newfoundland labrador hydro
a nalcor energy company

Hydro Place. 500 Columbus Drive.
P.O. Box 12400. St. John's. NL
Canada A1B 4K7
t. 709.737.1400 f. 709.737.1800
www.nlh.nl.ca

July 12, 2018

The Board of Commissioners of Public Utilities
Prince Charles Building
120 Torbay Road, PO Box 21040
St. John's, NL A1A 5B2

**Attention: Ms. Cheryl Blundon**
**Director of Corporate Services and Board Secretary**

Dear Ms. Blundon:

**Re: The Board's Investigation and Hearing into Supply Issues and Power Outages on the Island Interconnected System —Operational Studies —Stage 3 reports**

Further to Hydro's correspondence of August 4, 2017, please find attached the following report:

- Operational Study —Stage 3 —LIL Power Transfer with MFA Filter Switching (phased monopole approach)

Should you have any questions, please contact the undersigned.

Yours truly,

***NEWFOUNDLAND AND LABRADOR HYDRO***

Michael Ladha
Legal Counsel & Assistant Corporate Secretary

ML/bs

cc: Gerard Hayes – Newfoundland Power
Paul Coxworthy – Stewart McKelvey Stirling Scales
Dennis Brown, Q.C. – Consumer Advocate
Danny Dumaresque
ecc: Roberta Frampton Benefiel – Grand Riverkeeper® Labrador
Larry Bartlett – Teck Resources Limited
Denis Fleming – Cox & Palmer

**Engineering Support Services for:**

# RFI Studies

## Newfoundland and Labrador Hydro

**Attention:** Mr. Rob Collett

# LIL Power Transfer with MFA Filter Switching (phased monopolar approach)

**Technical Note:** TN1205.60.03
**Date of issue:** June 25, 2018

**Prepared By:**
**TransGrid Solutions Inc.**
100-78 Innovation Dr.
Winnipeg, MB R3T 6C2
CANADA

# Disclaimer

This technical note was prepared by TransGrid Solutions Inc. ("TGS"), whose responsibility is limited to the scope of work as shown herein. TGS disclaims responsibility for the work of others incorporated or referenced herein. This technical note has been prepared exclusively for Newfoundland and Labrador Hydro and the project identified herein and must not be reused or modified without the prior written authorization of TGS.

# Revisions

| | |
|---|---|
| Project Name: | RFI Studies |
| Document Title: | LIL Power Transfer with MFA Filter Switching (phased monopolar approach) |
| Document Type: | Technical Note |
| Document No.: | TN1205.60.03 |
| Last Action Date: | June 25, 2018 |

| Rev. No. | Status | Prepared By | Checked By | Date | Comments |
|---|---|---|---|---|---|
| 00 | DFC | R. Brandt, R. Ostash | R. Ostash | April 4, 2018 | Preliminary draft Issued for review by Hydro |
| 01 | IFA | R. Brandt, R. Ostash | R. Ostash | April 9, 2018 | Updated report based on comments received from Hydro on April 9, 2018. |
| 02 | IFA | R. Brandt, R. Ostash | R. Ostash | June 11, 2018 | Updated report based on comments received from Hydro on April 30, 2018. |
| 03 | ABC | R. Brandt, R. Ostash | R. Ostash | June 25, 2018 | Updated report based on comments received and approval from Hydro on June 25, 2018. |

**Legend of Document Status:**

| | |
|---|---|
| Approved by Client | ABC |
| Draft for Comments | DFC |
| Issued for Comments | IFC |
| Issued for Approval | IFA |
| Issued for Information | IFI |
| Returned for Correction | RFC |
| Approval not Required | ANR |

# Table of Contents

**1. Summary ..... 1**
1.1 Monopolar Operation ..... 1
1.2 Bipolar Operation ..... 2
**2. Background ..... 3**
2.1 Previous Study - Limiting LIL Power Transfer ..... 3
2.2 Previous Study – Using SPS to Cross-trip LIL ..... 3
**3. Study Models and Criteria ..... 5**
3.1 Labrador System ..... 5
3.2 LIL ..... 5
3.3 Study Criteria ..... 5
3.4 PSSE Base Cases ..... 6
**4. Study Results – LIL Monopole ..... 7**
4.1 Overvoltages: Loss of MFA Reactor ..... 7
4.2 Undervoltages: Loss of L3101 or L3102 ..... 8
**5. Study Results – LIL Bipole ..... 10**
5.1 Loss of MFA Reactor ..... 10
5.2 Loss of 315 kV CHF-MFA line ..... 11
**6. Conclusions ..... 12**
6.1 Monopolar Operation ..... 12
6.2 Bipolar Operation ..... 13

# 1. Summary

Previous operational studies[1] identified steady state voltage violations at Muskrat Falls (MFA) during the phased monopolar approach. Voltages >1.1 pu could occur if the MFA reactor tripped, and voltages <0.9 pu could occur if one of the two 315 kV lines from Muskrat Falls to Churchill Falls (L3101 or L3102) tripped. These studies assumed that both MFA filters were required to be in-service, and if one of the filters tripped, the LIL and the MFA reactor would also automatically trip. To maximize power transfer, a special protection scheme (SPS) was therefore proposed to cross-trip the LIL, filters, and the reactor if line L3101 or L3102 tripped or to cross-trip the LIL and filters if the MFA reactor tripped.

It has since been determined that the LIL monopole can operate up to 225 MW with only one MFA filter in-service[2], and that the undervoltage trip setting for the MFA reactor could be set to switch the reactor off if the steady state voltage at MFA goes below 0.9 pu.

Further, Hydro has advised that a capital project involving the Muskrat Falls-Happy Valley Interconnection was not approved. Rather than being supplied via a 315 kV interconnection at Muskrat Falls, Happy Valley load will continue to be supplied from Churchill Falls. The modification of this assumption requires that voltage regulation of the transmission system be reassessed.

This report updates the analysis on the steady state voltage issues at Muskrat Falls based on this latest information.

## 1.1 Monopolar Operation

This analysis determined an operating guideline for the monopole that specifies the number of filters that should be in-service at Muskrat Falls (based on LIL power transfer and Labrador operating conditions) in order to prevent overvoltage if the MFA reactor trips.

Table 1-1 lists the LIL power transfer at which two MFA filters can be in-service. Only one MFA filter should be in-service for LIL power transfers below these levels, including the orange cells which can have only one MFA filter in-service at LIL transfer of 225 MW. Slight overvoltages will still occur in these cases (orange cells) if the MFA reactor trips.

**Table 1-1. LIL power transfer to switch 2nd filter in-service**

| HVY load (MW)[3] | CHF voltage (pu) | | | |
|---|---|---|---|---|
| | 0.975 | 0.985 | 0.995 | 1.005 |
| | LIL Power Transfer (MW) | | | |
| 0 | 175 | 215 | >225 | >225 |
| 10 | 175 | 210 | >225 | >225 |
| 15 | 170 | 210 | >225 | >225 |
| 25 | 160 | 205 | >225 | >225 |

[1] TGS report TN1205.54.01, "Operational Studies: Maritime Link, SOP Syncs and LIL Monopole", Feb. 2, 2018.
TGS report TN1205.55.01, "Maximization of LIL Power Transfer using SPS (phased monopolar approach)", Mar. 5, 2018.

[2] TGS report TN1205.57.01, "AC Filter Operational Limits Study", April 9, 2018.

[3] As noted above, the MFA-HVY Interconnection was not approved. Cases with more than 0 MW of Happy Valley load are provided for reference only.

| HVY load (MW)[3] | CHF voltage (pu) | | | |
|---|---|---|---|---|
| | 0.975 | 0.985 | 0.995 | 1.005 |
| | LIL Power Transfer (MW) | | | |
| 35 | 155 | 195 | 220 | >225 |
| 45 | 150 | 175 | 210 | >225 |
| 55 | 130 | 175 | 205 | >225 |
| 65 | 125 | 155 | 185 | 225 |
| 75 | 105 | 145 | 175 | 210 |
| 80 | 100 | 135 | 165 | 205 |
| 90 | 75 | 110 | 160 | 180 |
| 100 | 55 | 105 | 140 | 170 |

This operating guideline, together with the fact that the MFA reactor has been configured to trip upon undervoltage detection when the steady state voltage drops below 0.9 pu, ensure acceptable voltage regulation of the transmission system. This will allow the LIL to operate over the full range of 45 MW to 225 MW under all Labrador operating conditions during the phased monopolar approach.

The following worst-case violations are summarized as follows:

1. Under highest voltage system conditions, i.e. with no load at Happy Valley, Churchill Falls 735 kV voltage at 1.005 pu and LIL transferring minimum power of 45 MW, a **1.12 pu** overvoltage occurs at MFATS2 if the MFA reactor trips (with only one MFA filter in-service).
2. Under lowest voltage system conditions, i.e. with 100 MW load at Happy Valley, Churchill Falls 735 kV voltage at 0.975 pu and LIL transferring maximum power of 225 MW, a **0.87 pu** undervoltage occurs at MFATS2 if line L3101 or L3012 trips (with two MFA filters in-service). [4]

## 1.2 Bipolar Operation

Bipolar operation up to 225 MW will require that two filters be in service at MFA. This will require the implementation of a reactive power controller for the LIL. Such a controller would trigger the rapid automatic removal of filters to keep voltages within acceptable limits. As rapid filter removal would result in unacceptable harmonic distortion, a pole would have to be subsequently tripped.

[4] This is no longer a consideration as the MFA-HVY Interconnection was not approved.

# 2. Background

This section is for information only. It presents the LIL transfer limits that were previously imposed by the other studies that assumed that both MFA filters were required to be in-service for the LIL to operate.

## 2.1 Previous Study - Limiting LIL Power Transfer

A previous study identified the LIL power transfer limits to keep the voltage at Muskrat Falls above 0.9 pu in case L3101 or L3102 trips, assuming that the MFA reactor cannot be tripped. These LIL power transfer limits are provided in Table 2-1. The limits are given over the expected operating range of Churchill Falls 735 kV voltage and Happy Valley load (being fed off Muskrat Falls 138 kV tap).

**Table 2-1. LIL power transfer limits from previous study[5]**

| | CHF Voltage (pu) | | | |
|---|---|---|---|---|
| HVY Load (MW) | 0.975 | 0.985 | 0.995 | 1.005 |
| | LIL Transfer (MW) | | | |
| 35 | 145 | 160 | 175 | 185 |
| 45 | 135 | 150 | 160 | 175 |
| 55 | 125 | 140 | 150 | 165 |
| 65 | 115 | 128 | 140 | 155 |
| 75 | 100 | 115 | 125 | 135 |
| 80 | 95 | 108 | 120 | 130 |
| 90 | 80 | 93 | 105 | 118 |
| 100 | 65 | 75 | 86 | 103 |

## 2.2 Previous Study – Using SPS to Cross-trip LIL

In order to increase the allowable LIL power transfer, another study was performed in which an SPS was used to trip the LIL, its filters and the reactor if line L3101 or L3102 trips or is out-of-service. With this SPS in place, Table 2-2 summarizes the increased power transfer limits for the LIL compared to Table 2-1.

[5] In order to keep MFATS2 voltage above 0.9 pu following loss of L3101 or L3102, in accordance with Transmission Planning Criteria.

**Table 2-2. LIL Power Transfer Limits using SPS if L3101 or L3102 trips**

| SPS in place | System Condition | LIL Transfer Limit [6,7] | | | | |
|---|---|---|---|---|---|---|
| Cross-trip LIL, filters and reactor for loss of L3101 or L3102 | ML (and ML frequency controller) in-service | | CHF Voltage (pu) | | | |
| | | HVY Load (MW) | 0.975 | 0.985 | 0.995 | 1.005 |
| | | | LIL Transfer (MW) | | | |
| | | 35 | 225 | 225 | 225 | 225 |
| | | 45 | 220 | 225 | 225 | 225 |
| | | 55 | 215 | 225 | 225 | 225 |
| | | 65 | 205 | 220 | 225 | 225 |
| | | 75 | 185 | 210 | 225 | 225 |
| | | 80 | 180 | 202 | 225 | 225 |
| | | 90 | 165 | 190 | 215 | 225 |
| | | 100 | 155 | 175 | 200 | 225 |
| | ML (or ML frequency controller) out-of-service | | CHF Voltage (pu) | | | |
| | | HVY Load (MW) | 0.975 | 0.985 | 0.995 | 1.005 |
| | | | LIL Transfer (MW) | | | |
| | | 35 | 200 | 200 | 200 | 200 |
| | | 45 | 200 | 200 | 200 | 200 |
| | | 55 | 200 | 200 | 200 | 200 |
| | | 65 | 200 | 200 | 200 | 200 |
| | | 75 | 185 | 200 | 200 | 200 |
| | | 80 | 180 | 200 | 200 | 200 |
| | | 90 | 165 | 190 | 200 | 200 |
| | | 100 | 155 | 175 | 200 | 200 |

[6] Orange cells – Limit LIL power transfer in order to maintain 0.95 pu voltage during n-0 conditions
[7] Green cells – Limit LIL power transfer in order to prevent Island frequency from dropping below 58 Hz following the loss of the LIL

# 3. Study Models and Criteria

The Labrador system is the area of focus for this study[8].

## 3.1 Labrador System

No Muskrat Falls (MFA) generators were in-service for this study.

The Labrador system around Muskrat Falls is shown in Figure 3-1[9].

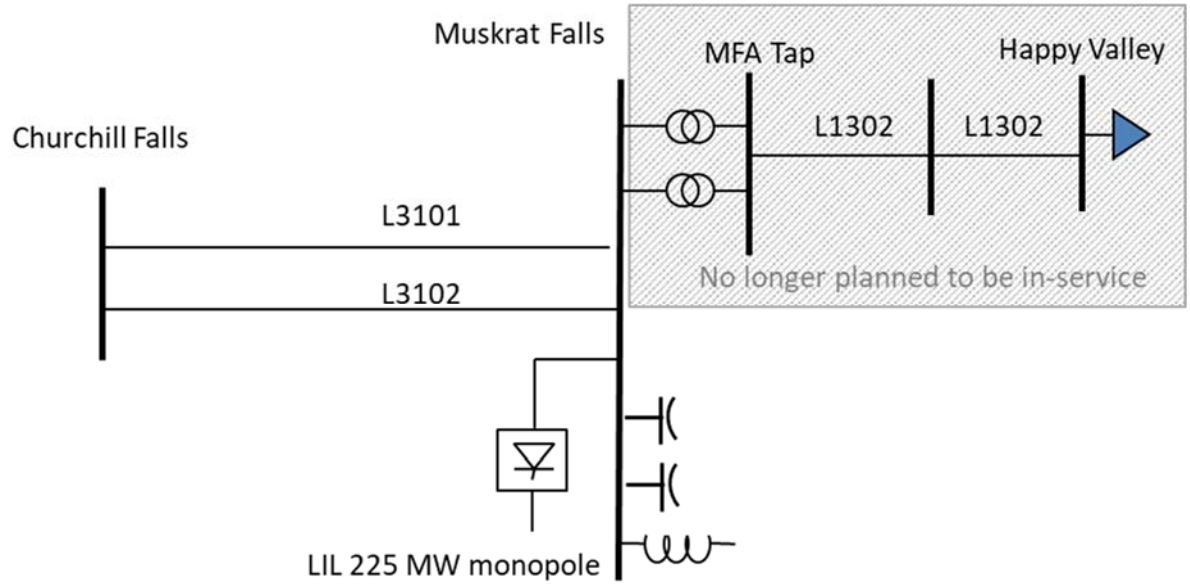


**Figure 3-1. Labrador system near Muskrat Falls**

## 3.2 LIL

It was assumed that the following LIL reactive power elements were available

- MFA: 2x72 MVAR filters (both Type A), 1x150 MVAR reactor
- SOP: 2x75 MVAR filters (one Type A, one Type B)

## 3.3 Study Criteria

The applicable Transmission Planning Criteria for this study is summarized as follows:

- Steady state voltage : 0.95 pu – 1.05 pu during n-0 conditions
- Steady state voltage : 0.90 pu – 1.1 pu during n-1 conditions

[8] Considerations relating to the Interconnected Island System are presented in Operational Studies: Maritime Link, SOP Syncs and LIL Monopole.
[9] The MFA-HVY Interconnection was not approved, however, analysis was performed to assess the impact of HVY loads for reference purposes.

## 3.4 PSSE Base Cases

Table 3-1 lists the base cases that were used to analyze the Labrador system in this study.

**Table 3-1: Base cases provided by Hydro**

| Number | Load Condition | Island Demand (MW) | LIL LAB to NF Flow (MW) |
|---|---|---|---|
| MON1 | Peak | 1727.8 | 225 |
| MON3 | Intermediate | 1246.2 | 225 |
| MON5 | Light | 762.9 | 225 |

The Happy Valley load and the Churchill Falls 735 kV bus voltage were varied in these bases cases in order to study the system over the expected operating ranges:

- Churchill Falls 735 kV voltage – from 0.975 pu to 1.005 pu
- Happy Valley load – from 0 MW to 100 MW[10]

[10] The MFA-HVY Interconnection was not approved, however, analysis was performed to assess the impact of HVY loads for reference purposes. Study results with a Happy Valley load of 0 MW therefore reflect actual system conditions.

# 4. Study Results – LIL Monopole

Loss of the MFA reactor and loss of one of the 315 kV MFA-CHF lines (L3101 or L3102) were tested over the full range of Labrador operating conditions, with Happy Valley load from 0 MW to 100 MW, and Churchill Falls 735 kV voltage from 0.975 pu to 1.005 pu. The goal was to determine how many MFA filters should be in-service for every operating condition in order to avoid overvoltages in case the MFA reactor trips. These same operating conditions were then tested to ensure that loss of one of the 315 kV MFA-CHF lines does not result in undervoltage, assuming the reactor is armed to trip if steady state voltage goes below 0.9 pu.

It should be noted that the results of the harmonic performance study[11] showed that the harmonic performance requirements at Muskrat Falls are met with only one filter in-service at MFA.

## 4.1 Overvoltages: Loss of MFA Reactor

Table 4-1 shows the LIL power transfer at which two MFA filters can be in-service without resulting in overvoltages in the MFA reactor trips. If the LIL power transfer level is lower than the value listed in Table 4-1, then only one MFA filter should be in-service for those Labrador system conditions.

**Table 4-1. LIL power transfer to switch 2nd filter in-service**

| HVY load (MW) | CHF voltage (pu) | | | |
|---|---|---|---|---|
| | 0.975 | 0.985 | 0.995 | 1.005 |
| | power over LIL (MW) | | | |
| 0 | 175 | 215 | >225 | >225 |
| 10 | 175 | 210 | >225 | >225 |
| 15 | 170 | 210 | >225 | >225 |
| 25 | 160 | 205 | >225 | >225 |
| 35 | 155 | 195 | 220 | >225 |
| 45 | 150 | 175 | 210 | >225 |
| 55 | 130 | 175 | 205 | >225 |
| 65 | 125 | 155 | 185 | 225 |
| 75 | 105 | 145 | 175 | 210 |
| 80 | 100 | 135 | 165 | 205 |
| 90 | 75 | 110 | 160 | 180 |
| 100 | 55 | 105 | 140 | 170 |

Please note that the cells in orange can have only one MFA filter in-service all the way up to LIL transfer of 225 MW, and even with only one filter in-service they will still experience slight violations of overvoltage criteria if the MFA reactor trips. The worst-case overvoltage that would occur is 1.12 pu with 0 MW Happy Valley load, CHF voltage of 1.005 pu and minimum LIL power transfer of 45 MW.

11

## 4.2 Undervoltages: Loss of L3101 or L3102

LIL power transfers of 225 MW were checked (with either 1 or 2 filters in-service according to the requirements in Table 4-1) to ensure that the voltage can remain above 0.9 pu following the loss of one of the 315 kV lines, assuming that the reactor will trip if voltage goes below 0.9 pu. In all cases, two MFA filters were in-service, except for the orange cells from Table 4-1 in which only one MFA filter should be in-service at 225 MW.

Table 4-2 summarizes the voltage at MFATS2 that occurs when a 315 kV line is out-of-service. In all cases, the reactor had to be placed out-of-service to keep the voltage above 0.9 pu. There was only one undervoltage violation (red text) that occurred even after placing the reactor out-of-service; with 100 MW Happy Valley load, CHF voltage of 0.975 pu and LIL transfer of 225 MW, the voltage at MFATS2 was 0.872 pu following loss of L3101.

**Table 4-2. LIL 225 MW power transfer with two filters in-service following trip of 315 kV line and 150 MVAR reactor**

| HVY load (MW) | CHF voltage (pu) | | | |
|---|---|---|---|---|
| | 0.975 | 0.985 | 0.995 | 1.005 |
| | MFA voltage (pu) | | | |
| 0 | 1.061 | 1.076 | N/A | N/A |
| 10 | 1.050 | 1.069 | N/A | N/A |
| 15 | 1.047 | 1.063 | N/A | N/A |
| 25 | 1.035 | 1.050 | N/A | N/A |
| 35 | 1.003 | 1.045 | 1.053 | N/A |
| 45 | 1.015 | 1.023 | 1.047 | N/A |
| 55 | 0.997 | 1.014 | 1.030 | N/A |
| 65 | 0.973 | 0.998 | 1.014 | 1.034 |
| 75 | 0.958 | 0.976 | 1.001 | 1.018 |
| 80 | 0.938 | 0.980 | 0.979 | 1.005 |
| 90 | 0.910 | 0.944 | 0.961 | 0.979 |
| 100 | 0.872 | 0.904 | 0.931 | 0.959 |

Additionally, all of the operating points from Table 4-1 that had only one MFA filter in-service (i.e. the filter switching points) were also checked at the maximum LIL power transfer that can occur with only one filter in-service to make sure that loss of a 315 kV will still meet criteria in those cases as well. Table 4-3 summarizes these results. In all cases, the reactor was placed out-of-service to keep the voltage above 0.9 pu. All voltages remained above 0.9 pu.

**Table 4-3. LIL maximum power transfer with one filter in-service following trip of 315 kV line and 150 MVAR reactor**

| HVY load (MW) | CHF voltage (pu) | | | |
|---|---|---|---|---|
| | 0.975 | 0.985 | 0.995 | 1.005 |
| | MFA voltage (pu) | | | |
| 0 | 1.017 | 0.989 | 0.977 | 0.992 |
| 10 | 1.007 | 0.979 | 0.965 | 0.980 |
| 15 | 1.007 | 0.985 | 0.963 | 0.978 |
| 25 | 1.012 | 0.982 | 0.950 | 0.965 |
| 35 | 1.029 | 0.981 | 0.963 | 0.952 |
| 45 | 0.994 | 0.991 | 0.961 | 0.938 |
| 55 | 1.011 | 0.982 | 0.954 | 0.930 |
| 65 | 1.007 | 0.990 | 0.971 | 0.937 |
| 75 | 1.009 | 0.983 | 0.971 | 0.931 |
| 80 | 0.969 | 0.979 | 0.971 | 0.937 |
| 90 | 1.015 | 0.998 | 0.958 | 0.949 |
| 100 | 1.015 | 0.980 | 0.964 | 0.944 |

# 5. Study Results – LIL Bipole

There is a possibility that the LIL may also be operated as a bipole up to 225 MW prior to the Muskrat Falls generators coming in to service. However, some of the harmonics are worse during bipolar operation. For bipolar operation, the results of the harmonic performance study[12] showed the following requirements in order to meet harmonic performance criteria:

- If both 315 kV MFA-CHF lines are in-service, then harmonic performance is met with one filter in-service below 130 MW, and two filters are required to be in-service above 130 MW power transfer
- If one of the 315 kV MFA-CHF lines are out-of-service, two filters need to be in-service

These operating points were tested in power flow to see if the steady state voltage criteria is met.

The Happy Valley interconnection to Muskrat Falls was not in-service for this bipolar analysis.

## 5.1 Loss of MFA Reactor

The two worst cases for overvoltage will be at minimum power of 90 MW with one filter in-service, and at 130 MW with 2 filters in-service. Loss of reactor was tested at both of these operating points, over the range of Churchill Falls voltage. The results are shown in Table 5-1.

**Table 5-1. Loss of MFA Reactor**

| LIL power transfer (MW) | Number of MFA filters in-service | CHF voltage (pu) | | | |
|---|---|---|---|---|---|
| | | 0.975 | 0.985 | 0.995 | 1.005 |
| | | MFA voltage (pu) | | | |
| 90 | 1 | 1.073 | 1.085 | 1.097 | 1.109 |
| 130 | 2 | 1.118 | 1.128 | 1.140 | 1.153 |
| 225 | 2 | 1.087 | 1.10 | 1.114 | 1.122 |

Operating with one filter in-service at minimum power of 90 MW meets steady state voltage criteria for loss of the MFA reactor, except for the slight violation that can occur (1.109 pu) if the Churchill Falls voltage is at 1.005 pu.

Operating with two filters in-service at 130 MW violates the 1.1 pu steady state voltage criteria for over the whole range of Churchill Falls voltage.

On this basis, bipolar operation will require the implementation of a reactive power controller for the LIL. Such a controller would trigger the rapid automatic removal of filters to keep voltages within acceptable limits. As rapid filter removal would result in unacceptable harmonic distortion, a pole would have to be subsequently tripped.

[12] TGS Study TN1205.57- AC Filter Operational Limits Study

## 5.2 Loss of 315 kV CHF-MFA line

The two operating ends of 90 MW and 225 MW LIL power transfer were tested for loss of one of the two 315 kV CHF-MFA lines, over the range of Churchill Falls voltage. The results are shown in Table 5-2. Please note that the harmonics analysis showed the need for two MFA filters to be in-service if one of these 315 kV lines was out of service.

If one of the 315 kV CHF-MFA lines trips, the MFA reactor will need to be tripped (via undervoltage detection relay) if the LIL power transfer is high enough and if CHF voltage is in its lower range in order to avoid violating the 0.9 pu steady state limit, however triping this reactor may then cause a violation of the 1.1 pu voltage limit.

As described above, the LIL reactive power controller must be implemented for operation as a bipole. If the Labrador system is operating with an outage of one of the 315 kV MFA-CHF lines, and if the MFA reactor is lost, the steady state voltage criteria will be significantly violated if the LIL is operating at minimum or low power, since the harmonic analysis requires two filters to be in-service. In this case, rapid filter removal would ensure acceptable system voltages. To ensure acceptable harmonic distortion following filter removal, a pole would have to be tripped.

**Table 5-2. Loss of 315 kV line CHF-MFA**

| LIL power transfer (MW) | Number of MFA filters in-service | CHF voltage (pu) | | | | CHF voltage (pu) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 0.975 | 0.985 | 0.995 | 1.005 | 0.975 | 0.985 | 0.995 | 1.005 |
| | | MFA voltage (pu) – Reactor In | | | | MFA voltage (pu) – Reactor Out | | | |
| 90 | 2 | 0.973 | 0.985 | 0.998 | 1.01 | 1.175 | 1.186 | 1.196 | 1.207 |
| 225 | 2 | 0.842 | 0.874 | 0.888 | 0.911 | 1.088 | 1.096 | 1.110 | 1.125 |

# 6. Conclusions

## 6.1 Monopolar Operation

It has been determined that the LIL monopole can operate with only one MFA filter in-service, and that the undervoltage trip setting for the MFA reactor could be set to trip the reactor if the steady state voltage at MFA goes below 0.9 pu. In addition, Hydro has advised that the Muskrat Falls-Happy Valley Interconnection was not approved. Rather than being supplied via a 315 kV interconnection at Muskrat Falls, Happy Valley load will continue to be supplied from Churchill Falls. This study re-evaluated the steady state voltage issues at Muskrat Falls during the phased monopolar approach based on this latest information.

This study determined an operating guideline that specifies the number of filters that should be in-service at Muskrat Falls (based on LIL power transfer and Labrador operating conditions) in order to prevent overvoltage if the MFA reactor trips. Table 6-1 lists the LIL power transfer at which two MFA filters can be in-service. Only one MFA filter should be in-service for LIL power transfers below these levels, including the orange cells which can have only one MFA filter in-service at LIL transfer of 225 MW. Slight overvoltages will still occur in these cases (orange cells) if the MFA reactor trips.

**Table 6-1. LIL power transfer to switch 2nd filter in-service**

| HVY load (MW) | CHF voltage (pu) | | | |
|---|---|---|---|---|
| | 0.975 | 0.985 | 0.995 | 1.005 |
| | LIL Power Transfer (MW) | | | |
| 0 | 175 | 215 | >225 | >225 |
| 10 | 175 | 210 | >225 | >225 |
| 15 | 170 | 210 | >225 | >225 |
| 25 | 160 | 205 | >225 | >225 |
| 35 | 155 | 195 | 220 | >225 |
| 45 | 150 | 175 | 210 | >225 |
| 55 | 130 | 175 | 205 | >225 |
| 65 | 125 | 155 | 185 | 225 |
| 75 | 105 | 145 | 175 | 210 |
| 80 | 100 | 135 | 165 | 205 |
| 90 | 75 | 110 | 160 | 180 |
| 100 | 55 | 105 | 140 | 170 |

This operating guideline, together with the fact that the MFA reactor will trip via undervoltage detection help to ensure voltage regulation at MFA. This will allow the LIL to operate over the full range of 45 MW to 225 MW under all Labrador operating conditions during the phased monopolar approach.

The following worst-case violations as summarized as follows:

1. Under highest voltage system conditions, i.e. with no load at Happy Valley, Churchill Falls 735 kV voltage at 1.005 pu and LIL transferring minimum power of 45 MW, a **1.12 pu** overvoltage occurs at MFATS2 if the MFA reactor trips (with only one MFA filter in-service).
2. Under lowest voltage system conditions, i.e. with 100 MW load at Happy Valley, Churchill Falls 735 kV voltage at 0.975 pu and LIL transferring maximum power of 225 MW, a **0.87 pu** undervoltage occurs at MFATS2 if line L3101 or L3012 trips (with two MFA filters in-service)[13].

## 6.2 Bipolar Operation

Bipolar operation up to 225 MW will require that two filters be in service at MFA. This will require the implementation of a reactive power controller for the LIL. Such a controller would trigger the rapid automatic removal of filters to keep voltages within acceptable limits. As rapid filter removal would result in unacceptable harmonic distortion, a pole would have to be subsequently tripped.

[13] This condition is no longer a consideration as the MFA-HVY Interconnection was not approved.