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May 13, 2015

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

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

Dear Ms. Blundon:

Re: Newfoundland and Labrador Hydro - the Board's Investigation and Hearing into Supply Issues and Power Outages on the Island Interconnected System – Nostradamus Upgrades Monthly Report

In accordance with item 2.1 of the Liberty Report Recommendations dated December 17, 2014, wherein Hydro is required to "provide the Board with monthly updates on the status of Nostradamus upgrades until the production model is fully in-service and shaken down", please find enclosed the original plus 12 copies of Hydro's report entitled *Accuracy of Nostradamus Load Forecasting at Newfoundland and Labrador Hydro Monthly Report: April 2015.*

We trust the foregoing is satisfactory. If you have any questions or comments, please contact the undersigned.

Yours truly,

NEWFOUNDLAND AND LABRADOR HYDRO

Geoffrey P. Young
Senior Legal Counsel

GPY/jc

cc: Gerard Hayes – Newfoundland Power
Paul Coxworthy – Stewart McKelvey Stirling Scales
Sheryl Nisenbaum – Praxair Canada Inc.
ecc: Roberta Frampton Benefiel – Grand Riverkeeper Labrador
Thomas Johnson – Consumer Advocate
Thomas O' Reilly – Cox & Palmer
Danny Dumaresque

Accuracy of Nostradamus Load Forecasting at Newfoundland and Labrador Hydro

Monthly Report: April 2015

Newfoundland and Labrador Hydro

May 12, 2015

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1. NOSTRADAMUS LOAD FORECASTING

1.1 Nostradamus

Newfoundland and Labrador Hydro (Hydro) uses software called Nostradamus, by Ventyx, for short-term load forecasting with a time frame of seven days. "The Nostradamus Neural Network Forecasting system is a flexible neural network based forecasting tool developed specifically for utility demand forecasting. Unlike conventional computing processes, which are programmed, neural networks use sophisticated mathematical techniques to train a network of inputs and outputs. Neural networks recognize and learn the joint relationships (linear or non-linear) between the ranges of variables considered. Once the network learns these intricate relationships, this knowledge can then easily be extended to produce accurate forecasts." (Nostradamus User Guide, Release 8.2, Ventyx, an ABB Company, May 2014).

The Nostradamus model is trained using a sequence of continuous historic periods of hourly weather and demand data, then forecasts system demand using predictions of those same weather parameters for the next seven days.

1.2 Short-Term Load Forecasting

Hydro uses its short-term load forecast to manage the power system and ensure adequate generating resources are available to meet customer demand.

1.2.1 Utility Load

Hydro contracts AMEC Foster Wheeler to provide the weather parameters in the form of hourly weather forecasts for a seven-day period. At the same time as the weather forecast data is provided, AMEC also provides observed data at the same locations for the previous 24 hours (calendar day). The forecast and actual data are automatically retrieved from AMEC and input to the Nostradamus database.

Nostradamus can use a variety of weather parameters for forecasting as long as a historical record is available for training. Hydro uses the following weather parameters: air temperature, wind speed, and cloud cover. Nostradamus can use each variable more than once, for example both the current and forecast air temperatures are used in forecasting load. Wind chill is not used explicitly as the neural network function of Nostradamus will form its own relationships between load, wind and temperature, which should be superior to the one formula used by Environment Canada to derive wind chill.

Weather data for four locations are used in Nostradamus: St. John's, Gander, Deer Lake, and Port aux Basques. Data from January 1, 2012 to October 31, 2014 are being used for training and verification purposes. The training and verification periods are selected to provide a sufficiently long period to ensure that a range of weather parameters are included, e.g., high and low temperatures, but short enough that the historic load is still representative of loads that can be expected in the future.

In addition to the weather and demand data, a parameter that indicates daylight hours each day is input to Nostradamus.

Demand data for the Avalon Peninsula alone and for the Island Interconnected System as a whole are input to Nostradamus automatically each hour. Only total utility load (conforming), Newfoundland Power's and Hydro's, is input in the Nostradamus model. Industrial load (non-conforming), which is not a function of weather is forecast outside the Nostradamus program and added to the forecasts from Nostradamus to derive the total load forecast.

During the process of training the Nostradamus model, it creates separate submodels for weekdays, weekends and holidays to account for the variation in customer use of electricity. Nostradamus has separate holiday groups for statutory holidays and also for days that are known to have unusual loads, for instance the days between Christmas and New Year's and the school Easter break.

1.2.2 Industrial Load

Industrial load tends to be almost constant, as industrial processes are independent of weather. Under the current procedure, the power-on-order for each Industrial Customer, plus the expected owned generation from Corner Brook Pulp and Paper (CBPP), is used as the industrial load forecasts unless System Operations engineers modify the forecast based on some knowledge of customer loads, for instance a decrease due to reduced production at CBPP or a ramp up in the load expected at Vale. Engineers can change the expected load in one or more cells of a seven by twenty-four hour grid, or can change the default value to be used indefinitely.

1.2.3 Supply and Demand Status Reporting

The forecast peak reported to the Board of Commissioners of Public Utilities (the Board) on the daily Supply and Demand Status Report is the forecast peak as of 7:20 am. The weather forecast for the next seven days and the observed weather data for the previous day are input at approximately 5:00 am. Nostradamus is then run every hour of the day and the most recent forecast is available for reference by System Operations engineers and the Energy Control Centre operators for monitoring and managing

available spinning reserves. The within day forecast updates are used by operators to decide if additional spinning reserve is required in advance of forecast system peaks.

1.3 Load Forecasting Improvements

Hydro implemented the following changes to the load forecasting process in 2014:

- Additional training for staff;
- Updating to the most recent Nostradamus software version;
- Revised training and verification periods and additional quality control of the weather data, including the data from January 2014 which will improve the capability of the model to forecast loads at low temperatures;
- Adding weather parameters for cloud cover and daylight hours;
- Modifying actual demand data used in Nostradamus training to remove unusual system conditions such as significant outages;
- Changing forecasting processes so that Nostradamus forecasts only utility load, with industrial forecasts done separately;
- Changing forecasting process to allow adjustments to the generated forecast to account for unusual system conditions (e.g., to account for an abnormal system configuration that may result in more or less system losses); and
- Creation of new plots and tables showing the load forecast, spinning reserve, and available reserve, which are available on demand to System Operations staff for managing the system.

The changes to the Nostradamus model have eliminated the erratic load shapes that were present in the forecasts at loads in excess of 1600 MW in January 2014 and improved the reliability of the peak forecast. In addition, improved model performance has allowed an increase in forecast update frequency to hourly throughout the day; previously the forecast was updated five times per day.

Hydro renewed its contract for weather forecasting services in January 2015 with improved frequency of weather forecasts and delivery of observed data. In February 2015, Hydro started receiving a second daily weather forecast at approximately 12:45 PM Newfoundland Standard Time each day. The second forecast was implemented on the Production system in April. A midday update of observed climate values, with values up to 11:00 am for the current day, started to be received on the Development environment on March 30th, 2015 and will be implemented on Production in mid-May.

Additional improvements to the forecasting process are planned for 2015, as follows:

- A further update to the software; and
- Monthly accuracy reporting on the weather forecasts from AMEC, which will improve the understanding of any Nostradamus forecast variance.

1.4 Potential Sources of Variance

Improvements made to the Nostradamus forecasting model and Hydro's processes for load forecasting have improved the reliability of the load forecasts and it is anticipated that planned revisions will further improve the accuracy.

As with any forecasting however, there will be ongoing discrepancies between the forecast and the actual values. Typical sources of variance in the load forecasting are as follows:

- Differences in the industrial load forecast due to unexpected changes in customer loads;
- Inaccuracies in the weather forecast, particularly temperature, wind speed or cloud cover; and
- Non-uniform customer behaviour which results in unpredictability.

2. APRIL 2015 FORECAST ACCURACY

Table 1 presents the daily forecast peak, the observed peak, and the available system capacity, as included in Hydro's daily Supply and Demand Status Reports submitted to the Board for each day in April 2015. The data are also presented in Figure 1. The actual peaks, as reported to the Board, varied from 1130 MW on April 26 to 1470 MW on April 9.

The available capacity during the month was between 1635 MW on April 13 and April 29 and 1925 MW on April 6. Reserves were sufficient throughout the period.

Table 2 presents error statistics for the peak forecasts during the month of April 2015. Figure 2 is a plot of the forecast and actual peaks, as shown in Figure 1, but with the addition of a bar chart showing the difference between the two data series. In both the tables and the figures, a positive error is an overestimate; a negative error is an underestimate.

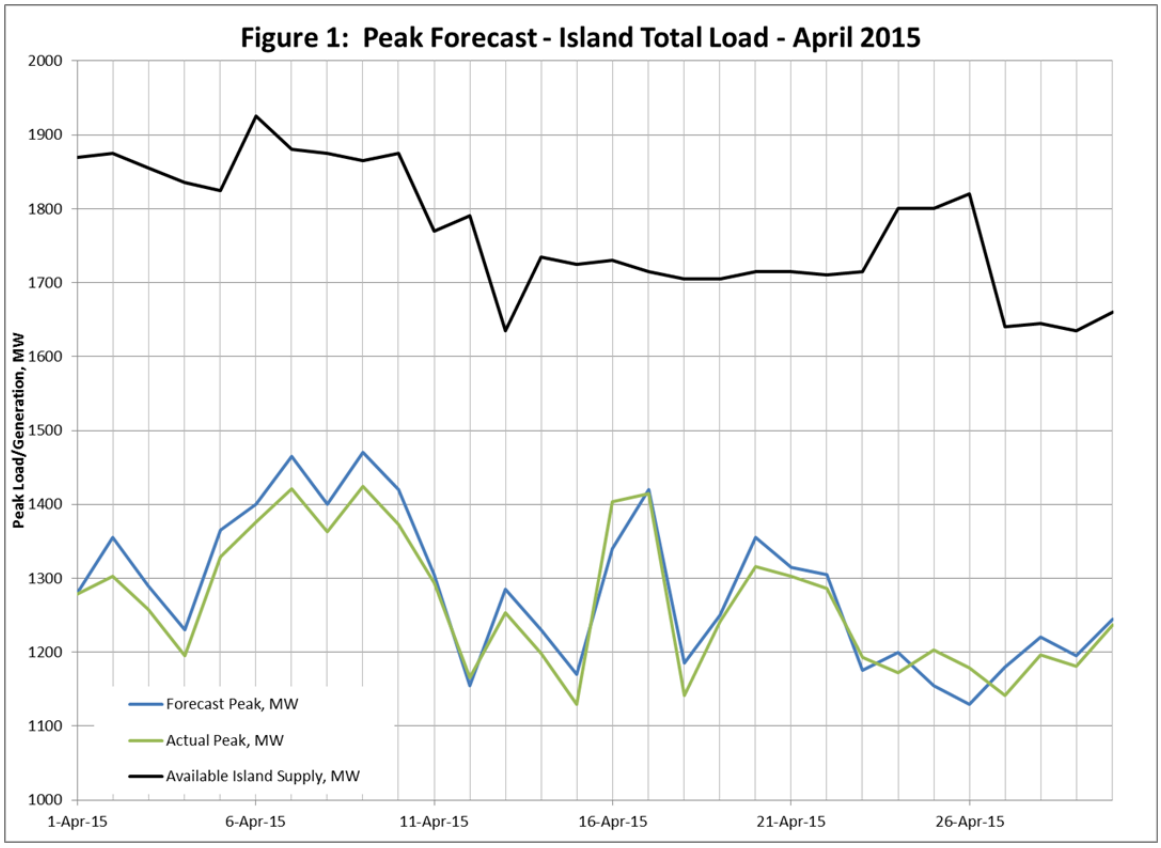
Table 1 April 2015 Load Forecasting Data

Date	Forecast Peak, MW	Actual Peak, MW	Available Island Supply, MW	Forecast Reserve, MW
1-Apr-15	1280	1279	1870	590
2-Apr-15	1355	1303	1875	520
3-Apr-15	1290	1258	1855	565
4-Apr-15	1230	1195	1835	605
5-Apr-15	1365	1329	1825	460
6-Apr-15	1400	1376	1925	525
7-Apr-15	1465	1421	1880	415
8-Apr-15	1400	1363	1875	475
9-Apr-15	1470	1424	1865	395
10-Apr-15	1420	1373	1875	455
11-Apr-15	1305	1294	1770	465
12-Apr-15	1155	1166	1790	635
13-Apr-15	1285	1253	1635	350
14-Apr-15	1230	1198	1735	505
15-Apr-15	1170	1130	1725	555
16-Apr-15	1340	1403	1730	390
17-Apr-15	1420	1414	1715	295
18-Apr-15	1185	1142	1705	520
19-Apr-15	1250	1241	1705	455
20-Apr-15	1355	1316	1715	360
21-Apr-15	1315	1303	1715	400
22-Apr-15	1305	1286	1710	405
23-Apr-15	1175	1193	1715	540
24-Apr-15	1200	1172	1800	600
25-Apr-15	1155	1203	1800	645
26-Apr-15	1130	1179	1820	690
27-Apr-15	1180	1142	1640	460
28-Apr-15	1220	1196	1645	425
29-Apr-15	1195	1181	1635	440
30-Apr-15	1245	1237	1660	415

Notes:

Forecast peak, available capacity and forecast reserve are rounded to the nearest 5 MW.

Forecast peak and available capacity presented is as reported to the Board. The forecast is updated hourly throughout the day for use in maintaining adequate generation reserves. Forecast Reserve = Available Island Supply - (Forecast Peak - CBPP Interruptible Load (when applicable) - the impact of voltage reduction).



The accuracy of the forecast peaks was good for the month of April with a range of 4.5% below the actual peak to 4.0% above the actual peak. On several days the forecast peak essentially matched the actual peak; on the worst day it was 63 MW too low. On average, the forecast peak was 30 MW different than the actual peak, or 2.4%.

In Hydro's opinion, for the month of April, the variations between Nostradamus' daily forecast peak and the actual peaks are acceptable.

Table 2 April 2015 Analysis of Forecast Error

Date	Actual Peak, MW	Forecast Peak, MW	Error, MW	Absolute Error, MW	Percent Error	Absolute Percent Error	Actual/ Forecast
1-Apr-15	1279	1280	1	1	0.1%	0.1%	0.1%
2-Apr-15	1303	1355	52	52	4.0%	4.0%	3.8%
3-Apr-15	1258	1290	32	32	2.5%	2.5%	2.5%
4-Apr-15	1195	1230	35	35	2.9%	2.9%	2.8%
5-Apr-15	1329	1365	36	36	2.7%	2.7%	2.6%
6-Apr-15	1376	1400	24	24	1.7%	1.7%	1.7%
7-Apr-15	1421	1465	44	44	3.1%	3.1%	3.0%
8-Apr-15	1363	1400	37	37	2.7%	2.7%	2.6%
9-Apr-15	1424	1470	46	46	3.2%	3.2%	3.1%
10-Apr-15	1373	1420	47	47	3.4%	3.4%	3.3%
11-Apr-15	1294	1305	11	11	0.9%	0.9%	0.8%
12-Apr-15	1166	1155	-11	11	-0.9%	0.9%	-1.0%
13-Apr-15	1253	1285	32	32	2.6%	2.6%	2.5%
14-Apr-15	1198	1230	32	32	2.7%	2.7%	2.6%
15-Apr-15	1130	1170	40	40	3.5%	3.5%	3.4%
16-Apr-15	1403	1340	-63	63	-4.5%	4.5%	-4.7%
17-Apr-15	1414	1420	6	6	0.4%	0.4%	0.4%
18-Apr-15	1142	1185	43	43	3.8%	3.8%	3.6%
19-Apr-15	1241	1250	9	9	0.7%	0.7%	0.7%
20-Apr-15	1316	1355	39	39	3.0%	3.0%	2.9%
21-Apr-15	1303	1315	12	12	0.9%	0.9%	0.9%
22-Apr-15	1286	1305	19	19	1.5%	1.5%	1.5%
23-Apr-15	1193	1175	-18	18	-1.5%	1.5%	-1.5%
24-Apr-15	1172	1200	28	28	2.4%	2.4%	2.3%
25-Apr-15	1203	1155	-48	48	-4.0%	4.0%	-4.2%
26-Apr-15	1179	1130	-49	49	-4.2%	4.2%	-4.3%
27-Apr-15	1142	1180	38	38	3.3%	3.3%	3.2%
28-Apr-15	1196	1220	24	24	2.0%	2.0%	2.0%
29-Apr-15	1181	1195	14	14	1.2%	1.2%	1.2%
30-Apr-15	1237	1245	8	8	0.6%	0.6%	0.6%
Minimum	1130	1130	-63	1	-4.5%	0.1%	-4.7%
Average	1266	1283	17	30	1.4%	2.4%	1.3%
Maximum	1424	1470	52	63	4.0%	4.5%	3.8%

Notes:

Forecast peak is rounded to the nearest 5 MW

Forecast peak presented is as reported to the Board. The forecast is updated hourly throughout the day for use in maintaining adequate generation reserves.

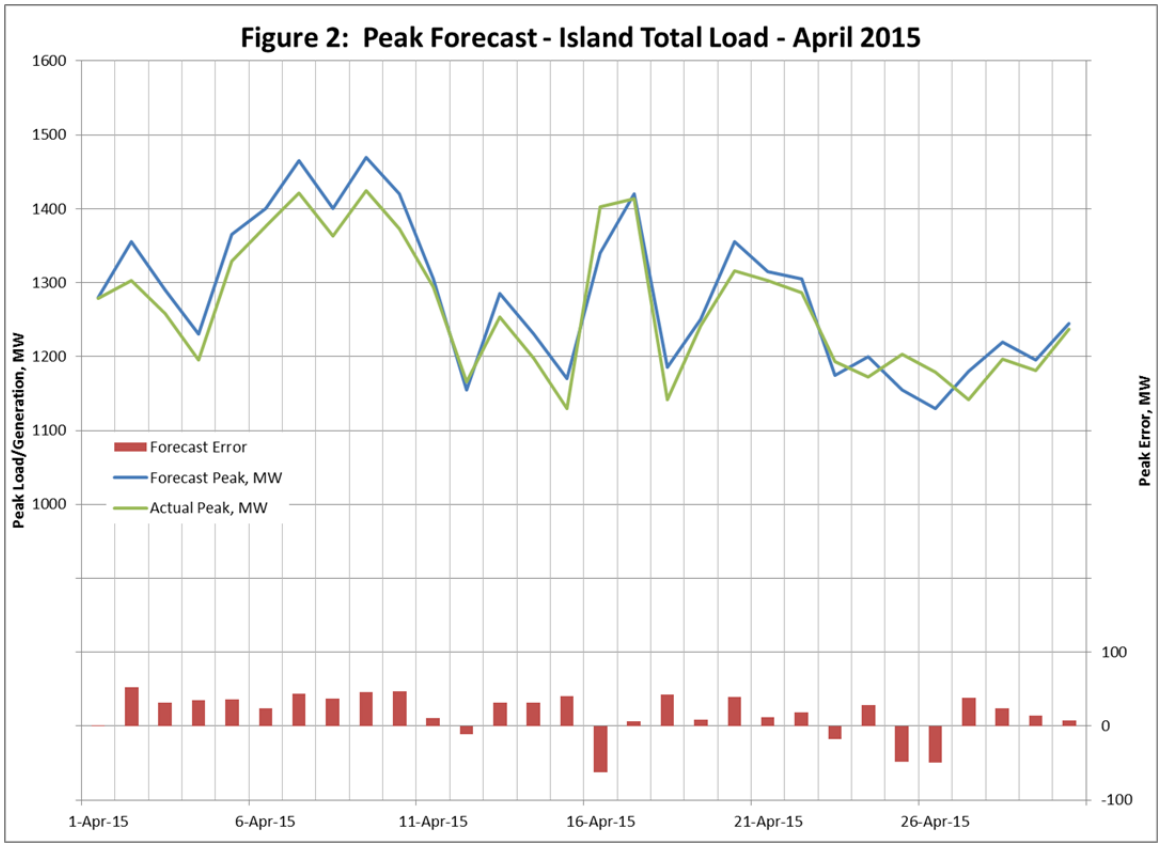


Figure 2: Peak Forecast - Island Total Load - April 2015
Peak Load/Generation, MW
Peak Error, MW
1600
1500
1400
1300
1200
1100
1000
100
0
-100
Forecast Error
Forecast Peak, MW
Actual Peak, MW
1-Apr-15
6-Apr-15
11-Apr-15
16-Apr-15
21-Apr-15
26-Apr-15