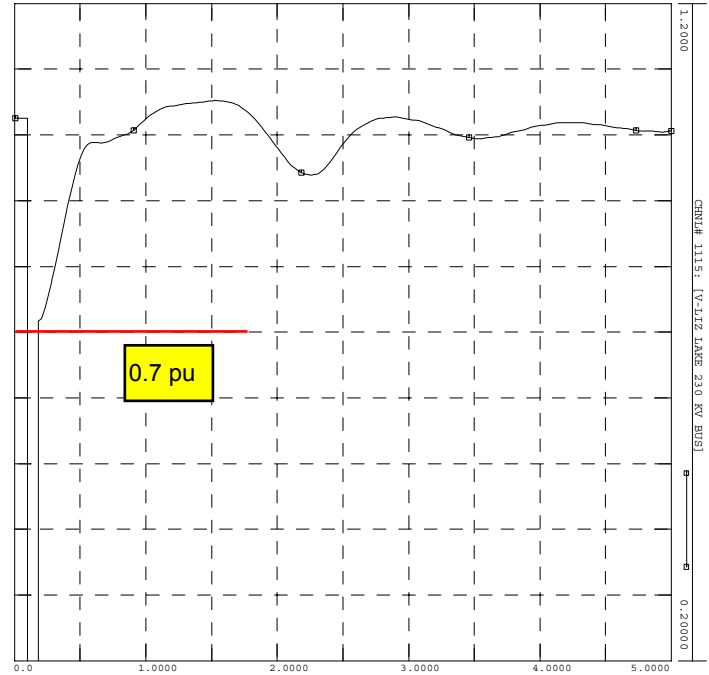
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MON, AUG 28 2006 10:33
 LIZARD LAKE Q-GEN (MVAR)



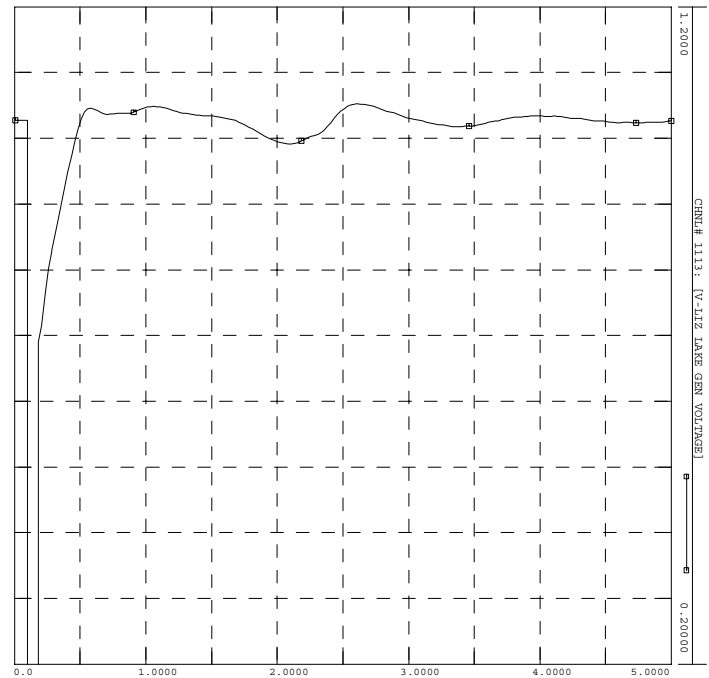
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MON, AUG 28 2006 10:33
 LIZARD LAKE 230 KV BUS



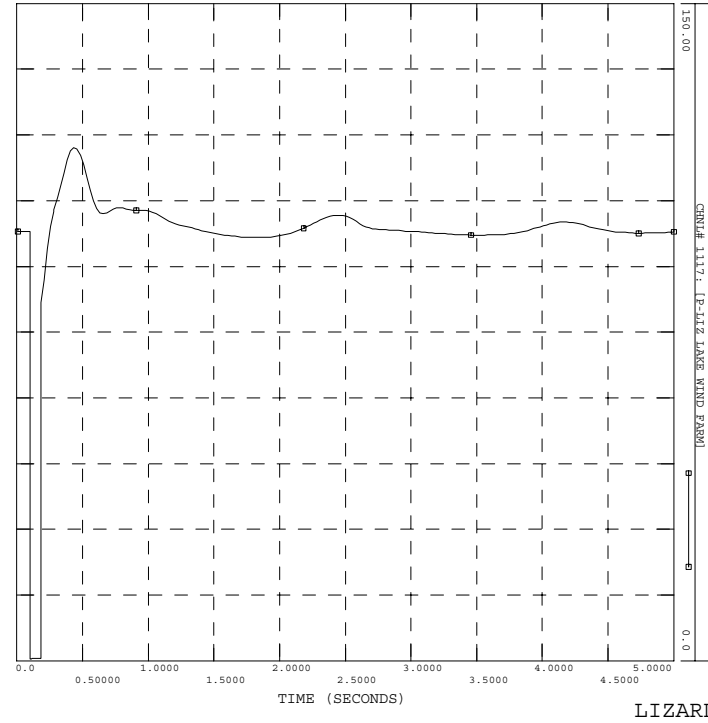
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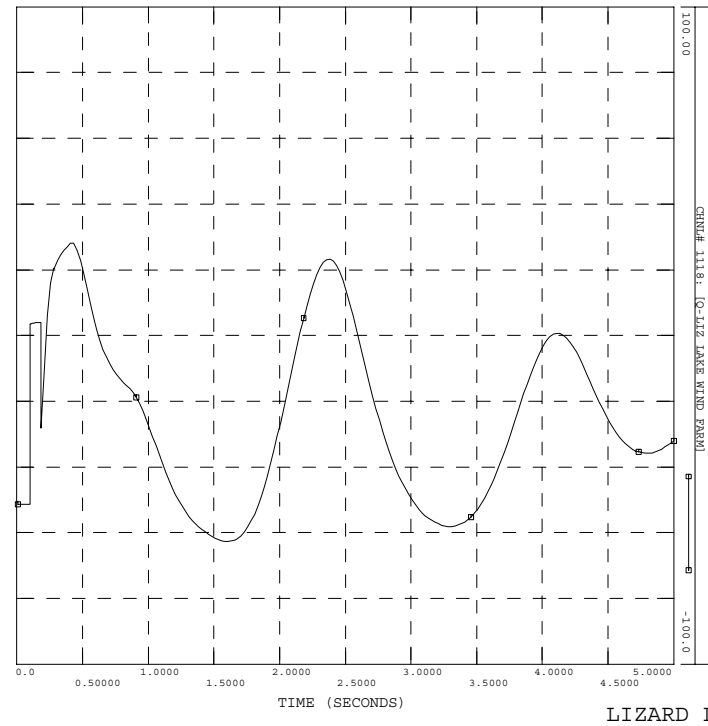
MON, AUG 28 2006 10:33
 LIZARD LAKE GEN VOLT



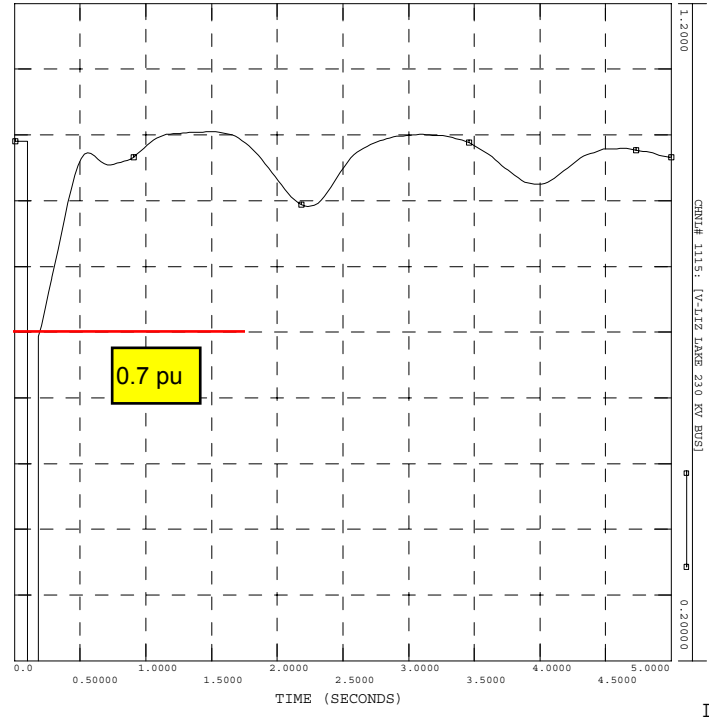
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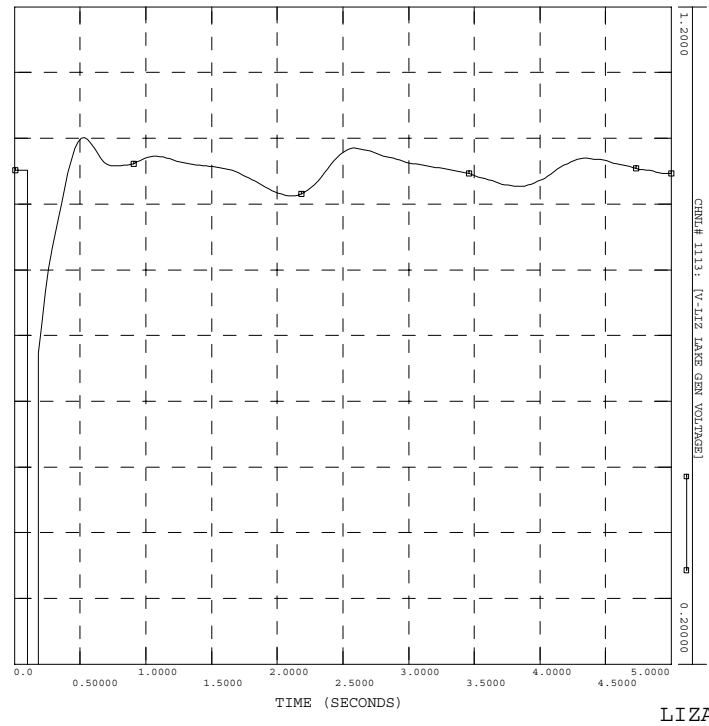
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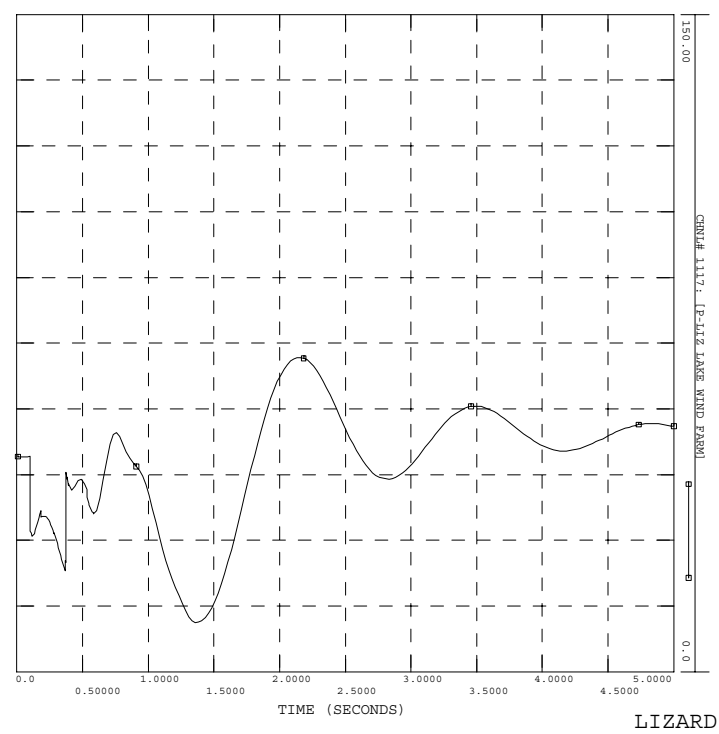
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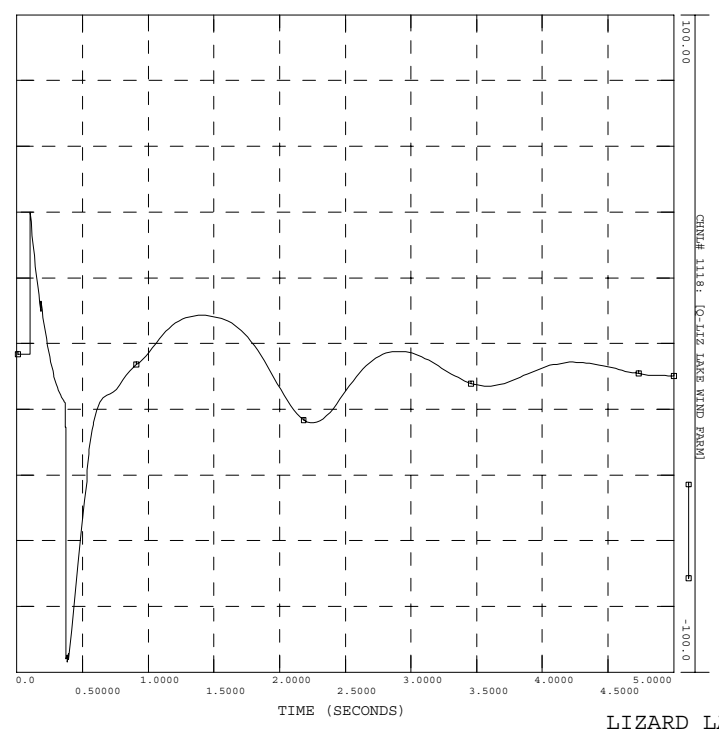
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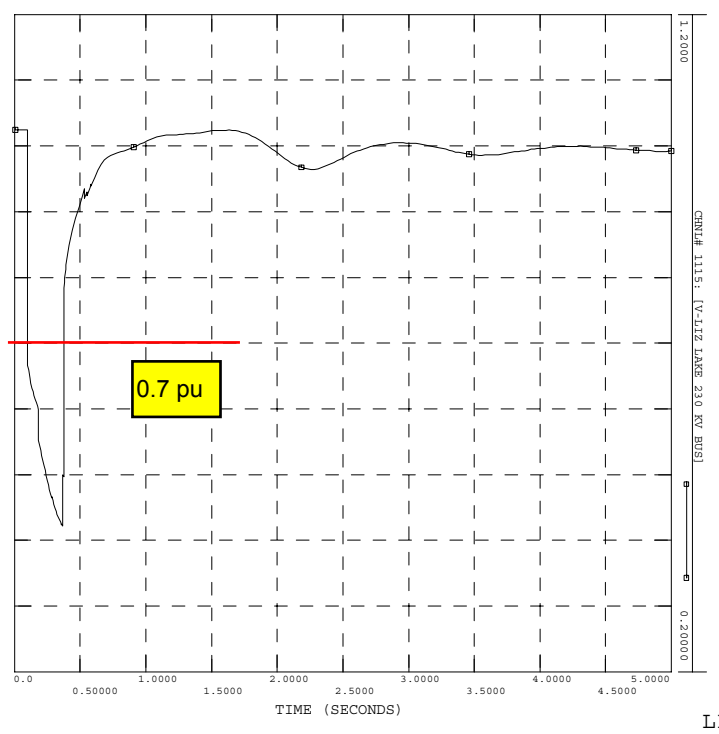
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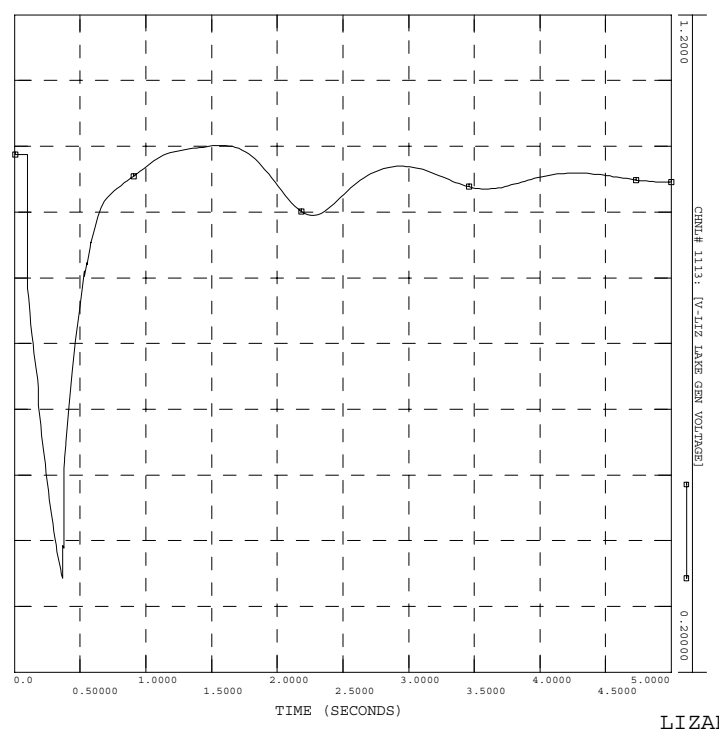
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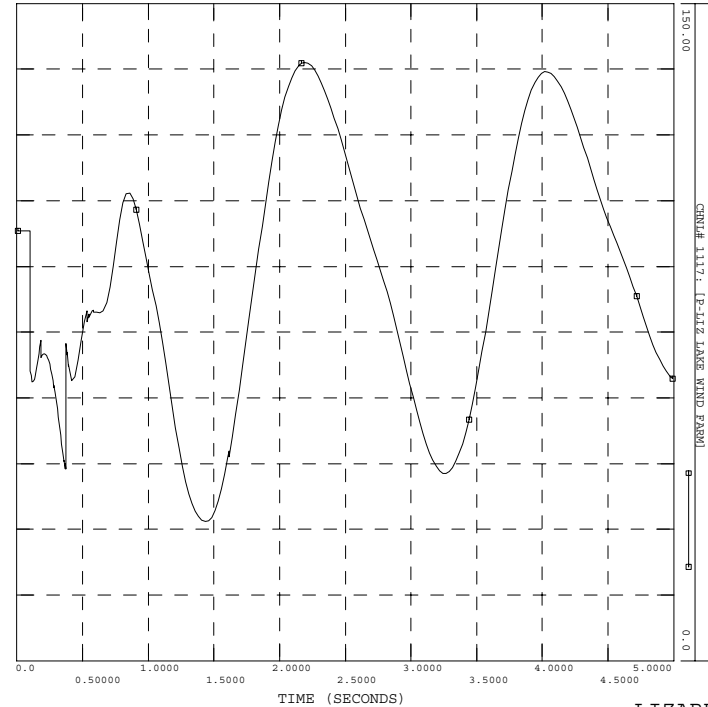
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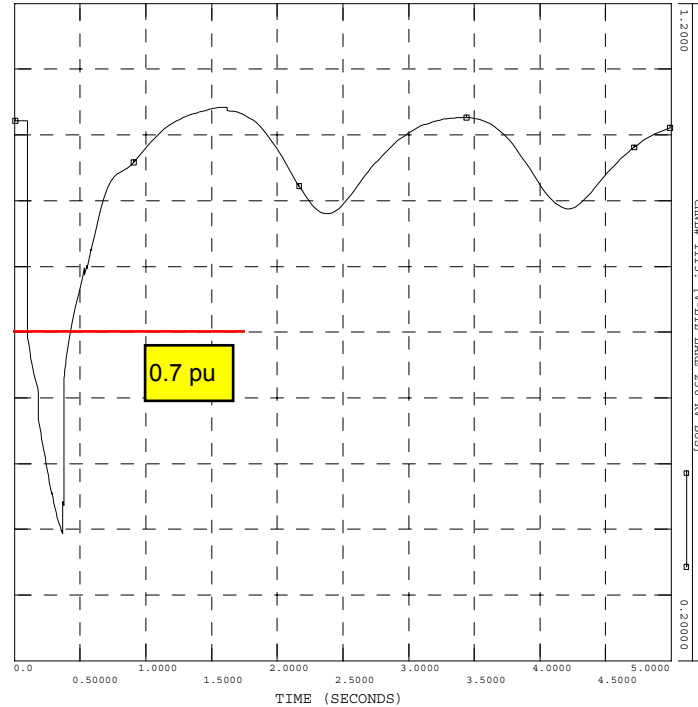
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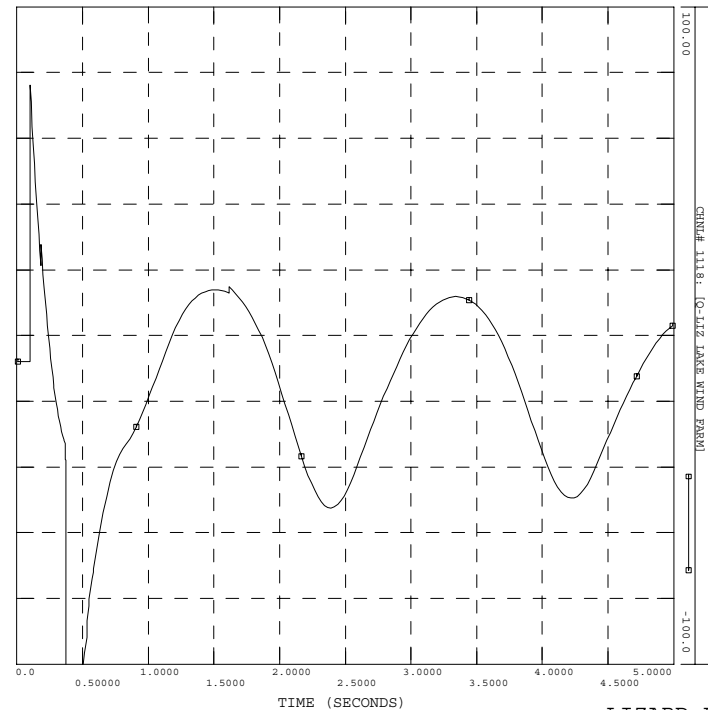
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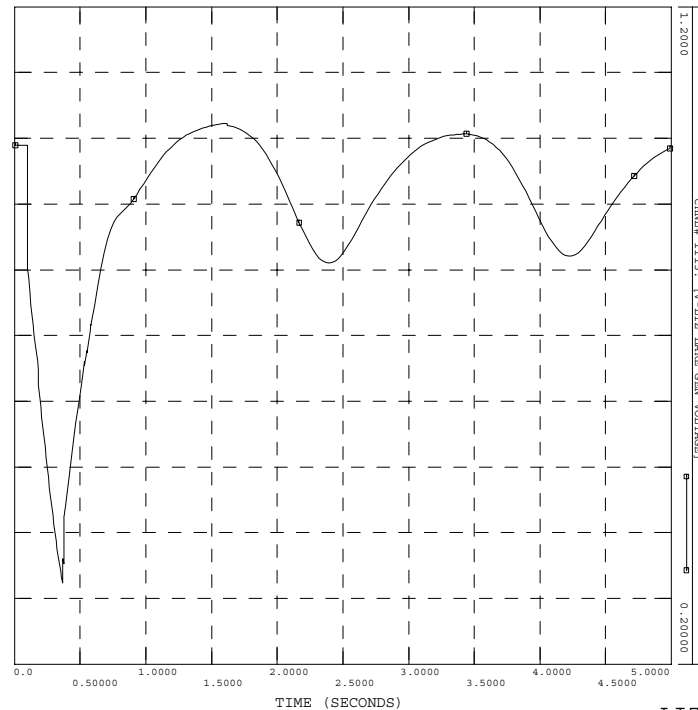
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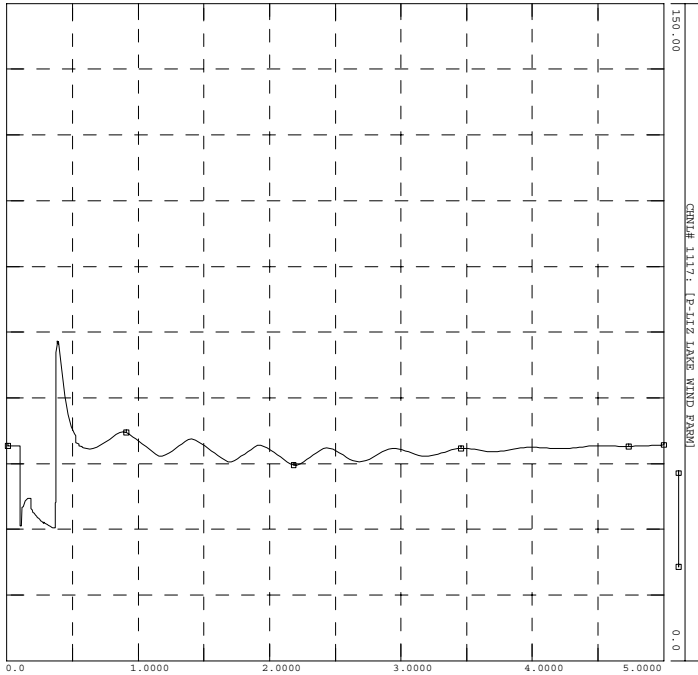
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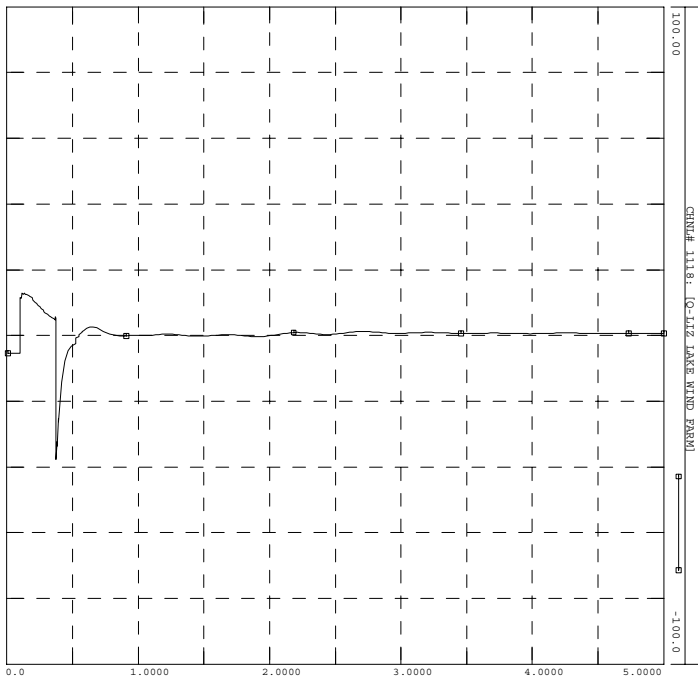
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MON, AUG 28 2006 10:34
 LIZARD LAKE POWER (MW)



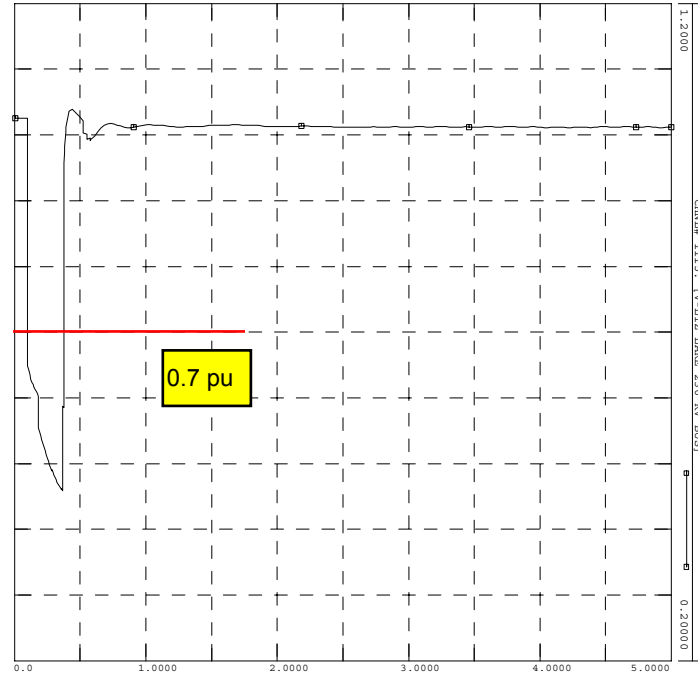
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MON, AUG 28 2006 10:34
 LIZARD LAKE Q-GEN (MVAR)



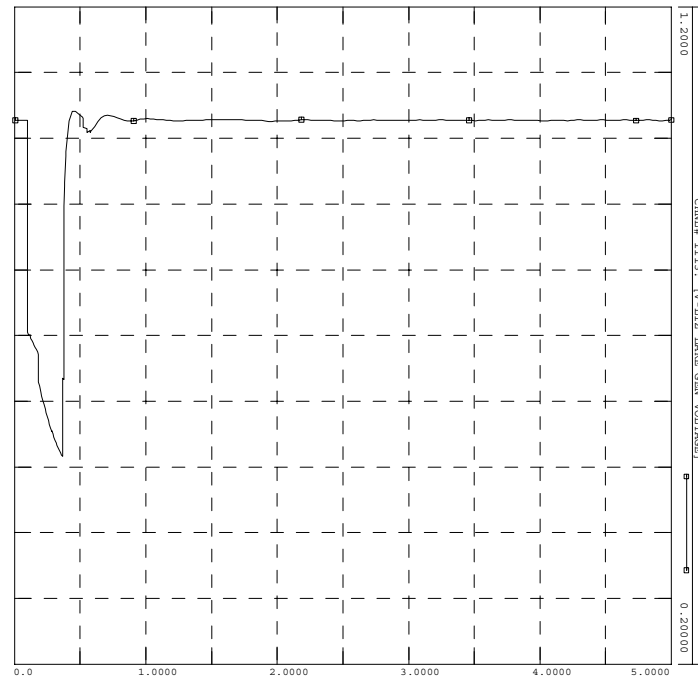
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MON, AUG 28 2006 10:34
 LIZARD LAKE 230KV

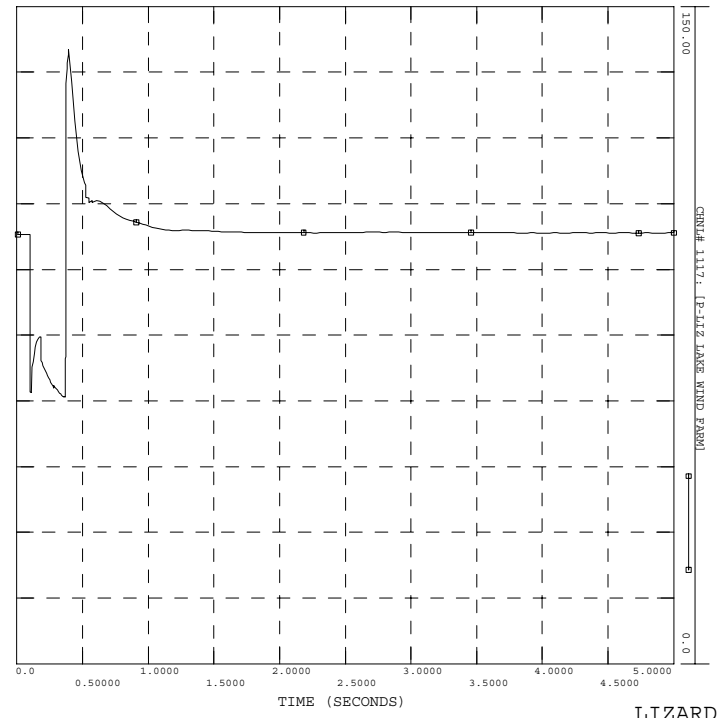


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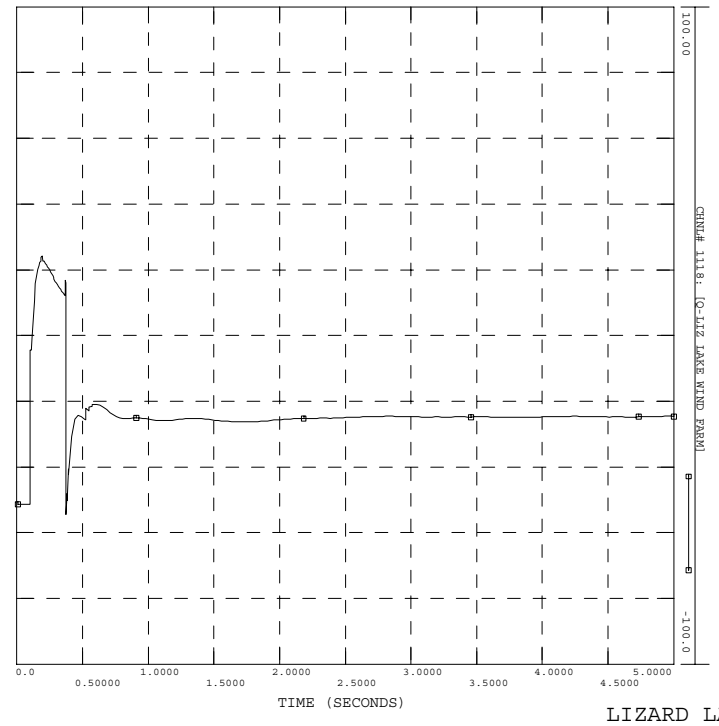


MON, AUG 28 2006 10:34
 LIZARD LAKE GEN VOLT

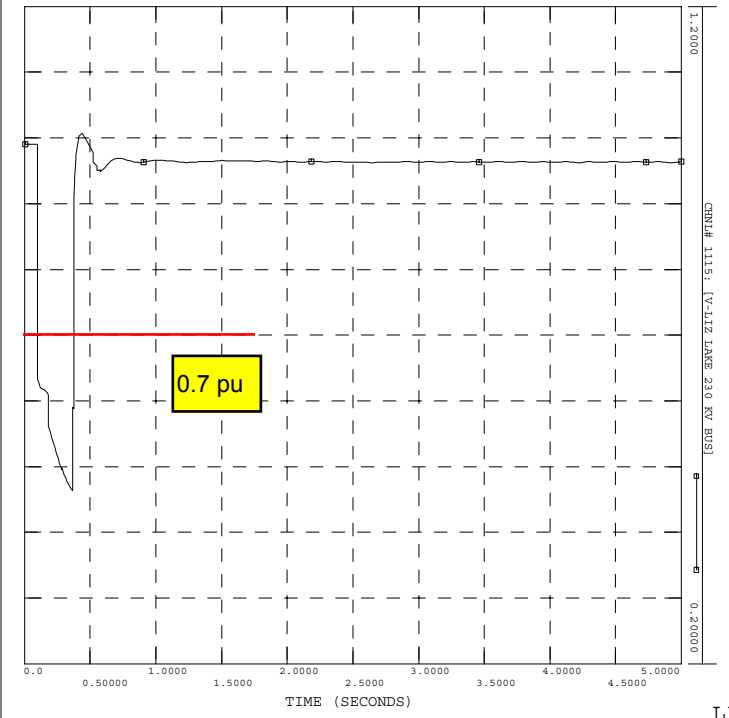
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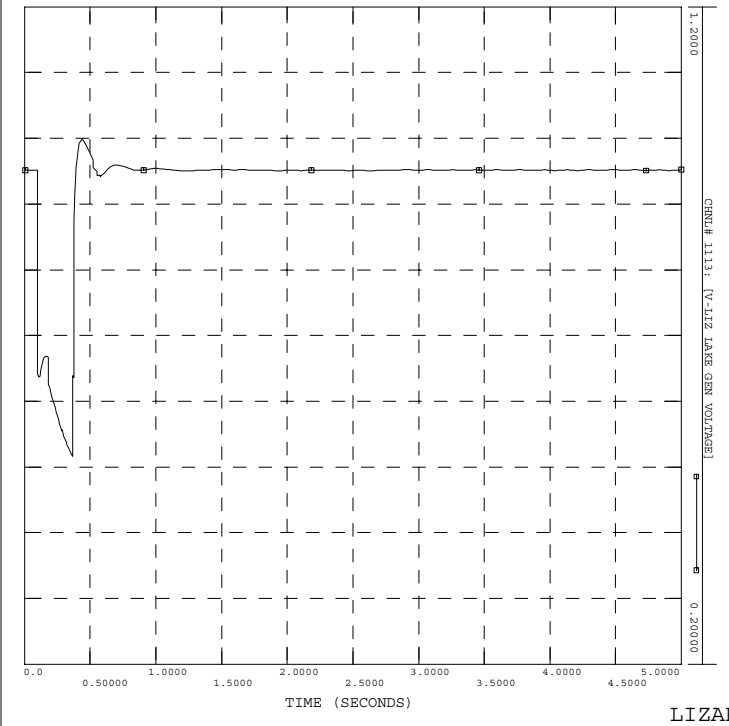
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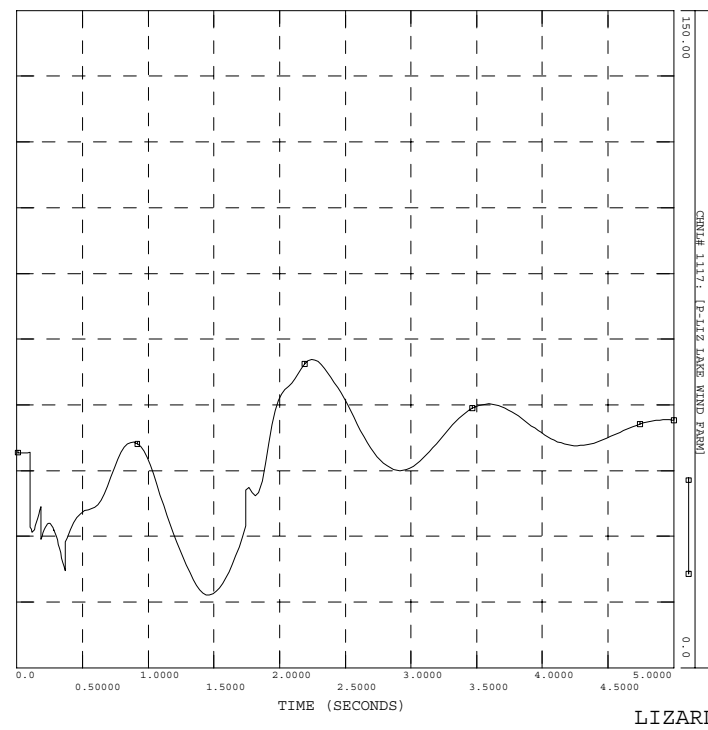
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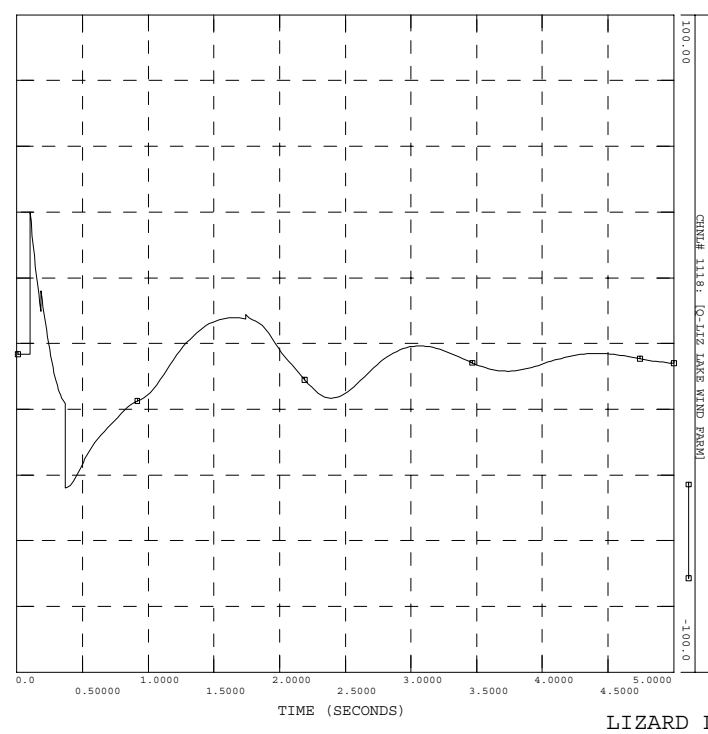


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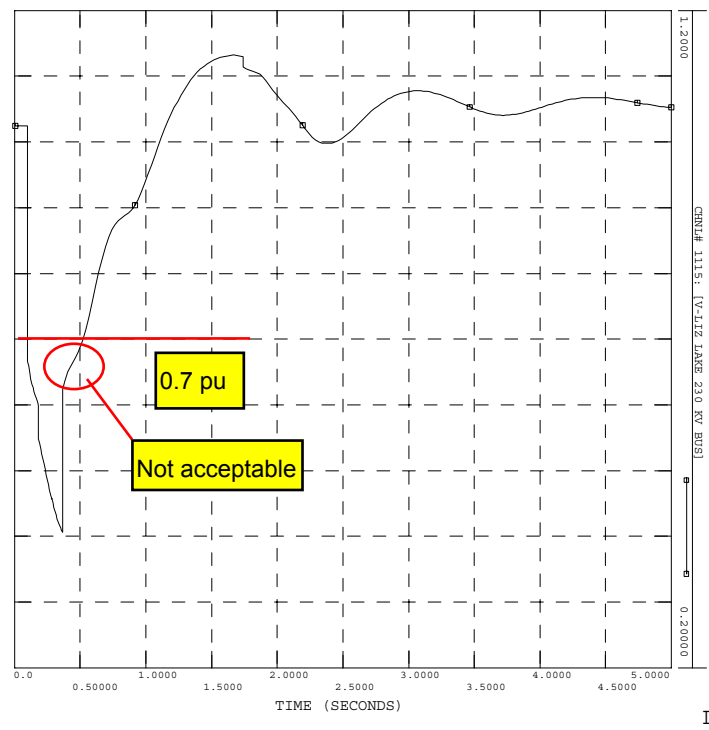
MON, AUG 28 2006 10:35
 LIZARD LAKE POWER (MW)

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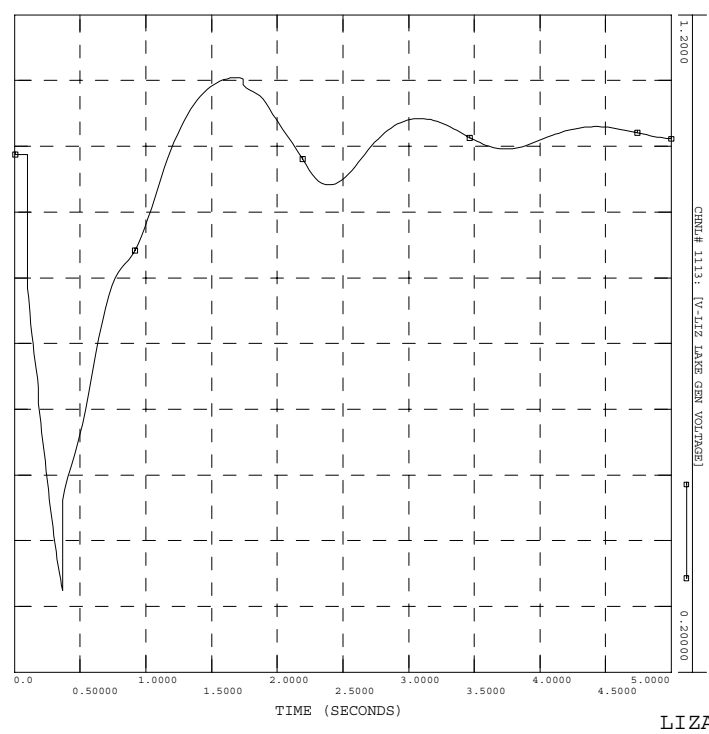
MON, AUG 28 2006 10:35
 LIZARD LAKE Q-GEN (MVAR)

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MON, AUG 28 2006 10:35
 LIZARD LAKE 230KV

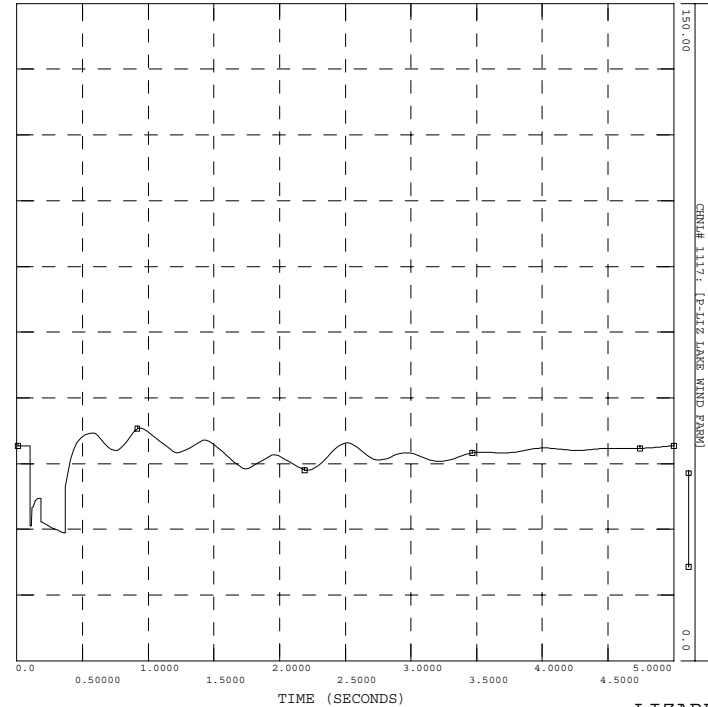
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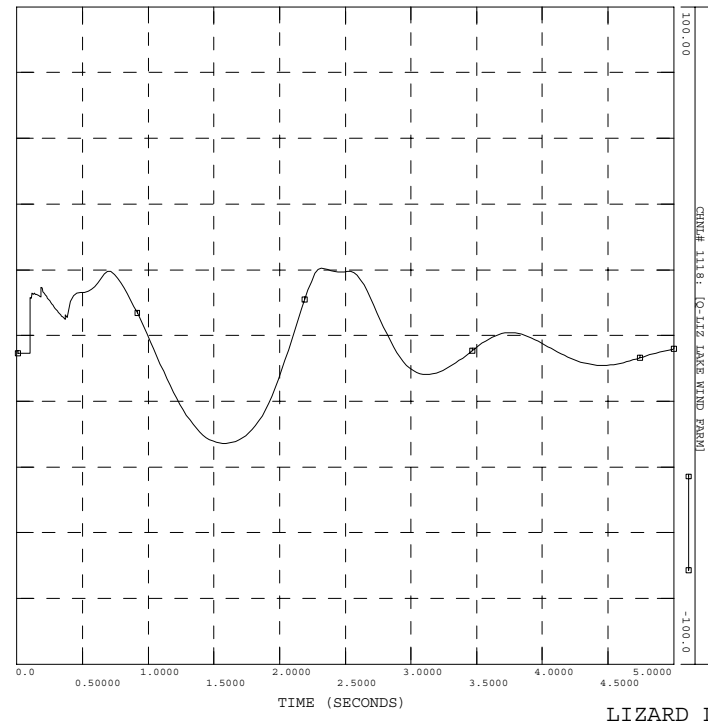
MON, AUG 28 2006 10:35
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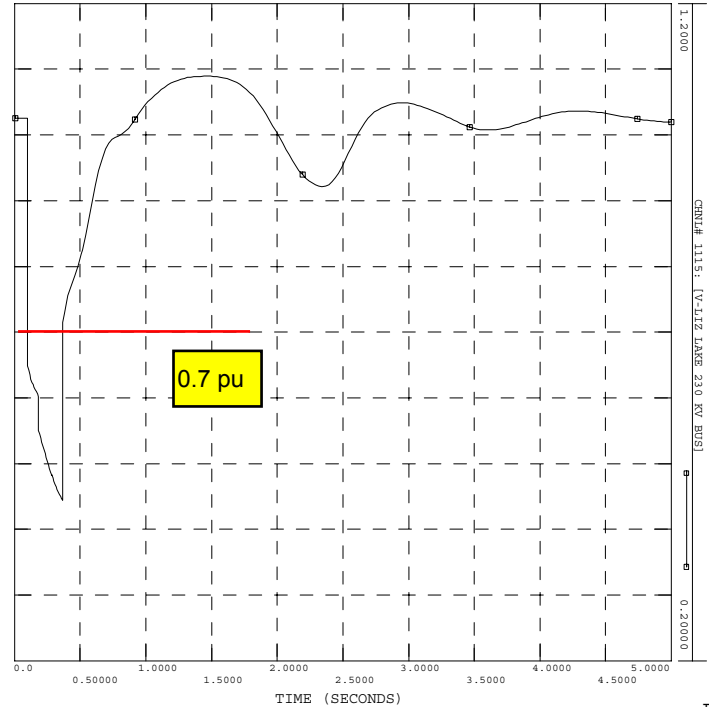
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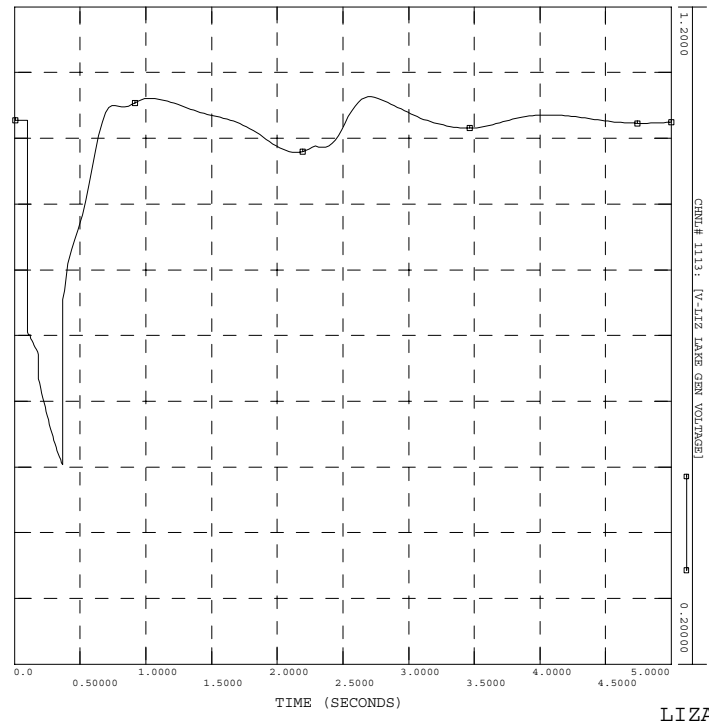
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Appendix B:

ACCC Results - Thermal Overloads with OTDF $\geq 2\%$

Contingency	Overloaded Lines	Line Name	Line Rating C (MVA)	50 MW Wind Farm -Year 2009 Overload (%)															
				MHEX = -700 Low NDEX				MHEX = 2175 Low NDEX				MHEX = -700 High NDEX				MHEX = 2175 High NDEX			
				Base Case	Wind-Dors	Wind-GR	OTDF	Base Case	Wind-Dors	Wind-GR	OTDF	Base Case	Wind-Dors	Wind-GR	OTDF	Base Case	Wind-Dors	Wind-GR	OTDF
MH-010	67519 BRANDON7 110 67720*BRANE 7 110 3	BE3	81.2	100.1	100.7	102.6	4.1	none	none	100.2	new	103.8	104.3	106.2	3.9	101.8	102.5	104.3	4.10
109 MR11	67519*BRANDON7 110 67521 NEPIWA 7 110 1	BNS	38.1	none	none	none	0.0	none	none	none	0.0	none	none	none	0.0	none	100.7	none	new
82 CB3	67524 CORNWLS4 230 67617*CORNW1 7 110 1	n/a	176.0	100.7	101.3	101.7	3.6	none	none	none	0.0	109.0	109.7	110.1	3.9	none	none	none	0.00
164 CORN BK	67524 CORNWLS4 230 67617*CORNW1 7 110 1	n/a	176.0	100.7	101.3	101.8	3.9	none	none	none	0.0	109.0	109.7	110.1	3.9	none	none	none	0.00
82 CB3	67524 CORNWLS4 230 67618*CORNW427 110 1	n/a	176.0	100.1	100.7	101.2	3.9	none	none	none	0.0	108.3	109.0	109.4	3.9	none	none	none	0.00
164 CORN BK	67524 CORNWLS4 230 67618*CORNW427 110 1	n/a	176.0	100.1	100.7	101.2	3.9	none	none	none	0.0	108.3	109.0	109.4	3.9	none	none	none	0.00
25A G82R	67557*LETELER4 230 66752 DRAYTON4 230 1	L20D	461.4	none	none	none	0.0	104.7	105.4	105.3	6.5	none	none	none	0.0	none	none	none	0.00
				100 MW Wind Farm - Year 2009 Overload (%)															
MH-003	67503 DORSEY 4 230 67530*ROSSER 4 230 3	D16R	503.5	none	none	100.2	new	none	none	none	0.0	none	none	none	0.0	none	none	none	0.00
MH-010	67519 BRANDON7 110 67720*BRANE 7 110 3	BE3	81.2	100.1	101.4	105.1	4.1	none	none	102.7	new	103.8	105.0	108.7	4.0	101.8	103.1	106.7	4.02
109 MR11	67519*BRANDON7 110 67521 NEPIWA 7 110 1	BNS	38.1	none	none	none	0.0	none	none	none	0.0	none	none	none	0.0	none	102.3	100.4	new
82 CB3	67524 CORNWLS4 230 67617*CORNW1 7 110 1	n/a	176.0	100.7	102.0	102.6	3.4	none	none	none	0.0	109.0	110.4	110.9	3.4	none	none	none	0.00
164 CORN BK	67524 CORNWLS4 230 67617*CORNW1 7 110 1	n/a	176.0	100.7	102.0	102.6	3.4	none	none	none	0.0	109.0	110.4	110.9	3.4	none	none	none	0.00
82 CB3	67524 CORNWLS4 230 67618*CORNW427 110 1	n/a	176.0	100.1	101.4	102.0	3.4	none	none	none	0.0	108.3	109.7	110.3	3.6	none	none	none	0.00
164 CORN BK	67524 CORNWLS4 230 67618*CORNW427 110 1	n/a	176.0	100.1	101.4	102.0	3.4	none	none	none	0.0	108.3	109.7	110.3	3.6	none	none	none	0.00
25A G82R	67557*LETELER4 230 66752 DRAYTON4 230 1	L20D	461.4	none	none	none	0.0	104.7	106.0	105.9	6.1	none	none	none	0.0	none	none	none	0.00
				50 MW Wind Farm -Year 2014 Overload (%)															
MH-010	67519 BRANDON7 110 67720*BRANE 7 110 3	BE3	81.2	none	none	none	0.0	none	none	none	0.0	none	none	none	0.0	none	none	100.7	new
82 CB3	67524 CORNWLS4 230 67617*CORNW1 7 110 1	n/a	176.0	none	none	none	0.0	none	none	none	0.0	106.1	106.7	106.8	2.5	none	none	none	0.0
164 CORN BK	67524 CORNWLS4 230 67617*CORNW1 7 110 1	n/a	176.0	none	none	none	0.0	none	none	none	0.0	106.1	106.7	106.8	2.5	none	none	none	0.0
82 CB3	67524 CORNWLS4 230 67618*CORNW427 110 1	n/a	176.0	none	none	none	0.0	none	none	none	0.0	105.5	106.1	106.2	2.5	none	none	none	0.0
164 CORN BK	67524 CORNWLS4 230 67618*CORNW427 110 1	n/a	176.0	none	none	none	0.0	none	none	none	0.0	105.5	106.1	106.2	2.5	none	none	none	0.0
25A G82R	67557*LETELER4 230 66752 DRAYTON4 230 1	L20D	461.4	none	none	none	0.0	106.1	106.9	106.9	7.5	none	none	none	0.0	none	none	none	0.0
				100 MW Wind Farm - Year 2014 Overload (%)															
MH-010	67519 BRANDON7 110 67720*BRANE 7 110 3	BE3	81.2	none	none	none	0.0	none	none	none	0.0	none	none	none	0.0	none	100.2	102.2	new
82 CB3	67524 CORNWLS4 230 67617*CORNW1 7 110 1	n/a	176.0	none	none	100.0	new	none	none	none	0.0	106.1	107.3	107.5	2.5	none	none	none	0.0
164 CORN BK	67524 CORNWLS4 230 67617*CORNW1 7 110 1	n/a	176.0	none	none	100.0	new	none	none	none	0.0	106.1	107.3	107.2	2.1	none	none	none	0.0
82 CB3	67524 CORNWLS4 230 67618*CORNW427 110 1	n/a	176.0	none	none	none	0.0	none	none	none	0.0	105.5	106.9	106.9	2.5	none	none	none	0.0
164 CORN BK	67524 CORNWLS4 230 67618*CORNW427 110 1	n/a	176.0	none	none	none	0.0	none	none	none	0.0	105.5	106.7	106.6	2.1	none	none	none	0.0
25A G82R	67557*LETELER4 230 66752 DRAYTON4 230 1	L20D	461.4	none	none	none	0.0	106.1	107.7	107.5	7.5	none	none	none	0.0	none	none	none	0.0