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Annacis Island Wastewater Treatment Plant Cogeneration System

Interconnection System Impact Study

Report No: T&S Planning 2017-040

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Revision 0

British Columbia Hydro and Power Authority

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Revision Number	Date of Revision	Revised By

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EXECUTIVE SUMMARY

[redacted] the Interconnection Customer (IC), proposes to replace the four existing biogas-fueled generators with four higher-rated generators of the same type to provide increased load displacement power. The IC also plans to replace the two existing standby diesel generators with two higher-rated generators. This project will be located inside the existing customer-owned station Annacis Island Wastewater Treatment Plant (AWT) which is located about 5 km from Ingledow Substation (ING) in Surrey, British Columbia.

This report documents the evaluation of the system impact of interconnecting the proposed generating facilities and identifies the required system modifications to obtain acceptable system performance with the interconnection of the proposed Annacis Island Wastewater Treatment Plant (AIWWTP) project's new generators. This project is the replacement of four 0.8 MW biogas-fueled generator with four new similar units rated 2.0 MW each (and 2.46 MVA each). The new generators will be connected to the two 12.47 kV buses within the customer's electrical distribution system. The treatment plant's two 64/12.47 kV transformers are fed from customer's two connections to BC Hydro's 60 kV circuits 60L31 and 60L71 fed from Ingledow substation. The Points of Interconnection (POI) are on the two short taps from the BC Hydro circuits to the customer's station. The maximum power injection to the BCH system is 0 MW because the treatment plant's load will always be more than the combined power output from the biogas-fueled generators. The two new standby diesel generators will operate only when the station is isolated from the BC Hydro system. The IC's proposed Commercial Operation Date (COD) is November 2018, however the required network upgrades identified below will not be able to complete by that COD.

To interconnect the AIWWTP Cogeneration System project and its facilities to the BCH Transmission System at the POI, this System Impact Study (SIS) has identified the following conclusions:

- No equipment overload and voltage violation has been identified. No adverse impact to the dynamic behavior of the Transmission System has been identified.
- The over-voltages due to sources within an ungrounded 60 kV system will be prevented by addition of direct transfer trip signals to AWT to ensure generators are disconnected from the BC Hydro system. During any operation of the 60 kV transmission system with the ING end of 60L31 or of 60L71 open (but the line still tied to ANN station) the IC will need to modify the operation at AWT so that no generators are connected with the affected 60 kV line.
- To prevent over-voltages the opening of 60L31 and 60L71 at ING will be delayed by 6 cycles so that AWT will be tripped first.
- An ADSS fibre optic line will be installed on one single pole line 60L31 or 60L71 from ANN to AWT with a distance 1.75 km.

- Out of step protection function is required at the replacement biogas-fueled generators and will be provided by the IC.
- Islanded operation will not be arranged. Power quality protection will be required to trip the IC's 60 kV circuit breaker to prevent/mitigate possible inadvertent islanded operation while still connected with other customers.
- The non-binding good-faith cost estimate for Interconnection Network Upgrades required to interconnect the proposed project to BCH Transmission System is $1.097 million, and the estimated time to complete the Interconnection Network Upgrades is January 31st 2019. The work required within the IC facilities is not part of Interconnection Network Upgrades.

After the required network upgrades are put in service, the customer will take some time to complete commissioning of generating facilities. Thus the IC's originally proposed COD will need to be rescheduled.

The Interconnection Facilities Study report will provide greater detail 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 Interconnection System Impact Study (SIS) report is as described in Table 1 below.

Table 1: Summary Project Information

Project Name	Annacis Island Wastewater Treatment Plant Cogeneration	
Interconnection Customer	[redacted]	
Point of Interconnection	The short taps from 60L31 & 60L71 to the customer's station AWT.	
IC Proposed COD	November 2018	
Type of Interconnection Service	NRIS ☒	ERIS ☐
Maximum Power Injection (MW)	0.0 (Summer)	0.0 (Winter)
Number of Generator Units	Four (new, replacing 4 smaller units)	
Plant Fuel	Biogas	

[redacted] the Interconnection Customer (IC), is an existing load customer located in Lower Mainland on Annacis Island with four existing biogas-fueled generators for load displacement. BC Hydro's abbreviation for the IC's station is AWT. There is no power export from AWT and historically BCH supplies the difference between the plant's load and co-generation.

[redacted] proposes to replace the existing four 0.8 MW generators with four generators each rated 2.0 MW. The IC's own station load will be increased to about a 14 MW level as the expected operating load. The four 2.0 MW generators will provide only load displacement and so the IC will not export power into the transmission grid.

The Point of Interconnection is on 60L31 and 60L71, at the existing entrance gate to AWT, and 5 km from ING.

Inside AWT the four new 12.47 kV generator units CG1 to CG4 will have these major parameters:

	Rated MVA	Rated MW	PF (lag/lead)	
CG1	2.458	2.0	0.8 / 0.9	(new)
CG2	2.458	2.0	0.8 / 0.9	(new)
CG3	2.45	2.0	0.8/ 0.9	(new)
CG4	2.458	2.9	0.8/ 0.9	(new)

The IC's station AWT as well as the 60 kV transmission system in the area are shown in Figure 1 and the geographical locations of AWT in the Lower Mainland is shown in Figure 2.

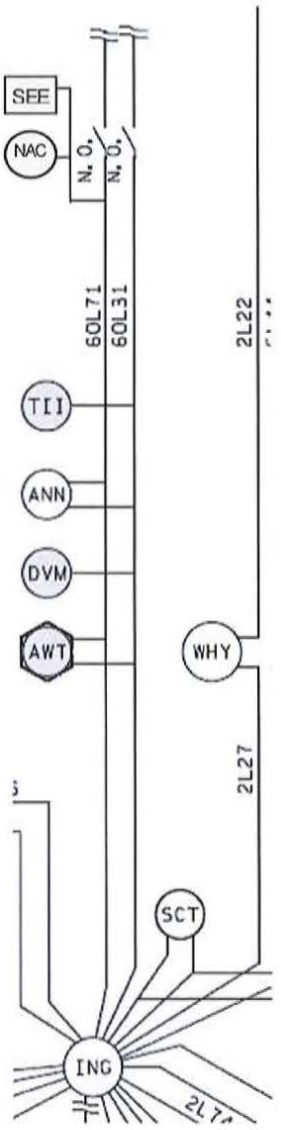


Figure 1 – AWT and Local 60 kV Transmission System

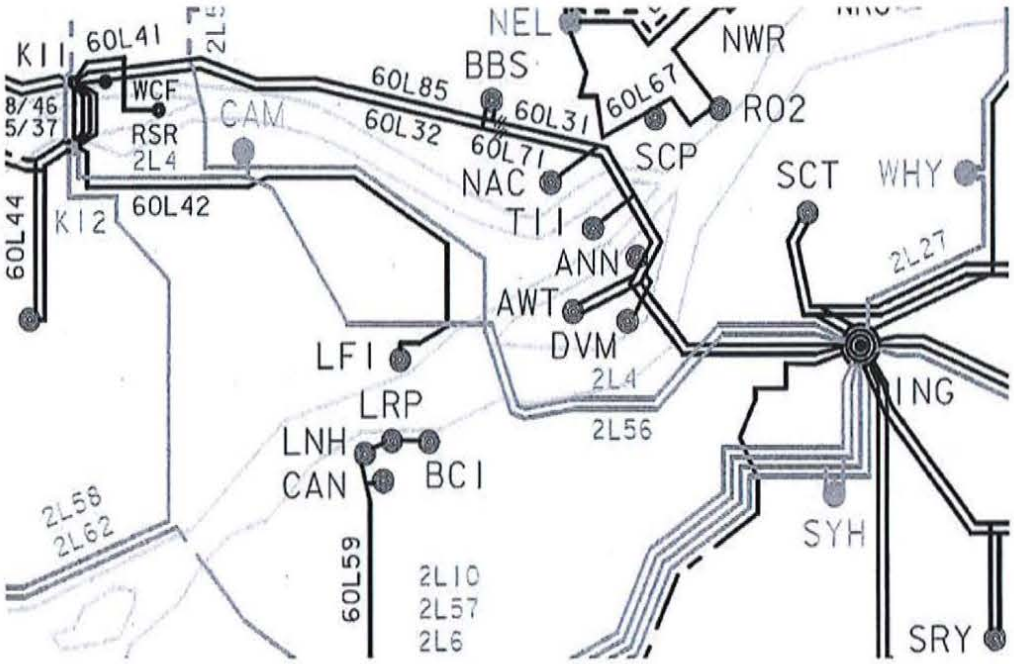


Figure 2 - The Geographic Location of AWT in the Lower Mainland.

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 interconnecting the proposed generating project in compliance with the NERC/WECC reliability standards and the BC Hydro transmission planning criteria.

3.0 TERMS OF REFERENCE

This study investigates and addresses the voltage and overloading issues of the transmission network in the vicinity of AWT 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 requirements for local area protection schemes (LAPS). 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. 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.

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 include generation, transmission facilities, and load forecasts representing the queue position applicable to this project. Applicable seasonal conditions and the appropriate study years for the study horizon are also incorporated. The 2017/18 heavy winter and 2018 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. Additional assumptions are made to complete the study and the report, whenever such information is unavailable.

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 Pre-Outage Power Flows

Pre-outage power flows were prepared to assess the impact of the proposed interconnection using two basic system load conditions:

1. 2017/18 winter peak load;
2. 2018 summer light load;

and defined generation conditions.

The steady-state power flow studies indicated the following findings:

- no voltage violations are observed; and,
- no circuits overloaded before and after the proposed interconnection.

Table 2 below shows the power flow study results for the 2018 system normal condition. This study case has 2018 Light Summer load conditions with 14.0 MW total AWT load, and 8.0 MW total output from the IC's cogen units CG-1,2,3,4.

Table 2: Power Flow Study Results – Pre-Outage Case

Voltages in per unit (pu) on 60 kV or 12.5 kV base; power flow P & Q in MW, Mvar					
ING60	60L31 P, Q	AWT60 on 60L31	60L71 P, Q	AWT60 on 60L71	
1.073 pu	4.7 , 1.8	1.071 pu	4.6 , 1.8	1.071 pu	
CG1, CG2 voltage, and each P, Q			CG3, CG4 voltage, and each P, Q		
1.000 pu, 2.0 MW, 0.7 MVar			1.000 pu, 2.0 MW, 0.7 Mvar		

Notes :

1. In the pre-outage case the loads' P & Q values and the operating conditions for the generators and the switchable shunt capacitors are approximate, based on data submissions for the study.

5.2 First Contingency Power Flows

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 there are no voltage violation conditions due to the addition of the IC's project.

Table 3 below shows the contingency study results on the 2018 light summer load conditions and the generation outputs same as those used for Table 2.

Table 3: Power Flow Study Results – after Single Element Contingency

case	Voltages in per unit (pu) on 60 kV or 12.5 kV base; power flow P & Q in MW, Mvar					
60L71 outage	ING60	60L71 P, Q	AWT60 on 60L71	60L31 P, Q	AWT60 on 60L31	
	1.073 pu	-----	out	6.3 , 2.9	1.071 pu	
	CG1, CG2 generators voltage, and each P. Q			CG3, CG4 generators voltage, and each P, Q		
	off			1.000 pu, 2.0 MW, 0.7 Mvar		
60L31 outage	ING60	60L31 P, Q	AWT60 on 60L31	60L71 P, Q	AWT60 on 60L71	
	1.073 pu	-----	out	6.3 , 2.9	1.071 pu	
	CG4, CG4 generators voltage, and each P. Q			CG1, CG2 generators voltage, and each P, Q		
	off			1.000 pu, 2.0 MW, 0.7 Mvar		

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 generating project was based on the IC's data submission plus any additional assumptions where the IC's data was incomplete or inappropriate. The models and data values of the IC's key components are shown in Appendix B.

The new biogas-fuelled generators have a low inertia (the existing units which will be removed are assumed to have similar inertia data). The expected durations of multi-phase 60 kV line faults in the area are long enough to cause these generators to lose synchronism especially if they are operating at high MW output levels. The IC is required (by BC Hydro's TIR) to be able to detect the loss of synchronism and immediately trip off the affected generator(s). The generators' expected slip centre locations are well inside the generators and so there would be no impact on other BC Hydro customers. Out of step protection is required at the IC's facilities and must be provided by the IC. BCH can provide apparent impedance versus time plots of stable and unstable swings if requested.

The transient stability study results for 2018 Light Summer are summarized in the following Table 4. The load conditions and the generation outputs at generating plant SEE and at AWT's generators are same as those used for Tables 2 and 3.

Table 4: Dynamic Performance Results

Case	Contingency	fault type and location	fault clearing and line trip	SEE gen rotor swing	AWT generators rotor swing	Comments (see also notes 1 & 2 below)
1	(Nothing tripped)	3-phase at ING 230 kV bus	6 cy	40 degrees	20 degrees	Acceptable stability
2	60L31 ING-ANN	SLG at ING end	18 cy assumed for test	less than 5 degrees	less than 15 degrees	Acceptable stability
3	60L31 ING-ANN	3-phase at ING end	12 cy: due to detect 3cy, delay 6cy, and CB 3cy	68 degrees	slips	SEE acceptable, but AWT generators slip - slip centers will be inside the AWT units
4	60L31 ING-ANN	3-phase at ING end	13 cy: due to detect 3cy, delay 6cy, and CB assumed 4cy	78 degrees	slips	SEE acceptable, but AWT generators slip - slip centers will be inside the AWT units
5	60L31 ING-ANN	3-phase at ING end	14 cy: due to detect 3cy, delay 6cy, and CB assumed 5cy	90 degrees	slips	SEE acceptable, but AWT generators slip - slip centers will be inside the AWT units

Notes:

1. The expected fault duration for 60L31 or 60L71 fault includes the 6 cycle delay required with the DTTs to SEE generator on 60L71 (and also the DTTs to AWT).
2. The SEE performance case for a 3-phase fault on 60L31 with assumed duration 12 cy shows that the marginal performance for durations 13 or 14 cycles will be improved by the expected 60 kV CB replacements at ING (CB interrupting times 3 cycles).

5.4 Analytical Studies

In the 60L31 and 60L71 transmission system the stations with generators are the existing generating plant SEE and the IC's station AWT. Both stations have main transformers that are delta winding on the HV 60kV side which means that a 60 kV line trip causes these generators to become sources in an ungrounded system. To prevent over-voltages when lines are tripped it is important that the ungrounded sources be cleared first on the occurrence of a ground fault with the other system connections delayed in clearing until it is assured that the ungrounded sources have been removed. For the existing generating station SEE the necessary direct transfer trip (DTT) facility is already in place, initiated from the ING ends of 60L31 and 60L71. It will be necessary to add DTT signals initiated from ING ends of 60L31 & 60L71 to the AWT station to trip the associated portion of the AWT station so that none of the AWT on-line generators will stay connected to the 60 kV line that is being tripped.

During any operation of the 60 kV transmission system with the ING end of 60L31 or of 60L71 open (but the line still tied to ANN station) the IC will need to modify the operation at AWT so that no generators are connected with the affected 60 kV line. This operating restriction eliminates the need to provide additional DTTs initiated from the ANN ends of 60L31 and 60L71.

5.5 Fault Analysis

The short circuit analysis for the System Impact Study is based upon the latest BCH system short circuit 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.

5.6 Transmission Line upgrade requirements

To accommodate the fibre to be added from ANN to AWT, some of the poles on 60L31 or 60L71 may have to be upgraded.

5.7 BCH Station Upgrades or Additions

No station upgrades or additions are identified for this project.

5.8 Protection and Control & Telecommunications

Protection

Protection Work Required by BCH:

As required for the prevention of over-voltages caused by a 60 kV line trip, it will be necessary to provide direct transfer trips (DTT) from the ING end of 60L31 to the AWT station, and from the ING end of 60L71 to the AWT station. The opening of each line at ING will be delayed by 6 cycles. Two Class 2 telecommunications channel must be provided for the direct transfer trips from ING to AWT.

Protection Work Required by the IC:

- Review/approve entrance setting.
- The IC has expressed interest in removing the reverse power flow relay from the facility. B C Hydro disagrees with this as the existing reverse power flow relay provides means of disconnecting the customer facility when it is contributing fault current for 60L31 and 60L71 line faults.
- Review underfrequency load shedding setting.
- Provide out of step protection.
- Provide power quality protection

Control

Control Work Required by BCH at ING:

- Provide alarms at ING for the new DTTs from ING to AWT in accordance with standardized alarm guidelines.

Control Work Required by BCH at BCH Control Centres

- The IC's telemetry and status will be routed to the ING DCP site and connect directly to the AREVA FEPs. Re-configure AREVA FEPs at ING DCP.
- Update the database and displays as required to accommodate the new alarms and IPP telemetry points. Update the network model to show the new generators.

Control Work Required by the IC:

- Provide alarms at AWT for the new DTTs from ING to AWT in accordance with standardized alarm guidelines.
- Provide the required telemetry (MW, MVAR, kV, MWh hourly) and interconnection status (DWG#: A80E1004Z, 81-221B, 81-222B, 81-223B, 81-224B, 84-001B, 84-002B) via a new DNP3 RTU/IED to FVO and SIO (per TIR). Continuous communications at 9600 bps to the ING DCP is required (or alternatively satellite communications to the ING DCP).
- Install Power Parameter Information System (PPIS) to ensure proper power quality is maintained for on-line, off-line, steady and dynamic states. The IC is also responsible for providing a communications link for remote interrogation of the PPIS equipment by BCH servers. As a minimum it can be a dial-up telephone line. Alternative communications include IP cellular modem, IP satellite, BCH WAN (where appropriate) and are subject to BCH review and approval.

Telecom

The DTT signals from ING to AWT will require the addition of the following telecom circuits:

1. WECC Class 2 DTT from ING to AWT for 60L31.
2. WECC Class 2 DTT from ING to AWT for 60L71.

The selected communications alternative is fibre on one single pole line 60L31 or 60L71 from ANN to AWT, a distance 1.75 km. Other options using microwave and requiring towers were rejected due to higher costs.

Telecom Work Required by BCH at ANN:

- Install 48 strand single mode ADSS from ANN to AWT.
- Install a fiber patch panel and terminate the fibre.
- Install two RFL FSU facing AWT and connect it to two fibre pair to AWT. (The RFL FSU devices may be powered from the 129 VDC station battery.).
- Install one module, dual port MPS, in the ANN HPX-1A DACS.
- Install one RS530 DCE cable, from DACS to V.35 distribution panel.
- Install one V.35 cable from V.35 distribution panel to RFL FSU device.
- Install two 64 kbps multifunction tele-protection circuit to ING.

Telecom Work Required by the IC at AWT:

- Install 48 strand ADSS from ANN.
- Terminate the ANN-AWT fibre on a patch panel.
- Install one PDR2000 digital signal relaying device, and two RFL FSU devices equipped with single fiber modules. Connect them to two fibre pairs to ANN.
- If the PDR2000 digital signal relaying devices are to be powered off a station battery using DC to DC converters, then install dual DC-DC converters.

Telecom Work Required by BCH at ING:

- Install one PDR2000 digital signal relaying device.
- Install one V.35 card in the ING 3645 DACS.
- Install two V.35 cables from PDR2000 to the ING 3645 DACS.
- Install two 64 kbps multi-function tele-protection circuit to ANN.

The telecom conceptual diagram is shown in Appendix C.

5.9 Islanding

The AWT normal operation is with the station split so that each half is supplied by one of the two 60 kV lines 60L31 or 60L71. When one of those lines trips the affected AWT

(half) station is able to operate as its own isolated load using the ICs available generation.

Deliberate islanded operation of the AWT generators to supply other BC Hydro load stations is not arranged. If an inadvertent island with other nearby BCH customer load stations forms that island, depending on the island configuration, might not quickly collapse. Power quality protection to trip the IC's 60 kV circuit breaker will be required.

5.10 Black Start Capability

It is not applicable to this load customer with some cogeneration to offset load.

5.11 Cost Estimate and Schedule

The non-binding, good faith cost estimate for the Interconnection Network Upgrades required to interconnect the proposed project to BCH Transmission System is $ 1.097 million (including 20% contingency). An accuracy range of -35% to +100% is applied to this cost estimate. The Interconnection Facilities Study report will provide more detailed information of the cost estimates.

The estimated time to complete the Interconnection Network Upgrades is January 31st 2019. A more detailed construction timeline will be provided in the Interconnection Facilities Study report.

6.0 REVENUE METERING

Existing revenue metering at AWT has two existing 3-element points of metering: one on 60L71 and the other on 60L31. Both points of metering utilize 40250-115 V VTs and 100/200-5 A CTs with 100 A connected on the primary side.

Present connected load is 21.4 MW, and the operating load is 6.1 MW. New connected load increases by 10.1 MW and the new operating/max load will be 13.5 MW, which implies current of 152 A at 0.8pf, 64 kV. It is recommended to change the primary tap from 100 to 200 for both points of metering.

Site visit to inspect the condition of metering cabinets for both points of metering is recommended to make sure they can accommodate ION 8650 in future.

BC Hydro Revenue (class) metering is not required for the generators.

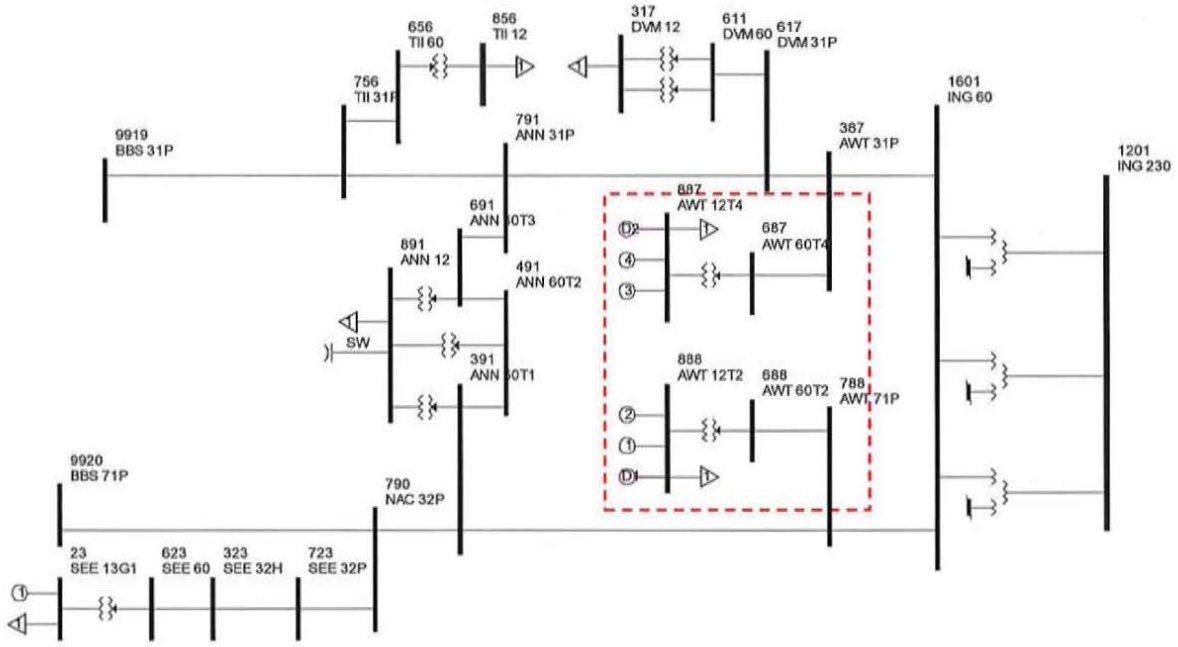
The estimated cost to complete the metering changes is $10.7k, which is not included in the network upgrade cost.

7.0 CONCLUSIONS & DISCUSSION

In order to accommodate the replacement of the four biogas-fueled generators at the AWT station, this SIS has identified the following issues and requirements:

- No additional unacceptable equipment overload conditions in the Transmission System were observed in the power flow analysis due to the replacement of the biogas- fueled generators under normal conditions and after N-1 contingencies.
- No adverse impact to the dynamic behavior of the Transmission System has been identified.
- The over-voltages due to sources within an ungrounded 60 kV system will be prevented by addition of direct transfer trip signals to AWT to ensure generators are disconnected from the BC Hydro system. During any operation of the 60 kV transmission system with the ING end of 60L31 or of 60L71 open (but the line still tied to ANN station) the IC will need to modify the operation at AWT so that no generators are connected with the affected 60 kV line.
- To prevent over-voltages the opening of 60L31 and 60L71 at ING will be delayed by 6 cycles so that AWT will be tripped first.
- An ADSS fibre optic line will be installed on one single pole line 60L31 or 60L71 from ANN to AWT with a distance 1.75 km.
- Out of step protection function is required at the replacement biogas-fueled generators and will be provided by the IC.
- Islanded operation will not be arranged. Power quality protection will be required to trip the IC's 60 kV circuit breaker to prevent/mitigate possible inadvertent islanded operation.
- The non-binding good-faith cost estimate for Interconnection Network Upgrades required to interconnect the proposed project to BCH Transmission System is $1.097 million, and the estimated time to complete the Interconnection Network Upgrades is January 31st 2019. The work required within the IC facilities is not part of Interconnection Network Upgrades.

APPENDIX A – Area Single Line Diagram with the IC Project



APPENDIX B – Power flow and Dynamic Models and Data

The key power flow and dynamic model data:

IC's 64/12.47 kV transformers T2 and T4.

Transformer	Max Rating MVA	Base MVA	Impedance (% on Base MVA)	Voltage (HV/LV winding)	Connection HV	Connection LV
T2	28	15	7.22	64 / 12.47	Delta	YRG
T4	28	15	7.38	64 / 12.47	Delta	YRG

Generator Model (GENROU):

Biogas (CG-1 to CG-4) Unit Rating: 2.458 MVA, 12.47 kV, 2.0 MW, +0.8/-0.9 PF, Ra=0.006 (pu)]

Unit	T'_{do}	T''_{do}	T'_{qo}	T''_{qo}	H_{GT}	D	X_d	X_q	X'_d	X'_q	X''_d	Xl	S(1.0	S(1.0)
biogas	3.83	0.038	0.76	0.019	1.08	0.	2.32	1.21	0.276	1.1	0.237	0.20	0.27	0.67

Compensator COMP – at exciter input, due to multiple units on same bus (typical setting).

Units	Model	Xe
biogas	COMP	-0.05

Exciter Model ESAC8B data & settings (submitted data & settings as much as possible).

Units	TR	KP	KI	KD	TD	KA	TA	VRMAX	VRMIN	TE
biogas	0.005	80	20	10	0.015	1.0	0.005	12.6	0.0	0.148
	KE	E1	SE(E1)	E2	SE(E2)					
	1.0	6.75	0.1	9.0	0.4					

APPENDIX C – Telecom Conceptual Diagram