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Long Lake Hydro Project

Interconnection System Impact Study

Report No. ASP2010-T053

August 2010

British Columbia Hydro and Power Authority

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Executive Summary

The XXXX, the Interconnection Customer (IC), proposes to develop Long Lake Hydro Energy project to deliver electric energy to BC Hydro (BCH) through the 2008 Clean Power Call (CPC). This project consists of one generating station located near Stewart, British Columbia.

This report identifies the required system modifications for interconnecting the proposed Long Lake Hydro Project. The Long Lake Hydro Project consists of two identical generating units in one station. The maximum power injection is 34.2 MW at the Point of Interconnection (POI) which is the new established Long Lake Hydro Terminal Station (LNT) on the 138 kV transmission line 1L381, located approximately 7.5 km from STW substation. The proposed Commercial Operation Date (COD) is November 15, 2012.

In order to interconnect the Long Lake Hydro project and its facilities to the BCH Transmission System, this System Impact Study (SIS) has identified the following issues and requirements:

- Construction of a new 138 kV switching station (LNT) at the POI on line 1L381.
- No unacceptable voltage performance in the Transmission System was observed in the power flow and transient stability analysis under normal and N-1 contingencies.
- No unacceptable equipment overload condition in the Transmission System was observed in the power flower simulations under normal and N-1 contingencies.
- No voltage instability has been observed in the Transmission System.
- Static exciters with power system stabilizer are required for the LNL generator units for system damping requirements.
- Islanded operation is not allowed. Power quality protection is required to prevent/mitigate possible islanded operation.
- Electromagnetic transient voltage violation conditions have been identified for the ferro-resonance and self-excitation conditions. Respective schemes of tripping the IC units prior to line switching in the SKA/ AYH ends as removing driving force from system, and addition of a 138kV 3MVAR shunt capacitors for de-tuning circuit are required.
- The voltage dip due to transformer inrush when energizing the IC transformer after the plant is out of service appears to exceed the limits stated in the BC Hydro's interconnection guide. Consequently, a transformer inrush control scheme may be required. The IC will be responsible for undertaking the studies required to determine the necessity of an inrush mitigation scheme.
- The non-binding good faith cost estimate for Interconnection Network Upgrades is $29.0M.
- The estimated time to construct the Network Upgrades is estimated at 24 months.

The Interconnection Facilities Study report will provide greater details of the Interconnection Network Upgrade requirements and associated cost estimates and estimated construction timeline for this project.

Table of Contents

1.0 Introduction

The project reviewed in this SIS report is as described in Table 1 below.

Table 1: Summary Project Information

Project Name	Long Lake Hydro Project	
Interconnection Customer (IC)	XXXX	
Point of Interconnection (POI)	A new 138 kV station, Long Lake Hydro Terminal Station (LNT) on the 138 kV circuit 1L381 and located about 7.5 km from Stewart (STW) substation.	
IC Proposed COD	November 15, 2012	
Type of Interconnection Service	NRIS ☒	ERIS ☐
Maximum Power Injection (MW)	34.2 (Summer)	34.2 (Winter)
Number of Generator Units	2	
Plant Fuel	Hydro	

XXXX, the Interconnection Customer (IC), proposes to develop the Long Lake Hydro Project to deliver electric energy to BC Hydro (BCH) through the 2008 Clean Power Call (CPC).

The Long Lake Hydro Project will directly connect to the 138 kV transmission line, 1L381, at the new Long Lake Hydro Terminal Station (LNT), via a 10 km customer-owned 138 kV transmission line. The proposed maximum power to be injected into BCH system is 34.2 MW.

After addition of the Long Lake Hydro Terminal Station (LNT), the existing circuit, 1L381 AYH-STW, will be split into two lines: one between AYH and LNT which is still designated as 1L381 and the other between LNT and STW which is designated as 1L402.

The Point of Interconnection (POI) is the new LNT substation. The proposed Commercial Operation Date (COD) is November 15, 2012. Figure 1 shows the connection of the Long Lake Hydro Project to the BCH Transmission System.

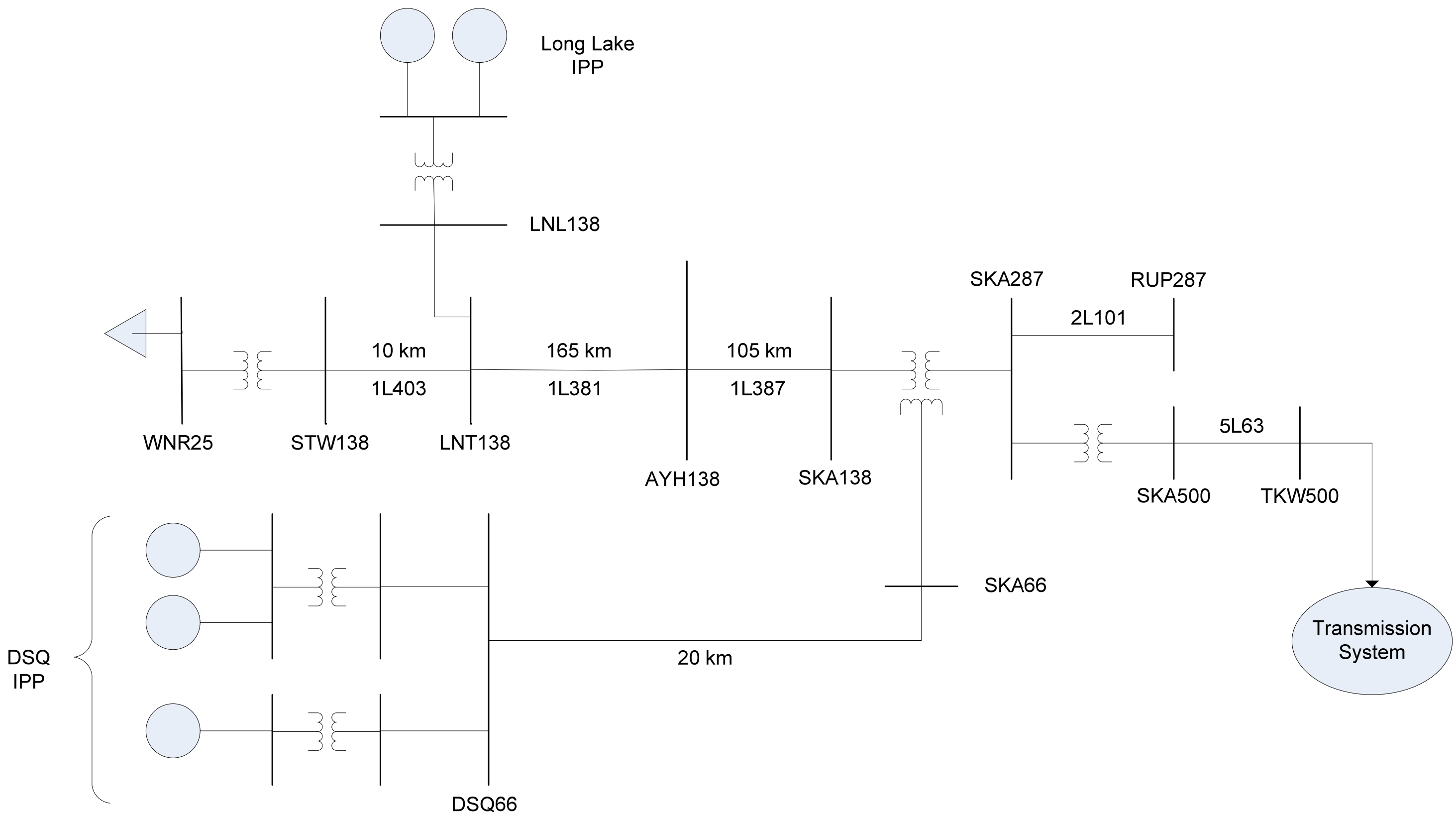

Figure 1 – Long Lake Hydro Project geographical interconnection scheme.

2.0 Purpose of Study

The purpose of this SIS is to assess the impact of the interconnection of the proposed project on the BCH Transmission System. This study will identify constraints and Network Upgrades required for the reliable operation of the Transmission System.

3.0 Terms of Reference

This study investigates and addresses the voltage and overloading issues of the transmission networks as a result of the proposed interconnection. Topics studied include equipment thermal loading and rating requirements, system transient stability and voltage stability, transient over-voltages, protection coordination, operation flexibility, telecom requirements and high level remedial action scheme requirements. BCH planning methodology and criteria are used in the studies.

The SIS does not investigate operating restrictions and other factors for possible second contingency outages. Subsequent internal network studies will determine the requirements for reinforcements or operating restrictions/instructions for those kinds of events. Impact to the bulk Transmission System is not included in the SIS and will be covered in a separate study.

The work necessary to implement the network improvements identified in this SIS report will be described in greater detail in the Interconnection Facilities Study report for this project.

4.0 Assumptions

The power flow conditions studied are base cases that include generation, transmission facilities, and load forecast representing the queue position applicable to this project. Applicable seasonal conditions and the appropriate study years for the study horizon are also incorporated. The 2012 heavy winter, 2013 heavy summer and light summer load flow base cases were selected for this study.

- The study is based on the model and data information provided by the IC in the Generator Interconnection Data Form for this project. Reasonable assumptions are made to complete the study and the report, whenever such information is unavailable. Static exciters with power system stabilizer are required for the LNL generator units for system damping requirement.

The following proposed reinforcement is included:

The addition of a 3 circuit breaker ring switching station on 1L381 at the POI. This is required to mitigate the impact on the reliability of the supply to Stewart.

The fault clearing times employed in this impact study are described in the table below:

Outage Facility	3Φ Fault Location	Fault Clearing Time (~)	
		Close End	Far End
MEZ 25 kV Feeder 25F52	MEZ	48.5	48.5
60L383 (SKA-TER) , or 60L394 (SKA-KAL)	SKA 66	11	TER or KAL 11
1L387 (SKA-AYH)	SKA 138	8	N/R
2L101 (SKA-RUP)	SKA 287	6	N/R
2L99 (SKA-MIN)	SKA 287	6	N/R
2L103 (MIN-KIT)	MIN 287	8	N/R
SKA T2 and T4	SKA T2 HV side	6	N/R

SKA T1, T5 and T6	SKA T1 HV side	6	N/R
KMO- KIT 287kV line	KMO 287 (Single Phase fault) Auto-reclosed 74 ~ after fault.	12	12
SKA500-TKW500 line	SKA 500 (Single Phase fault) Auto-reclosed SKA-64~; TKW62~ after fault.	4	4

Note: “~” denotes cycles.
“N/R” denotes Not Required.

5.0 System Studies

Power flow, short circuit and transient stability studies were carried out to evaluate the impact of the proposed interconnection. Studies were also performed to determine the protection, control and communication requirements and to evaluate possible over-voltage issues.

5.1 Steady State Pre-outage Power Flows

Pre-outage power flows are prepared to assess the impact of the IC connection using three basic system load conditions: 2012 winter peak load, 2013 summer light load and 2013 summer peak load, and defined generation conditions. The steady-state power flow studies have indicated:

- Bus voltages are acceptable.
- No circuits are overloaded before and after the IC connection.

Table 1 provides the power flow study results for the IC interconnection

Table 1- Steady State Power Flow Study Results for the IC Interconnection

System Load Condition	System configuration	MW Injection from LNL	Bus Voltage (in per unit)				Power Flow (MW)				Comment
			STW 138	AY H 138	SKA 66	SKA 287	1L387 (AYH-SKA Rating: 63 MVA)	SKA T4 (Rating: 93MVA)	SKA T5 (Rating: 93MVA)	5L63 (SKA-TKW Rating 1732 MVA)	
2012 HW	Normal	34	1.04	0.97	1.03	1.02	21	-7	-8	320	Acceptable.
2013 HS	Normal	34	1.04	0.97	1.00	1.02	126	1	1	370	Acceptable.
2013 LS	Normal	34	1.04	0.97	0.98	1.01	29	6	7	413	Acceptable
2013 LS	Normal- (no IPP)	0	1.02	0.99	0.98	1.01	-3	-3	-3	362	Acceptable.

Note: - 'HW', 'HS' and 'LS'denote heavy winter, heavy summer and light summer system conditions respectively.

Table 2- Steady State Power Flow Study Results for LNL IPP

System Load Condition	System contingency	MW Injection from LNL	Bus Voltage (in per unit)				Power Flow (MW)				Comment
			STW 138	AYH 138	SKA 66	SK A 287	1L387 (AYH-SKA Rating: 63 MVA)	SKAT4 (Rating: 93MVA)	SKA T5 (Rating: 93MVA)	5L63 (SKA-TKW) (Rating: 1732 MVA)	
2013 LS	2L101 (SKA-RUP)	34	1.04	0.97	0.98	1.0 0	29	6	7	411	Acceptable.
2013 LS	2L99 (SKA-MIN)	34	1.04	0.97	0.98	1.0 2	29	6	7	44	Acceptable.
2013 LS	SKA T2& T4	34	1.04	0.98	0.99	1.0 2	29	6	7	413	Acceptable.

5.2 Power Flow Based First Contingency Study

Power flow based single contingency (N-1) studies have been conducted to check if the post-disturbance performance including bus voltage deviation and facility loading meets the planning criteria under different system load conditions including heavy winter, heavy summer and light summer.

The studies have indicated that there is no transmission equipment over-loading problem and no voltage deviation violation conditions due to the addition of the Long Lake Hydro Project.

The contingency study results based on the most severe 2013 summer light load are listed in Table 2 above.

5.3 Transient Stability Study

A series of transient stability studies under various system operating conditions including the heavy winter case and the most severe light summer case have been performed. The model of the proposed generation project was based on the IC’s data submission plus additional assumptions where the IC’s data was incomplete/ inappropriate. The models and data values of the key components are shown in Appendix A.

Transient stability studies have been performed using the 2013 light summer base cases for the worst system conditions to assess the impact of 34 MW maximum power injections from LNL Project. Some results are tabulated in Table 3 below. No transient instability and transient voltage performance violations have been observed based on the studied scenarios and contingencies. Faults on 1L387 (SKA-AYH) will result in islanding of the IC plant. Power quality type protection systems are required to trip off the units and prevent islanding operation.

Out of step protection are required and should be provided by the IC as standard generator protective equipment against slips caused by unexpected contingencies. Summary of system stability study results under the most severe 2013 light summer load condition is shown in below.

Table 3- Transient Stability Study Results

(Pre-outage condition: 2013 LS with 34 MW injections from the project)

case	Outage	Three Phase Fault Location	Clearing time (cycles)	Max Rotor Swing (deg)	Min/ Max voltage (pu)	Duration of voltage dip below 0.8 pu (seconds)	Comments
2009 Light Summer Case With Heavy Alcan to BCH export							
1	MEZ 25 kV feeder 25F52	MEZ25	48.5	12	0.92pu @ SKA138	0.	Acceptable.
2	60L383 or 60L394	SKA66 or SKA T4 66 kV side	11	22	0.91pu @ SKA138	0.	Acceptable. LNL-DSQ IPP's tripped by out of step relay.
3a	1L387	SKA138	8	18	0.91pu @ SKA138	0.	Acceptable.LNL islanded.
3b	1L387	AYH138	98	8	0.92pu @ SKA138	0.	Acceptable.LNL islanded.
4	SKA T2, T4	SKA287	6	40	0.85pu @ DSQ66	0.	Acceptable.
5	SKA T1, T5, T6	SKA287	6	60	0.78 @ DSQ66	0.13	Acceptable. Long Lake island to be removed.
6	2L101	SKA287	6	50	0.99 @ SKA138	0.	Acceptable. Rupert area islanded. 2L103 (MIN-KIT) tripped due to v-MIN< 0.85pu.
7	KMO-KIT 287 kV line Single phase	KMO287 ***Single line to ground fault***	12 (auto-reclose 86 ~ after fault)	38	0.80 @SKA138	0.	Acceptable.Existing KMO export limit confirmed. (See Appendix B)
8	SKA-TKW 5L63 kV line Single phase	KMO287 ***Single line to ground fault***	4 (auto-reclose 46 ~ after fault)	28	0.86 @SKA138	0.	Acceptable. Existing KMO export limit confirmed.

(All above stability swings except for island conditions are acceptable according to the BCH/ WECC Reliability Criteria.)

5.4 Islanding

Islanded operation is normally not an acceptable practice in BCH. Power quality protection will be required at the generating units to detect abnormal system conditions such as under/over voltage and under/over frequency and subsequently trip the units. The settings of these protective relays must conform to existing BCH practice for generating plants so that the generator will not trip for normal ranges of voltages and frequencies.

5.5 Fault Analysis

The short circuit analysis for the CPC System Impact Studies are based upon the latest BCH system short circuit model, which includes project equipment and impedances provided by the successful CPC Interconnection Customers. The model included higher queued projects and planned system reinforcements but excluded the Northwest Transmission Line (NTL) and other lower queued projects. At this stage, the report does not provide Thevenin impedances at the POI due to uncertainties associated with the system reinforcement options identified for the CPC projects and the statuses of higher queued projects. However, these Thevenin impedances, including the ultimate fault levels at POI, will be made available to Interconnection Customers upon request.

BCH will work with the IC to provide accurate data as required during the project design phase.

5.6 Analytical Studies

Certain unacceptable electromagnetic transient temporary and transient voltage issues were identified due to ferro-resonance and self- excitation conditions. Applicable correction schemes have been adopted for connecting this project. Respective schemes of tripping IC units prior to line switching at the SKA/ AYH ends and addition of a 138kV 3MVAR shunt capacitor for de-tuning the circuit are required. The application of a fixed switchable 138 kV shunt capacitor at STW will lower the 5th resonance level and also minimize the impact of the project on the existing 4th harmonic resonance condition. Combined with a controlled transformer de-energization/energization, the impact on the system 4th harmonic resonance can be minimized. Detailed technical and economical review will be required at a later stage in the interconnection process.

In an earlier report by BC Hydro, fourth harmonic resonance on 1L381 was identified. This resonance could potentially result in over voltages that could in turn, result in transformer saturation. BC Hydro has installed a neutral capacitor on Stewart's T3 to short out the 4^{th} harmonic current. This transformer's neutral capacitor and related components must be replaced with a minimum of 1.2 kA rating. The IC should conduct its own studies to determine if it needs to implement measures to mitigate the impact of this resonant condition at their facility.

The Long Lake 138kV entrance breaker should be an independent pole breaker and the IC transformer should be energized using point-on-wave closing to reduce the voltage sag to acceptable levels.

The IC should consider applying neutral blocking capacitors in the 138kV neutral of the generator step-up transformer to block the flow of quasi-DC currents caused by solar magnetic storms. Half-cycle saturation of the transformer will inject harmonics (including fourth) in the exciting currents which could cause unacceptable voltage distortion in the SKA-STW system.

Any opening of 1L387 at SKA or 1L381 at AYH for no fault conditions when Long Lake plant is connected must be prevented to prevent unacceptable temporary overvolatges. This requires that a DTT facility be implemented at SKA and at AYH which will open the 138kV breaker to Long Lake before opening the local breaker for any supervisory (local or remote) signal that would open these breakers.

5.7 Protection and Control & Telecommunications

Protection, control and telecom requirements for the new LNL generator addition have been reviewed. The main items are summarized below:

Protection and Control

New LNL Station

Provide primary and standby communication independent protection for the three line terminals.

Received DTTs from AYH and SKA will trip the LNL 1L403 terminal.

AYH Station

Replace existing 1L381 protection, which use non-directional overcurrent relays with primary and standby protection using SEL-421-2 relays. A three phase set of CVTs will be required for the AYH 1L381 terminal.

Manual opening of AYH 1L381 terminal will initiate DTT to LNL, with delayed opening at AYH.

STW Station

Provide protection for a 138 kV shunt capacitor bank. Provide logic to switch the capacitor bank depending on how many of the IC generators are connected to the system.

Review STW protection and revise settings as necessary due to increased fault level.

SKA Station

Replace existing electro-mechanical relays used for SKA 1L387 protection with primary and standby protection using SEL-421-2 relays.

Manual or protection initiated opening of SKA 1L387 terminal will initiate DTT to LNL, with delayed opening at SKA.

Telecommunications

Summary of Protection/RAS/SCADA Requirements

- Provide Class 2 communications facilities for DTT from AYH to LNL, and for DTT from SKA to LNL.
- Provide Class 2 communications facilities from the IC plant to STW, for two DTTs to indicate whether one or both of the IC's generators is connected to the system.
- Provide one continuous 2400 bps channel between LNL and WSN DCP via SKA.
- Provide one dial-up line into LNL for remote access to relays.

Summary of Telecommunication Work

- New Power Line Carrier will be installed between the following sites for this project: SKA-AYH, AYH-MZN, MZN-LNL
- ADSS fibre will be installed between LNL and STW, approximately 7.5km.
- High Voltage Entrance equipment will be installed at LNL.
- Teleprotection equipment will be installed at the following sites: SKA, LNL, AYH

5.8 BCH System Black Start Capability

BCH does not require the proposed project to have black start (self-start) capability.

However, if the IC desires their facilities to be energized from the BCH system, the IC is required to apply for an Electricity Supply Agreement. Upon receipt of this application, a plant pick-up study would be required to assess the impact of energizing the IC's facilities.

A high level plant pick-up screening was performed as part of the SIS and any issues are identified in Section 5.6.

5.9 Transmission Line Upgrade Requirements

The POI is located close to a flood plane. The POI station may have to be moved across the highway, thereby triggering either a relocation of the existing transmission line 1L381 (Aiyansh to Stewart), or a longer loop circuit.

The Transmission Line Upgrade Requirements consist of:

- Installation of two standard vertical dead-end 138 kV structures to form the loop in/out arrangement from the existing circuit 1L381.
- Two standard vertical dead-end structures for change in conductor tension just outside the station fence.
- Likely installation of up to and estimated eight standard single pole 138 kV overhead structures (four structures for each leg of the new loop circuit).
- Installation of approximately 10 spans of overhead three phase conductor.
- Acquisition and clearing of new right-of-way for the loop circuits.

5.10 Additional BCH Station Upgrades/Additions

To accommodate the Long Lake Hydro project's interconnection into the Transmission System, a new three-breaker ring substation at the POI is required to terminate the IC's 138 kV line into the system. The POI requires that the interconnection substation to be built on a potential flood plane by the side of the river. To avoid building on the flood plain it may be necessary to build the interconnecting substation on the other side (i.e. east) of the highway. This change of location would require the relocation of portions of 1L381 to the east of the highway.

The following modifications at Aiyansh substation are required:

- Add one 138 kV CVT.
- Replace existing 1CB1 to ensure the TRV requirements are met.

5.11 Other Issues

This generating project is located in the northwest area of BC which is prone to low frequency inter-area oscillations among the WECC inter-connected systems. Power system stabilizers (PSS) have been installed in various power plants in the area for decades in order to maintain reliable and efficient system operation. The LNL generator units should be equipped with static exciters and PSS to maintain acceptable system damping. The proposed DECS 200 excitation system should be upgraded to the DECS 400, the static exciter with the PSS2A type PSS.

5.12 Cost Estimate and Schedule

The non-binding good faith cost estimate for the Interconnection Network Upgrades is $29.029M. The Interconnection Facilities Study report will provide more detailed information of the cost estimates.

The estimated time to construct the Interconnection Network Upgrades is estimated at 24 months after the Standard Generation Interconnection Agreement is signed and BCH capital project is approved. A more detailed construction timeline will be provided in the Interconnection Facilities Study report.

BCH system upgrades triggered by CPC projects are being determined and the IC may be required to post security to cover one or more upgrade. Further information will be provided over the next few months.

6.0 Conclusion & Discussion

In order to interconnect the Long Lake Hydro Project to the BCH Transmission System at the POI, this SIS has identified the following issues and requirements:

- Construction of a new 138 kV switching station (LNT) at the POI.
- No unacceptable steady state voltage condition in the Transmission System was observed in the power flow and transient stability analysis.
- No unacceptable equipment overload condition in the Transmission System was observed.
- No voltage instability has been observed in the Transmission System.
- Static exciters with power system stabilizer are required for the LNL generator units for system damping requirement.
- Islanded operation is not allowed. Power quality protection is required to prevent/mitigate possible islanded operation. Due to the possibility of islanding conditions that the power quality protection may not cover, for opening of 1L387 at SKA or 1L381 at AYH, a transfer tripping scheme is required to prevent the Long Lake Hydro plant from islanded operation and un-acceptable over-voltage conditions.
- Electromagnetic transient voltage violation conditions have been identified for the ferro-resonance and self-excitation conditions. Respective schemes of tripping the IC units prior to line switching on the SKA/ AYH ends and addition of a 138kV 3MVAR shunt capacitor for de-tuning circuit is required.
- The voltage dip due to transformer inrush when energizing the IC transformer appears to exceed the limits stated in the BC Hydro’s interconnection guide. Consequently, a transformer inrush control scheme may be required. The IC will be responsible for undertaking the studies required to determine the necessity of an inrush mitigation scheme;

Appendix A Long Lake Hydro Project Model and Data

The contents of this section have been removed due to the proprietary nature of the information.

LNL Excitation Control System Model

The contents of this section have been removed due to the proprietary nature of the information.

Appendix B Post disturbance stability swings of the BCH- LNL interconnected system

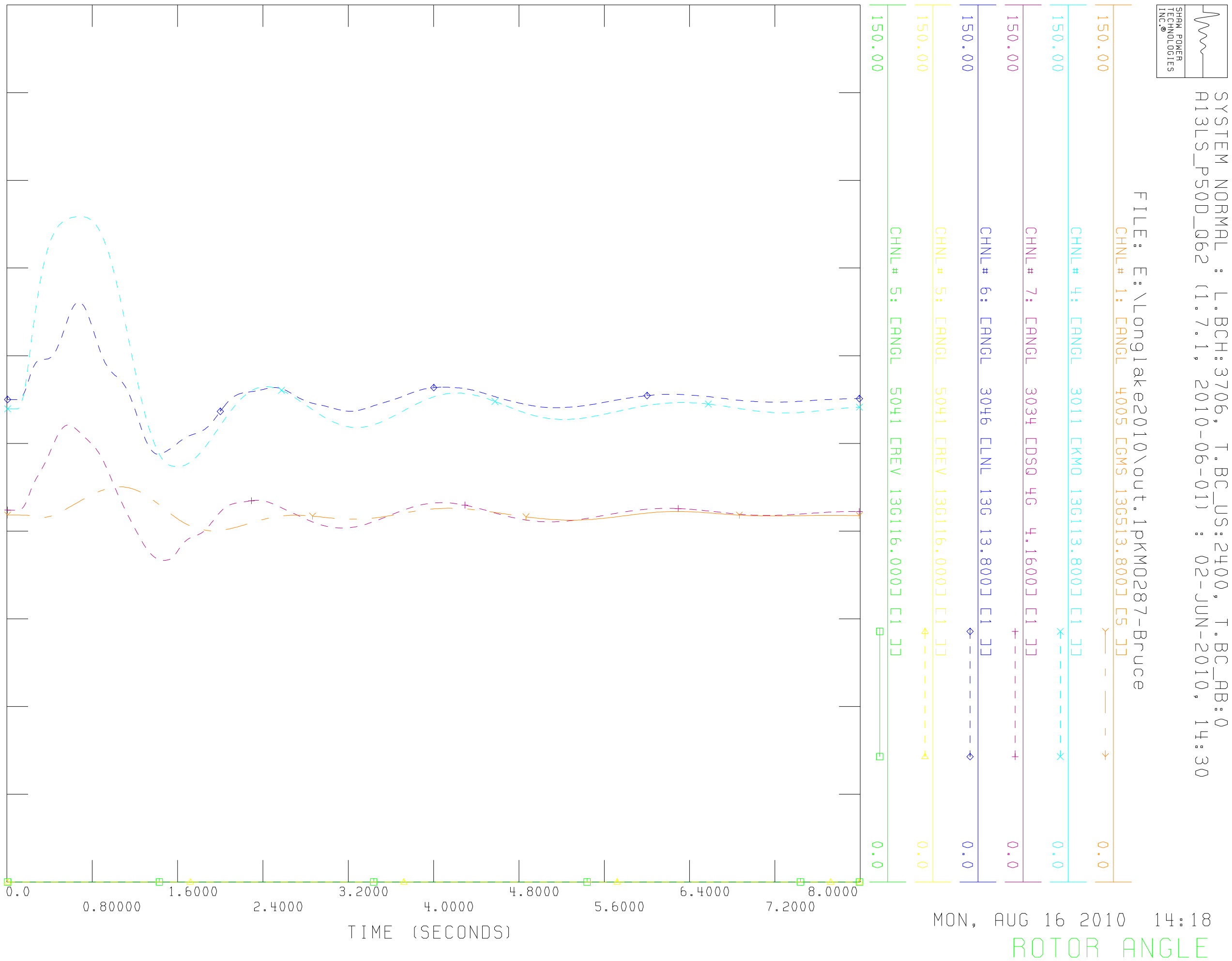

Figure A 1-1: Stability swings of rotor angle for a single phase 12 cycle fault at KMO with successful auto-reclose on KMO-KIT 287 kV line.

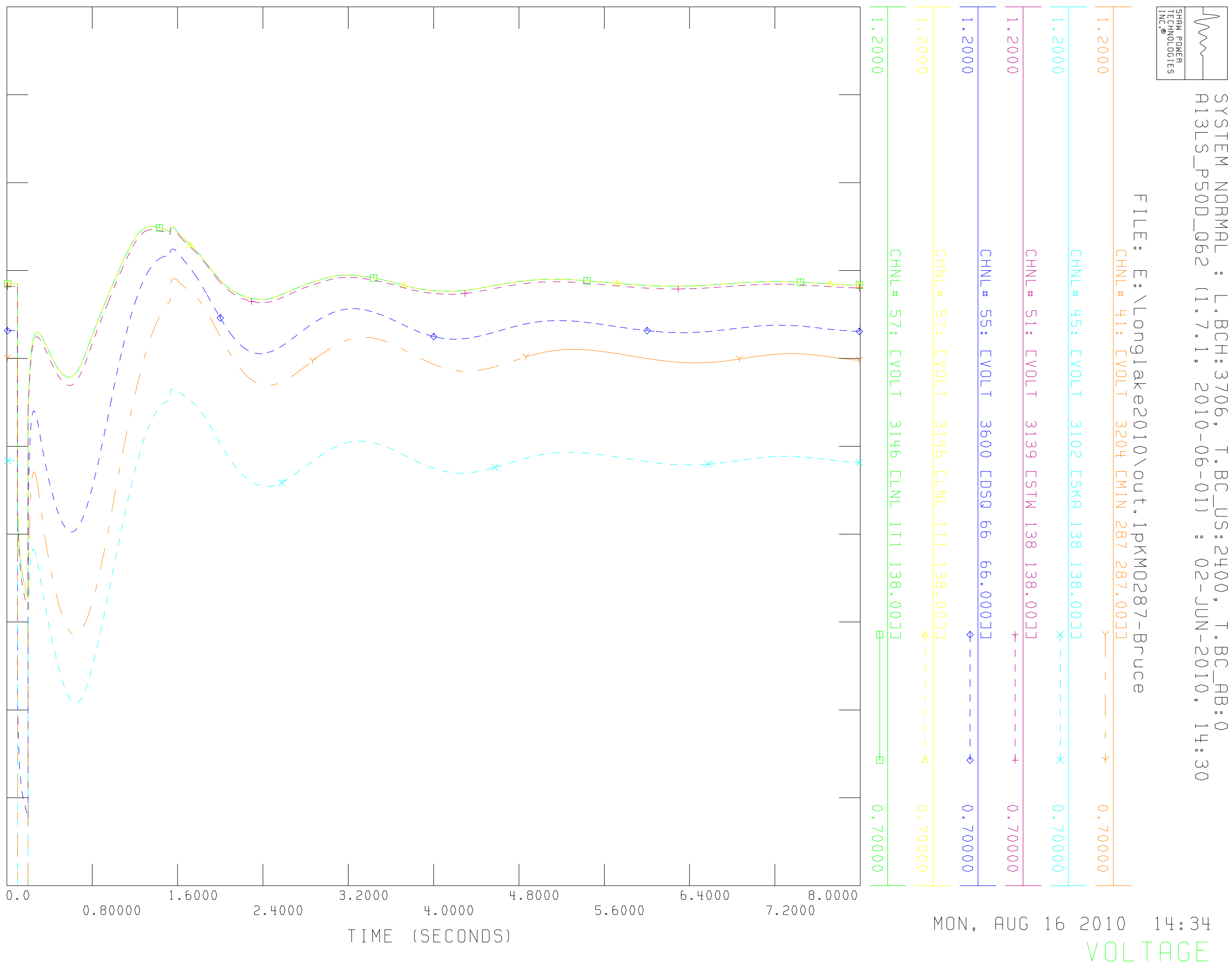

Figure A 1-2: Stability swings of bus voltage for single phase 12 cycle fault at KMO with successful auto-reclose on KMO-KIT 287 kV line.

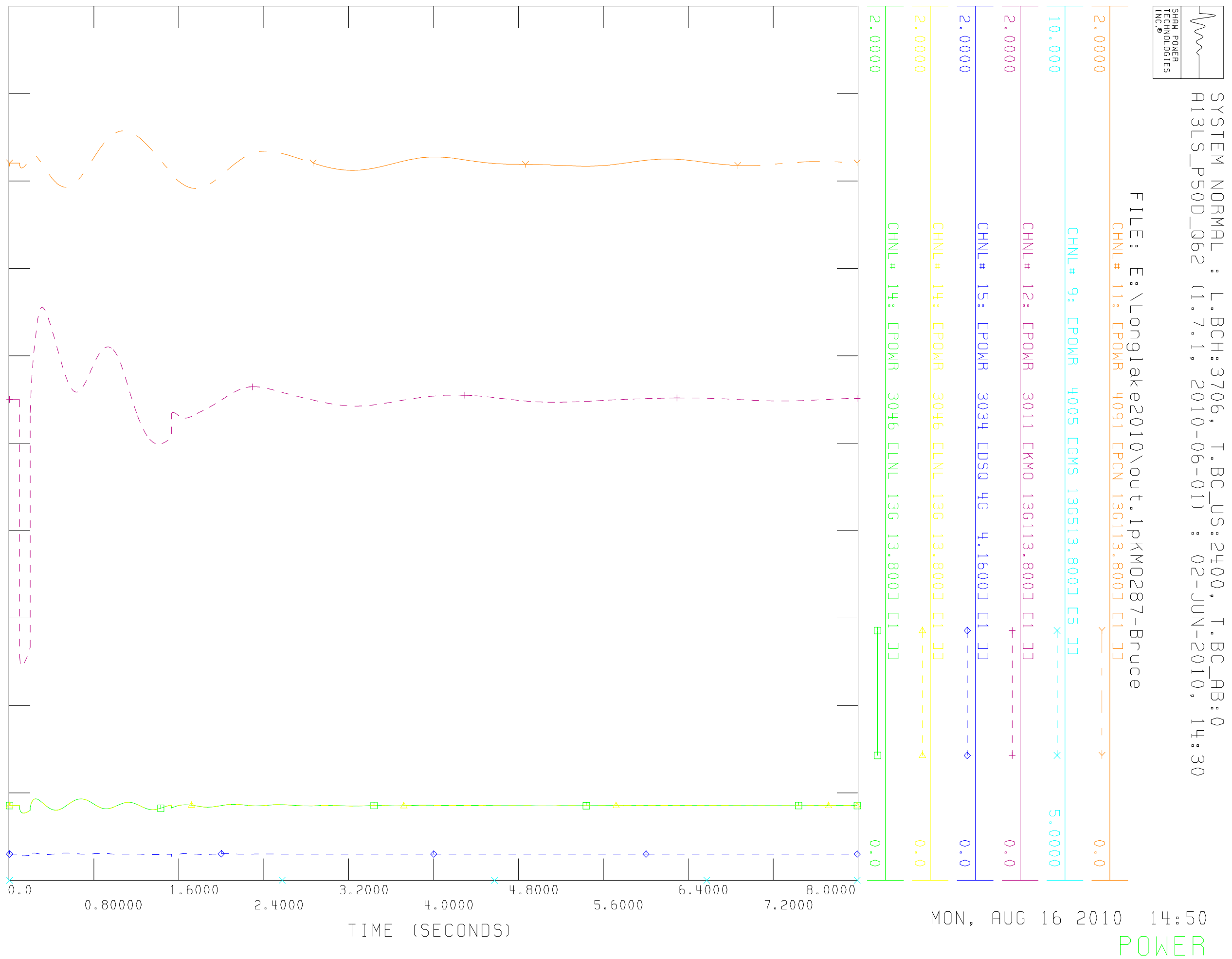

Figure A 1-3: Stability swings of power for a single phase 12 cycle fault at KMO with successful auto-reclose on KMO-KIT 287 kV line.

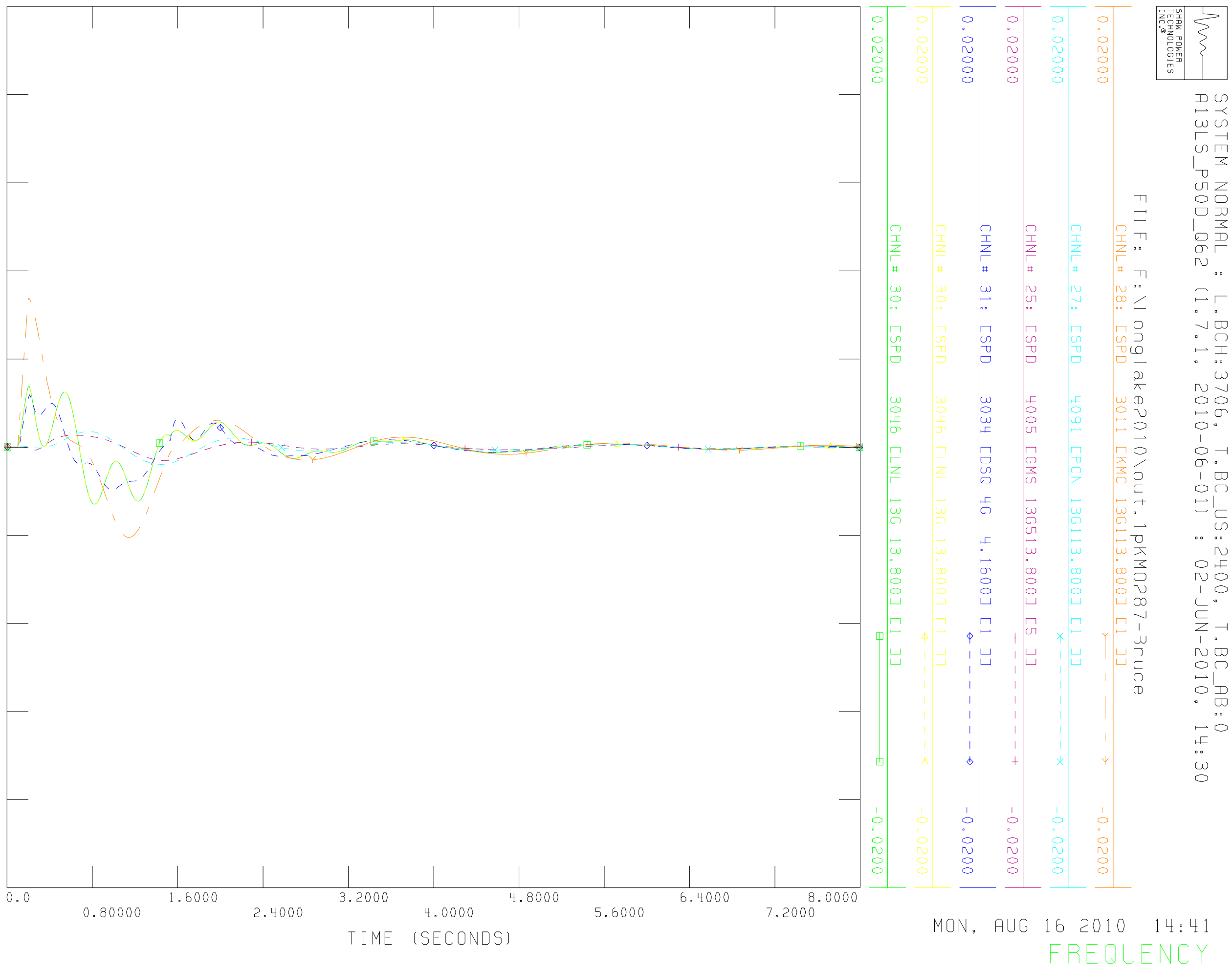

Figure A 1-4: Stability swings of frequency for a single phase 12 cycle fault at KMO with successful auto-reclose on KMO-KIT 287 kV line.

