# ATCO Electric
# Hangingstone Substation

# HARMONIC STUDY

Prepared By
Pierre Archambault, PEng
Power Survey International Inc.
8025 Trans Canada Hwy.
St-Laurent, QC
H4S 1S4
CANADA

Rev.: 6 March 2007

# TABLE OF CONTENTS





Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

# 1. GENERAL

## 1.1 Purpose of this Study

The purpose of this study is to check the influence of harmonic filters keeping harmonic distortion at Hangingstone Substation in compliance with IEEE 519 guidelines. This study is based on the ETAP Power Station simulation software version 5.5.0 and electrical data as indicated in Section 1.2

## IEEE 519 Guidelines for Current Distortion



**Table 10-3—Current Distortion Limits for General Distribution Systems (120 V Through 69 000 V)**

| Maximum Harmonic Current Distortion in Percent of $I_L$ | | | | | | |
|---|---|---|---|---|---|---|
| Individual Harmonic Order (Odd Harmonics) | | | | | | |
| $I_{sc}/I_L$ | <11 | 11≤*h*<17 | 17≤*h*<23 | 23≤*h*<35 | 35≤*h* | TDD |
| <20* | 4.0 | 2.0 | 1.5 | 0.6 | 0.3 | 5.0 |
| 20<50 | 7.0 | 3.5 | 2.5 | 1.0 | 0.5 | 8.0 |
| 50<100 | 10.0 | 4.5 | 4.0 | 1.5 | 0.7 | 12.0 |
| 100<1000 | 12.0 | 5.5 | 5.0 | 2.0 | 1.0 | 15.0 |
| >1000 | 15.0 | 7.0 | 6.0 | 2.5 | 1.4 | 20.0 |
| Even harmonics are limited to 25% of the odd harmonic limits above. | | | | | | |
| Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed. | | | | | | |
| * All power generation equipment is limited to these values of current distortion, regardless of actual $I_{sc}/I_L$. | | | | | | |
| where<br>$I_{sc}$ = maximum short-circuit current at PCC.<br>$I_L$ = maximum demand load current (fundamental frequency component) at PCC. | | | | | | |

Values for Isc/IL < 20 do apply here.



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

## IEEE 519 Guidelines for Voltage Distortion

**Table 10-2—Low-Voltage System Classification and Distortion Limits**

| | Special Applications* | General System | Dedicated System† |
|---|---|---|---|
| Notch Depth | 10% | 20% | 50% |
| THD (Voltage) | 3% | 5% | 10% |
| Notch Area ($A_N$)‡ | 16 400 | 22 800 | 36 500 |

NOTE — The value $A_N$ for other than 480 V systems should be multiplied by V/480

*Special applications include hospitals and airports.
†A dedicated system is exclusively dedicated to the converter load.
‡In volt-microseconds at rated voltage and current.



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

## 1.2 Data

The following documents were available and used for programming the ETAP simulation model:

ATCO Electric Harmonic Filter Specification Hangingstone Substation, March 2006
Excel.Hangingstone ION 701T.xls
HangingstoneSystemDataR0.doc: Hangingstone Substation System Data, September 19, 2006
HangingstoneSystemDataR1.doc: Hangingstone Substation System Data, Rev1
Word.vfd information.doc: VFD Details
Operating Single Line Diagram, 820S Hangingstone
Operating Single Line Diagram, 718S Parsons Creek, sheet 1
Operating Single Line Diagram, 718S Parsons Creek, sheet 2
Operating Single Line Diagram, 875S Algar Substation
Operating Single Line Diagram, 848S Ruth Lake, sheet 1
Operating Single Line Diagram, 848S Ruth Lake, sheet 2
Operating Single Line Diagram, 848S Ruth Lake, sheet 3
Operating Single Line Diagram, 848S Ruth Lake, sheet 4
Operating Single Line Diagram, 860S Crow Substation
Operating Single Line Diagram, 883S Gregoire Substation
Operating Single Line Diagram, 833S Mariana Substation
Operating Single Line Diagram, 885S McMillan Substation

All above documents have been summed and included in AtcoData.pdf file on the report disk.



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

## 1.3 Assumptions

Following the data specified above and having installed the one line diagram on ETAP, a load flow run was performed assuming a 100% service factor for all loads.

**Utility Impedance Values (100 MVA base):**
**Ruth Lake**
Positive Sequence: R = 2.764 % X = 13.073 %
0 Sequence: R = 1.285 % X = 12.237 %
**Mc Millan**
Positive Sequence: R = 1.710 % X = 10.127 %
0 Sequence: R = 0.377 % X = 5.665 %

### AC Drives - Harmonic Current Injection

The following table summarizes the harmonic injection for all drives:

| | GREGOIRE AND CROW | | HANGINGSTONE | | ALGAR | | MARIANA | |
|---|---|---|---|---|---|---|---|---|
| n | Amplitude | Angle | Amplitude | Angle | Amplitude | Angle | Amplitude | Angle |
| 2 | 0.16 | 58.00 | | | | | | |
| 3 | 0.59 | 121.00 | | | | | | |
| 4 | 0.12 | 44.00 | | | | | | |
| 5 | 23.52 | 111.00 | 43.71 | 0.00 | 42.00 | 0.00 | | |
| 6 | 0.10 | 102.00 | | | | | | |
| 7 | 6.08 | 109.00 | 7.87 | 0.00 | 14.30 | 0.00 | | |
| 8 | 0.03 | 75.00 | | | | | | |
| 9 | 0.09 | -169.00 | | | | | | |
| 10 | 0.00 | 0.00 | | | | | | |
| 11 | 4.57 | -158.00 | 11.05 | 0.00 | 7.90 | 0.00 | | |
| 12 | 0.03 | -108.00 | | | | | | |
| 13 | 4.20 | -178.00 | 5.12 | 0.00 | 3.20 | 0.00 | | |
| 14 | 0.03 | 78.00 | | | | | | |
| 17 | 1.80 | 37.00 | 3.70 | 0.00 | 3.70 | 0.00 | | |
| 19 | 1.37 | -94.00 | 2.30 | 0.00 | 2.30 | 0.00 | | |
| 23 | 0.75 | -92.00 | 2.30 | 0.00 | 2.30 | 0.00 | 1.00 | 0.00 |
| 25 | 0.56 | -70.00 | 1.40 | 0.00 | 1.40 | 0.00 | 0.50 | 0.00 |
| 29 | 0.49 | -20.00 | | | | | | |
| 31 | 0.54 | 7.00 | | | | | | |



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

**Algar Drive**

This drive had to be slightly adjusted to meet as close as possible the 5th and 7th current distortions mentioned in *Hangingstone Substation Data Revision 1,* Figures 4.0, 10.0, 14.0 and 18.0. These drives included the drive filters as mentioned in the same reference, page 5.

**Gregoire and Crow Drives**

All 12-pulse AC drives were simulated with each two 6-pulse AC drives and filters. The drive filters were included following *Hangingstone Substation Data Revision 1*, pages 10 and 13. All 6-pulse drives are fed from a 10 MVA 3-winding drive transformers Y / YD.

**Mariana Drive**

One 24-pulse AC drive simulated with two 24-pulse AC drives and filters (filters as per *Hangingstone Substation Data Revision 1*, page 5) fed from a 10 MVA 3-winding drive transformer Y / YY.

**Hangingstone (additional) Drive**

An additional non-linear load of 1,850 KVA (2000 HP or 7.43% of the total load at Hangingstone Substation) had to be included here, following various preliminary test runs which indicated without any doubt that there is no other possibility of reaching considerable 5th and 7th harmonic current and corresponding voltage distortions at the substation resulting only from the main drives at the pumping stations. These preliminary results were listed in Section 2.1: Scenario 1 – No Filters



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

The drive harmonic current amplitudes above indicated were adjusted slightly to meet as close as possible the data for steady-state FFT of 25KV bus currents included in *Hangingstone Substation System Data* (Figures: 4.0; 10.0; 14.0 and 18.0) Only 5th and 7th harmonic currents could be aligned to some extend: it is almost impossible to get better results considering the strong drive to drive harmonic interaction.

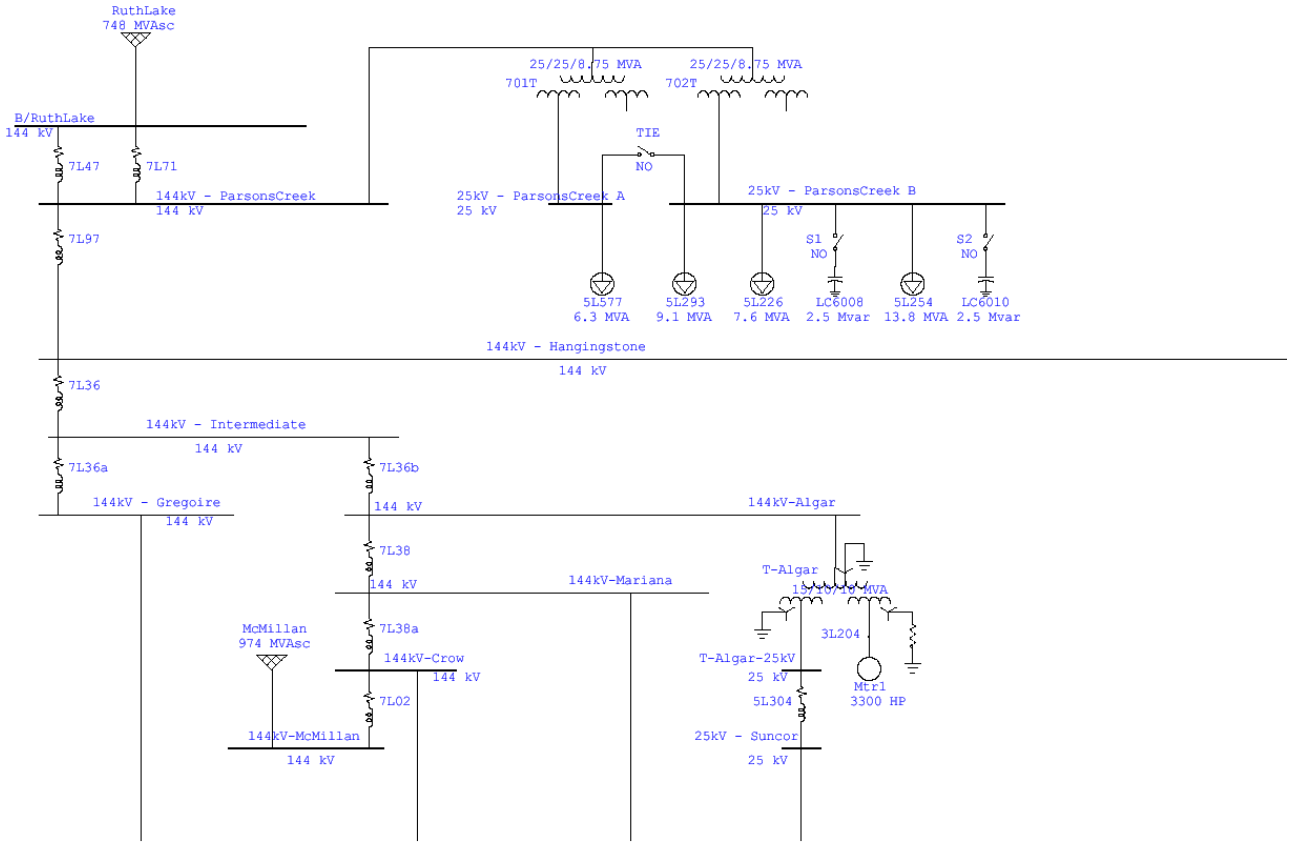
## RESULTING HARMONIC CURRENTS - % OF FUNDAMENTAL

| | Algar | | Crow | | Gregoire | | Mariana | |
|---|---|---|---|---|---|---|---|---|
| n | DATA | ETAP | DATA | ETAP | DATA | ETAP | DATA | ETAP |
| 2 | 0.0000 | 0.0571 | 0.0000 | 0.2142 | 0.0000 | 0.1861 | 0.0000 | 0.0748 |
| 3 | 0.2730 | 0.0000 | 0.2460 | 0.0000 | 0.2480 | 0.0000 | 0.8920 | 0.0000 |
| 4 | 0.0000 | 0.0252 | 0.0000 | 0.1078 | 0.0000 | 0.2313 | 0.0000 | 0.1730 |
| **5** | **3.2800** | **3.1881** | **0.9340** | **0.8833** | **1.7400** | **0.9385** | **1.3400** | **0.9442** |
| 6 | 0.2730 | 0.0000 | 0.4920 | 0.0000 | 0.6200 | 0.0000 | 0.0000 | 0.0000 |
| **7** | **0.6560** | **1.1353** | **0.9830** | **0.3584** | **2.1100** | **1.0964** | **0.4460** | **0.9146** |
| 8 | 0.1370 | 0.0021 | 0.0980 | 0.0082 | 0.3100 | 0.0060 | 0.0000 | 0.0099 |
| 9 | 0.0660 | 0.0000 | 0.2460 | 0.0000 | 0.3100 | 0.0000 | 0.2230 | 0.0000 |
| 10 | - | 0.0000 | - | 0.0000 | - | 0.0000 | - | 0.0000 |
| 11 | - | 0.0077 | - | 0.0125 | - | 0.0125 | - | 0.0075 |
| 13 | - | 0.0011 | - | 0.0044 | - | 0.0043 | - | 0.0014 |
| 14 | - | 0.0001 | - | 0.0009 | - | 0.0009 | - | 0.0002 |
| 17 | - | 0.0662 | - | 0.0873 | - | 0.0814 | - | 0.0206 |
| 19 | - | 0.0460 | - | 0.0739 | - | 0.0694 | - | 0.0118 |
| 23 | - | 0.0904 | - | 0.0723 | - | 0.0683 | - | 0.0433 |
| 25 | - | 0.0553 | - | 0.0589 | - | 0.0502 | - | 0.0188 |
| 29 | - | 0.0009 | - | 0.0308 | - | 0.0305 | - | 0.0157 |
| 31 | - | 0.0009 | - | 0.0334 | - | 0.0335 | - | 0.0292 |

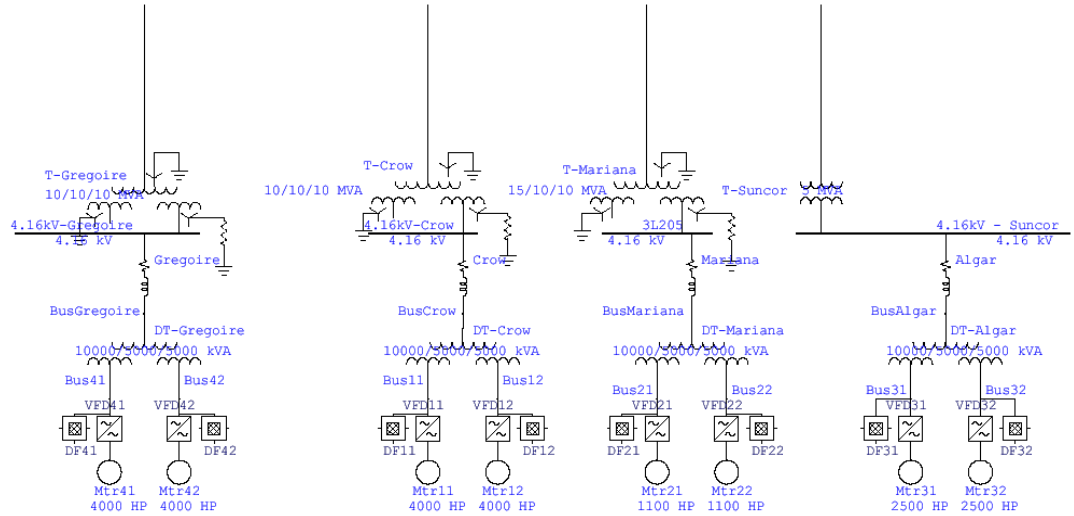


Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

## 1.4 ETAP One-Line Diagram



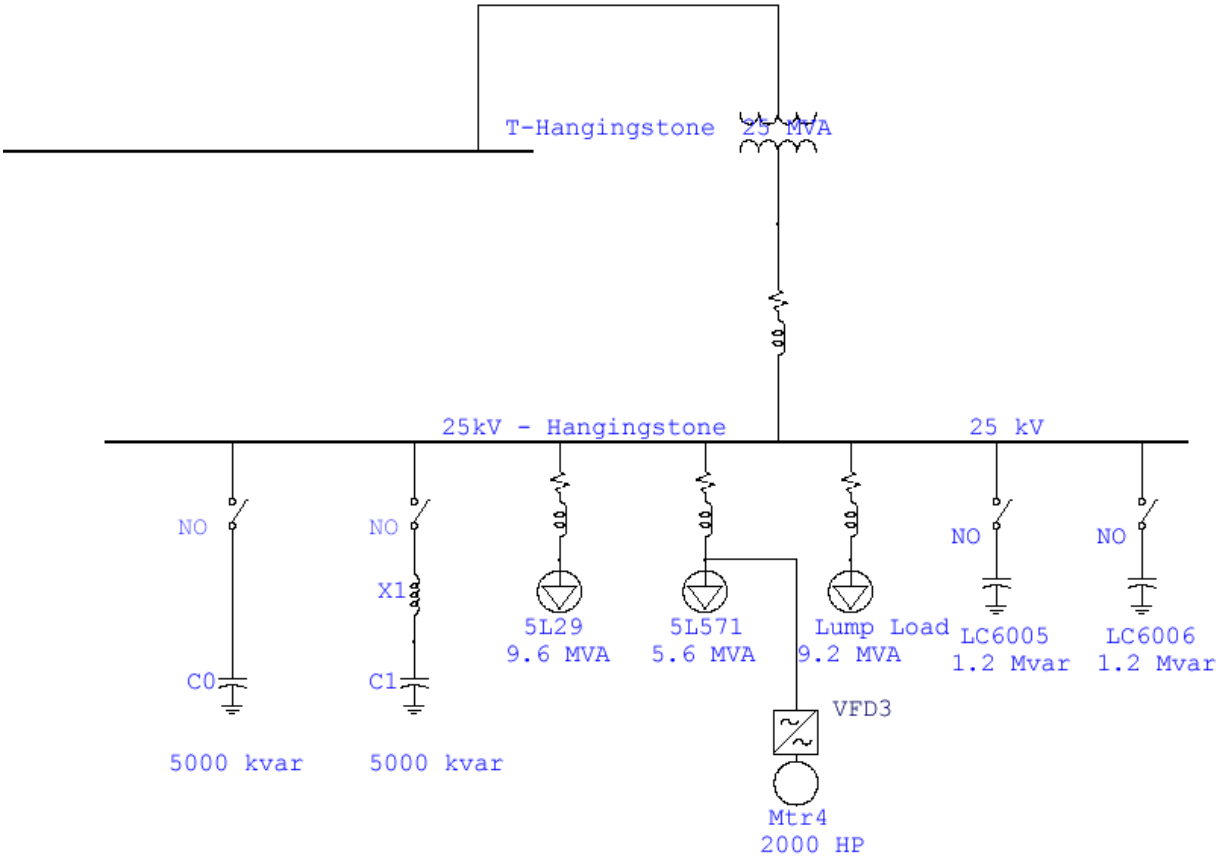

page 1 12:37:04 Jan 24, 2007 Project File: ATCO






Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

CONTINUATION (144kV Hangingstone Bus)






Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

## 1.5 Load Flow Report



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

| | | | |
|---|---|---|---|
| Project: | ETAP | Page: | 1 |
| Location: | 5.5.0C | Date: | 01-24-2007 |
| Contract: | | SN: | PWERSURVEY |
| Engineer: | | Revision: | Base |
| Filename: ATCO | Study Case: LF | Config.: | BASE |

## LOAD FLOW REPORT

| Bus | | Voltage | | Generation | | Load | | Load Flow | | | | | XFMR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | kV | % Mag. | Ang. | MW | Mvar | MW | Mvar | ID | MW | Mvar | Amp | % PF | % Tap |
| 3L204 | 4.160 | 97.934 | -2.0 | 0 | 0 | 2.612 | 1.044 | 144kV-Algar | -2.612 | -1.044 | 398.7 | 92.9 | |
| | | | | | | | | & T-Algar-25kV | | | | | |
| 3L205 | 4.160 | 100.583 | -1.4 | 0 | 0 | 0 | 0 | BusMariana | 1.897 | -3.727 | 577.1 | -45.4 | |
| | | | | | | | | 144kV-Mariana | -1.897 | 3.727 | 577.1 | -45.4 | |
| | | | | | | | | & T-Mariana~2 | | | | | |
| 4.16kV-Crow | 4.160 | 100.451 | -2.3 | 0 | 0 | 0 | 0 | BusCrow | 6.833 | -1.398 | 963.7 | -98.0 | |
| | | | | | | | | 144kV-Crow | -6.833 | 1.398 | 963.7 | -98.0 | |
| | | | | | | | | & T-Crow~2 | | | | | |
| 4.16kV-Gregoire | 4.160 | 97.674 | -4.2 | 0 | 0 | 0 | 0 | BusGregoire | 6.833 | -0.486 | 973.4 | -99.7 | |
| | | | | | | | | 144kV - Gregoire | -6.833 | 0.486 | 973.4 | -99.7 | |
| | | | | | | | | & T-Gregoire~2 | | | | | |
| 4.16kV - Suncor | 4.160 | 97.781 | -9.2 | 0 | 0 | 0 | 0 | BusAlgar | 4.276 | -1.141 | 628.1 | -96.6 | |
| | | | | | | | | 25kV - Suncor | -4.276 | 1.141 | 628.1 | -96.6 | |
| 25kV - Hangingstone | 25.000 | 94.595 | -6.0 | 0 | 0 | 0 | 0 | Bus2 | 9.059 | 2.819 | 231.6 | 95.5 | |
| | | | | | | | | Bus3 | 5.284 | 1.641 | 135.1 | 95.5 | |
| | | | | | | | | Bus4 | 8.681 | 2.700 | 222.0 | 95.5 | |
| | | | | | | | | Bus1 | -23.024 | -7.160 | 588.7 | 95.5 | |
| 25kV - ParsonsCreek A | 25.000 | 97.837 | -2.0 | 0 | 0 | 6.027 | 1.638 | 701T~3 | -6.027 | -1.638 | 147.4 | 96.5 | |
| | | | | | | | | & 144kV - ParsonsCreek | | | | | |
| 25kV - ParsonsCreek B | 25.000 | 94.957 | -6.3 | 0 | 0 | 28.854 | 7.841 | 702T~3 | -28.854 | -7.841 | 727.2 | 96.5 | |
| | | | | | | | | & 144kV - ParsonsCreek | | | | | |
| 25kV - Suncor | 25.000 | 96.856 | -5.5 | 0 | 0 | 0 | 0 | T-Algar-25kV | -4.299 | 0.855 | 104.5 | -98.1 | |
| | | | | | | | | 4.16kV - Suncor | 4.299 | -0.855 | 104.5 | -98.1 | |
| 144kV-Algar | 144.000 | 98.348 | -1.7 | 0 | 0 | 0 | 0 | 144kV - Intermediate | 6.634 | 3.262 | 30.1 | 89.7 | |
| | | | | | | | | 144kV-Mariana | -13.665 | -3.724 | 57.7 | 96.5 | |
| | | | | | | | | T-Algar-25kV | 7.031 | 0.463 | 28.7 | 99.8 | |
| | | | | | | | | & 3L204 | | | | | |
| 144kV-Crow | 144.000 | 99.947 | -0.1 | 0 | 0 | 0 | 0 | 144kV-McMillan | -22.673 | 6.053 | 94.1 | -96.6 | |
| | | | | | | | | 144kV-Mariana | 15.827 | -4.919 | 66.5 | -95.5 | |
| | | | | | | | | T-Crow~2 | 6.847 | -1.134 | 27.8 | -98.7 | |
| | | | | | | | | & 4.16kV-Crow | | | | | |
| 144kV - Gregoire | 144.000 | 97.669 | -2.0 | 0 | 0 | 0 | 0 | 144kV - Intermediate | -6.847 | 0.217 | 28.1 | -99.9 | |
| | | | | | | | | T-Gregoire~2 | 6.847 | -0.217 | 28.1 | -99.9 | |
| | | | | | | | | & 4.16kV-Gregoire | | | | | |
| 144kV - Hangingstone | 144.000 | 97.486 | -1.7 | 0 | 0 | 0 | 0 | 144kV - Intermediate | 0.264 | -7.577 | 31.2 | -3.5 | |
| | | | | | | | | 144kV - ParsonsCreek | -23.373 | -1.557 | 96.3 | 99.8 | |



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

| | | | | | |
|---|---|---|---|---|---|
| Project: | | ETAP | | Page: | 2 |
| Location: | | 5.5.0C | | Date: | 01-24-2007 |
| Contract: | | | | SN: | PWERSURVEY |
| Engineer: | | | | Revision: | Base |
| Filename: | ATCO | Study Case: | LF | Config.: | BASE |

| Bus | | Voltage | | Generation | | Load | | Load Flow | | | | | XFMR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | kV | % Mag. | Ang. | MW | Mvar | MW | Mvar | ID | MW | Mvar | Amp | % PF | % Tap |
| | | | | | | | | Bus1 | 23.109 | 9.134 | 102.2 | 93.0 | |
| 144kV - Intermediate | 144.000 | 97.797 | -1.8 | 0 | 0 | 0 | 0 | 144kV - Hangingstone | -0.250 | 6.307 | 25.9 | -4.0 | |
| | | | | | | | | 144kV - Gregoire | 6.858 | -1.205 | 28.5 | -98.5 | |
| | | | | | | | | 144kV-Algar | -6.608 | -5.102 | 34.2 | 79.2 | |
| 144kV-Mariana | 144.000 | 99.419 | -1.0 | 0 | 0 | 0 | 0 | 144kV-Algar | 13.785 | 1.083 | 55.8 | 99.7 | |
| | | | | | | | | 144kV-Crow | -15.685 | 2.588 | 64.1 | -98.7 | |
| | | | | | | | | T-Mariana--2 | 1.900 | -3.671 | 16.7 | -46.0 | |
| | | | | | | | | & 3L205 | | | | | |
| * 144kV-McMillan | 144.000 | 100.000 | 0.0 | 22.696 | -6.214 | 0 | 0 | 144kV-Crow | 22.696 | -6.214 | 94.3 | -96.4 | |
| 144kV - ParsonsCreek | 144.000 | 98.478 | -0.8 | 0 | 0 | 0 | 0 | B/RuthLake | -27.032 | -7.344 | 114.0 | 96.5 | |
| | | | | | | | | B/RuthLake | -31.609 | -5.487 | 130.6 | 98.5 | |
| | | | | | | | | 144kV - Hangingstone | 23.598 | 0.110 | 96.1 | 100.0 | |
| | | | | | | | | 25kV - ParsonsCreek A | 6.034 | 1.766 | 25.6 | 96.0 | |
| | | | | | | | | & 701T--3 | | | | | |
| | | | | | | | | 25kV - ParsonsCreek B | 29.009 | 10.955 | 126.2 | 93.6 | |
| | | | | | | | | & 702T--3 | | | | | |
| * B/RuthLake | 144.000 | 100.000 | 0.0 | 59.380 | 9.640 | 0 | 0 | 144kV - ParsonsCreek | 27.351 | 5.957 | 112.2 | 97.7 | |
| | | | | | | | | 144kV - ParsonsCreek | 32.029 | 3.683 | 129.3 | 99.3 | |
| Bus1 | 25.000 | 94.609 | -6.0 | 0 | 0 | 0 | 0 | 25kV - Hangingstone | 23.026 | 7.166 | 588.7 | 95.5 | |
| | | | | | | | | 144kV - Hangingstone | -23.026 | -7.166 | 588.7 | 95.5 | |
| Bus2 | 25.000 | 93.203 | -7.0 | 0 | 0 | 8.974 | 2.617 | 25kV - Hangingstone | -8.974 | -2.617 | 231.6 | 96.0 | |
| Bus3 | 25.000 | 93.243 | -7.0 | 0 | 0 | 5.236 | 1.527 | 25kV - Hangingstone | -5.236 | -1.527 | 135.1 | 96.0 | |
| Bus4 | 25.000 | 93.217 | -7.0 | 0 | 0 | 8.600 | 2.508 | 25kV - Hangingstone | -8.600 | -2.508 | 222.0 | 96.0 | |
| Bus11 | 4.160 | 101.458 | -5.5 | 0 | 0 | 3.401 | 1.256 | Bus73 | 0.002 | -2.190 | 299.6 | -0.1 | |
| | | | | | | | | Bus12 | -3.403 | 0.934 | 482.7 | -96.4 | |
| | | | | | | | | & BusCrow | | | | | |
| Bus12 | 4.160 | 101.981 | -6.9 | 0 | 0 | 3.401 | 1.256 | Bus68 | 0.002 | -2.213 | 301.2 | -0.1 | |
| | | | | | | | | BusCrow | -3.403 | 0.957 | 481.0 | -96.3 | |
| | | | | | | | | & Bus11 | | | | | |
| Bus21 | 4.160 | 103.636 | -2.4 | 0 | 0 | 0.942 | 0.362 | Bus69 | 0.002 | -2.285 | 306.0 | -0.1 | |
| | | | | | | | | Bus22 | -0.944 | 1.923 | 286.9 | -44.1 | |
| | | | | | | | | & BusMariana | | | | | |
| Bus22 | 4.160 | 104.945 | -2.7 | 0 | 0 | 0.942 | 0.362 | Bus70 | 0.002 | -2.343 | 309.9 | -0.1 | |
| | | | | | | | | BusMariana | -0.944 | 1.981 | 290.2 | -43.0 | |
| | | | | | | | | & Bus21 | | | | | |
| Bus31 | 4.160 | 98.622 | -11.3 | 0 | 0 | 2.131 | 0.799 | Bus71 | 0.001 | -1.468 | 206.6 | 0.0 | |
| | | | | | | | | Bus32 | -2.132 | 0.669 | 314.4 | -95.4 | |
| | | | | | | | | & BusAlgar | | | | | |
| Bus32 | 4.160 | 99.024 | -12.2 | 0 | 0 | 2.131 | 0.799 | Bus72 | 0.001 | -1.480 | 207.4 | 0.0 | |



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

| | | | | | |
|---|---|---|---|---|---|
| Project: | | ETAP | | Page: | 3 |
| Location: | | 5.5.0C | | Date: | 01-24-2007 |
| Contract: | | | | SN: | PWERSURVEY |
| Engineer: | | | | Revision: | Base |
| Filename: | ATCO | Study Case: | LF | Config.: | BASE |

| Bus | | Voltage | | Generation | | Load | | Load Flow | | | | | XFMR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | kV | % Mag. | Ang. | MW | Mvar | MW | Mvar | ID | MW | Mvar | Amp | % PF | % Tap |
| | | | | | | | | BusAlgar | -2.132 | 0.681 | 313.7 | -95.3 | |
| | | | | | | | | & Bus31 | | | | | |
| Bus41 | 4.160 | 97.928 | -7.7 | 0 | 0 | 3.401 | 1.256 | Bus63 | 0.001 | -1.747 | 247.6 | -0.1 | |
| | | | | | | | | Bus42 | -3.402 | 0.491 | 487.2 | -99.0 | |
| | | | | | | | | & BusGregoire | | | | | |
| Bus42 | 4.160 | 98.139 | -9.2 | 0 | 0 | 3.401 | 1.256 | Bus66 | 0.001 | -1.755 | 248.1 | -0.1 | |
| | | | | | | | | BusGregoire | -3.402 | 0.498 | 486.3 | -98.9 | |
| | | | | | | | | & Bus41 | | | | | |
| Bus63 | 4.160 | 97.928 | -7.7 | 0 | 0 | 0.001 | -1.747 | Bus41 | -0.001 | 1.747 | 247.6 | -0.1 | |
| Bus66 | 4.160 | 98.139 | -9.2 | 0 | 0 | 0.001 | -1.755 | Bus42 | -0.001 | 1.755 | 248.1 | -0.1 | |
| Bus68 | 4.160 | 101.981 | -6.9 | 0 | 0 | 0.002 | -2.213 | Bus12 | -0.002 | 2.213 | 301.2 | -0.1 | |
| Bus69 | 4.160 | 103.636 | -2.4 | 0 | 0 | 0.002 | -2.285 | Bus21 | -0.002 | 2.285 | 306.0 | -0.1 | |
| Bus70 | 4.160 | 104.945 | -2.7 | 0 | 0 | 0.002 | -2.343 | Bus22 | -0.002 | 2.343 | 309.9 | -0.1 | |
| Bus71 | 4.160 | 98.622 | -11.3 | 0 | 0 | 0.001 | -1.468 | Bus31 | -0.001 | 1.468 | 206.6 | 0.0 | |
| Bus72 | 4.160 | 99.024 | -12.2 | 0 | 0 | 0.001 | -1.480 | Bus32 | -0.001 | 1.480 | 207.4 | 0.0 | |
| Bus73 | 4.160 | 101.458 | -5.5 | 0 | 0 | 0.002 | -2.190 | Bus11 | -0.002 | 2.190 | 299.6 | -0.1 | |
| BusAlgar | 4.160 | 97.785 | -9.3 | 0 | 0 | 0 | 0 | 4.16kV - Suncor | -4.274 | 1.148 | 628.1 | -96.6 | |
| | | | | | | | | Bus31 | 4.274 | -1.148 | 628.1 | -96.6 | |
| | | | | | | | | & Bus32 | | | | | |
| BusCrow | 4.160 | 100.442 | -2.4 | 0 | 0 | 0 | 0 | 4.16kV-Crow | -6.829 | 1.416 | 963.7 | -97.9 | |
| | | | | | | | | Bus11 | 6.829 | -1.416 | 963.7 | -97.9 | |
| | | | | | | | | & Bus12 | | | | | |
| BusGregoire | 4.160 | 97.631 | -4.4 | 0 | 0 | 0 | 0 | 4.16kV-Gregoire | -6.829 | 0.504 | 973.4 | -99.7 | |
| | | | | | | | | Bus41 | 6.829 | -0.504 | 973.4 | -99.7 | |
| | | | | | | | | & Bus42 | | | | | |
| BusMariana | 4.160 | 100.701 | -1.4 | 0 | 0 | 0 | 0 | 3L205 | -1.896 | 3.733 | 577.1 | -45.3 | |
| | | | | | | | | Bus21 | 1.896 | -3.733 | 577.1 | -45.3 | |
| | | | | | | | | & Bus22 | | | | | |
| T-Algar-25kV | 25.000 | 98.636 | -2.9 | 0 | 0 | 0 | 0 | 25kV - Suncor | 4.413 | -0.698 | 104.6 | -98.8 | |
| | | | | | | | | 3L204 | -4.413 | 0.698 | 104.6 | -98.8 | |
| | | | | | | | | & 144kV-Algar | | | | | |
| 701T~3 | 4.160 | 97.799 | -2.0 | 0 | 0 | 0 | 0 | 144kV - ParsonsCreek | 0.000 | 0.000 | 0.0 | 0.0 | |
| | | | | | | | | & 25kV - ParsonsCreek A | | | | | |
| 702T~3 | 4.160 | 94.775 | -6.7 | 0 | 0 | 0 | 0 | 144kV - ParsonsCreek | 0.000 | 0.000 | 0.0 | 0.0 | |
| | | | | | | | | & 25kV - ParsonsCreek B | | | | | |
| T-Crow~2 | 25.000 | 99.877 | 0.3 | 0 | 0 | 0 | 0 | 4.16kV-Crow | 0.000 | 0.000 | 0.0 | 0.0 | |
| | | | | | | | | & 144kV-Crow | | | | | |
| T-Gregoire~2 | 25.000 | 97.681 | -1.6 | 0 | 0 | 0 | 0 | 4.16kV-Gregoire | 0.000 | 0.000 | 0.0 | 0.0 | |



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

| | | | | | |
|---|---|---|---|---|---|
| Project: | | ETAP | | Page: | 4 |
| Location: | | 5.5.0C | | Date: | 01-24-2007 |
| Contract: | | | | SN: | PWERSURVEY |
| Engineer: | | | | Revision: | Base |
| Filename: | ATCO | | Study Case: LF | Config.: | BASE |

| Bus | | Voltage | | Generation | | Load | | Load Flow | | | | | XFMR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | kV | % Mag. | Ang. | MW | Mvar | MW | Mvar | ID | MW | Mvar | Amp | % PF | % Tap |
| | | | | | | | | & 144kV - Gregoire | | | | | |
| T-Mariana~2 | 25.000 | 99.206 | -0.9 | 0 | 0 | 0 | 0 | 3L205 | 0.000 | 0.000 | 0.0 | 0.0 | |
| | | | | | | | | & 144kV-Mariana | | | | | |

* Indicates a voltage regulated bus ( voltage controlled or swing type machine connected to it)

# Indicates a bus with a load mismatch of more than 0.1 MVA

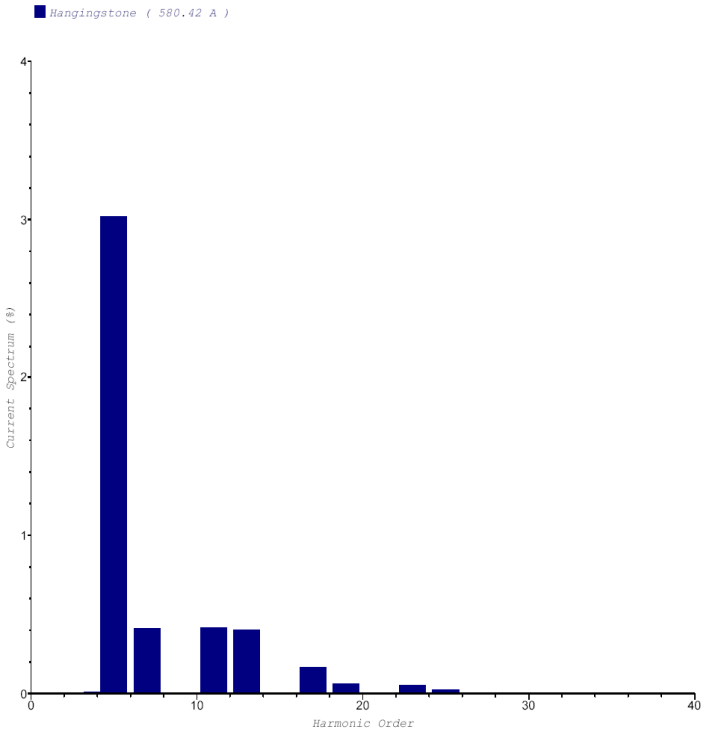


Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

# 2. RESULTS

## 2.1 Scenario 1: No Filters

### CURRENT SPECTRUM – HANGINGSTONE 25 KV SUPPLY:




| n | Measured | Preliminary | Final Model |
|---|---|---|---|
| 1 | 100 | 100 | 100 |
| 2 | 0.1600 | 0.0036 | 0.0036 |
| 3 | 2.5000 | 0.0000 | 0.0000 |
| 4 | 0.0000 | 0.0067 | 0.0078 |
| 5 | 3.0300 | 0.0753 | 3.0204 |
| 6 | - | 0.0000 | 0.0000 |
| 7 | 0.4160 | 0.1049 | 0.4130 |
| 8 | 0.0000 | 0.0007 | 0.0009 |
| 9 | 0.4000 | 0.0000 | 0.0000 |
| 10 | - | 0.0000 | 0.0000 |
| 11 | 0.4160 | 0.0020 | 0.4154 |
| 13 | 0.4000 | 0.0004 | 0.4002 |
| 14 | - | 0.0001 | 0.0002 |
| 17 | - | 0.0028 | 0.1658 |
| 19 | - | 0.0033 | 0.0645 |
| 23 | - | 0.0005 | 0.0545 |
| 25 | - | 0.0010 | 0.0247 |
| 29 | - | 0.0010 | 0.0017 |
| 31 | - | 0.0005 | 0.0008 |
| | | | |
| THD | 4.2462 | - | 3.1083 |

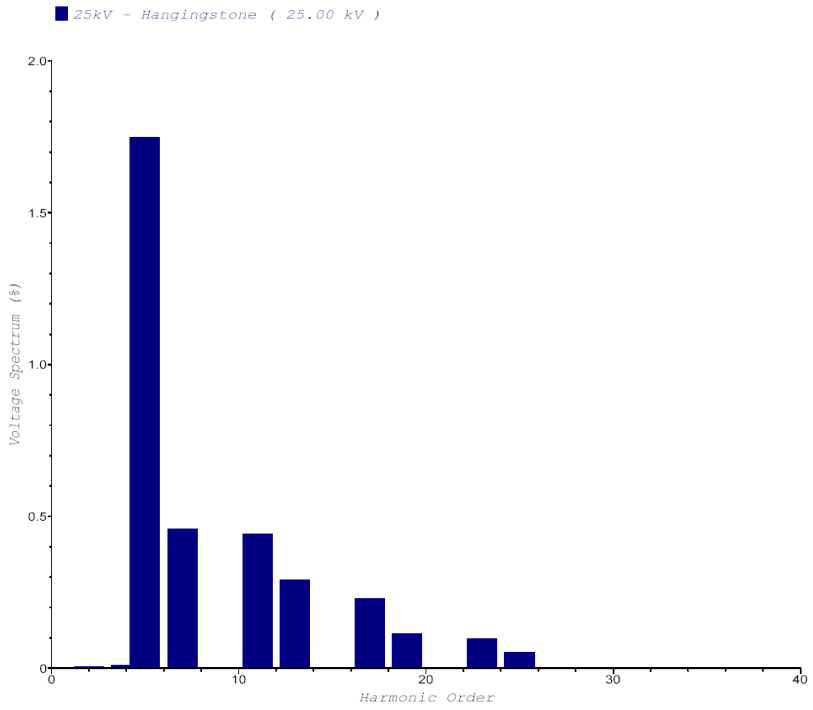
## Comments

The 5th and 7th harmonic currents predicted by the preliminary model were much lower than the measured values as per *ATCO Electric Harmonic Filter Specification*, Page 4. The measured current harmonic values of about 3.03% for the 5th harmonic current are most probably not caused by the large 12-pulse drives, not even if considering severe voltage unbalance and / or severe phase shifting of the drive transformers. The much higher than predicted 5th and 7th harmonic currents could though be caused by other non-linear loads connected from the Hangingstone Substation. This fact obliged us to include an additional non-linear load at Hangingstone. The herewith obtained results are listed under the last two columns named *Preliminary* and *Final Model*. The *Final Model* was used for simulating Scenarios 2 (one 5 MVAR 5th harmonic filter at Hangingstone) and 3 (one 5 MVAR 5th harmonic filter plus one 5 MVAR capacitor bank at Hangingstone). The 3rd harmonic distortion (due to load unbalance) cannot be simulated properly with ETAP.



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

## VOLTAGE SPECTRUM – HANGINGSTONE 25 KV BUS:




| n | Measured | Preliminary | Final Model |
|---|---|---|---|
| 1 | 100 | 100 | 100 |
| 2 | 0.0000 | 0.0039 | 0.0041 |
| 3 | 0.8000 | 0.0000 | 0.0000 |
| 4 | 0.0000 | 0.0074 | 0.0087 |
| 5 | 2.6000 | 0.0767 | 1.7489 |
| 6 | - | 0.0000 | 0.0000 |
| 7 | 0.2400 | 0.1183 | 0.4592 |
| 8 | 0.0000 | 0.0008 | 0.0008 |
| 9 | 0.2300 | 0.0000 | 0.0000 |
| 10 | - | 0.0000 | 0.0000 |
| 11 | 0.3200 | 0.0022 | 0.4412 |
| 13 | 0.1000 | 0.0004 | 0.2917 |
| 14 | - | 0.0001 | 0.0001 |
| 17 | - | 0.0028 | 0.2287 |
| 19 | - | 0.0035 | 0.1145 |
| 23 | - | 0.0006 | 0.0971 |
| 25 | - | 0.0012 | 0.0523 |
| 29 | - | 0.0011 | 0.0006 |
| 31 | - | 0.0006 | 0.0003 |
| | | | |
| THD | 2.7610 | - | 1.9045 |

## Comments

The harmonic voltages predicted by the ETAP *Preliminary* model are much lower than the measured values as per *ATCO Electric Harmonic Filter Specification*, Page 4. Same comments as for current harmonics apply. The *Final Model* predicts much closer results.



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

## 2.2 Scenario 2: 5 MVAR 5th harmonic filter

One 5 MVAR 5th harmonic filter (tuned at 4.8 h) was connected on the simulation. The harmonic current spectrum in the main supply line indicates an increased 5th harmonic distortion of 0.4236 %. The THD value is well below the IEEE 519 TDD limit of 5%. The results for different sub-scenarios are listed below under columns *NO 6000* (no other capacitor banks 6005, 6006, 6008 and 6010 connected); *6008,10* for capacitor banks 6008 and 6010 connected only; *6005,08,10* for capacitor banks 6005, 6008 and 6010 connected and *ALL 6000* for 6005, 6006, 6008 and 6010 connected.

**CURRENT SPECTRUM – HANGINGSTONE 25 KV SUPPLY:**

| n | NO 6000 | 6008,10 | 6005,08,10 | ALL 6000 |
|---|---|---|---|---|
| 1 | 100 | 100 | 100 | 100 |
| 2 | 0.0041 | 0.0042 | 0.0045 | 0.0048 |
| 3 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4 | 0.0485 | 0.0481 | 0.0504 | 0.0514 |
| 5 | 0.4236 | 0.4409 | 0.4502 | 0.4588 |
| 6 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 7 | 0.2018 | 0.2321 | 0.2490 | 0.2706 |
| 8 | 0.0008 | 0.0006 | 0.0005 | 0.0005 |
| 9 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 10 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11 | 0.4918 | 0.3760 | 0.4252 | 0.4469 |
| 13 | 0.2214 | 0.2249 | 0.2889 | 0.3696 |
| 14 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| 17 | 0.1229 | 0.1231 | 0.1886 | 0.1944 |
| 19 | 0.0667 | 0.0621 | 0.0909 | 0.0751 |
| 23 | 0.0669 | 0.0676 | 0.1025 | 0.0630 |
| 25 | 0.0370 | 0.0374 | 0.0529 | 0.0283 |
| 29 | 0.0010 | 0.0010 | 0.0018 | 0.0019 |
| 31 | 0.0005 | 0.0005 | 0.0009 | 0.0009 |
| | | | | |
| THD | 0.7341 | 0.6837 | 0.7672 | 0.8191 |

## Comments

The herewith obtained results are all below IEEE 519 limits. Adding capacitor banks 6008 and 6010 increased slightly the 5th and 7th harmonic current distortions, but reduced higher order harmonic currents resulting altogether in lower THD values. Adding 6005 and 6006 capacitor banks result higher distortions in general, but with exception of the 11th harmonic. The overall impact of adding all of the 6000 capacitor banks is minor.



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

## VOLTAGE SPECTRUM – HANGINGSTONE 25 KV BUS:

| n | NO 6000 | 6008,10 | 6005,08,10 | ALL 6000 |
|---|---|---|---|---|
| 1 | 100 | 100 | 100 | 100 |
| 2 | 0.0044 | 0.0044 | 0.0045 | 0.0048 |
| 3 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4 | 0.0179 | 0.0177 | 0.0173 | 0.0514 |
| 5 | 0.2310 | 0.2300 | 0.2340 | 0.4588 |
| 6 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 7 | 0.2323 | 0.2130 | 0.2383 | 0.2706 |
| 8 | 0.0005 | 0.0004 | 0.0005 | 0.0005 |
| 9 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 10 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11 | 0.2848 | 0.3922 | 0.4391 | 0.4469 |
| 13 | 0.1661 | 0.1602 | 0.2041 | 0.3696 |
| 14 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| 17 | 0.1693 | 0.1695 | 0.2551 | 0.1944 |
| 19 | 0.1088 | 0.1136 | 0.1612 | 0.0751 |
| 23 | 0.1160 | 0.1155 | 0.1751 | 0.0630 |
| 25 | 0.0736 | 0.0735 | 0.1058 | 0.0283 |
| 29 | 0.0011 | 0.0011 | 0.0015 | 0.0019 |
| 31 | 0.0006 | 0.0006 | 0.0007 | 0.0009 |
| | | | | |
| THD | 0.5251 | 0.5818 | 0.6923 | 0.8191 |

## Comments

The 5th harmonic voltages are, as expected, much lower now when compared with Scenario 1 running without filters. This is the case for all harmonic voltages but the 4th harmonic voltage, which increased slightly due to the parallel resonance introduced by the shunt filter. This increase is without implications though. All harmonic voltage distortions are well below IEE 519 limits.



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

## 2.3 Scenario 3: 5 MVAR 5th harmonic filter and 5 MVAR Capacitor Bank

A combination of 5th harmonic filter (tuned at 4.8 h) and a 5 MVAR capacitor bank are connected now. The harmonic current spectrum in the main supply line indicates slightly higher harmonic distortions.

**CURRENT SPECTRUM – HANGINGSTONE 25 KV SUPPLY:**

| n | NO 6000 | 6008,10 | 6005,08,10 | ALL 6000 |
|---|---|---|---|---|
| 1 | 100 | 100 | 100 | 100 |
| 2 | 0.0056 | 0.0057 | 0.0061 | 0.0066 |
| 3 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4 | 0.0503 | 0.0501 | 0.0486 | 0.0468 |
| 5 | 0.4568 | 0.4741 | 0.4796 | 0.4839 |
| 6 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 7 | 0.3176 | 0.3414 | 0.3869 | 0.4353 |
| 8 | 0.0011 | 0.0009 | 0.0011 | 0.0014 |
| 9 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 10 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11 | 0.5651 | 0.3738 | 0.3216 | 0.2754 |
| 13 | 0.3604 | 0.3704 | 0.2904 | 0.2268 |
| 14 | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| 17 | 0.0862 | 0.0865 | 0.0657 | 0.0528 |
| 19 | 0.0364 | 0.0350 | 0.0278 | 0.0232 |
| 23 | 0.0243 | 0.0250 | 0.0191 | 0.0153 |
| 25 | 0.0106 | 0.0109 | 0.0082 | 0.0065 |
| 29 | 0.0016 | 0.0017 | 0.0017 | 0.0017 |
| 31 | 0.0008 | 0.0008 | 0.0008 | 0.0008 |
| | | | | |
| THD | 0.8779 | 0.7939 | 0.7586 | 0.7462 |

## Comments

The herewith obtained results are also below IEEE 519 limits. Adding capacitor banks 6008 and 6010 increased slightly harmonics 2nd to 7th, but reduced some higher order harmonic currents resulting thus in lower THD values. Adding 6005 and 6006 capacitor banks result in even higher harmonic distortions for the 5th and 7th, but lowering further the THD value. The overall impact of adding all 6000 capacitor banks is minor.



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

## VOLTAGE SPECTRUM – HANGINGSTONE 25 KV BUS:

| n | NO 6000 | 6008,10 | 6005,08,10 | ALL 6000 |
|---|---|---|---|---|
| 1 | 100 | 100 | 100 | 100 |
| 2 | 0.0048 | 0.0048 | 0.0050 | 0.0051 |
| 3 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4 | 0.0142 | 0.0141 | 0.0131 | 0.0120 |
| 5 | 0.2488 | 0.2477 | 0.2523 | 0.2571 |
| 6 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 7 | 0.4088 | 0.3630 | 0.4186 | 0.4748 |
| 8 | 0.0010 | 0.0008 | 0.0009 | 0.0008 |
| 9 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 10 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11 | 0.3197 | 0.3804 | 0.3276 | 0.2816 |
| 13 | 0.2655 | 0.2591 | 0.2037 | 0.1599 |
| 14 | 0.0001 | 0.0001 | 0.0001 | 0.0000 |
| 17 | 0.1124 | 0.1125 | 0.0849 | 0.0678 |
| 19 | 0.0567 | 0.0565 | 0.0436 | 0.0354 |
| 23 | 0.0434 | 0.0434 | 0.0336 | 0.0273 |
| 25 | 0.0233 | 0.0233 | 0.0182 | 0.0148 |
| 29 | 0.0003 | 0.0003 | 0.0002 | 0.0002 |
| 31 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| | | | | |
| THD | 0.6482 | 0.6507 | 0.6313 | 0.6351 |

## Comments

The 5th harmonic voltages are still much lower compared with Scenario 1. This is the case for all harmonic voltages but the 4th harmonic voltage, which increased very slightly due to the parallel resonance introduced by the shunt filter. All harmonic voltage distortions are well below IEE 519 limits.



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

## 2.4 Faulting Utilities

The following tables show currents and voltage harmonics at Hangingstone when faulting Ruth Lake and McMillan utility supplies. Up direction variations are marked in red.

### CURRENT HARMONICS, SCENARIO 1

| | Measured | ETAP Model | | |
|---|---|---|---|---|
| n | RL+MM ON | | RL OFF | MM OFF |
| 1 | 100 | 100 | 100 | 100 |
| 2 | 0.1600 | 0.0036 | 0.0073 | 0.0130 |
| 3 | 2.5000 | 0.0000 | 0.0000 | 0.0000 |
| 4 | 0.0000 | 0.0078 | 0.0104 | 0.0102 |
| 5 | 3.3300 | 3.0204 | 1.8978 | 2.7088 |
| 7 | 0.4160 | 0.4130 | 0.2604 | 0.2091 |
| 8 | 0.0000 | 0.0009 | 0.0003 | 0.0025 |
| 9 | 0.4000 | 0.0000 | 0.0000 | 0.0000 |
| 11 | 0.4160 | 0.4154 | 0.6276 | 0.8913 |
| 13 | 0.4000 | 0.4002 | 0.3208 | 0.3322 |
| 14 | - | 0.0002 | 0.0000 | 0.0001 |
| 17 | - | 0.1658 | 0.1246 | 0.1241 |
| 19 | - | 0.0645 | 0.0667 | 0.1018 |
| 23 | - | 0.0545 | 0.0395 | 0.0538 |
| 25 | - | 0.0247 | 0.0183 | 0.0237 |
| 29 | - | 0.0017 | 0.0013 | 0.0010 |
| 31 | - | 0.0008 | 0.0012 | 0.0009 |
| THD | 4.2462 | 3.1083 | 2.0466 | 2.8837 |

### VOLTAGE HARMONICS, SCENARIO 1

| | Measured | ETAP Model | | |
|---|---|---|---|---|
| n | RL+MM ON | | RL OFF | MM OFF |
| 1 | 100 | 100 | 100 | 100 |
| 2 | 0.0000 | 0.0041 | 0.0106 | 0.0152 |
| 3 | 0.8000 | 0.0000 | 0.0000 | 0.0000 |
| 4 | 0.0000 | 0.0087 | 0.0146 | 0.0115 |
| 5 | 2.6000 | 1.7489 | 1.5389 | 1.7824 |
| 7 | 0.2400 | 0.4592 | 0.3081 | 0.3764 |
| 8 | 0.0000 | 0.0008 | 0.0004 | 0.0024 |
| 9 | 0.2300 | 0.0000 | 0.0000 | 0.0000 |
| 11 | 0.3200 | 0.4412 | 0.4830 | 0.7224 |
| 13 | 0.1000 | 0.2917 | 0.3435 | 0.3729 |
| 14 | - | 0.0001 | 0.0000 | 0.0001 |
| 17 | - | 0.2287 | 0.2179 | 0.1597 |
| 19 | - | 0.1145 | 0.1237 | 0.1248 |
| 23 | - | 0.0971 | 0.0959 | 0.0972 |
| 25 | - | 0.0523 | 0.0521 | 0.0520 |
| 29 | - | 0.0006 | 0.0007 | 0.0004 |
| 31 | - | 0.0003 | 0.0005 | 0.0003 |
| THD | 2.7610 | 1.9045 | 1.6998 | 2.0083 |



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

## CURRENT HARMONICS, SCENARIO 2

| | RL+MM ON | RL OFF | MM OFF | | RL+MM ON | RL OFF | MM OFF |
|---|---|---|---|---|---|---|---|
| n | ALL 6000 | ALL 6000 | ALL 6000 | | NO 6000 | NO 6000 | NO 6000 |
| 1 | 100 | 100 | 100 | | 100 | 100 | 100 |
| 2 | 0.0048 | 0.0056 | 0.0179 | | 0.0041 | 0.0083 | 0.0150 |
| 4 | 0.0514 | 0.0503 | 0.0642 | | 0.0485 | 0.0453 | 0.0610 |
| 5 | 0.4588 | 0.4568 | 0.5797 | | 0.4236 | 0.3623 | 0.5250 |
| 7 | 0.2706 | 0.3176 | 0.3399 | | 0.2018 | 0.3637 | 0.3714 |
| 8 | 0.0005 | 0.0011 | 0.0019 | | 0.0008 | 0.0004 | 0.0032 |
| 11 | 0.4469 | 0.5651 | 0.7465 | | 0.4918 | 0.3883 | 0.4565 |
| 13 | 0.3696 | 0.3604 | 0.3369 | | 0.2214 | 0.1654 | 0.1864 |
| 14 | 0.0001 | 0.0002 | 0.0001 | | 0.0001 | 0.0000 | 0.0001 |
| 17 | 0.1944 | 0.0862 | 0.1417 | | 0.1229 | 0.1017 | 0.1303 |
| 19 | 0.0751 | 0.0364 | 0.1179 | | 0.0667 | 0.0589 | 0.0787 |
| 23 | 0.0630 | 0.0243 | 0.0627 | | 0.0669 | 0.0504 | 0.0662 |
| 25 | 0.0283 | 0.0108 | 0.0272 | | 0.0370 | 0.0266 | 0.0368 |
| 29 | 0.0019 | 0.0017 | 0.0010 | | 0.0010 | 0.0008 | 0.0006 |
| 31 | 0.0009 | 0.0009 | 0.0010 | | 0.0005 | 0.0008 | 0.0006 |
| THD | 0.8191 | 0.8779 | 1.0796 | | 0.7341 | 0.6788 | 0.8304 |

## VOLTAGE HARMONICS, SCENARIO 2

| | RL+MM ON | RL OFF | MM OFF | | RL+MM ON | RL OFF | MM OFF |
|---|---|---|---|---|---|---|---|
| n | ALL 6000 | ALL 6000 | ALL 6000 | | NO 6000 | NO 6000 | NO 6000 |
| 1 | 100 | 100 | 100 | | 100 | 100 | 100 |
| 2 | 0.0048 | 0.0048 | 0.0172 | | 0.0044 | 0.0111 | 0.0161 |
| 4 | 0.0514 | 0.0142 | 0.0207 | | 0.0179 | 0.0213 | 0.0227 |
| 5 | 0.4588 | 0.2488 | 0.2326 | | 0.2310 | 0.2452 | 0.2272 |
| 7 | 0.2706 | 0.4088 | 0.2520 | | 0.2323 | 0.2219 | 0.2619 |
| 8 | 0.0005 | 0.0010 | 0.0020 | | 0.0005 | 0.0003 | 0.0024 |
| 11 | 0.4469 | 0.3197 | 0.5788 | | 0.2848 | 0.3159 | 0.3613 |
| 13 | 0.3696 | 0.2655 | 0.3617 | | 0.1661 | 0.1817 | 0.2047 |
| 14 | 0.0001 | 0.0001 | 0.0001 | | 0.0001 | 0.0000 | 0.0001 |
| 17 | 0.1944 | 0.1124 | 0.1739 | | 0.1693 | 0.1615 | 0.1447 |
| 19 | 0.0751 | 0.0567 | 0.1388 | | 0.1088 | 0.1077 | 0.1016 |
| 23 | 0.0630 | 0.0433 | 0.1081 | | 0.1160 | 0.1196 | 0.1159 |
| 25 | 0.0283 | 0.0233 | 0.0569 | | 0.0736 | 0.0770 | 0.0726 |
| 29 | 0.0019 | 0.0003 | 0.0004 | | 0.0011 | 0.0012 | 0.0007 |
| 31 | 0.0009 | 0.0001 | 0.0004 | | 0.0006 | 0.0011 | 0.0007 |
| THD | 0.8191 | 0.6482 | 0.8054 | | 0.5251 | 0.5483 | 0.5860 |



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

## CURRENT HARMONICS, SCENARIO 3

| | RL+MM ON | RL OFF | MM OFF | | RL+MM ON | RL OFF | MM OFF |
|---|---|---|---|---|---|---|---|
| n | ALL 6000 | ALL 6000 | ALL 6000 | | NO 6000 | NO 6000 | NO 6000 |
| 1 | 100 | 100 | 100 | | 100 | 100 | 100 |
| 2 | 0.0066 | 0.0147 | 0.0247 | | 0.0056 | 0.0119 | 0.0208 |
| 4 | 0.0468 | 0.0466 | 0.0582 | | 0.0503 | 0.0473 | 0.0624 |
| 5 | 0.4839 | 0.5122 | 0.5944 | | 0.4568 | 0.3908 | 0.5516 |
| 6 | 0.0000 | 0.0000 | 0.0000 | | 0.0000 | 0.0000 | 0.0000 |
| 7 | 0.4353 | 0.2745 | 0.1783 | | 0.3176 | 0.2831 | 0.2149 |
| 8 | 0.0014 | 0.0005 | 0.0036 | | 0.0011 | 0.0004 | 0.0031 |
| 11 | 0.2754 | 0.6125 | 0.5971 | | 0.5651 | 0.8218 | 0.9410 |
| 13 | 0.2268 | 0.1622 | 0.1319 | | 0.3604 | 0.2575 | 0.2276 |
| 14 | 0.0002 | 0.0000 | 0.0001 | | 0.0002 | 0.0000 | 0.0001 |
| 17 | 0.0528 | 0.0362 | 0.0481 | | 0.0862 | 0.0650 | 0.0941 |
| 19 | 0.0232 | 0.0208 | 0.0327 | | 0.0364 | 0.0320 | 0.0489 |
| 23 | 0.0153 | 0.0124 | 0.0151 | | 0.0243 | 0.0187 | 0.0241 |
| 25 | 0.0065 | 0.0061 | 0.0059 | | 0.0106 | 0.0089 | 0.0096 |
| 29 | 0.0017 | 0.0013 | 0.0009 | | 0.0016 | 0.0013 | 0.0010 |
| 31 | 0.0008 | 0.0011 | 0.0009 | | 0.0008 | 0.0011 | 0.0009 |
| | | | | | | | |
| THD | 0.7462 | 0.8623 | 0.8756 | | 0.8779 | 0.9913 | 1.1419 |

## VOLTAGE HARMONICS, SCENARIO 3

| | RL+MM ON | RL OFF | MM OFF | | RL+MM ON | RL OFF | MM OFF |
|---|---|---|---|---|---|---|---|
| n | ALL 6000 | ALL 6000 | ALL 6000 | | NO 6000 | NO 6000 | NO 6000 |
| 1 | 100 | 100 | 100 | | 100 | 100 | 100 |
| 2 | 0.0051 | 0.0131 | 0.0192 | | 0.0048 | 0.0123 | 0.0179 |
| 4 | 0.0120 | 0.0139 | 0.0151 | | 0.0142 | 0.0163 | 0.0178 |
| 5 | 0.2571 | 0.2616 | 0.2515 | | 0.2488 | 0.2647 | 0.2450 |
| 6 | 0.0000 | 0.0000 | 0.0000 | | 0.0000 | 0.0000 | 0.0000 |
| 7 | 0.4748 | 0.3157 | 0.3779 | | 0.4088 | 0.3022 | 0.4282 |
| 8 | 0.0008 | 0.0004 | 0.0022 | | 0.0010 | 0.0004 | 0.0029 |
| 11 | 0.2816 | 0.4220 | 0.4671 | | 0.3197 | 0.6310 | 0.7312 |
| 13 | 0.1599 | 0.1555 | 0.1433 | | 0.2655 | 0.2670 | 0.2463 |
| 14 | 0.0000 | 0.0000 | 0.0000 | | 0.0001 | 0.0000 | 0.0000 |
| 17 | 0.0678 | 0.0651 | 0.0603 | | 0.1124 | 0.1089 | 0.1025 |
| 19 | 0.0354 | 0.0354 | 0.0366 | | 0.0567 | 0.0575 | 0.0593 |
| 23 | 0.0273 | 0.0272 | 0.0273 | | 0.0434 | 0.0431 | 0.0434 |
| 25 | 0.0148 | 0.0149 | 0.0148 | | 0.0233 | 0.0234 | 0.0231 |
| 29 | 0.0002 | 0.0002 | 0.0001 | | 0.0003 | 0.0003 | 0.0002 |
| 31 | 0.0001 | 0.0001 | 0.0001 | | 0.0001 | 0.0002 | 0.0002 |
| | | | | | | | |
| THD | 0.6351 | 0.6142 | 0.6718 | | 0.6482 | 0.8055 | 0.9251 |

### Comments

Only the 7th and 11th harmonics show some upwards trend depending on the configuration of the capacitor banks. All harmonic distortions are well below IEEE 519 limits. Switching off one of the utility feeders is not critical.



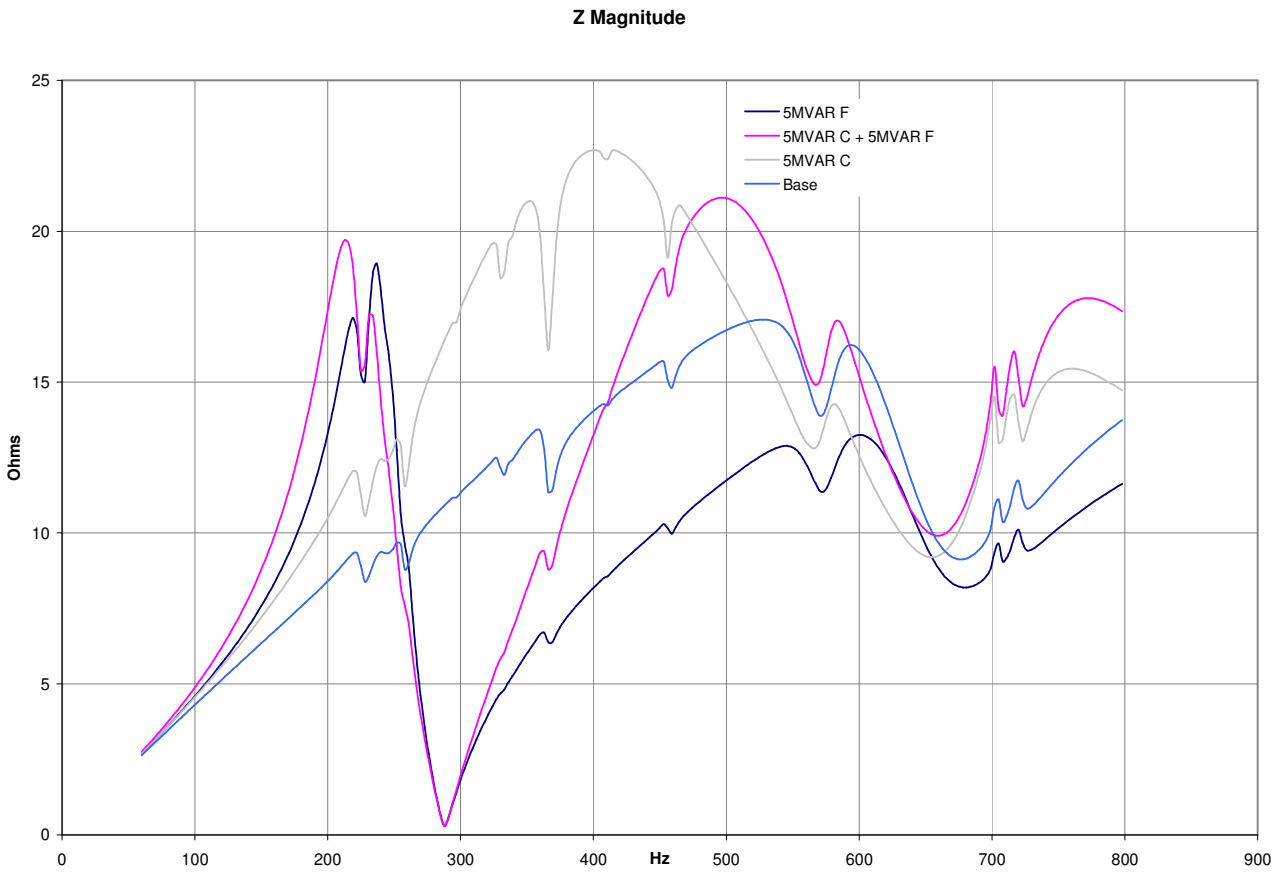
Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

# 3. CONCLUSIONS

## 3.1 Comparing Scenarios

The following graph highlights the bus impedance scans for all three scenarios, resulting in almost similar shape, but lower values compared with the scans presented in *ATCO Electric Harmonic Filter Specification*, sheet 26. This divergence could be caused by the different assumptions taken for elaborating the models and possibly related to different calculation methods. Similar impacts are detected though on both models, when connecting the 5 MVAR filter and 5 MVAR capacitor bank in parallel and this is important.

The following graph for the Hangingstone Substation 25 kV bus was recorded from the ETAP simulation. Additional poles and zeros are apparent from this graph: they do result from the drive filters, which perhaps were not considered in ATCO simulations.






Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

## Comments

Connecting a 5 MVAR filter or a combination of filter and capacitor bank will introduce an increase of harmonic current import down from the 144 kV level as well as absorbing any 5th harmonic current coming directly from the Hangingstone Substation. Connecting in parallel a capacitor bank of 5 MVAR will not introduce any major additional impact when compared with the 5 MVAR 5th harmonic filter of Scenario 2, considering the very slight ringing effect between 7th and 10th harmonic.

The following harmonic current table summarizes the results for all three scenarios, including all possible sub-scenarios:

**CURRENT HARMONICS- HANGINGSTONE 25KV SUPPLY**

| | SCENARIO 1 | | SCENARIO 2 | | | | SCENARIO 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| n | Measured | Final Model | NO 6000 | 6008,10 | 6005,08,10 | ALL 6000 | NO 6000 | 6008,10 | 6005,08,10 | ALL 6000 |
| 1 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 2 | 0.1600 | 0.0036 | 0.0041 | 0.0042 | 0.0045 | 0.0048 | 0.0056 | 0.0057 | 0.0061 | 0.0066 |
| 3 | 2.5000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4 | 0.0000 | 0.0078 | 0.0485 | 0.0481 | 0.0504 | 0.0514 | 0.0503 | 0.0501 | 0.0486 | 0.0468 |
| 5 | 3.3300 | 3.0204 | 0.4236 | 0.4409 | 0.4502 | 0.4588 | 0.4568 | 0.4741 | 0.4796 | 0.4839 |
| 6 | - | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 7 | 0.4160 | 0.4130 | 0.2018 | 0.2321 | 0.2490 | 0.2706 | 0.3176 | 0.3414 | 0.3869 | 0.4353 |
| 8 | 0.0000 | 0.0009 | 0.0008 | 0.0006 | 0.0005 | 0.0005 | 0.0011 | 0.0009 | 0.0011 | 0.0014 |
| 9 | 0.4000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 10 | - | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11 | 0.4160 | 0.4154 | 0.4918 | 0.3760 | 0.4252 | 0.4469 | 0.5651 | 0.3738 | 0.3216 | 0.2754 |
| 13 | 0.4000 | 0.4002 | 0.2214 | 0.2249 | 0.2889 | 0.3696 | 0.3604 | 0.3704 | 0.2904 | 0.2268 |
| 14 | - | 0.0002 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0002 | 0.0002 | 0.0002 | 0.0002 |
| 17 | - | 0.1658 | 0.1229 | 0.1231 | 0.1886 | 0.1944 | 0.0862 | 0.0865 | 0.0657 | 0.0528 |
| 19 | - | 0.0645 | 0.0667 | 0.0621 | 0.0909 | 0.0751 | 0.0364 | 0.0350 | 0.0278 | 0.0232 |
| 23 | - | 0.0545 | 0.0669 | 0.0676 | 0.1025 | 0.0630 | 0.0243 | 0.0250 | 0.0191 | 0.0153 |
| 25 | - | 0.0247 | 0.0370 | 0.0374 | 0.0529 | 0.0283 | 0.0106 | 0.0109 | 0.0082 | 0.0065 |
| 29 | - | 0.0017 | 0.0010 | 0.0010 | 0.0018 | 0.0019 | 0.0016 | 0.0017 | 0.0017 | 0.0017 |
| 31 | - | 0.0008 | 0.0005 | 0.0005 | 0.0009 | 0.0009 | 0.0008 | 0.0008 | 0.0008 | 0.0008 |
| THD | 4.2462 | 3.108292 | 0.7341 | 0.6837 | 0.7672 | 0.8191 | 0.8779 | 0.7939 | 0.7586 | 0.7462 |

Scenario 3 (including all its variations of the capacitor banks 6005 to 6010) delivers acceptable results well below IEEE 519 limits, without introducing any major resonances. All THD values are acceptable.



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

The following harmonic voltage table summarizes the results for all three scenarios, including all possible sub-scenarios:

**VOLTAGE HARMONICS – HANGINGSTONE 25 KV BUS**

| | SCENARIO 1 | | SCENARIO 2 | | | | SCENARIO 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| n | Measured | Final Model | NO 6000 | 6008,10 | 6005,08,10 | ALL 6000 | NO 6000 | 6008,10 | 6005,08,10 | ALL 6000 |
| 1 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 2 | 0.0000 | 0.0041 | 0.0044 | 0.0044 | 0.0045 | 0.0048 | 0.0048 | 0.0048 | 0.0050 | 0.0051 |
| 3 | 0.8000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4 | 0.0000 | 0.0087 | 0.0179 | 0.0177 | 0.0173 | 0.0514 | 0.0142 | 0.0141 | 0.0131 | 0.0120 |
| 5 | 2.6000 | 1.7489 | 0.2310 | 0.2300 | 0.2340 | 0.4588 | 0.2488 | 0.2477 | 0.2523 | 0.2571 |
| 6 | - | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 7 | 0.2400 | 0.4592 | 0.2323 | 0.2130 | 0.2383 | 0.2706 | 0.4088 | 0.3630 | 0.4186 | 0.4748 |
| 8 | 0.0000 | 0.0008 | 0.0005 | 0.0004 | 0.0005 | 0.0005 | 0.0010 | 0.0008 | 0.0009 | 0.0008 |
| 9 | 0.2300 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 10 | - | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 11 | 0.3200 | 0.4412 | 0.2848 | 0.3922 | 0.4391 | 0.4469 | 0.3197 | 0.3804 | 0.3276 | 0.2816 |
| 13 | 0.1000 | 0.2917 | 0.1661 | 0.1602 | 0.2041 | 0.3696 | 0.2655 | 0.2591 | 0.2037 | 0.1599 |
| 14 | - | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0000 |
| 17 | - | 0.2287 | 0.1693 | 0.1695 | 0.2551 | 0.1944 | 0.1124 | 0.1125 | 0.0849 | 0.0678 |
| 19 | - | 0.1145 | 0.1088 | 0.1136 | 0.1612 | 0.0751 | 0.0567 | 0.0565 | 0.0436 | 0.0354 |
| 23 | - | 0.0971 | 0.1160 | 0.1155 | 0.1751 | 0.0630 | 0.0434 | 0.0434 | 0.0336 | 0.0273 |
| 25 | - | 0.0523 | 0.0736 | 0.0735 | 0.1058 | 0.0283 | 0.0233 | 0.0233 | 0.0182 | 0.0148 |
| 29 | - | 0.0006 | 0.0011 | 0.0011 | 0.0015 | 0.0019 | 0.0003 | 0.0003 | 0.0002 | 0.0002 |
| 31 | - | 0.0003 | 0.0006 | 0.0006 | 0.0007 | 0.0009 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| THD | 2.7610 | 1.9045 | 0.5251 | 0.5818 | 0.6923 | 0.8191 | 0.6482 | 0.6507 | 0.6313 | 0.6351 |

Scenario 3 (including all its variations of the capacitor banks 6005 to 6010) delivers acceptable results well below IEEE 519 limits, without introducing any major resonances. All THD values are acceptable.



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

## 3.2 Recommendations

A combined harmonic filter and capacitor bank as per Scenario 3 would present a minor ringing effect at about 500 Hz (h = 8.33) while keeping harmonic distortions within reasonable distance from IEEE 519 limits. The filter combination will attenuate the 5th harmonic distortion, it will also keep the 7th harmonic distortion almost unchanged, but it will probably double any existing 3rd harmonic voltage distortion.

The following tables illustrate the 5 MVAR Filter currents and voltages for sizing its reactors and capacitors appropriately.

**REACTOR CURRENTS, Amps**

| | 5 MVAR FILTER | | | | 5 MVAR FILTER + 5MVAR CAP BANK | | | |
|---|---|---|---|---|---|---|---|---|
| n | NO 6000 | 6008,10 | 6005,08,10 | ALL 6000 | NO 6000 | 6008,10 | 6005,08,10 | ALL 6000 |
| 1 | 116.34 | 116.48 | 117.03 | 117.58 | 118.66 | 118.80 | 119.36 | 119.94 |
| 2 | 0.0122 | 0.0123 | 0.0126 | 0.0129 | 0.0134 | 0.0135 | 0.0138 | 0.0142 |
| 4 | 0.2701 | 0.2676 | 0.2608 | 0.2486 | 0.2146 | 0.2138 | 0.1973 | 0.1820 |
| 5 | 15.5321 | 15.4623 | 15.7323 | 16.0112 | 16.7290 | 16.6514 | 16.9625 | 17.2872 |
| 7 | 1.6660 | 1.5274 | 1.7093 | 1.9323 | 2.9319 | 2.6035 | 3.0025 | 3.4055 |
| 8 | 0.0028 | 0.0022 | 0.0025 | 0.0030 | 0.0054 | 0.0042 | 0.0045 | 0.0043 |
| 11 | 0.8505 | 1.1714 | 1.3115 | 1.3683 | 0.9548 | 1.1360 | 0.9785 | 0.8410 |
| 13 | 0.3933 | 0.3794 | 0.4834 | 0.6148 | 0.6290 | 0.6138 | 0.4825 | 0.3788 |
| 14 | 0.0001 | 0.0001 | 0.0002 | 0.0003 | 0.0002 | 0.0002 | 0.0001 | 0.0001 |
| 17 | 0.2877 | 0.2880 | 0.4335 | 0.4401 | 0.1910 | 0.1911 | 0.1443 | 0.1153 |
| 19 | 0.1626 | 0.1698 | 0.2410 | 0.1932 | 0.0848 | 0.0845 | 0.0652 | 0.0529 |
| 23 | 0.1400 | 0.1395 | 0.2115 | 0.1303 | 0.0523 | 0.0525 | 0.0406 | 0.0330 |
| 25 | 0.0814 | 0.0813 | 0.1169 | 0.0634 | 0.0258 | 0.0258 | 0.0201 | 0.0164 |
| 29 | 0.0011 | 0.0011 | 0.0015 | 0.0007 | 0.0003 | 0.0003 | 0.0002 | 0.0002 |
| 31 | 0.0005 | 0.0005 | 0.0006 | 0.0003 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| 47 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 49 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | | | | | | | | |
| RMS | 117.39 | 117.52 | 118.10 | 118.69 | 119.88 | 120.00 | 120.60 | 121.23 |
| 1.35xRMS | 158.47 | 158.65 | 159.44 | 160.23 | 161.83 | 162.00 | 162.81 | 163.66 |



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392

## CAPACITOR VOLTAGES, % of 25 kV

| | 5 MVAR FILTER | | | | 5 MVAR FILTER + 5MVAR CAP BANK | | | |
|---|---|---|---|---|---|---|---|---|
| n | NO 6000 | 6008,10 | 6005,08,10 | ALL 6000 | NO 6000 | 6008,10 | 6005,08,10 | ALL 6000 |
| 1 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 2 | 0.0053 | 0.0053 | 0.0055 | 0.0056 | 0.0058 | 0.0059 | 0.0060 | 0.0061 |
| 4 | 0.0585 | 0.0579 | 0.0565 | 0.0538 | 0.0465 | 0.0463 | 0.0427 | 0.0394 |
| 5 | 2.6903 | 2.6781 | 2.7248 | 2.7732 | 2.8975 | 2.8840 | 2.9381 | 2.9942 |
| 7 | 0.2061 | 0.1890 | 0.2115 | 0.2391 | 0.3627 | 0.3221 | 0.3715 | 0.4213 |
| 8 | 0.0003 | 0.0002 | 0.0003 | 0.0003 | 0.0006 | 0.0004 | 0.0005 | 0.0005 |
| 11 | 0.0670 | 0.0922 | 0.1033 | 0.1077 | 0.0752 | 0.0894 | 0.0770 | 0.0662 |
| 13 | 0.0262 | 0.0253 | 0.0322 | 0.0410 | 0.0419 | 0.0409 | 0.0321 | 0.0252 |
| 14 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 17 | 0.0147 | 0.0147 | 0.0221 | 0.0224 | 0.0097 | 0.0097 | 0.0074 | 0.0059 |
| 19 | 0.0074 | 0.0077 | 0.0110 | 0.0088 | 0.0039 | 0.0039 | 0.0030 | 0.0024 |
| 23 | 0.0053 | 0.0053 | 0.0080 | 0.0049 | 0.0020 | 0.0020 | 0.0015 | 0.0012 |
| 25 | 0.0028 | 0.0028 | 0.0040 | 0.0022 | 0.0009 | 0.0009 | 0.0007 | 0.0006 |
| 29 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 31 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 47 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 49 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | | | | | | | | |
| SUM | 103.08 | 103.08 | 103.18 | 103.26 | 103.45 | 103.41 | 103.48 | 103.56 |



Power Survey Ltd.
8025 Trans-Canada Highway
St. Laurent, Quebec, H4S 1S4
Phone: (514) 333-8392