Q. **Reference: Reliability and Resource Adequacy Study, Volume III, Section 6.2**
Apart from the study in section 6.2, has Hydro performed any other studies in which the LIL is supplying less than its full rated power? If so, please provide a copy of the studies.

A. Newfoundland and Labrador Hydro ("Hydro") has performed a series of studies that contemplate different levels of availability of the Labrador-Island Link ("LIL").

A number of studies have been conducted with respect to the capability of the LIL prior to the full in-service of the Muskrat Falls Generating Station. As part of Hydro's Stage III operational studies, an analysis was performed to identify system limits for Phased Approach Monopolar Operation. In these cases, the LIL capacity is limited to 225 MW. Operational studies are also ongoing to assess transitional system limits as Muskrat Falls generating units are brought online. All completed studies (refer to Table 1) have been submitted to the Board of Commissioners of Public Utilities as part of Phase II of the Investigation and Hearing into Supply Issues and Power Outages on the Island Interconnected System, and ongoing studies[1] will be provided as they are completed.

The Newfoundland and Labrador System Operator ("NLSO") and Hydro also perform annual assessments to confirm compliance with Transmission Planning Criteria. These analyses include the assessment of contingencies involving the LIL. The 2019 Assessments were completed in the first quarter of 2019 and are included in PUB-NLH-025, Attachment 1 and PUB-NLH-025, Attachment 2.[2] The results of the analysis indicate that there are no criteria violations in the event of applicable LIL contingencies.

[1] These studies include: Operational Study - Stage 4, Part C – Labrador Limits Study, Stage 4, Part D – Transitional Operating Limits Study, and Stage 4, Part E, High Power Operating Limits Study
[2] Hydro intends to file these studies with the Board of Commissioners of Public Utilities annually.

Table 1: Completed Studies

Report Stage	Report Title
Stage 1	"Operational Studies: Maritime Link ONLY," TransGrid Solutions, September 8, 2017. "Operational Studies: Maritime Link ONLY," (Revised), TransGrid Solutions, November 10, 2017.
Stage 2	"Operational Studies: Maritime Link & Soldiers Pond Synchronous Condensers," TransGrid Solutions, November 10, 2017.
Stage 3	"Operational Studies: Maritime Link, SOP Syncs and LIL Monopole, TransGrid Solutions, February 27, 2018. "Maximization of LIL Power Transfer using SPS (phased monopolar approach), TransGrid Solutions, March 5, 2018. "LIL Power Transfer with MFA Filter Switching (phased monopolar approach), TransGrid Solutions, June 25, 2018. "AC Filter Operational Limits Study," TransGrid Solutions, June 25, 2018.
Stage 4	"Stage 4A LIL Bipole: Preliminary Assessment of High Power Operation," TransGrid Solutions, November 21, 2018. "Stage 4B: Power System Stabilizer Design," TransGrid Solutions, November 8, 2018.

NLSO Report

2019 Annual Planning Assessment

Doc # TP-R-027

Date: March 2019

newfoundland labrador hydro
a nalcor energy company

Executive Summary

A key function of the Newfoundland and Labrador System Operator (NLSO) is to ensure the coordinated development of a safe, reliable and economical transmission system for transmission customers. The NLSO Transmission Planning Process involves the execution of power system studies to demonstrate that the power system meets Transmission Planning Criteria. An annual assessment of the transmission system is utilized to determine the timing of system additions/modifications to ensure long term safe, reliable, and economical operation.

This report addresses the NL Transmission System, which is comprised of transmission facilities located in NL, operating at a voltage level of 230 kV or higher, including, the Labrador-Island Link, the Labrador Transmission Assets and Island Interconnected System.[1]

The near-term planning horizon covers the period 2019 to 2023. The assessment of the near-term horizon focuses on Year Two (2020) and Year Five (2023) study cases. The long-term planning horizon covers the period from 2023 to 2028. The assessment of the long-term horizon focuses on Year Ten (2028) study case.

Conclusions of the 2019 Annual Planning Assessment are specified as follows:

- The NL Transmission System includes Radial and Local Networks where outages to system elements may result in customer impacts. Transmission Planning Criteria are not strictly applied in these cases. Rather, these systems are designed to meet customer reliability and cost requirements.
- For the Labrador West Local Network, a set of criteria were defined as part of the Labrador Interconnected System Transmission Expansion Study in 2018. An expansion plan was developed to meet the baseline load forecast and ensure compliance with criteria.
- The steady state contingency analysis on the Labrador West Local Network indicates:
    - A violation in the Transmission Planning Criteria following the loss of a synchronous condenser or capacitor bank C1 at the Wabush Terminal Station in Year 2. The installation of a 23 MVar capacitor bank on bus B16 will resolve this violation prior to Year 5.
- Transmission Planning Criteria are strictly applied to the Primary Transmission System. Steady state analyses were performed and the following conditions were confirmed:
    - There are no pre-contingency transmission equipment overloads or voltage violations in the near-term or long-term planning horizons

[1] A separate annual assessment is performed by Newfoundland and Labrador Hydro (Hydro) to address all other transmission system facilities in both Newfoundland and Labrador with a rated voltage of 46 kV and above.

  - There are no steady state overloads or voltage violations due to a transmission line, generator, synchronous condenser, or shunt element contingencies in the near-term or long-term planning horizons
  - There are no steady state transformer overloads in the near or long term planning horizons
- The short circuit analyses were performed and it was confirmed that there are no issues with circuit breaker ratings in the near-term or long-term planning horizons.
- The stability analysis for Years Two, Five and Ten is currently in progress as part of ongoing operational studies. These studies will be completed in 2019 and results will be incorporated in the 2020 assessment.

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1 INTRODUCTION

The NLSO Transmission Planning Process involves the execution of power system studies to ensure compliance with Transmission Planning Criteria and to determine the timing of system additions and modifications.

The 2019 Annual Planning Assessment covers the near-term planning horizon through review of the 2020 and 2023 load cases and the long-term planning horizon through review of the 2028 load cases.

This report addresses the NL Transmission System, which is comprised of transmission facilities located in NL, operating at a voltage level of 230 kV or higher, including, the Labrador-Island Link, the Labrador Transmission Assets and Island Interconnected System.[2] Analysis is performed to ensure compliance with TP-S-007 NLSO Standard – Transmission Planning Criteria.

Figure 1 provides a map of the Newfoundland and Labrador Interconnected System post completion of the Lower Churchill Project.

[2] Newfoundland and Labrador Hydro (Hydro) performs an annual assessment of NL interconnected system, which includes all system elements 46 kV and above that are under its operational control and not included in the NLSO assessment.

Figure 1 : Newfoundland and Labrador Interconnected System

2 SELECTION OF STUDY CASES

System models have been developed to reflect the latest load forecast and completed system changes and proposed additions/modifications for future years. The study cases are defined as follows:

- Year One as 2019 (the current year)
- Year Two as 2020
- Year Five as 2023
- Year Ten as 2028.

2.1 Near-Term Planning Horizon Cases

The near-term planning horizon covers Years One to Five. The 2019 Annual Assessment uses Years Two (2020) and Year Five (2023), which are defined by the system additions summarized in the sections below. Load flow plots for Year Two and Year Five are provided in Appendix A and Appendix B.

2.1.1 Year Two (2020) System Additions

The following system additions are included in the 2020 study cases:

- The Labrador-Island HVdc Link (LIL) in operation in Bipole Mode
- There is one 206 MW generating unit in service at Muskrat Falls Generating Station (MFAGS)
- There are two Soldiers Pond 175 MVAR synchronous condensers in service for analysis (the third unit is available)
- There are no firm export commitments on the Maritime Link (ML)
    - The Nova Scotia Block flow begins following commissioning of the third unit at Muskrat Falls Generating Station
- The addition of Synchronous Condenser #3 at the Wabush Terminal Station[3]

2.1.2 Year Five (2023) System Additions

The following system additions are included in the 2023 study cases:

- The Muskrat Falls Generating Station (MFAGS) is complete
- The MFAST2 315 kV, 150 MVAR shunt reactor is removed from service
- Wabush Terminal Station upgrades include:

[3] In accordance with the Labrador Interconnected System Transmission Expansion Study, November 2018.

  - 23 MVar capacitor bank has been added to bus B16
  - Transformers T4 and T5 have been replaced with 125 MVA units
- The LIL is operating in Bipole Mode up to its rated capacity of 900 MW
- Holyrood Thermal Generating Station is removed from service with Unit 3 remaining in synchronous condenser mode only
- Stephenville gas turbine has been removed from service
- Hardwoods gas turbine is removed from service as a generator, but can be operated as a synchronous condenser
- The ML exports are set at the NS Block (157 MW at Bottom Brook terminal Station 2 – BBKTS2) in both the peak and light load cases

2.2 Long-Term Planning Horizon Case

The long-term planning horizon covers Years Six to Ten. The 2019 Annual Assessment uses Year Ten (2028) to assess the long-term planning horizon. Load flow plots for Year Ten are provided in Appendix C.

2.2.1 Year Ten (2028) System Additions

According to the current baseline transmission plan, there are no long-term planning horizon system additions or modifications beyond those found in the Year Five (2023) study cases.

3 SPECIAL CONSIDERATIONS

The study period for the 2019 Annual Planning Assessment covers the period 2020 to 2028. Special considerations for this study period are discussed in the sections below.

3.1 Western Labrador

The Labrador Interconnected System Transmission Expansion Study was filed with the Newfoundland and Labrador Board of Commissioners of Public Utilities in 2018. This study defined the required system upgrades to ensure sufficient transmission system capacity to meet the baseline load forecast. These upgrades were incorporated into the Year Two (2020), Year Five (2023), and Year Ten (2028) study case, as indicated in Sections 2.1.1 and 2.1.2, respectively. The analysis of this system is discussed in Section 5.2.1.

3.2 Operational Studies

Hydro is undertaking a set of operational studies for the interconnection of Lower Churchill Project assets into the Newfoundland and Labrador Transmission System. The objective of the studies is to identify system impacts and operating limits to allow for the development of instructions to be used by operators in Hydro's Energy Control Centre.

Operational studies will be completed in 2019 and will be included as part of the 2020 assessment.

4 LOAD FORECAST

The 2019 Annual Planning Assessment is based upon the following load forecasts prepared by the Market Analysis Section, Rural Planning Department, Newfoundland and Labrador Hydro:

- Island Interconnected 10 Year P50 and P90 Peak Demand Summary – Fall 2018 dated November 2018; and
- Labrador Interconnected 10 Year P50 and P90 Peak Demand Summary – Summer 2018 dated July, 2018.

The Island and Labrador Interconnected forecasts are summarized in Table 1.

Table 1 – Operating Load Forecasts (P90) - Island and Labrador Interconnected System

Forecasted Demand (MW)				
Year	Island Interconnected (Fall 2018)	Labrador Interconnected (Summer 2018)		
		Lab East	Lab West	Total
2018/19	**1,717.5**	81.7	342.4	**424.1**
2019/20	**1,716.1**	83.3	358.4	**441.7**
2020/21	**1,722.3**	83.5	369.0	**452.5**
2021/22	**1,724.9**	83.8	377.1	**460.9**
2022/23	**1,729.1**	84.0	377.3	**461.3**
2023/24	**1,731.2**	84.3	377.6	**461.9**
2024/25	**1,736.8**	84.9	377.9	**462.8**
2025/26	**1,742.2**	85.4	378.2	**463.6**
2026/27	**1,752.0**	85.9	378.5	**464.4**
2027/28	**1,762.0**	86.4	378.8	**465.2**
2028/29	**1,768.6**	86.9	379.1	**466.0**
2029/30	**1,775.1**	87.5	379.4	**466.9**
2030/31	**1,781.7**	88.0	379.6	**467.6**
2031/32	**1,788.3**	88.5	379.9	**468.4**
2032/33	**1,794.9**	89.0	380.2	**469.2**
2033/34	**1,801.5**	89.6	380.5	**470.1**
2034/35	**1,808.1**	90.1	380.7	**470.8**
2035/36	**1,814.6**	90.6	381.0	**471.6**
2036/37	**1,821.2**	91.1	381.2	**472.3**
2037/38	**1,827.8**	91.7	381.4	**473.1**
2038/39	**1,834.4**	92.2	381.7	**473.9**

5 STEADY STATE ANALYSIS

The NL Transmission System consists of Radial Networks, Local Networks as well as the Primary Transmission System. Radial Network and Local Networks allow for the delivery of electricity to specific customers and Transmission Planning Criteria are not strictly applied. Rather, these systems are designed to meet customer reliability and cost requirements. In such a network, the loss of a transmission system element may result in a customer impact. This is in contrast to the Primary Transmission System, where all Transmission System Criteria are strictly enforced.

Steady state analysis is performed for all of the system defined above and consists of pre-contingency analysis, with all equipment in service, and contingency analysis. These analyses are performed to ensure that with all equipment in service under normal operation, power flow through all elements does not exceed their normal rating and voltages are within acceptable limits. The ratings are defined as per TP-S-001 - NLSO Facilities Rating Guide. The results of the steady state analysis are described in the sections below.

Load flow plots during normal operation of the NL Transmission System for Year Two, Year Five, and Year Ten are provided in Appendix A, Appendix B, and Appendix C, respectively.

5.1 Radial Networks

5.1.1 Supply to Vale Inco

Vale Inco is supplied by radial transmission line TL208. There are no overloads to this transmission line under normal operation. In the event of an outage to this transmission line, there will be a customer interruption. This consequence is accepted by the radial customer.

5.1.2 Supply to Stephenville Area

The Stephenville area is supplied by radial transmission line TL209. There are no overloads to this transmission line under normal operation. In the event of an outage to this transmission line, the network is supplied by the local 66 kV network. This system is addressed as part of Hydro's Annual Assessment.

5.2 Local Networks

5.2.1 The Labrador West System

The transmission system in western Labrador is considered a local network and consists of two 230 kV transmission lines that connect Churchill Falls Terminal Station #1 to the Wabush Terminal Station. These transmission lines are designated as L23 and L24. This network also includes three synchronous condensers at the Wabush Terminal Station (SC1, SC2, and SC3).

Criteria for this local network were defined as part of Hydro's Labrador Interconnected System Transmission Expansion Study that was completed in 2018. Criteria were defined in this study to specify that there shall be no customer interruption for the loss of a synchronous condenser, a capacitor bank, a power transformer, or a 46 kV transmission line. Loss of load is permitted for a 230 kV transmission line outage. The voltage on the 230 kV bus at the Wabush Terminal Station is below 0.95 per unit during peak conditions for Year 2, but this is deemed acceptable given the system is considered a local network. The installation of a 23 MVar capacitor bank on bus B16 will resolve an outage of SC3 contingency prior to Year 5.

For the purposes of the NLSO annual assessment, analysis was performed to assess the impact of the loss of the 230 kV transmission line, a synchronous condenser, a capacitor bank. Other contingencies are addressed as part of Hydro's annual assessment.

There are violations to the planning criteria following the loss of a synchronous condenser or capacitor bank C1 in Year 2. The installation of a 23 MVar capacitor bank on bus B16 will resolve these violations prior to Year 5.

There is a reduction in transfer capacity with the loss of a 230 kV line, which is considered acceptable based on the criteria established for this local network. Table 2 provides a summary of the transfer limits to the Labrador West system following the loss of a 230 kV line.

Table 2 - Transfer Capacity to Lab West (N-1)

Contingency	Transfer Capacity to Lab West (MW)
Normal Operation	**387**
Loss of L23 or L24 (Winter)	271*
Loss of L23 or L24 (Summer)	156**
* Voltage Violation ** Thermal Rating Violation of L23 or L24	

5.3 Primary Transmission System

Analysis was performed to assess steady state contingencies for the Primary Transmission System. Transmission Planning Criteria are applied to the network to ensure that no system events result in the interruption of load or firm imports or export commitments.

5.3.1 Bay d'Espoir System

The Bay d'Espoir System consists of a network of 230 kV transmission lines that includes the following:

- TL234 between Bay d'Espoir Terminal Station and Upper Salmon Terminal Station
- TL263 between Upper Salmon Terminal Station to Granite Canal Terminal Station
- TL269 between Granite Canal Terminal Station to Bottom Brook Terminal Station

This network also includes hydraulic generating facilities at Bay d'Espoir, Upper Salmon and Granite Canal Generation Stations. The Bay d'Espoir Generation Station is the largest plant on the Island Interconnected System with a total capacity of approximately 613 MW. The largest unit at the Bay d'Espoir Generation Station is BDE Unit #7 (154.4 MW), which can also operate as a synchronous condenser.

This network also includes a 15 MVAR reactor at Granite Canal Tap Terminal Station.

Steady state analysis indicates that within the near and long term horizons, there are no violations within this network under normal operation or any contingency event involving the loss of any 230 kV line, generator, reactor or synchronous machine.

In the event of an outage to the Granite Canal Tap Shunt Reactor, TL269 would be removed from service in accordance with NLSO operating instruction TOP-P-068 - Granite Canal Tap Shunt Reactor. There are no violations to Transmission Planning Criteria associated with this scenario.

5.3.2 Bay d'Espoir - Western Avalon Corridor

Bay d'Espoir Terminal Station is interconnected to Western Avalon Terminal station through a network of 230 kV transmission lines that includes the following:

- TL202 and TL206 between Bay d'Espoir Terminal Station and Sunnyside Terminal Station
- TL267 between Bay d'Espoir Terminal Station and Western Avalon Terminal Station
- TL203 between Sunnyside Terminal Station and Western Avalon Terminal Station
- TL207 between Sunnyside Terminal Station and Come by Chance Terminal Station
- TL237 between Come by Chance Terminal Station and Western Avalon Terminal Station

This network also includes four 37.35 MVAR capacitor banks at Come by Chance Terminal Station.

Steady state analysis indicates that within the near and long term horizons there are no violations in this corridor under normal operation or any contingency event involving the loss of a line or capacitor bank.

Operating limits in this corridor are defined in accordance with NLSO Operating instruction TOP-P-076 - NL Transmission System Operating Limits. Transient stability considerations included in this operating instruction will be revisited as part of Operational Studies, as addressed in Section 7.

5.3.3 Avalon Peninsula System

The Avalon Peninsula is the largest load center on the Island Interconnected System that is comprised of a network of 230 kV transmission lines that include the following:

- TL201 and TL217 between Western Avalon Terminal Station and Soldiers Pond Terminal Station
- TL265 and TL268 between Soldiers Pond Terminal Station and Holyrood Terminal Station
- TL242 and TL266 between Soldiers Pond Terminal Station and Hardwoods Terminal Station
- TL236 between Hardwoods Terminal Station and Oxen Pond Terminal Station
- TL218 between Oxen Pond Terminal Station and Holyrood Terminal Station

This network also includes the following generators and synchronous condensers:

- Holyrood Generation Station
  - Unit 1 – 170 MW (Largest Unit)
  - Unit 2 – 170 MW
  - Unit 3 – 150 MW[4]
  - GT – 123.5 MW

- Soldiers Pond Generation Station
  - SC1 (175 MVAR, -90 MVAR)
  - SC2 (175 MVAR, -90 MVAR)
  - SC3 (175 MVAR, -90 MVAR)

Steady state analysis indicates that within the near and long term horizons, there are no violations within this network under normal operation or any contingency event involving the loss of any 230 kV line, generator, or synchronous condenser.

[4] Can operate as a synchronous condenser

Operating limits on the Avalon Peninsula are defined in accordance with NLSO Operating instruction TOP-P-076 - NL Transmission System Operating Limits. Transient stability considerations included in this operating instruction will be revisited as part of Operational Studies, as addressed in Section 7.

5.3.4 Western Island Interconnected System

The Western Island Interconnected system consists of a network of 230 kV transmission lines that include the following:

- TL204 and TL231 between Bay d'Espoir Terminal Station and Stony Brook Terminal Station
- TL205 and TL232 between Stony Brook Terminal Station and Buchans Terminal Station
- TL233 between Buchans Terminal Station and Bottom Brook Terminal Station
- TL211 between Bottom Brook Terminal Station and Massey Drive Terminal Station
- TL228 between Buchans Terminal Station and Massey Drive Terminal Station
- TL248 between Massey Drive Terminal Station and Deer Lake Terminal Station
    - Loss of this line isolates Cat Arm generation
- TL247 between Deer Lake Terminal Station and Cat Arm Terminal Station
    - Loss of this line isolates Cat Arm generation

This network also includes two hydro generating facilities, Cat Arm and Hinds Lake Generation Stations.

Steady state analysis indicates that within the near and long term horizons, there are no violations on this network under normal operation or the loss of any 230kV line or generator.

Operating limits for the Western Island Interconnected are defined in accordance with NLSO Operating instruction TOP-P-076 - NL Transmission System Operating Limits. Transient stability considerations included in this operating instruction will be revisited as part of Operational Studies, as addressed in Section 7.

Considerations associated with outages to TL248 are defined in accordance with NLSO Operating instruction TOP-P-022 - TL248 Planned and Forced Outage

5.3.5 The Exploits System

This network only includes the 230 kV line from Stony Brook Terminal Station to the Grand Falls Terminal Station (TL235). The loss of this line isolates Exploits generation from the rest of the Island Interconnected System, which results in no violations within the near or long term horizon.

5.3.6 The Labrador 315 kV System

The Labrador Interconnected System consists of two 315 kV transmission lines between Churchill Falls Terminal Station #2 and Muskrat Falls Terminal Station #2. These two lines are designated as L3101 and L3102.

Table 3 provides a summary of the pre-contingency transformer loading levels across the planning horizons for transformers located on the Labrador Island Interconnected System that fall under the planning authority of the NLSO.

Table 3 - Transformer Peak Loads

Transformer	2020		2023		2028	
	MVA	%	MVA	%	MVA	%
CFTS2-T1	86.49	10.3%	***NOTE 1***			
CFTS2-T2	86.25	10.3%				

Notes:

1 - The power transfer limits and the operational philosophy of the two parallel 315 kV lines L3101 and L3102 between Churchill Falls (CHFTS2) and Muskrat Falls (MFA) are currently being assessed as part of the ongoing operational studies. The outcome of this study will determine the future loading on CFTS2-T1 and CFTS2-T2

Table 4 provides the transformer loading with the largest transformer out of service.

Table 4 – Transformer Peak Loads – Loss of Largest Transformer

Transformer	2020		2023		2028	
	MVA	%	MVA	%	MVA	%
CFTS2-T1	161.34	19.2%	***NOTE 1***			
CFTS2-T2	***Out of Service***					

Notes:

1 - The power transfer limits and the operational philosophy of the two parallel 315 kV lines L3101 and L3102 between Churchill Falls (CHFTS2) and Muskrat Falls (MFA) are currently being assessed as part of the ongoing operational studies. The outcome of this study will determine the future loading on CFTS2-T1 and CFTS2-T2

Power flow limits for the 315 kV network in Labrador are being investigated as part of operational studies to be completed in 2019. The results of the analysis will be incorporated into the 2020 annual assessment.

5.3.7 The Labrador Island Link

The Labrador Island Link (LIL) is an HVdc bipole that electrically connects the Island and Labrador Interconnected Systems and terminates at the Muskrat Falls Converter Station and the Soldiers Pond Converter Station. Steady state analysis indicates that within the near and long term horizons, there are no violations under normal operation or any contingency event involving the loss of pole or an ac filter at the Muskrat Falls or Soldiers Pond station.

A detailed assessment of system operating limits associated with the Labrador Island Link will be performed as part of Operational Studies to be performed in 2019. These limits will be addressed in the 2020 annual assessment.

5.3.8 The Maritime Link

The Maritime Link (ML) is an HVdc bipole that electrically connects the Island Interconnected System to Nova Scotia via two 170km subsea cables. The link terminates at Bottom Brook Terminal Station in Newfoundland and Woodbine Terminal Station in Nova Scotia. Steady state analysis indicates that within the near and long term horizons, there are no violations under normal operation or any contingency event involving the loss of pole or an ac filter at Bottom Brook Terminal Station.

A detailed assessment of system operating limits associated with the Maritime Link will be performed as part of Operational Studies to be performed in 2019. These limits will be addressed in the 2020 annual assessment.

6 SHORT CIRCUIT ANALYSIS

Short circuit analysis is required to ensure that the prospective short circuits at equipment locations do not exceed the interrupting capacity of the circuit breakers used to protect the equipment. Short circuit analysis for Year Two, Year Five and Year Ten was performed and the results indicate that there are no circuit breaker rating violations.

7 STABILITY ANALYSIS

A review of the stability analysis for Year Two, Five, and Ten is currently in progress as part of ongoing operational studies. The objective of these operational studies is to assess the Island and Labrador Interconnected Systems following the completion of the Lower Churchill Project. The results of these studies will be included in the 2020 annual assessment.

8 CONCLUSIONS

The 2019 Annual Planning Assessment focuses on Year Two (2020) and Year Five (2023) for the near-term planning horizon and Year Ten (2028) for the long-term planning horizon.

Conclusions of the 2019 Annual Planning Assessment are specified as follows:

- The NL Transmission System includes Radial and Local Networks where outages to system elements may result in customer impacts. Transmission Planning Criteria are not strictly applied in these cases. Rather, these systems are designed to meet customer reliability and cost requirements.
- For the Labrador West Local Network, a set of criteria were defined as part of the Labrador Interconnected System Transmission Expansion Study in 2018. An expansion plan was developed to meet the baseline load forecast and ensure compliance with criteria.
- The steady state contingency analysis on the Labrador West Local Network indicates:
    - A violation in the Transmission Planning Criteria following the loss of a synchronous condenser or capacitor bank C1 at the Wabush Terminal Station in Year 2. The installation of a 23 MVar capacitor bank on bus B16 will resolve this violation prior to Year 5.
- Transmission Planning Criteria are strictly applied to the Primary Transmission System. Steady state analyses were performed and the following conditions were confirmed:
    - There are no pre-contingency transmission equipment overloads or voltage violations in the near-term or long-term planning horizons
    - There are no steady state overloads or voltage violations due to a transmission line, generator, synchronous condenser, or shunt element contingencies in the near-term or long-term planning horizons
    - There are no steady state transformer overloads in the near or long term planning horizons
- The short circuit analyses were performed and it was confirmed that there are no issues with circuit breaker ratings in the near-term or long-term planning horizons.
- The stability analysis for Years Two, Five and Ten is currently in progress as part of ongoing operational studies. These studies will be completed in 2019 and results will be incorporated in the 2020 assessment.

9 REFERENCE DOCUMENTS

Labrador Interconnected System Transmission Expansion Study, November 5, 2018

NLSO Operating instruction TOP-P-022 - TL248 Planned and Forced Outage

NLSO operating instruction TOP-P-068 - Granite Canal Tap Shunt Reactor

NLSO Operating instruction TOP-P-076 - NL Transmission System Operating Limits

TP-S-001 NLSO Standard – Facilities Rating Guide

TP-S-003 NLSO Standard – Annual Planning Assessment

TP-S-007 NLSO Standard – Transmission Planning Criteria

APPENDIX A

Load Flow Plots Primary Transmission System Year Two (2020) – Peak and Light Cases

Figure 2 – IIS (2020 Peak Conditions)

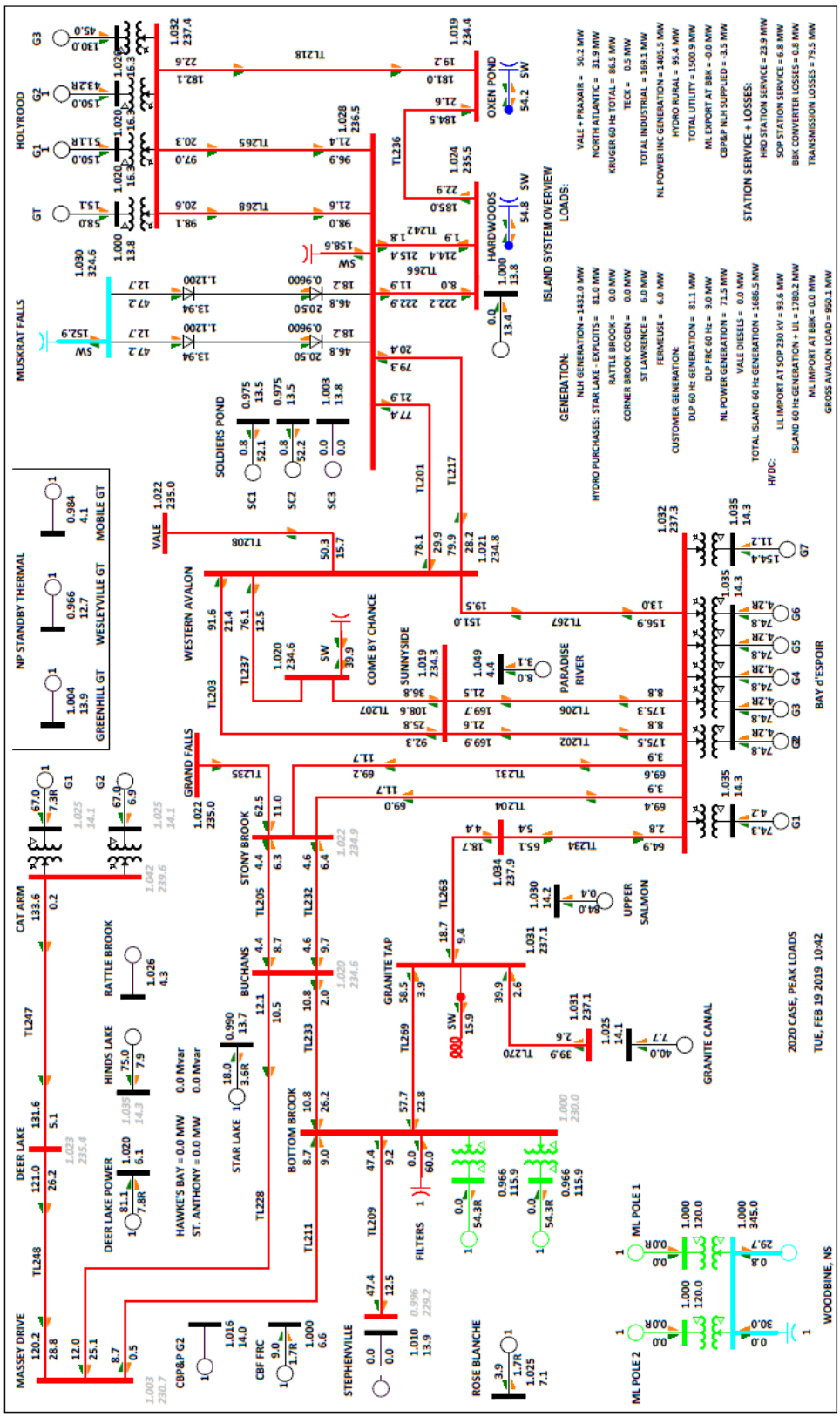


Figure 3 – LIS (2020 Peak Conditions)

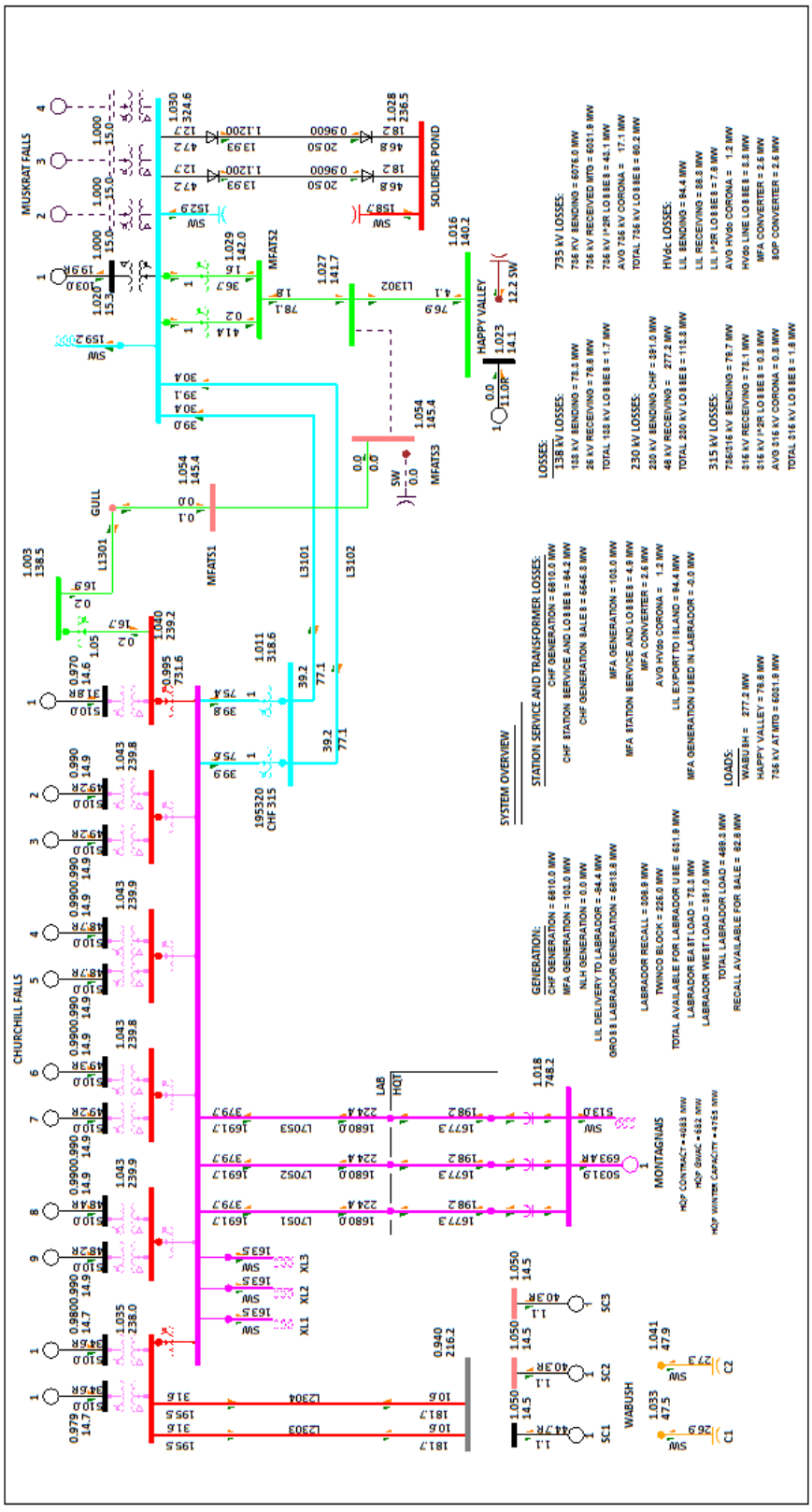


Figure 4 - IIS (2020 Light Conditions)

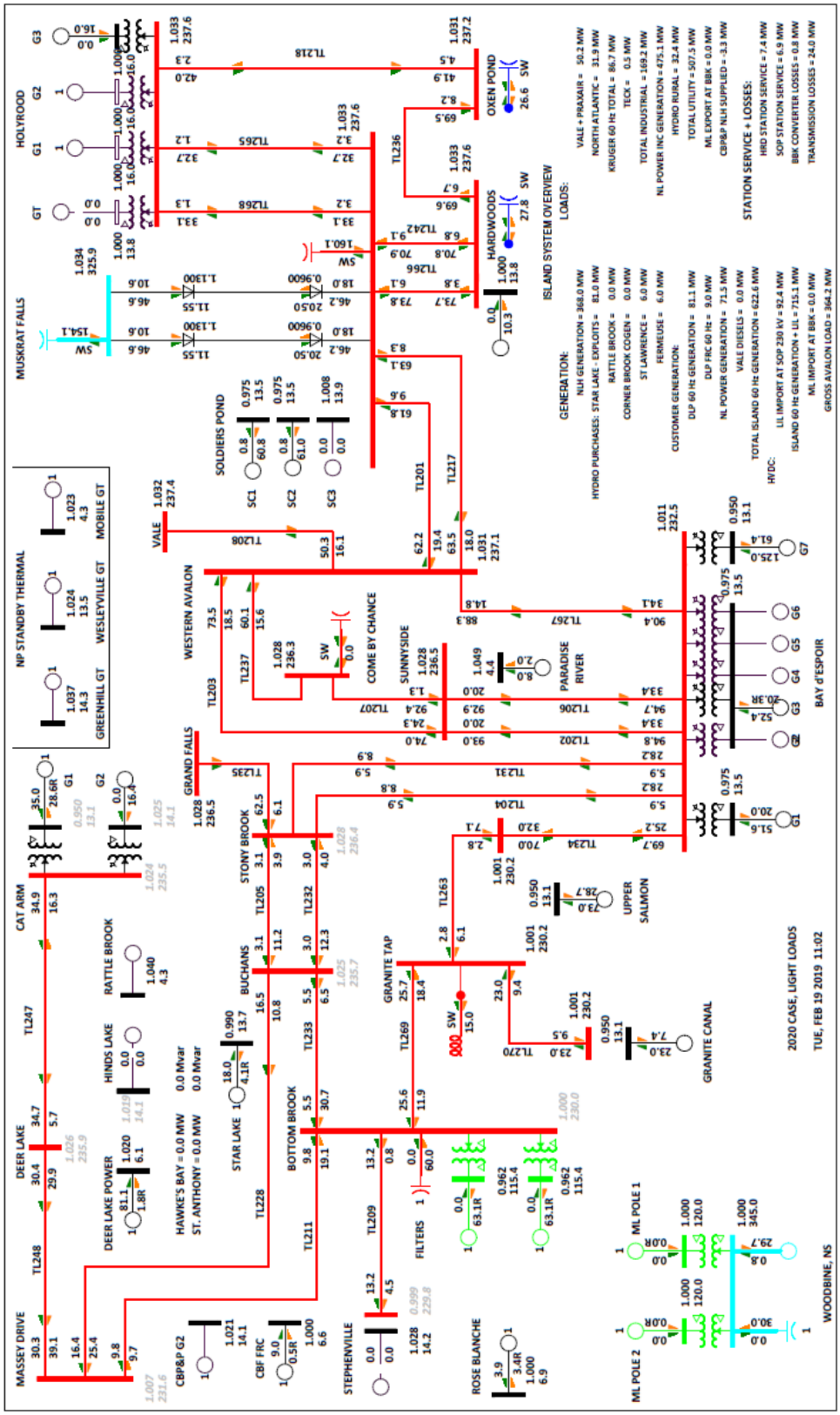
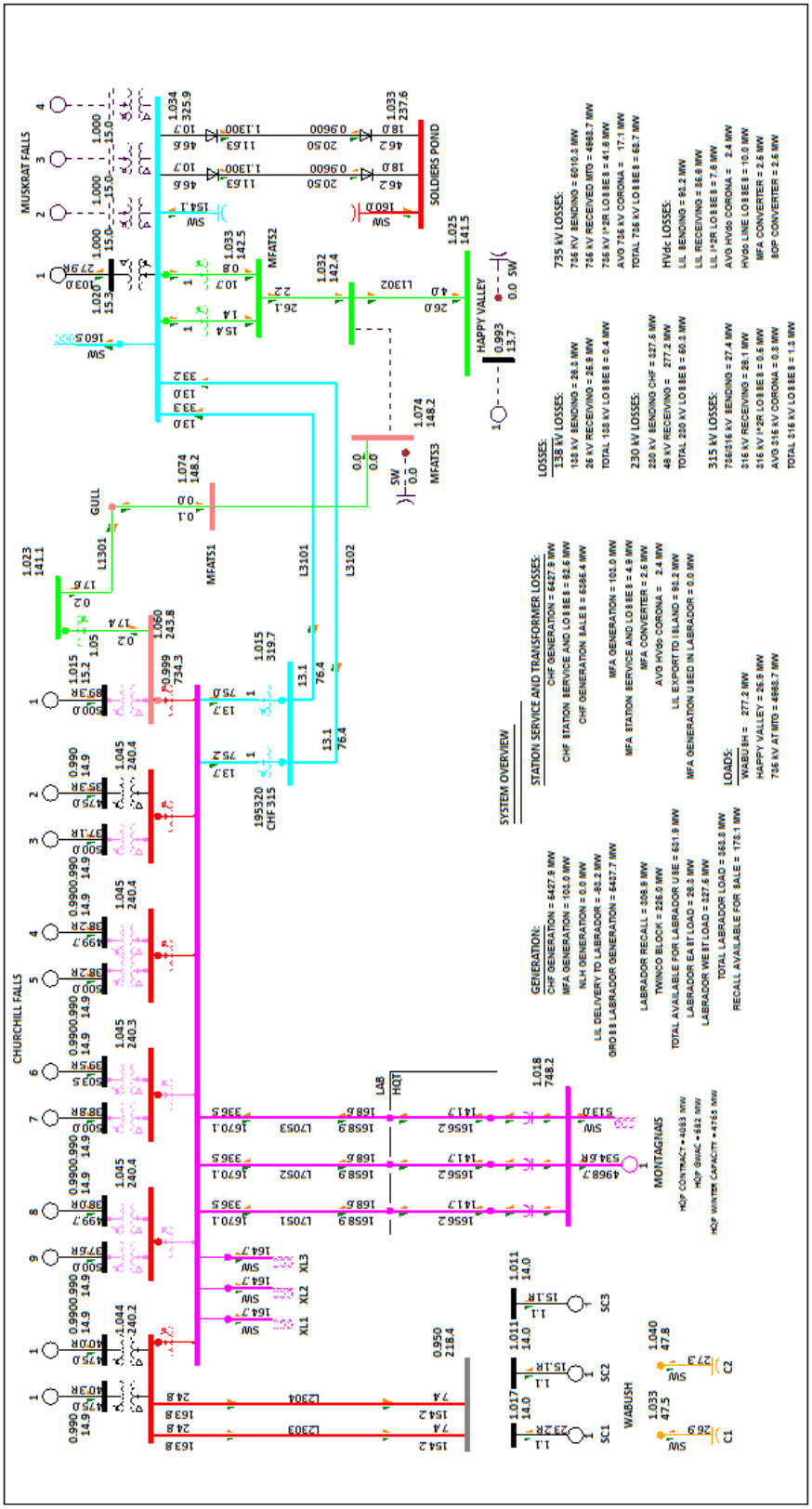


Figure 5 - LIS (2020 Light Conditions)



APPENDIX B

Load Flow Plots Primary Transmission System Year Five (2023) – Peak and Light Cases

Figure 6 - IIS (2023 Peak Conditions)

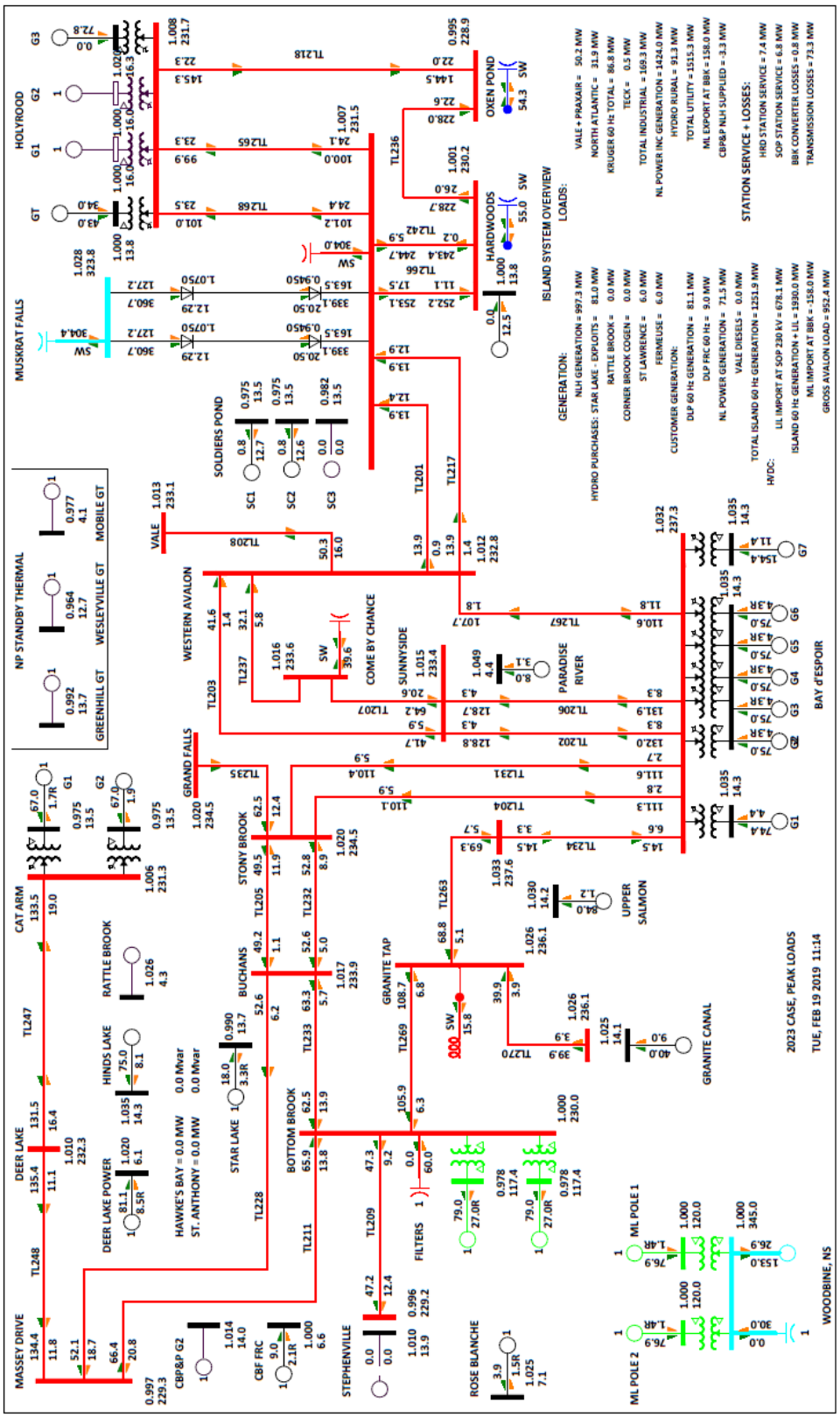


Figure 7 - LIS (2023 Peak Conditions)

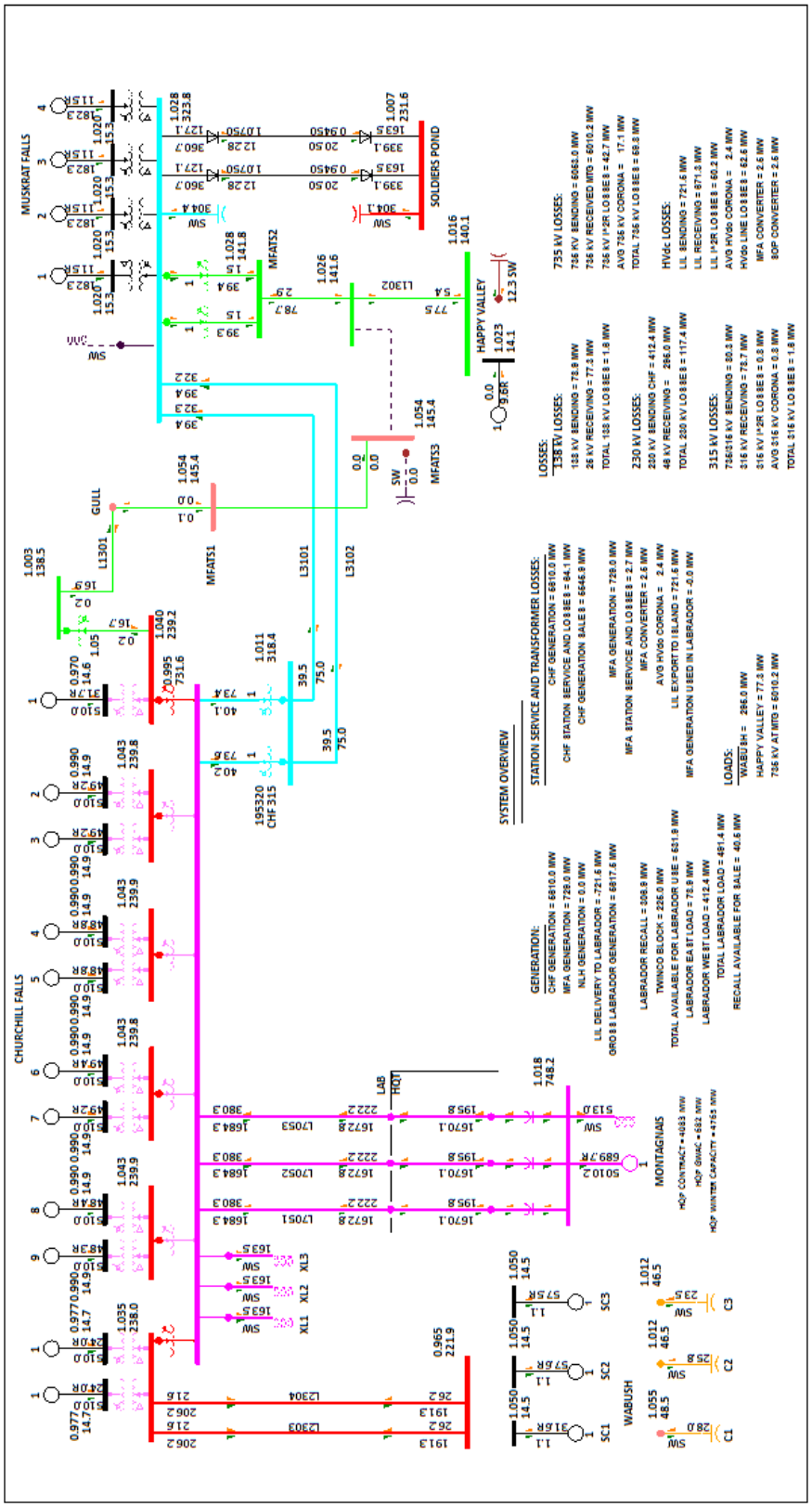


Figure 8 - IIS (2023 Light Conditions)

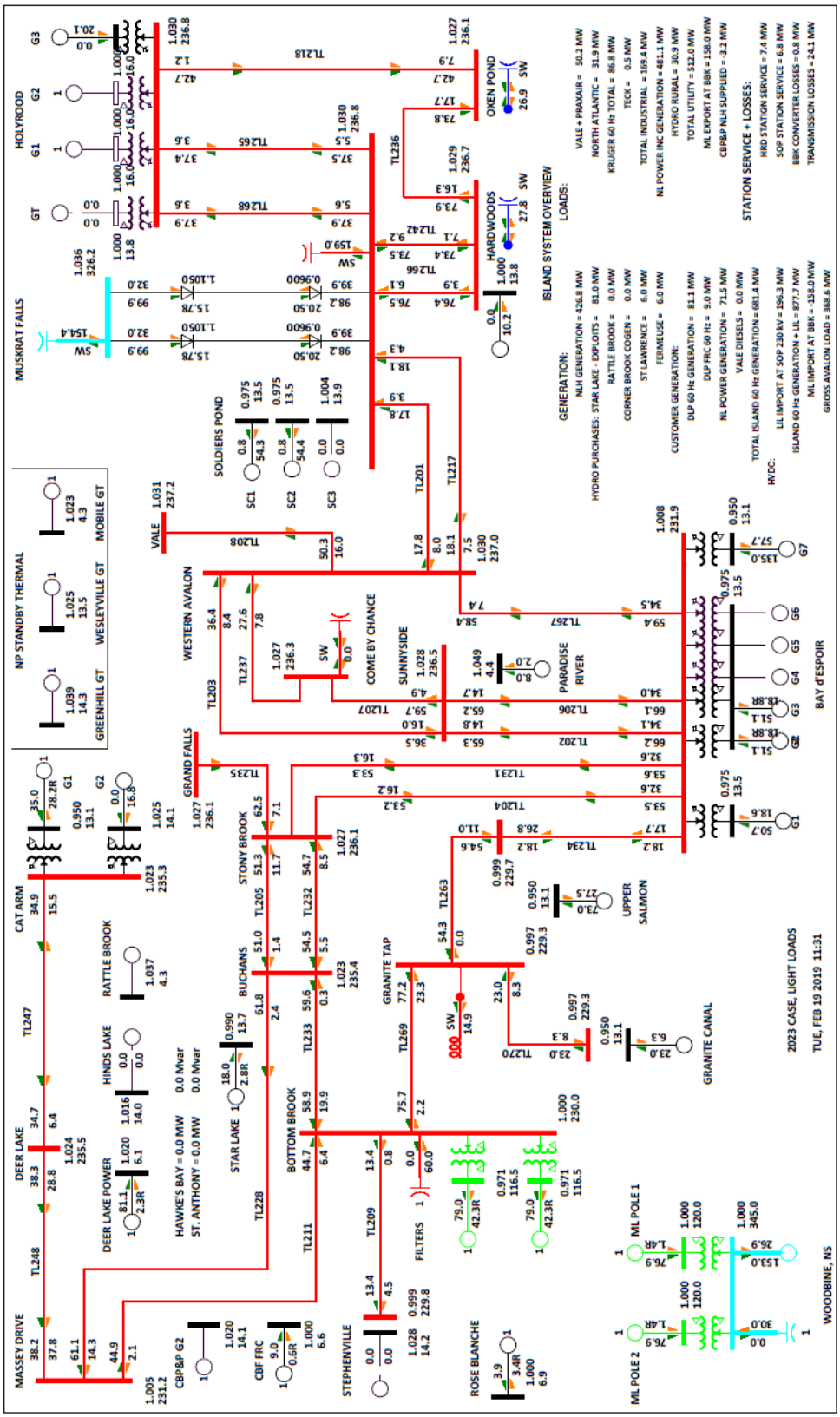
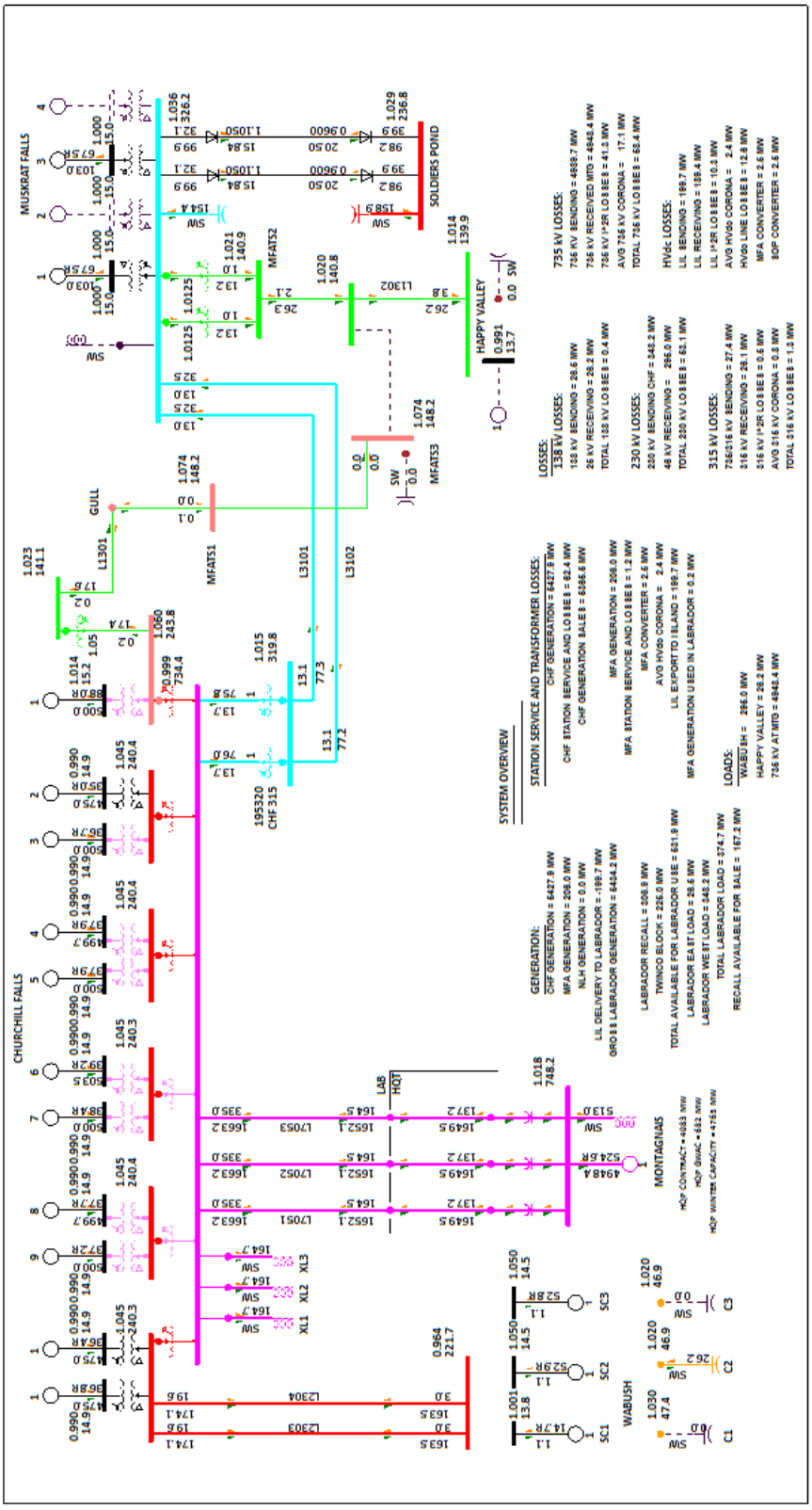


Figure 9 - LIS (2023 Light Conditions)



APPENDIX C

Load Flow Plots Primary Transmission System Year Ten (2028) – Peak and Light Cases

Figure 10 - IIS (2028 Peak Conditions)

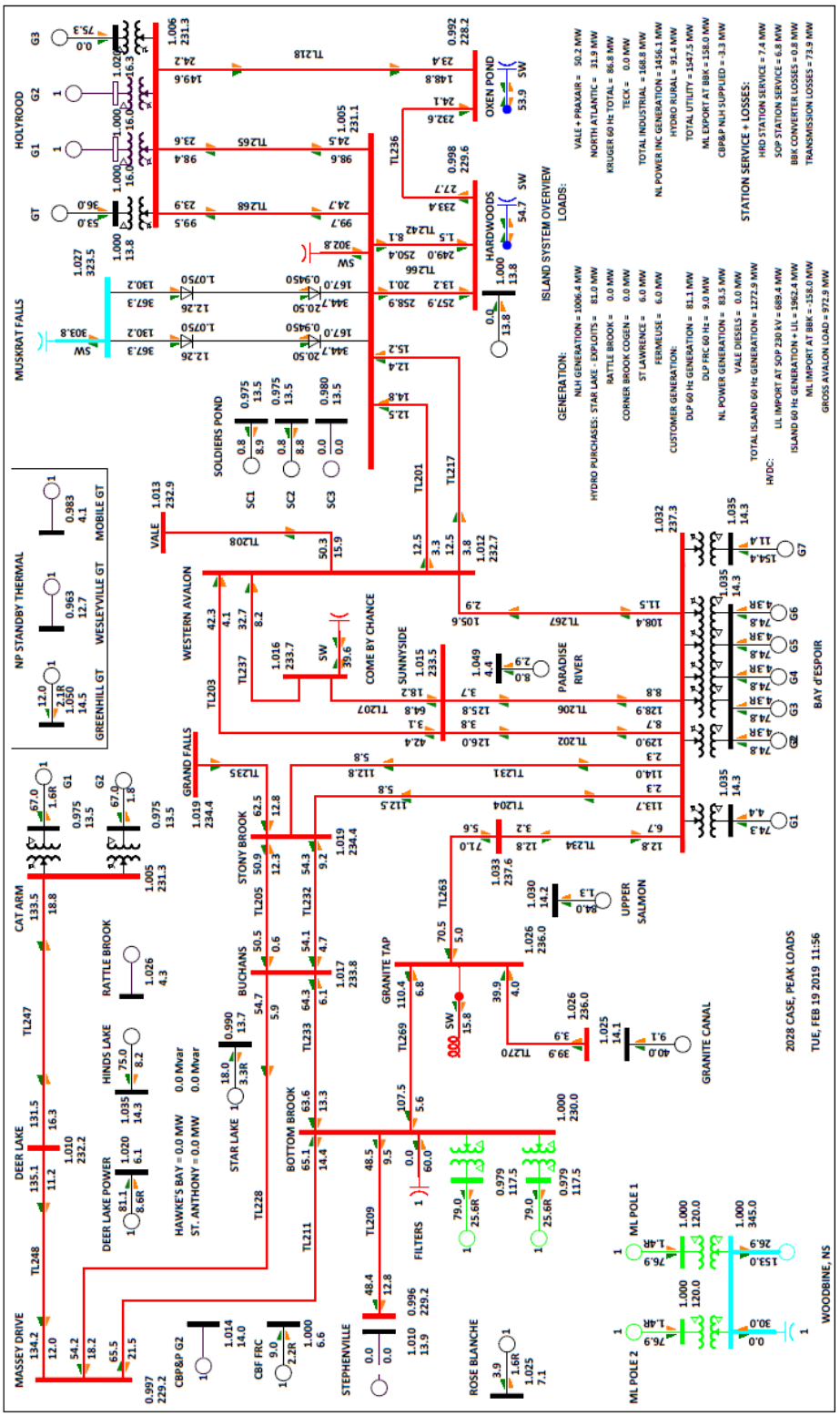


Figure 11 - LIS (2028 Peak Conditions)

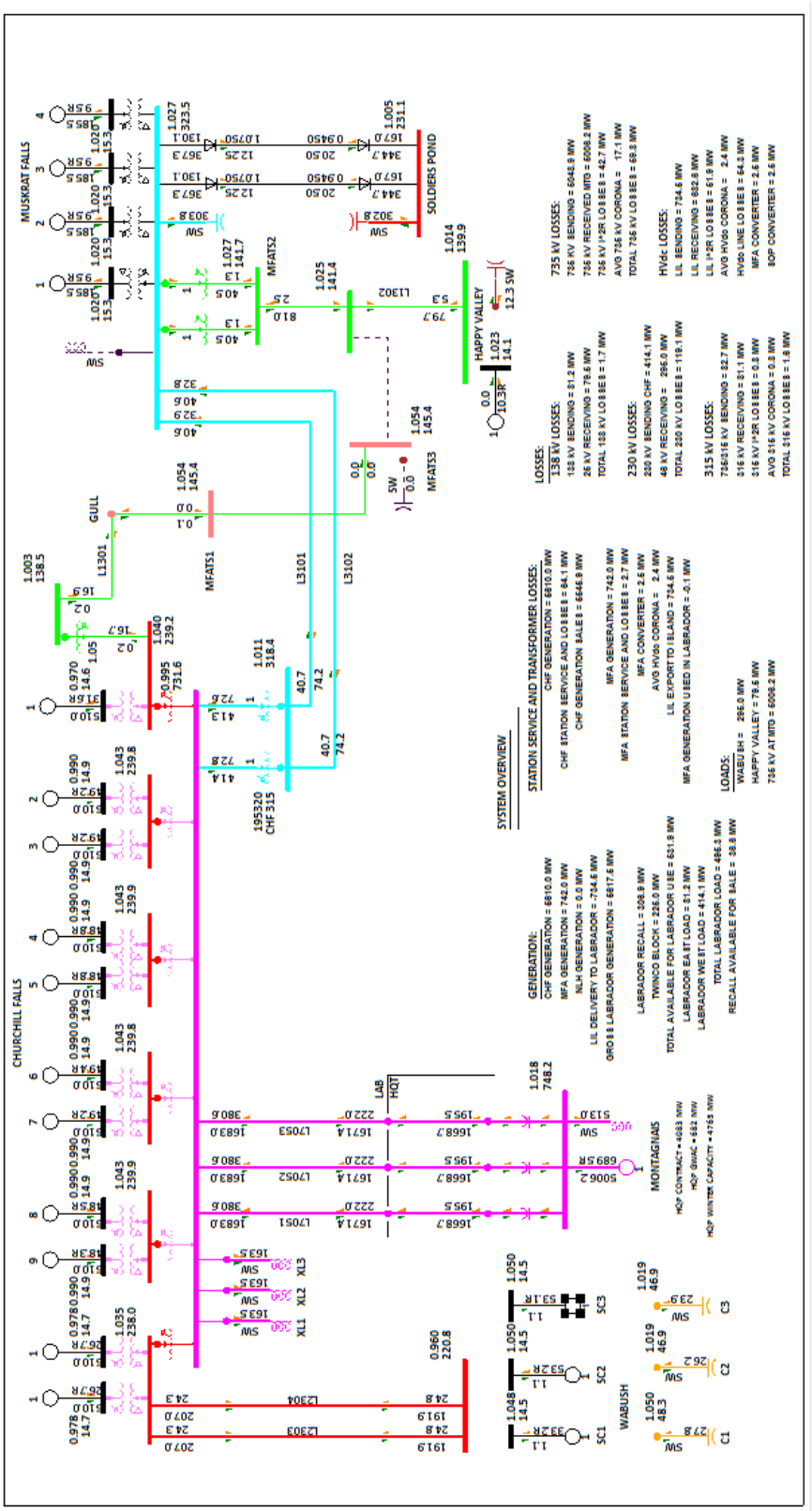


Figure 12 - IIS (2028 Light Conditions)

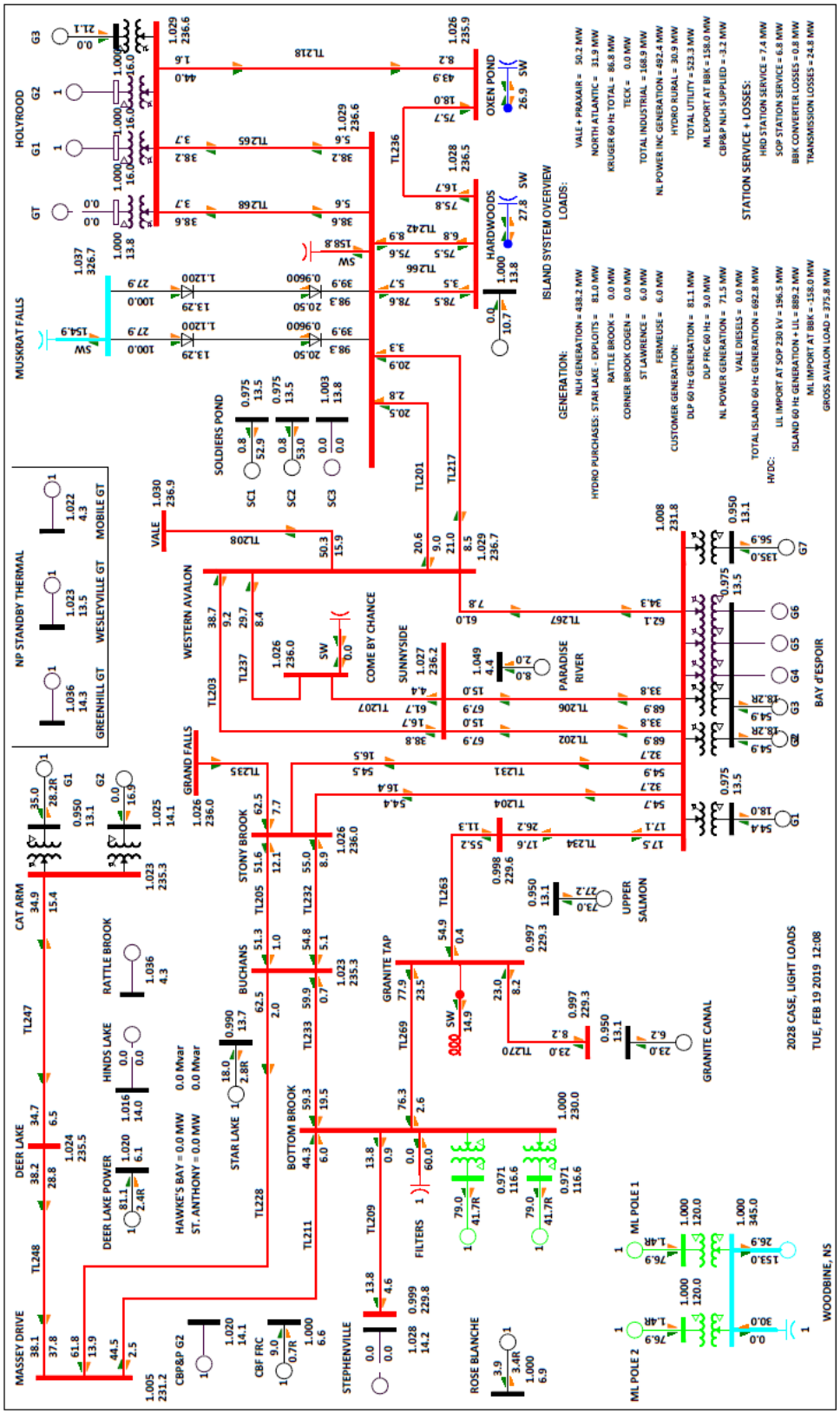
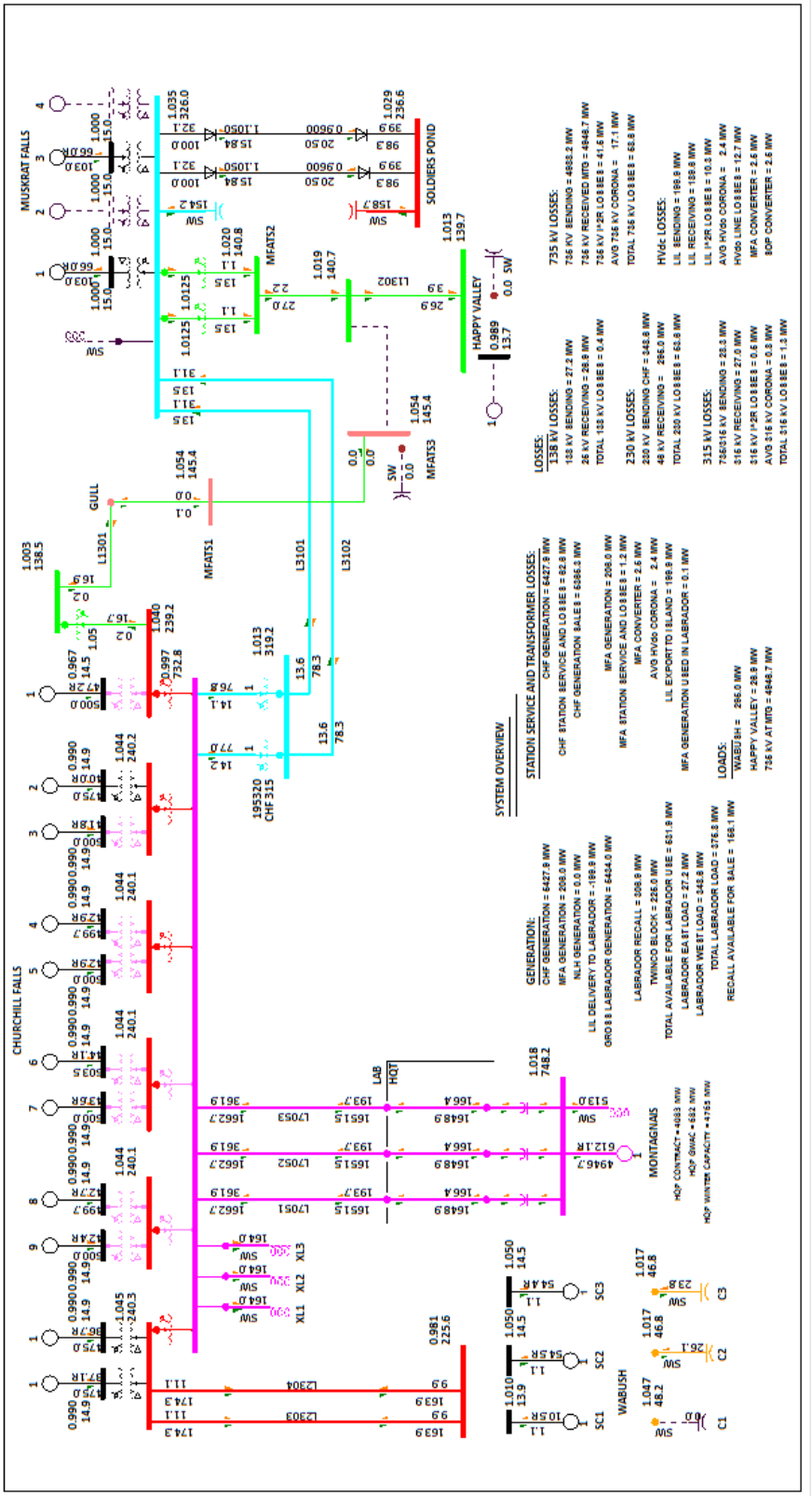


Figure 13 - LIS (2028 Light Conditions)



Document Summary

Document Owner:	Transmission Planning
Document Distribution:	NLSO

Revision History

Revision	Prepared by	Reason for change	Effective Date
1	M. Carter	Approved for release	2019/03/29
2	M. Carter	Minor Edits	2019/05/23

Document Approvers

Position	Signature	Approval Date
Manager, Transmission Planning		2019/03/29

Document Control

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NL Hydro Report

2019 Annual Planning Assessment

Doc # TP-R-028

Date: March 2019

newfoundland labrador hydro
a nalcor energy company

EXECUTIVE SUMMARY

Newfoundland and Labrador Hydro (Hydro) ensures the coordinated development of a safe, reliable and economical transmission system for the benefit of users within the Province of Newfoundland and Labrador.

The Hydro transmission planning process involves the execution of power system studies to ensure compliance with Transmission Planning Criteria and to determine the timing of system additions and modifications.

The annual assessment of the NL Transmission System is performed by the Newfoundland and Labrador System Operator (NLSO). This system is comprised of transmission facilities located in NL operating at a voltage level of 230 kV or higher including the Labrador-Island Link, the Labrador Transmission Assets and Island Interconnected System. A separate annual assessment is performed to address all other transmission system facilities with a rated voltage of 46 kV and above that are under the operational control of Hydro. This document provides an overview of Hydro's assessment.

The near-term planning horizon covers the period 2019 to 2023. The assessment of the near-term horizon focuses on Year Two (2020) and Year Five (2023) study cases. The long-term planning horizon covers the period from 2023 to 2028. The assessment of the long-term horizon focuses on Year Ten (2028) study case.

The 2019 Annual Planning Assessment reveals:

- The pre-contingency steady state analysis indicates no transmission equipment overloads or voltage violations in the near-term or long-term planning horizons.
- The steady state line out contingency analysis indicates no transmission equipment overloads or voltage violations in the near-term or long-term planning horizons.
- The steady state multi-transformer station transformer contingencies analysis indicates:
    - A transformer overload at the Happy Valley Terminal Station in Year Two. This will be mitigated by installing a fourth 30/40/50 MVA transformer as part of the Muskrat Falls – Happy Valley Interconnection project.
    - A transformer overload at the Wabush Terminal Station in Year Five. This overload will be mitigated as per the plan outlined in the Labrador Interconnected System Transmission Expansion Study. Two of the existing 230/46 kV transformers, T4 and T5, will be replaced with a 75/100/125 MVA transformer. The system modifications will be complete prior to Year Five.
    - A transformer overload at the Wabush Substation in Year Two. This overload will be mitigated as per the plan outlined in the Labrador Interconnected System Transmission Expansion Study. Two of the existing 46/12.5 kV transformers, T4 and T6, will be utilized, while the other two, T3 and T5, will be removed from service. An additional 25

MVA unit, T7, complete with OLTC for voltage regulation, will be installed. These system modifications will be complete prior to Year Five.

- The analysis of looped system transformer contingencies indicates:
  - For the Hardwoods - Oxen Pond 66 kV Loop, the loss of Oxen Pond T3 (a 230/66 kV, 150/200/250 MVA unit) will result in the highest load levels on the remaining transformers. Following the retirement of the Hardwoods Gas Turbine in the near-term horizon, it is expected that there will be a transformer overload within the loop in the long-term horizon. In the near-term horizon, any transformer overload on this loop can be resolved by opening the 66kV loop.
  - Following the retirement of the Stephenville Gas Turbine, backup supply for the area will be addressed by the addition of a 230/66 kV, 40/53.3/66.7 MVA power transformer at Bottom Brook Terminal Station. This addition will provide capacity to the Stephenville area via the 66 kV network in the event of the loss of existing 230/66 kV transformer T3 at Stephenville Terminal Station or loss of 230 kV transmission line TL209.
- The steady state generator contingency analysis indicates there is a violation following the loss of a synchronous condenser at Wabush Terminal Station in Year 2. The installation of a 23 MVAR capacitor bank on bus B16 will resolve this violation prior to Year 5. This is outlined in more detail in the Labrador Expansion Study.
- The steady state shunt contingency analysis indicates there are no violation to the Transmission Planning Criteria
- The short circuit analysis reveals no issues with circuit breaker ratings in the near-term or long-term planning horizons.

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1 INTRODUCTION

The 2019 Annual Planning Assessment covers the near-term planning horizon through review of the 2020 and 2023 load cases and the long-term planning horizon through review of the 2028 load cases.

This report addresses the NL Interconnected Transmission System, which is comprised of transmission facilities located in NL, operating at a voltage level of 46 kV or higher. It is noted that NL Transmission System facilities are addressed separately as part of the NLSO 2019 Annual Planning Assessment.[1] Analysis is performed to ensure compliance with appropriate criteria, including those defined in TP-S-007 NLSO Standard – Transmission Planning Criteria.

Figure 1 provides a map of the Newfoundland and Labrador Interconnected System post completion of the Lower Churchill Project.

[1] The NLSO 2019 Annual Planning Assessment addresses the NL Transmission System, which is comprised of transmission facilities located in NL, operating at a voltage level of 230 kV or higher, including, the Labrador-Island Link, the Labrador Transmission Assets and Island Interconnected System

Figure 1 –Newfoundland and Labrador Interconnected System

2 SELECTION OF STUDY CASES

System models have been developed to reflect the latest load forecast including recent completed system changes and approved additions/modifications for future years. The current planning is defined as follows:

- Year One as 2019 (the current year)
- Year Two as 2020
- Year Five as 2023
- Year Ten as 2028.

2.1 Near-Term Planning Horizon Cases

The near-term planning horizon covers Years One to Five. The 2019 Annual Assessment uses Years Two (2020) and Year Five (2023), which are defined by the system additions summarized in the sections below.

2.1.1 Year Two (2020) System Additions

The following system additions are included in the 2020 study cases:

- Happy Valley Terminal Station (HVYTS) is supplied via a new 138 kV transmission line connecting the Muskrat Falls Terminal Station 2 (MFATS2) to the Muskrat Falls Construction Power Station (MFATS3), where it taps into existing 138 kV transmission line, L1302
- Synchronous Condenser 3 at Wabush Terminal Station is in service
- The Labrador-Island HVdc Link (LIL) in operation in Bipole Mode
- There is one 206 MW generating unit in service at Muskrat Falls Generating Station (MFAGS)
- There are two Soldiers Pond 175 MVAR synchronous condensers in service for analysis (the third unit is available)
- There are no firm export commitments on the Maritime Link (ML)
    - The Nova Scotia Block flow begins following commissioning of the third unit at Muskrat Falls Generating Station

2.1.2 Year Five (2023) System Additions

The following system additions are included in the 2023 study cases:

- The Muskrat Falls Generating Station (MFAGS) is complete
- The MFAST2 315 kV, 150 MVAR shunt reactor is removed from service
- HVYTS has an additional 138/25 kV 50 MVA transformer, T5
- The Happy Valley North Side Diesel Plant is retired

- Transmission system upgrades[2] are in service at Wabush Terminal Station including:
  - The addition of 23 MVAR of capacitor banks
  - The replacement of transformers T4 and T5 with 75/100/125 MVA units
- Wabush Substation upgrades include:
  - Transformers T3 and T5 have been removed from service
  - Transformer T6 has been connected to bus B5, and transformer T4 is available as a spare
  - A new 25 MVA transformer T7 has been connected to bus B3
  - A bus tie has been added to connect buses B3 and B5.
- 46 kV transmission lines L32, L33 and L40 in western Labrador have been reconductored with 559.5 AAAC Darien conductor
- The LIL is operating in Bipole Mode up to its rated capacity of 900 MW
- Holyrood Thermal Generating Station has been removed from service, with the exception of Unit 3, which is in operation in synchronous condenser mode
- Stephenville gas turbine has been removed from service
- Hardwoods gas turbine is out of service as a generator, but can be operated as a synchronous condenser
- The ML exports are set at the NS Block (157 MW at Bottom Brook terminal Station 2 – BBKTS2) in both the peak and light load cases

2.2 Long-Term Planning Horizon Case

The long-term planning horizon covers Years Six to Ten. The 2019 Annual Assessment uses Year Ten (2028) to assess the long-term planning horizon.

2.2.1 Year Ten (2028) System Additions

At present there are no long-term planning horizon system additions or modifications beyond those found in the Year Five (2023) study cases.

[2] In accordance with the Labrador Interconnected System Transmission Expansion Study, November 2018.

3 SPECIAL CONSIDERATIONS

The study period for the 2019 Annual Planning Assessment covers the period 2020 to 2028. Special considerations for this study period are discussed in the sections below.

3.1 Western Labrador

The Labrador Interconnected System Transmission Expansion Study was filed with the Newfoundland and Labrador Board of Commissioners of Public Utilities in 2018. This study defined the required system upgrades to ensure sufficient transmission system capacity to meet the baseline load forecast. These upgrades were incorporated into the Year Two (2020), Year Five (2023), and Year Ten (2028) study cases, as indicated in Sections 2.1.1 and 2.1.2, respectively. The analysis of this system is discussed in Section 5.

4 LOAD FORECAST

The 2019 Annual Planning Assessment is based upon the following load forecasts prepared by the Market Analysis Section, Rural Planning Department, Newfoundland and Labrador Hydro:

- Island Interconnected 10 Year P50 and P90 Peak Demand Summary – Fall 2018 dated November 2018; and
- Labrador Interconnected 10 Year P50 and P90 Peak Demand Summary – Summer 2018 dated July, 2018.

The Island and Labrador Interconnected forecasts are summarized in Table 1.

Table 1 – Operating Load Forecasts (P90) - Island and Labrador Interconnected System

Forecasted Demand (MW)				
Year	Island Interconnected (Fall 2018)	Labrador Interconnected (Summer 2018)		
		Lab East	Lab West	Total
2018/19	**1,717.5**	81.7	342.4	**424.1**
2019/20	**1,716.1**	83.3	358.4	**441.7**
2020/21	**1,722.3**	83.5	369.0	**452.5**
2021/22	**1,724.9**	83.8	377.1	**460.9**
2022/23	**1,729.1**	84.0	377.3	**461.3**
2023/24	**1,731.2**	84.3	377.6	**461.9**
2024/25	**1,736.8**	84.9	377.9	**462.8**
2025/26	**1,742.2**	85.4	378.2	**463.6**
2026/27	**1,752.0**	85.9	378.5	**464.4**
2027/28	**1,762.0**	86.4	378.8	**465.2**
2028/29	**1,768.6**	86.9	379.1	**466.0**
2029/30	**1,775.1**	87.5	379.4	**466.9**
2030/31	**1,781.7**	88.0	379.6	**467.6**
2031/32	**1,788.3**	88.5	379.9	**468.4**
2032/33	**1,794.9**	89.0	380.2	**469.2**
2033/34	**1,801.5**	89.6	380.5	**470.1**
2034/35	**1,808.1**	90.1	380.7	**470.8**
2035/36	**1,814.6**	90.6	381.0	**471.6**
2036/37	**1,821.2**	91.1	381.2	**472.3**
2037/38	**1,827.8**	91.7	381.4	**473.1**
2038/39	**1,834.4**	92.2	381.7	**473.9**

5 STEADY STATE ANALYSIS

The steady state analysis consists of pre-contingency analysis, for which the assessment assumes that all equipment is in service, and contingency analysis. The analysis is performed to ensure that with all equipment in service under normal operation, power flows in all elements are at or below normal rating and voltages are within acceptable limits. The ratings are defined as per TP-S-001 - NLSO Facilities Rating Guide. The results of the steady state analysis are described in the sections below.

5.1 Summary of Pre-Contingency Transformer Peak Loads

Table 2 provides a summary of the pre-contingency transformer loading levels.[3] A review of the pre-contingency peak cases for the near and long-term horizons indicates that there are no transformer overloads.

Table 2 – Pre Contingency Transformer Load Levels[1]

Station	Unit	Rating	2020		2023		2028	
		MVA	MVA	%	MVA	%	MVA	%
Barachoix	T1	10/13.3/16.7	7.91	47.3%	7.64	45.7%	7.73	46.3%
Bay d'Espoir	T10	15/20/25	10.86	43.5%	10.64	42.5%	10.77	43.1%
	T12	15/20/25	7.05	42.2%	7.12	42.7%	7.20	43.1%
	T11	10/13.3/16.7	10.78	43.1%	10.56	42.2%	10.69	42.8%
Bear Cove	T1	10/13.3/16.7	5.62	33.6%	5.46	32.7%	5.52	33.1%
Berry Hill	T1	15/20/25	2.03	8.1%	1.96	7.8%	1.97	7.9%
Bottom Brook[2]	T1	25/33.3/41.7	25.01	60.0%	24.36	58.4%	25.15	60.3%
	T2	15/20/25	0.36	1.4%	0.00	0.0%	0.00	0.0%
	T3	25/33.3/41.7	7.67	18.4%	7.64	18.3%	7.62	18.3%
	T4	40/53.3/66.6	N/A		0.34	0.5%	0.34	0.5%
Bottom Waters	T1	10/13.3/16.7	12.63	75.6%	11.00	65.8%	10.07	60.3%
Buchans	T1	40/53.3/66.6	15.10	22.6%	15.06	22.6%	15.37	23.0%
	T2	5/6.6/8.3	2.86	34.5%	2.79	33.6%	2.85	34.3%
Churchill Falls	T31	75/100/125	***Note 3***					
	T32	25/33/42						
Come By Chance	T1	30/40/50	20.95	41.9%	20.96	41.9%	20.96	41.9%
	T2	30/40/50	20.96	41.9%	20.96	41.9%	20.96	41.9%
Coney Arm	T1	2.5/3.3/4.0	0.00	0.0%	0.00	0.0%	0.00	0.0%
Conne River	T1	2.5	2.90	87.9%	2.80	84.9%	2.84	85.9%
Cooper Hill	T1	7.5/10	2.33	23.3%	2.37	23.7%	2.41	24.1%
Corner Brook Converter	T1	21/28	9.00	32.2%	9.00	32.2%	9.00	32.2%
	T2	21/28	9.14	32.6%	9.23	33.0%	9.23	33.0%
Cow Head	T1	5/6.7/8.3	1.97	23.7%	1.89	22.8%	1.91	23.0%
Daniel's Harbor	T1	1/1.3	0.60	46.4%	0.58	44.9%	0.59	45.3%
	T2	1	0.60	45.9%	0.58	44.4%	0.58	44.9%
Deer Lake	T1	25/33.3/41.7	3.17	9.5%	6.34	19.0%	6.71	20.1%

[3] Churchill Falls Terminal Station #2 power transformers CFTS2-T1 and CFTS2-T2 are addressed in the NLSO annual assessment.

	T2	45/60/75	24.13	32.2%	27.28	36.4%	27.39	36.5%
Doyles	T1	25/33.3/41.7	25.00	59.9%	24.35	58.4%	25.08	60.1%
Duck Pond	T1	10/13.3/16.7	0.59	3.5%	0.59	3.5%	0.00	0.0%
English Harbour West	T1	5/6.7	2.92	43.5%	2.82	42.1%	2.85	42.6%
Farewell Head	T1	10/13.3/16.7	7.10	42.5%	6.64	39.7%	6.18	37.0%
Glenburnie	T1	1.5/3.3	2.22	67.4%	2.14	64.8%	2.16	65.5%
Grand Falls Frequency Converter	T1	30/40/50	22.61	45.2%	22.73	45.5%	22.75	45.5%
	T2	30/40/50	23.24	46.5%	23.45	46.9%	23.49	47.0%
	T3	30/40/50	20.77	41.5%	20.66	41.3%	20.64	41.3%
Grandy Brook	T1	7.5/10/12.5	5.32	42.6%	5.13	41.1%	5.00	40.0%
Hampden	T1	2.5/3.3/4.0	1.46	36.4%	1.40	35.1%	1.37	34.3%
Happy Valley[4]	T1	30/40/50	39.58	79.2%	27.10	54.2%	27.87	55.7%
	T2	15/20/25//28	22.07	78.8%	15.11	54.0%	15.54	55.5%
	T4	15/20/25//28	22.07	78.8%	15.11	54.0%	15.54	55.5%
	T5	30/40/50	N/A		27.10	54.2%	27.87	55.7%
Hardwoods	T1	75/100/125	84.43	67.5%	89.37	71.5%	91.55	73.2%
	T2	40/53.3/66.6	43.08	64.6%	45.60	68.4%	46.72	70.0%
	T3	40/53.3/66.6	46.52	69.7%	49.24	73.8%	50.44	75.6%
	T4	75/100/125	83.76	67.0%	88.66	70.9%	90.83	72.7%
Hawke's Bay	T1	5/6	4.15	61.9%	4.01	59.8%	4.05	60.4%
	T2	2.5/3.3	2.27	68.9%	2.20	66.6%	2.22	67.3%
Holyrood[5]	T5	15/20/25	20.82	83.3%	20.69	82.8%	21.20	84.8%
	T10	15/20/25	20.27	81.1%	20.15	80.6%	20.64	82.6%
	T6	25/33.3/41.7	10.18	24.4%	11.26	27.0%	11.60	27.8%
	T7	25/33.3/41.7	10.12	24.3%	11.18	26.8%	11.53	27.6%
	T8	75/100/125	29.56	23.6%	32.67	26.1%	33.67	26.9%
Howley[6]	T2	7.5/10/12.5	3.12	25.0%	3.04	24.3%	2.99	23.9%
Jackson's Arm	T1	5/6.6/8.3	1.58	19.0%	1.52	18.3%	1.48	17.9%
Main Brook	T1	1.5	0.80	53.2%	0.79	53.0%	0.78	51.7%
Massey Drive	T1	75/100/125	55.89	44.7%	49.69	39.8%	49.88	39.9%
	T2	40/53.3/66.6	31.73	47.6%	32.34	48.5%	33.09	49.6%
	T3	75/100/125	56.24	45.0%	57.32	45.9%	58.65	46.9%
Muskrat Falls TS1	T1	2	0.07	3.7%	0.07	3.7%	0.07	3.7%
Muskrat Falls TS2	T5	75/100/125	44.83	35.9%	42.82	34.3%	44.05	35.2%
	T6	75/100/125	40.22	32.2%	42.90	34.3%	44.14	35.3%
Muskrat Falls TS3	T1	30/40/50	0.00	0.0%	0.00	0.0%	0.00	0.0%
Oxen Pond	T1	75/100/125	151.46	60.6%	154.35	61.7%	158.15	63.3%
	T2	150/200/250	73.04	58.4%	74.43	59.5%	76.26	61.0%
	T3	150/200/250	151.46	60.6%	154.35	61.7%	158.15	63.3%
Parson's Pond	T1	1/1.3	0.9	69.5%	0.83	63.9%	0.81	62.5%
Peter's Barren	T1	15/20/25	9.18	36.7%	8.87	35.5%	8.96	35.8%
Plum Point	T1	10/13.3/16.7	4.12	24.6%	3.96	23.7%	4.00	23.9%
Quartzite	T1	15/20/25	16.42	65.7%	16.65	66.6%	16.93	67.7%
	T2	15/20/25	16.31	65.2%	16.54	66.1%	16.81	67.3%
Rocky Harbour	T1	5/6.6/8.3	4.22	50.8%	4.07	49.0%	4.11	49.5%
Roddickton	T2	5/6.6/8.3	2.97	59.5%	2.89	57.8%	2.82	56.5%
South Brook	T1	5/6.6/8.3	7.93	95.6%	7.72	93.0%	7.53	90.7%
Stephenville	T3	40/53.3/66.6	49.65	74.4%	49.44	74.1%	50.68	76.0%
Stony Brook	T1	75/100/125	102.82	82.3%	96.64	77.3%	97.51	78.0%
	T2	75/100/125	101.59	81.3%	95.48	76.4%	96.34	77.1%

St. Anthony Airport[7]	T1	15/20/25	14.71	58.8%	6.39	25.6%	6.17	24.7%
Sunnyside	T1	75/100/125	70.69	56.6%	76.89	61.5%	73.23	58.6%
	T4	75/100/125	71.20	57.0%	77.44	62.0%	73.76	59.0%
Vanier	T1	15/20/25	11.56	46.2%	11.74	47.0%	11.98	47.9%
	T2	15/20/25	11.73	46.9%	11.92	47.7%	12.16	48.7%
Voisey's Bay Nickel	T1	75/100/125	30.40	24.3%	28.40	22.7%	28.39	22.7%
	T2	75/100/125	27.11	21.7%	26.97	21.6%	26.96	21.6%
Wabush Terminal[8]	T1	35/47/65	*35.23*	*58.8%*	*35.26*	*59.0%*	*35.25*	*59.0%*
	T2	35/47/65	36.31	60.6%	36.35	60.8%	36.35	60.8%
	T3	35/47/65	35.76	59.7%	35.79	59.9%	35.80	59.9%
	T4	35/47/65	47.02	78.5%	72.15	62.7%	72.63	63.2%
	T5	35/47/65	46.50	77.6%	72.15	62.7%	72.63	63.2%
	T6	35/47/65	46.25	77.2%	33.2	55.5%	33.42	55.9%
	T7	50/66.6/83.3	67.01	87.3%	48.1	62.8%	48.42	63.2%
	T8	50/66.6/83.3	49.45	64.4%	49.49	64.6%	49.50	64.6%
Wabush Substation[9]	T3	5/6.6/8.3	8.17	98.4%	N/A			
	T4	5/6.6/8.3	SPARE		SPARE			
	T5	3.0	SPARE		N/A			
	T6	10/13.3/16.7	12.13	72.6%	8.19	49.0%	8.35	50.0%
	T7	15/20/25	N/A		12.23	48.9%	12.48	49.9%
Western Avalon	T1	15/20/25	15.52	62.1%	15.08	60.3%	15.44	61.7%
	T2	15/20/25	15.81	63.2%	15.36	61.4%	15.72	62.9%
	T3	25/33.3/41.7	17.29	41.5%	16.08	38.6%	16.42	39.4%
	T4	25/33.3/41.7	17.20	41.2%	15.99	38.4%	16.33	39.2%
	T5	75/100/125	50.41	40.3%	46.87	37.5%	47.85	38.3%
Wiltondale	T1	1.0	0.07	4.5%	0.06	4.3%	0.07	4.4%

Notes:

1. Generator step up transformers and converter transformers are not included as these units have been sized for the full unit capability.
2. A new 230/66 kV, 40/53.3/66.7 MVA power transformer is to be added at Bottom Brook Terminal Station, as described in Section 5.3.3.
3. With the Muskrat Falls-Happy Valley Interconnection in place, Churchill Falls power transformers T31/T32 serve as a backup source of supply for L1301 and the transmission system in eastern Labrador. Under normal operation, these transformers are not loaded.
4. As part of the Muskrat Falls – Happy Valley Interconnection project, a fourth 138/25 kV, 30/40/50 MVA transformer (HVY T5) will be in service by the end of Year Two.
5. HRD T7 has failed and will be replaced as discussed in Section 5.3.3
6. Rattle Brook assumed to in operation at 4 MW
7. St. Anthony Diesel Plant is in-service for capacity support
8. Wabush Terminal Station transformers T4 and T5 to be replaced as discussed in Section 5.3.2.
9. The power transformer configuration at Wabush Substation will be modified prior to Year Five as per Section 5.3.2.

5.2 Review of Radial Systems

Radial systems will be impacted by loss of a transmission line are summarized in Table 2.

Table 2 – Radial Transmission Systems and Impact of Line Loss

TL #	kV	From	To	Impact
214	138	Bottom Brook	Doyles	Loss of load in Doyles/Port-aux-Basques area. Newfoundland Power owns mobile gas turbine and mobile diesel located at Grand Bay as well as Rose Blanche hydro site which can supply limited load in area.
215	66	Doyles	Grand Bay	Loss of load in Port-aux-Basques area. Newfoundland Power owns mobile gas turbine and mobile diesel located at Grand Bay as well as Rose Blanche hydro site which can supply limited load in area.
220	69	Bay d'Espoir	Barachoix	Loss of load on the Connaigre Peninsula
221	66	Peter's Barren	Hawke's Bay	Loss of load in the Hawke's Bay/Port Saunders area. Hydro maintains a 5 MW diesel plant at Hawke's Bay that provides limited back up.
226	66	Deer Lake	Berry Hill	Loss of load in Bonne Bay. TL226 can be isolated in various locations such that Bonne bay area loads can be supplied from Berry Hill following line switching.
227	66	Berry Hill	Daniel's Harbour	Loss of load from Sally's Cove to Parson's Pond. TL227 can be isolated in various locations such that loads from Sally's Cove to Daniel's Harbour can be supplied from either Berry Hill or Peter's Barren following line switching.
229	66	Wiltondale	Glenburnie	Loss of load on western arm of Bonne Bay to Woody Point
239	138	Deer Lake	Berry Hill	Loss of load on Great Northern Peninsula north of Bonne Bay. Hydro maintains 5 MW diesel plant at Hawke's Bay and 9.7 MW diesel plant at St. Anthony. With TL239 out switching on the 66 kV will permit up to 25 MVA to be supplied from Deer Lake on the 66 kV TL226 to Berry Hill and then through the Berry Hill 138/66 kV transformer to the 138 kV system via TL259.
241	138	Berry Hill	Plum Point	Loss of load on Great Northern Peninsula north of Daniel's Harbour. Hydro maintains 9.7 MW diesel plant at St. Anthony that provides limited back up.
244	138	Plum Point	Bear Cove	Loss of load on Great Northern Peninsula Bear Cove and north. Hydro maintains 9.7 MW diesel plant at St. Anthony that provides limited back up.
250	138	Bottom Brook	Grandy Brook	Loss of load in Burgeo
251	69	Howley	Hampden	Loss of load in White Bay
252	69	Hampden	Jackson's Arm	Loss of load Jackson's area of White Bay
254	66	Boyd's Cove	Farewell Head	Loss of load Fogo and Change Islands
256	138	Bear Cove	St. Anthony Airport	Loss of load St. Anthony – Roddickton area. Hydro maintains 9.7 MW diesel plant at St. Anthony that provides limited back up.
257	69	St. Anthony Airport	Roddickton	Loss of load main brook and Roddickton
259	138	Berry Hill	Peter's Barren	Loss of load on Great Northern Peninsula north of Parson's Pond. Hydro maintains 5 MW diesel plant at Hawke's Bay and 9.7 MW diesel plant at St. Anthony. With TL259 out switching on the 66 kV will permit up to 25 MVA to be supplied from Berry Hill on the 66 kV TL227 to Peter's Barren and then through the Peter's Barren 138/66 kV transformer to the 138 kV system via TL259.
260	138	Seal Cove	Bottom Waters	Loss of load on the Baie Verte Peninsula
261	69	St. Anthony Airport	St. Anthony Diesel	Loss of load in the St. Anthony area. Hydro maintains 9.7 MW diesel plant at St. Anthony that provides limited back up.
262	66	Peter's Barren	Daniel's Harbour	Loss of load in Daniel's Harbour area. Switching on the 66 kV results in supply of Daniel's harbour via TL227
264	66	Buchans	Duck Pond	Loss of industrial customer
L1301	138	Churchill Falls/Muskrat Falls	Happy Valley	The system is being reconfigured as part of the Muskrat Falls – Happy Valley interconnection, but will remain a radial system.

				Loss of load upper Lake Melville area. Hydro maintains a 25 MW gas turbine in Happy Valley that provides limited back up.

5.3 Review of Steady State Contingencies

A listing of the steady state contingencies considered as part of the analysis is provided in Table 3.[4]

Table 3 – Steady State Contingency Analysis Contingency List

Line Outs	**From**	**To**	**Considerations**
TL210	Stony Brook	Cobb's Pond	
TL219	Sunnyside	Salt Pond	TL212 is parallel line with lower rating
TL222	Stony Brook	Springdale	Opens 138 kV loop
TL223	Springdale	Indian River	Opens 138 kV loop
TL224	Indian River	Howley	Opens 138 kV loop
TL245	Deer Lake	Howley	Opens 138 kV loop
Multi Transformer Stations	**Station**	**Unit**	**Rationale**
	Wabush Terminal	T7	Largest unit on 46 kV Bus #1
		T8	Largest unit on 46 kV Bus #2
	Wabush Substation	T6	Largest unit in Station
	Quartzite	T1	Two units of same rating
	Vanier	T1	Two units of same rating
	Churchill Falls TS2	T1	Two units of same rating
	Muskrat Falls TS2	T5	Two units of same rating
	Happy Valley	T1	Largest unit, run gas turbine
	Bottom Brook	T1	Two units same rating, close bus tie
	Massey Drive	T1	Largest unit close 66 kV Bus tie, CBP&P and NP on same bus
	Bay d'Espoir	T10	Two units same rating
	Grand Falls	T2	Requires use of 13.8/6.9 kV tie transformers
	Holyrood	T5	Two units of same rating
	Western Avalon	T1	Two units of same rating
Looped Systems	**Station**	**Unit**	**Rationale**
HWD-OPD	Oxen Pond	T3	Largest unit in Hardwoods – Oxen Pond Loop
WAV-HRD	Holyrood	T8	Largest unit in Western Avalon – Holyrood loop. Alternative unit is WAV T5
STB-SSD	Stony Brook	T1	Largest unit in Stony Brook – Sunnyside Loop. Alternative unit is SSD T1
Generation	**Station**	**Unit**	**Rationale**
	Wabush Terminal	SC3	Loss of voltage support. Same rating as SC1 and SC2
	Happy Valley Terminal[1]	GT	Loss of voltage support
Shunts	**Station**	**Unit**	**Rationale**
	Wabush Terminal	C1	Loss of voltage support
		C2	Loss of voltage support
	Bear Cove	R1	Light load cases only
	Plum Point	R2	Light load cases only
	St. Anthony Airport	C3	Peak load cases
	Hardwoods	C1	Two cap banks of same rating
	Oxen Pond	C2	Largest cap bank in station
	Happy Valley Terminal	C1	Loss of voltage support

[4] Contingencies that have an impact on the NL Transmission System are addressed in the NLSO Annual Assessment.

5.3.1 Line Out Contingencies

A review of the steady state line out contingency analysis concluded that there are no violations to the Transmission Planning Criteria following the loss of lines listed in Table 4.

5.3.2 Summary of Multi Transformer Station Contingency Loading

Table 5 provides the transformer loading for each multi transformer station with the largest transformer out of service. Mitigations for overload conditions are addressed in the following section. A review of the multi-transformer station transformer contingencies analysis indicates:

- A transformer overload at the Happy Valley Terminal Station in Year Two. This will be mitigated by installing a fourth 30/40/50 MVA transformer as part of the Muskrat Falls – Happy Valley Interconnection project.
- A transformer overload at the Wabush Terminal Station in Year Five. This overload will be mitigated as per the plan outlined in the Labrador Interconnected System Transmission Expansion Study. Two of the existing 230/46 kV transformers, T4 and T5, will be replaced with a 75/100/125 MVA transformer. The system modifications will be complete prior to Year Five.
- A transformer overload at the Wabush Substation in Year Two. This overload will be mitigated as per the plan outlined in the Labrador Interconnected System Transmission Expansion Study. Two of the existing 46/12.5 kV transformers, T4 and T6, will be utilized, while the other two, T3 and T5, will be removed from service. An additional 25 MVA unit, T7, complete with OLTC for voltage regulation, will be installed. These system modifications will be complete prior to Year Five.

Table 5– Multi Transformer Contingency Load Levels[1]

Station	Unit	Rating MVA	2020		2023		2028	
			MVA	%	MVA	%	MVA	%
Bay d'Espoir	T10	15/20/25	*Out-of-Service*					
	T12	15/20/25	22.15	88.6%	21.71	86.8%	22.00	88.0%
Bottom Brook[2]	T1	25/33.3/41.7	25.01	60.0%	24.39	58.5%	25.15	60.3%
	T3	25/33.3/41.7	*Out-of-Service*					
Churchill Falls	T31	75/100/125	***Note 3***					
	T32	25/33/42						
Daniel's Harbour	T1	1/1.3	*Out-of-Service*					
	T2	1	1.20	92.3%	1.16	89.3%	1.17	90.2%
Grand Falls Frequency Converter	T1	30/40/50	32.60	65.2%	32.68	65.4%	32.70	65.4%
	T2	30/40/50	*Out-of-Service*					
	T3	30/40/50	30.99	62.0%	30.90	61.8%	30.88	61.8%
Happy Valley[4]	T1	30/40/50	*Out-of-Service*					
	T2	15/20/25//28	29.38	**104.9%**	15.65	55.9%	16.28	58.2%
	T4	15/20/25//28	29.38	**104.9%**	15.65	55.9%	16.28	58.2%
	T5	30/40/50	N/A		28.08	56.2%	29.20	58.4%
Hawke's Bay[5]	T1	5/6.7	*Out-of-Service*					
	T2	2.5/3.3	1.90	57.6%	1.84	55.7%	1.88	57.0%
Holyrood	T5	15/20/25	12.16	48.7%	12.86	51.4%	13.06	52.3%
	T10	15/20/25	*Out-of-Service*					
Massey Drive[6]	T1	75/100/125	*Out-of-Service*					
	T2	40/53.3/66.6	46.11	69.1%	45.37	68.0%	46.16	69.2%
	T3	75/100/125	81.73	65.4%	80.41	64.3%	81.82	65.5%
Muskrat Falls TS2	T5	75/100/125	*Out-of-Service*					
	T6	75/100/125	85.06	68.0%	85.73	68.6%	88.21	70.6%

Labrador West 46kV[7]	QTZ-T1	15/20/25	*Out-of-Service*					
	QTZ-T2	15/20/25	20.4	81.6%	20.7	82.8%	21.1	84.3%
	VAN-T1	15/20/25	20.4	81.6%	20.7	82.8%	21.1	84.3%
	VAN-T2	15/20/25	20.4	81.6%	20.7	82.8%	21.1	84.3%
Voisey's Bay Nickel	T1	75/100/125	54.4	43.8%	54.83	43.9%	54.8	43.9%
	T2	75/100/125	*Out-of-Service*					
Wabush Terminal[8,9]	T1	35/47//65	46.6	77.2%	35.32	59.2%	35.33	59.2%
	T2	35/47//65	48.1	79.6%	36.41	61.0%	36.42	61.0%
	T3	35/47//65	47.3	78.4%	35.86	60.1%	35.87	60.1%
	T4	35/47//65	53.4	88.4%	*Out-of-Service*		*Out-of-Service*	
	T5	35/47//65	52.8	87.5%	106.11	92.5%	106.81	93.1%
	T6	35/47//65	52.5	87.0%	48.83	81.8%	49.15	82.4%
	T7	50/66.6/83.3	*Out-of-Service*		70.74	92.5%	71.21	93.1%
	T8	50/66.6/83.3	65.4	84.6%	49.58	64.8%	49.59	64.9%
Wabush Substation[10]	T3	5/6.6/8.3	5.23	63.0%	N/A			
	T4	5/6.6/8.3	12.46	**150.1%**	6.80	81.9%	6.94	83.6%
	T5	3.0	2.85	71.2%	N/A			
	T6	10/13.3/16.7	*Out-of-Service*		14.06	84.2%	14.34	85.9%
	T7	15/20/25	N/A		*Out-of-Service*			
Western Avalon	T1	15/20/25	*Out-of-Service*					
	T2	15/20/25	23.17	92.7%	22.53	90.1%	23.07	92.3%

Notes:

1. The loading provided is with the largest transformer in the station removed from service and back up generation on line where applicable.
2. Bottom Brook 138 kV bus tie switch B2B3 closed
3. With the Muskrat Falls-Happy Valley Interconnection in place, Churchill Falls power transformers T31/T32 serve as a backup source of supply for L1301 and the transmission system in eastern Labrador. Under normal operation, these transformers are not loaded.
4. As part of the Muskrat Falls – Happy Valley Interconnection project, a fourth 138/25 kV, 30/40/50 MVA transformer (HVY T5) will be in service by the end of Year Two.
5. Hawke's Bay diesels online for 5 MW
6. 66 kV bus tie B2B4-1 closed
7. Using distribution tie-switches, load can be split evenly between QTZ and VAN
8. Wabush Terminal Station transformers T4 and T5 to be replaced as discussed at the beginning of this section
9. 50 Mw of Bus B15 load transferred to Bus B13 via feeder 5A to offload Bus B15
10. The power transformer configuration at Wabush Substation will be modified prior to Year Five as per Section 5.3.2.

5.3.3 Summary of Looped System Transformer Contingency Loading

Table 6 provides the transformer loading for each Looped System following the loss of the largest transformer in the Loop. Mitigations for each prospective overload condition are addressed in the following section. The analysis of looped system transformer contingencies indicates:

- For the Hardwoods - Oxen Pond 66 kV Loop the loss of Oxen Pond T3 (a 230/66 kV, 150/200/250 MVA unit) will result in the highest loads levels on the remaining transformers. Following the retirement of the Hardwoods Gas Turbine in the near-term horizon, it is expected that there will be a transformer overload within the loop in the long-term horizon. In the near-term horizon, any transformer overload on this loop can be resolved by opening the 66kV loop.
- The 230/138 kV, 35/33.3/41.7 MVA HRD T7 power transformer has failed and there is a plan proposed for its replacement. It has been confirmed that this transformer will have to be replaced with a power transformer of the same rating (at a minimum). With this replacement, no transformer overloads are expected in the Holyrood - Western Avalon 138 kV Loop in the near or long-term horizons.

- For the Stony Brook – Sunnyside 138 kV Loop, overload of the remaining 230/138 kV transformers is expected for the loss of a 230/138 kV, 75/100/125 MVA transformer at Stony Brook Terminal Station. These transformer overloads are addressed operationally by opening the 138kV loop.
- The Stephenville – Bottom Brook 66 kV Loop operates normally open at the Bottom Brook end such that all load in the Stephenville area is supplied via 230 kV transmission line TL209. The backup supply for this system is currently provided by the Stephenville Gas Turbine, which is available at a rated capacity of 50 MW and is to be retired prior to Year 5. Backup supply for the Stephenville area will be addressed by the addition of a 230/66 kV, 40/53.3/66.7 MVA power transformer at Bottom Brook Terminal Station. This addition will provide capacity to the Stephenville area via the 66 kV network in the event of the loss of existing 230/66 kV transformer T3 at Stephenville Terminal Station or loss of 230 kV transmission line TL209.

Table 6– Looped System Transformer Contingency Load Levels[1]

Station	Unit	Rating	2020		2023		2028	
		MVA	MVA	%	MVA	%	MVA	%
Hardwoods – Oxen Pond 66 kV Loop								
Hardwoods	T1	75/100/125	78.1	61.8%	95.6	75.5%	98.2	76.7%
	T2	40/53.3/66.6	39.8	59.3%	48.8	74.2%	50.1	76.3%
	T3	40/53.3/66.6	43.0	80.0%	52.7	99.9%	**54.1**	**102.8%**
	T4	75/100/125	77.4	61.4%	94.9	76.8%	97.4	79.0%
Oxen Pond	T1	75/100/125	237.1	91.0%	247.3	95.8%	253.4	97.1%
	T2	150/200/250	114.3	87.7%	119.3	92.5%	122.2	95.0%
	T3	150/200/250	*Out-of-Service*					
Holyrood - Western Avalon 138 kV Loop[2]								
Holyrood	T6	25/33.3/41.7	12.7	29.5%	13.6	32.5%	14.0	33.5%
	T7	25/33.3/41.7	12.6	29.3%	13.5	32.3%	13.9	33.3%
	T8	75/100/125	36.7	28.5%	39.4	30.6%	40.6	31.6%
Western Avalon	T1	15/20/25	17.8	69.8%	17.2	68.1%	17.6	69.7%
	T2	15/20/25	18.1	71.1%	17.5	69.3%	17.9	71.0%
	T3	25/33.3/41.7	34.4	81.3%	32.1	76.4%	32.8	78.0%
	T4	25/33.3/41.7	34.3	80.9%	31.9	75.9%	32.6	77.6%
	T5	75/100/125	*Out-of-Service*					
Stony Brook - Sunnyside 138 kV Loop[3]								
Sunnyside	T1	75/100/125	91.1	72.3%	90.0	70.8%	93.0	73.4%
	T4	75/100/125	91.7	72.8%	90.6	72.1%	93.7	74.8%
Stony Brook	T1	75/100/125	*Out-of-Service*					
	T2	75/100/125	125.8	97.8%	125.3	97.5%	127.8	99.6%
Stephenville – Bottom Brook 66kV Loop								
Stephenville	T3	40/53.3/66.6	*Out-of-Service*					
Bottom Brook	T2	15/20/25	2.9	11.6%	N/A			
	T4	40/53.3/66.6	N/A		53.2	79.8%	54.7	82.0%

Notes:

1. The operation of each loop of transformers assumes the loss of the largest unit contained within the loop at each end to provide for maximum operational reliability. If there is more than one transformer with the same rating, the one with the lowest impedance is chosen to be switched off. In scenarios where there is a transformer overloaded, it may be mitigated by breaking the loop in various locations to offload the overloaded transformer.
2. HRD T7 has failed and will be replaced as described in Section 5.3.3
3. The following generation is assumed to be online within this 138kV loop: Greenhill Gas Turbine, Paradise River, Wesleyville Gas Turbine, St. Anthony Diesels, Hind's Lake, Hawke's Bay Diesel and Rattle Brook. With the loss of a transformer, the 138kV loop would also have to be opened to offload the remaining transformers within the loop.

5.3.4 Generator and Synchronous Condenser Contingency Analysis

A review of the steady state and contingency analysis revealed that there is a violation following the loss of a synchronous condenser at Wabush Terminal Station in Year 2. The installation of a 23 MVAR capacitor bank on bus B16 will resolve this violation prior to Year 5.

There are no violations to the Transmission Planning Criteria following the loss of any generator or synchronous condenser listed in Table 3.

5.3.5 Shunt Contingency Analysis

A review of the steady state shunt condenser contingency analysis revealed that there are no violations to the Transmission Planning Criteria following the loss of any shunt device listed in Table 3.

6 SHORT CIRCUIT ANALYSIS

Short circuit analysis is required to ensure that the prospective short circuits at equipment locations do not exceed the interrupting capacity of the circuit breakers used to protect the equipment. Short circuit analysis for Year Two, Year Five and Year Ten was performed for the results indicate that there are no circuit breaker rating violations.

7 STABILITY ANALYSIS

Transient stability analysis is performed for the the NL Transmission System and is considered as part of the annual assessment performed by the NLSO. Hydro does not perform transient stability analysis for transmission systems below 230 kV.

8 CONCLUSIONS

The 2019 Annual Planning Assessment focuses on Year Two (2020) and Year Five (2023) for the near-term planning horizon and Year Ten (2028) for the long-term planning horizon

The 2019 Annual Planning Assessment reveals:

- The pre-contingency steady state analysis indicates no transmission equipment overloads or voltage violations in the near-term or long-term planning horizons.
- The steady state line out contingency analysis indicates no transmission equipment overloads or voltage violations in the near-term or long-term planning horizons.
- The steady state multi-transformer station transformer contingencies analysis indicates:
    - A transformer overload at the Happy Valley Terminal Station in Year Two. This will be mitigated by installing a fourth 30/40/50 MVA transformer as part of the Muskrat Falls – Happy Valley Interconnection project.
    - A transformer overload at the Wabush Terminal Station in Year Five. This overload will be mitigated as per the plan outlined in the Labrador Interconnected System Transmission Expansion Study. Two of the existing 230/46 kV transformers, T4 and T5, will be replaced with a 75/100/125 MVA transformer. The system modifications will be complete prior to Year Five.
    - A transformer overload at the Wabush Substation in Year Two. This overload will be mitigated as per the plan outlined in the Labrador Interconnected System Transmission Expansion Study. Two of the existing 46/12.5 kV transformers, T4 and T6, will be utilized, while the other two, T3 and T5, will be removed from service. An additional 25 MVA unit, T7, complete with OLTC for voltage regulation, will be installed. These system modifications will be complete prior to Year Five.
- The analysis of looped system transformer contingencies indicates:
    - For the Hardwoods - Oxen Pond 66 kV Loop the loss of Oxen Pond T3 (a 230/66 kV, 150/200/250 MVA unit) will result in the highest loads levels on the remaining transformers. Following the retirement of the Hardwoods Gas Turbine in the near-term horizon, it is expected that there will be a transformer overload within the loop in the long-term horizon. In the near-term horizon, any transformer overload on this loop can be resolved by opening the 66kV loop.
    - Following the retirement of the Stephenville Gas Turbine, backup supply for the area will be addressed by the addition of a 230/66 kV, 40/53.3/66.7 MVA power transformer at Bottom Brook Terminal Station. This addition will provide capacity to the Stephenville area via the 66 kV network in the event of the loss of existing 230/66 kV transformer T3 at Stephenville Terminal Station or loss of 230 kV transmission line TL209.

- The steady state generator contingency analysis indicates there is a violation following the loss of a synchronous condenser at Wabush Terminal Station in Year 2. The installation of a 23 MVAR capacitor bank on bus B16 will resolve this violation prior to Year 5. This is outlined in more detail in the Labrador Expansion Study.
- The steady state shunt contingency analysis indicates there are no violations to the Transmission Planning Criteria.
- The short circuit analysis reveals no issues with circuit breaker ratings in the near-term or long-term planning horizons.

9 REFERENCE DOCUMENTS

Labrador Expansion Study, dated October 31, 2017

NLSO Standard – Transmission Facilities rating Guide (TP-S-001)

TP-S-003 NLSO Standard – Annual Planning Assessment

TP-S-007 NLSO Standard – Transmission Planning Criteria

Document Summary

Document Owner:	Transmission Planning
Document Distribution:	NL Hydro

Revision History

Revision	Prepared by	Reason for change	Effective Date
1	M. Carter	Approved for release	2019/03/29
2	M. Carter	Minor Edits	2019/05/23

Document Approvers

Position	Signature	Approval Date
Manager, Transmission Planning		2019/03/29

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