Undertaking U-9 Information with respect to additional system integration analysis, including

1) … if there was an assessment done or internal analysis, could that please be provided to the Board because it has not been previously when the Board asked about system integration studies.[1]

2) … if there was some type of internal memo or any written piece of paper that talked about how they had looked at the two previous studies and they were good enough, that's all that the Board would like to place on the record to ensure the record is complete for DG2. When Mr. Humphries made the statement, I took it that based on his knowledge and his experience, it gave him a level of comfort, but there hadn't been a specific piece of analysis done that would support that decision.[2]

3) … if there was that internal type of analysis done, the Board would request that Hydro file that as an undertaking so that we could -- MHI can assess then the level of - what had given the comfort.[3]

In the absence of a complete AC Integration Study, Manitoba Hydro International (MHI) maintained it did not have sufficient information to determine whether Nalcor's DG2 assumptions regarding AC Integration were valid.

This undertaking response describes other information considered by Nalcor in support of its DG2 decision with respect to the integration of the Labrador Island Transmission Link.

Attachment 1 contains working notes completed by Nalcor prior to DG2 on the effect of the change from Gull Island to Muskrat Falls. The documents include: Nalcor's working notes on the power factor requirements for Muskrat Falls, additional load flow results, and a document investigating construction power requirements.

Attachment 2 contains an internal analysis completed by Nalcor in 2008 on the effect of the current design on AC Integration with the Island system.

Nalcor took comfort in the results of the entire body of work completed prior to DG2, including the above. With the knowledge that these results and assumptions would be further tested and studied as part of its Phase III engineering, Nalcor concluded the results of the body of system integration work were acceptable and passed through DG2.

[1] Transcript, February 16, 2012, page 50
[2] Transcript, February 16, 2012, page 51
[3] Transcript, February 16, 2012, page 52

ATTACHMENT 1

Peter Thomas – Working Notes on Requirement for 0.90 power factor machines at Muskrat Falls - Summer 2010

Info taken from a number of preliminary studies and draft reports

MUSKRAT FALLS GENERATOR DATA

Table 1 provides the generator data for the Muskrat Falls machines. This data is the same as that used by Hydro-Québec TransÉnergie (HQT) and the New Brunswick System Operator (NBSO) in the completion of their respective System Impact Studies.

Table 1 Muskrat Falls Generator Parameters	
Plant capacity, MW	824
Number of units	4
Turbine rated capacity, MW	206
Generator rated MVA at 15^{0}C	217
Power Factor	0.95
Unsaturated reactances on machine base	
Direct axis synchronous reactance X_d, pu	1.027
Quadrature axis synchronous reactance X_q, pu	0.559
Direct axis transient reactance X'_d, pu	0.34
Direct axis subtransient reactance X''_d, pu	0.254
Leakage reactance X_l, pu	0.15
Time Constants	
Direct axis transient open circuit time constant T'_{do}, sec	7.41
Direct axis subtransient open circuit time constant T''_{do}, sec	0.07
Quadrature axis subtransient open circuit time constant T''_{qo}, sec	0.07
Saturation coefficient $S_{1.0}$	0.086
Saturation coefficient $S_{1.2}$	0.293
Inertia constant H, MW*sec/MVA	4.1

The generator capability curve has been estimated based upon the above data. In estimating the overexcited region the stator current limit is assumed from the rated MVA down to the 0.95 power factor line (rated operating point). For real power loadings below the rated operating point, the MVAR limit is based upon the field current limit being equal to the field current at the 0.95 power factor operating point. The underexcited region is based upon the stator current limit and a 10% margin on the V_T/X_d point along the MVAR axis.

Figure 1 provides the estimated capability curve for the Muskrat Falls generators.

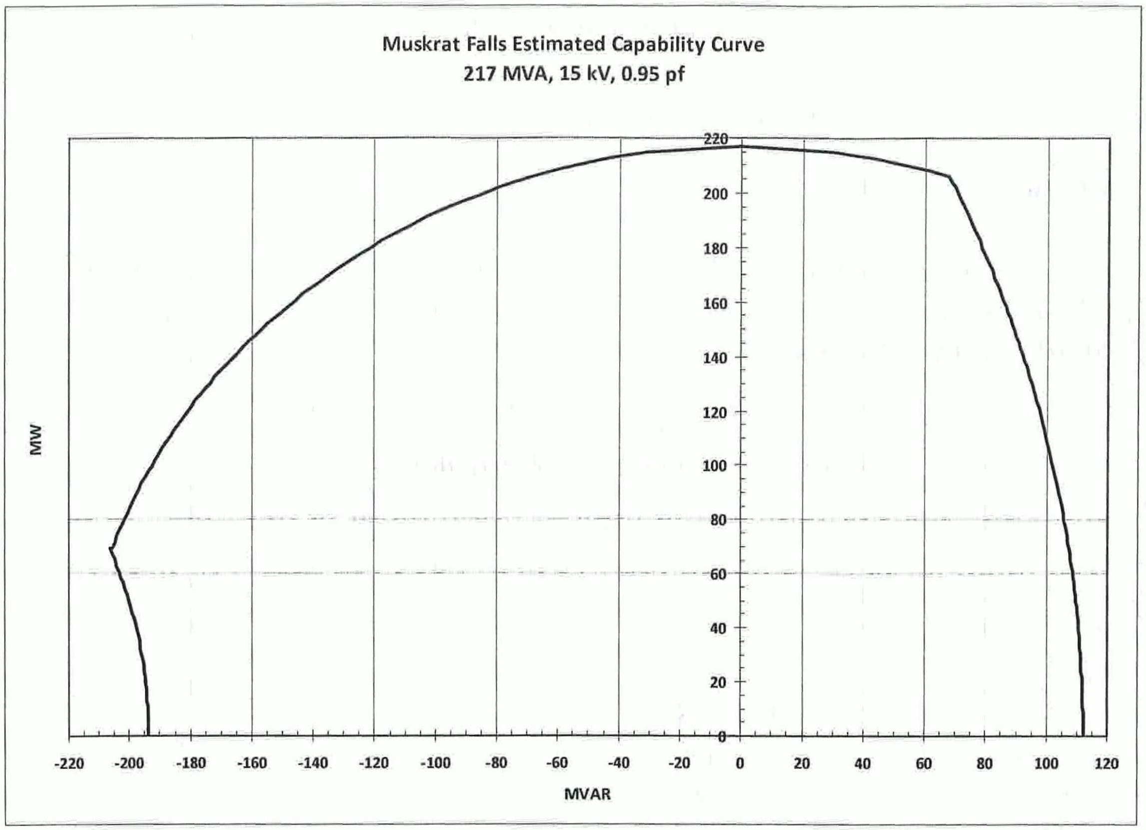


Figure 1 – Estimated Capability Curve – Muskrat Falls

TRANSFORMER DATA

The four Muskrat Falls unit transformers are rated 15/345 kV, 217 MVA with Z = 12%. The units are equipped with a de-energized tap changer on the high voltage winding with a range of +/- 5% in 2.5% steps. The winding configuration is L.V. DELTA/H.V. WYE GROUNDED.

345/735 kV autotransformers will consist of three single phase units rated 333/444 MVA, 345 kV/(735 kV/√3) per phase with Z = 11%. The units are equipped with a de-energized tap changer on the high voltage winding with a range of +/- 5% in 2.5% steps. The winding configuration is autotransformer with 13.8 kV DELTA tertiary.

With the construction of the Muskrat Falls facility, the 138 kV transmission line L1301 to Happy Valley will be terminated at Muskrat Falls. To facilitate the Labrador east supply, two 345/138 kV, 75/100/125 MVA autotransformers with Z = 11% will be installed at Muskrat Falls. Each transformer will be equipped with an on load tap changer (OLTC) having a range of +5/-15% in 1.25% steps. The transformers will be equipped with a DELTA tertiary winding.

HVdc TRANSMISSION SYSTEM

A 900 MW bipole HVdc transmission system is proposed between Muskrat Falls and Soldier's Pond. The 900 MW HVdc system is rated as follows:

- ± 320 kV;
- pole current of 1406 A;
- 816.4 MW receiving end power in bipole mode; and
- 394.3 MW receiving end power in monopole mode.

Both line commutated converter and voltage source converter technologies are being considered for this HVdc system.

Line Commutated Converter

The line commutated converter (LCC) technology requires ac harmonic filters. To ensure acceptable levels of filtering, ac filters are sized to approximately 25% of the converter rating. For the Muskrat Falls converter:

$$MVAR_{FILTER} = 0.25 * 900 \text{ MW} = 225 \text{ MVAR}$$

Further the total reactive power requirement of an LCC is approximately 55% of the converter rating. For the Muskrat Falls converter:

$$MVAR_{CONVERTER} = 0.55 * 900 = 495 \text{ MVAR}$$

Given that the ac filters will provide some of the reactive power for the LCC, the total reactive power requirement from the system can be calculated as:

$$MVAR_{SYSTEM} = MVAR_{CONVERTER} - MVAR_{FILTER} = 495 - 225 = 270 \text{ MVAR}$$

At rated output, each of the Muskrat Falls generators will have an overexcited capability of 68.2 MVAR or 272.8 MVAR for the entire plant at the terminals of the machines. To determine the reactive power capability from the Muskrat Falls plant at the point of common coupling with the converter, one must consider the reactive power consumption through the generator step up transformers. The reactive power consumption in each of the unit step up transformers is estimated as follows assuming zero resistance in the transformer winding:

$$Z_{TRF} = 0.12 * (345^2/217) = 65.82 \ \Omega$$

$$I_{TRF} = 217000 / (\sqrt{3})(345) = 363.1 \text{ A}$$

$$Q_{TRF} = 3\ I_{TRF}^2\ Z_{TRF} = (3)(363.1)^2(65.82)(10^{-6}) = 26.03 \text{ MVAR}$$

With each generator step up transformer consuming approximately 26 MVAR, the available reactive power from the plant for the LCC is calculated as:

$$Q_{AVAILABLE} = 4\ (68.2 - 26) = 168.8\ \text{MVAR}$$

Given a requirement for 270 MVAR from the ac system and only 168.8 MVAR available from the Muskrat Falls plant at full load, there is a 101 MVAR shortfall in reactive power capability. This shortfall increases to 143 MVAR if one unit at Muskrat Falls is out of service.

Several options are available to eliminate the reactive power shortfall. First one could consider the possibility of adding shunt capacitors. The addition of shunt capacitors will have to be investigated to determine if they will cause severe over voltages during certain equipment contingencies. Further, the addition of shunt capacitors will require an increase in the three phase short circuit contribution from the system to maintain the minimum equivalent short circuit ratio of 2.5 for proper commutation of the LCC.

A second option to reduce the reactive power short fall is to add synchronous condenser capability at the converter station. Two 150 MVAR synchronous condensers would be required to cover the reactive power short fall while considering planned maintenance of a synchronous condenser. The addition of synchronous condensers comes at a capital cost with long term additional maintenance costs. One benefit of the synchronous condensers is the improvement in the short circuit level and overall commutation performance of the LCC.

A third option to reduce the reactive power short fall is to reduce the power factor of the Muskrat Falls generators from 0.95 to 0.90. In going with 0.90 pf machines the unit rating increases to 228.9 MVA. At 206 MW the rated reactive power of each unit increases to 99.8 MVAR. Increasing the generator step up transformer to 228.9 MVA results in a transformer impedance of:

$$Z_{TRF} = 0.12 * (345^2/228.9) = 62.4\ \Omega$$

The rated current becomes:

$$I_{TRF} = 228900 / (\sqrt{3})(345) = 383\ \text{A}$$

And the reactive power consumed by the transformer is estimated at:

$$Q_{TRF} = 3\ I_{TRF}^2\ Z_{TRF} = (3)(383)^2(62.4)(10^{-6}) = 27.4\ \text{MVAR}$$

With each generator step up transformer consuming approximately 27.4 MVAR, the available reactive power from the plant for the LCC is calculated as:

$$Q_{AVAILABLE} = 4\ (99.8 - 27.4) = 289.6\ \text{MVAR}$$

With the full 0.90 pf plant in operation the reactive power available for the LCC exceeds the required 270 MVAR. With only three units on line at Muskrat Falls there is a 52.8 MVAR short fall in reactive power from the plant.

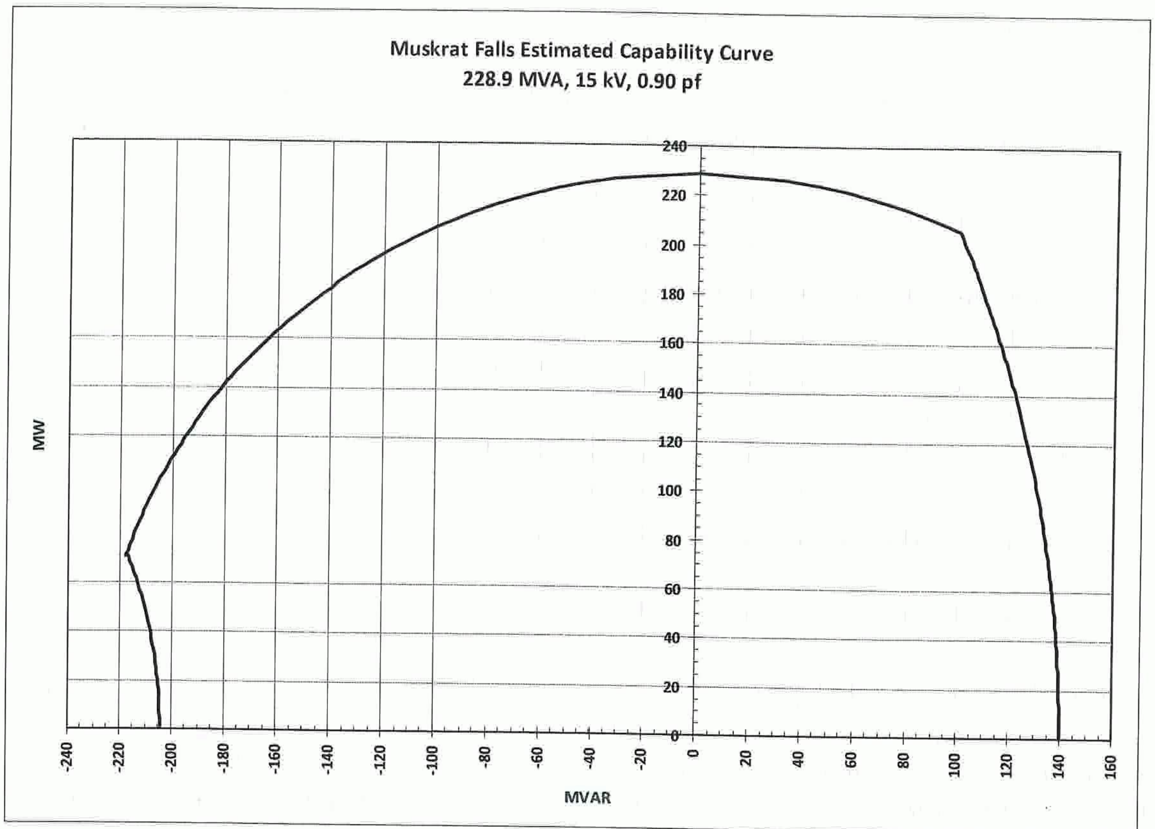


Figure 2 – Estimated Capability Curve – 206 MW, 0.90 pf Generator

Equivalent Short Circuit Ratio

For proper commutation of the LCC an equivalent short circuit ratio of 2.5 is desired. In essence:

$MVA_{SYSTEM} \geq (2.5 * PDC) + MVA_{FILTERS}$

where PDC equals the rated power of the converter

Then for the Muskrat Falls converter:

$MVA_{SYSTEM} \geq (2.5 * 900) + 225$

$MVA_{SYSTEM} \geq 2475$ MVA

In other words, to ensure proper commutation of the line commutated converter, the three phase short circuit level contribution from the ac system should be greater than 2475 MVA. This required short circuit level has an impact on the Muskrat Falls plant capability to supply the HVdc transmission system while electrically isolated from the Churchill Falls plant. To assess the impact the on an isolated mode of operation the short circuit contribution from the Muskrat Falls plant is calculated as follows:

Recall each unit is rated 206 MW @ 0.95 pf = 217 MVA and X''_d = 0.254 p.u. and the generator step up transformer is rated 217 MVA and Z = 12%.

On a 100 MVA base:

$X_{GEN} = (0.254 * 100)/217 = 0.11705$ p.u.
$X_{TRF} = (0.12 * 100)/217 = 0.0553$ p.u.
$X_{EQUIV} = X_{GEN} + X_{TRF} = 0.11705 + 0.0553 = 0.17235$ p.u.

At the point of common coupling each Muskrat Falls generation contributes:

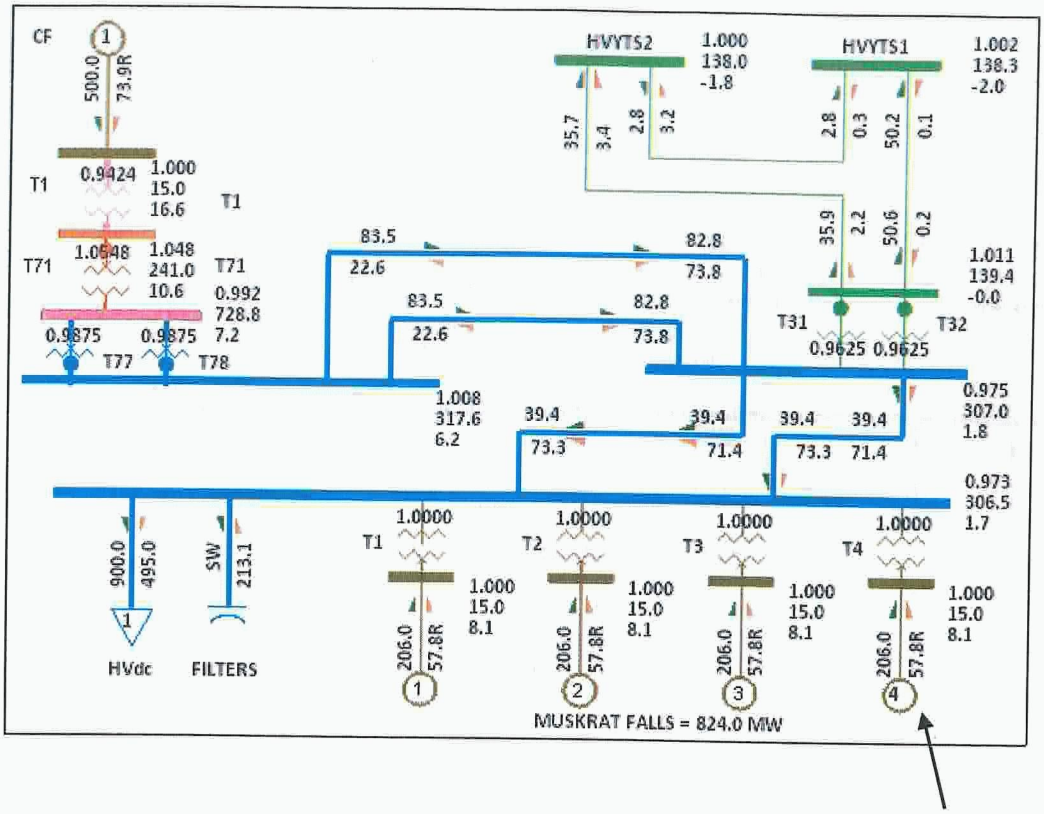
$100/ X_{EQUIV} = 100/0.17235 = 580$ MVA

Then the total plant contribution equals:

4 x 580 MVA = 2320 MVA

Given a total plant short circuit contribution of 2320 MVA, the Muskrat Falls plant alone is not capable of meeting the 2.5 equivalent short circuit ratio for the 900 MW rating. The calculated equivalent short circuit ratio for the case is 2.32. Additional short circuit contribution from the Churchill Falls plant may be warranted in this case. Note that reducing the HVdc power rating to 824 MW in an isolated mode of operation with a desired equivalent short circuit ratio of 2.5 requires a short circuit contribution of 2285 MVA from the Muskrat Falls plant. As well, changing the power factor of the Muskrat Falls plant from 0.95 to 0.90 is expected to increase the plant's short circuit contribution to 2448 MVA. This would yield an equivalent short circuit ratio of 2.47 for a 900 MW LCC rating.

Load Flow Plots for 0.90 power factor at Muskrat Falls



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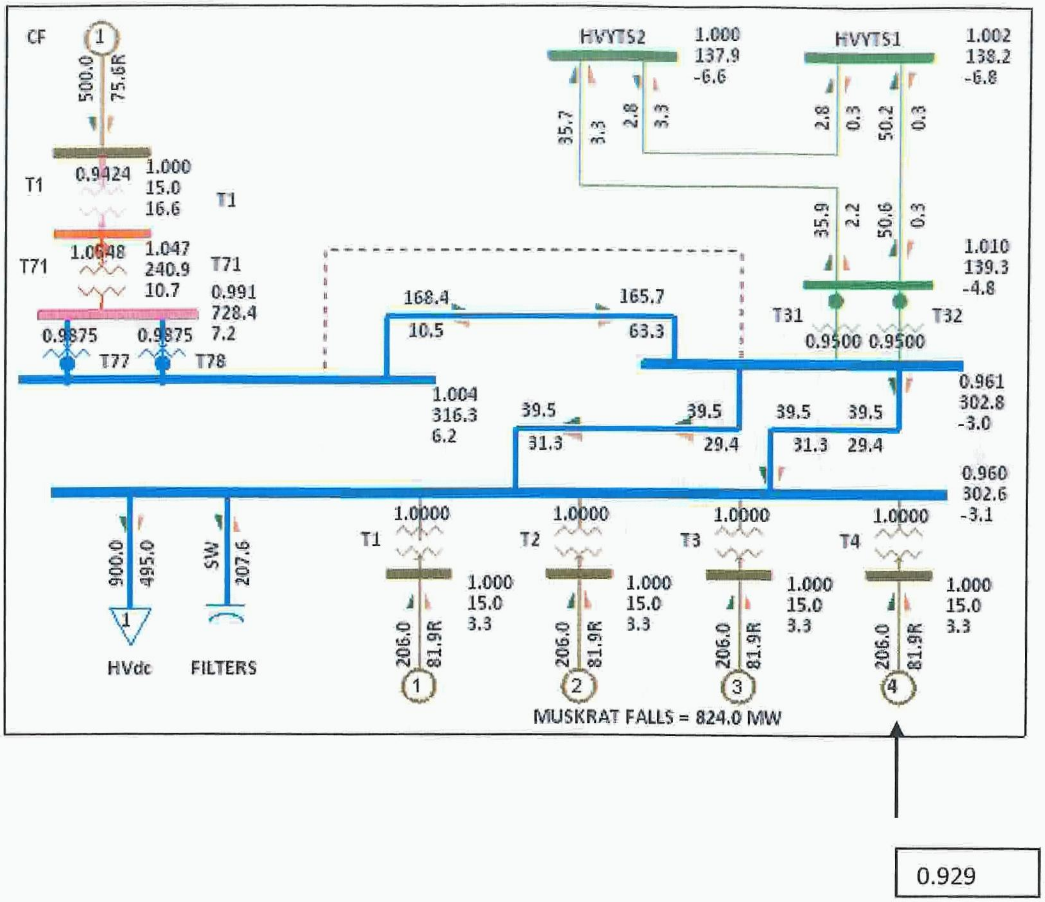
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15.0
16.6
T1
T71
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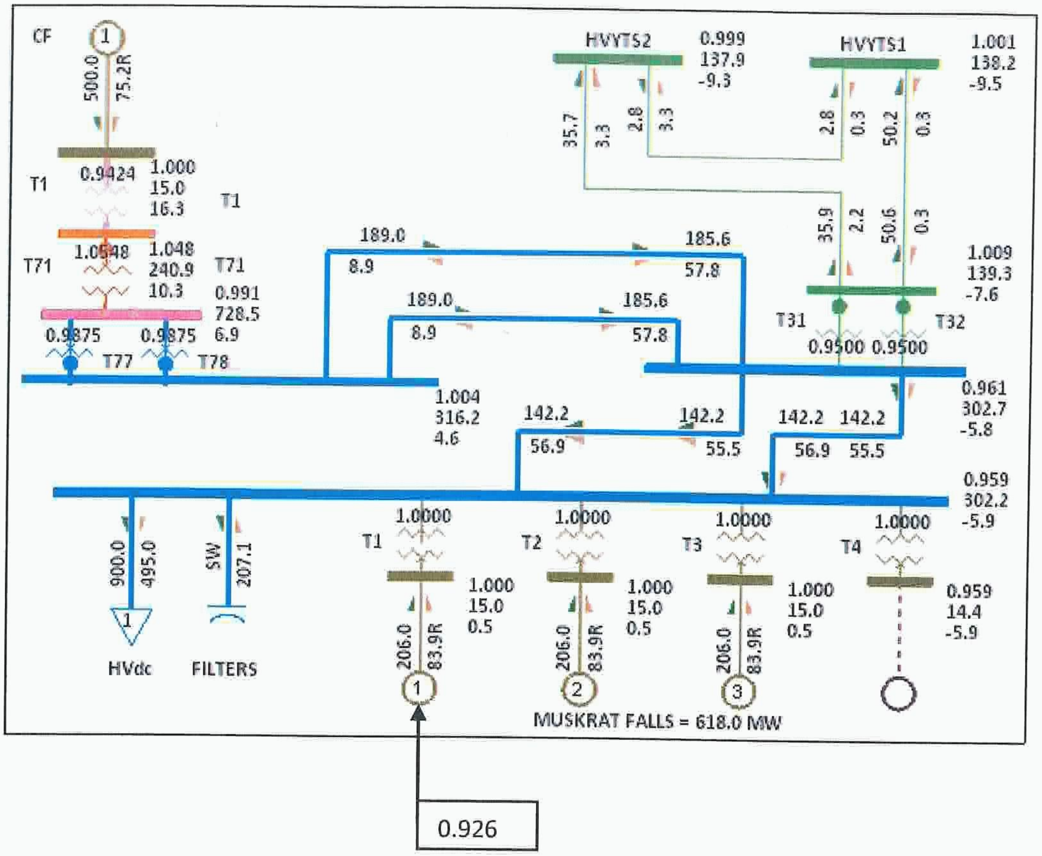
240.9
10.7
T71
0.991
728.4
7.2
0.9875
0.9875
T77
T78
HVYTS2
1.000
137.9
-6.6
HVYTS1
1.002
138.2
-6.8
35.7
3.3
2.8
3.3
2.8
0.3
50.2
0.3
35.9
2.2
50.6
0.3
1.010
139.3
-4.8
T31
T32
0.9500
0.9500
168.4
10.5
165.7
63.3
1.004
316.3
6.2
0.961
302.8
-3.0
39.5
31.3
39.5
29.4
39.5
31.3
39.5
29.4
0.960
302.6
-3.1
900.0
495.0
SW
207.6
HVdc
FILTERS
1.0000
T1
T2
T3
T4
1.000
15.0
3.3
206.0
81.9R
MUSKRAT FALLS = 824.0 MW
0.929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15.0
16.3
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T71
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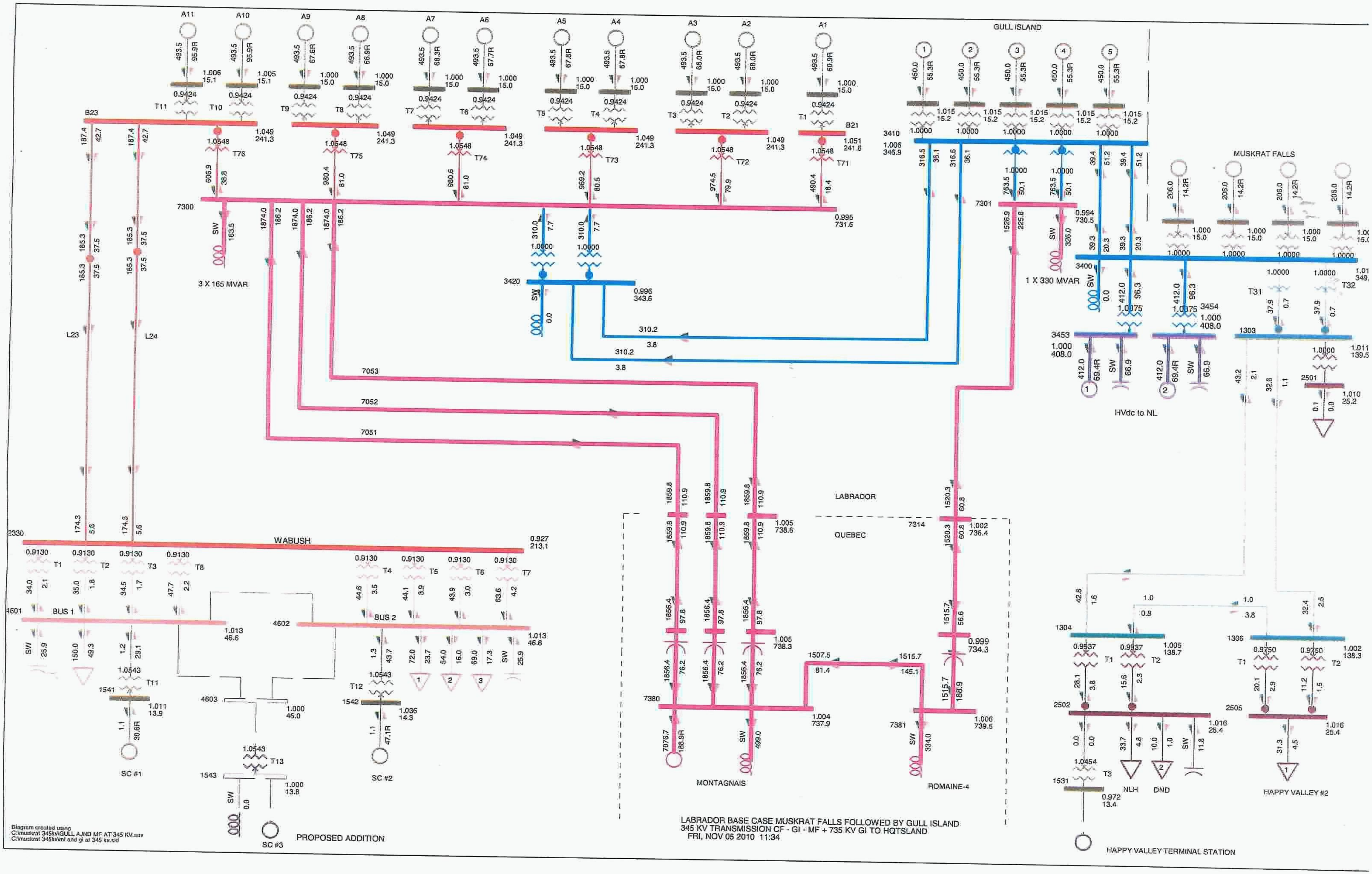
240.9
10.3
T71
0.991
728.5
6.9
0.9875
0.9875
T77
T78
1.004
316.2
4.6
HVYTS2
0.999
137.9
-9.3
HVYTS1
1.001
138.2
-9.5
35.7
3.3
2.8
3.3
2.8
0.3
50.2
0.3
35.9
2.2
50.6
0.3
1.009
139.3
-7.6
T31
T32
0.9500
0.9500
189.0
8.9
185.6
57.8
189.0
8.9
185.6
57.8
0.961
302.7
-5.8
142.2
56.9
142.2
55.5
142.2
142.2
56.9
55.5
0.959
302.2
-5.9
900.0
495.0
SW
207.1
1.0000
1.0000
1.0000
1.0000
T1
T2
T3
T4
1.000
15.0
0.5
1.000
15.0
0.5
1.000
15.0
0.5
0.959
14.4
-5.9
206.0
83.9R
206.0
83.9R
206.0
83.9R
HVdc
FILTERS
MUSKRAT FALLS = 618.0 MW
0.926


GULL ISLAND
MUSKRAT FALLS
WABUSH
LABRADOR
QUEBEC
MONTAGNAIS
ROMAINE-4
HVdc to NL
3 X 165 MVAR
1 X 330 MVAR
BUS 1
BUS 2
SC #1
SC #2
SC #3
PROPOSED ADDITION
NLH
DND
HAPPY VALLEY #2
HAPPY VALLEY TERMINAL STATION
L23
L24
7051
7052
7053
LABRADOR BASE CASE MUSKRAT FALLS FOLLOWED BY GULL ISLAND
345 KV TRANSMISSION CF - GI - MF + 735 KV GI TO HQTSLAND
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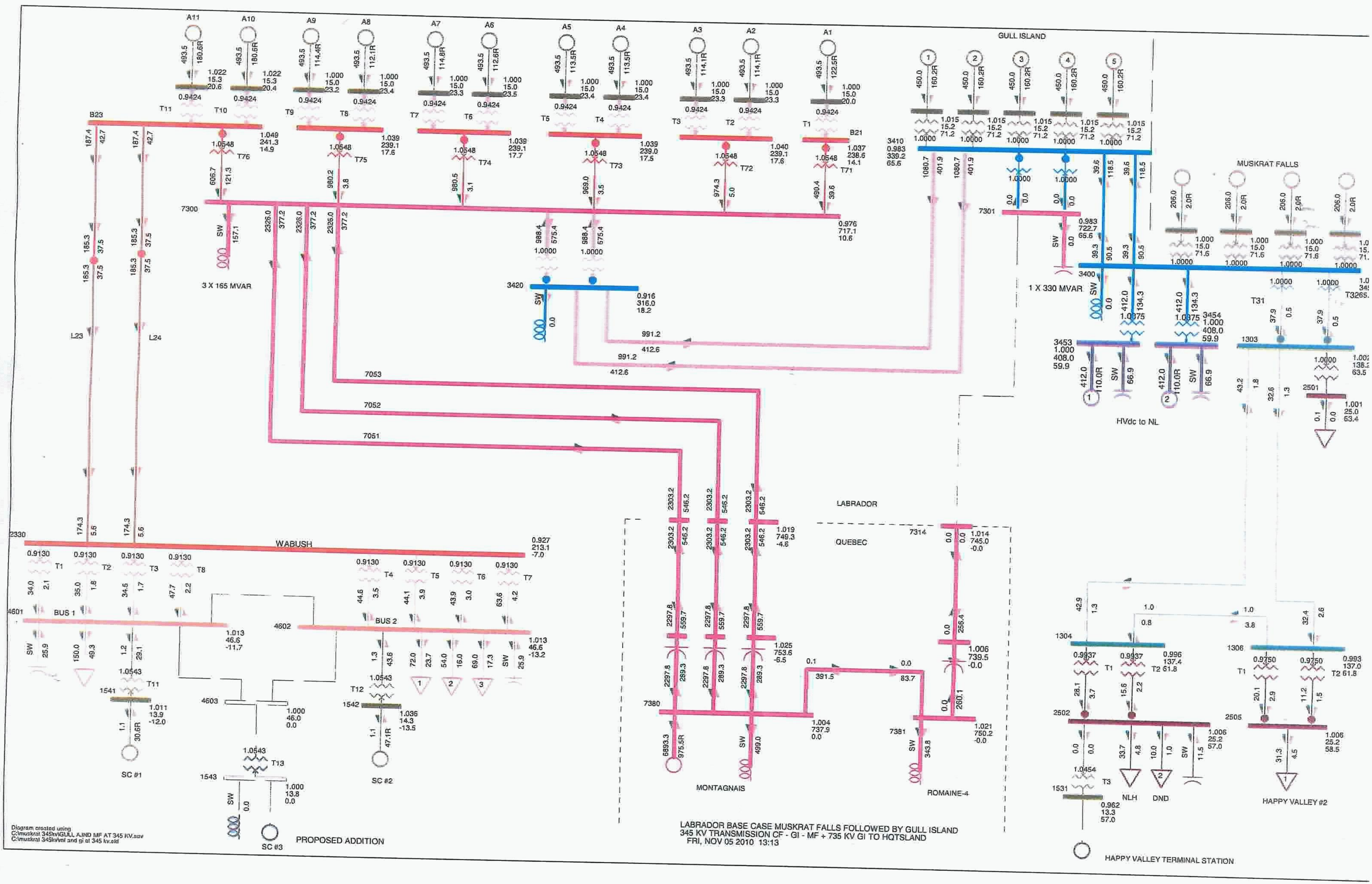

GULL ISLAND
MUSKRAT FALLS
WABUSH
BUS 1
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3 X 165 MVAR
1 X 330 MVAR
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PROPOSED ADDITION
NLH
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HAPPY VALLEY TERMINAL STATION
L23
L24
7051
7052
7053
Diagram created using
C:\muskrat 345kv\GULL AND MF AT 345 KV.sav
C:\muskrat 345kv\mf and gi at 345 kv.sld
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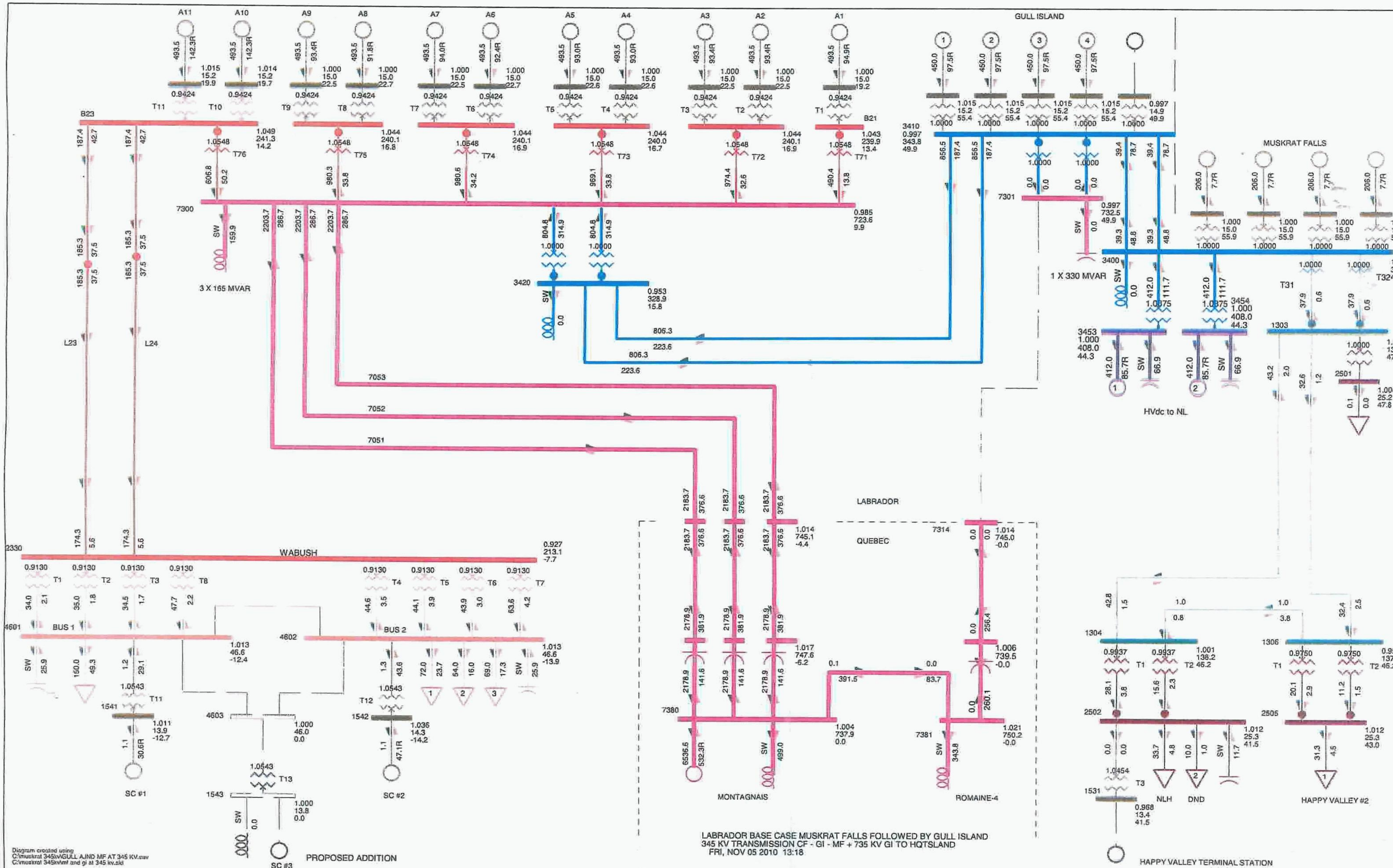

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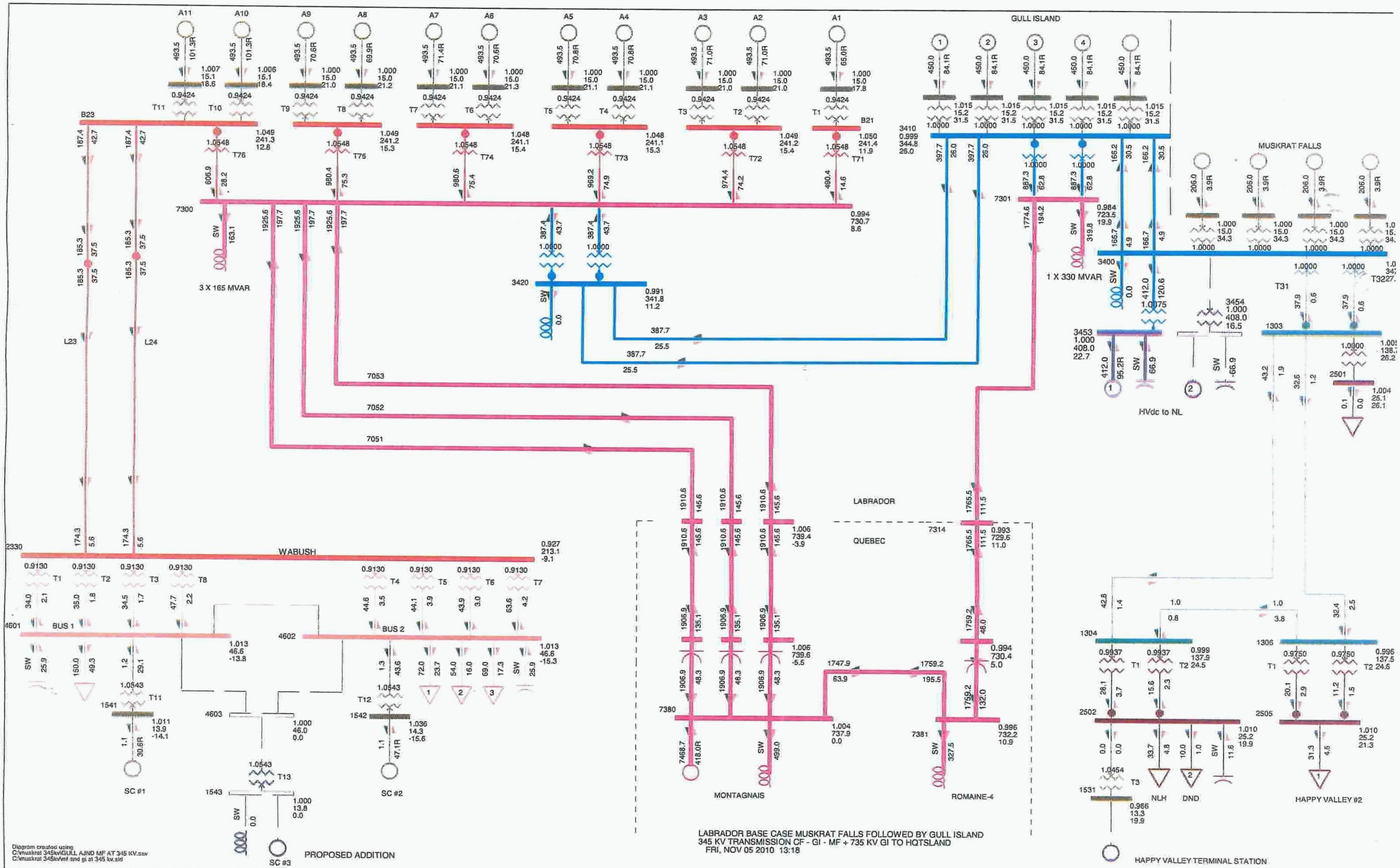
GULL ISLAND
MUSKRAT FALLS
WABUSH
LABRADOR
QUEBEC
MONTAGNAIS
ROMAINE-4
HVdc to NL
3 X 165 MVAR
1 X 330 MVAR
BUS 1
BUS 2
SC #1
SC #2
SC #3
PROPOSED ADDITION
NLH
DND
HAPPY VALLEY #2
HAPPY VALLEY TERMINAL STATION
LABRADOR BASE CASE MUSKRAT FALLS FOLLOWED BY GULL ISLAND
345 KV TRANSMISSION CF - GI - MF + 735 KV GI TO HQTSLAND
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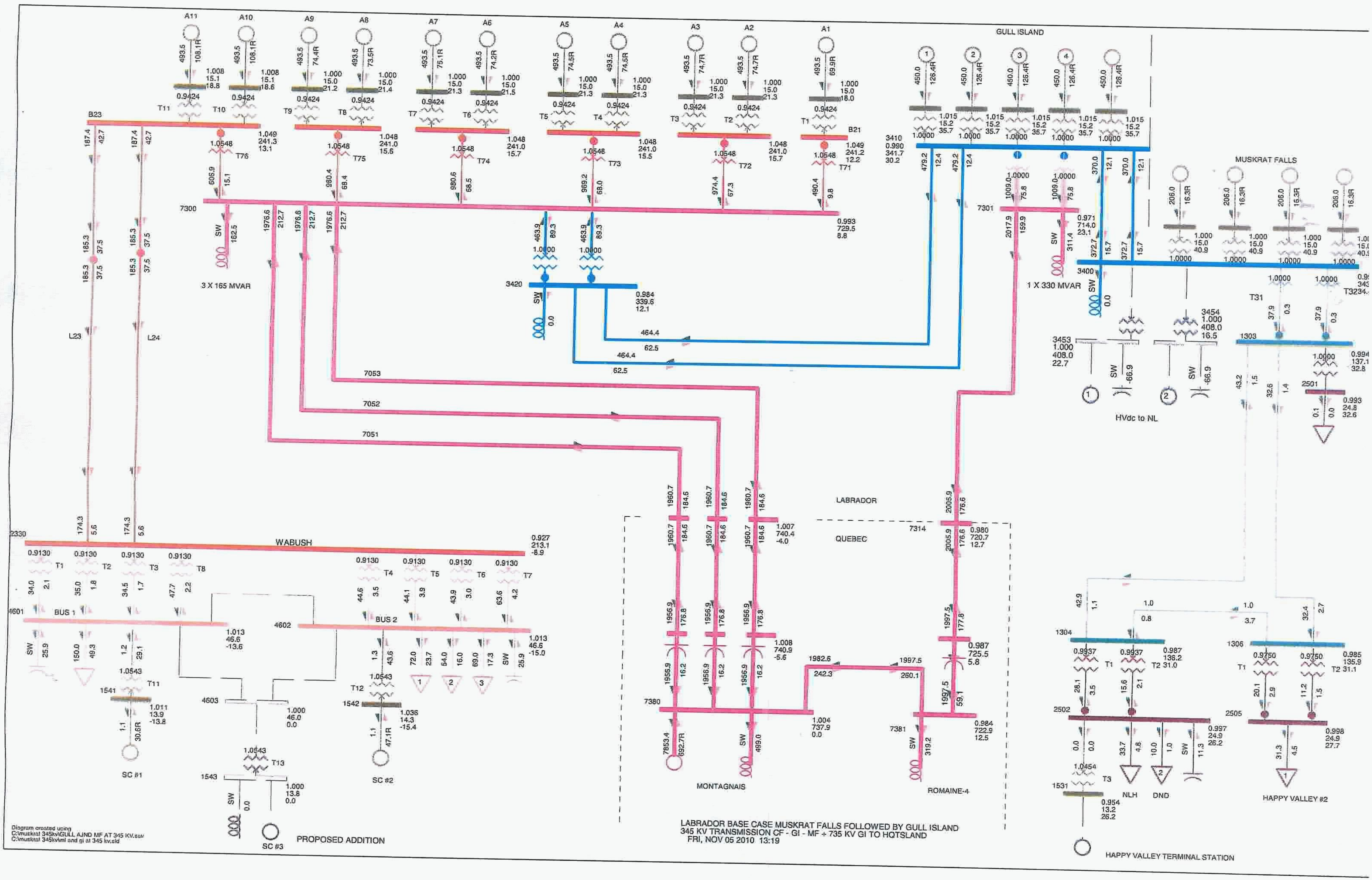
Diagram created using



GULL ISLAND
MUSKRAT FALLS
LABRADOR
QUEBEC
WABUSH
BUS 1
BUS 2
3 X 165 MVAR
1 X 330 MVAR
HVdc to NL
7053
7052
7051
L23
L24
B23
B21
7300
7301
3410
3420
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4601
4602
4603
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7381
1303
1304
1306
2501
2502
2505
1531
3453
3454
SC #1
SC #2
SC #3
PROPOSED ADDITION
MONTAGNAIS
ROMAINE-4
NLH
DND
HAPPY VALLEY #2
HAPPY VALLEY TERMINAL STATION
LABRADOR BASE CASE MUSKRAT FALLS FOLLOWED BY GULL ISLAND
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Diagram created using
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C:\muskrat 345kv\mf and gi at 345 kv.sld

REGISTERED PROFESSIONAL ENGINEER
THOMAS
SIGNATURE
Nov 9/10
PROVINCE OF NEWFOUNDLAND

Approved for Release	Nov 10/2010 Date

TRANSMISSION SYSTEM ANALYSIS

MUSKRAT FALLS FIRST CONSTRUCTION POWER
2010 UPDATE

Date: October 12, 2010

System Planning Department

newfoundland labrador hydro
a nalcor energy company

TABLE OF CONTENTS

INTRODUCTION

One possible configuration for the Lower Churchill Project (LCP) involves the development of Muskrat Falls prior to the development of Gull Island. The development of Muskrat Falls first includes the construction of two 345 kV transmission lines between Muskrat Falls and Churchill Falls, a distance of 260 km, and an HVdc transmission system between Muskrat Falls in Labrador and Soldiers Pond on the Island of Newfoundland. It is proposed to build the 345 kV transmission lines along the existing 138 kV transmission line right of way. To minimize the right of way width, one 345 kV transmission line will be built adjacent to the existing 138 kV transmission line, with the second 345 kV transmission line built in the existing 138 kV transmission line location once the 138 kV line has been removed from service. Upon completion the 138 kV transmission system supplying Happy Valley – Goose Bay would be terminated at a new 345/138 kV Muskrat Falls Terminal Station.

The LCP has advised that the 138/25 kV construction power station at Muskrat Falls will be located on the south side of the Churchill River. As a result, construction of approximately 5 km of 138 kV transmission line and 138 kV tap station will be required to connect the construction power station to the existing 138 kV transmission line near the existing Muskrat Falls 138/25 kV, 2MVA transformer station.

The purpose of this transmission system analysis is to investigate the impact of connecting 6 MVA of construction power load at Muskrat Falls to the Labrador East Transmission System and to identify transmission system limitations, constraints and required additions to mitigate limitations and constraint. The analysis is completed using the Siemens Power Technologies Int. software package PSS/E version 30.2.

This report is an update the System Planning Department report entitled "Transmission System Analysis Lower Churchill Project Construction Power Muskrat Falls Only Option" issued December 21, 2009.

THE EXISTING LABARDOR EAST TRANSMISSION SYSTEM

The Labrador East Transmission System is connected to the Churchill Falls 230 kV bus B21, which is supplied by generator A1 and 230/735 kV autotransformer T71 under normal operation. The transmission system consists of two 230/138 kV, 25/33/42 MVA autotransformers at Churchill Falls (T31 and T32), a 296 km long, 138 kV transmission line between Churchill Falls and Happy Valley – Goose Bay and a 138/25 kV terminal station at Happy Valley – Goose Bay. The 138/25 kV Happy Valley Terminal Station contains two 138/25 kV power transformers, (T1 is rated 25/30/50 MVA and T2 is rated 15/20/25//28 MVA), a 27 MW combustion turbine operated as a synchronous condenser under normal operation and a 11.4 MVAR, 25 kV four stage switched capacitor bank. There is a 2 MVA, 138/25 kV station at Muskrat Falls supplying a water pumping system. The single line diagram is shown in Figure 1.

Given the 138 kV transmission line length and subsequent level of charging, the de-energized tap changers on the 230/138 kV autotransformers at Churchill Falls have been placed in full buck (i.e. tap position 1 – 241.5 kV) in order to avoid excessive over voltages due to the Ferranti Effect on the Happy Valley end during line energization.

The Happy Valley combustion turbine transformer T3 is a 13.2/25 kV, 30/40 MVA unit. At present the transformer is in tap position 3 (25 kV) due to an occurrence of gasing with the transformer in tap position 4. In order to avoid the potential for overexciting the transformer, the combustion turbine/synchronous generator terminal voltage is limited to 14.12 kV (1.023 p.u.). The limitations on the T3 tap position and synchronous condenser terminal voltage in turn limit the MVAR output of the machine.

The existing Labrador East Transmission System therefore has a transfer limit on the order of 63 MW due to the sending ending voltage and limitations of the existing voltage compensating equipment at Happy Valley. The angular displacement across the 138 kV transmission line equals 33.3° for a 63 MW load level.

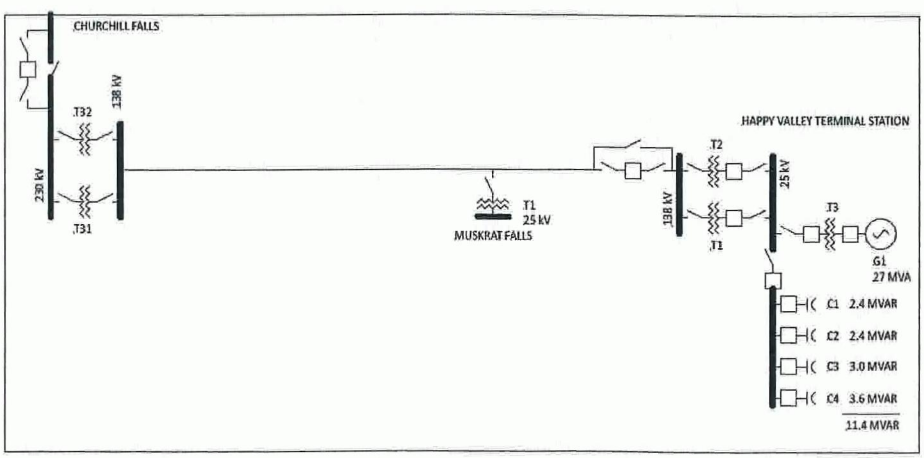

Figure 1 – Existing Labrador East Transmission System

LOAD FORECAST

Load forecast data for the Labrador East Transmission System are presented in Table 1. Happy Valley load figures are based upon the Spring 2010 Labrador Interconnected Load Forecast. Construction power loads at Muskrat Falls are based on descriptions provided in the 1999 SNC Agra Report[1] that specifies a peak power requirement of 6 MVA and a five-year construction period. Discussions with the Lower Churchill Project Controls Group indicate that under the proposed scheme, construction at Muskrat Falls would begin in 2013. It is assumed that the construction loads have a power factor of 0.95.

Table 1
Labrador East Transmission System Load Forecast

Year	Happy Valley Load		Muskrat Falls Load	
	MW	MVAR	MW	MVAR
2010	61.5	6.2	0.0	0.0
2011	62.2	6.2	0.0	0.0
2012	62.7	6.3	0.0	0.0
2013	63.3	6.4	3.5	1.2
2014	63.8	6.4	3.7	1.3
2015	64.4	6.5	5.8	1.9
2016	65.0	6.5	4.7	1.5
2017	65.5	6.6	3.2	1.1
2018	66.1	6.6	0.9	0.3

Hourly data from the Newfoundland and Labrador Hydro (NLH) Energy Management System (EMS) for Happy Valley indicate that at peak load periods, the load power factor is estimated to be 0.995.

In addition to firm energy sales, NLH provides secondary energy sales to the Canadian Department of National Defence (DND). These secondary sales are used to power an electric boiler to supplement oil-fired heating at 5-Wing Goose Bay. This arrangement permits DND to load the electric boiler such that the firm load plus secondary sales does not exceed the maximum transfer capability of the system, specified at 63 MW.

[1] Muskrat Falls Hydroelectric Development Final Feasibility Study – Volume 1 – Engineering Report, SNC-AGRA, January, 1999.

LOAD PROFILE

Hourly data from the NLH EMS was used to generate a load profile at the Happy Valley Terminal Station (HVY), as illustrated in Figure 2. Data from this graph is used to identify the timing and duration of periods when system loads would require the operation of the Happy Valley Combustion Turbine for system support.

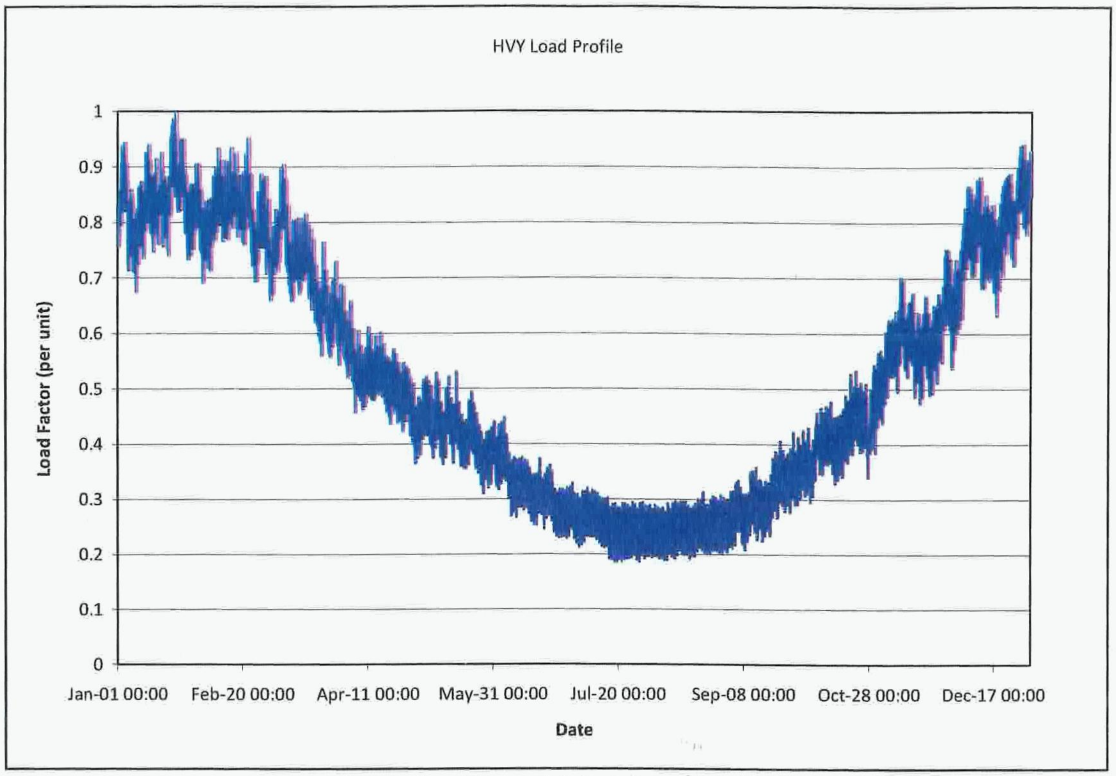

Figure 2 – Happy Valley Load Profile

BASE ASSUMPTIONS

The following assumptions are used for the analysis:

- The Churchill Falls 230 kV bus voltage is held at 1.04 p.u.;
- The Churchill Falls T31 and T32 transformer tap changers remain in tap position 1 (full buck) to avoid excessive over-voltages on the 138 kV transmission system during service restoration;
- The Muskrat Falls construction power station will be located on the south side of the Churchill River approximately 5 km from the existing pumping station;
- Secondary sales to DND will be restricted by the maximum transfer capability of the Labrador East Power System; and
- The Happy Valley Terminal Station peak load will have a power factor of 0.995.

TRANSMISSION PLANNING CRITERIA

Transmission planning criteria requires that the transmission bus voltages be held between 0.95 p.u. and 1.05 p.u. under normal operation and that under contingency/emergency situations the transmission bus voltages be held between 0.90 p.u. and 1.10 p.u. The criteria is modified for the Labrador East Transmission System where 138 kV transmission voltages are permitted to fall below 0.90 p.u., while voltage support at Happy Valley provides acceptable voltages on the 25 kV distribution system. Given the short term nature of the construction power requirements, the following criteria are used for this analysis:

- The Happy Valley 25 kV bus voltage will be held between 25.5 kV (1.02 p.u.) and 26.1 kV (1.044 p.u.) under normal operation;
- As per standard NLH distribution planning criteria, 25 kV buses at Muskrat Falls will be held between 0.967 and 1.054 p.u.;
- The Happy Valley synchronous condenser terminal voltage will not exceed 14.12 kV or 1.023 p.u..

LOAD FLOW ANALYSIS

Peak and light load cases are used to assess the transfer capability of the Labrador East Transmission System with the Muskrat Falls construction power requirement added.

Peak Load 2012

Although construction of the Muskrat Falls development would officially begin in 2013, the 1999 SNC-Agra Report recommends that early work activities be scheduled for 2012. The report recommends that power for these activities would be supplied using the existing transformer at the Muskrat Falls pump site. This transformer is presently rated for 2 MVA, but may be uprated to 2.66 MVA through the addition of a set of cooling fans. Due to low system voltages, it is recommended that the total site load be limited to 2 MW. Low voltages would be controlled by the existing bank of 100 A voltage regulators at the Muskrat Falls pump site. The regulators would have adequate capacity for the increased load and would provide a regulation of +/-10% with thirty-two tap positions. Two spare 200 A regulators are also available in Happy Valley in case of equipment failure.

The System Planning Department report entitled "Transmission System Analysis Lower Churchill Project Construction Power Muskrat Falls Only Option" issued December 21, 2009 recommended the installation of the 138/25 kV, 30/40/50 MVA transformer with OLTC and 9 MVAR capacitor bank before December 2012. This advancement would eliminate the need for gas turbine operation and would allow for continued secondary energy sales to DND in 2012. Given that the construction power requirement has been relocated from the north side of the lower Churchill River to the south side, power supply for early works out of the existing Muskrat Falls pumping station will not meet the load requirement. As a result, it will be necessary to construct the 5 km long, 138 kV transmission line across the river, the 138 kV tap station and the 138/25 kV, 30/40/50 MVA construction power station on the south side of the river by the fall of 2012. Figure 3 provides the load flow plot of the 2012 peak load case with 2 MW delivered to the south side construction power station.

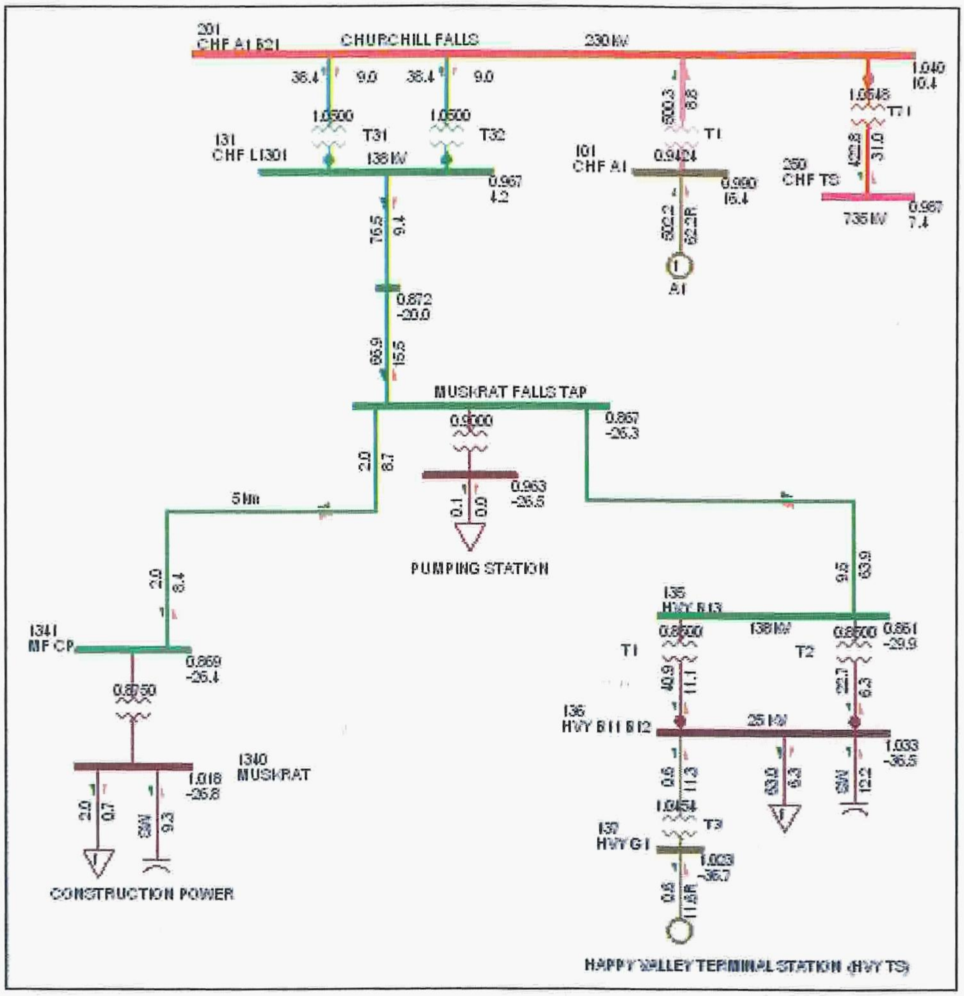

Figure 3 - Labrador East Transmission System in 2012

Peak Load 2013 - 2014

A 138/25 kV, 30/40/50MVA power transformer with OLTC and a 9 MVAR capacitor bank are required at Muskrat Falls to support construction power requirements. Recall that the 138/25 kV power transformer was sized at 30/40/50 MVA despite the forecast peak construction power load of 6 MVA in order to provide a sufficient short level on the 25 kV bus at Muskrat Falls to permit capacitor bank switching. With this equipment in place, the 138 kV transmission system will have the capacity to support the combined forecast load in Happy Valley and increasing construction power loads at Muskrat Falls until 2014. In 2014 the load flow analysis indicates a 101% overload of 230/138 kV autotransformers T31 and T32 at Churchill Falls, a 101% overload of 138/25 kV transformer T1 at Happy Valley and a Happy Valley 25 kV bus voltage of 1.018 p.u. (25.45 kV) for the peak load case. Figure 4 provides the load flow plot.

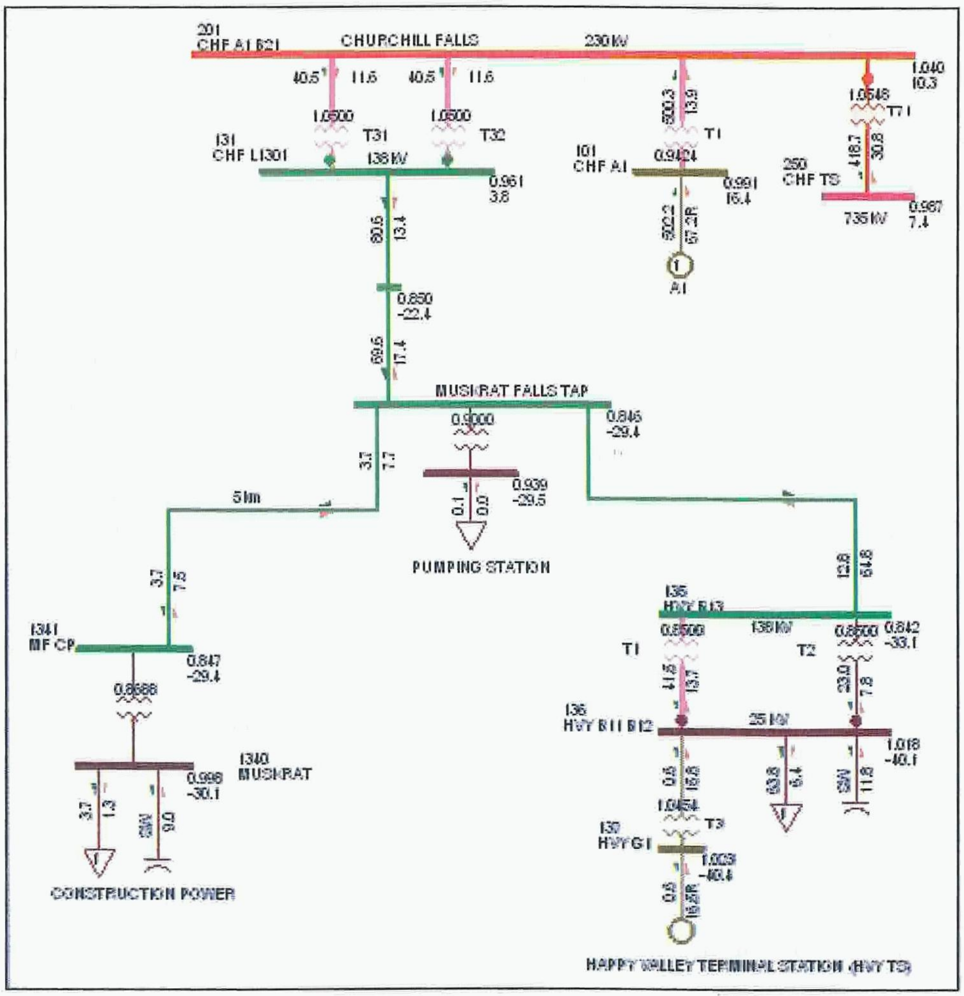

Figure 4 – 2014 Peak Load

Analysis of the 2014 peak load case indicates that when Happy Valley loads are in excess of 63.4 MW, operation of the Happy Valley Combustion Turbine would be required to prevent transformer overloads at both Happy Valley and Churchill Falls. Based on the forecasted load profile data, it is estimated that combustion turbine operation would be required for a total of three hours in 2014, for a total estimated energy output of 3 MWh. A plot of the 2014 Labrador East Transmission System, supported by the Happy Valley Combustion Turbine is provided in Figure 5.

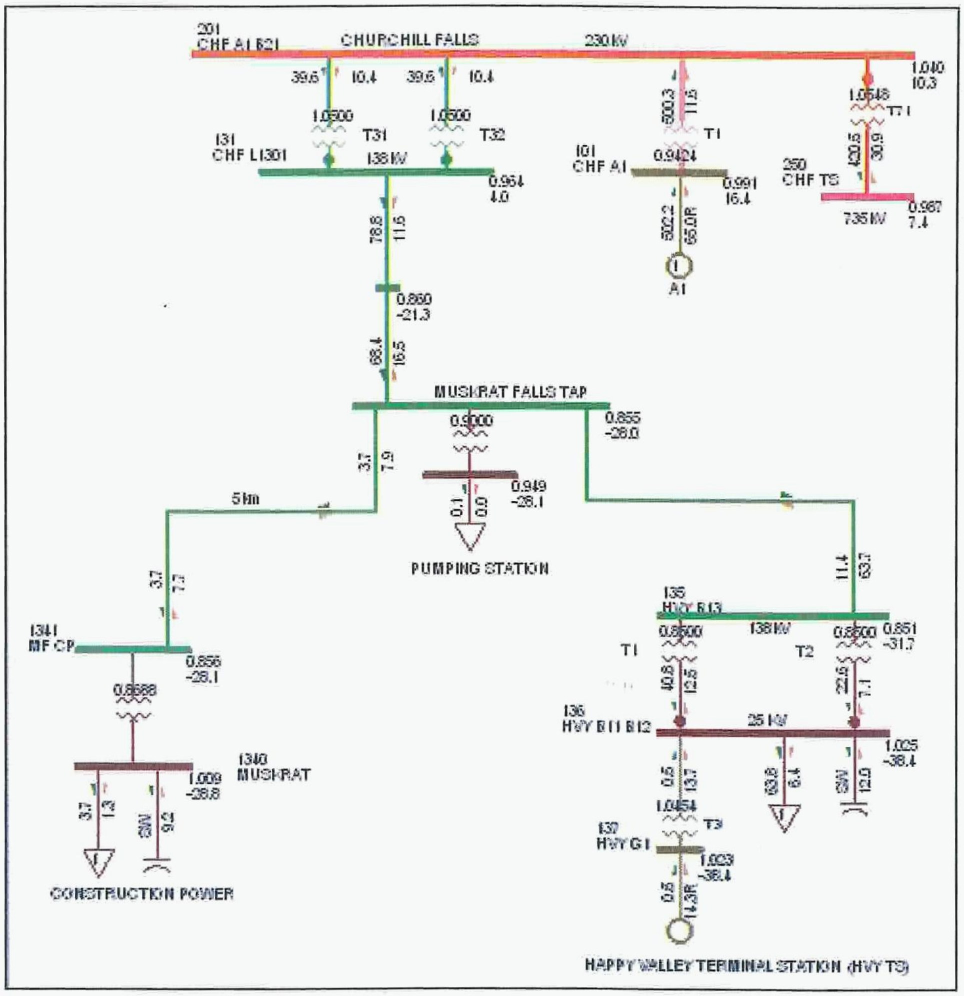

Figure 5 – Labrador East Transmission System in 2014
Combustion Turbine in Operation to Support Peak Load

Alternatively, completion of the first 345 kV transmission line between Churchill Falls and Muskrat Falls by the fall of 2014 would make it available for operation at 138 kV. Load flow analysis of the 2014 peak with the newly completed 345 kV transmission line operating at 138 kV indicates that there would be no need to operate the Happy Valley Combustion Turbine as a generator over peak. In fact, the use of the new 345 kV transmission line at 138 kV reduces the loading on the Churchill Falls 230/138 kV autotransformers from 101% to 87%. This is due to the fact that the new 345 kV transmission line will have a twin bundled conductor, which significantly reduces transmission losses and provides for increased line charging, which, in turn, increases 138 kV system voltages. Figure 6 provides the load flow plot with the 345 kV transmission line in service at 138 kV for the 2014 peak load.

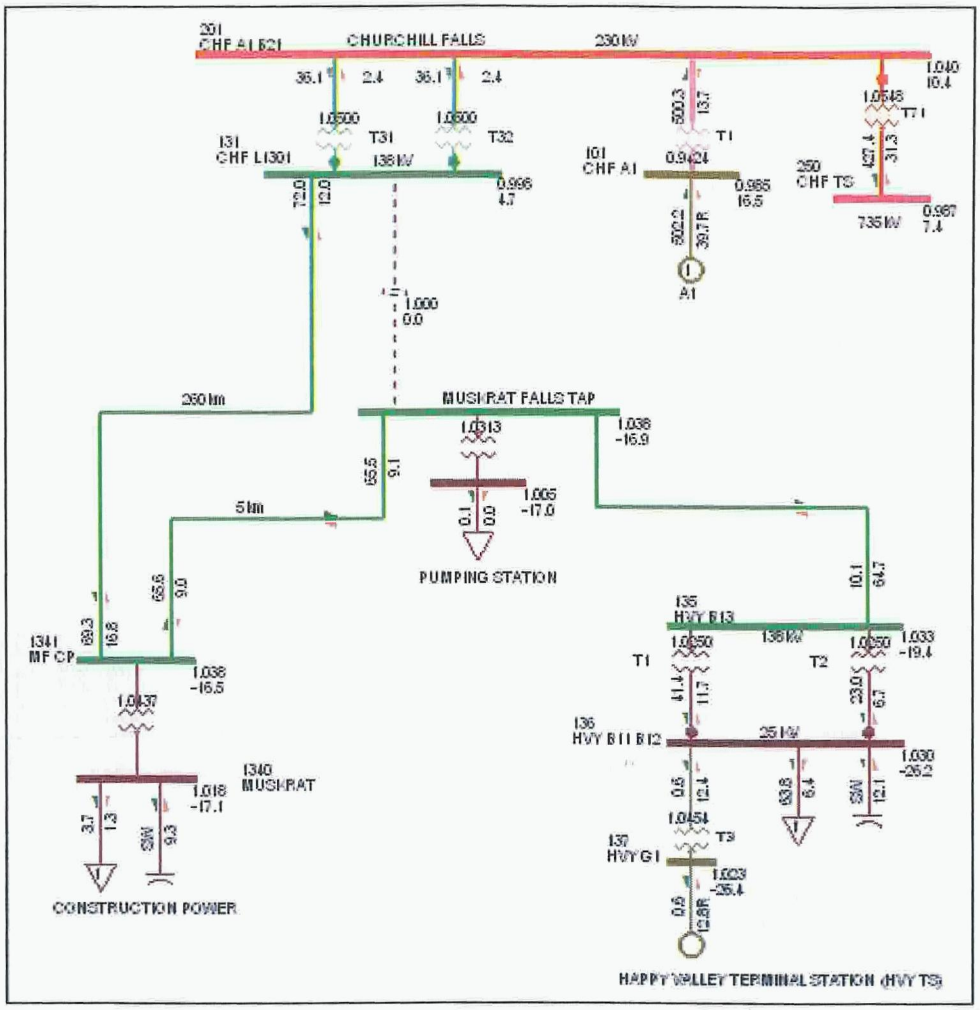

Figure 6 – 2014 Peak Load with First 345 kV Transmission Line Operating at 138 kV

With the first 345 kV transmission line completed in 2014 and operating at 138 kV, the existing 138 kV transmission line can be dismantled and the second 345 kV transmission line constructed in its location.

Peak Load 2015

Figure 7 provides the load flow plot of the 2015 peak load case with the fist 345 kV transmission line operating at 138 kV. The results indicate acceptable voltages across the transmission system and substantial margins on all OLTCs. The Churchill Falls 230/138 kV autotransformers are expected to be loaded to 90% of rating.

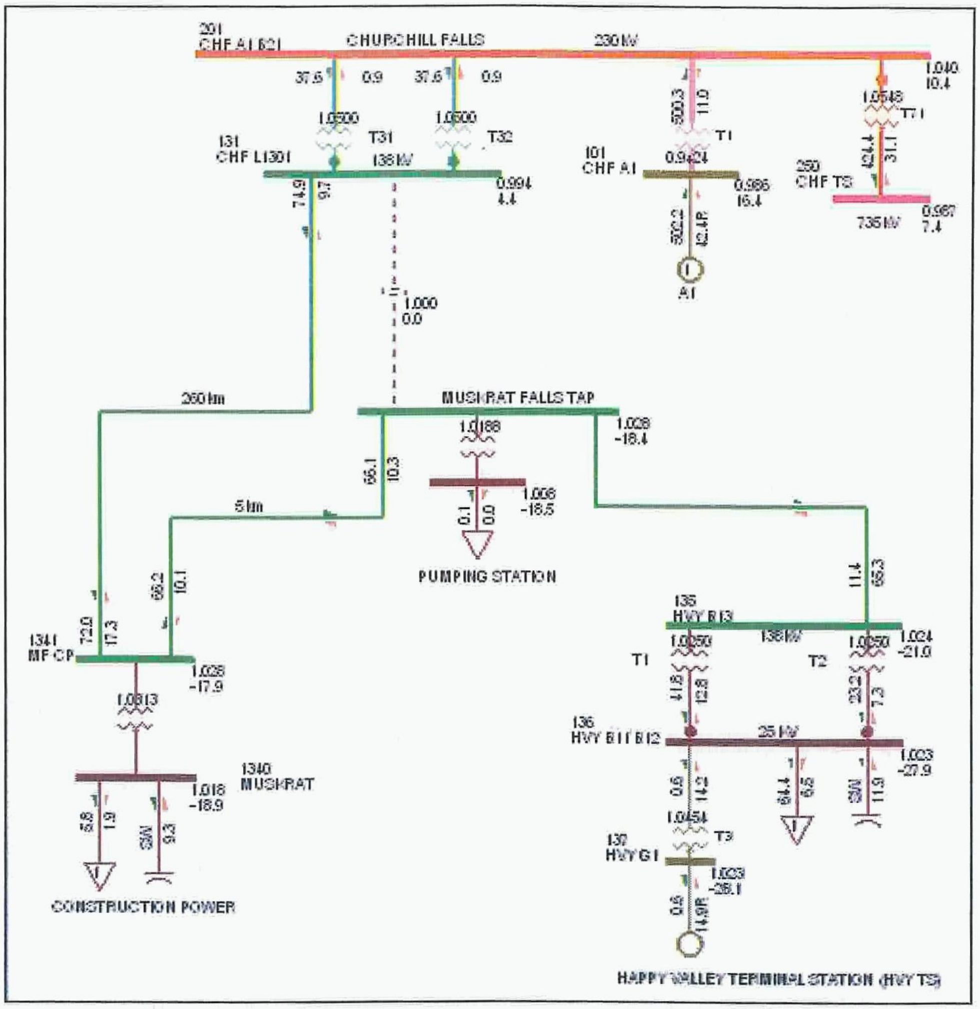

Figure 7 – 2015 Peak Load with First 345 kV Transmission Line Operating at 138 kV

Peak Load 2016

Figure 8 provides the load flow plot of the 2016 peak load case with the fist 345 kV transmission line operating at 138 kV. The results indicate acceptable voltages across the transmission system and substantial margins on all OLTCs. The Churchill Falls 230/138 kV autotransformers are expected to be loaded to 90% of rating.

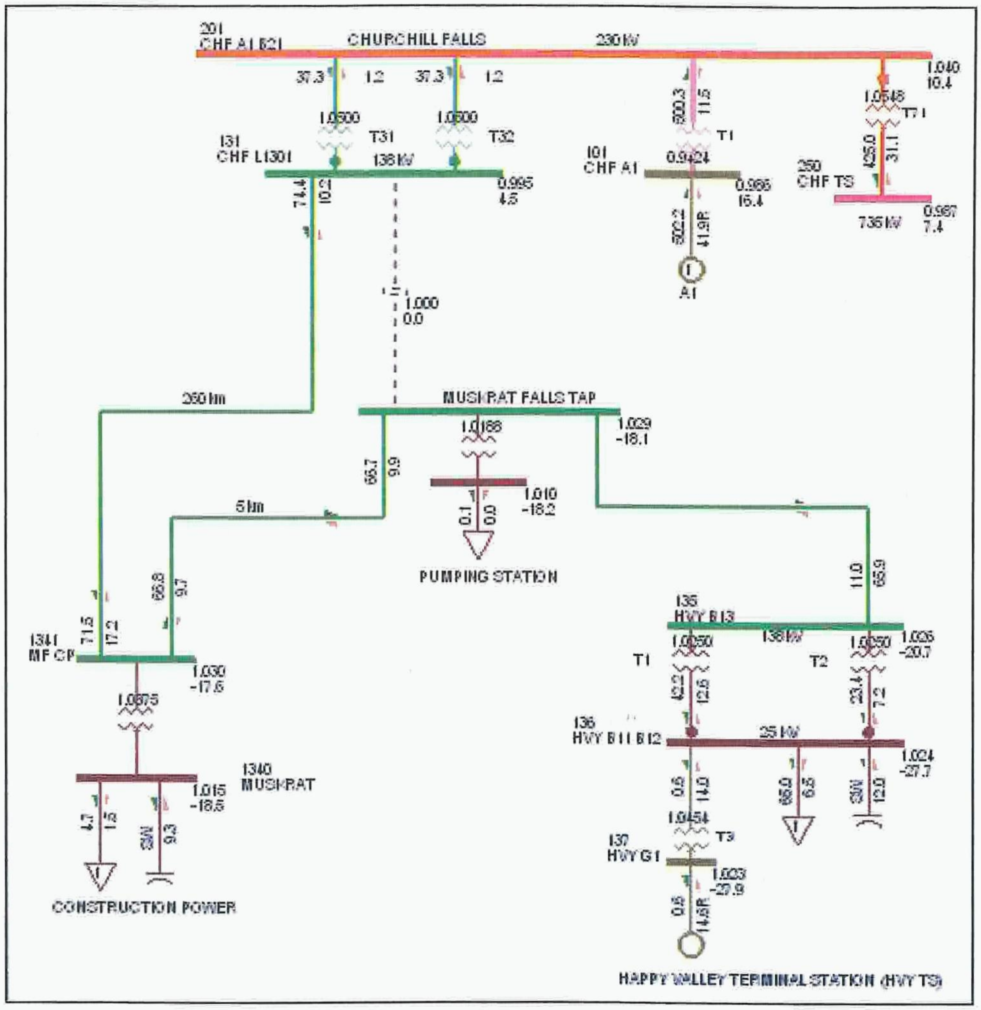

Figure 8 – 2016 Peak Load with First 345 kV Transmission Line Operating at 138 kV

Peak Load 2017

First power from Muskrat Falls is expected in late 2016 or early 2017. At this time the 345 kV station at Muskrat Falls will be required along with a 345 kV transmission line to Churchill Falls and at least one 345/735 kV autotransformers at Churchill Falls. With the existing 138 kV transmission line dismantled and a new 345 kV transmission line being constructed in its location, the 345 kV station at Muskrat Falls will require one 345/138 kV, 75/100/125 MVA autotransformer to be in service to supply the Happy Valley load in 2017 when first power from the Muskrat Falls generating station is available, if the second 345 kV transmission line is not complete. That is to say, if the second transmission line is not complete when first power is available, the first 345 kV transmission line operating at 138 kV will have to be reconnected for 345 kV operation and the Happy Valley 138 kV transmission system re-terminated at Muskrat Falls. If the second 345 kV transmission line were available, it would be used for first power out of Muskrat Falls and one could continue to supply the construction power load and Happy Valley at 138 kV using the first 345 kV transmission line. Re-termination of the first 345 kV transmission line for operation at 345 kV could then be delayed until 2018 with the commissioning of two 345/138 kV, 75/100/125 MVA autotransformers at Muskrat Falls.

Figure 9 provides the load flow plot of the 2017 peak load case with the fist 345 kV transmission line operating at 138 kV. The results indicate acceptable voltages across the transmission system and substantial margins on all OLTCs. The Churchill Falls 230/138 kV autotransformers are expected to be loaded to 89% of rating.

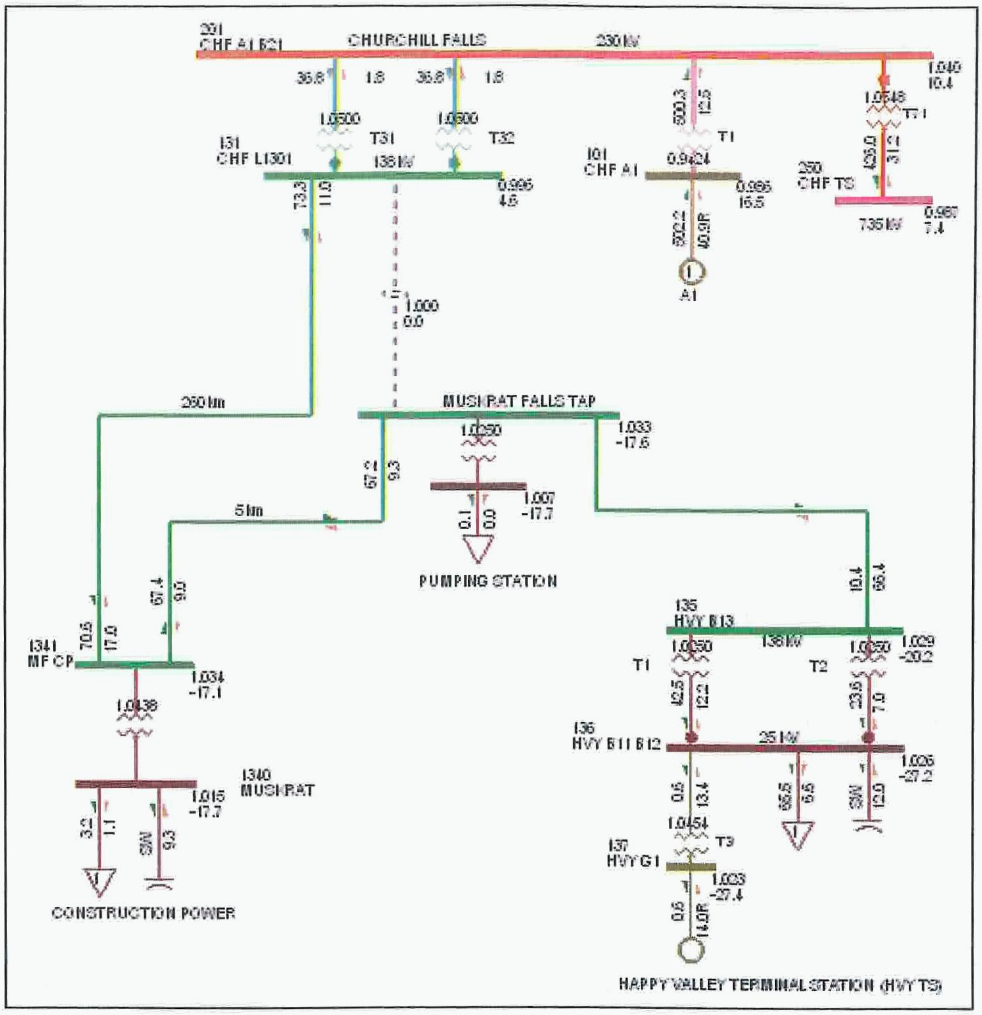

Figure 9 – 2017 Peak Load with First 345 kV Transmission Line Operating at 138 kV

Figure 10 provides the load flow plot of the 2017 peak load case with the first 345 kV transmission line operating at 345 kV, a single 735/345 kV autotransformer installed at Churchill Falls and a single 345/138 kV autotransformer installed at the Muskrat Falls 345 kV tap station. Note it is expected that due to space constraints crossing the Churchill River, only the two 345 kV transmission lines will cross the river. There will be a 345/138 kV tap station near the existing Muskrat Falls pumping station for installation of 345/138 kV autotransformers and 138 kV transmission line terminations for the Labrador East Transmission System to Happy Valley. Analysis of the case indicates that the shunt capacitor banks at the construction power station and the Happy Valley synchronous condenser will not be required over peak.

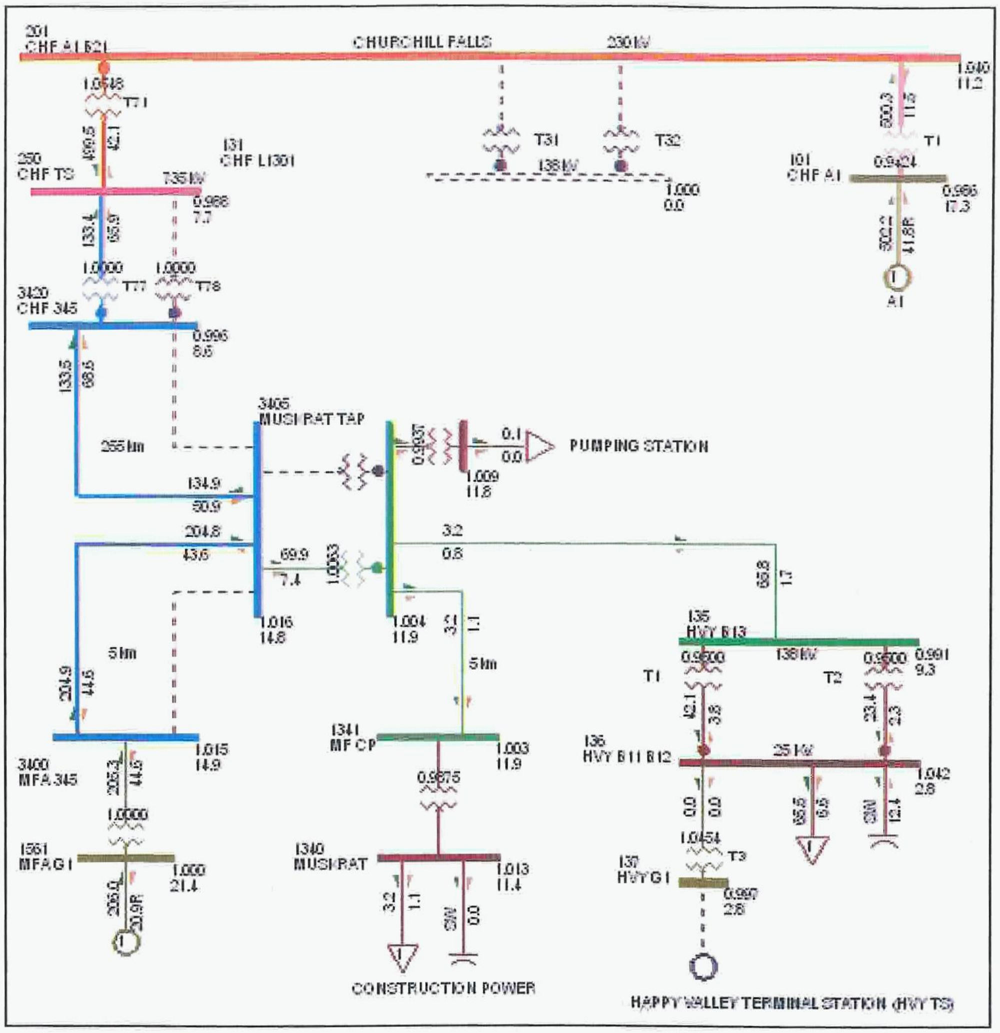

Figure 10 – 2017 Peak Load with First Power via a 345 kV Transmission Line

Light Load 2014

The most critical light load case occurs in 2014 with the first 345 kV transmission line operating at 138 kV. The 345 kV transmission line operating at 138 kV is expected to provide 21.4 MVAR of line charging. When combined with the 138 kV transmission line across the Churchill River and the 138 kV line segment to Happy Valley the total transmission line charging is calculated to equal 23.4 MVAR. By comparison, the existing 138 kV transmission line provides 18.1 MVAR of charging. As a result one can expect to observe higher transmission voltages under no load and light load conditions with the 345 kV transmission line operating at 138 kV than is experienced today.

Based upon the Happy Valley load profile given in Figure 2 one can expect the summer light load to equal approximately 20% of the winter peak. For 2014 the summer night time load then is estimated to equal 12.7 MW. A review of EMS hourly load data indicates that the power factor will equal 0.96 for this loading condition. With the Happy Valley load reduced to 12.7 MW the load flow analysis reveals that all 138 kV system voltages will be at or below 144.9 kV (1.05 p.u.) with the construction power load at 2.0 MW. Figure 11 provides the load flow plot. Should the construction power load fall below 2.0 MW during summer night time conditions it will be necessary to run the Happy Valley Combustion Turbine in synchronous condenser mode to reduce the 138 kV system voltage to within acceptable limits.

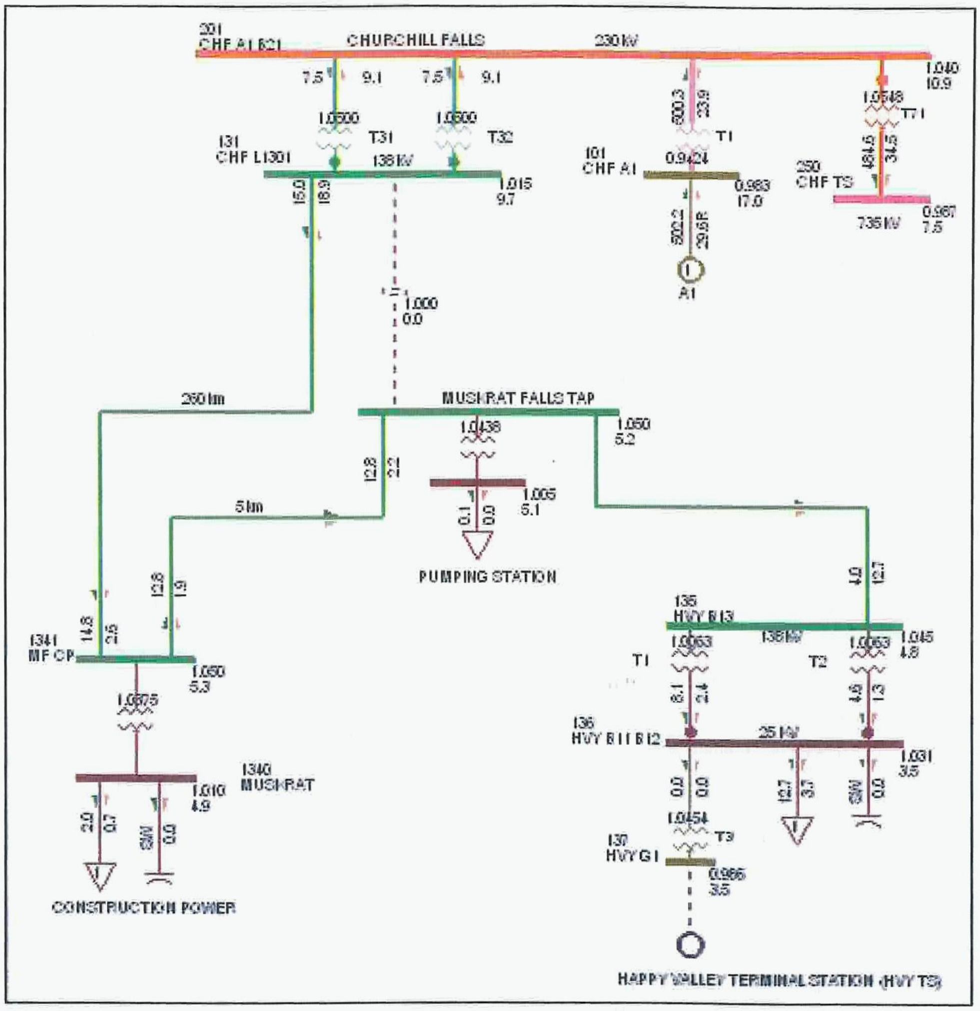

Figure 11 – 2014 Light Load with First 345 kV Transmission Line Operating at 138 kV

CONTINGENCY ANALYSIS

There are a number of contingencies that are of significance to the supply of construction power at Muskrat Falls from the Labrador East Transmission System.

System Restart

Following a trip of the 138 kV transmission line the system must be restarted. During the restoration process the 138 kV line would be energized from the Churchill Falls end to the Muskrat Falls 138 kV tap station and from there into the Muskrat Falls construction power station. Once load is restored at Muskrat Falls the 138 kV transmission line from the Muskrat Falls tap station to Happy Valley would be energized and service restored to Happy Valley customers.

Load flow analysis of restoration to the Muskrat Falls construction power station using the existing 138 kV transmission line indicates maximum 138 kV system voltages of 147.2 kV (1.067 p.u.). With the OLTC on the construction power transformer in tap position 1 (144900 V – tap ratio 1.05) the 25 kV bus voltage is expected to equal 25.4 kV (1.016 p.u.). Figure 12 provides the load flow plot.

For system loads beyond the year 2014 it is proposed to supply the Labrador East Transmission System by operating the newly constructed 345 kV transmission line between Muskrat Falls and Churchill Falls at 138 kV. Between 2014 and project completion, the existing 138 kV transmission line will be decommissioned and a second 345 kV transmission line built in its location. Restoration under this scenario would see the Muskrat Falls construction power station supplied directly from Churchill Falls via the new 345 kV transmission line operating at 138 kV. Load flow analysis of this restoration sequence indicates that the 138 kV bus voltage at the Muskrat Falls construction power station will reach 149.2 kV (1.081 p.u.). With the construction power transformer OLTC in tap position 1 (144900 V – tap ratio 1.05) the 25 kV bus voltage is expected to equal 25.8 kV (1.03 p.u.). Figure 13 provides the load flow plot.

A review of CAN/CSA C88-M90 Clause 3.3.4 indicates at subsection c that excitation exceeding 110% of rated volts per hertz is an unusual service condition that may affect the transformer performance and should receive special consideration. In both restoration cases the expected voltage on the high voltage winding is less than 110% of rated voltage. From an excitation perspective the restoration sequence is not expected to have an adverse impact on the construction power transformer.

Further, CAN/CSA C88-M90 Section 7.3.3 states:

> Transformers shall be capable of operating at no-load with the primary voltage required for the conditions of Clause 7.3.2, or 10% above rated voltage,

whichever is higher, without exceeding the temperature rises as defined in Clause 9.

From the restoration perspective with the construction power transformer energized at no load, the 138 kV winding voltages of 1.067 p.u. to 1.081 p.u. are not expected to cause adverse winding temperature rises during the system restart sequence.

The analysis to date indicates that system restoration should not be problematic for the proposed construction power transformer and 138 kV supply options.

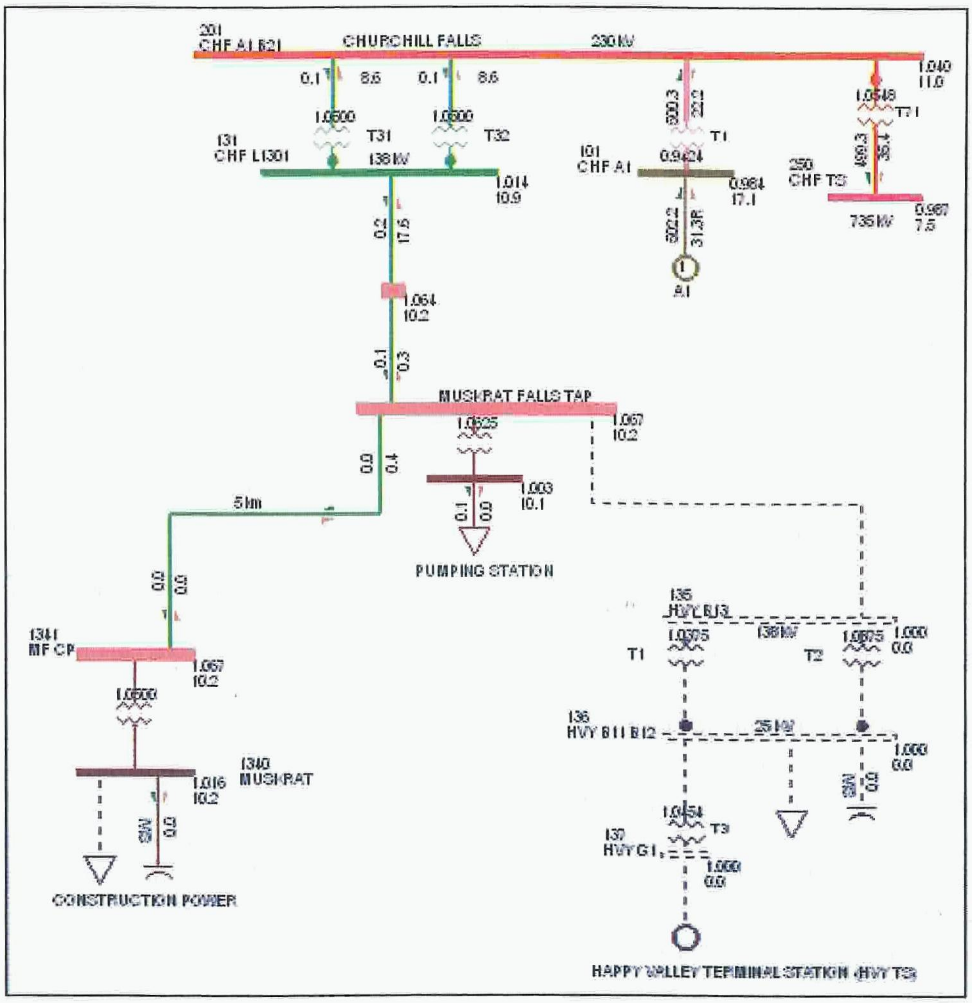

Figure 12 – System Restoration Using Existing 138 kV Transmission Line

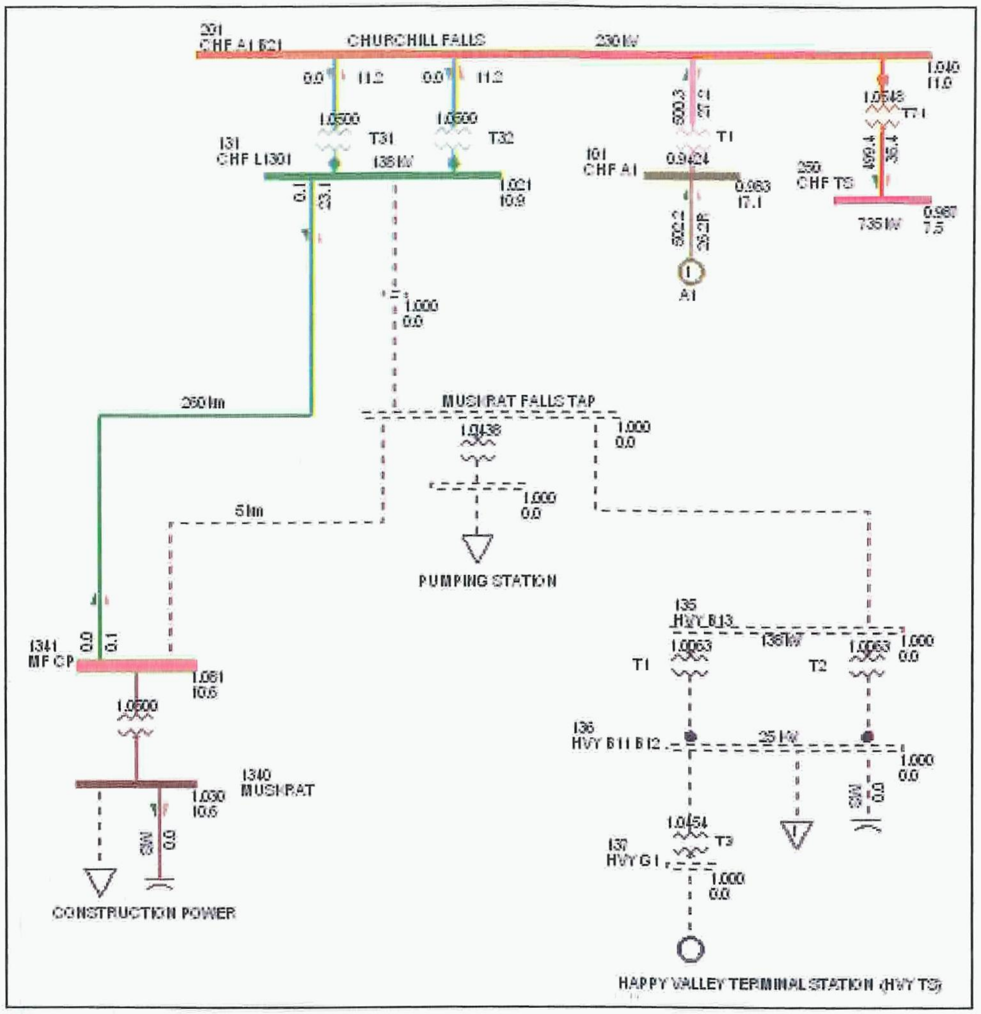

Figure 13 – System Restoration Using New 345 kV Transmission Line Operating at 138 kV

230/138 kV Autotransformer Outage

An outage to one of the 230/138 kV autotransformers at Churchill Falls will limit the sending end power on the 138 kV transmission line at Churchill Falls to 42 MVA (176 A) in order to avoid over loading of the remaining 230/138 kV unit. During this contingency, the Happy Valley Combustion Turbine would be operated as a generator with an output up to 27 MW to support the Labrador East Transmission System load.

Analysis of the 2012 peak load case with the construction power load at 2 MW indicates that with T32 out of service at Churchill Falls and Happy Valley Combustion Turbine at 27 MW, T31 will be loaded to 99% of its current rating. In addition, to maintain voltages within acceptable ranges, only 3.0 MVAR and 2.4 MVAR of switched capacitors will be required at Muskrat Falls and Happy Valley respectively.

In 2013, the loss of Churchill Falls T32 with the Happy Valley Combustion Turbine at 27 MW will result in Churchill Falls T31 being loaded to 106% of rating. In order to reduce the loading on T31 to 100%, load reduction at Muskrat Falls will be required. Analysis indicates that in order to remove the overload on T31 with T32 out of service and the combustion turbine at Happy Valley operating at 27 MW, the construction power load must be reduced to 0 MW. Analysis also indicates that with the construction power load at 3.5 MW and T32 out, the Happy Valley load cannot exceed 60 MW if T31 loading is not to exceed 100%. Using the Happy Valley load shape provided in Figure 2, an estimate of the number of hours of construction power load reduction can be developed. Based upon the Happy Valley load shape, it is estimated that the Muskrat Falls construction power load will have to be reduced to a minimum of 0 MW for up to 20 hours in 2013.

In 2014 the first 345 kV transmission line will be operating at 138 kV. Loss of Churchill Falls T32 will result in a 105% loading on T31 over peak with the Happy Valley Combustion Turbine at 27 MW. Only one capacitor bank will be required at each of Muskrat Falls and Happy Valley to maintain acceptable transmission system voltages. Analysis indicates that reducing the construction power load to 3.0 MW during the Happy Valley peak will be sufficient to reduce the T31 loading to 100%. With the construction power load at its peak of 3.7 MW, the Happy Valley load must be limited to 63.0 MW during an outage to Churchill Falls T32. Based upon the Happy Valley load shape, it is estimated that the Muskrat Falls construction power load will have to be reduced to a minimum of 3.0 MW for 3 hours in 2014.

In 2015 loss of Churchill Falls T32 is expected to result in a 110% loading on T31 over peak with the Happy Valley Combustion Turbine at 27 MW. Only one capacitor bank will be required at Muskrat Falls and Happy Valley to maintain acceptable transmission system voltages. Increasing the number of capacitor banks in service during the outage will increase the MVAR flow through the 230/138 kV transformer to the Churchill Falls 230 kV bus, thereby increasing the transformer loading unnecessarily. Analysis indicates that reducing the construction power load to 2.2 MW during the Happy Valley peak is sufficient to reduce the T31 loading to 100%. Note that all capacitor banks can be removed from service in this case. With the construction power load at its peak of 5.8 MW, the Happy Valley load must be limited to 61.3 MW during an outage to Churchill Falls T32. Based upon the Happy Valley load shape, it is estimated that the Muskrat Falls construction power load will have to be reduced to a minimum of 2.2 MW for 15 hours in 2015.

In 2016 loss of Churchill Falls T32 is expected to result in a 109% loading on T31 over peak with the Happy Valley Combustion Turbine at 27 MW. Only one capacitor bank will be required at Muskrat Falls and Happy Valley to maintain acceptable transmission system voltages. Increasing the number of capacitor banks in service during the outage will increase the MVAR flow through the 230/138 kV transformer to the Churchill Falls 230 kV bus, thereby increasing the transformer loading unnecessarily. Analysis indicates that reducing the construction power load to 2.0 MW during the Happy Valley peak is sufficient to reduce the T31 loading to 100%. Note that all capacitor banks can be removed from service in this case. With the construction power load at its peak of 4.7 MW, the Happy Valley load must be limited to 62.3 MW during an outage to Churchill Falls T32. Based upon the Happy Valley load shape, it is estimated that the Muskrat Falls construction power load will have to be reduced to a minimum of 2.0 MW for 10 hours in 2016.

In 2017 loss of Churchill Falls T32 is expected to result in a 107% loading on T31 over peak with the Happy Valley Combustion Turbine at 27 MW. Only one capacitor bank will be required at Muskrat Falls and Happy Valley to maintain acceptable transmission system voltages. Increasing the number of capacitor banks in service during the outage will increase the MVAR flow through the 230/138 kV transformer to the Churchill Falls 230 kV bus, thereby increasing the transformer loading unnecessarily. Analysis indicates that reducing the construction power load to 1.5 MW during the Happy Valley peak is sufficient to reduce the T31 loading to 100%. Note that all capacitor banks can be removed from service in this case. With the construction power load at its peak of 3.2 MW, the Happy Valley load must be limited to 63.7 MW during an outage to Churchill Falls T32. Based upon the Happy Valley load shape, it is estimated that the Muskrat Falls construction power load will have to be reduced to a minimum of 1.5 MW for 6 hours in 2017.

Table 2 summarizes the results of the Churchill Falls 230/138 kV transformer outage.

Table 2
Summary of Churchill Falls 230/138 kV Autotransformer Contingency

Year	T31 Loading	Maximum Station Load - MW		Duration of Load Reduction (hours)
		Muskrat Falls	Happy Valley	
2012	99%	2.0	62.7	0
2013	106%	0.0	60.0	20
2014	105%	3.0	63.0	3
2015	110%	2.2	61.3	15
2016	109%	2.0	62.3	10
2017	107%	1.5	63.7	6

Note:
For loss of 230/138 kV autotransformer at Churchill Falls in a given year, the Muskrat Falls construction power load must be reduced to the value shown when the Happy Valley load exceeds the value shown for that year.

RECOMMENDATIONS

Based on the analyses contained in this report, the following recommendations are made to support construction power requirements at Muskrat Falls:

1. The proposed relocation of the construction camp and associated shops to the south side of the Churchill River, renders use of the existing 138/25 kV, 2/2.66 MVA transformer at the Muskrat Falls pump site for early construction efforts in 2012 appears ineffective given its location relative to the proposed construction efforts.

2. Ensure that the 138 kV tap station along the Trans Labrador Highway, the 5 km long 138 kV transmission line crossing the Churchill River, the 138/25 kV, 30/40/50 MVA with OLTC power transformer and a 9 MVAR capacitor bank are in operation at Muskrat Falls before December of 2012. Delays in this installation would require the operation of the HVY Gas Turbine for a significant energy output in the winter of 2012/2013.

3. Completion of the first 345 kV transmission line between Churchill Falls and Muskrat Falls by the fall of 2014 with operation at 138 kV will eliminate 230/138 kV autotransformer over loading at Churchill Falls and negate the need to install a third 230/138 kV, 75/100/125 MVA autotransformer with OLTC at Churchill Falls to meet load requirements with all equipment in service.

4. An outage to one of the existing 230/138 kV, 25/33/42 MVA autotransformers (T31 or T32) at Churchill Falls during peak load periods will require operation of the Happy Valley Combustion Turbine at 27 MW and load reductions at the Muskrat Falls construction power station to remove overloads on the remaining Churchill Falls autotransformer. Analysis has indicated that the load reduction at the Muskrat Falls construction site is estimated to last between 3 and 20 hours depending upon the year of the outage. The decision to add a third 230/138 kV, 75/100/125 MVA autotransformer at Churchill Falls to meet load requirements during an autotransformer contingency is one of cost versus risk.

5. Decommission the existing 138 kV transmission line section between Churchill Falls and Muskrat Falls following completion of the first 345 kV transmission line with operation at 138 kV.

6. Installation of the first 345/735 kV autotransformer at Churchill Falls and the first 345/138 kV, 75/100/125 MVA autotransformer with OLTC at Muskrat Falls for first power at Muskrat Falls in late 2016.

7. Completion of second 345 kV transmission line between Churchill Falls and Muskrat Falls by late 2016 for first power or swing over of first 345 kV line to 345 kV operation in summer of 2016 with 5 above completed.

8. Install second 345/735 kV autotransformer at Churchill Falls summer of 2017.

9. Decommission the 230/138 kV autotransformers Churchill Falls and Muskrat Falls following completion of project (end of 2018).

10. Install a second 345/138 kV, 75/100/125 MVA autotransformer with OLTC at Muskrat Falls for service following the completion of the Muskrat Falls Project (end of 2018).

11. Relocate the 138/25 kV, 30/40/50 MVA construction power transformer to a second 138/25 kV terminal station in Happy Valley. This new station would be tied to the existing station via a 138 kV transmission line of approximately 8 km in length. A second 138 kV transmission line of approximately 35 km in length would run from Muskrat Falls to the new 138/25 kV terminal station to increase reliability of supply to the area.

ATTACHMENT 2

HYDRO
THE POWER OF COMMITMENT

INTEROFFICE MEMORANDUM

DATE: November 5, 2008

TO: R. Kaushik

FROM: P. Thomas

SUBJECT: **Island System Upgrades – No New Oil Refinery**

A load flow analysis has been completed to determine the Island System upgrades required given that there will be no new oil refinery and that system collapse following a three phase fault on the 230 kV bus at Bay d'Espoir is deemed to be acceptable. Preliminary analysis of the dynamic performance of the system by TransGrid Solutions indicates that without the 3 x 300 MVAR synchronous condensers at Piper's Hole (note that the Pipers Hole Terminal Station would not be required without the new oil refinery), either a new 230 kV transmission line is required between Bay d'Espoir and Western Avalon with 50% series compensation or a 400 MVAR SVC plus 100 MVAR switched capacitor bank is required at Sunnyside. Given the congestion in the Sunnyside Terminal Station, it is undesirable to add the SVC and switched capacitor bank to this site. Therefore, this analysis of the required Island System upgrades is completed with the following base assumptions:

- 3 x 300 MVAR synchronous condensers at Soldiers Pond;
- 50% series compensation of TL202 and TL206 (Bay d'Espoir – Sunnyside);
- new 230 kV transmission line Bay d'Espoir to Western Avalon with 50% series compensation;
- third 25 MW wind farm; and
- second 50 MW combustion turbine at Hardwoods Terminal Station in 2012.

The base case load flows used in the TransGrid HVdc integration study were modified to reflect the removal of the 175 MW oil refinery. The system load and generation dispatch is given in Appendix A. The cases are summarized below.

BC1M denotes the modified BC1 case. This case represents the 2016 peak load case without the new oil refinery. The HVdc is dispatched at maximum output and the Island hydro resources are placed in an economic dispatch.

BC2M denotes the modified BC2 case. This case also represents the 2016 peak load case without the new oil refinery. The Island hydro resources are dispatched at maximum output and the HVdc dispatched to make up the remainder of the system load.

BC3M denotes the modified BC3 case. This is the future peak load case without the new oil refinery. The case has dispatched both the Island hydro resources and the HVdc at maximum values. The case depicts the year 2036 based upon the August 2006 Provincial Load Forecast (PLF).

BC45M denotes the modified BC4 and BC5 cases. The original BC4 nd BC5 were developed to provide a minimum load case (i.e. summer night). The original 625 MW total was based upon a total system load of 450 MW (including 166 MW of industrial load) plus a new 175 MW oil refinery. Removing the new oil refinery brings the summer night load back to 450 MW. Previous discussions with Operations indicate that the minimum generation on the Island for water management reasons would leave the HVdc to supply approximately 77 MW plus any incremental system losses. As a result, under minimum load and minimum Island generation the HVdc is scheduled at 80 MW for both BC4 and BC5 at a 450 MW system load level.

BC6M denotes the modified BC6 case. The original BC6 and BC7 were developed to provide a typical spring/fall loading. With the new oil refinery removed from the case the system load is set at 825 MW. BC6M has the HVdc dispatched at 562 MW.

BC7M denotes the modified BC7 case with the system load set at 825 MW and the HVdc set at 80 MW. The Island hydro units are scheduled in an economic dispatch.

BC8M denotes the modified Island export case BC8. The case assumes a system summer night load of 450 MW enabling the HVdc to export approximately 444 MW.

BC14M is a newly developed case with the no new oil refinery and a system summer day time load of 750 MW. The case assumes minimum Island generation as per BC6M with maximum HVdc.

BC15M is a newly developed case with the same loading as BC14M. However, in BC15M the HVdc is scheduled at 80 MW.

Once all of the modified base cases were prepared the PSS/E activity ACCC (AC Contingency Calculation) was used to assess the impact of equipment outages on the eastern portion of the 230 kV Island system. The contingencies considered (summarized in the table below) match those utilized by TransGrid in DC1020 with three exceptions. First, C8 is not used in this study as there is no Pipre's Hole Terminal Station. Second, C9 (Piper's Hole to Bay d'Espoir) is taken to mean Sunnyside to Piper's Hole for this analysis. Finally, two new contingencies are added C12 loss of a 300 MVAR synchronous condenser at Soldiers Pond and C13 loss of the new Bay d'Espoir to Western Avalon 230 kV line.

In reviewing transmission line overloads due to line outages, redispatch of Island generation, operation of combustion turbines and adjustment to HVdc power levels are assumed to be acceptable means of reducing transmission line loadings to within acceptable levels and thereby eliminate the need for line rebuild/modifications for specific contingencies.

System Planning utilizes three transmission line ratings for overload monitoring. These are as follows:

- Rate A – 30°C ambient temperature for summer day time;
- Rate B - 15°C ambient temperature for spring/fall; and
- Rate C - 0°C ambient temperature for winter peak.

Contingencies for Steady State Analysis	
Contingency	Description
C1	Soldiers Pond to Holyrood 230 kV line (TL217 or TL242)
C2	Soldiers Pond to Hardwoods 230 kV line (TL242)
C3	Soldiers Pond to Oxen Pond 230 kV line (TL218)
C4	Soldiers Pond to Western Avalon line (TL217)
C5	Western Avalon to Come By Chance 230 kV line (TL237)
C6	Come By Chance to Sunnyside 230 kV line (TL207)
C7	Western Avalon to Sunnyside 230 kV line (TL203)
C8	Sunnyside to Piper's Hole 230 kV line – Not Used For This Study
C9	Piper's Hole (SSD) to Bay d'Espoir 230 kV line (TL202 or TL206)
C1-	Hardwoods gas turbine in synchronous condenser mode
C11	Synchronous condenser unit #3 at Holyrood
C12	Synchronous condenser unit #1 at Soldiers Pond
C13	Bay d'Espoir to Western Avalon 230 kV line

For the peak load case BC1M the contingency analysis indicates that there are no transmission overloads or voltage violations. A maximum transmission loading of 92.5% of the winter rating (Rate C) was observed on TL201 between Soldiers Pond and Hardwoods for contingency C2. Similarly, there were no overloads for BC2M and again the maximum transmission line loading observed was 92.5% of the winter rating on TL201 between Soldiers Pond and Hardwoods for contingency C2.

For the future peak load case, BC3M, there were no voltage violations observed. However the loading on TL201 between Soldiers Pond and Hardwoods reached 118.9% and 104.8% of the winter rating (Rate C) for contingencies C2 and C3 respectively. Operation of 100 MW and 50 MW of combustion turbine remove the TL201 overloads due to C2 and C3 respectively.

No transmission line overloads (Summer Rate A) or voltage violations were observed for the summer night, minimum HVdc load case BC45M.

Analysis of the spring/fall load cases BC6M and BC7M revealed no voltage violation or transmission line overloads using the Rate B line rating. It was noted that under the summer rating (Rate A), TL201 between Western Avalon and Soldiers Pond would be loaded to 119.3% of rating for contingency C4 in case BC6M. Reduction of the HVdc by 48 MW and start up of a unit a Bay d'Espoir was sufficient to remove this overload. In BC7M with minimum HVdc infeed a number of line overloads were observed based upon the summer rating. These overloads were successfully removed by operation of the combustion turbines at Hardwoods or increase in HVdc infeed power. While, it is common practice to use the 15°C ambient rating for the spring/fall loading case, application of the 30°C ambient rating does highlight the potential for thermal overload at some future point.

The export case BC8M reveals that thermal uprating of TL202 and TL206 along with rebuild of TL201 and TL203 are necessary to avoid transmission overloads.

The summer daytime cases BC14M and BC15M are evaluated using Rate A. Under maximum HVdc infeed (BC14M) the analysis indicates that TL201 between Western Avalon and Soldiers Pond would be loaded to 100.5% for contingency C4. Reduction in the Hvdc with increase in off Avalon generation will remove the slight overload. Under minimum HVdc infeed (BC15M) the analysis indicates a 100.7% load on TL201 for C4, a 102.6% load on TL203 for C5, a 116% load on TL203 for C6, a 115.6% load on TL203 for C13, a 101.4% load on TL202/206 for C9 and a 100% load on TL02/206 for C13. Operation of a Hardwoods combustion turbine at loadings between 25 and 45 MW, or increases in the HVdc infeed power are sufficient to remove the overloads in case BC15M. No voltage violations were observed in the summer daytime cases.

A short circuit study was completed to determine the impact the proposed system additions will have on prospective short circuit levels and subsequently circuit breaker change out. The following table summarizes the results.

Short Circuit Analysis Results Modified HVdc with No New Oil Refinery			
Faulted Bus	3Φ MVA	LG MVA	Circuit Breakers to Replace
STB 230	2527	2703	None
STB 138	1544	1872	None
BDE 230	4614	5308	1 – B4B5
BDE 69	293	302	None
SSD 230	3331	2723	None
SSD 138	1699	1911	None
CBC 230	3042	2328	None
WAV 230	4172	3914	None
WAV 138	1762	1990	None
WAV 66	514	339	None
HRD 230	6232	6747	9 – B1B11, B1L17, B12L17, B2B11, B2L42, B12L42, B3L18, B3B13, B12B15
HRD 138	1924	2226	None
HRD 66	671	583	None
HWD 230	5136	5018	None
HWD 66	2665	2482	4 – B7T1, B7T2, B7T5, B7B8
OPD 230	4358	4035	None
OPD 66	2187	1704	None

The results indicate that the removal of the Piper's Hole Terminal Station and 3 x 300 MVAR synchronous condensers is sufficient to reduce the short circuit levels in the Bay d'Espoir – Sunnyside region such that only one 230 kV circuit breaker must be replaced. The combination of a new 50 MW combustion turbine at Hardwoods and the three new synchronous condensers at Soldiers Pond increases the Hardwoods short circuit levels to the point where four 66 kV circuit breakers at Hardwoods must be replaced. A review of the short circuit levels at Hardwoods following the addition of the second combustion turbine in 2012, prior to the Soldiers Pond Converter Station, indicates that the addition of the new combustion turbine on its own does not increase the short circuit levels to the point where circuit breaker change out is warranted in 2012.

Summary

In summary, the contingency analysis of the proposed Island system configuration with a 230 kV transmission line added between Bay d'Espoir and Western Avalon, 3 x 300 MVAR synchronous condensers at Soldiers Pond, no Piper's Hole Terminal Station and no new oil refinery revealed the following conclusions:

- There were no steady state voltage violations for any line out contingency;
- No transmission line overloads were observed for the 2016 peak load case;
- Overloads to TL201 between Soldiers Pond and Hardwoods in the future peak (2036) case can be relieved through operation of the Hardwoods combustion turbine(s);
- No transmission line overloads were observed in the summer night time load case;
- During spring/fall day time loading conditions with maximum HVdc infeed there is potential for overloading of TL201 (Western Avalon to Soldiers Pond) for loss of TL217. The overload can be reduced through reduction in the HVdc power injection and start up of off Avalon generation;
- During spring/fall day time loading conditions with minimum HVdc infeed there is potential for overloading of TL201 (Western Avalon to Soldiers Pond), TL203 (Sunnyside to Western Avalon) and TL202/206 (Bay d'Espoir to Sunnyside) for various transmission line contingencies. The overloads can be reduced through increase in the HVdc power injection or start up of Hardwoods combustion turbines;
- During summer day time conditions with maximum HVdc infeed there is potential for overloading of TL201 (Western Avalon to Soldiers Pond) for loss of TL217. The overload can be reduced through reduction in the HVdc power injection and start up of off Avalon generation;
- During summer day time loading conditions with minimum HVdc infeed there is potential for overloading of TL201 (Western Avalon to Soldiers Pond), TL203 (Sunnyside to Western Avalon) and TL202/206 (Bay d'Espoir to Sunnyside) for various transmission line contingencies. The overloads can be reduced through increase in the HVdc power injection or start up of Hardwoods combustion turbines; and
- For maximum export capability thermal uprating of TL202 and TL206 along with rebuild of TL201 and TL203 are required.

As a result, unless there is a requirement to export from the Island system, thermal uprating of TL202 and TL206, and rebuild of TL201 and TL203 is not required prior to completion of the Soldier's Pond Converter Station.

With respect to short circuit levels and circuit breaker replacement:

- One 230 kV circuit breaker at Bay d'Espoir must be replaced;
- Nine 230 kV circuit breakers at Holyrood must be replaced; and
- Four 66 kV circuit breakers at Hardwoods must be replaced.

I trust the foregoing is satisfactory for your purposes. Should you have any questions, please do not hesitate to call.

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System Planning Specialist

cc: 6208-53-0128/PWH

Appendix A
System Load and Generation Dispatch

System Upgrades Analysis
HVDC System Integration Study - No New Oil Refinery - 3rd Circuit
Generation Dispatch for Base Case Scenarios

	Base Cases								
	BC1M	BC2M	BC3M	BC45M	BC6M	BC7M	BC8M	BC14M	BC15M
NLH System Load (MW)	1497.8	1497.8	1792.6	449.5	825	825	453.7	749.5	749.5
Industrial (MW)	161.8	161.8	161.8	161.8	161.8	161.8	161.8	161.8	161.8
NP + NLH (MW)	1336	1336	1630.8	287.7	663.2	663.2	291.9	587.7	587.7
Generation Dispatch									
HVDC at Soldiers Pond	769.5	476	769.3	78.6	562	78.7	-443.9	485.7	78.7
NLH - Hydro									
Bay d'Espoir Unit 1	59.7	74.5	74.5	64.7	62.1	63	73.4	61.5	60.4
Bay d'Espoir Unit 2	off	75	75	off	off	63.1	73.9	off	60.8
Bay d'Espoir Unit 3	60.7	75	75	65.4	63.1	63.1	73.9	62.5	60.8
Bay d'Espoir Unit 4	off	75	75	off	off	63.1	73.9	off	off
Bay d'Espoir Unit 5	60.7	75	75	65.4	off	63.1	73.9	off	60.8
Bay d'Espoir Unit 6	60.7	75	75	off	off	off	73.9	off	off
Bay d'Espoir Unit 7	135	154	154	sc	sc	135	154	sc	135
Cat Arm Unit 1	35	63.5	65	35	sc	35	65	sc	35
Cat Arm Unit 2	35	63.5	65	sc	sc	35	65	sc	35
Upper Salmon	75	84	84	70	64	75	84	64	75
Hinds Lake	67	75	75	off	off	67	75	off	67
Granite Canal	30	40	40	22	off	20	40	off	20
Paradise River	8	8	8	8	off	8	8	off	off
NLH - Thermal									
Hardwoods CT1	sc	sc	sc	off	sc	sc	sc	off	off
Hardwoods CT2	sc	sc	sc	off	off	off	off	off	off
Stephenville CT1	sc	sc	sc	sc	off	off	sc	off	off
NUGS									
Star Lake	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4
Rattle Brook	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
CBP&P	15	15	15	15	15	15	15	15	15
Exploits	14	14	14	14	14	14	14	14	14
Wind									
St. Lawrence	25	25	25	0	12	12	0	12	12
Fermuse	25	25	25	0	12	12	0	12	12
Goulds	25	25	25	0	12	12	0	12	12
Total Generation	1521.3	1538.5	1834.8	459.1	837.2	855.1	540.0	759.7	774.5
Transmission Losses	23.5	40.7	42.2	9.6	12.2	30.1	86.3	10.2	25.0

Notes
Bay d'Espoir plant is used as the swing bus on the Island System. Units 1 - 6 have max output of 75 MW
Bay d'Espoir Unit 7 has a max output of 154 MW
For BC8 export over infeed increased towards 430 MW until NLH generation equals max as outlined in Table.