Q. (Re: Response to CA-NLH-168) Please provide an analysis of the Happy Valley – Goose Bay demand/supply situation currently, during Muskrat Falls construction, and following Muskrat Falls construction showing that the additional 10.5 MW transfer capability afforded by facilities added for Muskrat Falls construction is of value to customers.

A. Please see CA-NLH-223, Attachment 1.

_____	_____
Approved for Release	Date

ENGINEERING BRIEF

EASTERN LABRADOR TRANSFER CAPABILITY 2013 TO 2018

Date: February 1, 2014

System Planning Department

newfoundland labrador hydro
a nalcor energy company

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1.0 INTRODUCTION

As part of Newfoundland and Labrador Hydro's (Hydro's) 2013 General Rate Application, the Consumer Advocate (CA) has made the following request for information:

> ***CA-NLH-223***
> ***(Re: Response to CA-NLH-168) Please provide an analysis of the Happy Valley – Goose Bay demand/supply situation currently, during Muskrat Falls construction, and following Muskrat Falls construction showing that the additional 10.5 MW transfer capability afforded by facilities added for Muskrat Falls construction is of value to customers.***

The purpose of this Engineering Brief is to present the transfer capability of the transmission system in eastern Labrador for the period 2013 to 2018 in response to CA-NLH-223 using the spring 2013 Labrador Interconnected Load Forecast.

The analysis is completed using the Siemens Power Technologies Int. software package PSS/E version 32.

2.0 THE TRANSMISSION SYSTEM EASTERN LABRADOR

The transmission system in eastern Labrador 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. Prior to the addition of equipment to support the construction power requirements at Muskrat Falls, the transmission system consisted 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 (HVYTS) 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 (Muskrat Falls Terminal Station 1 – MFATS1) supplying a water pumping system. The single line diagram is shown in Figure 1.

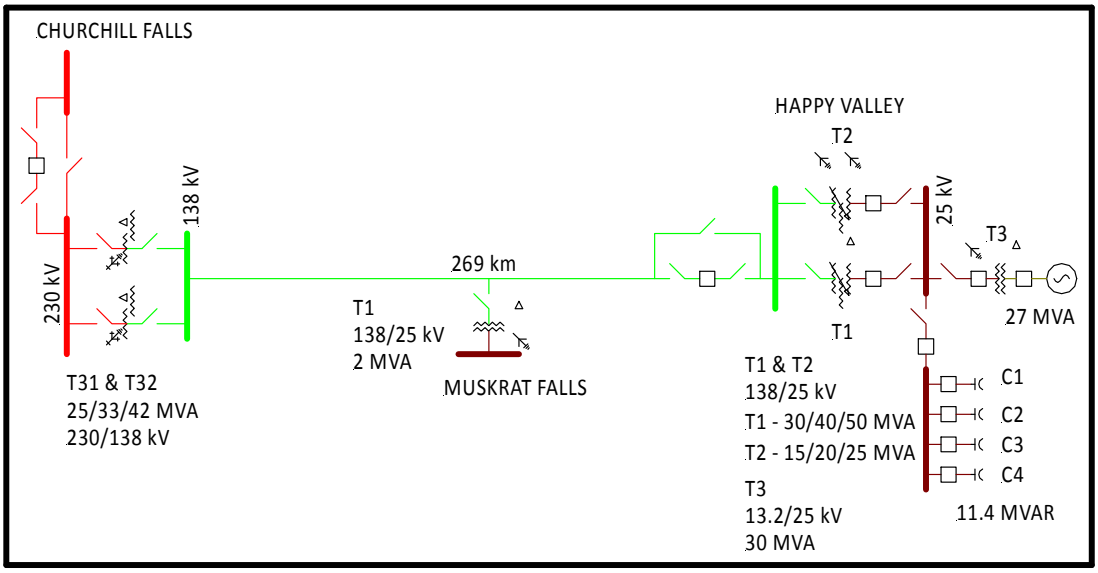

Figure 1 –Transmission System Eastern Labrador Pre Muskrat Falls Construction

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. The transformer is in tap position 3 (25 kV). 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.

Figure 2 provides a load flow plot of the existing transmission system in eastern Labrador under maximum transfer levels. With all equipment in service the system is capable of delivering up to 63 MW to Happy Valley Terminal Station. At this load level the on load tap changers (OLTCs) on HVYTS transformers T1 and T2 are in the full boost position (tap position 33 – 117,300 V – tap ratio 0.85). The resultant 25 kv bus voltage equals 25.5 kV (1.022 pu) which is the minimum acceptable voltage at the 25 kV bus to ensure acceptable voltages to customers at the remote end of the 25 kV distribution system. Beyond this load level one can expect the distribution system voltages to fall to unacceptable levels. To maintain acceptable system voltages should the load in Happy Valley - Goose Bay exceed the 63 MW level, Hydro would start the two 2.5 MW diesel generators at the North Side Diesel Plant to effect peak load reduction, and request Churchill Falls (Labrador) Corporation to increase the 230 kV bus voltage at Churchill Falls if practical to do so.

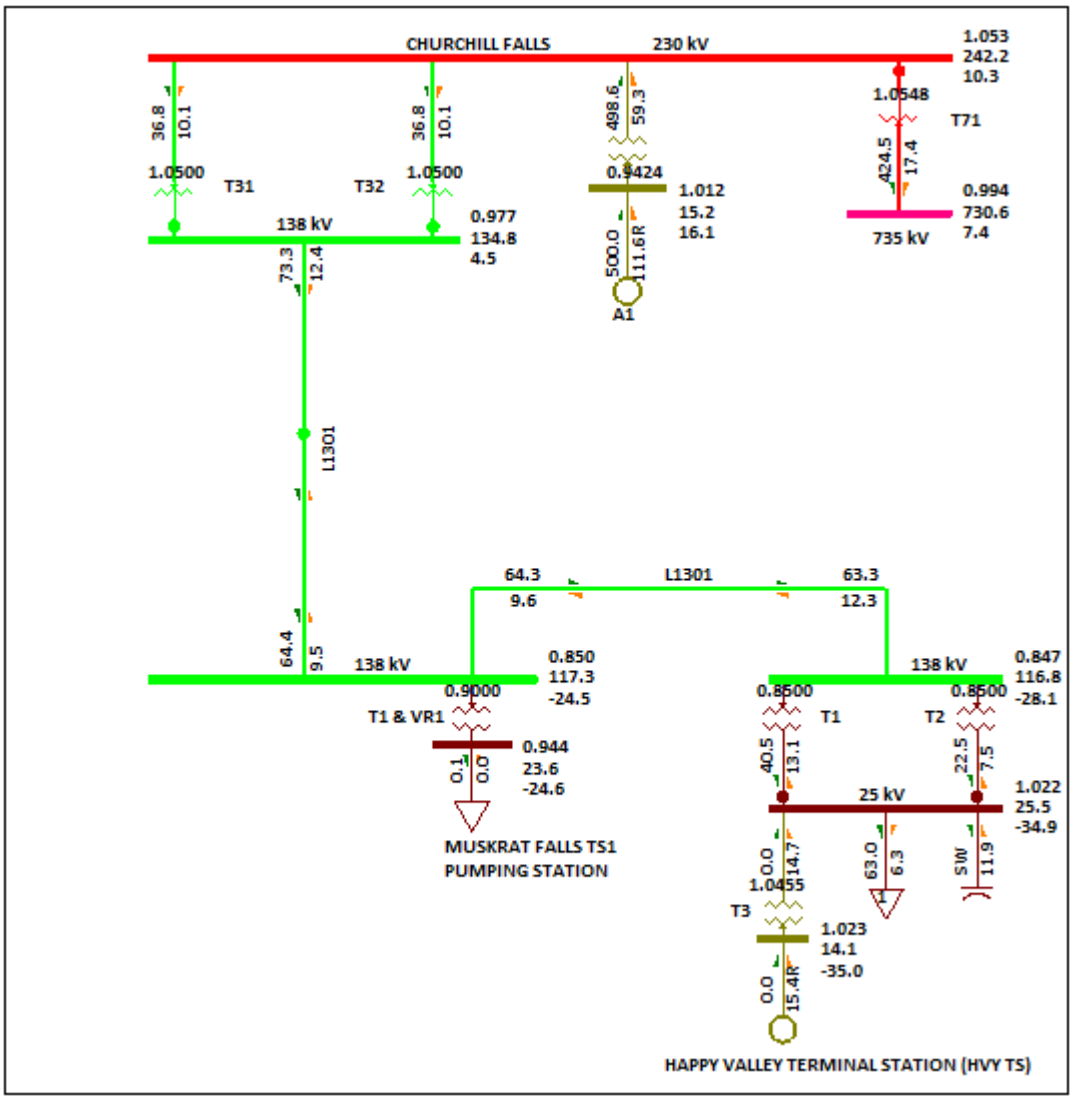

Figure 2 – Existing Transfer Limit Eastern Labrador

3.0 TRANSMISSION SYSTEM ADDITIONS FOR MUSKRAT FALLS CONSTRUCTION POWER

A number of additions have been made to the transmission system in eastern Labrador to facilitate supply of construction power at Muskrat Falls. The existing 138 kV transmission line was tapped and a new 138/25 kV terminal station (Muskrat Falls Terminal Station 3 – MFATS3) constructed. The new station includes 138 kV disconnect switches and circuit breakers for station and transmission line protection and isolation for maintenance, a 138/25 kV, 30/40/50 MVA power transformer, T1, complete with on load tap changer and six 25 kV, 3.6 MVAR switched shunt capacitor banks to provide the necessary voltage support. Given the increase in load on the 138 kV transmission line, a new 230/138 kV, 75/100/125 MVA autotransformer with an on load tap changer was installed in Churchill Falls. This new transformer replaced the existing 42 MVA T31 at Churchill Falls with the existing 42 MVA T32 remaining in place as the energized spare transformer should there be a failure of the new T31. Figure 3 provides the single line diagram of the system.

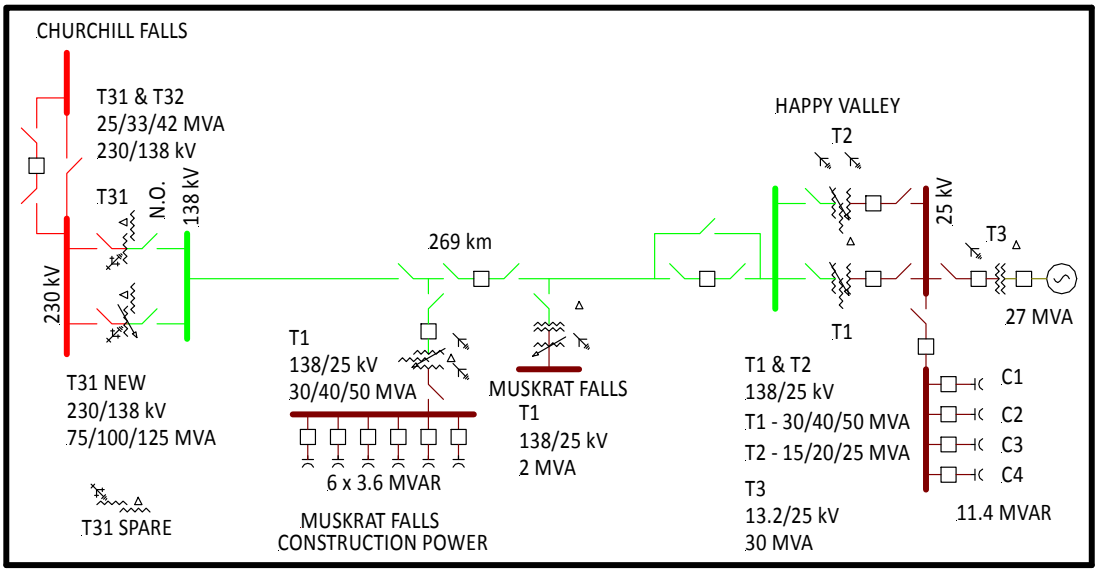

Figure 3 –Transmission System Eastern Labrador with Muskrat Falls Construction

4.0 LOAD FORECAST

The 2013 load forecast data for the transmission system in eastern Labrador are summarized in Table 1. The load figures are based upon the Spring 2013 Labrador Interconnected Load Forecast.

Table 1: Eastern Labrador Load Forecast

Year	Happy Valley – Goose Bay kW	Muskrat Falls Construction kW
2013	65,842	10,400
2014	66,820	12,600
2015	67,801	12,400
2016	68,468	8,100
2017	69,198	7,000
2018	69,648	0
2019	70,097	0

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.

Information from the Lower Churchill Project indicates a net load power factor of approximately 0.943[1] for the Muskrat Falls construction power load.

[1] The construction site load is expected to have a power factor of 0.95 and the construction camp load is expected to have a power factor of 0.975. Combined with the reactance of the connecting 25 kV distribution line the net power factor at the terminal station is estimated at 0.943.

5.0 PLANNING CRITERIA

Traditional transmission planning criteria requires that the transmission bus voltages be held between 0.95 p.u. and 1.05 p.u. of nominal voltage under normal operation (i.e. 131.1 kV to 144.9 kV) and between 0.90 p.u. and 1.10 p.u. (i.e. 124.2 kV to 151.8 kV) under contingency/emergency situations. Given that there are no intermediate customers connected to the 138 kV transmission system in eastern Labrador, the voltage criteria has been relaxed in eastern Labrador. Transmission level bus voltages are permitted to fall below 0.90 p.u. as long as the voltage support at Happy Valley provides acceptable voltages on the 25 kV distribution system.

On the distribution system:

- The Happy Valley 25 kV bus voltage must be held between 25.5 kV (1.02 p.u.) and 26.1 kV (1.044 p.u.) under normal operation to provide acceptable voltages to customers on the remote ends of the 25 kV distribution feeders;
- The Muskrat Falls (MFATS3) 25 kV bus voltage must be held between 25.7 kv (1.029 p.u.) and 26.3 kV (1.052 p.u.) to provide acceptable voltages on the remote end of the distribution feeder; and
- The Happy Valley synchronous condenser terminal voltage will not exceed 14.12 kV or 1.023 p.u.

6.0 CHURCHILL FALLS T31 TAP CHANGER LIMITATIONS

The new 230/138 kV, 75/100/125 MVA autotransformer at Churchill Falls is equipped with a 17 position on load tap changer (OLTC) on the high voltage winding having a regulating range of +5%/-15% (241.5 kV to 195.5 kV) to control the 138 kV bus voltage at Churchill Falls. Analysis indicates that with the Churchill Falls 230 kV bus voltage at 241.5 kV (1.05 p.u.) a 138 kV bus voltage of 152.3 kV (1.103 p.u.) can be expected at HVYTS under no load conditions with the Churchill Falls OLTC in tap position 3 (235,750 V – tap ratio 1.025). Therefore, permitting the T31 OLTC to move beyond tap position 3 can be expected to result in unacceptably severe over voltages on the transmission system should there be a sudden loss of load at Happy Valley – Goose Bay. Figure 4 provides the load flow plot of the case.

For analysis purposes the Churchill Falls T31 OLTC is limited to the regulating range of tap position 1 (241,500 V – tap ratio 1.05) to tap position 3 (235,750 V – tap ratio 1.025).

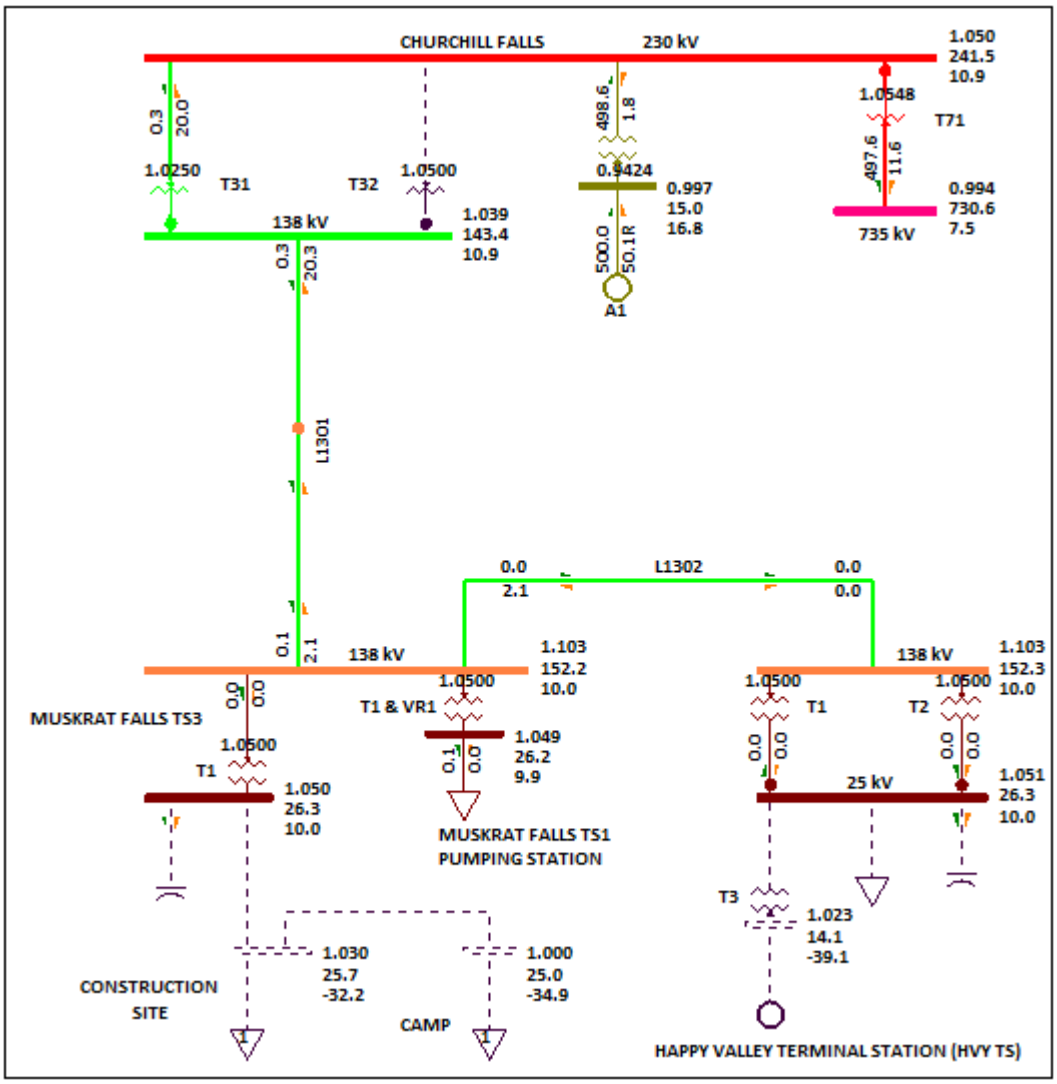

Figure 4 – Eastern Labrador at No Load – Churchill Falls T31 in Tap 3

7.0 2013 TO 2018 TRANSFERS

The following pages provide the load flow analysis of the forecast loads for the period 2013 to 2018. The load flow plots demonstrate the transfer capability of the transmission system in eastern Labrador to meet the forecast load for the study period. One must be cognizant that the transfer capacity of a given radial transmission system, such as that found in eastern Labrador, is dependent upon the sending end voltage level, the amount of voltage control equipment contained within the system and the power factor of the load to be supplied. Reducing the sending end bus voltage will reduce the quantity of load that can be supplied if acceptable bus voltages are to be maintained at the receiving end.

7.1 2013 Peak Load

The forecast peak for 2013 includes a HVYTS load of 65.8 MW and a MFATS3 load of 10.4 MW. Figure 5 provides the load flow plot. With Churchill Falls T31 in tap position 1 acceptable 25 kV bus voltages are observed at both MFATS3 and HVYTS – 26.2 kV (1.05 p.u.) and 25.8 kV (1.033 p.u.) respectively. Neither OLTC at MFATS3 or HVYTS are in the maximum tap position of 33 (117,300 V – tap ratio 0.85), indicating additional load can be accommodated.

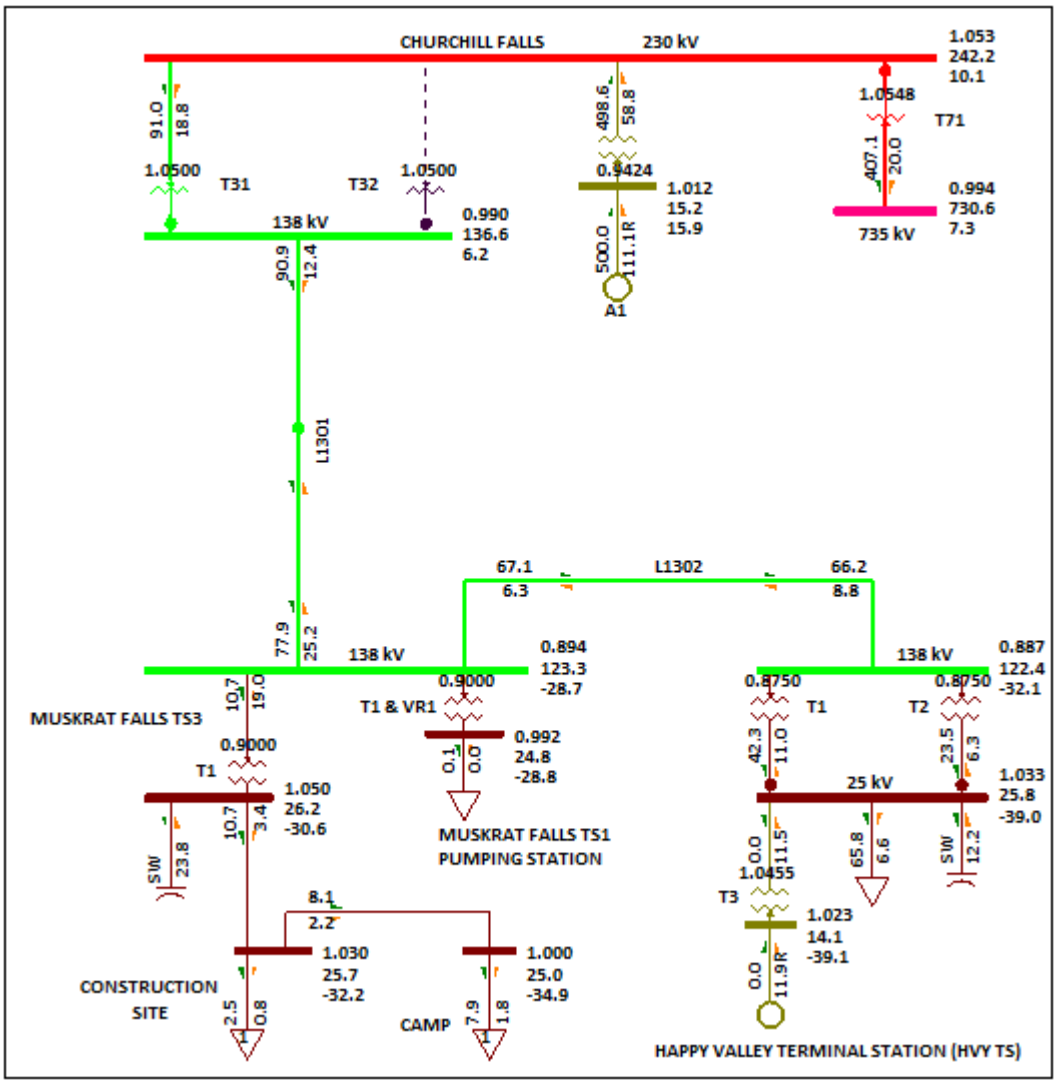

Figure 5 – 2013 Peak Load Case

7.2 2014 Peak Load

The forecast peak for 2014 includes a HVYTS load of 66.8 MW and a MFATS3 load of 12.6 MW. Figure 6 provides the load flow plot. With Churchill Falls T31 in tap position 2 (238,625 V – tap ratio 1.0375) acceptable 25 kV bus voltages are observed at both MFATS3 and HVYTS – 25.9 kV (1.037 p.u.) and 25.5 kV (1.018 p.u.) respectively. The HVYTS T1 and T2 OLTCs are in the maximum tap position of 33 (117,300 V – tap ratio 0.85). The MFATS3 T1 OLTC is in tap position 31 (119,025 V – tap ratio 0.8625).

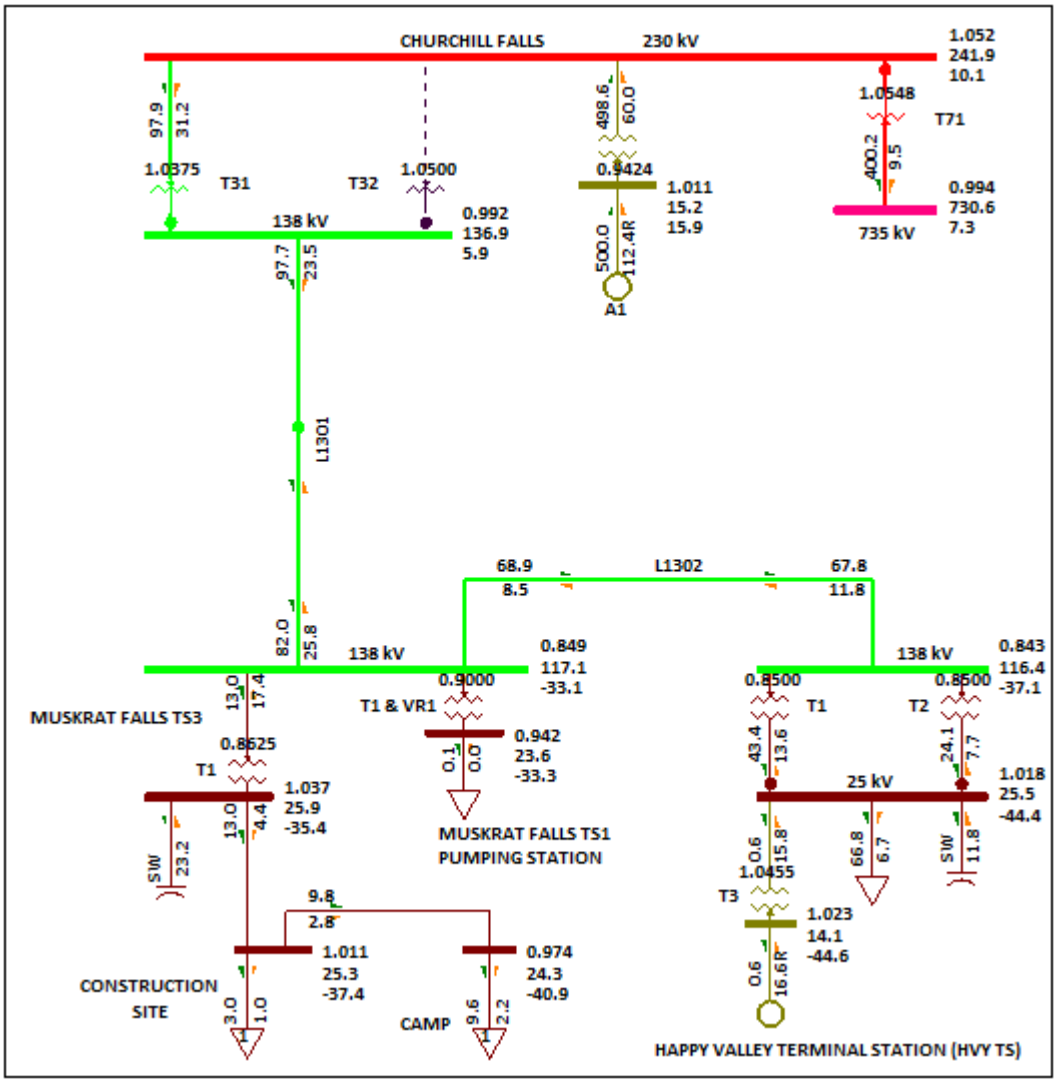

Figure 6 - 2014 Peak Load Case

7.3 2015 Peak Load

The forecast peak for 2015 includes a HVYTS load of 67.8 MW and a MFATS3 load of 12.4 MW. Figure 7 provides the load flow plot. With Churchill Falls T31 in tap position 3 (235,750 V – tap ratio 1.025) acceptable 25 kV bus voltages are observed at both MFATS3 and HVYTS – 26.3 kV (1.051 p.u.) and 25.6 kV (1.025 p.u.) respectively. The HVYTS T1 and T2 OLTCs are in the maximum tap position of 33 (117,300 V – tap ratio 0.85). The MFATS3 T1 OLTC is in tap position 31 (119,025 V – tap ratio 0.8625).

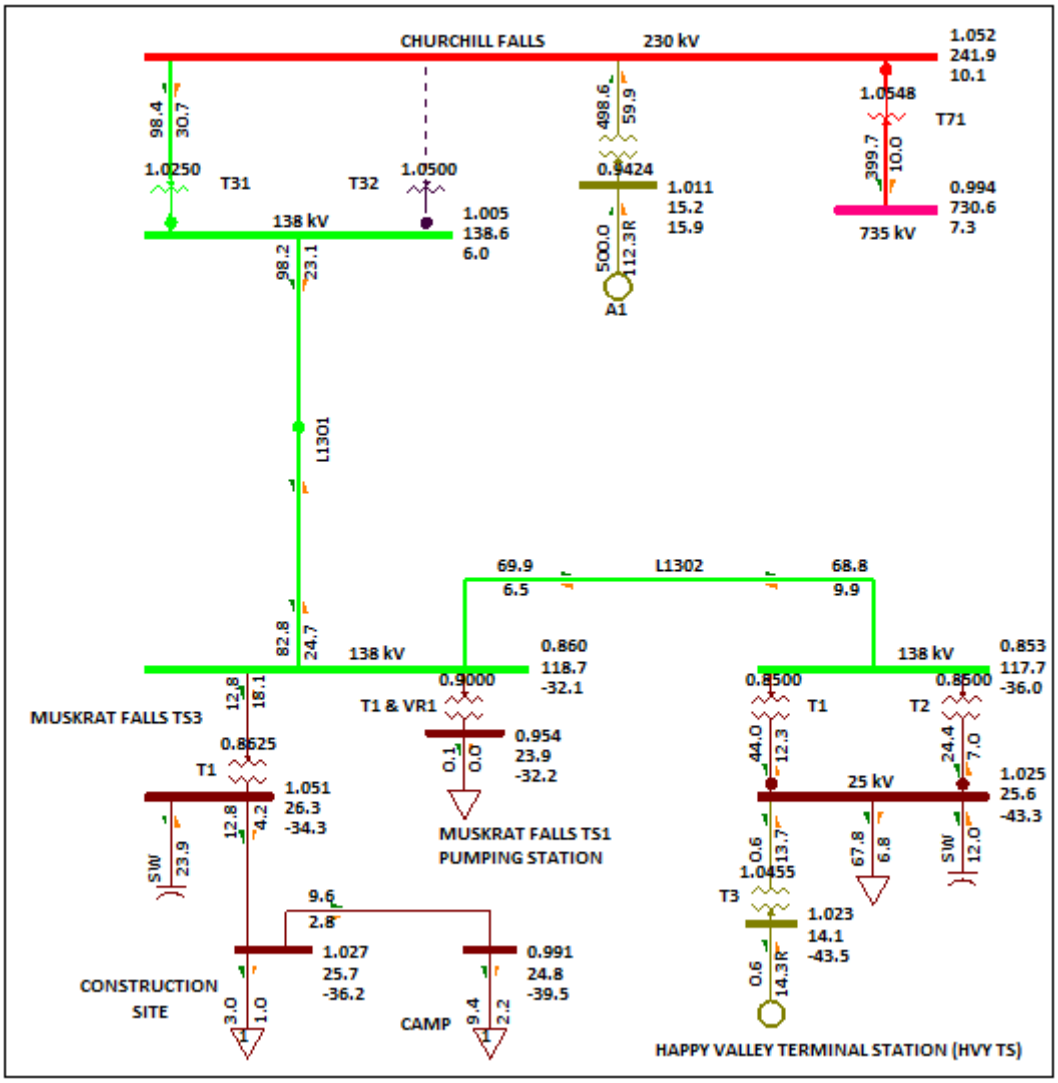

Figure 7 - 2015 Peak Load Case

7.4 2016 Peak Load

The forecast peak for 2016 includes a HVYTS load of 68.4 MW and a MFATS3 load of 8.1 MW. Figure 8 provides the load flow plot. The total system load in 2016 is forecast to be less than that of 2015 (2016 76.5 MW vs 2015 80.2 MW). Therefore with Churchill Falls T31 in tap position 1 (241,500 V – tap ratio 1.05) acceptable 25 kV bus voltages are observed at both MFATS3 and HVYTS – 26.1 kV (1.043 p.u.) and 25.7 kV (1.030 p.u.) respectively. The HVYTS T1 and T2 OLTCs are in the maximum tap position of 33 (117,300 V – tap ratio 0.85). The MFATS3 T1 OLTC is in tap position 28 (121,613 V – tap ratio 0.88125).

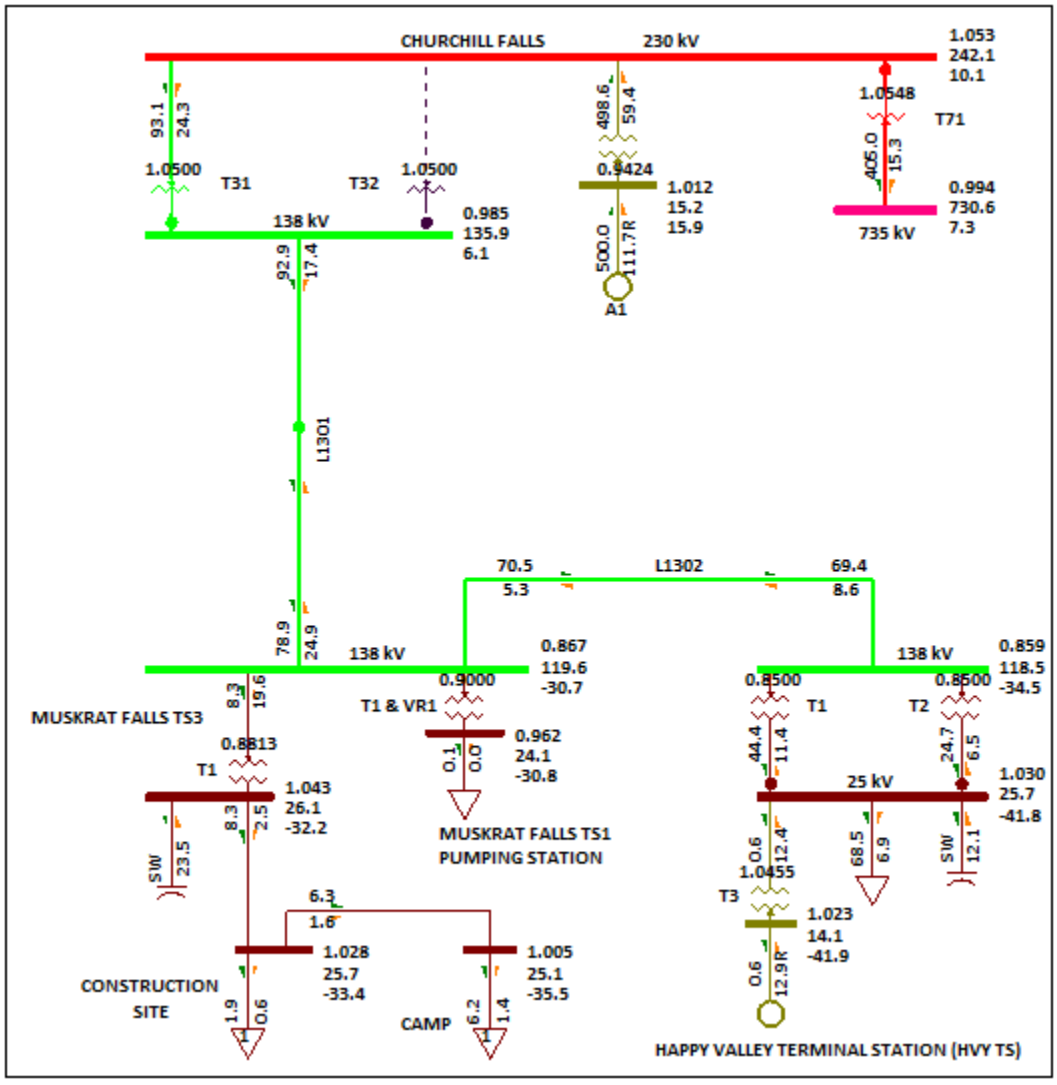

Figure 8 - 2016 Peak Load Case

7.5 2017 Peak Load

The forecast peak for 2017 includes a HVYTS load of 69.2 MW and a MFATS3 load of 7.0 MW. Figure 9 provides the load flow plot. With Churchill Falls T31 in tap position 1 (241,500 V – tap ratio 1.05) acceptable 25 kV bus voltages are observed at both MFATS3 and HVYTS – 26.0 kV (1.040 p.u.) and 25.8 kV (1.031 p.u.) respectively. The HVYTS T1 and T2 OLTCs are in the maximum tap position of 33 (117,300 V – tap ratio 0.85). The MFATS3 T1 OLTC is in tap position 29 (120,750 V – tap ratio 0.8875).

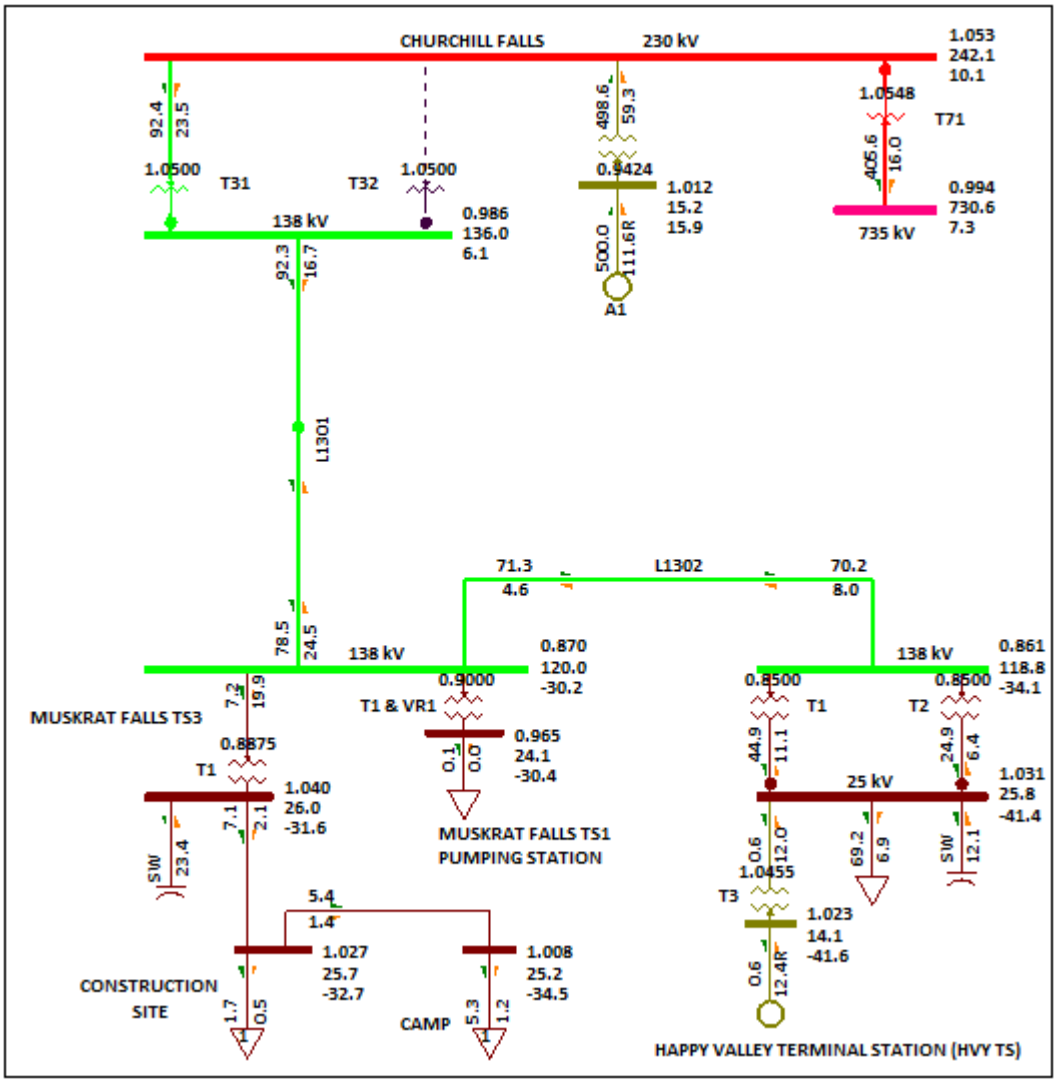

Figure 9 - 2017 Peak Load Case

7.6 2018 Peak Load

The forecast peak for 2018 includes a HVYTS load of 69.6 MW. The MFATS3 load is set at 0 MW as the construction program is complete. However, the MFATS3 transformer and six 3.6 MVAR capacitor banks are kept in service to support the system voltage and HVYTS load. One will recall that prior to the addition of the equipment at MFATS3 the transfer capacity of the transmission system in eastern Labrador was 63 MW. Figure 10 provides the load flow plot of the 2018 peak load case with a 69.6 MW transfer. With Churchill Falls T31 in tap position 1 (241,500 V – tap ratio 1.05) acceptable 25 kV bus voltages are observed at both MFATS3 and HVYTS – 26.2 kV (1.048 p.u.) and 25.9 kV (1.038 p.u.) respectively. The HVYTS T1 and T2 OLTCs are in tap position of 17 (131,100 V – tap ratio 0.95). The MFATS3 T1 OLTC is in tap position 9 (138,000 V – tap ratio 1.000) permitting maximum reactive power flow from the capacitor banks into the transmission system. Given the position of the HVYTS T1 and T2 OLTCs, additional HVYTS load can be transmitted before low voltages will be experienced.

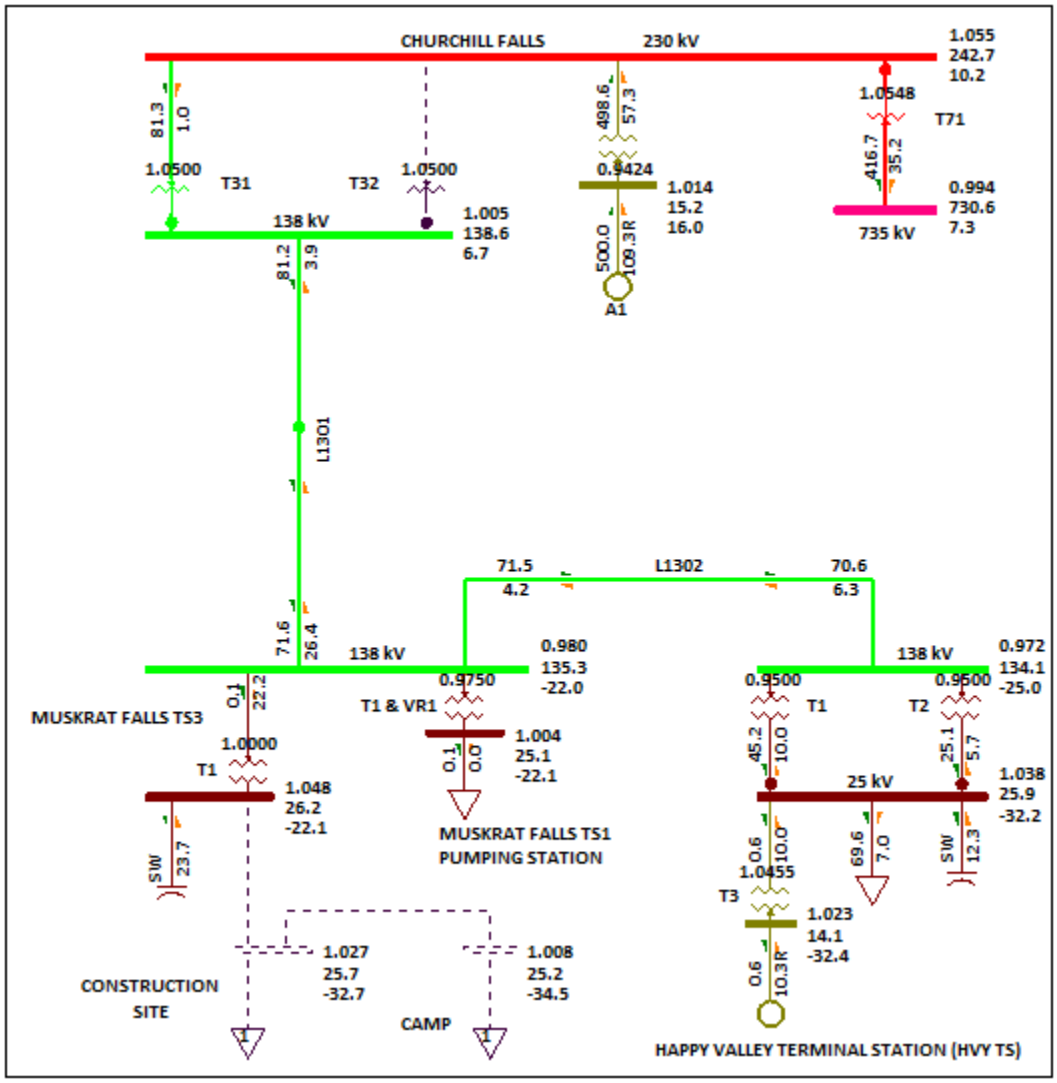

Figure 10 - 2018 Peak Load Case

8.0 MAXIMUM TRANSFER CAPABILITY

Figure 11 provides the load flow plot of a maximum transfer limit for the transmission system in eastern Labrador assuming the equipment installed for the Muskrat Falls construction power remains in service following completion of the development. With the Churchill Falls 230 kV bus voltage set at 241.5 kV (1.050 p.u.), the T31 OLTC in tap position 3 (235,750 V – tap ratio 1.025), and all voltage support equipment in service, a maximum load of 79.0 MW can be delivered at the HVYTS 25 kV bus. For the 79 MW load level, the HVYTS T1 and T2 OLTCs are in the maximum tap position of 33 (117,300 V – tap ratio 0.85) to maintain a minimum acceptable 25 kV bus voltage of 25.5 kV (1.021 p.u.).

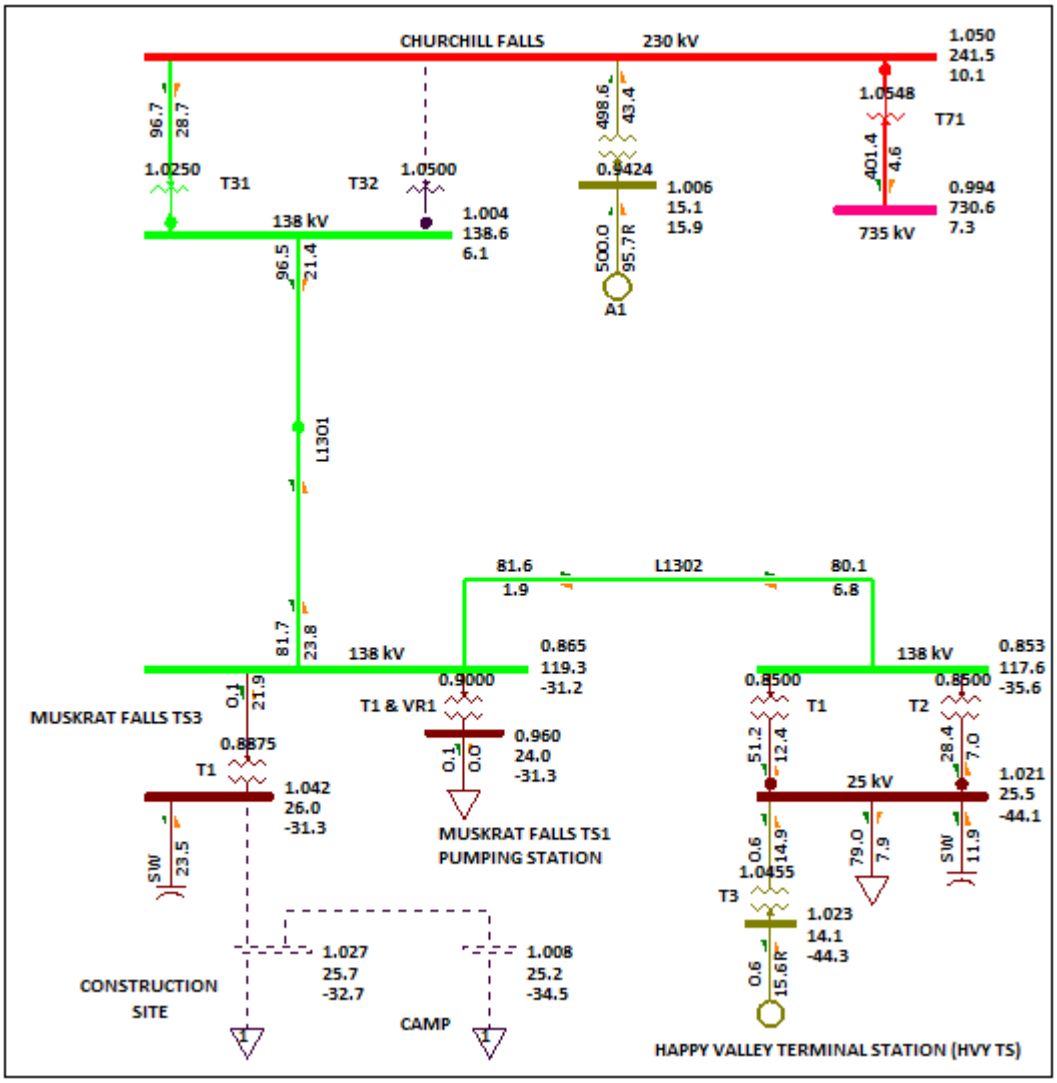

Figure 11 – Maximum Transfer Case

9.0 SUMMARY

The analysis presented in this Engineering Brief demonstrates a maximum transfer capability of the existing transmission system in eastern Labrador of 63 MW.

A 138/25 kV terminal station (Muskrat Falls Terminal Station 3 – MFATS3) including six 25 kV, 3.6 MVAR switched shunt capacitor banks and a new 230/138 kV, 75/100/125 MVA autotransformer with an on load tap changer to control the 138 kV bus voltage at Churchill Falls have been added to the transmission system to permit supply of the construction power load.

Load flow analysis of the combined Happy Valley – Goose Bay and Muskrat Falls construction power loads for the period 2013 to 2017 indicate that the transmission system is able to transfer the required load with the system additions.

Load flow analysis indicates that following the completion of the Muskrat Falls construction phase use of the new Churchill Falls T31 and shunt capacitor banks at MFATS3 are required to deliver the 2018 Happy Valley – Goose Bay load.

Load flow analysis has set the maximum transfer capacity of the transmission system in eastern Labrador at 79 MW assuming a Churchill Falls sending end bus voltage of 241.5 kV (1.05 p.u.) and all equipment added for Muskrat Falls construction power in service.

In summary, the results of the analysis contained within this Engineering Brief demonstrate the capability of the transmission system in eastern Labrador to supply the load during the Muskrat Falls construction phase and the benefit the newly installed equipment will have for the Happy Valley – Goose Bay customers following completion of the project.