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June 16, 2014

The Board of Commissioners of Public Utilities
Prince Charles Building
120 Torbay Road, P.O. Box 21040
St. John's, Newfoundland & Labrador
A1A 5B2

Attention: Ms. Cheryl Blundon
Director Corporate Services & Board Secretary

Dear Ms. Blundon:

Re: The Board's Investigation and Hearing into Supply Issues and Power Outages on the Island Interconnection System

In accordance with the Board's Interim Report dated May 15, 2014, wherein the Board required the filing of reports on today's date with respect to the above noted matter, please find enclosed the original plus 12 copies of Hydro's:

- Hydro Place Emergency Power Report;
- Protection and Control Systems Report;
- Terminal Station and P&C Resource Requirements Report;
- Terminal Station Transformers Report; and
- Generation Availability Report.

Should you have any questions, please contact the undersigned.

Yours truly,

NEWFOUNDLAND AND LABRADOR HYDRO

Geoffrey P. Young
Senior Legal Counsel

GPY/cp

cc: Gerard Hayes – Newfoundland Power
Paul Coxworthy – Stewart McKelvey Stirling Scales
Sheryl Nisenbaum – Praxair Canada Inc.
Roberta Frampton Benefiel – Grand Riverkeeper Labrador

Thomas Johnson – Consumer Advocate
Thomas O' Reilly – Cox & Palmer
Danny Dumaresque

Investigation and Hearing into Supply Issues and Power Outages on the Island Interconnected System

REPORT TO THE BOARD OF COMMISSIONERS OF PUBLIC UTILITIES RELATED TO TERMINAL STATION TRANSFORMERS

Newfoundland and Labrador Hydro

June 16, 2014

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1 BACKGROUND AND INTRODUCTION

At approximately 0905 hours on January 4, 2014 the 75/100/125 MVA, 230/138 kV transformer designated T1 at Sunnyside Terminal Station faulted resulting in the operation of five circuit breakers to isolate Sunnyside T1. Hydro's post event inspection and analysis revealed that the most probable cause of the event was a bushing failure within the T1 transformer tank. During the event one of the five circuit breakers at Sunnyside Terminal Station failed to open (B1L03), thus keeping transformer T1 energized, which resulted in a fire and irreparable damage to the transformer. Transmission line TL203 opened at the Western Avalon Terminal Station end to de-energize the transformer T1. Backup protection systems on TL237 at both Come By Chance and Western Avalon Terminal Stations also operated tripping TL237 and isolating the Avalon Peninsula from the rest of the power system. The end result was an outage to the Avalon Peninsula.

At 1222 hours on January 4, 2014 the 75/100/125 MVA, 230/138 kV transformer designated T5 at Western Avalon Terminal Station faulted and had to be isolated during the restoration process. Hydro's post event inspection determined that there was an internal failure of the Western Avalon T5 tap changer.

This Report is in response to the request by the PUB in its Interim Report dated May 15, 2015 that Hydro file reports with the Board by June 16, 2014 in relation to the following transformer issues:

a) System studies in relation to the relocation of the repaired T5 transformer from Western Avalon to Sunnyside, including a plan to address potential further failures.
b) A study in relation to the availability and necessity of a replacement transformer for T5 at Western Avalon, addressing schedule, estimated costs, the resources required, and how these requirements will be met.
c) A plan for the study to determine if abnormal system disturbances may have caused the T5 failure at Western Avalon.

2 TRANSFORMER REPLACEMENT AND REFURBISHMENT

The Sunnyside transformer T1 is one of four 75/100/125 MVA, 230/138 kV transformers supplying the Stony Brook – Sunnyside 138 kV Loop. There are two 230/138 kV transformers at Stony Brook Terminal Station (T1 and T2) and two 230/138 kV transformers at Sunnyside Terminal Station (T1 and T4). This 138 kV loop supplies loads including the Burin Peninsula, the north east coast from Clarenville (including the Bonavista Peninsula) to Gander, central Newfoundland from Gander west to Deer Lake (including the Baie Verte Peninsula and White Bay) and the Great Northern Peninsula. The Stony Brook – Sunnyside Loop is connected to the 230 kV network at Deer Lake via a single 45/60/75 MVA, 230/138 kV transformer (Deer Lake T2). Under normal operation the connection at Deer Lake provides a voltage control point for the 138 kV transmission system on the Great Northern Peninsula and a transmission path for Hinds Lake and Deer Lake Power generation to the 230 kV network. During transformer contingencies at Stony Brook or Sunnyside, the Deer Lake T2 transformer provides approximately 2 MVA of support to the Stony Brook – Sunnyside Loop due to its remote location and relative size. Within this loop Hydro operates the 75 MW Hinds Lake Generating Station and the 8 MW Paradise River Generating Station. In addition, Hydro maintains two standby diesel plants at Hawke’s Bay (5 MW) and St. Anthony (9.7 MW). The non-utility generator Rattle Brook (4 MW) is connected to this loop as well as the Newfoundland Power standby combustion turbines at Wesleyville and Greenhill. The St. Lawrence wind farm is also connected to the loop, however, the wind farm capacity is not relied upon for firm capacity calculations.

The Western Avalon transformer T5 is one of six 230/138 kV transformers supplying the Western Avalon to Holyrood 138 kV Loop. Both the Western Avalon and Holyrood Terminal Stations contain three 230/138 kV transformers. Each station contains two 25/33.3/41.6 MVA transformers (Western Avalon T3 and T4, Holyrood T6 and T7) and one 75/100/125 MVA transformer (Western Avalon T5, Holyrood T8). This 138 kV loop is used to supply

Newfoundland Power's customers from Blaketown to Conception Bay North and as far east as the town of Holyrood in Conception Bay South.

Hydro's transmission planning criteria with respect to transformer capacity planning for each of these 138 kV loops is that there should be sufficient transformer capacity installed to ensure that peak load can be supplied with the largest transformer in the loop out of service. This is considered an N-1 planning criteria. The underlying premise is that the failed transformer will be either repaired or replaced. During the repair/replacement time period, it is understood that the potential loss of a second transformer and subsequent potential for unsupplied energy (i.e. customer outage) in the loop is an acceptable risk. This N-1-1 contingency (i.e. one transformer out with subsequent loss of a second transformer in the same loop) has not been considered in Hydro's transformer capacity planning practices to date.

The events of January 4, 2014 resulted in the loss of 125 MVA of transformer capacity (i.e. the loss of the largest unit in the loop) in two separate 138 kV loops.

2.1 System Studies and Analysis

Given the loss of transformer capacity in both the Stony Brook – Sunnyside 138 kV Loop and the Western Avalon – Holyrood 138 kV Loop, Hydro initiated a study to determine the impact should there be a second transformer failure in either loop and the potential mitigation strategies with existing 230/138 kV transformer capacity located within the system. The analysis was completed with the assumption that the process to purchase and install new 230/138 kV transformers in each loop could take between 18 and 24 months. Typically the delivery of a new large transformer is between 12 and 18 months when allowances are made for specification preparation, tendering, evaluation, and award, in addition to the time required for engineering, manufacture, and delivery. A combination of Hydro's fast track tendering and the fortunate availability of a vendor manufacturing slot at this time have drastically reduced the time required.

A copy of the full system study analysis completed by Hydro is included in Appendix A. The following sections summarize the results.

2.1.1 Analysis of Stony Brook – Sunnyside 138 kV Loop

Load flow analysis of the Stony Brook – Sunnyside 138 kV Loop demonstrated that following loss of Sunnyside T1 there was sufficient transformer capacity remaining to supply the forecast 2014 – 2015 peak load.

For subsequent loss of a second 125 MVA transformer in the loop the analysis demonstrated a requirement to reduce load to prevent low voltage conditions and/or transformer overload of the remaining two 125 MVA transformers. For loss of Sunnyside T4 the entire loop load is supplied by 2 x 125 MVA transformers at Stony Brook. The analysis indicated a maximum loop load of 194 MW[1], or approximately 62% of the 2014 peak load forecast, with 138 kV bus voltages on the Burin Peninsula falling to 90% (Hydro's minimum acceptable transmission system bus voltage under contingency).

For loss of a 125 MVA transformer at Stony Brook (i.e. one transformer in service at each end of the loop) the analysis demonstrated substantial overloading of the in service Stony Brook transformer during peak load periods. Operation of the standby thermal generation including Greenhill and Wesleyville combustion turbines and Hawke's Bay and St. Anthony diesel plants along with opening the 138 kV transmission line 146L (Gander to Gambo) was found to result in transformer loadings of 111% at Stony Brook and 101% at Sunnyside for the 2014-15 peak load period.

Under this severe N-1-1 contingency, Hydro would endeavour to continue to supply the load for short periods by exceeding the nameplate rating of the transformer(s) while monitoring the transformer temperature and dissolved gases to ensure no loss of life or damage to the transformer during the overload condition. This may be possible because the transformers are rated based upon an ambient air temperature not to exceed 40 °C, an average ambient air temperature of 30 °C in any one day and an average ambient air temperature of 20 °C in any

[1] Total 138 kV Loop load in this case equals the total load on Stony Brook T1 and T2 plus Greenhill and Wesleyville combustion turbine output plus Paradise River output.

one year.[2] The Stony Brook – Sunnyside 138 kV Loop will experience peak load when the ambient air temperature is at or below 0 °C which will provide additional cooling to the transformers under those circumstances.

If the transformer loading cannot exceed its nameplate rating, in order to alleviate the overload on the Stony Brook transformer, loads between Grand Falls and Gander would have to be reduced to approximately 86% of the peak load value with 146 L open. To alleviate the overload on Sunnyside T4 the loads between Gambo to Clarenville and the Burin Peninsula would have to be reduced to approximately 98% of the peak load value with 146L open. Combined, the peak load reduction with 146L open between Gander and Gambo and only one 125 MVA transformer at each of Stony Brook and Sunnyside is estimated to equal 21 MW.

The analysis demonstrated that a second transformer loss in the Stony Brook - Sunnyside 138 kV Loop (N-1-1) could result in unsupplied energy for customers supplied by the loop. A high level estimate for an N-1-1 contingency involving Sunnyside T1 and T4 transformers indicated unsupplied energy in the amount of 54,237 MWh for a one year period. The estimate for an N-1-1 contingency involving one 125 MVA transformer at both Stony Brook and Sunnyside results in approximately 3,564 MWh of unsupplied energy for a one year period.

The analysis demonstrates the risk to customer outage should there be a second transformer failure in the Stony Brook – Sunnyside 138 kV Loop at the time of peak load during an anticipated 18 to 24 month replacement period, thus emphasizing the need to replace the failed transformer, T1 prior to the winter of 2014/2015.

2.1.2 Analysis of Western Avalon – Holyrood 138 kV Loop

Load flow analysis of the Western Avalon - Holyrood 138 kV Loop demonstrated that following loss of Western Avalon T5 there was sufficient transformer capacity remaining to supply the forecast peak load to 2018.

[2] CAN/CSA-C88-M90 Power Transformers and Reactors Clause 3.2.

For subsequent loss of the second 125 MVA transformer in the loop, Holyrood T8, analysis indicated that that there would be sufficient transformer capacity remaining in the loop (4x 41.7 MVA transformers) to supply the peak load.

Analysis of loss of Western Avalon T4 and T5, a 41.7 MVA unit and a 125 MVA unit in the N-1-1 contingency, revealed no overloading of the remaining transformers in the loop.
The analysis of the Western Avalon – Holyrood 138 kV Loop revealed that there is sufficient transformer capacity within the loop for an N-1-1 transformer contingency involving Western Avalon T5 and a second transformer.

2.2 Sunnyside Terminal Station Alternatives

Two alternative solutions to addressing the situation associated with the Sunnyside T1 transformer failure were examined:

a) Transformer Relocations; and
b) New Transformer Replacement of Sunnyside T1.

2.2.1 Transformer Relocations

Given the margins on transformer capacity within the Western Avalon – Holyrood 138 kV Loop, an analysis was completed to determine the most appropriate transformer that could be relocated to the Stony Brook – Sunnyside 138 kV Loop if the purchase and installation of a new 125 MVA transformer to return both loops to full transformer capacity were to extend beyond the upcoming 2014-15 winter peak season. The analysis demonstrated that relocation of a 41.7 MVA transformer from the Western Avalon – Holyrood 138 kV Loop did not provide adequate transformer capacity in the Stony Brook – Sunnyside 138 kV Loop for loss of a 125 MVA transformer.

Similarly, relocation of one of the 125 MVA units from Stony Brook to Sunnyside and temporary relocation of the Deer Lake 75 MVA T2 to Stony Brook were found to not provide adequate transformer capacity for loss of a 125 MVA or the relocated Deer Lake T2. The analysis determined that the "best fit" for this alternative would be to relocate the Western Avalon T5 transformer to Sunnyside once the tap changer had been repaired and purchase a new 125 MVA transformer to replace Western Avalon T5 in 2015-16. The analysis identified that relocation of Western Avalon T5 to Sunnyside followed by loss of Holyrood T8 and one of the 41.7 MVA transformers in the Western Avalon – Holyrood 138 kV Loop would result in no unsupplied energy for the 2014-2015 peak load period. The analysis identified that this arrangement would result in approximately 6,717 MWh of unsupplied energy in the year 2018 if the 125 MVA was not re-instated at Western Avalon. This relocation yields a significantly lower risk than leaving the Stony Brook – Sunnyside 138 kV Loop with only three 125 MVA transformers in service.

2.2.2 New Transformer Replacement of Sunnyside T1 Transformer

In May 2014, Hydro's discussions with transformer vendors confirmed that if an order for a new 230/138 kV, 75/100/125 MVA transformer was placed in early June 2014, a transformer could be manufactured and delivered to site by the end of September 2014. This would allow for installation in October 2014 resulting in the unit being commissioned and operational in November 2014. Consequently, Hydro is preparing an application to the Board for the purchase and installation of a new 230/138 kV, 75/100/125 MVA transformer to replace the failed Sunnyside T1. To maintain the viability of this option, Hydro has prepared the transformer specification and has received tenders.

The project proposal is a two year project with the transformer commissioned by November 2014. An additional 230kV breaker would be added to the terminal station between June and September of 2015 to simplify and improve the existing transformer protection configuration.

The project scope includes:

2014

- Purchase and install a new 230/138 kV 75/100/125 MVA transformer including foundation, wiring and protection and control relays;
- Purchase and install a new 230kV disconnect switch (to replace existing B1T1 damaged by fire) complete with support structure, foundation and new power and protection/control wiring;
- Purchase and install a new 138kV breaker (B2T1 damaged by fire) complete with current transformers, support structure, foundation and new power and protection/control wiring;
- Purchase and install a new station service transfer switch (damaged by fire) complete with new conduit and associated power cables for the redundant station service;
- Purchase and install new High Voltage (HV) bus work, risers, station post insulators and connectors to complete the installation of the above equipment; and
- Purchase of new 230 kV circuit breaker for Sunnyside T1.

2015

- Install new 230kV breaker complete with Current Transformers (CTs) and support structure (purchased in 2014);
- Modify protection panels for the addition of the 230kV breaker; and
- Modify breaker failure protection for the Sunnyside Terminal Station to include the installation of a new 230kV breaker.

The current project costs and schedule summary, to be presented in the application to the Board for the purchase and installation of a new transformer at Sunnyside are shown in Tables 2.1 and 2.2 below. These are the gross costs and will be net of insurance proceeds for the Sunnyside T1 loss.

Table 2.1 - Sunnyside T1 New Transformer Budget Estimate				
Project Cost:*($ x1,000)*	**2014**	**2015**	**Beyond**	**Total**
Material Supply	2,817.2	110.0	0.0	2,927.2
Labour	1,331.6	401.9	0.0	1,733.6
Consultant	86.4	28.8	0.0	115.2
Contract Work	1,419.7	329.5	0.0	1,749.2
Other Direct Costs	79.5	89.6	0.0	169.1
Interest and Escalation	116.6	74.5	0.0	191.1
Contingency	1,146.9	192.0	0.0	1,338.9
TOTAL	**6,997.9**	**1,226.4**	**0.0**	**8,224.2**

Table 2.2 - Sunnyside T1 New Transformer Project Schedule for 2014/2015	
Activity	**Milestone**
Initial Planning and Equipment Ordering Tendering (Transformer, Breakers , Disconnect and Protective Devices)	April/June 2014
Equipment Delivery 2014 Equipment Delivery 2015	July 2014 June 2015
Equipment Installations and Commissioning 2014 Equipment Installations and Commissioning 2015	Aug - Nov 2014 June - Aug 2015
Project In Service 2014 Project In Service 2015	November 2014 September 2015
Project Completion and Close Out	September 2015

2.2.3 Sunnyside T1 Recommended Action Plan

Hydro's analysis indicates that both the Stony Brook – Sunnyside and Western Avalon – Holyrood 138 kV Loops require the 125 MVA transformer capacity lost as a result of the Sunnyside T1 and Western Avalon T5 failures for long term, reliable supply to customers. While the risk of damage is viewed as relatively small during a transformer relocation, there is a potential risk of damage to large transformers nonetheless with each relocation operation. Having ascertained that a new transformer can be manufactured and commissioned at Sunnyside Terminal Station for the coming winter peak season, proceeding with the transformer purchase and repairing the Western Avalon T5 tap changer at Western Avalon Terminal Station avoids the risks of potential damage associated with relocation of Western Avalon T5 to Sunnyside and eliminates the risk of the Stony Brook – Sunnyside 138 kV Loop being exposed to an unsuccessful tap changer repair on a relocated Western Avalon T5. To this end, Hydro is recommending replacement of the damaged Sunnyside T1 transformer with a new transformer in 2014 and the addition of a new 230kV breaker for Sunnyside T1 in 2015 for improved protection.

Further, Hydro is proposing to repair the Western Avalon T5 tap changer at Western Avalon and return the unit to service at that location. Hydro is preparing an application to present to the Board for this transformer repair. The scope of this work includes the following:

- Verification of transformer T5
    - Drain the oil from the T5 transformer and tap changer;
    - Pressurize the transformer with dry breathable air;
    - Perform an internal inspection of transformer;
    - Perform an internal inspection of the tap changer;
    - Perform transformer winding resistance tests;
    - Perform Transformer Turns Ratio Test (TTR);
    - Perform Sweep Frequency Response Test on transformer; and
    - Assess tests results (internal review with external validation) to verify transformer is in good condition to return to service.
- Secure transformer and order parts
    - Pressurize the transformer with dry air;
    - Store transformer oil on site in tanks with secondary confinement via containment berms;
    - Perform daily checks of the transformer dry air pressure and the containment berms under the oil storage tanks;
    - Order tap changer; and
    - Prepare contract documents for installation of the tap changer.
- Install tap changer
    - Purge the transformer of nitrogen;
    - Pressurize the transformer with dry breathable air;

  - Engineering to review and approve work methods for installation of new tap changer;
  - Install protective barriers to protect transformer windings from welding and cutting operations to modify transformer the tank for the new tap changer;
  - Modify the transformer tank;
  - Remove protective barriers in order to install the new tap changer;
  - Install the new tap changer into the tank; and
  - Extend transformer winding leads and connect to the tap changer.
- Clean-up and oil filling
  - Spray down the inside of the transformer with oil;
  - Jack one end of the transformer tank to pool oil for pumping out;
  - Pump out the transformer;
  - Wipe out the transformer;
  - Perform final inspection of transformer and work before filling with oil;
  - Draw vacuum on the transformer as per transformer manufacturer recommendations;
  - Refill the transformer with heated oil; and
  - Degasify the transformer.
- Test Transformer and Return to Service
  - Engineering to consult with transformer manufacturer to determine final tests required before energizing transformer and associated tap changer. The test should include but not be limited to the following:
    - Perform Megger Test;
    - Perform Winding Resistance Test;
    - Perform TTR Test;
    - Perform Doble Test; and
    - Execute the 6 year Preventative Maintenance (PM) on the transformer and tap changer.

- Remove isolation and energize transformer with load side disconnect open for 24 hours prior to loading transformer. Monitor transformer;
- Load transformer and monitor for another 24 hours; and
- Return to normal operation.

Western Avalon T5 would be scheduled to return to service in October 2014.

2.2.4 Western Avalon T5 Transformer Refurbishment Project Cost and Schedule Summary

The current project costs and schedule summary, as presented in the application to the Board for the purchase and installation of the project, are shown in Tables 2.3 and 2.4 below.

Table 2.3 - Western Avalon T5 Refurbishment Budget Estimate

Project Cost:*($ x1,000)*	**2014**	**2015**	**Beyond**	**Total**
Material Supply	215.4	0.0	0.0	215.4
Labour	341.6	0.0	0.0	341.6
Consultant	42.4	0.0	0.0	42.4
Contract Work	542.9	0.0	0.0	542.9
Other Direct Costs	29.3	0.0	0.0	29.3
Interest and Escalation	46.6	0.0	0.0	46.6
Contingency	234.3	0.0	0.0	234.3
TOTAL	**1,452.5**	**0.0**	**0.0**	**1,452.5**

Table 2.4 - Western Avalon T5 Refurbishment Project Schedule

2014 Scheduled Work Items			
Activity		**Start**	**End**
Planning	Scope, schedule and budget review	February	May
Design/Procurement	Prepare Specification for Major Inspection	June	July
Installation/Inspection	Complete Inspection	Aug	Sept
Commissioning	Complete Commissioning	Sept	Sept
Closeout	Project Closeout	Oct	Oct

2.3 Program Management

The Sunnyside T1 transformer replacement and Western Avalon T5 transformer refurbishment projects have been set up as projects within an overall 2014 Incremental Capital Work Program. Blair Seckington, a senior consultant with AMEC and having over 31 years with Ontario

Hydro/Ontario Power Generation, has been retained to act as overall Program Manager leading a team of both internal and external resources.

2.4 Contingency Plan

Should unforeseen delays in the manufacturing process for the Sunnyside T1 replacement transformer be identified such that the new transformer would not be available for the 2014-2015 winter peak load season, Hydro will endeavour to maintain the opportunity to relocate the repaired Western Avalon T5 transformer to Sunnyside in late fall 2014.

In order to mitigate the risk of a failure or an unsuccessful repair to the Western Avalon T5 tap changer, Hydro, as part of the transformer specification and tendering process for the Sunnyside T1 replacement, has secured an option for a second 230/138 kV, 75/100/125 MVA purchase for delivery in 2015.

3 SYSTEM STUDY OF T5 TRANSFORMER FAILURE

Given the proximity of the Sunnyside and Western Avalon Terminal Stations; an intermediate 230 kV shunt capacitor bank at Come By Chance Terminal Station; the failure of two 230/138 kV transformers within the same 24 hour period; and the significant volume of switching events during the outages and restoration processes, the potential exists that the abnormal system configurations may have been a contributing factor to the failure of the Western Avalon T5 tap changer on January 4, 2014. To this end a system study of the events is warranted to assist in determination of the cause of the Western Avalon T5 tap changer failure.

3.1 Study Purpose and Scope

Hydro has engaged TransGrid Solutions of Winnipeg, Manitoba to complete an analysis of the restoration sequence of January 4, 2014 to determine if power system harmonics and/or transients associated with the switching events were of significant magnitude to adversely impact the Western Avalon transformer T5 resulting in the phase-to-phase fault within the on load tap changer.

3.2 Study Plan and Schedule

TransGrid Solutions have been completing on line background harmonic measurements on the 230 kV buses at Western Avalon, Holyrood and Hardwoods Terminal Stations as part of the input data for the HVdc converter design for the Soldiers Pond Converter Station since mid-January 2014. TransGrid's knowledge of the background harmonics at Western Avalon Terminal Station, and the data itself, will be an integral part of the overall analysis and conclusions for the study. The analysis will be led by TransGrid with input data provided by Hydro. The study will take the following steps:

- Data collection
    - Hydro will provide a load flow base case for the pre-event system conditions at 0900 hours, January 4, 2014 in standard PSS®E format;
    - Hydro will provide equipment details including:

- Detailed sequence of events;
- Raw data of the fault traces associated with Sunnyside T1 and western Avalon T5 faults;
- Details of 230 kV circuit breakers; and
- Details of 230/138 kV transformers (type, connection, saturation, etc.).

- PSCAD™ model development
    - TransGrid will update existing models of Island Interconnected System used for HVdc converter station specifications;
    - Benchmark updated PSCAD™ with pre-fault PSS®E load flow model; and
    - Benchmark updated PSCAD™ model against pre-fault trace data from fault recorders.
- Simulate the sequence of events for the January 4, 2014 restoration effort
- Analysis of resultant waveforms obtained during PSCAD™ simulation to determine presence of harmonics, ferro-resonance or other abnormalities
- Investigation of source of abnormality if observed
- Report preparation

With study initiation in June 2014, project completion is anticipated by September 30, 2014.

APPENDIX A

Transmission System Analysis
Review of Transformer Capacity
Stony Brook – Sunnyside 138 kV Loop
Following Failure of Sunnyside T1

JUNE 13, 2014

Approved for Release | Date

TRANSMISSION SYSTEM ANALYSIS

Review of Transformer Capacity
Stony Brook – Sunnyside 138 kV Loop
Following Failure of Sunnyside T1

Date: June 13, 2014
Revision 3

System Planning Department

REGISTERED PROFESSIONAL ENGINEER
PEG Newfoundland and Labrador
JONATHAN MATCHEM
SIGNATURE
JUNE 13, 2014
DATE
NEWFOUNDLAND & LABRADOR

newfoundland labrador hydro
a nalcor energy company

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INTRODUCTION

At 9:05 am on Saturday, January 4, 2014, power transformer T1 at the Sunnyside Terminal Station (SSD TS) suffered a catastrophic failure resulting in the loss of power and energy to many customers throughout the Province during a period of extremely cold and windy winter weather. Due to incorrect operation of the power system protection equipment, all transmission lines connected to SSD TS were inadvertently tripped resulting in the shutdown of the Holyrood Thermal Generating Plant. SSD T1 is a 75/100/125 MVA, 230/138/6.9 kV autotransformer manufactured by Canadian General Electric in 1978 with a 17 position On-Load Tap Changer (OLTC) providing -5/+15/% voltage regulation on the 138 kV Stony Brook (STB) – Sunnyside (SSD) transmission loop in 1.25% steps. The STB-SSD 138 kV transmission loop is supplied by four 75/100/125 MVA, 230/138 kV autotransformers; two units installed at STB and the remaining two installed at SSD. The system services customer loads in central Newfoundland, the Bonavista Peninsula, the Clarenville area and the Burin Peninsula, with the majority of the 138 kV transmission owned by Newfoundland Power (NP).

The purpose of this review is to assess the remaining transformer capacity in the STB – SDD 138 kV Loop and make recommendation on the required course of action. The load flow analysis is completed using the Siemens Power Technologies Int. software package PSS®E version 32.2.1.

TRANSMISSION PLANNING CRITERIA

The transmission planning criteria used by the System Planning Department of Newfoundland and Labrador Hydro and reviewed by the Public Utilities Board of Newfoundland and Labrador considers:

- NLH's bulk transmission system (i.e. 230 kV and 138 kV loops) is planned to be capable of sustaining the single contingency loss of any transmission element without loss of system stability;
- In the event a transmission element is out of service, power flow in all other elements of the power system should be at or below normal rating;
- The NLH system is planned to be able to sustain a successful single pole reclose for a line to ground fault based on the premise that all system generation is available;
- Transformer additions at all major terminal stations (i.e. two or more transformers per voltage class) are planned on the basis of being able to withstand the loss of the largest unit;
- For single transformer stations there is a back-up plan in place which utilizes NLH's and/or Newfoundland Power's mobile equipment to restore service;
- For normal operations, the system is planned on the basis that all voltages be maintained between 95% and 105%; and
- For contingency or emergency situations voltages between 90% and 110% is considered acceptable.

With respect to the STB – SSD 138 kV Loop the transmission planning criteria requires that there be sufficient transformer capacity to supply the peak load with one of the four 125 MVA transformers out of service. The underlying principle being that following the failure of a transformer in the loop Hydro must evaluate the transformer capacity versus load situation and make recommendation on an appropriate course of action. With the development of this criterion (i.e. N-1) it must be recognized that transformer purchases may take 18 to 24 months and therefore sudden loss of a second transformer in the loop (i.e. N-1-1) could result in a quantity of unsupplied energy. To reduce the amount of unsupplied energy during for extended periods, Hydro would, when required following a transformer failure, make an unbudgeted capital submission to the Board of Commissioners of Public Utilities (the Board) rather than follow the regular Capital Budget schedule.

LOAD FORECAST

Annually, forecasted peak load data obtained from NP are used to develop updated PSS®E models of the Island Interconnected System to determine system upgrades to meet the growing demand for electricity. An acceptable level of performance is determined by planning the system using Hydro's Transmission Planning Criteria which has been accepted by the Board. NLH monitors all power transformers in the system and routinely checks for overloads, which would indicate a lack of installed transmission capacity to service the customer load.

The STB-SSD 138 kV Loop has an installed transformation capacity of 500 MVA with a single contingency (N-1) firm capacity of 375 MVA. In the event of a second transformer failure (N-1-1), the system can only service a load up to 250 MVA assuming the performance of the power system is within planning limits.

From NP's 2014 -2018 Infeed Load Forecast, the STB-SSD transmission system is expected to experience a peak load of 312.1 MW in 2014. Assuming a 0.975 power factor for customer loads in the region, the expected peak for the system is 320.1 MVA. Energy Management System (EMS) data was collected on loadings of each power transformer in the STB-SSD 138 kV Loop to determine the system's load shape. The largest hourly peak loading for the power system was determined for the period 2010 to 2013 to develop the load shape for analysis. Using NF Power's Five Year Infeed Forecast, the load shape was scaled to coincide with the 2014 peak load of 320.1 MVA. Figure 1 provides a plot of the load shape and the transformer capacity.

The figure assumes that the NP Greenhill Combustion Turbine is available under contingecy for 20 MW and the Wesleyville Combustion Turbine is available for 10 MW.

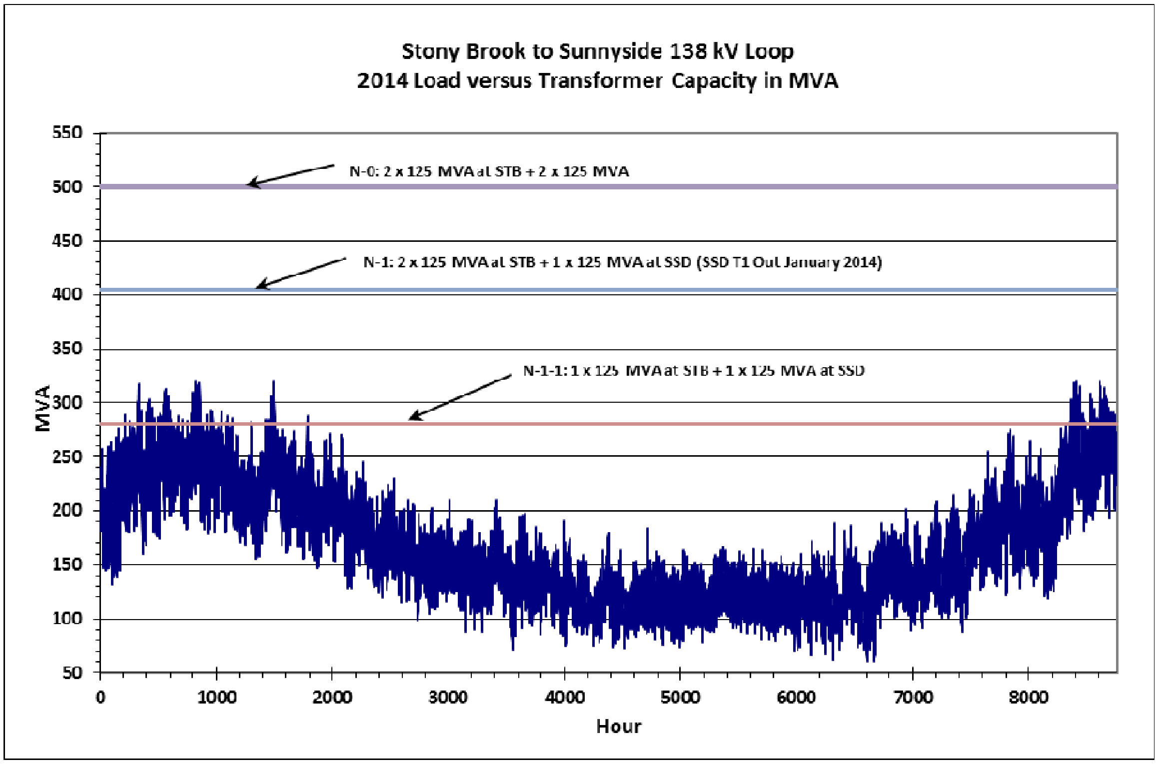

Figure 1: STB – SSD 138 kV Loop 2014 Load versus Transformer Capacity

One notes that there is sufficient transformer capacity in the STB – SSD Loop to supply all load following the loss of SSD T1. With the loss of a second 125 MVA transformer in the loop there will be insufficient transformer capacity to supply all load. As a result a quantity of unsupplied energy can be expected should there be a second transformer failure until the 125 MVA of transformer capacity is re-instated at SSD.

LOAD FLOW ANALYSIS

To determine the impact of a double contingency transformer outage on the STB-SSD 138 kV Loop, a number of steady state load flows were completed.

As shown in Figure 2, a loss of SSD T1 does not adversely affect the performance of the transmission system over the 2014 winter peak. There are no transformer overloads and bus voltages are within 0.95 and 1.05 p.u. Assuming the loss of SSD T1 is the status quo, two subsequent contingencies were explored including the loss of SSD T4 and either STB T1 or STB T2.

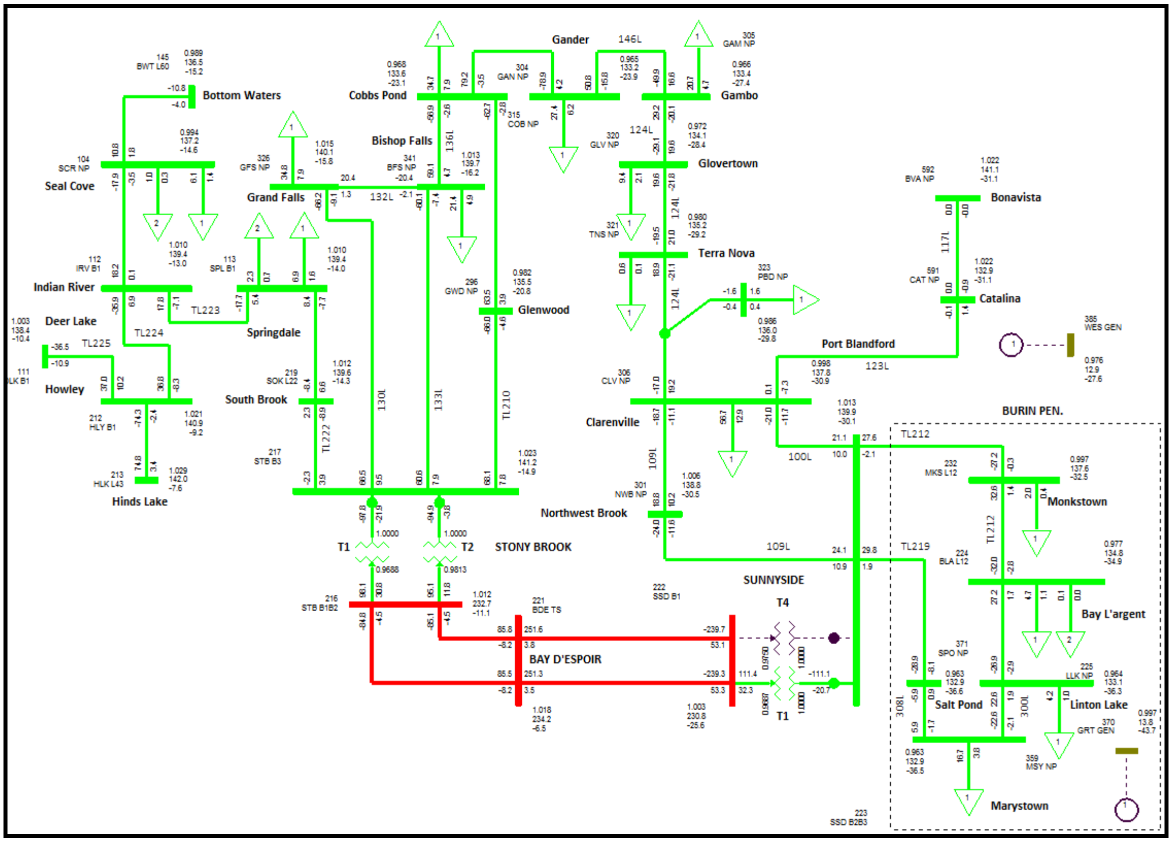

Figure 1: STB-SSD 138 kV Transmission System - SSD T1 Out of Service

Loss of SSD Transformer T4

A subsequent loss of SSD T4 would require the system to shed load to maintain adequate system bus voltages over peak. Assuming the operation NP's Greenhill and Wesleyville combustion turbines on the Burin Peninsula and central NL, the system would need to shed 118 MW of load to minimize 230/138 kV transformer overloads. This results in the ability to maintain 194 MW of supplied load in those areas. The resulting transmission system is shown in Figure 3.

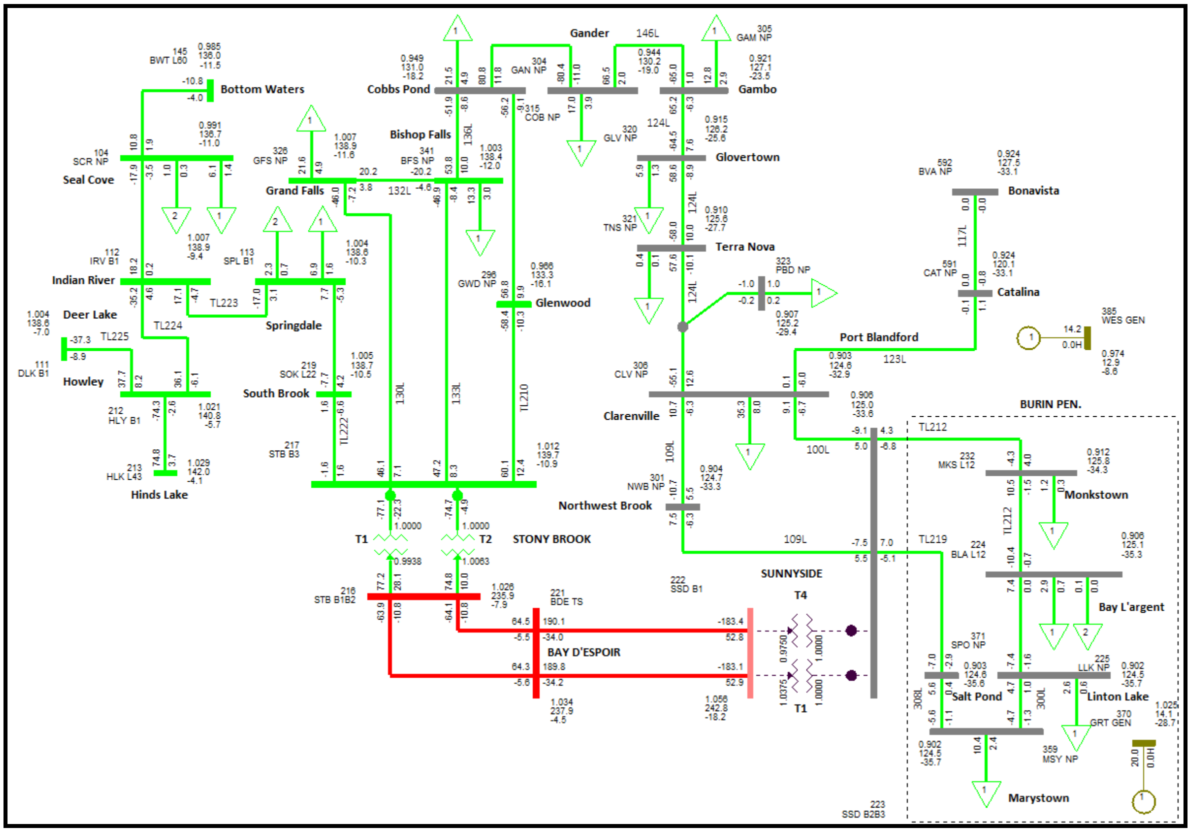

Figure 2: STB-SSD 138 kV Transmission System - SSD T1/T4 Out of Service – Load Reduced to 194 MW

Loss of STB Transformer T1 or T2

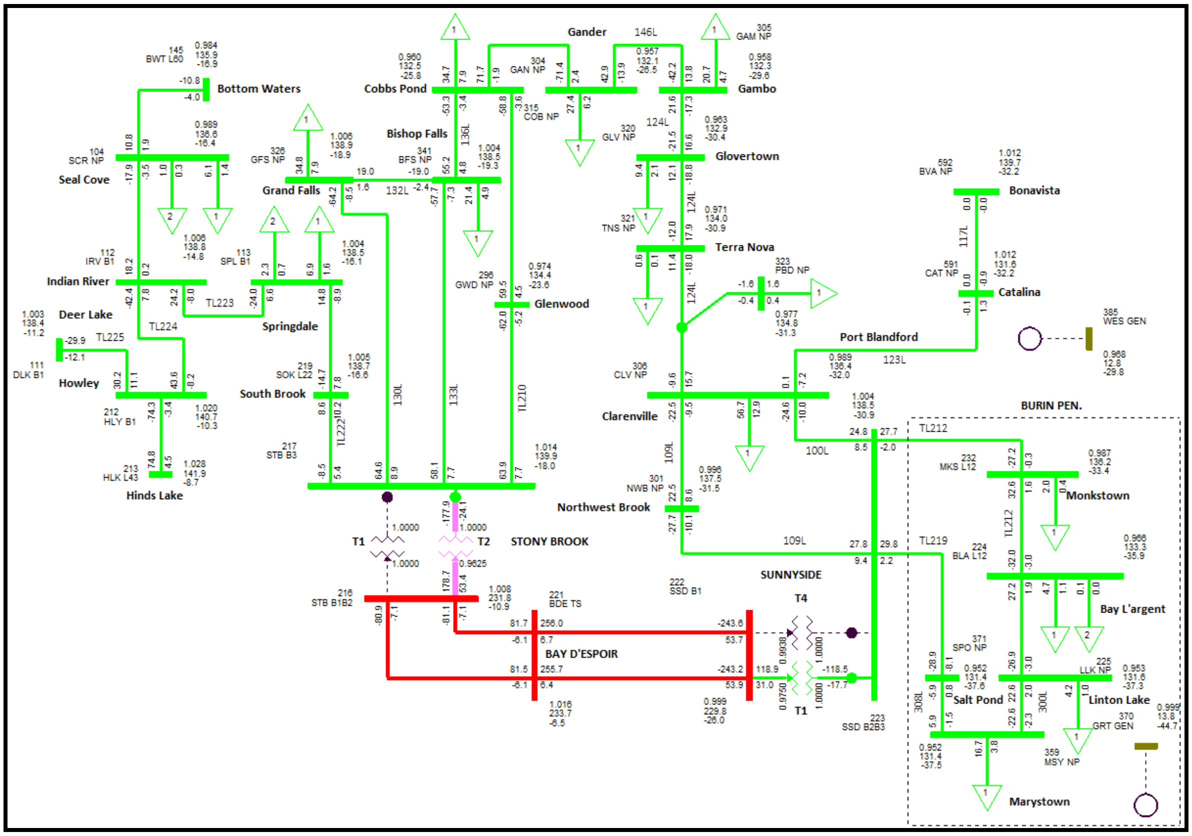

Figure 3: STB-SSD 138 kV Transmission System – STB T1/SSD T1 Out of Service

An overload on the remaining autotransformer is simulated to occur for the loss of a 125 MVA unit in the STB Terminal Station over the winter peak. In the event of a loss of STB T1 or T2, the parallel unit in service will experience a loading of 148% its rated MVA as shown in Figure 4. With the 138 kV transmission system in this configuration, inflows from the 230 kV transmission system into the STB-SSD loop is greater from the STB end than the SSD end. To reduce transformer loading over peak, transmission line 146L between Gander and Gambo can be opened, effectively splitting the loop load between the two 230 kV terminal stations. As a result, more load is serviced through the remaining autotransformer in SSD TS while offloading STB T2.

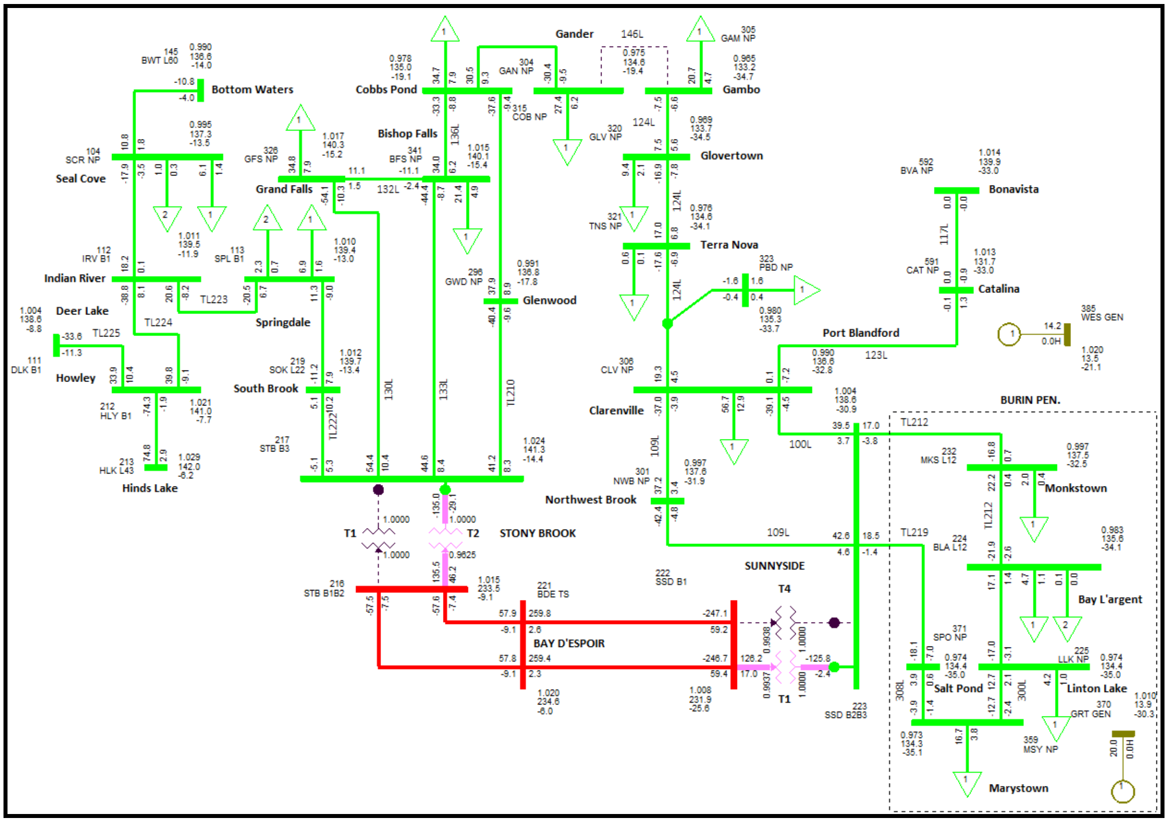

Figure 4: STB-SSD 138 kV Transmission System – STB T1/SSD T1 Out of Service – 146L Removed from Service NF Power Greenhill and Wesleyville Combustion Turbines Online

Assuming the Greenhill and Wesleyville CTs are online for generation the loading experienced on STB T2 is reduced from 148% rated MVA to 113% as shown in Figure 5. It should be noted that SSD T4 is simulated to experience a minor overload of 1% in this configuration over peak, which may be considered acceptable during double contingency operation.

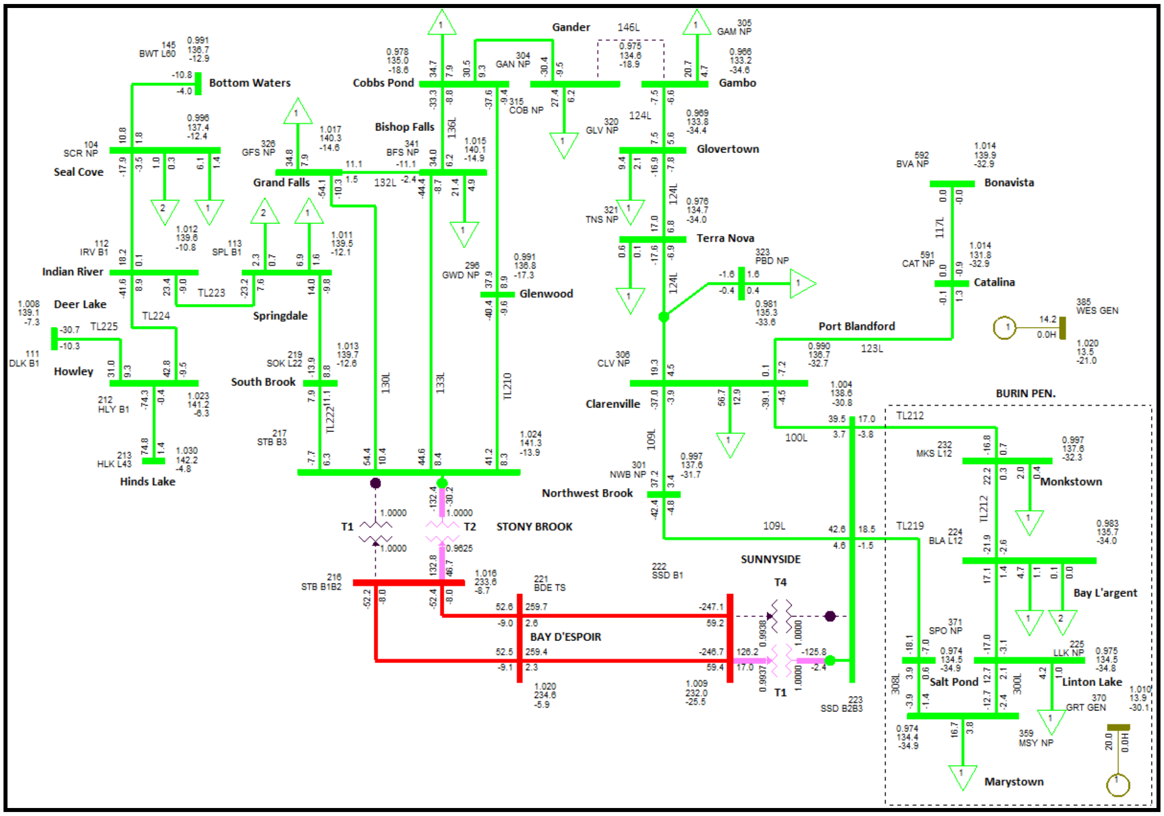

Figure 5: STB-SSD 138 kV Transmission System – STB T1/SSD T1 Out of Service – 146L Removed from Service St. Anthony/Hawks Bay Diesel Plant, Greenhill and Wesleyville Combustion Turbines Online

To further reduce the overload on STB T1 for loss of STB T2, standby generation in the form of diesel generators can be brought online. In this case, 146L has been removed from service, both the Hawks Bay and St. Anthony diesel plants are generating at full capacity with the Greenhill and Wesleyville CTs online for MWs. Figure 6 displays the system configuration in this case; reducing the loading on STB T1 from 113% to 111% of MVA rating.

Temporary Transformer Install – Relocate Holyrood/Western Avalon Autotransformer

In an effort to reduce the risk of long term unsupplied energy to customers for the loss of a second 125 MVA autotransformer in the STB-SSD 138 kV Loop, a number of alternatives were considered, including the relocation of either a 41.7 MVA or 125 MVA autotransformer from the Western Avalon (WAV) to Holyrood (HRD) 138 kV Loop to replace SSD T1 until a new replacement transformer can be installed in its place.

EMS load data was collected for all six autotransformers installed in the WAV-HRD 138 kV Loop to determine the historical loading of the system from 2010 to 2013 and plotted in Figure 7. It is clear from the plot that the peak load for the transmission system of 134.7 MVA occurred in the winter of 2013. NF Power has forecasted a relatively flat load profile for this region from 2014-2018, with a total peak load of 154.9 MVA in 2014 to 155.1 MVA in 2018. As a result, a steady state load flow analysis was completed for the forecasted 2014 peak load of 154.9 MVA at a power factor of 0.975. The installed transformer capacity in the WAV-HRD 138 kV Loop is 416.8 MVA (2 x 41.7 MVA + 1 x 125 MVA at each of WAV and HRD) with a firm capacity of 291.8 MVA.

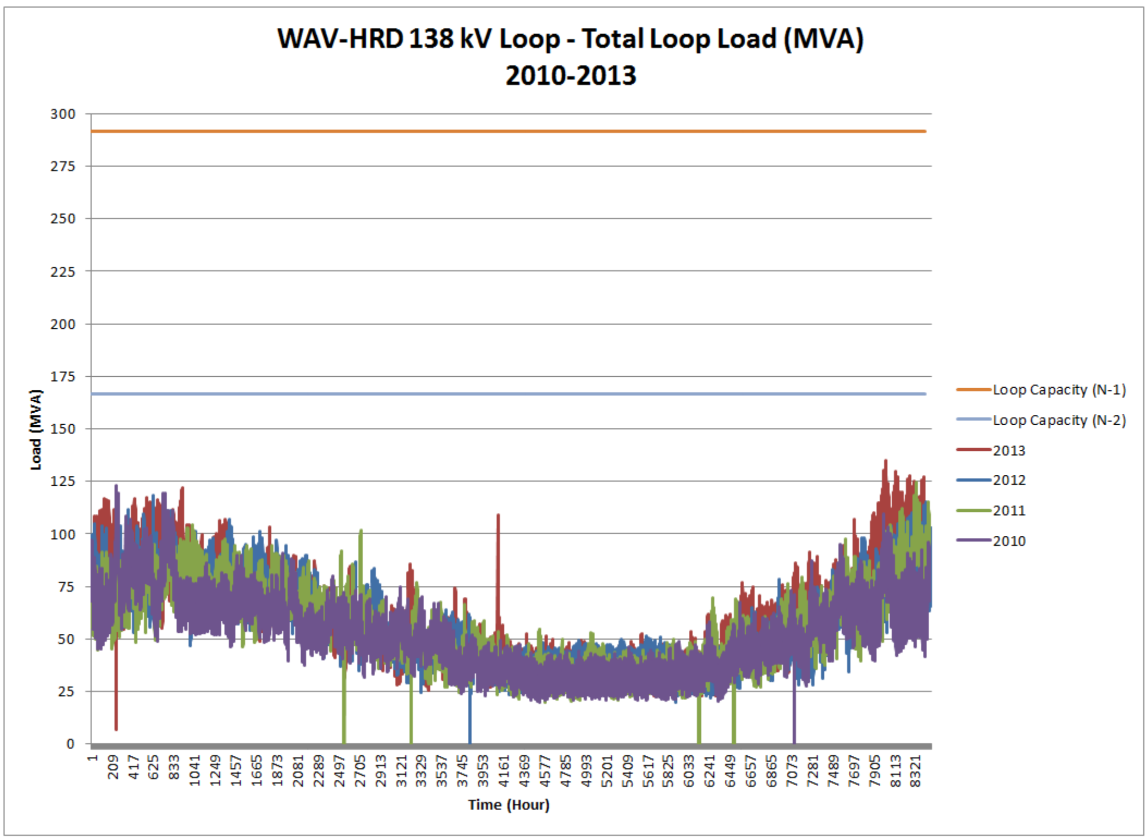

Figure 6: WAV-HRD 138 kV Loop - Total Transformer Load (2010-2013)

Temporary Transformer Install – Relocate Holyrood/Western Avalon 41.7 MVA Autotransformer

The relocation of a 41.7 MVA autotransformer from the WAV-HRD Loop to the STB-SSD Loop will reduce the firm transformer capacity of the WAV-HRD 138 kV Loop from 291.8 MVA to 250.1 MVA and increase firm capacity in the STB-SSD 138 kV Loop from 250 MVA to 291.7 MVA. A number of steady state load flows were completed on both systems to determine the performance of each assuming the worst case loss of another transformer in the respective loop.

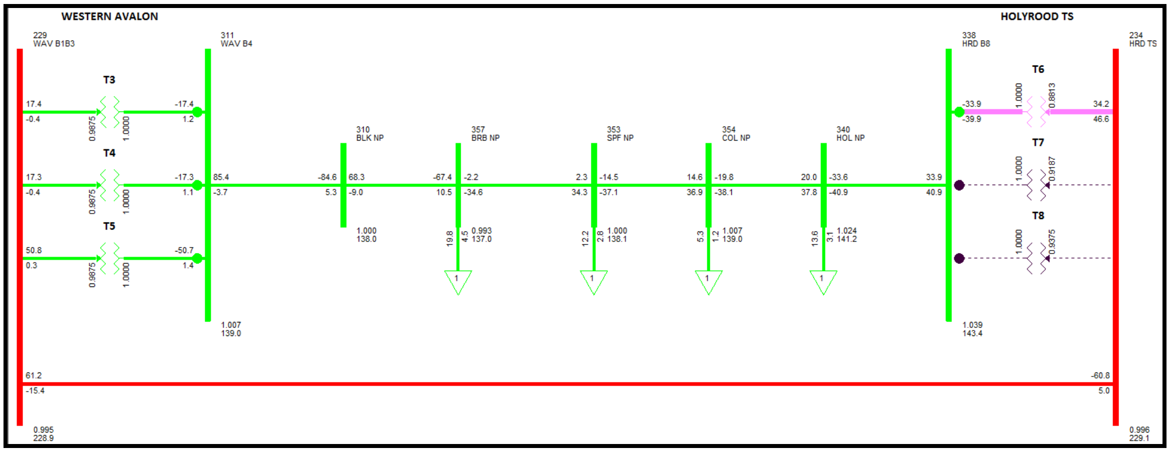

Figure 7: WAV-HRD 138 kV Loop – Relocate HRD T7 to SSD, HRD T8 Out of Service

The removal of a 41.7 MVA from the WAV-HRD 138 kV Loop will have a negative impact on the performance of the system for loss of another transformer in the same station in which the temporary replacement was taken. For example, in Figure 8, a 41.7 MVA autotransformer is relocated from the Holyrood Terminal Station, leaving a 125 MVA and 41.7 MVA transformer in parallel to supply loads in that area. The subsequent loss of the remaining 125 MVA transformer at HRD will load the 41.7 MVA transformer to 139% its rated capacity. The three autotransformers located at WAV are loaded to 42% of their nameplate rating.

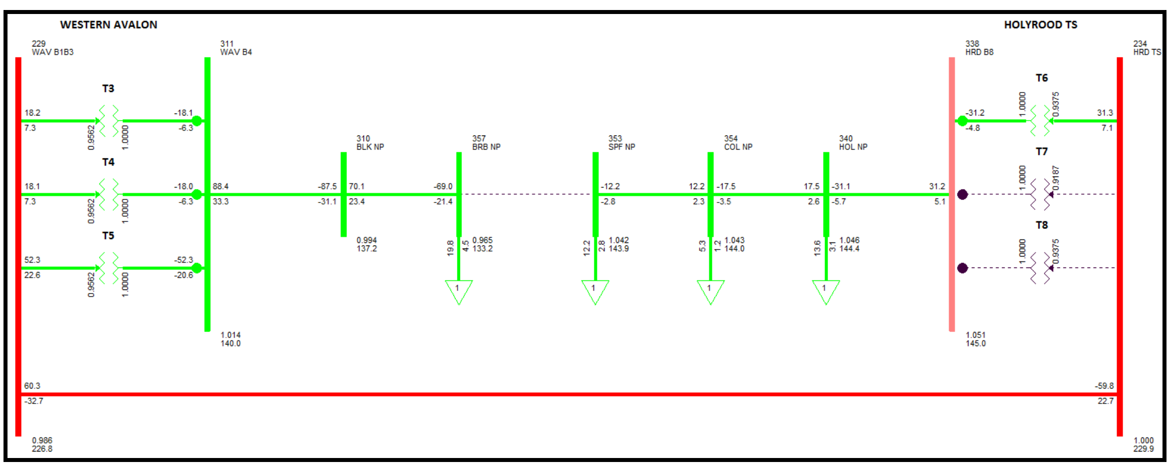

Figure 8: WAV-HRD 138 kV Loop – Relocate HRD T7 to SSD, HRD T8 Out of Service – Transmission Line L38 Out of Service

Loading on the HRD end of the transmission system can be reduced by taking a 138 kV transmission line out of service to break the loop and service customer loads in the area from either WAV or HRD. Opening transmission line 39L between the Bay Roberts Substation (BRB) and the Springfield Substation (SPF) reduces loading on HRD T6 to 77%. The three autotransformers in WAV are loaded between 46-48 % of nameplate rating as shown in Figure 9.

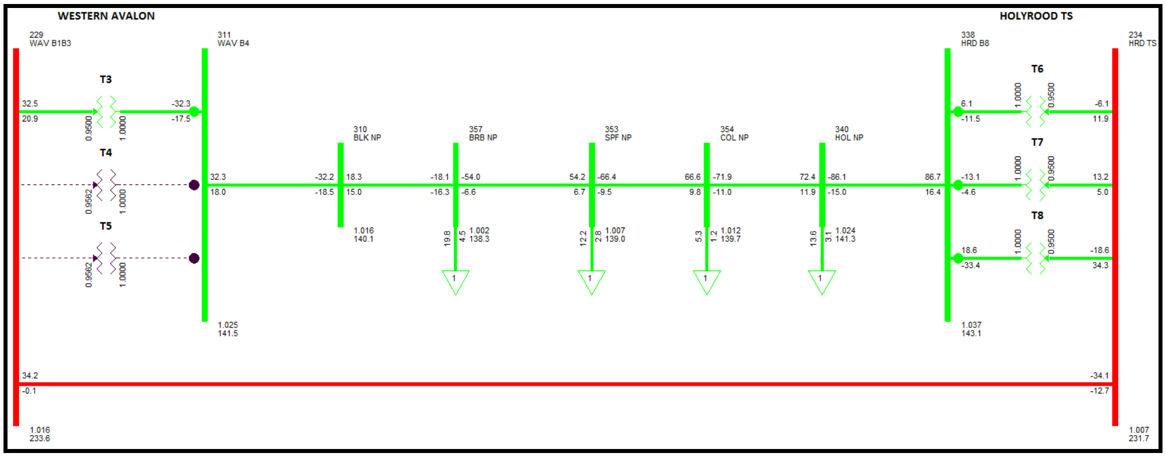

Figure 9: WAV-HRD 138 kV Loop – Relocate WAV T4 to SSD, WAV T5 Out of Service

The relocation of a 41.7 MVA transformer from WAV, rather than HRD, to SSD would improve the performance of the WAV-HRD Loop under contingency. A subsequent loss of WAV T5 (125 MVA) loads the remaining 41.7 MVA transformer WAV T3 to 91% of its nameplate rating as shown in Figure 10. Autotransformers T6-T8 in HRD are loaded from 31-34% of nameplate rating.

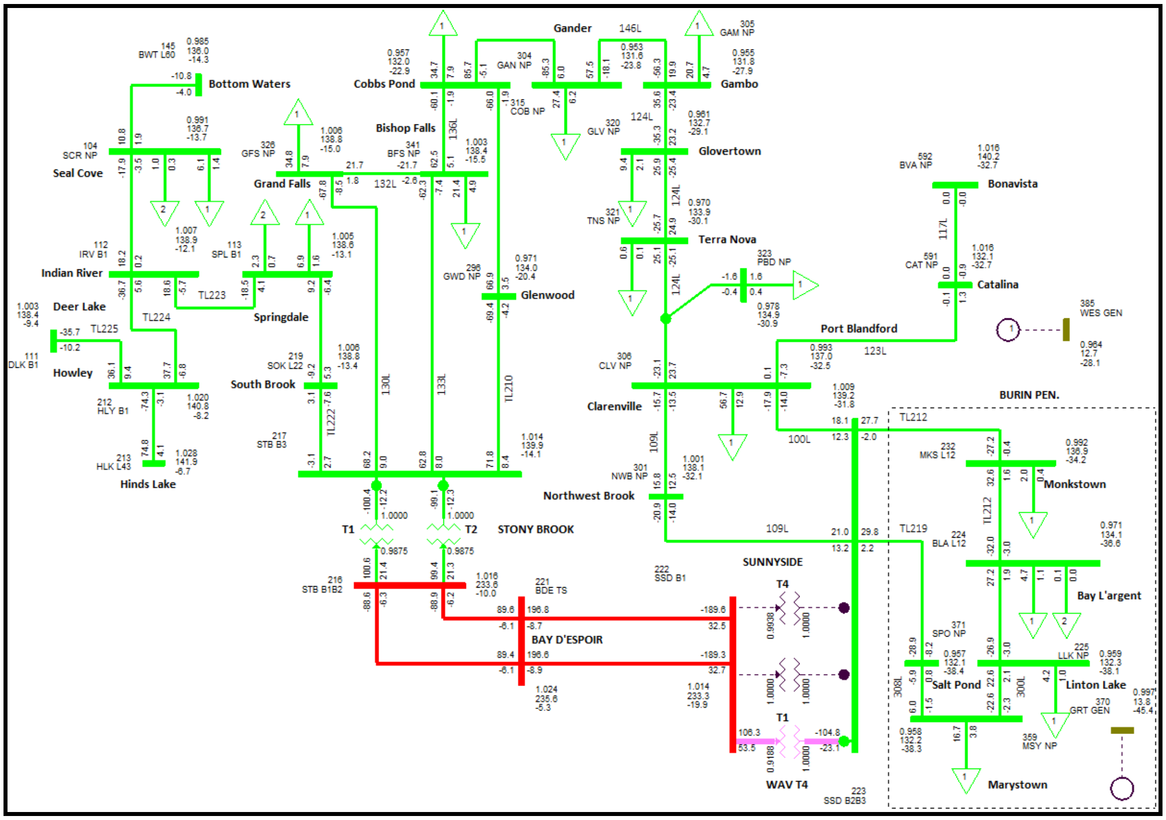

Figure 10: STB-SSD 138 kV Transmission System – WAV T4 Relocated to SSD – SSD T1/T4 Out of Service

The addition of the 41.7 MVA transformer at the SSD from WAV would provide additional transformer capacity in the STB-SSD 138 kV Loop. However, the subsequent loss of SSD T4 would load the remaining 41.7 MVA unit to 281% of its rating as shown in Figure 11. As a result, it is suggested that a 125 MVA autotransformer from the WAV be relocated to SSD to provide additional transformer capacity in the STB-SSD transmission system for the subsequent loss of SSD T4.

Temporary Transformer Install – Relocate Holyrood/Western Avalon 125 MVA Autotransformer

Consideration was given to the relocation of a 125 MVA transformer from the WAV-HRD 138 kV Loop to replace the failed autotransformer in SSD. Referencing Figure 10, it is clear that the relocation of WAV T5 would not have a significant negative impact on the performance of the WAV-HRD Loop for the loss of a parallel autotransformer. In the event HRD T8 (125 MVA) is forced out of service, loading on the four remaining 41.7 MVA autotransformers in the system are well below nameplate rating as shown in Figure 12. In this case, WAV T3/T4 and HRD T6/T7 are loaded to 82% and 71% of their respective ratings.

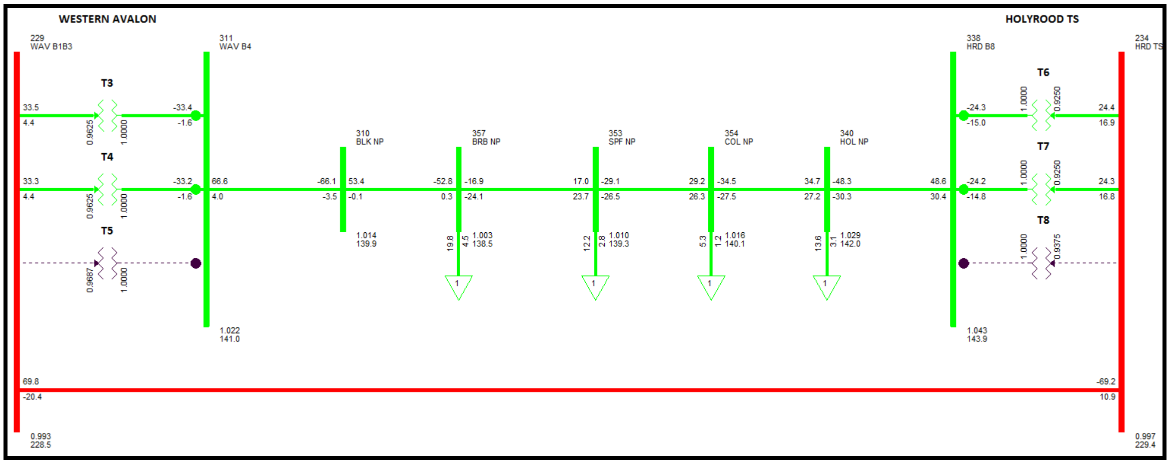

Figure 11: WAV-HRD 138 kV Loop – Relocate WAV T5 to SSD, HRD T8 Out of Service

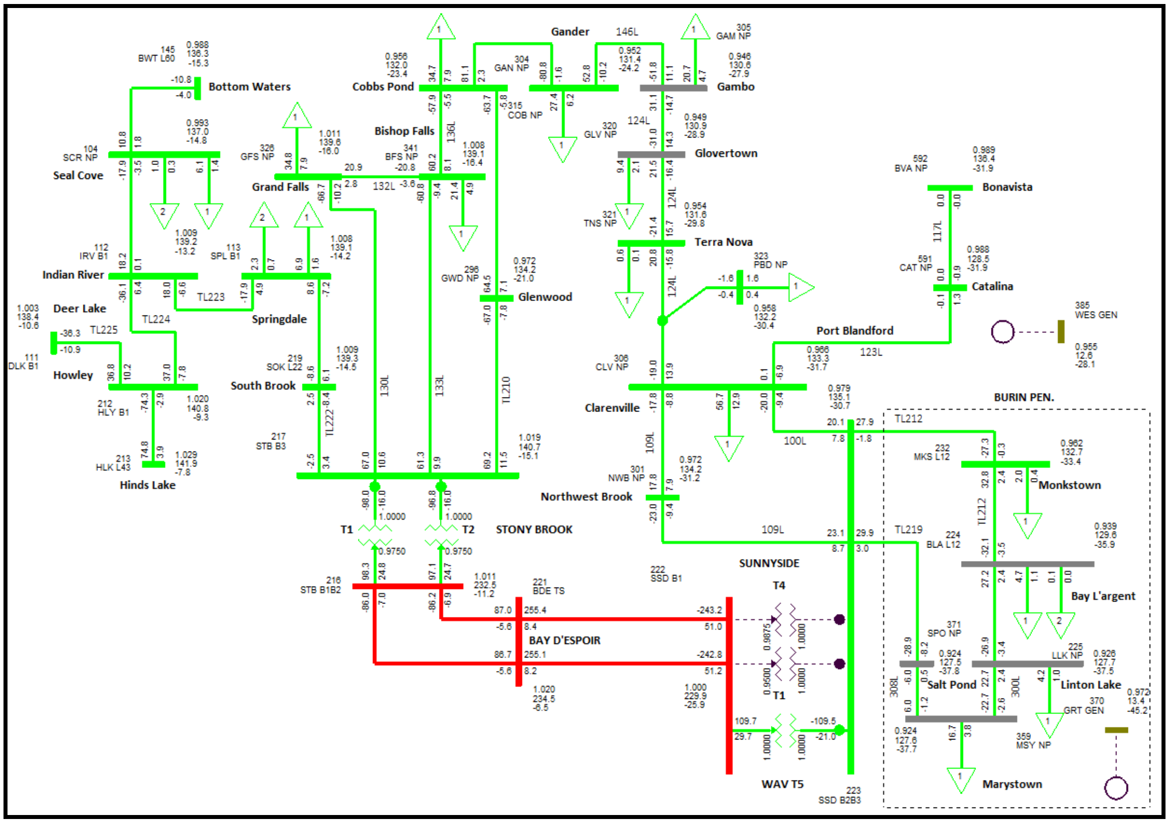

Figure 12: STB-SSD 138 kV Transmission System – WAV T5 Relocated to SSD – SSD T1/T4 Out of Service

Assuming the installation of WAV T5 at SSD TS, a subsequent outage of SSD T1 will load SSD T5 to 91% of its nameplate rating. Loading on STB transformers T1 and T2 are 80% of rated MVA in this case as shown in Figure 13.

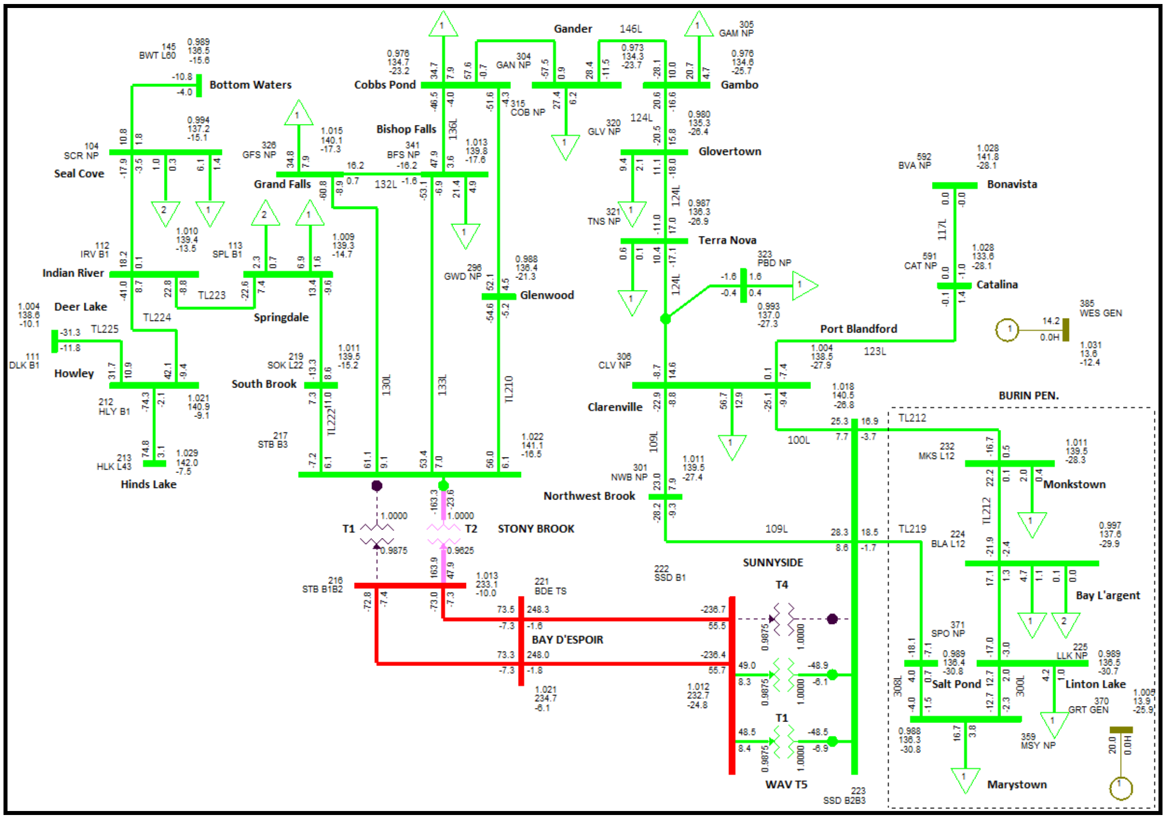

Figure 13: STB-SSD 138 kV Transmission System – WAV T5 Relocated to SSD – STB T1 Out of Service Greenhill and Wesleyville CT Online

In the event STB T1 or T2 is forced out of service in this configuration, the parallel transformer is loaded 135% of its nameplate rating as shown in Figure 14. This assumes the operation of the Greenhill and Wesleyville CTs for system support during the contingency.

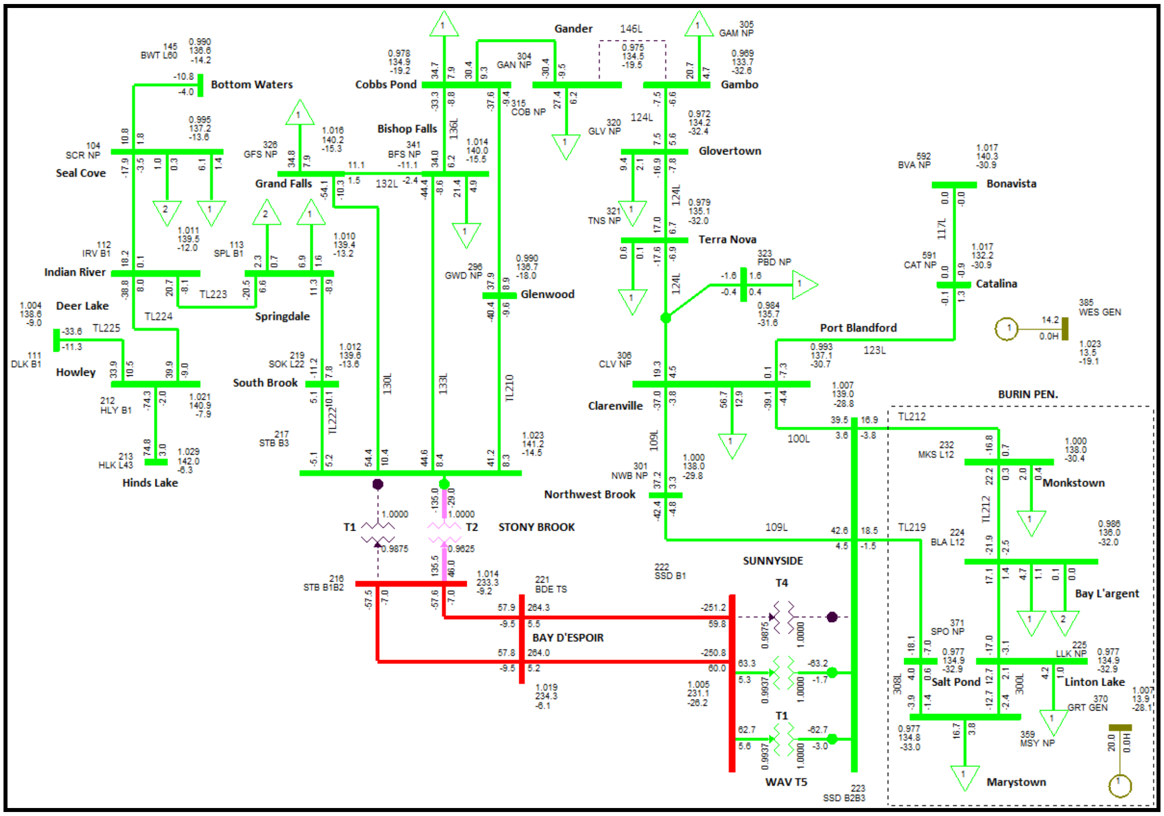

Figure 14: STB-SSD 138 kV Transmission System – WAV T5 Relocated to SSD – STB T1 Out of Service Greenhill and Wesleyville CT Online – Transmission Line 146L Out of Service

To reduce loading of the STB autotransformer, the 138 kV transmission loop can be broken by taking a transmission line out of service. Opening of the transmission circuit 146L between Gander and Gambo has the greatest effect on load reduction at the STB TS. In this configuration, STB T1/T2 is loaded to 113% of its nameplate rating in the event the parallel transformer is removed from service as shown in Figure 15.

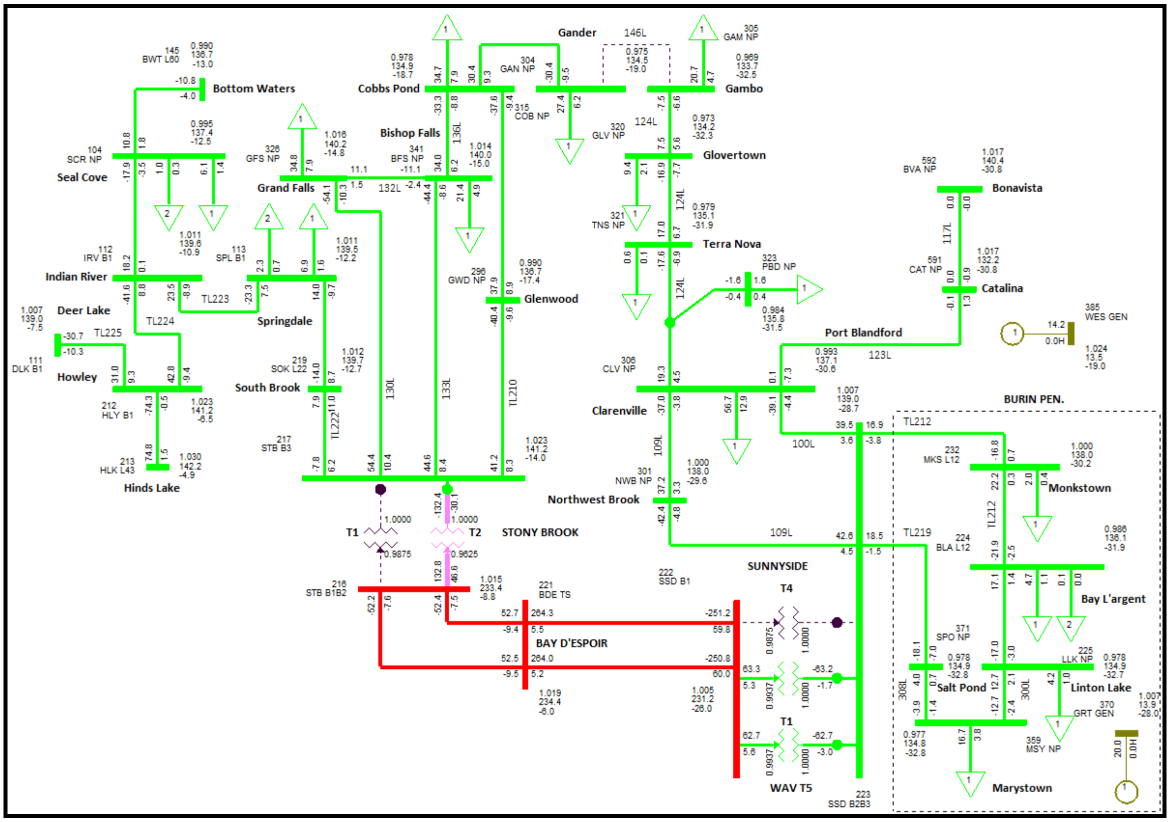

Figure 15: STB-SSD 138 kV Transmission System – WAV T5 Relocated to SSD – STB T1 Out of Service
Greenhill and Wesleyville CT Online – Hawks Bay and St. Anthony Diesel Plants Online
Transmission Line 146L Out of Service

Loading on the single STB transformer can be further reduce to 111% rated MVA by operating both Hawks Bay and St. Anthony diesel plants at full capacity as shown in Figure 16.

Temporary Transformer Install – Relocate STB 125 MVA and Deer Lake 75 MVA Autotransformers

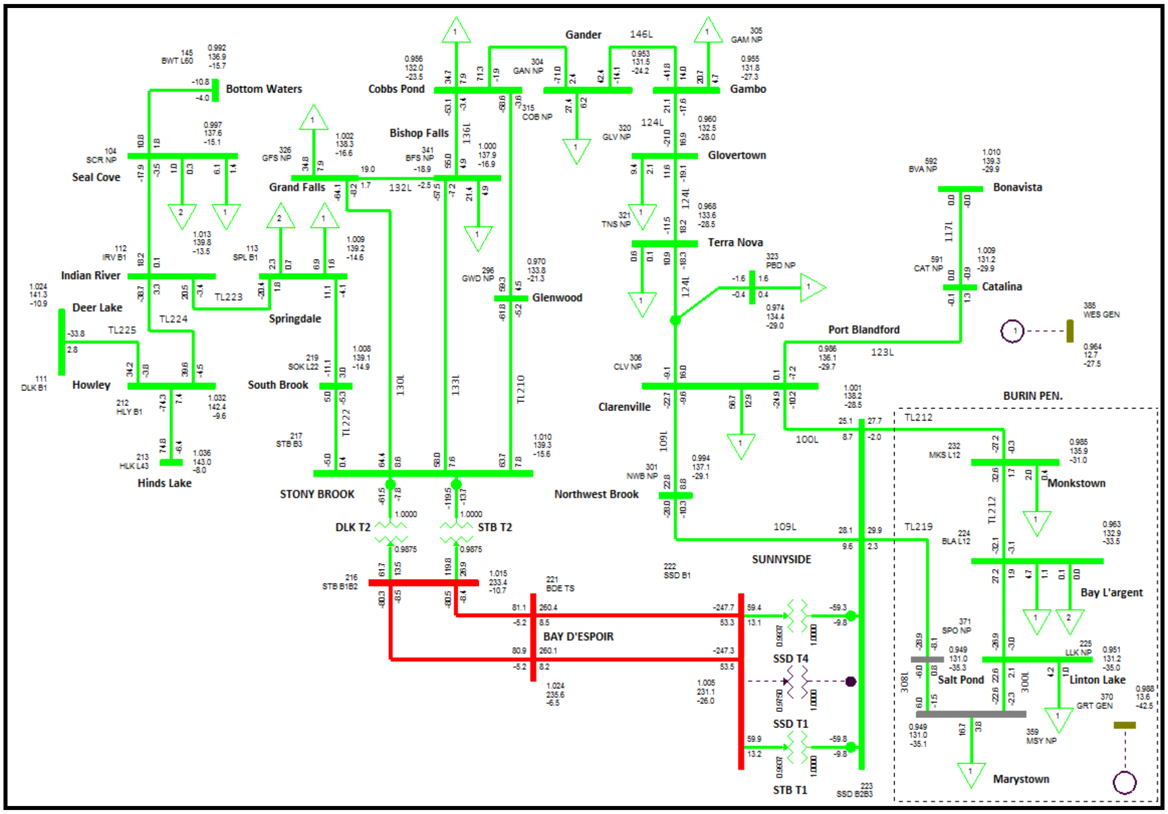

Figure 16: STB-SSD 138 kV Transmission System – STB T1 Relocated to SSD, DLK T2 Relocated to STB

Consideration was given to the relocation of a 125 MVA autotransformer from the Stony Brook Terminal Station to replace the failed autotransformer in SSD. In addition, the 75 MVA 230/138 kV autotransformer DLK T2 from the Deer Lake terminal station would be relocated to Stony Brook. Power flow through DLK T2 has historically been light over peak and therefore the relocation should not have a significant impact on the transmission system. The new transformer configuration is shown in Figure 17.

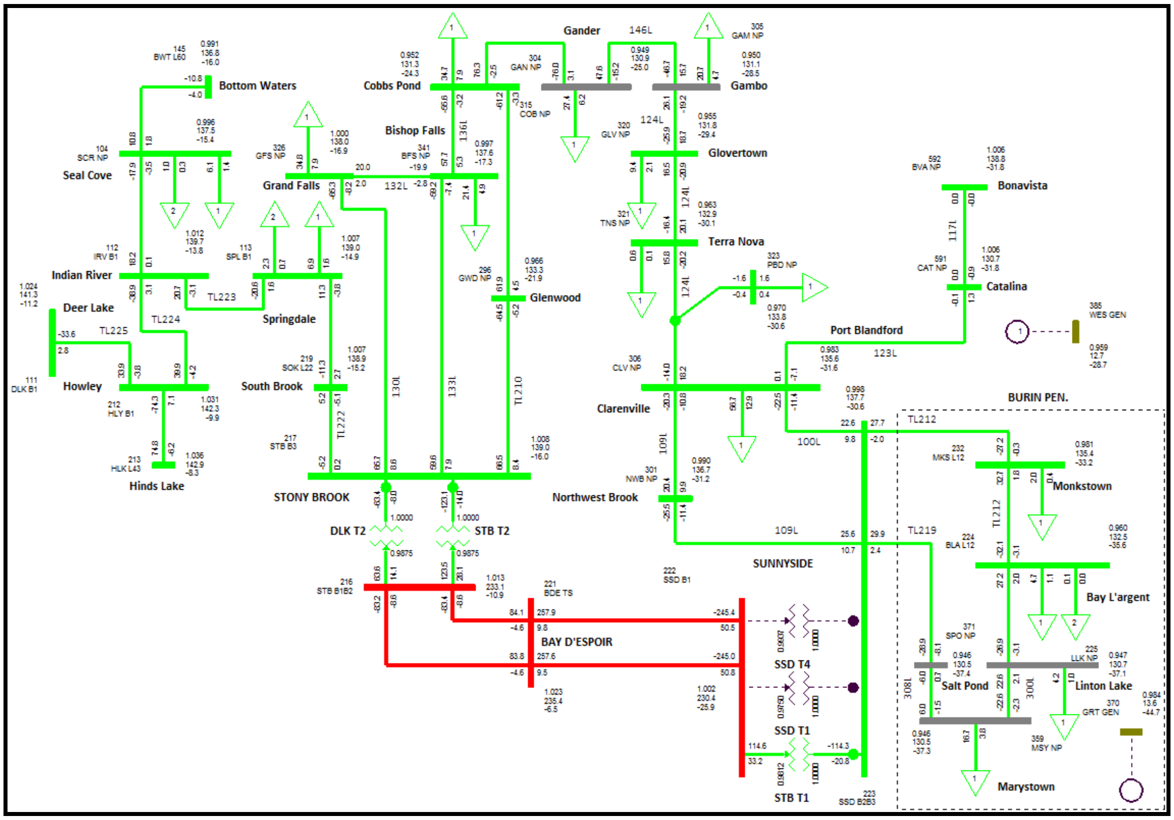

Figure 17: STB-SSD 138 kV Transmission System – STB T1 Relocated to SSD, DLK T2 Relocated to STB SSD T4 Out of Service

In this new configuration, the transmission system is not negatively impacted for the forced outage of the remaining SSD transformer T4. As shown in Figure 18, the 125 MVA STB transformer moved to SSD is loaded to 95% of its nameplate rating, while DLK T2 and STB T2 located at the Stony Brook Terminal Station are loaded to 85% and 100% of their respective ratings. 138 kV bus voltages on the Burin Peninsula are slightly below 0.95 pu but are within planning criteria for a single contingency outage. Operation of NP's combustion turbines is not required under this contingency.

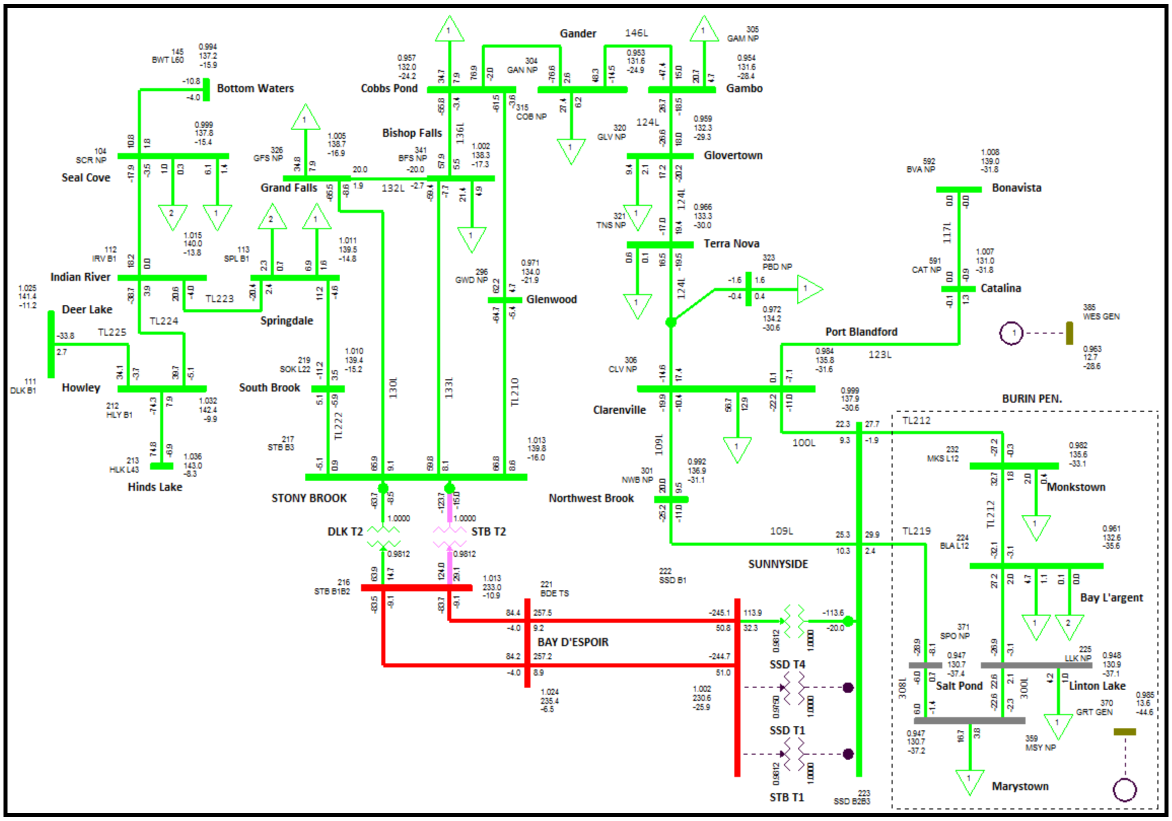

Figure 18: STB-SSD 138 kV Transmission System – STB T1 Relocated to SSD, DLK T2 Relocated to STB
STB T1 Out of Service

A forced outage of the relocated Stony Brook transformer at the Sunnyside Terminal Station will increase power flow through the STB TS. In this scenario, as shown in Figure 19, the 125 MVA STB transformer is loaded to 101% of its nameplate rating, while DLK T2 is loaded to 83%. Taking into consideration that this scenario is an N-1-1 contingency situation, a 1% transformer overload is considered acceptable for a short period of time. Sunnyside transformer T4 is loaded to 94% of its rated MVA. 138 kV bus voltages on the Burin Peninsula are slightly below 0.95 pu but are within planning criteria for a single contingency outage. Operation of NP's combustion turbines is not required under this contingency.

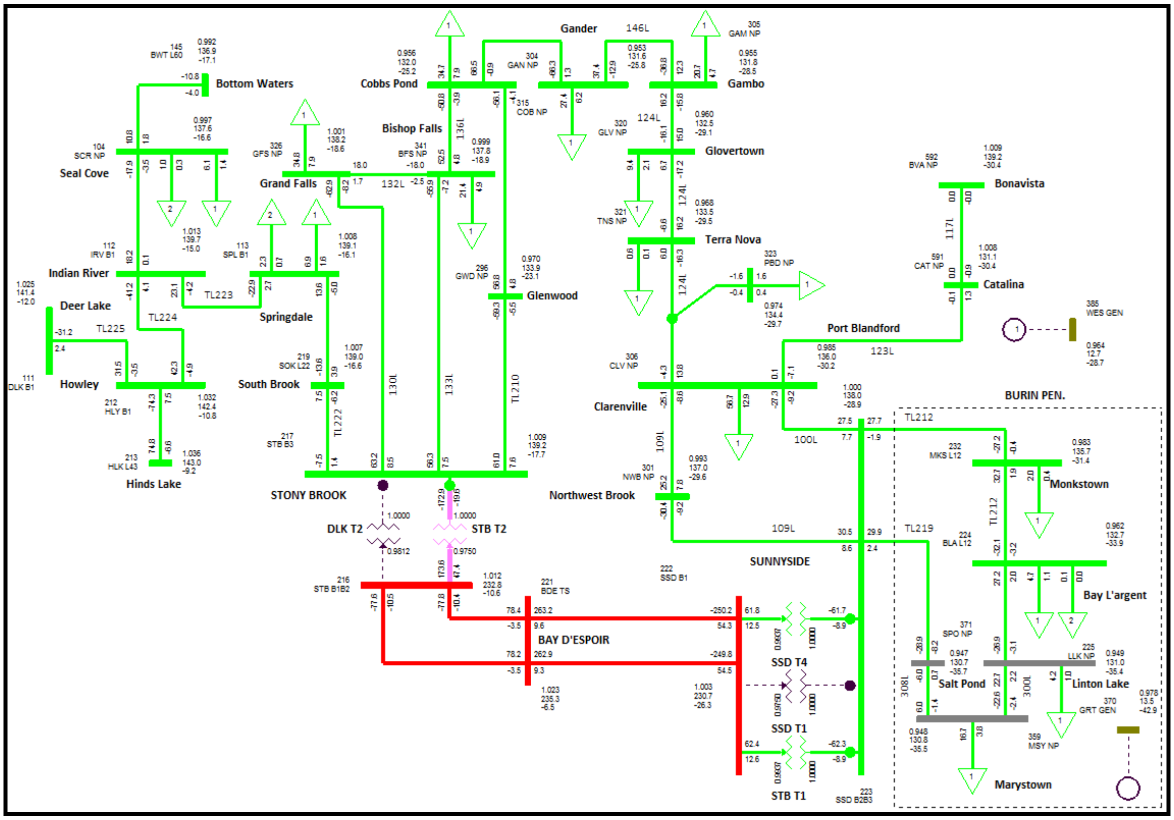

Figure 19: STB-SSD 138 kV Transmission System – STB T1 Relocated to SSD, DLK T2 Relocated to STB
DLK T2 Out of Service

An outage of the relocated Deer Lake transformer DLK T2 at the STB TS will increase power flow through the remaining in service 125 MVA transformer at Stony Brook. In this scenario, as shown in Figure 20, the 125 MVA STB transformer is loaded to 142% of its nameplate rating, while parallel transformers at SSD are loaded to 51%.

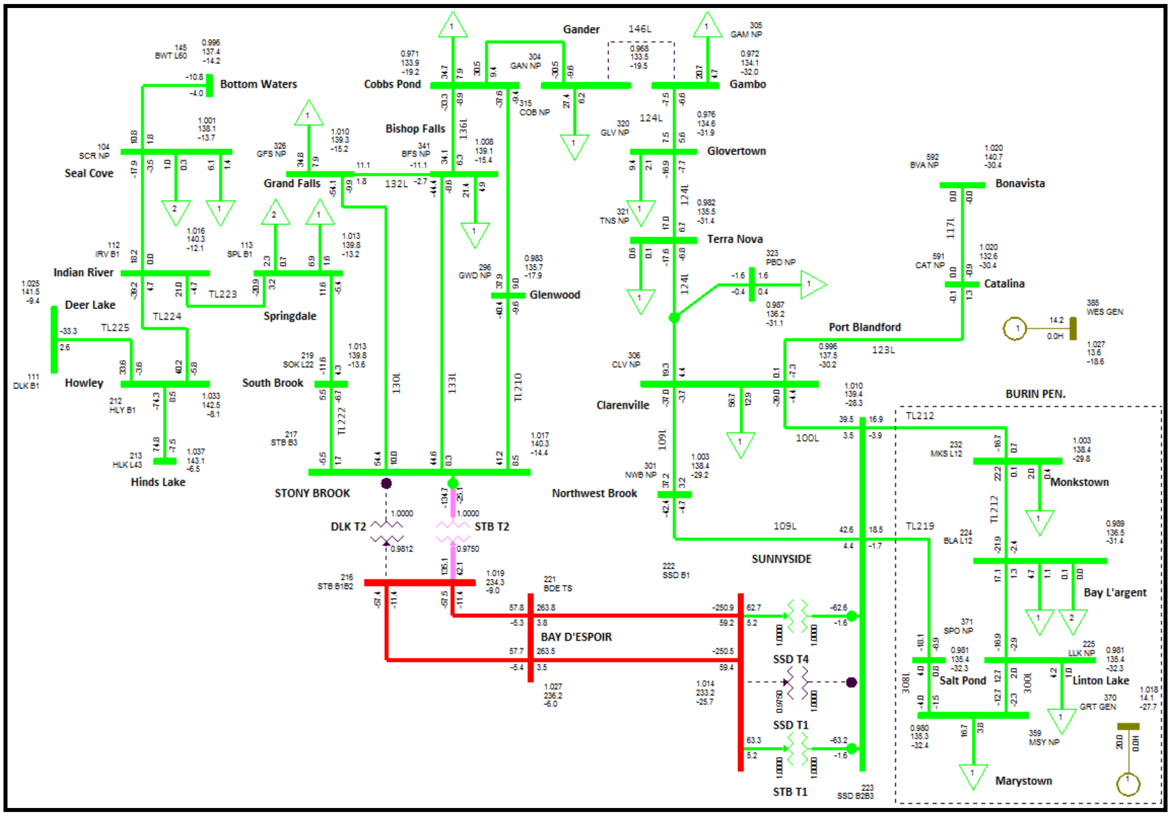

Figure 20: STB-SSD 138 kV Transmission System – STB T1 Relocated to SSD, DLK T2 Relocated to STB DLK T2 Out of Service
Greenhill and Wesleyville CT Online – Transmission Line 146L Out of Service

To reduce power flow through the Stony Brook Terminal Station and offloaded the overloaded STB T2 autotransformer, both of NP's combustion turbines were brought online for generation and 138 kV transmission 146L was opened between Gander and Gambo. In this configuration, as shown in Figure 21, STB T2 is loaded to 111% of nameplate MVA rating, while parallel transformers in SSD are loaded to 50% of their respective ratings.

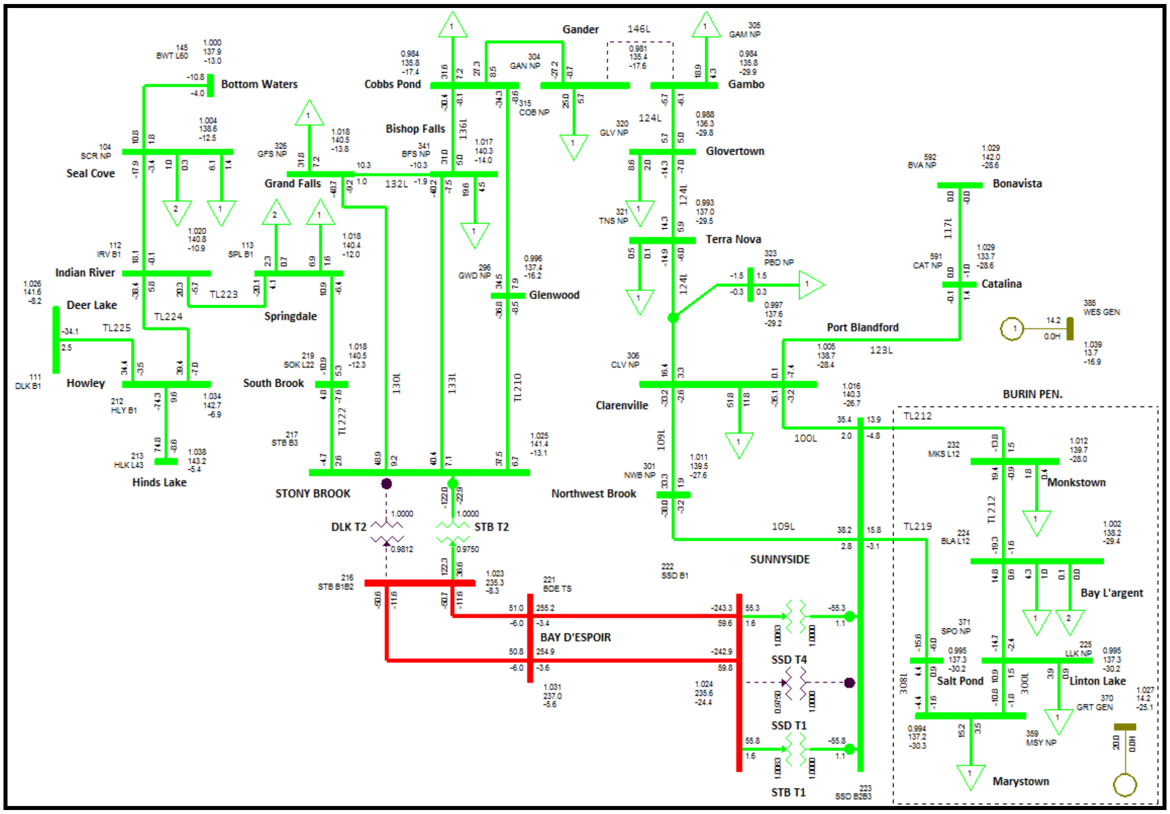

Figure 21: STB-SSD 138 kV Transmission System – STB T1 Relocated to SSD, DLK T2 Relocated to STB
DLK T2 Out of Service
Greenhill and Wesleyville CT Online – Transmission Line 146L Out of Service
Area Load Reduced from 312.1 MW to 288 MW (27.1 MW of Load Shed)

To relieve the overload on transformer STB T2, 27.1 MW of load must be shed between the central and burin peninsula power systems. As shown in Figure 22, both of NP's combustion turbines were brought online for generation and 138 kV transmission 146L was opened between Gander and Gambo and the area customer load was scaled to 288 MW. In this configuration, STB T2 is loaded to 100% of nameplate MVA rating, while parallel transformers in SSD are loaded to 44% of their respective ratings.

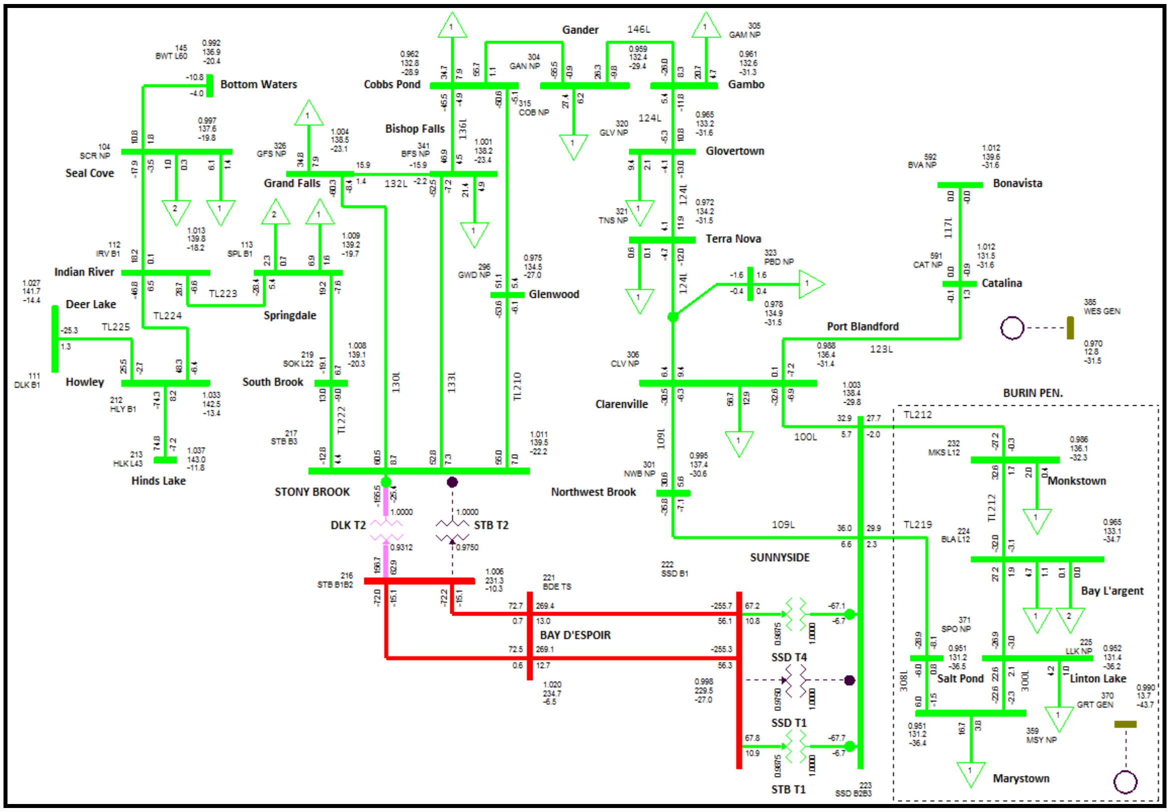

Figure 22: STB-SSD 138 kV Transmission System – STB T1 Relocated to SSD, DLK T2 Relocated to STB – STB T2 Out of Service

An outage of the 125 MVA Stony Brook transformer will increase power flow through the relocated 75 MVA Deer Lake transformer T2 at Stony Brook. In this scenario, as shown in Figure 23, DLK T2 is loaded to 224% of its nameplate rating, while parallel transformers at SSD are loaded to 55%.

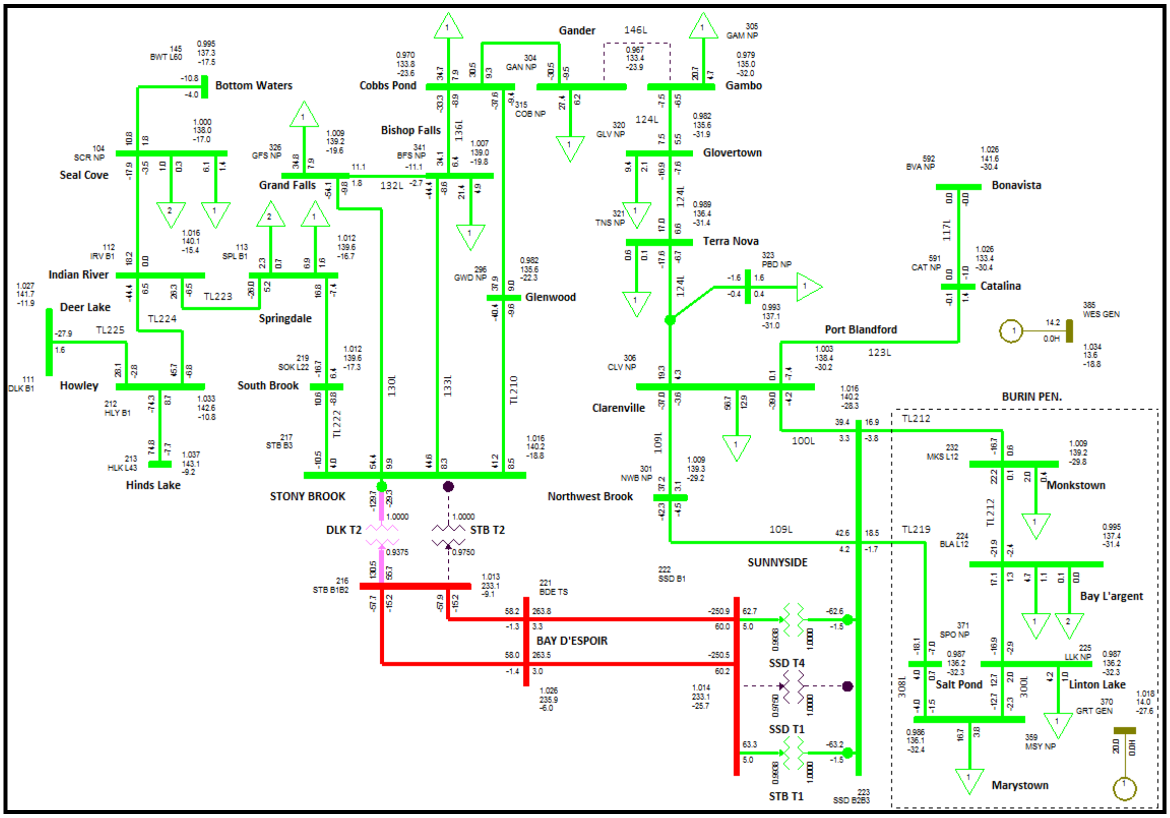

Figure 23: STB-SSD 138 kV Transmission System – STB T1 Relocated to SSD, DLK T2 Relocated to STB STB T2 Out of Service Greenhill and Wesleyville CT Online – Transmission Line 146L Out of Service

To reduce power flow through the Stony Brook Terminal Station and offloaded the overloaded DLK T2 autotransformer, both of NP's combustion turbines were brought online for generation and 138 kV transmission 146L was opened between Gander and Gambo. In this configuration, as shown in Figure 24, DLK T2 is loaded to 187% of nameplate MVA rating, while parallel transformers in SSD are loaded to 50% of their respective ratings.

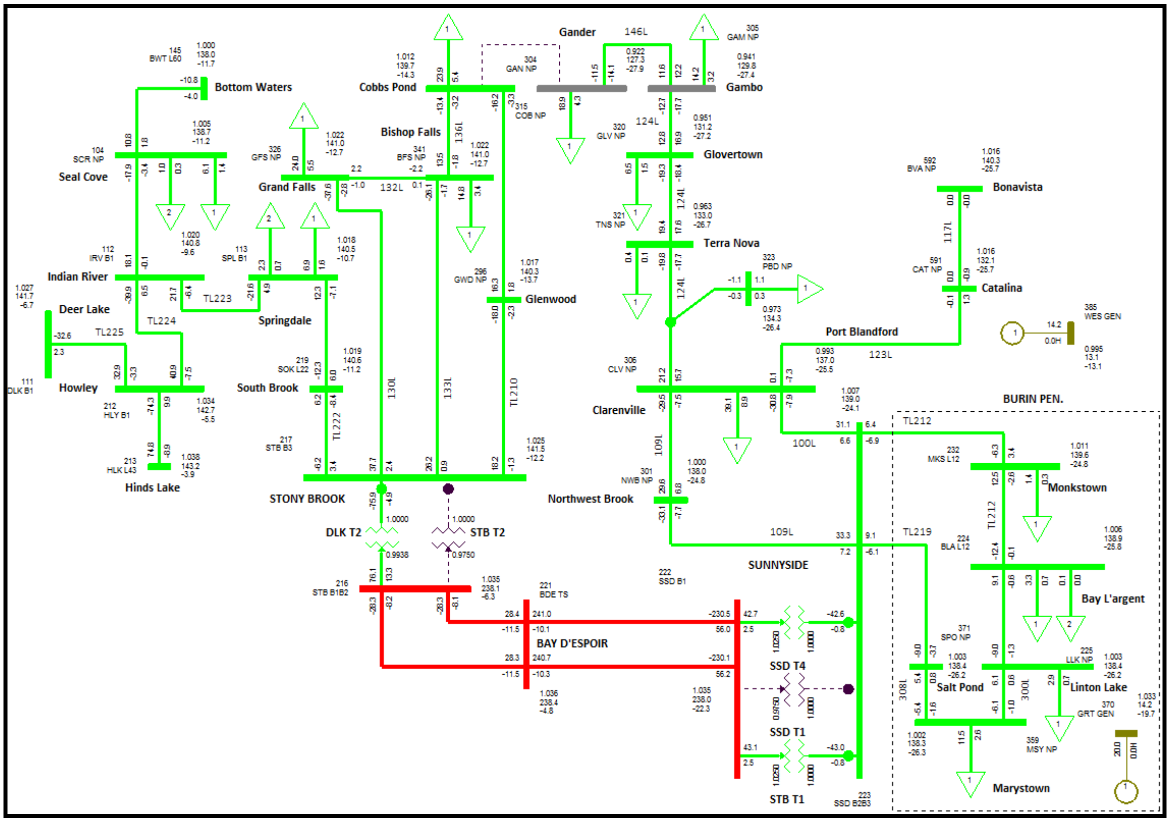

Figure 24: STB-SSD 138 kV Transmission System – STB T1 Relocated to SSD, DLK T2 Relocated to STB STB T2 Out of Service
Greenhill and Wesleyville CT Online – Transmission Line 146L Out of Service
Area Load Reduced from 312.1 MW to 215 MW (97.1 MW of Load Shed)

To relieve the overload on transformer DLK T2, 97.1 MW of load must be shed between the central and burin peninsula power systems. As shown in Figure 25, both of NP's combustion turbines were brought online for generation and 138 kV transmission 146L was opened between Gander and Cobbs Pond and the area customer load was scaled to 215 MW. In this configuration, DLK T2 is loaded to 100% of nameplate MVA rating, while parallel transformers in SSD are loaded to 34% of their respective ratings.

Temporary Transformer Install – Relocate STB 125 MVA, Deer Lake 75 MVA and WAV/HRD 41.7 MVA Autotransformers

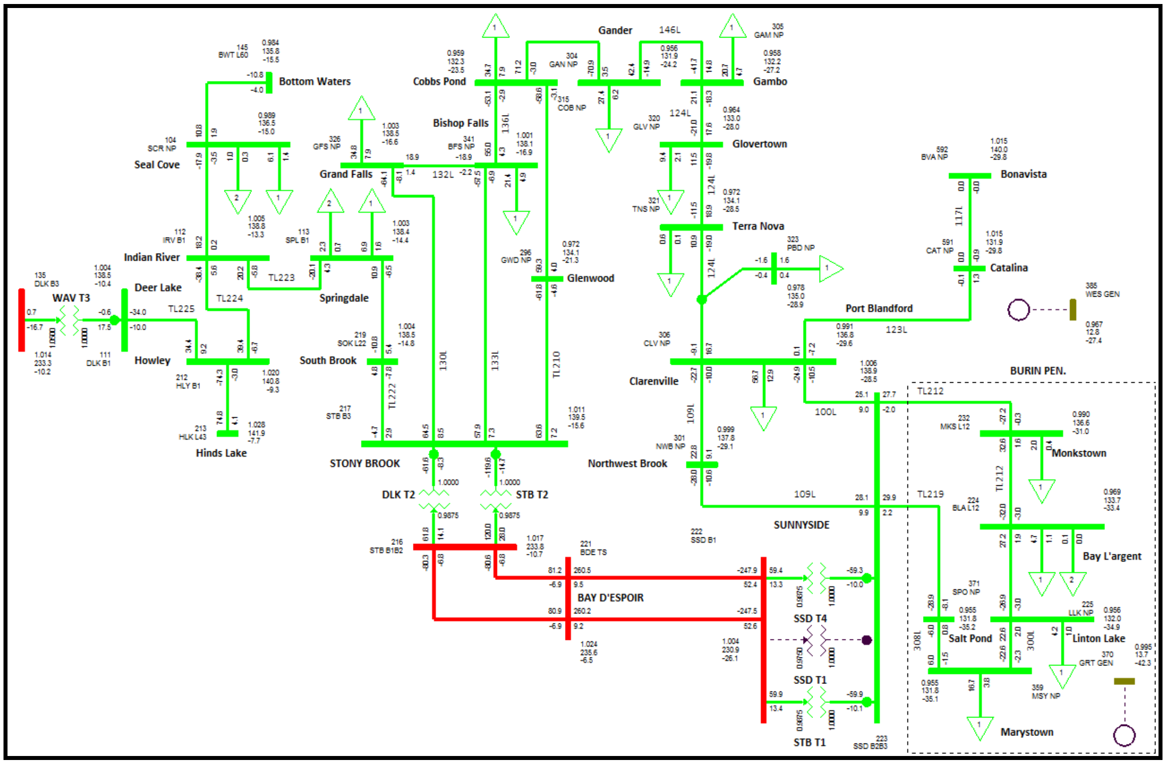

Figure 25: STB-SSD 138 kV Transmission System
STB T1 Relocated to SSD, DLK T2 Relocated to STB, WAV T3 Relocated to DLK – All Lines in Service

In addition to the STB and DLK transformer relocations, consideration was given to relocating a 41.7 MVA autotransformer from the WAV/HRD 138 kV transmission system to replace the DLK T2 autotransformer. The additional transformer relocation could provide additional benefits to the system over peak from west coast generation sources. Making reference to Figures 9 and 10, it is clear that it is preferable to remove a 41.7 MVA transformer from WAV as opposed to HRD as the later would require the opening of the looped transmission system. As a result, it has been assumed that WAV T3 has been relocated to Deer Lake to replace DLK T2.

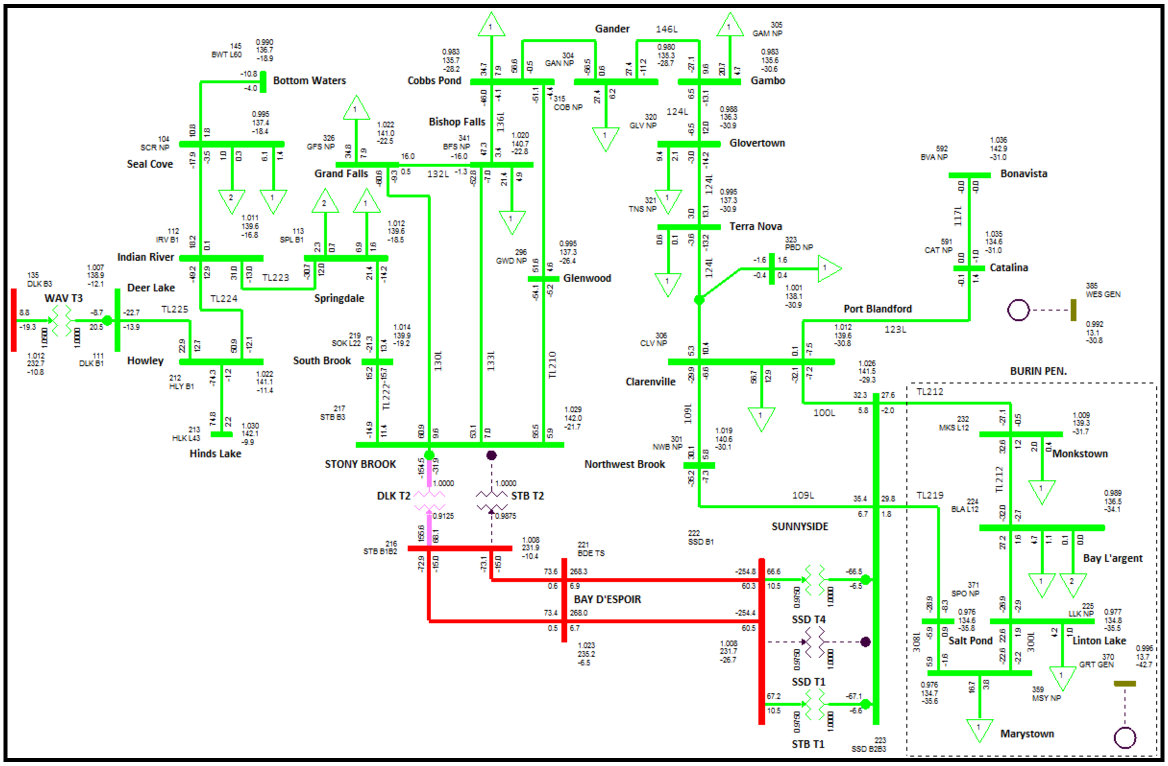

Figure 26: STB-SSD 138 kV Transmission System
STB T1 Relocated to SSD, DLK T2 Relocated to STB, WAV T3 Relocated to DLK – STB T2 Out of Service

In the event that STB T2 is forced out of service, loading on the remaining 75 MVA autotransformer at Stony Brook is loaded to 225% of its nameplate MVA rating as shown in Figure 27.

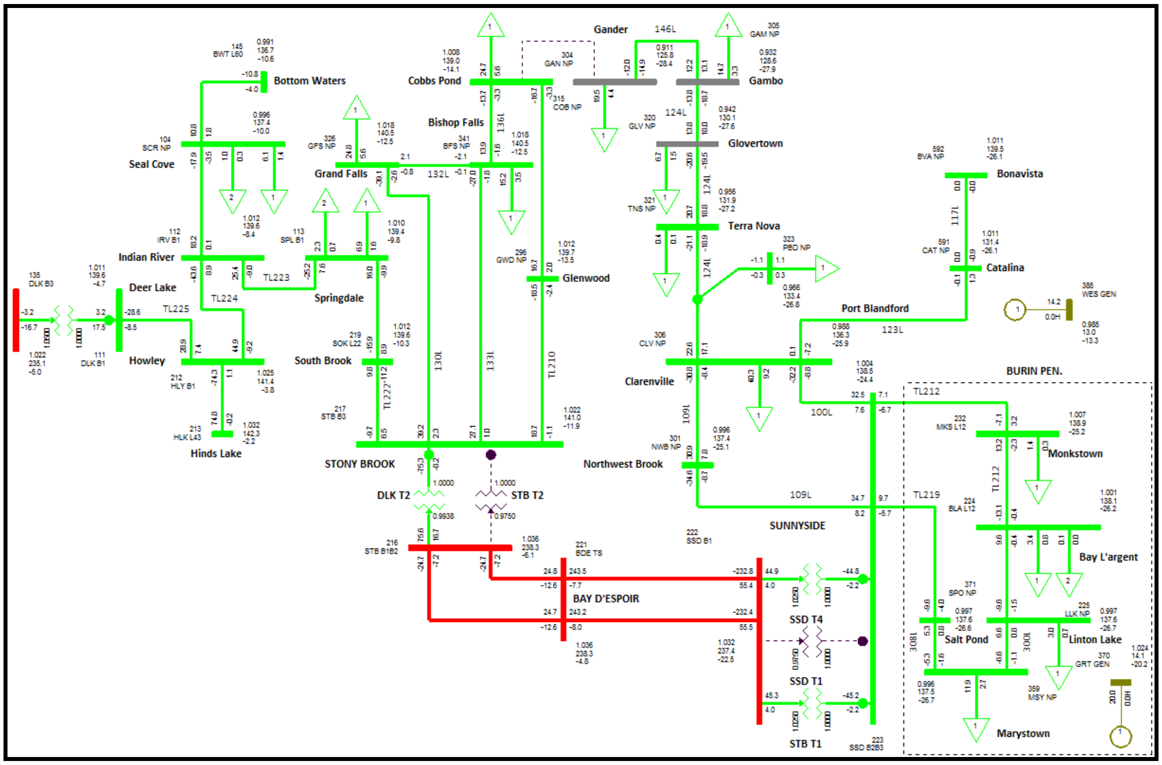

Figure 27: STB-SSD 138 kV Transmission System
STB T1 Relocated to SSD, DLK T2 Relocated to STB, WAV T3 Relocated to DLK – STB T2 Out of Service
Greenhill and Wesleyville CT Online – Transmission Line 146L Out of Service
St. Anthony and Hawk's Bay Diesel Plants Online at Rated Generation
Area Load Reduced from 312.1 MW to 222 MW (90.1 MW of Load Shed)

To relieve the overload on transformer DLK T2, 90.1 MW of load must be shed between the central and burin peninsula power systems. As shown in Figure 28, both of NP's combustion turbines were brought online for generation, Hawk's Bay and St. Anthony diesel plants are generating at capacity, 138 kV transmission line 146L was opened between Gander and Cobbs Pond and the area customer load was scaled to 222 MW. In this configuration, DLK T2 is loaded to 100% of nameplate MVA rating, while parallel transformers in SSD are loaded to 36% of their respective ratings.

UNSUPPLIED ENERGY

Hydro's approach to Business Continuity has been to assess the maximum acceptable down time for a piece of equipment against a level of unsupplied energy equaling 833 MWh.

The load flow analysis indicates that for the N-1-1 event where both STB and SSD T1 are out of service, opening of 146L between Gander and Gambo along with operation of the Wesleyville and Greenhill combustion turbines and Hawke's Bay and St. Anthony diesels is effective in reducing the overload on the remaining STB transformer to 111%. If one limits the loading in the STB – SSD 138 kV Loop such that there is no overloading of the remaining two 125 MVA transformers there are 274 hours in which load would have to be curtailed. The total unsupplied energy for the year based upon the load shape equates to 3564 MWh for the entire year.

The load flow analysis indicates that for the N-1-1 event where both SSD T1 and T4 are out of service, a total loop load of 194 MW can be supplied via the remaining two 125 MVA transformers at STB. With the STB – SSD 138 kV Loop load limited to 194 MW under this contingency there would be 1688 hours during the year during which load curtailment would be required. The total unsupplied energy for the year equates to 54237 MWh.

To reduce the risk of unsupplied energy in the STB – SSD 138 kV Loop, the load flow analysis considered the relocation of a 230/138 kV transformer from the WAV – HRD 138 kV Loop. The preferred option would be to relocate WAV T5, a 125 MVA unit leaving two 41.7 MVA transformers at WAV and two 41.7 MVA and one 125 MVA transformers at HRD. With this action the transformer capacity in the STB – SSD 138 kV Loop would be returned to normal. The total installed transformer capacity in the WAV – HRD 138 kV Loop would be reduced to 291.8 MVA and the firm capacity equal to 166.8 MVA. Recall that the NP forecast peak for the WAV – HRD 138 kV loop equals 155.1 MVA in 2018. Consequently, relocation of WAV T5 to SSD with subsequent loss of the 125 MVA unit at HRD (T8) would not result in overload of the remaining four 41.7 MVA transformers in the WAV – HRD 138 kV Loop out to the year 2018. With WAV T5 relocated to SSD and future loss of both a 125 MVA and 41.7 MVA transformer in the WAV – HRD 138 kV Loop (N-1-1) there would be 731 hours in 2018 during which load reduction would be required in the loop to avoid transformer overload. This equates to approximately 6717 MWh of unsupplied energy in the WAV – HRD 138 kV Loop for 2018 during an N-1-1 event.

CONCLUSIONS AND RECOMMENDATIONS

The transmission planning criteria for the 230/138 kV looped systems including the Stony Brook to Sunnyside system is based upon being able to supply peak load during loss of the largest transformer in the loop. This is consistent with N-1 contingency planning. The underlying premise is that following the loss of a transformer in the loop Hydro would review the loop loading relative to the remaining transformer capacity and make recommendation on an unbudgeted capital project to purchase new transformer capacity if required.

On January 4, 2014 Hydro experienced a failure of a 230/138 kV, 75/100/125 MVA transformer (T1) at its Sunnyside Terminal Station. The result has been the reduction in installed transformer capacity in the STB – SSD 138 kV Loop from 500 MVA to 375 MVA. The loop is now in an N-1 contingency state. The analysis conducted within this report is intended to assess the impact of an N-1-1 contingency in which a second transformer in the STB – SSD 138 kV Loop fails prior to the repair/replacement of the failed transformer at SSD.

The analysis has concluded that the 75/100/125 MVA, 230/138 kV autotransformer WAV T5 be relocated to SSD to minimize the loss of load hours on the STB – SSD 138 kV Loop in the event a second transformer in the STB - SSD 138 kV transmission loop is forced out of service. In this configuration the STB - SSD 138 kV Loop is returned to normal operation following the failure of SSD T1.

With respect to the WAV – HRD 138 kV Loop, relocation of WAV T5 to SSD will reduce the installed transformer capacity in the loop from 416.8 MVA to 291.8 MVA. The forecasted load for the WAV – HRD 138 kV Loop equals 155.1 MVA in 2018. With a firm transformer capacity of 166.8 MVA in the WAV – HRD 138 kV Loop following the relocation of WAV T5 to SSD, there is no expectation of unsupplied energy in the WAV – HRD Loop for an N-1 contingency (i.e. loss of HRD T8 – 125 MVA). Analysis indicates that with the relocation of WAV T5 to SSD, an N-1-1 event in the WAV – HRD 138 kV Loop will result in transformer overloading and a requirement to reduce load. In 2018 an N-1-1 event will result in 731 hours which load reduction would be required in the loop to avoid transformer overload. This equates to approximately 6717 MWh of unsupplied energy in the WAV – HRD 138 kV Loop.

It is recommended that Hydro begin the process to relocate WAV T5 to SSD to replace the failed SSD T1 transformer this summer to ensure sufficient transformer capacity in the STB – SSD 138 kV Loop for the 2014-15 winter season.

Further, it is recommended that Hydro proceed with the timely replacement of the relocated transformer capacity with the purchase and installation of a new 230/138 kV, 75/100/125 MVA autotransformer for WAV.