BC hydro
FOR GENERATIONS

[redacted]

Lower Wahleach Hydroelectric Project

# Interconnection System Impact Study

Report no.: T&S Planning 2016 - 048

May 2016

British Columbia Hydro and Power Authority

© British Columbia Hydro and Power Authority 2016. All rights reserved.

## Acknowledgements

**This System Impact Study report was prepared by:** Terence Munroe, Interconnection Planning

**Reviewed by:** Allen Hiebert, Interconnection Planning

**Approved by:** Robert Pan, Manager, Interconnection Planning

**Contributors in the respective disciplines:**

[redacted]

[redacted]

Terence Munroe, Interconnection Planning

[redacted]

[redacted]

Derek Collins, Stations Planning

@ British Columbia Hydro and Power Authority 2016. All rights reserved. 

[redacted]

[redacted]

Guihua Wang, Performance Planning

[redacted]

[redacted]

Terry Martinich, Analytical Studies

[redacted]

[redacted]

Ming Lu, Transmission Design

@ British Columbia Hydro and Power Authority 2016. All rights reserved.

[redacted]

[redacted]

Amitpal Bimbhra, Protection and Control Planning

[redacted]

[redacted]

Foad Kasiri, Telecom Planning

[redacted]

[redacted]

Al Villanueva, Revenue Metering

@ British Columbia Hydro and Power Authority 2016. All rights reserved. 

## Disclaimer of Warranty and Limitation of Liability

This report was prepared by the British Columbia Hydro And Power Authority ("BCH") or, as the case may be, on behalf of BCH by persons or entities including, without limitation, persons or entities who are, or were, employees, agents, consultants, contractors, subcontractors, professional advisers or representatives of, or to, BCH (individually and collectively, "BCH Personnel").

This report is to be read in the context of the methodology, procedures and techniques used, BCH's or BCH's Personnel's assumptions, and the circumstances and constraints under which BCH's mandate to prepare this report was performed. This report is written solely for the purpose expressly stated in this report, and for the sole and exclusive benefit of the person or entity who directly engaged BCH to prepare this report. Accordingly, this report is suitable only for such purpose, and is subject to any changes arising after the date of this report. This report is meant to be read as a whole, and accordingly no section or part of it should be read or relied upon out of context.

Unless otherwise expressly agreed by BCH:

1. any assumption, data or information (whether embodied in tangible or electronic form) supplied by, or gathered from, any source (including, without limitation, any consultant, contractor or subcontractor, testing laboratory and equipment suppliers, etc.) upon which BCH's opinion or conclusion as set out in this report is based (individually and collectively, "Information") has not been verified by BCH or BCH's Personnel; BCH makes no representation as to its accuracy or completeness and disclaims all liability with respect to the Information;
2. except as expressly set out in this report, all terms, conditions, warranties, representations and statements (whether express, implied, written, oral, collateral, statutory or otherwise) are excluded to the maximum extent permitted by law and, to the extent they cannot be excluded, BCH disclaims all liability in relation to them to the maximum extent permitted by law;
3. BCH does not represent or warrant the accuracy, completeness, merchantability, fitness for purpose or usefulness of this report, or any information contained in this report, for use or consideration by any person or entity. In addition BCH does not accept any liability arising out of reliance by a person or entity on this report, or any information contained in this report, or for any errors or omissions in this report. Any use, reliance or publication by any person or entity of this report or any part of it is at their own risk; and
4. In no event will BCH or BCH's Personnel be liable to any recipient of this report for any damage, loss, cost, expense, injury or other liability that arises out of or in connection with this report including, without limitation, any indirect, special, incidental, punitive or consequential loss, liability or damage of any kind.

@ British Columbia Hydro and Power Authority 2016. All rights reserved.

## Copyright Notice

Copyright and all other intellectual property rights in, and to, this report are the property of, and are expressly reserved to, BCH. Without the prior written approval of BCH, no part of this report may be reproduced, used or distributed in any manner or form whatsoever.

## Executive Summary

[redacted], the Interconnection Customer (IC), is proposing to develop the Lower Wahleach Hydroelectric Project (LWH) in the Fraser Valley area of Lower Mainland, British Columbia to deliver electric energy to BC Hydro (BCH). The hydroelectric plant consists of one 11.1 MVA unit proposed to be connected via a tap connection onto the BCH 60 kV circuit, 60L95, between Wahleach Generating Station (WAH) and Hope Station (HOP). The Point of Interconnection (POI) is at a point located 10.2 km from WAH. The maximum power injection into the BCH system at the POI, after internal losses and loads, is 10 MW. The proposed Commercial Operation Date (COD) used for this project study is February 28, 2017. (The IC has recently indicated the revised date for COD is early 2019. This is not incorporated into the study results provided in this report.)

This report documents the evaluation of the system impact of interconnecting the proposed generating facility and identifies the required system modifications and facility restrictions to obtain acceptable system performance with the interconnection of the proposed project. To interconnect the LWH project and its facilities to the BCH system onto 60L95 via a tap connection, this SIS has identified the following conclusions and requirements:

1. WAH T1 transformer (75 MVA, 345/199.2/13.2 kV) would be overloaded to 80 MVA (107%) in pre-contingency system normal conditions (i.e. N – 0) during light summer (LS) load levels. The LWH plant is required to reduce its generation output to 5 MW or lower during the off-peak summer hours, i.e. May – August, 10 pm – 6 am (inclusive);
2. A control scheme is required to ensure WAH T1 is not overloaded at any time of the year. If WAH T1 loading exceeds the 75 MVA ampacity rating and the overloading sustains for a prescribed time period, a Direct Transfer Trip (DTT) signal is sent from WAH to LWH to trip the LWH entrance breaker or generator. LWH shall provide for DTT receiving facilities to receive the trip signals from WAH;
3. The above mentioned overload on WAH T1 can be exacerbated to 117% for the loss of WAH or HOP loads and the control scheme can be used to address the N-1 conditions. LWH may need to be offline during this time;
4. Non-protective tripping of 60L95 WAH terminal breakers requires a DTT sent to LWH 60 kV entrance breaker with delayed opening of WAH breakers (i.e. open LWH breaker first) to avoid Transient Over-voltage concerns;
5. Islanded operation is not arranged for the Lower Wahleach Hydro Project. Protective or non-protective tripping of breakers at WAH end of 60L95 can result in the IC becoming islanded with HOP+HPS loads. A DTT signal to LWH entrance breaker is required to remove LWH from the islanded 60 kV system.
6. Power Quality protection can also be used to trip the unit off during the islanded scenarios if the DTT signal(s) fails to act. Three-phase Voltage Transformers (VTs) at LWH plant are required for power quality protection;

@ British Columbia Hydro and Power Authority 2016. All rights reserved. 

7. WECC Class 3 telecommunication channels are required for implementing DTT signals between WAH and LWH;
8. A voltage sag of 12% is expected at the POI caused by random closing of the LWH entrance breaker to pick up the 12 MVA transformer from the grid which exceeds BCH interconnection guidelines for generators. The IC is required to take necessary measures for controlling the magnetizing inrush currents and to meet the guidelines;
9. Replacement of line protection relays at WAH terminal of 60L95 is required. Revisions and/or modifications are required for WAH 3L3 and WAH T1 protection. Minor control work is required to recommission telemetry, alarms and remote access. Updates of BC Hydro control centers are required to reconfigure the existing equipment to accommodate the new IC's facilities;
10. The LWH generator can go unstable for certain system faults and the IC is required to detect the resulting slip conditions quickly and isolate its generator from the BCH system using out-of-step protection. The expected swing centre is located inside the LWH plant (within its generator). This measure can be accepted to achieve required system performance if no other generator is connected to 60L95 in future;
11. LWH plant is required to be offline for any of the following conditions:
    - WAH 60L95 Outage
    - WAH T1 Outage
    - WAH - ROS 3L3 Outage
    - WAH 60kV re-connection at ALZ 60L93 (not normal condition)

A non-binding good faith cost estimate for the identified Interconnection Network Upgrades is $1.90 million. The implementation period to construct the identified network upgrades is estimated at 12-15 months, with all required outages, permits and contracts in place in time for construction. The work required within the IC's facilities and Revenue Metering costs are not part of the Interconnection Network Upgrades. The Interconnection Facilities Study report will provide greater details of the Interconnection Network Upgrade requirements with the associated cost estimate for this project.

@ British Columbia Hydro and Power Authority 2016. All rights reserved. 

# Table of Contents



@ British Columbia Hydro and Power Authority 2016. All rights reserved. 

## 1. Introduction

The project reviewed in this Interconnection System Impact Study (SIS) is as described in Table 1 below:

Table 1: Summary of Project Information

| | | | |
|---|---|---|---|
| Project Name | Lower Wahleach Hydroelectric Project | | |
| Interconnection Customer | [redacted] | | |
| Point of Interconnection (POI) | 60L95, 10.2 km from WAH station | | |
| IC Proposed COD | February 28, 2017 | | |
| Type of Interconnection Service | NRIS ☒ | ERIS ☐ | |
| Maximum Power Injection (MW) | 10 (Summer) | 10 (Winter) | |
| Number of Generator Units | 1 | | |
| Plant Fuel | Hydro | | |

The Interconnection Customer (IC), [redacted], is proposing to develop the Lower Wahleach Hydroelectric project (LWH), located east of BCH's Wahleach Generating Station (WAH), in the Fraser Valley area of Lower Mainland, British Columbia.

The hydro-electric plant consists of one 11.1 MVA unit operating with a 0.9/0.9 (lag/lead) power factor. The maximum power (10 MW) from the 6.9 kV generator will be stepped up to the 60 kV level through a single 12 MVA, 69/6.9 kV transformer unit. The power will then be transmitted through a short IC owned 60 kV, 0.08 km transmission line which is connected to the BC Hydro (BCH) circuit 60L95 (28.6 km) that runs between WAH and HOP stations. This point is a tap connection onto 60L95 and is the official Point of Interconnection (POI). The maximum power injection at the POI, after LWH station load consumption and line losses, is 10 MW. The proposed Commercial Operation Date (COD) used in this study is February 28, 2017.

The Wahleach 60 kV area is comprised mainly of residential (and some industrial) load with minimal projected load growth in the near future. This 60 kV system is normally connected to BCH's 360 kV bulk electric system at WAH generating station. During system normal conditions with all elements in service, excess generated power in the area, not consumed by load, will be transferred into the adjacent 360 kV system, through circuit 3L3, via WAH T1 (345/199.2/13.2 kV, 75 MVA). If an extended outage is to occur on either 3L3 circuit or WAH T1, the 60 kV system can be connected to the 230 kV transmission system through circuit 60L93 (60D24 normally open at WAH) which runs between WAH and Atchelitz (ALZ). The 60L95 disconnect switch (60D23) will be open at WAH during this N – 1 operating condition.

The circuit 60L95 stemming from WAH station serves the Hope town load (HOP) and Hope Pumping Station (HPS) during system normal conditions. Protection on circuit 60L95 is presently available only at the WAH 60 kV end and faults on this line are cleared at WAH only. During an extended outage of 60L95, when disconnected at WAH end, HOP and HPS loads are transferred onto 60L10.

WAH transformers T1, T3, T5, and circuit 3L3 all share the same protection zone. A fault (and successive tripping) on any one of these elements will result in the IC becoming temporarily islanded. A

@ British Columbia Hydro and Power Authority 2015. All rights reserved. 

contingency on circuit 3L3 will send a generation shedding signal to WAH G1 when pre-contingency flows on 3L3 (WAH – ROS) > 15 MW. When this happens, LWH and other generating plants in the 60 kV area will momentarily be operating in a 60 kV island serving load which may potentially have matched load levels close to area generation.

The IC interconnection scheme incorporating the above information is shown in Figure 1 below:

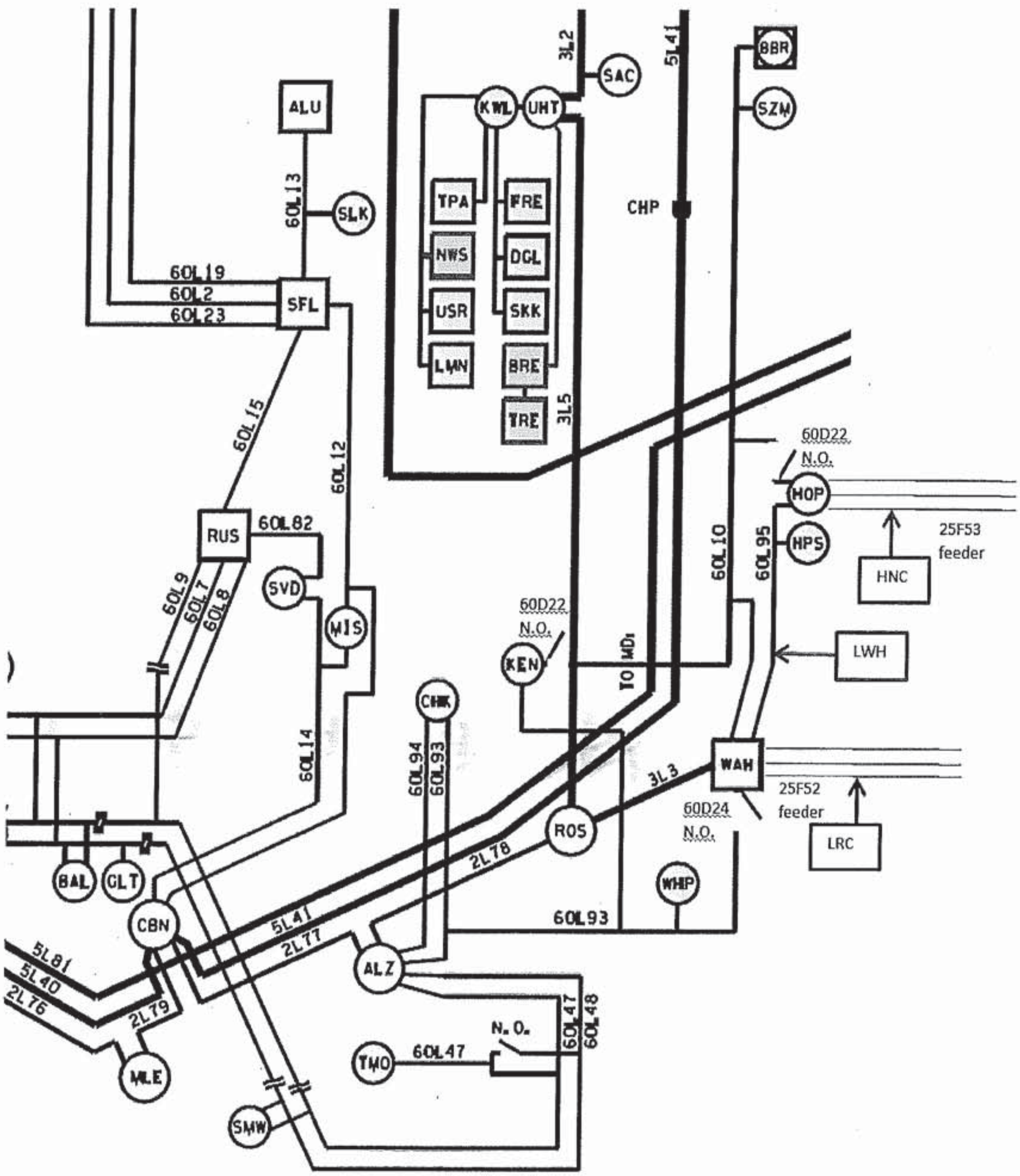


**Figure 1: Lower Wahleach Hydroelectric Project Interconnection Single Line Diagram**

@ British Columbia Hydro and Power Authority 2015. All rights reserved.

## 2. Purpose of Study

The purpose of this SIS is to assess the impact of the proposed interconnection on the BCH Transmission System. This study will identify constraints and Network Upgrades required for interconnecting the proposed generating project in compliance with the North American Electric Reliability Corporation (NERC) and Western Electricity Coordinating Council (WECC) reliability standards and the BCH transmission planning criteria.

## 3. 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 the proposed interconnection for system normal and single contingency conditions. The studied topics include equipment thermal loading and rating requirements, system transient stability and voltage stability, transient over-voltages, potential harmonic resonances, 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 network studies will determine the requirements for reinforcements or operating restrictions/instructions for those types of events.

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

## 4. Assumptions

The studied power flow conditions include generation, transmission facilities, and load forecasts representing the BCH interconnection queue position applicable to this project. Applicable seasonal conditions and the appropriate study years for the study horizon are also incorporated. As a result, BC Hydro 2016 Heavy Winter (HW), 2017 Heavy Summer (HS) and Light Summer (LS), 2017 HW, and 2018 HS and LS power flow base cases were selected for this study. The IC's latest data submission, as of March 2015, has been used in this study.

## 5. System Studies and Results

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

@ British Columbia Hydro and Power Authority 2015. All rights reserved. 

## 5.1. Steady State Power Flows

Steady state pre-outage (N – 0) power flows were prepared and single element (N – 1) contingency studies were conducted. This was to determine if the pre-contingency and post-contingency performance, including bus voltage deviations and facility loading levels, met the NERC Mandatory Reliability Standards (MRS) and WECC/BCH transmission planning criteria.

### 5.1.1 During System Normal (All I/S)

The system normal steady-state (N – 0) power flow studies have indicated that with maximum Lower Wahleach Hydroelectric power injection into the BCH transmission system (10 MW) and area generation set at their Maximum Continuous Rating (MCR) levels:

- Wahleach (WAH) T1 transformer (75 MVA, 345/199.2/13.2 kV) would be potentially overloaded to 80 MVA (107% of rating) under system normal conditions when area generation is operating at MCR levels in scenarios with local area loads at lightly loaded levels. The transformer rating of 75 MVA cannot be exceeded at any time of the year. Consequently, LWH is required to restrict generation output to 5 MW or lower during the off-peak summer hours, i.e. May – August, 10 pm – 6 am (inclusive). The IC has agreed to these power restrictions at its facility.
- No unacceptable voltage conditions are observed in the power flow analysis due to Lower Wahleach Hydroelectric Project for system normal conditions.

WAH T1, a water cooled unit, has limited overload capability which has been confirmed as 75 MVA year-round. Historical data plus future planned generation indicates the majority of potential overloads to be expected during summer months. However, overloading on WAH T1 due to LWH could also occur in the winter months as well.

Single contingency (N – 1) power flow studies have indicated that with maximum Lower Wahleach Hydroelectric injection into the transmission system (10 MW) and area generation set at MCR levels:

- Loss of WAH or HOP feeder loads for light and heavy summer load levels in both 2017 and 2018 will exacerbate any potential overloads on WAH T1 to 117%. The control scheme (proposed below) to protect WAH T1 for the system normal (N-0) condition can be used for the post contingency (N – 1) scenario. If required, LWH can be offline for the loss of either HOP or WAH loads. If this action is not sufficient to remove the WAH T1 overload, reduction of WAH G1 output will need to be used to address the overload concern under the N-1 scenario.
- No additional unacceptable voltage conditions are observed after various N – 1 condition events.

A control scheme is required to ensure WAH T1 is not overloaded at any time of the year. This control scheme can also be used to mitigate potential overloads on WAH T1 for single contingency (N – 1)

@ British Columbia Hydro and Power Authority 2015. All rights reserved. 

events. If WAH T1 is overloaded above its rating for a short prescribed time period, a Direct Transfer Trip (DTT) signal is required to trip the LWH entrance breaker and remove LWH plant from the system.

### 5.1.2 Abnormal Operating Conditions with 3L3/WAH T1 Out-of-Service

Any outages on 60L95 (disconnected at WAH end) will have the HOP+HPS loads transferred onto 60L10. There is no 60L10 line protection at HOP end and LWH is required to be offline during this time.

With an extended outage on circuit 3L3 (WAH – ROS) or transformer WAH T1, the WAH 60 kV area can be connected to the 230 kV system at Atchelitz (ALZ) via circuit 60L93 to serve load. During this configuration, 60L95 will be disconnected at the WAH end for protection purposes. There is no 60L10 line protection at HOP and LWH is required to be offline in this operating scenario. Consequently, LWH is required to be offline when the WAH 60 kV system is connected via 60L93 at ALZ for short-term outages.

In the unexpected event that WAH T1 fails permanently and the Wahleach 60 kV load will be served from the ALZ 60L93 supply on a long term basis, LWH may need to be offline on a long term basis.

The details can be determined in a future operational study and area generation must be adjusted to allowable levels so as not to overload the existing 60L93. Loss of either HOP or WAH feeder loads can result in overloads on 60L93. Loss of WAH T2 may overload WAH T5 depending on WAH G1 output.

A summary of the study results are shown below in Table 2:

@ British Columbia Hydro and Power Authority 2015. All rights reserved. 

**Table 2: Power Flow Results**

| Contingency | Base Case | Bus Voltages (p.u.) | | | | Power Flows (MW / % Amps) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | LWH POI | HOP 60T1 | WAH 60 | WAH 360 | LWH POI to WAH (60L95) | LWH POI to HOP (60L95) | 60L10 (into WAH) | WAH T1 | 3L3 (WAH - ROS) | 3L5 (UHT - ROS) | 2L78 (ROS - ALZ) |
| none (all-in-service) | b18HW | 1.04 | 1.03 | 1.05 | 1.01 | -4.3 | 14.3 | 3.4 | 67.1 | 66.9 | 335.0 | 398.5 |
| 60L10 | b18HW | 1.04 | 1.03 | 1.05 | 1.01 | -4.3 | 14.3 | n/a | 63.7 | 63.5 | 336.1 | 396.2 |
| 60L95 | b18HW | n/a | n/a | 1.05 | 1.01 | n/a | n/a | 3.4 | 71.4 | 71.1 | 333.5 | 401.3 |
| 60L93 (N.O.) | b18HW | 1.04 | 1.03 | 1.05 | 1.01 | -4.3 | 14.3 | 3.4 | 67.1 | 66.9 | 335.0 | 398.5 |
| WAH load | b18HW | 1.04 | 1.03 | 1.05 | 1.01 | -4.3 | 14.3 | 3.4 | 78.3 (106%) | 78.0 | 331.2 | 405.8 |
| HOP Load | b18HW | 1.05 | 1.05 | 1.05 | 1.01 | 9.9 | 0.1 | 3.4 | 81.2 (110%) | 80.9 | 330.2 | 407.8 |
| 3L3, T1, T3, T5 | b18HW | n/a | n/a | n/a | 1.01 | n/a | n/a | n/a | n/a | 0.0 | 357.2 | 353.7 |
| WAH G1 | b18HW | 1.04 | 1.02 | 1.04 | 1.01 | -4.3 | 14.3 | 3.3 | 2.1 | 2.1 | 356.4 | 354.9 |
| LWH G1 | b18HW | 1.04 | 1.03 | 1.05 | 1.01 | -14.3 | 14.3 | 3.4 | 57.0 | 56.9 | 338.3 | 391.8 |
| none (all-in-service) | b18LS | 1.05 | 1.04 | 1.05 | 1.02 | 2.9 | 7.1 | 4.5 | 78.7 (107%) | 78.4 | 306.6 | 382.1 |
| 60L10 | b18LS | 1.05 | 1.04 | 1.05 | 1.02 | 2.9 | 7.1 | n/a | 74.2 (100%) | 74.0 | 308.1 | 379.1 |
| 60L95 | b18LS | n/a | n/a | 1.05 | 1.02 | n/a | n/a | 4.5 | 75.8(103%) | 75.5 | 307.6 | 380.2 |
| 60L93 (N.O.) | b18LS | 1.05 | 1.04 | 1.05 | 1.02 | 2.9 | 7.1 | 4.5 | 78.7 (106%) | 78.4 | 306.6 | 382.1 |
| WAH load | b18LS | 1.05 | 1.04 | 1.05 | 1.02 | 2.9 | 7.1 | 4.5 | 86.6 (117%) | 86.3 | 304.0 | 387.4 |
| HOP Load | b18LS | 1.05 | 1.05 | 1.05 | 1.02 | 9.9 | 0.1 | 4.5 | 85.7 (116%) | 85.3 | 304.3 | 386.7 |
| 3L3, T1, T3, T5 | b18LS | n/a | n/a | n/a | 1.03 | n/a | n/a | n/a | n/a | 0.0 | 332.6 | 329.5 |
| WAH G1 | b18LS | 1.05 | 1.05 | 1.06 | 1.02 | 2.9 | 7.1 | 4.5 | 13.7 | 13.7 | 328.0 | 338.6 |
| LWH G1 | b18LS | 1.05 | 1.04 | 1.05 | 1.02 | -7.1 | 7.1 | 4.5 | 68.7 | 68.4 | 309.9 | 375.4 |

@ British Columbia Hydro and Power Authority 2015. All rights reserved.

## 5.2. Transient Stability Study

A series of transient stability studies, under selected system operating conditions including 2018 light summer load conditions, 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 best available dynamic models were used at the time of the study.

Transient stability studies were performed using the 2018 light summer base case to assess the impact of a 10 MW maximum power injection from Lower Wahleach Hydroelectric Project on the transmission network in the area. The transient stability studies have indicated that in system normal conditions, with maximum power injection from LWH plant and area generation operating at their MCR levels:

- The achievable fault clearing time with the existing 60 kV circuit breakers at WAH is 11 cycles. A close-in multiphase fault on 60L10 near WAH will cause the LWH unit to go unstable. For this and other contingencies on the transmission system, the IC is required to detect the resulting slip conditions quickly, using Out-of-Step protection, to isolate the LWH unit from the BCH system. The expected swing centre is located inside the LWH plant (within the generator). This conclusion will need to be reviewed if another generator is connected to 60L95 in the future.
- For faults past Zone 1 (85% of line to HOP), longer fault durations of 30 cycles or more show acceptable results.

During a 3L3/T1 outage, with WAH 60kV system connected to ALZ 60L93, multiphase faults at ALZ 60kV bus that are cleared within 15 cycles were found to be acceptable. A summary of the system stability studies for the 2018 light summer load condition is shown in Table 3 below:

@ British Columbia Hydro and Power Authority 2015. All rights reserved. 

**Table 3: Transient Stability Study Results for Lower Wahleach Hydroelectric injection of 10 MW (using 2018LS case)**

| System Load | Case | Outage | 3Φ Fault Location | Fault Clearing Time (cycles) | Generator max rotor swing (deg) (Δδ = δmax - δinitial) | | | | | Stability Performance | Minimum Transient Voltage (p.u.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Close End | LWH | WAH | HNC | BBH | LRC | | |
| 2018 LS | 1 | IC owned circuit | LWH 60 kV | LWH - 19 | - | 15° | 104° | 36° | 105° | Stable | > 0.90 |
| | 2 | 60L10 | WAH 60 kV bus | WAH - 7 | 102° | 18.5° | 69° | OOS | 74° | Stable | > 0.90 |
| | 3 | 60L95 | WAH 60 kV bus | WAH - 9 | - | 21° | 106° | 64.5° | 120° | Marginally Stable | > 0.90 |
| | 4 | 3L5 | ROS 360 kV bus | ROS - 9 | 102° | 56° | 100° | 76° | 86° | Stable | > 0.90 |
| | 5 | 2L78 | ROS 360 kV bus | ROS - 8 | 96° | 106° | 91° | 85° | 87° | Stable | > 0.90 |

@ British Columbia Hydro and Power Authority 2015. All rights reserved.

## 5.3 Remedial Action Scheme (RAS)

There is no Remedial Action Scheme (RAS) required for transient instability or steady state issues under contingent scenarios in order to interconnect the Lower Wahleach Hydroelectric project at this study stage.

## 5.4 Analytical Studies

Time domain simulation studies indicate that tripping 60L95 for no fault may produce transient overvoltages on the HOP 25 kV distribution bus that could exceed BC Hydro power quality guidelines, while the ensuing temporary overvoltage is only marginally acceptable. A Direct Transfer Trip (DTT) from WAH to LWH is required which, for any non-protective trip of 60L95, will open the IC's entrance breaker before the WAH line terminal is opened. The DTT, which is already required for anti-islanding and for avoiding overloading of the WAH transformer T1, may be utilized for this additional purpose.

The interconnecting transformer proposed for LWH will have an impedance-grounded wye HV winding. The HV windings of the transformers at HPS and at HOP are delta-connected. Hence, the clearing of single line-to-ground faults on 60L95 will result in a neutral shift and possible 1.7 per unit temporary overvoltage on the two unfaulted 60 kV phases. Rather than subjecting all of the equipment connected to the isolated and faulted 60 kV subnetwork to this overvoltage and, since LWH will be tripped anyway, either by slower power quality protection or anti-islanding protection, it is recommended to trip LWH by DTT. The DTT would be initiated from line protection at WAH for any fault on the line and there would be no requirement to delay the opening of the WAH end of 60L95.

A voltage sag of 12% is expected at the POI caused by random closing of the LWH entrance breaker to pick up the 12 MVA transformer from the grid. This exceeds BC Hydro interconnection guidelines for generators. Therefore, the magnetizing inrush currents must be controlled. This can be achieved by controlled pole closing using independent pole breakers and a special commercially available controller. There may be other methods to reduce the inrush currents, such as by using a switching device that employs pre-insertion resistors which are appropriately rated and are bypassed after a pre-defined time after energization.

## 5.5 Transmission Line Upgrades

The transmission line upgrade scope of work for BCH will be to own, design, and build a "standard" 60kV tap at the POI located on 60L95. The tap shall include the following:

- One tap structure;
- Three disconnect switch structures (to be confirmed in the definition stage).

@ British Columbia Hydro and Power Authority 2015. All rights reserved. 

It is recommended that a dead-end structure be placed on the IC side as the demarcation point. Additional right of way may be required to accommodate the above tap. Vegetation clearing may be required if necessary.

The design and build of the tap may be carried out by the IC for BCH. If this is the case, BCH will carry out an owner's engineering review of the tap portion of the work.

## 5.6 BCH Station Upgrades or Additions

No major station upgrades or changes at WAH station are currently anticipated for the interconnection of the Lower Wahleach Hydroelectric Project.

## 5.7 Protection and Control

Protection and control requirements for the proposed IC project are summarized below. Detailed requirements will be stated in the Facilities Study.

For preliminary protection analysis, it was assumed that the Lower Wahleach Hydroelectric (LWH) entrance transformer (12 MVA 69kV/6.9kV) is connected HV wye grounded/LV delta with transformer impedances of $Z_1$ = 9% and $Z_0$ = 9%. Also, the HV winding has a 35 $\Omega$ neutral grounding reactor (NGR) as scoped by the IC.

**Protection work required by BCH:**

For successful integration of the new IC's facilities, line protection relays at WAH terminal of 60L95 will be replaced. Revisions and/or modifications will be made to WAH 3L3 and WAH T1 protection as well.

The following Direct Transfer Trips (DTTs) from WAH to LWH are required:

- Class-3 DTT: from WAH to LWH for the following condition:
  - Alarm signal to LWH to alleviate WAH T1 overload condition by IC operator action;
- Class-3 DTT: from WAH to LWH for following conditions:
  - Protection operation or manual opening of WAH 60L95;
  - Protection operation or manual opening of WAH 3L3 or WAH T1;
  - For WAH T1 overload condition not mitigated from the alarm signal sent to IC.

Class-2 availability for these Class-3 channels must be maintained through a combination of alarms and operating orders while the LWH plant is operating. The LWH plant will be required to go offline if the channel is unavailable for more than four hours.

@ British Columbia Hydro and Power Authority 2015. All rights reserved. 

**Protection work required by the IC:**

The IC will provide entrance protection in accordance with BC Hydro's "60 kV to 500 kV Technical Interconnection Requirements (TIR) for Power Generators." At the LWH high voltage side, three-phase Voltage Transformers are required for power quality protection. The IC shall provide DTT receiving facilities to trip the entrance breaker or generator on receiving the DTT signals from WAH. As mentioned earlier, the swing center is located inside the LWH plant (within the generator) and the IC is responsible to detect these slip conditions and isolate its generator from the BCH system.

<u>LWH plant Operating Restrictions:</u>

- For WAH 60L95 Outage: LWH must go Offline
- For WAH T1 Outage: LWH must go Offline
- For WAH - ROS 3L3 Outage: LWH must go Offline
- For WAH 60kV connection from ALZ 60L93: LWH must go Offline

**Control work required by BCH:**

- In association with WAH line protection replacement and revisions/modifications to WAH 3L3, WAH T1, minor control work is required to recommission telemetry, alarms and remote access. No control work is required at Hope (HOP) or Atchelitz (ALZ) substations under this project.
- BC Hydro control centers are required to reconfigure the existing equipment to accommodate the new IC's facilities, include the generator into the network model, and add the new telemetry and alarm points.

**Control work required by the IC:**

- The IC will provide SCADA data reporting to BCH control centers in accordance with the "60 kV to 500 kV Technical Interconnection Requirements (TIR) for Power Generators," including required telemetry and status information, which should be available to the Energy Management System (EMS) at BCH's Ingledow (ING) site with appropriate telecom facilities. Continuous communications or broadband IP satellite from the IC to BC Hydro control centers is acceptable provided the performance objective stated in the TIR is met. The IC's telemetry and status will be routed to the appropriate Data Collection Platform (DCP).
- The IC is responsible for providing a communications link for remote interrogation of the Power Plant Information System (PPIS) equipment by BCH servers.

It is assumed that BC Hydro Control centres will have no control over the IC's facilities.

@ British Columbia Hydro and Power Authority 2015. All rights reserved. 

## 5.8 Telecommunications

The telecommunication requirements for the proposed IC project are summarized below:

- WECC Class 3 DTT from WAH to LWH for an alarm signal to indicate WAH T1 transformer overload;
- WECC Class 3 DTT from WAH to LWH for:
    a. Opening of WAH 60L95;
    b. Opening of WAH 3L3 or WAH T1;
    c. WAH T1 overload;
- Supervisory Control and Data Acquisition (SCADA) circuit, minimum of 9600bps, from LWH to Ingledow (ING) Data Collection Point (DCP) via WAH.

**Telecommunication work required by BCH:**

- Install equipment to receive the leased T1 from LWH, connect the T1 to the WAH DACS;
- Install a PDR2000 facing LWH;
- Cross connect the SCADA circuit from LWH to ING DCP.

**Telecommunication Work required by the IC:**

- Install a telephone high voltage entrance system to connect to Telus;
- Install a Digital Access Cross Connect Switch (DACS) to interface to the T1 lease from Telus; the DTT and SCADA circuits will be carried over this T1 to WAH;
- Install a PDR2000 tele-protection terminal with V.35 interface facing WAH.

## 5.9 Islanding

Islanding is not arranged for this project. If an islanding scenario occurs, a direct transfer trip (DTT) will be required to isolate the generator from a system security operation (anti-islanding) point of view. Additional anti-islanding protection (i.e. Power Quality), in the event the DTT signal fails, will also be required at the hydroelectric facility to detect abnormal system conditions to subsequently trip the unit.

The IC is connected onto circuit 60L95 which serves the HOP and HPS loads from WAH station during system normal conditions. Installation of anti-islanding protection is required by the Interconnection Customer for potential islanding scenarios under abnormal system conditions such as:

- Protective or non-protective tripping of WAH breakers can cause an unintentional island between LWH and HOP+HPS load. A DTT signal is required to trip LWH if this occurs. Anti-islanding protection (i.e. Power Quality) which is also required within the plant facilities can act to remove the unit from the system during abnormal conditions if the DTT signal fails.

@ British Columbia Hydro and Power Authority 2015. All rights reserved. 

- Protective and non-protective tripping of circuit 3L3 or WAH T1 can cause unintentional islanding of LWH plant with the Wahleach 60 kV area load. A DTT signal to isolate LWH from the 60 kV system will be required. Power quality protection can also be relied on to trip LWH if the DTT signal fails in order to avoid negative impacts to BCH customers when generation and load levels can possibly be matched.

## 5.10 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.

## 5.11 Cost Estimate and Schedule

The non-binding good faith cost estimate for the Interconnection Network Upgrades required to interconnect the proposed LWH project to the BCH Transmission system onto 60L95, via a tap connection, is $1.90 million. An accuracy range of -35% to 100% is applied to this cost estimate. The implementation period to construct the identified network upgrades is estimated at 12-15 months, with all required outages, permits and contracts in place in time for construction.

The estimate does not include any costs associated with the following:

- Any work required at the IC's facilities;
- Winter construction premium;
- Revenue Metering costs stated in Section 6 below;
- First Nations consultation and accommodation;
- Outage and related disruptions.

Major work included is:

- Installation of associated structures and equipment including three 60 kV disconnects and one tap structure at POI;

@ British Columbia Hydro and Power Authority 2015. All rights reserved. 

# 6 Revenue Metering

The estimated cost for installation of BCH Revenue Metering is $54k, which does not include any costs for civil, structural, and electrical work of Revenue Metering. Only the BCH Revenue Metering tasks (i.e. field and engineering) are covered. Refer to Appendix B for more information.

Specific metering information is provided in Table 6-1.

**Table 6-1: Revenue Metering Specific Information**

| | |
|---|---|
| **Metering Voltage (kV)** | 69 kV |
| **Max Current** | 84 Amps @ 69 kV |
| **Primary Voltage Point-of-Metering** | 69 kV at Customer substation LWH (Lower Wahleach Generating Station), primary side of power transformer (distance from POI <100m) |
| **Voltage Transformers** | 3 x 40250-115-115 V (to be supplied by IC) |
| **Current Transformers** | 3 x 100-5-5 A or 3 x 100x200-5-5 A;<br>100A is the connected primary tap if 100x200-5-5 A CT is used, rating factor 1.5 (to be confirmed and supplied by IC) |

# 7 Conclusions and Discussions

To interconnect the LWH project and its facilities to the BCH system onto 60L95 via a tap connection, this System Impact Study (SIS) has identified the following conclusions and requirements:

1. WAH T1 transformer (75 MVA, 345/199.2/13.2 kV) would be overloaded to 80 MVA (107%) in pre-contingency system normal conditions (i.e. N – 0) during light summer (LS) load levels. The LWH plant is required to reduce its generation output to 5 MW or lower during the off-peak summer hours, i.e. May – August, 10 pm – 6 am (inclusive);
2. A control scheme is required to ensure WAH T1 is not overloaded at any time of the year. If WAH T1 loading exceeds the 75 MVA ampacity rating and the overloading sustains for a prescribed time period, a Direct Transfer Trip (DTT) signal is sent from WAH to LWH to trip the LWH entrance breaker or generator. LWH shall provide for DTT receiving facilities to receive the trip signals from WAH;
3. The above mentioned overload on WAH T1 can be exacerbated to 117% for the loss of WAH or HOP loads and the control scheme can be used to address the N-1 conditions. LWH may need to be offline during this time;

@ British Columbia Hydro and Power Authority 2015. All rights reserved. 

4. Non-protective tripping of 60L95 WAH terminal breakers requires a DTT sent to LWH 60 kV entrance breaker with delayed opening of WAH breakers (i.e. open LWH breaker first) to avoid Transient Over-voltage concerns;
5. Islanded operation is not arranged for the Lower Wahleach Hydro Project. Protective or non-protective tripping of breakers at WAH end of 60L95 can result in the IC becoming islanded with HOP+HPS loads. A DTT signal to LWH entrance breaker is required to remove LWH from the islanded 60 kV system. Protective or non-protective tripping of circuit 3L3 or WAH T1 can also result in LWH plant temporarily operating in an islanded condition. Anti-islanding protection (i.e. Power Quality) can also be used to trip the unit off during the islanded scenarios if the DTT signal(s) fails to act. Three-phase Voltage Transformers (VTs) at LWH plant are required for power quality protection;
6. WECC Class 3 telecommunication channels are required for implementing DTT signals between WAH and LWH;
7. A voltage sag of 12% is expected at the POI caused by random closing of the LWH entrance breaker to pick up the 12 MVA transformer from the grid which exceeds BCH interconnection guidelines for generators. Examples of controlling the magnetizing inrush currents can be achieved by:
8. Controlled pole closing using independent pole breakers and a special commercially available controller or;
9. Using a switching device that employs pre-insertion resistors which are appropriately rated and are bypassed after a pre-defined time after energization;
10. Replacement of line protection relays at WAH terminal of 60L95 is required. Revisions and/or modifications are required for WAH 3L3 and WAH T1 protection. Minor control work is required to recommission telemetry, alarms and remote access. Updates of BC Hydro control centers are required to reconfigure the existing equipment to accommodate the new IC's facilities.
11. The LWH generator can go unstable for certain system faults and the IC is required to detect the resulting slip conditions quickly and isolate its generator from the BCH system using out-of-step protection. The expected swing centre is located inside the LWH plant (within its generator). This measure can be accepted to achieve required system performance if no other generator is connected to 60L95 in future.
12. LWH plant is required to be offline for any of the following conditions:
    - WAH 60L95 Outage
    - WAH T1 Outage
    - WAH - ROS 3L3 Outage
    - WAH 60kV re-connection at ALZ 60L93 (not normal condition)

A non-binding good faith cost estimate for the identified Interconnection Network Upgrades is $1.90 million. The implementation period to construct the identified network upgrades is estimated at 12-15 months, with all required outages, permits and contracts in place in time for construction. The work required within the IC's facilities and Revenue Metering costs are not part of the Interconnection Network Upgrades. The Interconnection Facilities Study report will provide greater details of the Interconnection Network Upgrade requirements with the associated cost estimate and estimated construction timeline for this project.

@ British Columbia Hydro and Power Authority 2015. All rights reserved. 

## Appendix A – Area Single Line Diagram

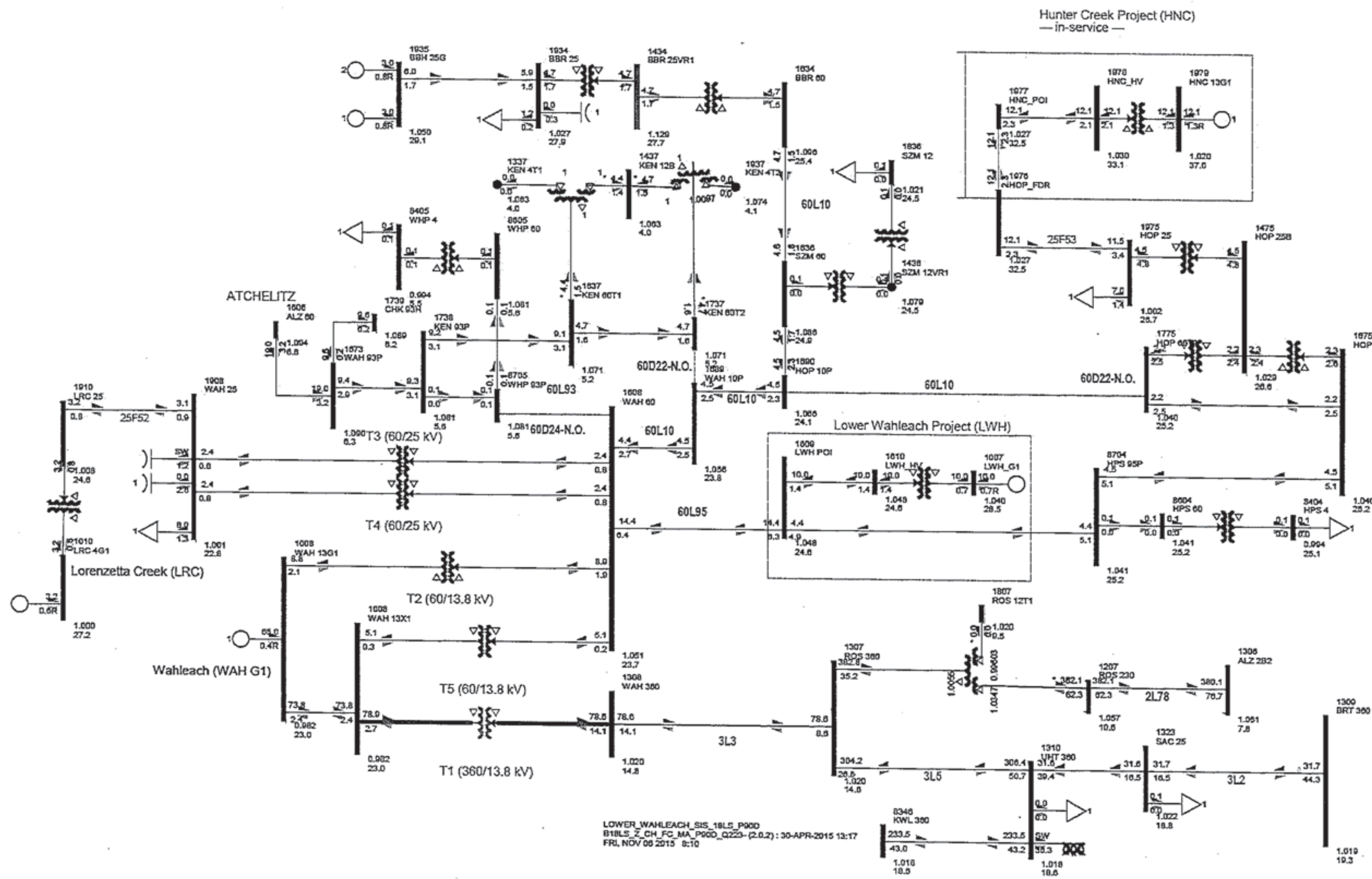


Figure A – 1: Area configuration in 2018 light summer

@ British Columbia Hydro and Power Authority 2015. All rights reserved.

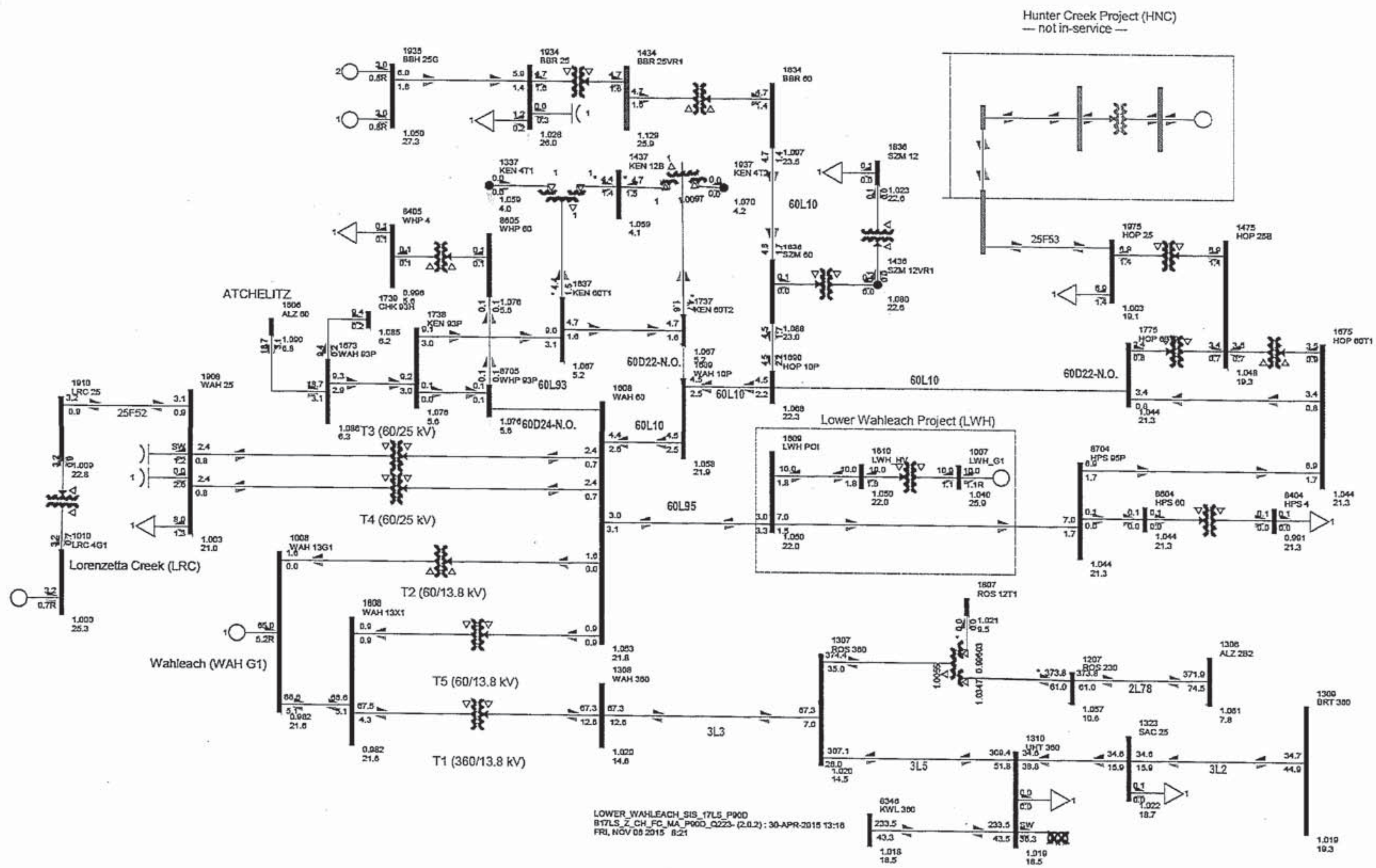


Figure A – 2: Area configuration in 2017 light summer

@ British Columbia Hydro and Power Authority 2015. All rights reserved.

## Appendix B – Revenue Metering Requirements

**Telecomunications for Revenue Metering - Power Generators:**

A telecommunications channel is required for remote read/download data from the main and the backup meters. The design, supply and installation of the communications equipment shall be coordinated between BCH Revenue Metering, BCH Telecom, the Power Generator and the Telecommunications Service Provider. The PG should provide a terminal / connector inside the BCH meter cabinet. Where the POI is on a 69 kV voltage class or higher BC Hydro transmission system **and** where a conventional wire-line telephone is installed, ground potential rise (GPR) protection shall be provided. Alternative technologies may be used, e.g. cellular, fiber optic, microwave, satellite etc. however these solutions must be discussed and approved by BCH before installation. BCH MV-90 Server must be able to access and download data from the meters remotely as they do when they dial in a site using a standard phone line (wireless or landline). For more details, please, refer to Section 8 of BCH Revenue Metering Requirements for Complex Metering published at the Revenue Metering webpage and at the BC Hydro external website.

**Revenue Metering:**

**Type of Connection: Transmission/Distribution Connected Power Generator (TVC-IPP)**

Revenue class meters approved and sealed by Measurement Canada (MC) shall be installed to meter the output of the generator(s). As per federal regulations, the meter will be periodically removed and re-verified in a MC authorized laboratory. The CTs and VTs supplied by the IPP and used on the metering scheme shall also be of a model/type approved by Measurement Canada. The IPP should send the CTs/VTs info to BC Hydro's Revenue Metering Department for approval, before committing to purchase the units.

The remote read load profile revenue metering installation should be in accordance with Canada federal regulations and BC Hydro Requirements for Complex Revenue Metering. The latest version of this document is published at BC Hydro webpage under Forms and Guides.

The location of the Point-of-Metering (POM) is subject to approval by BC Hydro's Revenue Metering department. The planning, design, installation and commissioning of the point of metering should be coordinated between the power generator and BC Hydro's Revenue Metering Department. The responsibilities and charges between the Interconnection Customer and BC Hydro shall be in accordance with Section 10 (10.1 and 10.2) of BC Hydro's Requirements for Complex Revenue Metering published at BC Hydro's website. For a complete list of field tasks, see table on pages 23-25.

All meters will be supplied and maintained by BC Hydro. Main and backup meters will use the same CTs and VTs secondaries and shall not share the secondary with any other equipment. The meter will be leased to the Interconnection Customer by BC Hydro. The revenue class instrument transformers (CTs and VTs units) will be supplied by the Interconnection Customer and must be a MC approved model. A list of approved models is available at the MC website under "Notice of Approval Database Section". The remote read load profile revenue metering equipment should be in accordance with BC Hydro Requirements for Remotely Read Load Profile Revenue Metering. The latest version of this document is published at BC Hydro webpage under Forms and Guides.

@ British Columbia Hydro and Power Authority 2015. All rights reserved. 

Main and backup bi-directional load profile interval meters are required to measure the power received and the power delivered by BC Hydro (BCH) during each 30 minute time period. The meters will be programmed for 5 minute intervals and will be remotely read each day by the BCH Enhanced Billing Group using MV-90 software. The POM requires a dedicated communications line that is provided by the Customer. This line should be available on the meter cabinet and it is for revenue metering use only. The communication line provided could be a protected landline or a wireless alternative approved by BC Hydro. The landline should be installed in accordance with *"IEEE Standard 487 Guide for the Protection of Wire-Line Communication Facilities Serving Electric Power Stations".* If there is digital cellular phone coverage for data (IP), due to IT security reasons, BC Hydro will supply the wireless communications equipment at an incremental cost to the Interconnection Customer.

A 3--element metering scheme with 3 CTs and 3 VTs connected L-N (Grd) will be used when the POM is located on the BC Hydro side of the power transformer.

For generation applications, all instrument transformer compartment doors shall be **key interlocked** with a BC Hydro side disconnect device and an Interconnection Customer 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* Interconnection Customer *side of the power transformer, the BC Hydro side disconnect device shall be on the BC Hydro side of the power transformer to insure that no-load losses.*

If the impedance and losses between the POM and the PODR are significant, the meters will be programmed to account for the line and/or transformer losses between the POM and PODR. The Interconnection Customer shall provide the line parameters data and the power transformer testing report data signed and stamped by a professional engineer.

Where two or more Interconnection Customers or one Interconnection Customer with more than one generating station/generator share a private power line to connect to the BCH system, a main POM located in the Point-of-Interconnection (POI) will be required, as well as an individual POM on each one of the generating stations/generators.

During the planning phase, BC Hydro's Revenue Metering Department should be contacted to discuss costs and specifics of the project. The Interconnection Customer should prepare and submit drawings showing the single line diagram (SLD), station lay-out and informing the proposed metering scheme, the length of the secondary cables needed (between CT/VT and the meter cabinet), meter cabinet location, CTs and VTs location, model/maker, connections, and MC Approval numbers, as well as any other related documentation.

**Information required in the design stage includes:**

1. Length of secondary cables
2. CT and VT models and approvals from Measurement Canada and if they come with a second set of secondaries
3. Single Line Diagram showing CTs, VTs, cabinets, all generating stations connecting to the POI
4. Identify whether revenue metering cabinets are indoors or outdoors - implication on whether cabinets need to be insulated
5. Communication medium contemplated to relay revenue metering data
6. 3-line diagram of the interconnection of the revenue metering CT & VT

@ British Columbia Hydro and Power Authority 2015. All rights reserved. 

7. Scaled Site Plan showing the relative location of the meter cabinet to the CT & VT (drawing showing the footprint for the sub)
8. Private power line parameters data and/or the power transformer testing data signed and stamped by a professional engineer
9. A set of manufacture switchgear drawings showing the installation of the revenue metering CT & VT (ensure the installation of the metering CT & VT complies with section 5.4 of BCH Requirements for Remotely Read Load Profile Revenue Metering, published at BCH website)
10. A simplified version of the lockout access steps to the revenue metering CT & VT (if already available)
11. Verification of dedicated 120V AC 15A circuit for the meter cabinet - as per section 6.4 of BCH requirements
12. Contact name/phone on site for equipment/material delivery.
13. Royal Mailing Address for the site (normal mailing address)
14. Interconnection Customer Billing Information
15. A copy of Measurement Canada issued Certificate of Registration for the Interconnection Customer
16. Operational Site Access for BC Hydro Meter Tech (for metering installation, maintenance, etc.)

The BC Hydro's Revenue Metering department can be contacted at: metering.revenue@bchydro.com.

@ British Columbia Hydro and Power Authority 2015. All rights reserved.