Interconnection System Impact Study

[redacted]

Pennask and Shinnish Creek Wind Project

Report No: T&S Planning 2014-072

December 2014

DRAFT

British Columbia Hydro and Power Authority

ACKNOWLEDGEMENTS

This report was prepared and reviewed by T&D, Interconnection Planning and approved by both Interconnection Planning and Transmission Generator Interconnections.

Revision Table

Revision Number	Date of Revision	Revised By

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EXECUTIVE SUMMARY

[redacted] the Interconnection Customer (IC), is proposing Pennask and Shinnish wind farm in the South Interior of British Columbia. The wind farm consists of two sites: one at Pennask Creek and the other at Shinnish Creek. Each site will have 7 Senvion wind turbines each rated at 2.05 MW. The total wind farm installed capacity is 28.7 MW. The IC will build 34.5 kV feeders from Pennask Creek and from Shinnish Creek to a common station (Pennask and Shinnish Wind, or PSW) where the power from these two sites are combined and stepped up to 138 kV.

The POI (Point-of-Interconnection) is a line tap on the 138 kV circuit 1L244 between Nicola (NIC) and Westbank (WBK) substations, at a distance of 38 km from NIC. The IC will build a 138 kV transmission line from PSW to the POI. The length of this tap line is 0.5 km. The Commercial Operation Date (COD) proposed by the IC is June 1 2015. The maximum power injection at the POI is about 27.5 MW, after accounting for the losses inside the wind farm.

This report documents the evaluation of the system impact of interconnecting the proposed generation facilities and identifies the required system modifications to obtain acceptable system performance with the interconnection of the subject project. To interconnect the IC's project and its facilities to the BCH Transmission System, this System Impact Study (SIS) has identified the following conclusions and requirements:

- There are no unacceptable pre-contingency or single contingency (N-1) overloads or voltage conditions observed for the proposed maximum power injection from PSW. Hence, no transmission element would need to be upgraded for this project.
- A 138 kV disconnect switch needs to be installed near the POI to connect the IC's tap line, and the existing 1L244 line protection relays at NIC needs to be replaced.
- A direct transfer trip (DTT) from NIC to the PSW 138 kV circuit breaker is needed to isolate the wind farm when 1L244 is disconnected from the system. A WECC Class 3 communication channel is required to support the DTT.
- It is the IC's responsibility to provide a non-redundant WECC Class 3 communication facility for the transfer trip and SCADA purposes. A pair of 4-wire Leased Line from Telus or microwave communication channels is acceptable.
- Transformer energization inrush mitigation control is required to avoid a negative impact on existing customers at WBK and BDM. This can be achieved by implementation of Point On Wave controller with flux calculation, Point On Wave with controlled opening/closing the IC's 138 kV breaker or by fast motorized disconnects with arcing horns by the IC at its PSW station.
- To keep the induced voltage by the 500 kV circuit 5L98 (NIC-VAS or Vaseux Lake) on the Shinnish 34.5 kV feeder within the acceptable limit, the center of the right-of-way for Shinnish 34.5 kV feeder that parallels 5L98 must be at least 47 meters from the center of the right-of-way for 5L98.

The good faith non-binding cost estimate to complete BCH Network Upgrades required for Pennask and Shinnish Wind Farm connection is $1.521 million for the leased line communication option and 1.773 million for the microwave communication option. The Network Upgrades identified above can be expected to complete in approximately 12 months after funding is approved. The Interconnection Facilities Study report will provide greater details of the necessary requirements and estimated timeline for the interconnection project.

The work required within the IC facilities is not part of this estimate and schedule.

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1.0 INTRODUCTION

[redacted] is proposing to develop the Pennask and Shinnish wind farm in the South Interior Region in British Columbia. The project consists of two different sites at Pennask Creek and Shinnish Creek. Each of these two sites will have 7 Savion wind turbines with a total capacity of 14.35 MW. The combined output from Pennask Creek and from Shinnish Creek is 28.7 MW. The IC will build two 34.5 kV feeders to connect the Pennask site and the Shinnish site to its Pennask and Shinnish Wind station (PSW). The Pennask feeder is 2.5 km long and the Shinnish feeder is 38 km long.

A 33 MVA 34.5/138 kV transformer at PSW steps up the voltage from 34.5 kV to 138 kV. A 3.75 MVA DSTATCOM which controls four 4 Mvar mechanically switchable capacitor banks is installed on the 34.5 kV side of PSW to provide additional reactive support. An IC built 0.5 km 138 kV overhead line connects PSW to the Transmission System via a new tap point on 1L244, 38 km from Nicola substation (NIC).

The following table provides a summary of the Pennask and Shinnish Wind Project:

Table 1: Pennask and Shinnish Project Information

Project Name	Pennask and Shinnish Wind Project	
Interconnection Customer (IC)	[redacted]	
Point of Interconnection (POI)	A tap on 1L244, 38.0 km from NIC	
IC Proposed COD	June 1 2015	
Type of Interconnection Service	NRIS ☒	ERIS ☐
Maximum Power Injection (MW) *	27.5 (Summer)	27.5 (Winter)
Number of Generator Units	14	
Plant Fuel	wind	

* *The maximum generation capacity of the project is 28.7 MW. But due to losses, only a maximum of 27.5 MW is achievable at the POI for injection into the grid.*

The figure below illustrates the configuration of the Pennask and Shinnish farm.

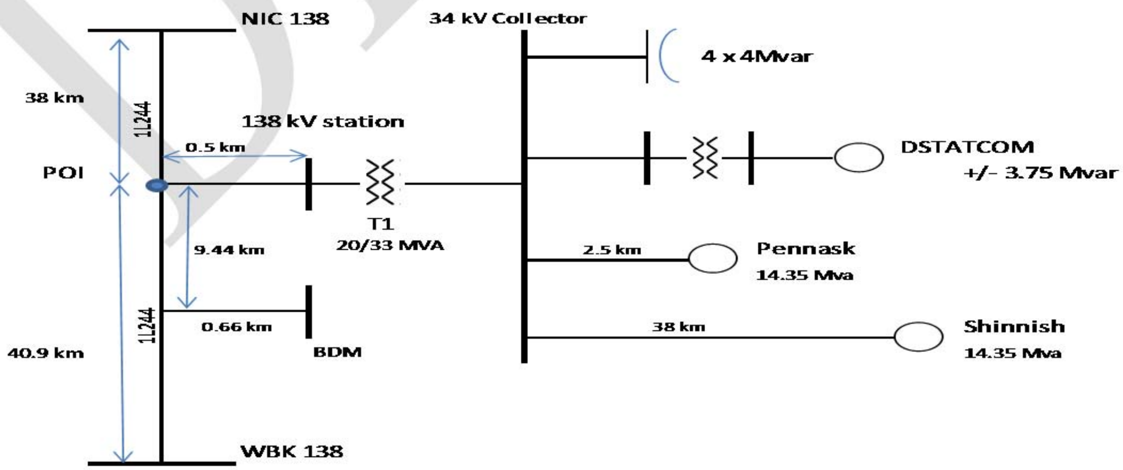


Figure 1: Sketch of Pennask and Shinnish Creek Wind Farm

Figure 2 below shows the geographic location of the proposed Pennask and Shinnish Creek Wind Farm in the South Interior region.

Figure 2: South Interior Area with the proposed Pennask and Shinnish Creek Wind Project

2.0 PURPOSE OF STUDY

The purpose of this study is to assess the impact on the BCH Transmission System, especially the Nicola –Westbank (WBK) area, due to the connection of the Pennask and Shinnish Creek Wind Farm. This study will identify constraints and Network Upgrades required for interconnecting the wind farm such that its performance is compliant with the North American Electric Reliability Corporation (NERC) and Western Electricity Coordinating Council (WECC) reliability standards, and the BCH transmission planning criteria.

3.0 TERMS OF REFERENCE

This study investigates and addresses the overloading, voltage deviation and stability issues of the transmission network in the Peace region as a result of integrating Pennask and Shinnish Creek wind farm. Topics studied include equipment thermal loading and rating requirements, system transient stability and voltage stability, transient over-voltages, protection coordination, operating flexibility, telecom requirements and high level requirements for Remedial Action Schemes (RAS). 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 BCH system studies will determine the requirements for reinforcements or operating restrictions/instructions for those kinds of events. Any use of firm or non-firm transmission delivery will require further analysis specific to the transmission service that may be requested later and will be reviewed in a separate study. Determination of any upgrades on the IC's facilities is beyond the SIS scope.

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 study was carried out based on the model, data and information submitted by the IC in February 2014 for the System Impact Study. Reasonable assumptions are made to complete the study whenever such information is unavailable.

The BCH 2015 and 2016 transmission system with winter heavy and summer light load/generation conditions are used in the studies.

5.0 SYSTEM STUDIES AND RESULTS

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 Power Flow Studies

The following figure is a single line diagram for the project and nearby area.

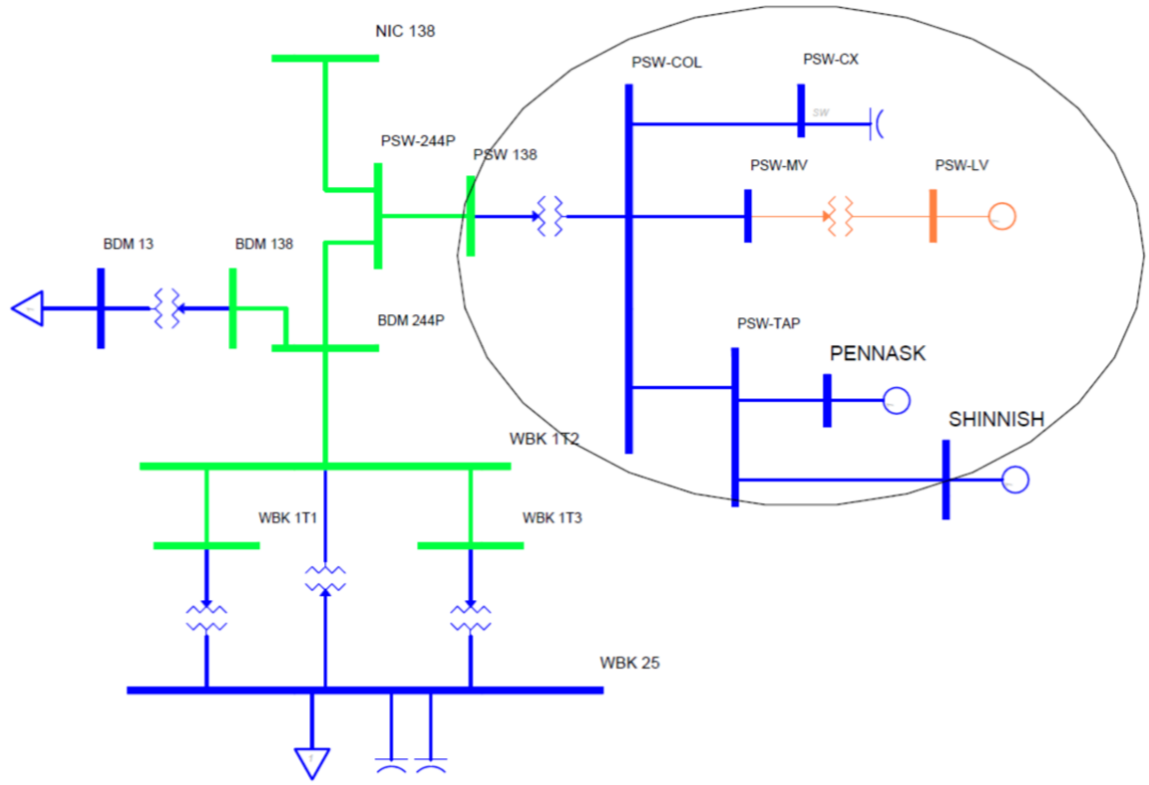


Figure 3: Pennask and Shinnish Wind Farm and nearby area Single Line Diagram

The wind farm is connected roughly half way between NIC and WBK and has a DSTATCOM and switchable capacitor banks to provide additional reactive support.

The minimum load at WBK is greater than the maximum combined output of the Pennask and Shinnish Wind Farms. Once injected into the Transmission System via the tap point on the radial circuit 1L244, all wind farm output will flow towards WBK and none towards NIC. Flows on 1L244 between the tap point (or the POI) and WBK will solely depend on the loads at Westbank and is not affected by the wind farm output. Loading on the NIC to POI section of 1L244 will be affected by the injection from the wind farm.

During system normal (N-0) and single contingency (N-1) conditions the wind farm is not observed to cause any voltage violation or equipment overloads in the transmission system.

In this study, the wind farm is observed to be able to control the voltage at the POI, and this should have a positive impact on West Bank 138 kV bus voltage.

Load flow study results are shown below. Table 2 below shows the voltages at key stations in the project area and flows on 1L244 during system normal and selected contingencies.

Table 2: Load flow Results

2016 Summer Light Load

	Voltages					NIC - PSW Tap		PSW Tap - WBK	
Contingency	NIC138	PSW 138	BDM 138	WBK 138	WBK 25	MW	Mvar	MW	Mvar
System Normal	1.027	1.020	1.016	1.003	1.006	6.5	4.8	33.9	6.8
Loss of NIC T5 & T3	1.026	1.020	1.016	1.003	1.006	6.5	3.4	33.9	6.8
Loss of 5L76 (NIC-ACK)	1.024	1.020	1.016	1.003	1.005	6.5	2.1	33.9	6.8
Loss of 1L243 (NIC-HLD)	1.030	1.020	1.017	1.004	1.006	6.7	6.8	33.9	6.8
Loss of 2L265 (NIC-VVW)	1.030	1.020	1.017	1.004	1.006	6.7	6.8	33.9	6.8

2015 Winter Heavy Load

	Voltages					NIC - PSW Tap		PSW Tap - WBK	
Contingency	NIC138	PSW 138	BDM 138	WBK 138	WBK 25	MW	Mvar	MW	Mvar
System Normal	1.037	1.020	1.008	0.974	1.020	55.5	6.6	82.1	22.3
Loss of NIC T5 & T3	1.036	1.018	1.007	0.973	1.020	55.6	5.2	82.1	22.3
Loss of 5L76 (NIC-ACK)	1.031	1.016	1.003	0.968	1.014	55.6	5.2	82.1	22.5
Loss of 1L243 (NIC-HLD)	1.039	1.020	1.008	0.974	1.020	55.6	8.2	82.1	22.3
Loss of 2L265 (NIC-VVW)	1.039	1.020	1.008	0.974	1.020	55.6	7.8	82.1	22.3

The area one-line diagram is shown in Appendix A.

5.2 Transient Stability Study

Transient stability studies were performed to assess the impact of 27.5 MW maximum power injection from the Pennask and Shinnish Wind project on the transmission network.

A series of transient stability studies under various system operating conditions including the winter heavy load and summer light load cases have been performed. A number of relevant contingencies in the area are used to test the dynamic performance of the subject project. The selected contingencies and the results are summarized in Table 3 below:

Table 3: List of Contingencies and transient stability results

Case	**Fault Description**	**Fault Duration**	**Pennask & Shinnish Wind Farm**
1	Fault on the low side of NIC 230/138 TX or on one of the 138 kV lines near NIC other than 1L244.	8 cycle	Stable, significant frequency excursion to 64~66 Hz during fault period observed.
2	Fault on the high side of NIC 500/230 TX	4 cycles	stable
3	Fault on 1L243 (NIC-HLD) near HLD	9 cycles	stable
4	Fault on 2L265 (NIC-VVW) near VVW	7 cycles	stable
5	Fault on 5L76 (NIC-ACK) near NIC with unsuccessful re-close	4 cycles	stable

For the contingencies listed above, Pennask and Shinnish wind turbines are able to maintain stability and recovered to their pre-fault states. In addition, the wind farm was not observed to introduce any stability issues in the transmission system. The interconnected system performance is acceptable.

A transfer trip to the IC's 138 kV circuit breaker from Nicola (NIC) will be used to isolate the wind farm during an islanded scenario when 1L244 is tripped due to protective or unintentional actions. The wind farm should not operate in an islanded state.

5.3 Fault Analysis

The short circuit analysis for the System Impact Study is based upon the latest BCH system model, which includes project equipment and impedances provided by the IC. The model included higher queued projects and planned system reinforcements but excluded lower queued projects. Thevenin impedances, including the ultimate fault levels at POI, are not included in this report but will be made available to the IC upon request.

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

5.4 Analytical Studies

An EMTP-RV study was performed using detailed wind turbine generator (WTG) models provided by the wind turbine manufacturer Senvion Canada.

Base on the transformer's HV (high voltage) grounded star and LV (low voltage) delta configuration, 10 Mvar 34.5 kV capacitor bank in service, and WBK load having a power factor of 0.95, the study result confirms the expected behavior of the wind farm is in line with the BC Hydro's TIR (60 kV to 500 kV Technical Interconnection Requirements For Power Generators), and the tap connection on 1L244 is acceptable.

Transformer energization voltage dip was found to be around 8% RMS (Root Mean Square) for uncontrolled energization. The IC is responsible for installing transformer energization inrush mitigation control in order to avoid a negative impact on existing customers at WBK and BDM. This can be achieved by implementation of Point On Wave controller with flux calculation, Point On Wave with controlled opening/closing the 138 kV circuit breaker or by fast motorized disconnects with arcing horns.

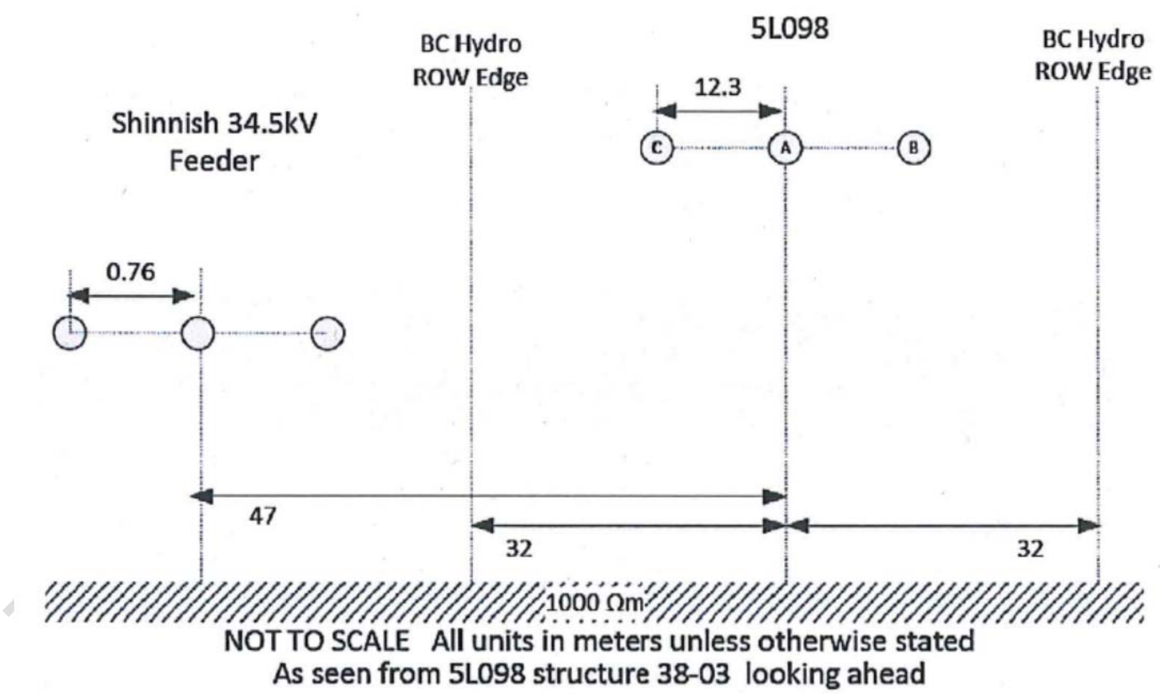
The analytical study also recommended a transfer trip from NIC to the PSW 138 kV circuit breaker to isolate the wind farm for 1L244 protective and non-protective tripping. The transfer trip requirement is described with more details in Section 5.7 below.

5.5 Transmission Line Upgrades

No transmission line upgrade requirement has been identified.

A 138 kV disconnect switch will be installed near the POI to connect the IC tap line between the POI and the PSW substation. The circuit 1L244 is a radial supply to WBK. Outages are undesirable. The tap connection should be made with a flying tap. This will require an outage but of only short duration.

The IC provided Google Earth diagram shows that the Shinnish 34.5kV feeder will closely parallel the 500 kV circuit 5L98 for approximately 16.6 km before crossing to the other side of 5L98 and continue onto the POI on 2L144. Due to this significant length of parallelism, an Induction Study was performed to determine the induced voltage on the 34.5 kV feeder by 5L98. The location of the circuit with respect to 5L98 in the parallel sections is illustrated in the following Diagram:



The calculated induced voltage on the IC's feeder must be below 5% of the rated phase to ground voltage for the induction level to be within permissible limits. For 34.5 kV, this limit is approximately 1kV.

The induction study shows that with a center-to-center separation of 47 meter between the Shinnish feeder and 5L98 right-of-ways, the total induced voltage is marginally acceptable.

5.6 BCH Station Upgrades or Additions

There is no additional BCH's station work identified.

5.7 Protection & Control and Telecommunications

Protection Requirements:

1. The existing 1L244 line protection at NIC is replaced with new primary and standby protection using SEL-421-4 relays.
2. A Direct Transfer Trip (DTT) from NIC to PSW 138 kV circuit breaker is installed to isolate the wind farm during an islanded scenario. A WECC Class 3 communication channel will be used to support the DTT.
3. There is no protection work at Westbank (WBK) Substation.
4. The IC must provide entrance protection, power quality protection, and redundant protection at PSW in accordance with the requirements laid out in the TIR.
5. Three phase Voltage Transformers at the PSW high voltage side are required for quality protection.

Control Requirements:

1. The IC is required to provide telemetry, status and meteorological information via a DNP3 RTU/IED (Distributed Network Protocol 3, Remote Terminal Unit/Intelligent Electronics Device) to the BCH Control Centres in accordance with TIR requirements.
2. The IC is responsible to provide a continuously reporting channel to the closest BCH station with appropriate telecom facilities
3. Due to 1L244 protection relay replacement at NIC, control work is required at NIC. There is no control work required at WBK.
4. The database and displays at BCH Control Centres will be updated to accommodate the SCADA points for the Pennask and Shinnish Wind Farm project.

Telecommunication Requirements:

The IC is responsible to provide a non-redundant WECC Class 3 communication facility for the implementation of the transfer trip from NIC to PSW, and to transmit wind farm SCADA data to BCH Control Centres.

The non-redundant WECC Class 3 telecommunication facility can either be a pair of 4-wire Leased Line from Telus or microwave communication channels.

Leased Line Option:

Two 4-wire leased line from TELUS to be installed from the wind farm to SIO (South Interior Office, or South Interior Control Centre), and BCH performs required changes at SIO and NIC.

The IC installs a Telenetics V3600 leased line modem, for connection to the RTU, and a GARD8000 tone signal relaying device for connection to the protective relay.

Microwave Link Option:

A line-of-sight path from PSW to HAM (Hamilton Mountain Repeater Station) is required for this option to be feasible. This will depend on the exact location of the PSW 138 kV station, the height of its antenna tower and the antenna mounting height at HAM. Once the location of 'PSW' is established, a radio path study would be required to determine microwave link feasibility.

A telecom Block diagram is attached in appendix D.

5.8 Islanding

Islanded operation is not arranged for Pennask and Shinnish Wind Farms. Direct transfer trip (DTT) will be utilized to isolate the wind farm by opening the 138 kV circuit breaker at PSW when an islanding scenario is detected. The back-up to the DTT are the wind farm's local protections which should disconnect itself from the system when an islanded condition is detected.

5.9 Black Start Capability

BCH does not require the proposed Pennask and Shinnish Wind farm 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.

5.10 Cost Estimate and Schedule

The good faith non-binding cost estimate to complete BCH Network Upgrades required for the Pennask and Shinnish Wind Farm connection is $1.521 million for leased line option and $1.773 million for microwave option.

The BCH Network Upgrade identified in this report can be expected to complete in approximately 12 months after funding is approved. This duration assumes that all necessary outages, if required, are available in time for line and station works.

The Interconnection Facilities Study report will provide greater details of the necessary requirements and the estimated timeline for this interconnection project.

This estimate does not include any costs associated with Revenue Metering, or any costs associated with 1L244 outages. The work required within the IC facilities is not part of this estimate and schedule.

6.0 REVENUE METERING

Measurement Canada (MC) approved and sealed Revenue Class meters will be supplied by BCH and installed at the IC's generating site at Pennask Creek and Shinnish Creek. The main point of metering (POM) is to be located on the high voltage side of the main power transformer at PSW. Additional points-of-metering is required at Pennask Creek and Shinnish Creek generation sites.

The IC is responsible for securing the real estate for the main point of metering. The IC is also responsible for supplying auxiliary power and telecom for revenue metering use. Metering equipment including CTs and VTs and the location of the POM are subjected to approval by BCH Revenue Metering department. The IC is responsible for the maintenance of the CTs and VTs, and BCH is responsible for the meters. Please refer to Appendix E for more detailed information.

The IC is encouraged to contact BCH Metering Department for more detailed information and requirements. metering.revenue@bchydro.com

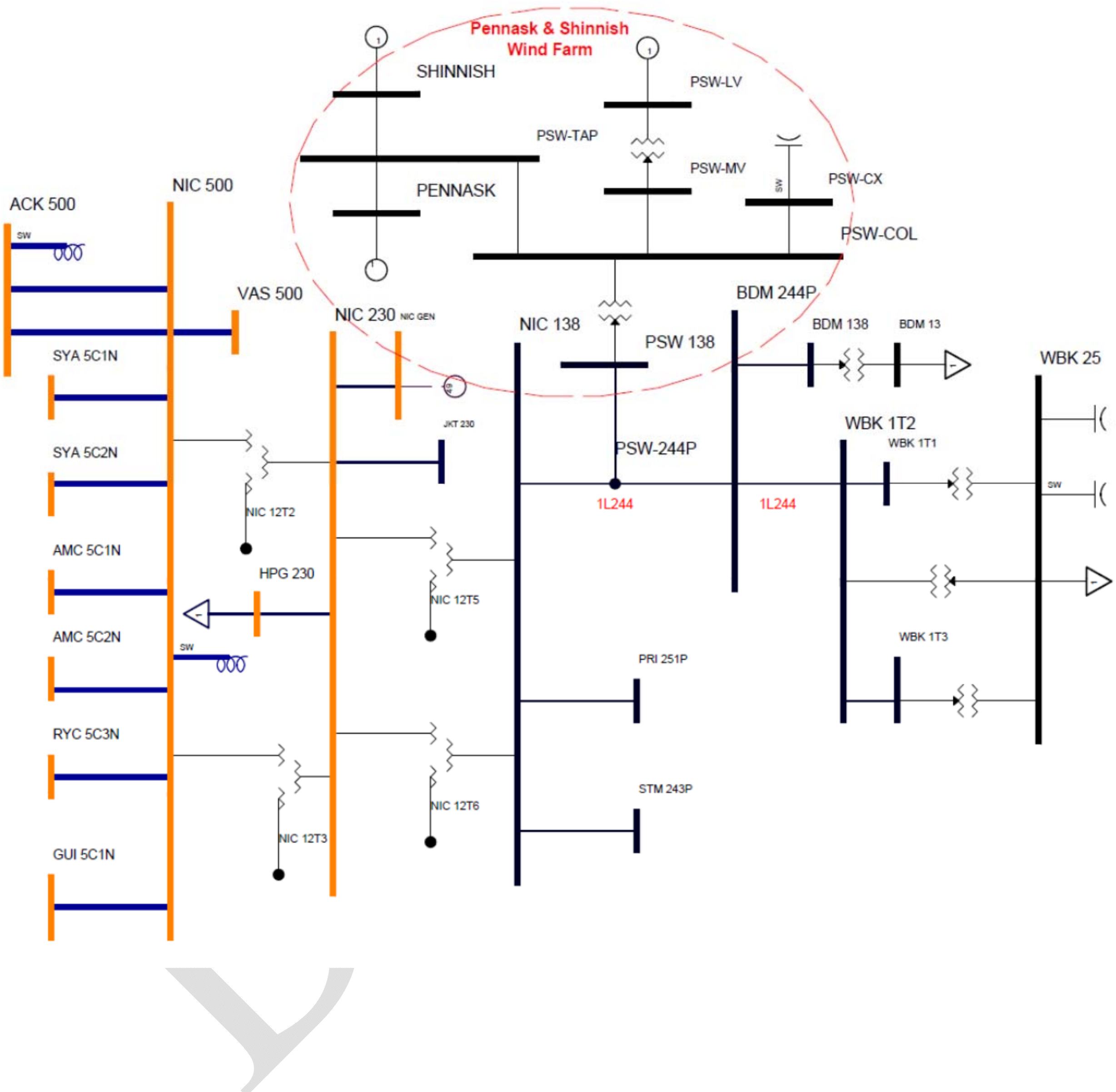
7.0 CONCLUSIONS & DISCUSSION

In power follow and transient stability studies, Pennask and Shinnish Wind Farm was not observed to cause any equipment overload, voltage violation and instability concerns. No transmission element upgrade has been identified.

1L244 line protection relays at NIC will need to be replaced and a direct transfer trip from NIC to PSW will be added. The IC is required to provide non-redundant WECC Class 3 telecom facility for transfer trip and SCADA purposes. This telecom facility can either be Telus leased lines or microwave channels.

To avoid any adverse impact on the customers at WBK and BDM, the IC must provide mitigation for its transformer energization inrush so that the voltage dip during transformer energization is within the acceptable limit and does not impact BCH customers.

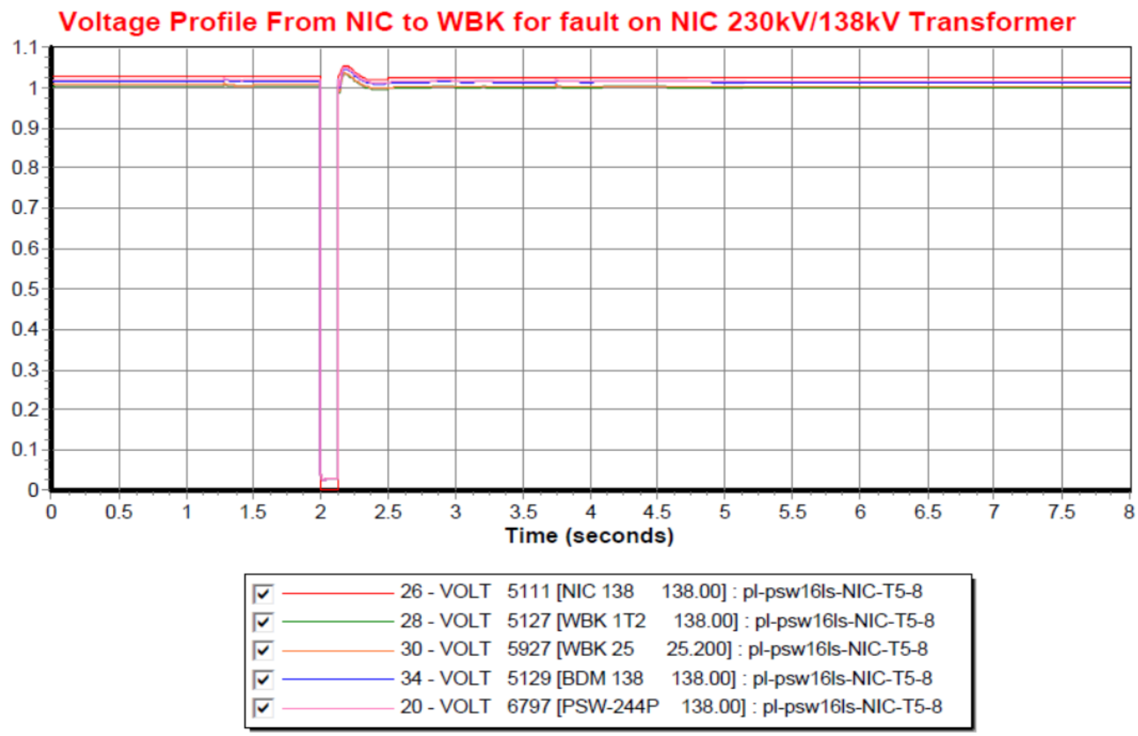
APPENDIX A – Area Single-line Diagram

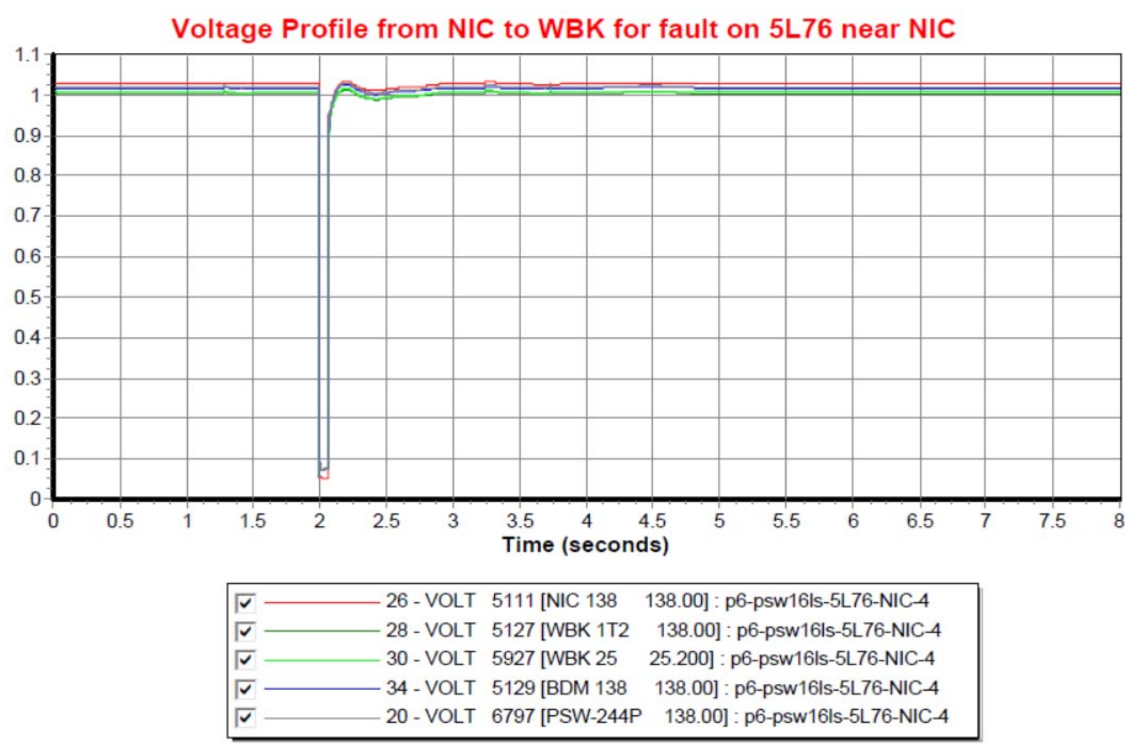


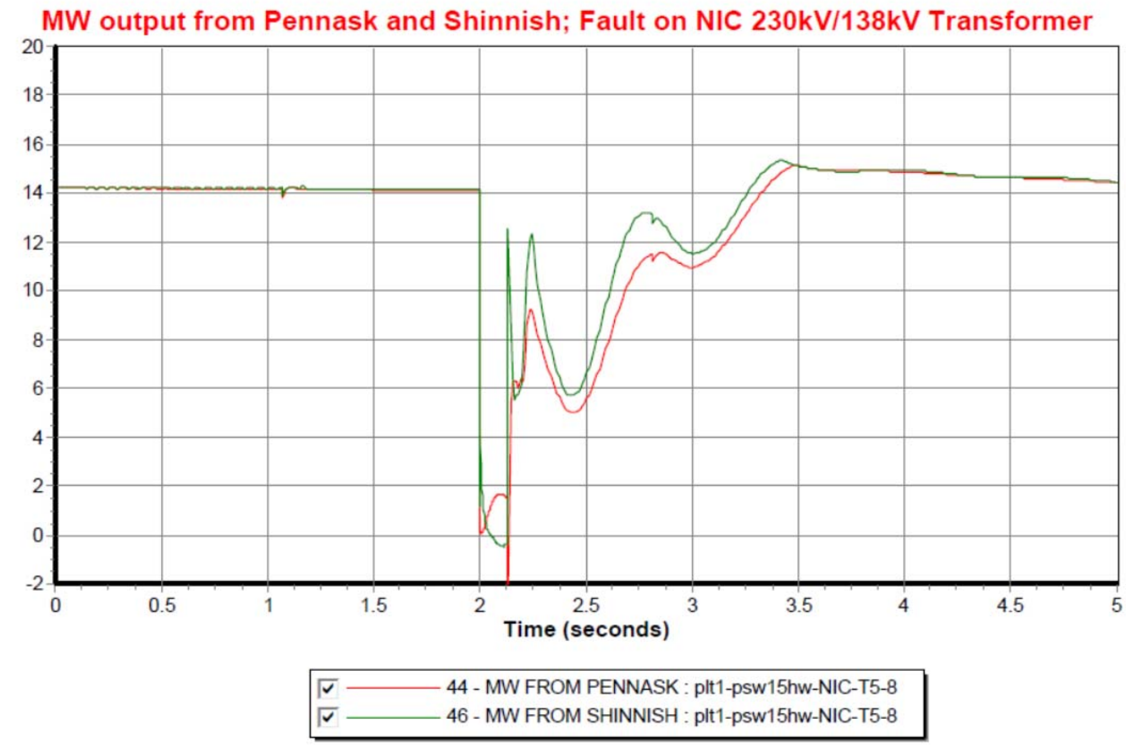
APPENDIX B – Dynamics Data

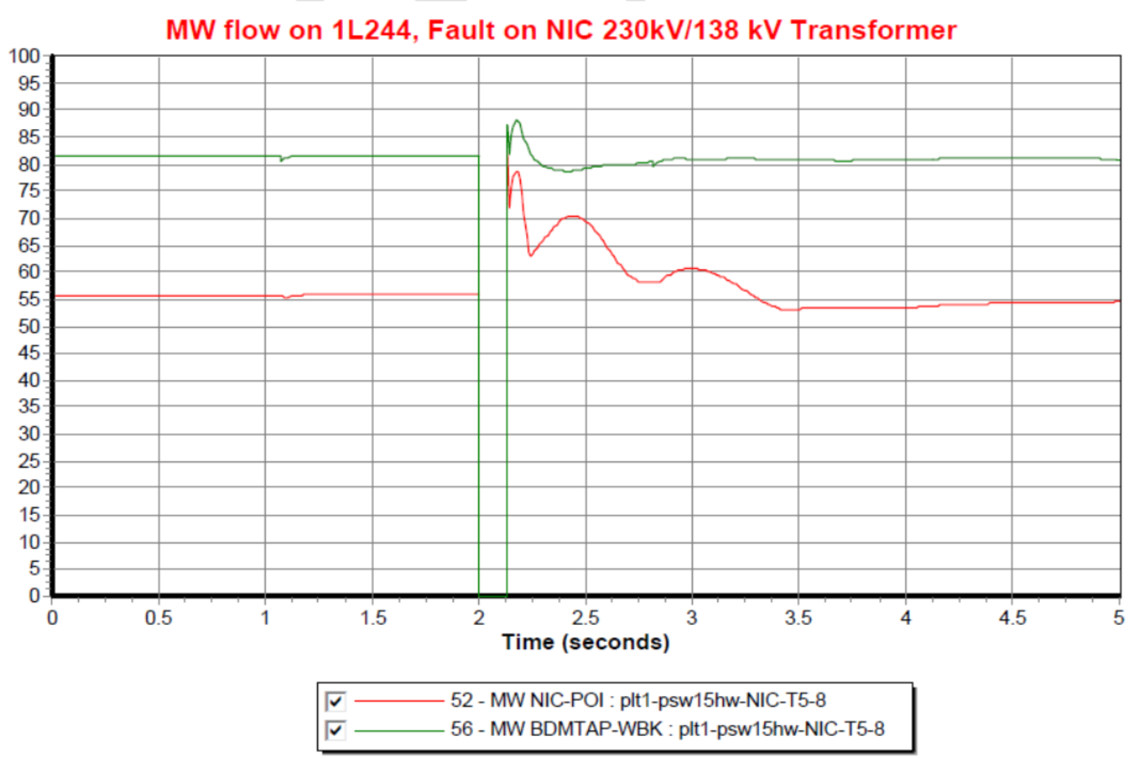
The wind turbine model used in this Pennask and Shinnish Wind Farm studies are proprietary and their data are not presented here.

APPENDIX C – Selected PSSE Dynamic Results

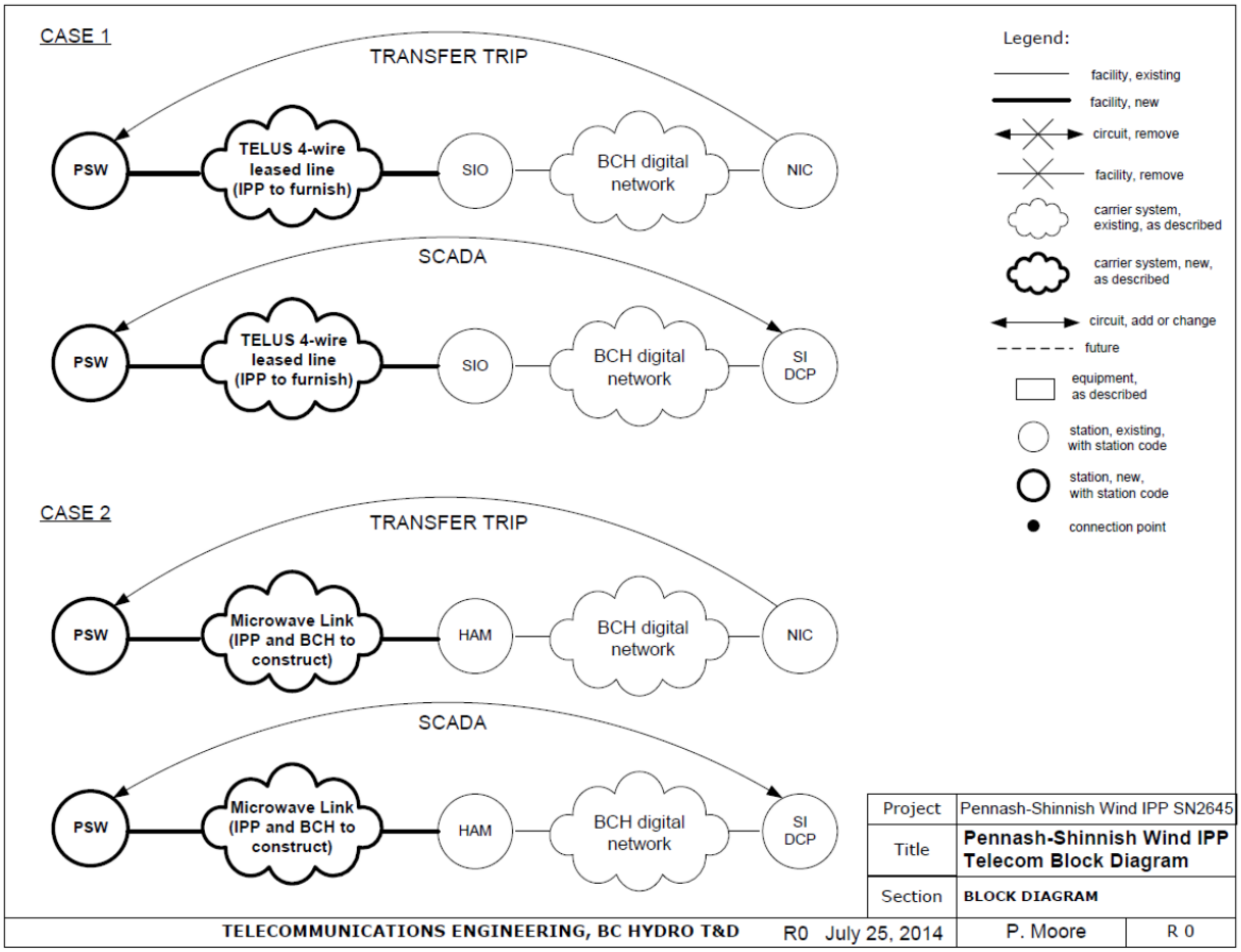





MW output from Pennask and Shinnish; Fault on NIC 230kV/138kV Transformer
Time (seconds)
44 - MW FROM PENNASK : plt1-psw15hw-NIC-T5-8
46 - MW FROM SHINNISH : plt1-psw15hw-NIC-T5-8


MW flow on 1L244, Fault on NIC 230kV/138 kV Transformer
Time (seconds)
52 - MW NIC-POI : plt1-psw15hw-NIC-T5-8
56 - MW BDMTAP-WBK : plt1-psw15hw-NIC-T5-8

APPENDIX D – Telecom Block Diagram



APPENDIX E – REVENUE METERING REQUIREMENTS

The revenue class meters for all Points-of-Metering (POM) will be Measurement Canada (MC) approved and supplied and maintained by BCH. The main meter will be leased by BCH to the Power Generators (PGs). As per federal regulations, the meter should be periodically removed and re-verified in a MC authorized laboratory. The CTs and VTs supplied by the PG and used on the metering scheme shall also be of a model/type approved by Measurement Canada. The PG should submit the models/maker/MC Approval number for BCH RM approval before committing to purchase the units.

The PG's remote read load profile revenue metering should be in accordance with the BCH Requirements for Complex Revenue Metering*.* The latest version of this document is published at BCH webpage under Forms and Guides. The revenue metering responsibilities and charges (PG and BCH) shall be in accordance with Section 10 (10.1 and 10.2). For details about the specific responsibilities, see table on pages.23-25.

Main and backup bi-directional load profile interval meters are required to measure the power received and the power delivered (by BCH to the PG) during each 30 minute time period. The meters will be programmed for 5 minutes interval and will be remotely read each day by BCH/ABSU Enhanced Billing Group using MV-90; the POM shall have a dedicated communications line (landline or wireless BCH approved IP alternative) available for revenue metering use only. If there is digital cell phone coverage for data, BCH will supply the wireless communications. In this case, there will be an incremental cost for the PG.

The revenue class meters (main and backup) are Measurement Canada (MC) approved and will be supplied and maintained by BCH. The main meter will be leased by BCH to the PG. The revenue class instrument transformers (CTs and VTs units) are supplied by the PG and should be Measurement Canada (MC) approved models.

The location of the POM(s) is (are) subjected to approval by BCH Revenue Metering department.

A *3*--element metering scheme with 3 CTs and 3 VTs connected L-N (L-Grd) shall be used at the PG Sub when the point of metering (POM) is located on the BCH side of the power transformer.

For generation applications, all instrument transformer compartment doors shall be **key interlocked** with a BCH side disconnect device and a Power Generator side disconnect device(s). The key interlocks shall prevent opening instrument transformer compartment door(s) unless all disconnect devices are visibly open. *Where the POM is on the Power Generator side of the power transformer, the BCH side disconnect device shall be on the BCH side of the power transformer to insure that no-load losses."*

The impedance and losses between the POM and the Point of Delivery/Receival (PODR) are significant; the meters will be programmed to account for the line and/or transformer losses between the POM and PODR. The PG or its consultant shall provide the line parameters data and the power transformer testing data signed and stamped by a professional engineer.

Note that where two or more PGs or one PG with more than one generation station/generator share a power line to connect to the BCH system, a main POM on the BCH side of the power transformer or in the POI will be needed, as well as an individual POM for each one of the generation stations/generators.

During the planning phase, BCH Revenue Metering department should be contacted to discuss the specifics of the project. The PG should send drawings to BCH Revenue Metering Department showing the Single Line Diagram (SLD) and informing the planned metering scheme, meter cabinet location, CTs and VTs model/maker, connections, location and MC Approval numbers, as well as any other related document.

The BCH Revenue Metering department can be contacted at: metering.revenue@bchydro.com