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April 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: March 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.
Thomas Johnson – Consumer Advocate
Thomas O' Reilly – Cox & Palmer
Danny Dumaresque
ecc: Roberta Frampton Benefiel – Grand Riverkeeper Labrador

Accuracy of Nostradamus Load Forecasting at Newfoundland and Labrador Hydro

Monthly Report: March 2015

Newfoundland and Labrador Hydro

April 9, 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 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, initially only on the Development[1] environment. A midday update of observed climate values, with values up to 11 am for the current day, started to be received on the Development environment on March 30, 2015. Both these midday updates are anticipated to be implemented on the Production

[1] Hydro runs Nostradamus (and other key software) on two servers: Development and Production. Changes are made on Development first and then are implemented on Production once testing is complete.

environment by mid-April. These midday updates are expected to improve the within day and 'tomorrow' load forecasts.

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

- A further update to the software once it is released by the vendor; 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. MARCH 2015 FORECAST ACCURACY

2.1 March Adjustments

On March 4, the Island Interconnected System experienced a supply disruption resulting from unanticipated generation issues on the Avalon Peninsula, causing voltages to decline in the region. Actual generation data automatically entered into Nostradamus was therefore not representative of what the true Island load would have been. Actual hourly data was therefore replaced with the forecast Island demand from the Nostradamus model on Hydro's Development system for the hours of 8 am through 12 pm on March 4.

2.2 Description of Forecast

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 March 2015. The data are also presented in Figure 1. The actual peaks, as reported to the Board, varied from 1210 MW on March 28 to 1683 MW on March 13.

The available capacity during the month was between 1795 MW on March 2 and 2035 MW on March 13 and March 20. Apart from the period of the disruption on March 4, reserves were sufficient throughout the period.

Table 1 March 2015 Load Forecasting Data

Date	Forecast Peak, MW	Actual Peak, MW	Available Island Supply, MW	Forecast Reserve, MW
1-Mar-15	1460	1412	1865	500
2-Mar-15	1515	1539	1795	380
3-Mar-15	1490	1570	1810	415
4-Mar-15	1630	*	*	*
5-Mar-15	1460	1472	1995	630
6-Mar-15	1620	1611	2020	500
7-Mar-15	1550	1500	1990	540
8-Mar-15	1385	1385	2015	725
9-Mar-15	1490	1493	2015	620
10-Mar-15	1625	1650	1990	465
11-Mar-15	1565	1578	2000	535
12-Mar-15	1485	1497	1880	490
13-Mar-15	1645	1683	2035	490
14-Mar-15	1610	1569	2020	510
15-Mar-15	1515	1527	2000	585
16-Mar-15	1535	1561	2010	575
17-Mar-15	1365	1368	2000	730
18-Mar-15	1345	1354	1990	740
19-Mar-15	1345	1332	2025	775
20-Mar-15	1405	1410	2035	725
21-Mar-15	1355	1328	2010	750
22-Mar-15	1375	1411	2020	740
23-Mar-15	1440	1498	1940	595
24-Mar-15	1455	1465	2005	645
25-Mar-15	1440	1431	1990	645
26-Mar-15	1415	1407	1990	670
27-Mar-15	1235	1231	1860	720
28-Mar-15	1200	1210	1870	765
29-Mar-15	1280	1265	1840	655
30-Mar-15	1385	1382	1845	555
31-Mar-15	1355	1344	1825	485

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 supply disruption of March 4th prevents analysis of the accuracy of the forecast .

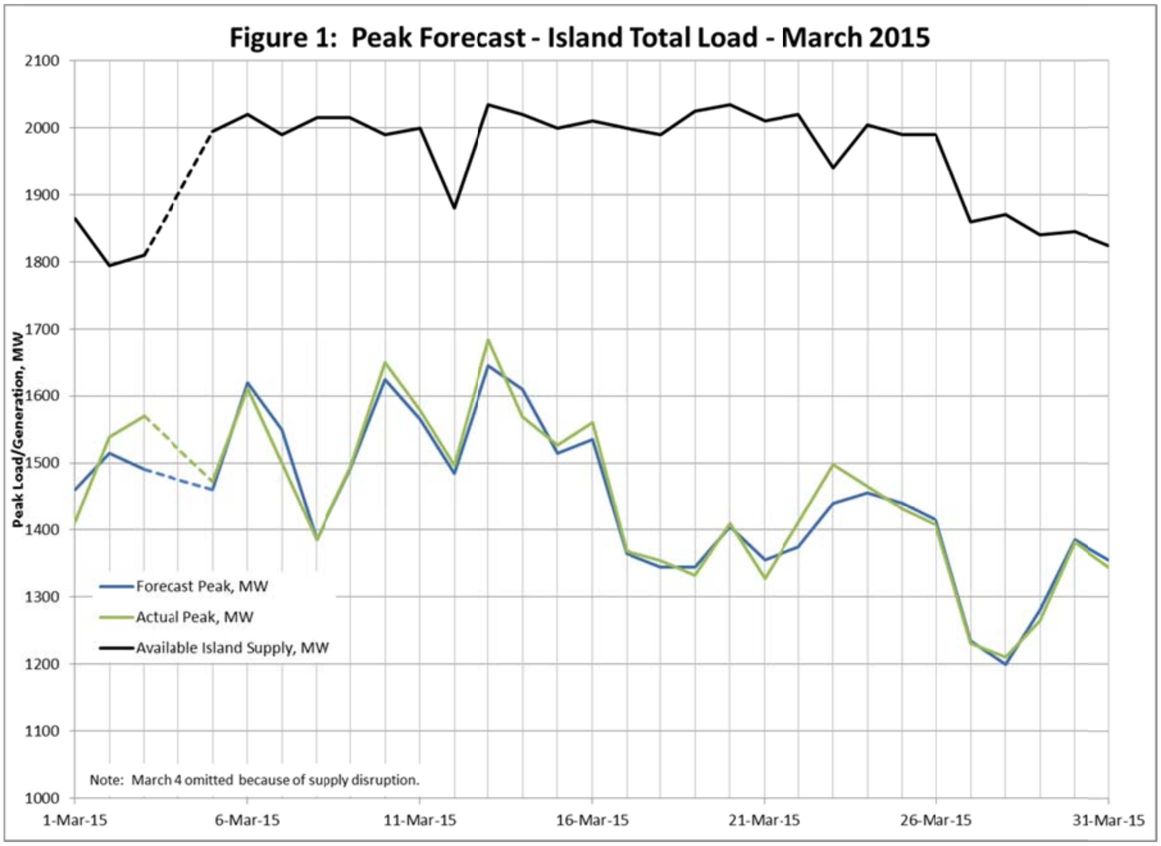


Figure 1: Peak Forecast - Island Total Load - March 2015

Table 2 presents error statistics for the peak forecasts during the month of March 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.

In March, the forecast peak was in a range between 5.1% below the actual peak and 3.4% above the actual peak. On several days the forecast peak essentially matched the actual peak; on the worst day it was 80 MW too low. On average, the forecast peak was 20 MW different than the actual peak, or 1.4%.

In the review of forecast accuracy statistics for March 2015 in Table 2, Hydro offers further detail on the difference found between forecast and actual peak for March 3. On March 3, the forecast underestimated the peak by 5%. Section 2.4 provides additional information about the forecast and load on March 4.

Table 2 March 2015 Analysis of Forecast Error

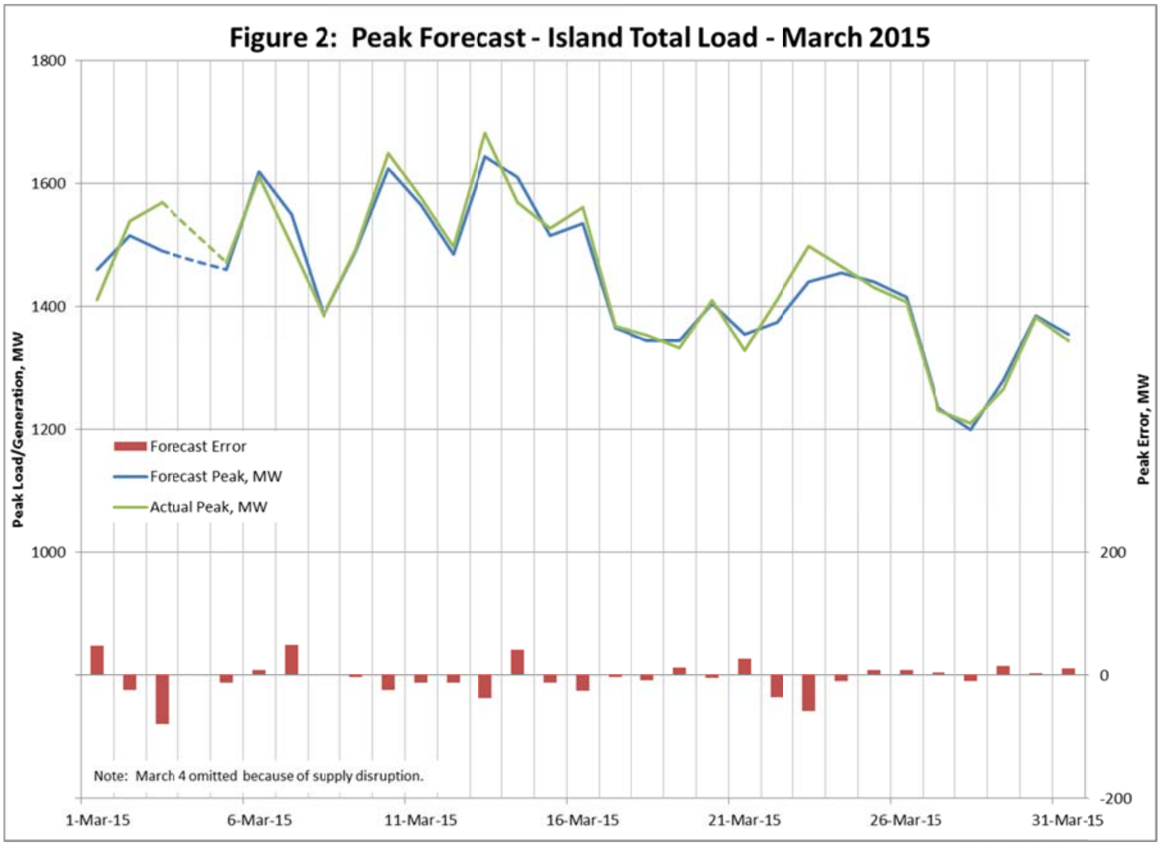
Date	Actual Peak, MW	Forecast Peak, MW	Error, MW	Absolute Error, MW	Percent Error	Absolute Percent Error	Actual/ Forecast
1-Mar-15	1412	1460	48	48	3.4%	3.4%	3.3%
2-Mar-15	1539	1515	-24	24	-1.6%	1.6%	-1.6%
3-Mar-15	1570	1490	-80	80	-5.1%	5.1%	-5.4%
4-Mar-15	*	1630	*	*	*	*	*
5-Mar-15	1472	1460	-12	12	-0.8%	0.8%	-0.8%
6-Mar-15	1611	1620	9	9	0.6%	0.6%	0.6%
7-Mar-15	1500	1550	50	50	3.3%	3.3%	3.2%
8-Mar-15	1385	1385	0	0	0.0%	0.0%	0.0%
9-Mar-15	1493	1490	-3	3	-0.2%	0.2%	-0.2%
10-Mar-15	1650	1625	-25	25	-1.5%	1.5%	-1.5%
11-Mar-15	1578	1565	-13	13	-0.8%	0.8%	-0.8%
12-Mar-15	1497	1485	-12	12	-0.8%	0.8%	-0.8%
13-Mar-15	1683	1645	-38	38	-2.3%	2.3%	-2.3%
14-Mar-15	1569	1610	41	41	2.6%	2.6%	2.5%
15-Mar-15	1527	1515	-12	12	-0.8%	0.8%	-0.8%
16-Mar-15	1561	1535	-26	26	-1.7%	1.7%	-1.7%
17-Mar-15	1368	1365	-3	3	-0.2%	0.2%	-0.2%
18-Mar-15	1354	1345	-9	9	-0.7%	0.7%	-0.7%
19-Mar-15	1332	1345	13	13	1.0%	1.0%	1.0%
20-Mar-15	1410	1405	-5	5	-0.4%	0.4%	-0.4%
21-Mar-15	1328	1355	27	27	2.0%	2.0%	2.0%
22-Mar-15	1411	1375	-36	36	-2.6%	2.6%	-2.6%
23-Mar-15	1498	1440	-58	58	-3.9%	3.9%	-4.0%
24-Mar-15	1465	1455	-10	10	-0.7%	0.7%	-0.7%
25-Mar-15	1431	1440	9	9	0.6%	0.6%	0.6%
26-Mar-15	1407	1415	8	8	0.6%	0.6%	0.6%
27-Mar-15	1231	1235	4	4	0.3%	0.3%	0.3%
28-Mar-15	1210	1200	-10	10	-0.8%	0.8%	-0.8%
29-Mar-15	1265	1280	15	15	1.2%	1.2%	1.2%
30-Mar-15	1382	1385	3	3	0.2%	0.2%	0.2%
31-Mar-15	1344	1355	11	11	0.8%	0.8%	0.8%
Minimum	1210	1200	-80	0	-5.1%	0.0%	-5.4%
Average	1449	1451	-5	20	-0.3%	1.4%	-0.3%
Maximum	1683	1645	50	80	3.4%	5.1%	3.3%

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.

*The supply disruption of March 4th prevents analysis of the accuracy of the forecast.



2.3 March 3, 2015

On March 3, the forecast peak from the model output at 7:20 am was 1490 MW occurring at approximately 8 pm; the actual peak was 1570 MW and occurred at approximately 7 pm. The absolute difference was 80 MW, 5.1% of the actual. Figure 3 includes an hourly plot of the load forecast for March 3 as well as several charts which examine components of the load forecast to assist in determining the sources of the differences between actual and forecast loads. Figure 3(a) shows the hourly distribution of the load forecast compared to the actual load.

Figure 3(b) shows the hourly distribution of the utility load forecast only, i.e., the load forecast with the industrial component removed. The difference between the forecast and actual utility loads at the time of the peak is similar to the difference between the actual and forecast total loads, so the industrial load forecast did not contribute to the discrepancy.

Figures 3(c) through 3(e) show elements of the weather forecast for St. John's. Actual temperature and winds speed throughout the day were similar to forecast, so errors in those forecasts did not contribute to the error in the peak load forecast.

Cloud cover was forecast to be 100% until approximately 9 am and then gradually decrease through the day with a cloud cover of only 20% by 8 pm. For most of the day cloud cover was greater than forecast. Cloud cover was 100% until 1 pm and was 80% for several hours in the afternoon. When the weather is sunny, the solar radiation warms peoples' homes and people tend to feel the cold less, so the absence of the forecast clearing likely contributed to the discrepancy in the forecast.

2.4 March 4, 2015

On March 4, the peak of the 7:20 am forecast was 1630 MW and was forecast to occur at 8 am. However, because of the supply disruption noted previously, the actual peak was 1538 MW and occurred at 7:05 am, shortly before the customer interruptions began. The most recent load data used in the 7:20 am forecast was from 7 am, i.e. before the event. Most customers were restored by mid-morning; the peak for the rest of the day was 1499 MW at 5 pm. As noted in Section 2.1, Nostradamus will use the forecast peak in future training using this period.

Figure 3 Accuracy Analysis - March 3, 2015