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June 12, 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: May 2015.*

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

Yours truly,

NEWFOUNDLAND AND LABRADOR HYDRO

Tracey L. Pennell
Legal Counsel

TLP/cp

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: May 2015

Newfoundland and Labrador Hydro

June 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 has implemented the following changes to the load forecasting process since January 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;
- Requirement for regular weather forecast accuracy reviewing and reporting from Amec; and
- Move to two weather forecasts per day and an update of observed weather data midday.

A new version (8.2.4) of the Nostradamus software was installed on the Development environment on May 19, 2015 and will be tested through May and June, prior to implementation on the Production environment.

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 MAY 2015 FORECAST ACCURACY

2.1 Description

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 May 2015. The data are also presented in Figure 1. The actual peaks, as reported to the Board, varied from 813 MW on May 31 to 1250 MW on May 1.

The available capacity during the month was between 1475 MW on May 15 and 1760 MW on May 27. Reserves were sufficient throughout the period.

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

Through the month of May the forecast peak was in a range between 3.3% below the actual peak and 7.2% above the actual peak. On the best days the forecast peak was essentially the same as the actual peak; on the worst day it was 75 MW too high. On average, the forecast peak was 21 MW different than the actual peak, or 2.1%.

In the review of forecast accuracy statistics for May 2015 in Table 2, Hydro offers further detail on the difference found between forecast and actual peak for May 6, 7, and 17.

Table 1 May 2015 Load Forecasting Data

Date	Forecast Peak, MW	Actual Peak, MW	Available Island Supply, MW	Forecast Reserve, MW
1-May-15	1255	1250	1655	400
2-May-15	1135	1101	1660	525
3-May-15	1035	1051	1640	605
4-May-15	1080	1046	1635	555
5-May-15	1020	995	1640	620
6-May-15	1050	984	1665	615
7-May-15	1110	1035	1650	540
8-May-15	1195	1193	1645	450
9-May-15	1130	1121	1655	525
10-May-15	1100	1138	1660	560
11-May-15	1045	1043	1640	595
12-May-15	1120	1120	1570	450
13-May-15	1135	1115	1630	495
14-May-15	1140	1105	1650	510
15-May-15	1035	1002	1475	440
16-May-15	855	845	1530	675
17-May-15	970	908	1545	575
18-May-15	965	996	1560	595
19-May-15	965	965	1685	720
20-May-15	850	859	1690	840
21-May-15	915	908	1640	725
22-May-15	925	909	1700	775
23-May-15	930	927	1725	795
24-May-15	940	967	1750	810
25-May-15	940	908	1750	810
26-May-15	845	841	1730	885
27-May-15	830	848	1760	930
28-May-15	845	858	1595	750
29-May-15	900	913	1580	680
30-May-15	865	866	1600	735
31-May-15	805	813	1640	835

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).

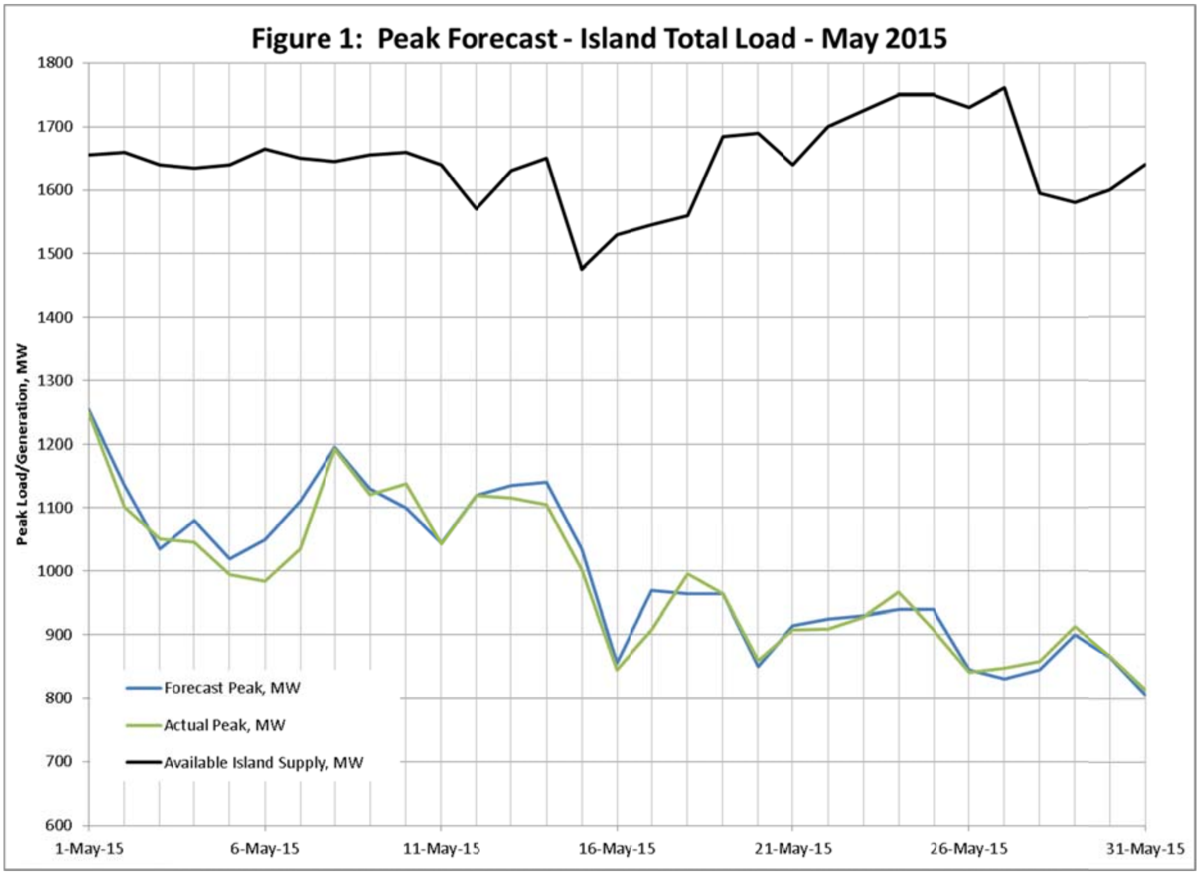


Figure 1: Peak Forecast - Island Total Load - May 2015
Peak Load/Generation, MW
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
1-May-15
6-May-15
11-May-15
16-May-15
21-May-15
26-May-15
31-May-15
Forecast Peak, MW
Actual Peak, MW
Available Island Supply, MW

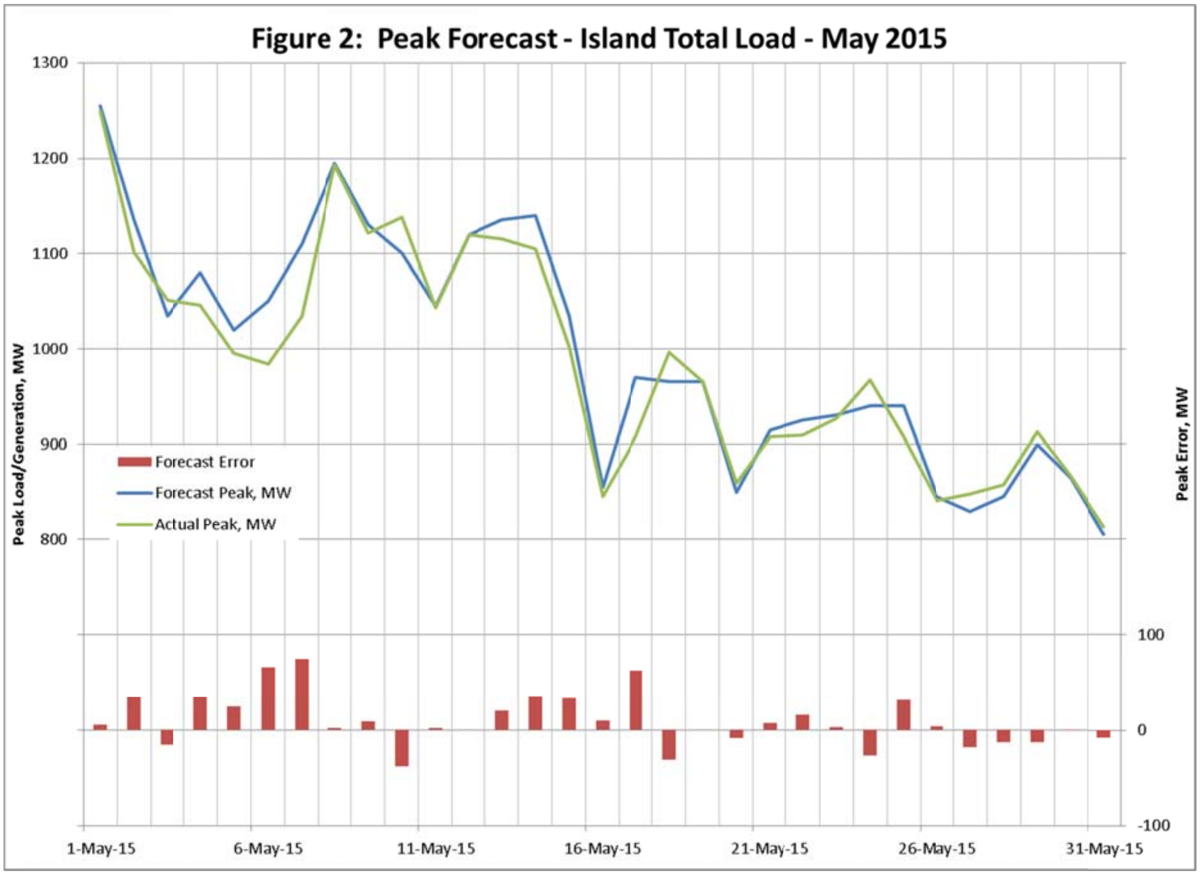
Table 2 May 2015 Analysis of Forecast Error

Date	Actual Peak, MW	Forecast Peak, MW	Error, MW	Absolute Error, MW	Percent Error	Absolute Percent Error	Actual/ Forecast
1-May-15	1250	1255	5	5	0.4%	0.4%	0.4%
2-May-15	1101	1135	34	34	3.1%	3.1%	3.0%
3-May-15	1051	1035	-16	16	-1.5%	1.5%	-1.5%
4-May-15	1046	1080	34	34	3.3%	3.3%	3.1%
5-May-15	995	1020	25	25	2.5%	2.5%	2.5%
6-May-15	984	1050	66	66	6.7%	6.7%	6.3%
7-May-15	1035	1110	75	75	7.2%	7.2%	6.8%
8-May-15	1193	1195	2	2	0.2%	0.2%	0.2%
9-May-15	1121	1130	9	9	0.8%	0.8%	0.8%
10-May-15	1138	1100	-38	38	-3.3%	3.3%	-3.5%
11-May-15	1043	1045	2	2	0.2%	0.2%	0.2%
12-May-15	1120	1120	0	0	0.0%	0.0%	0.0%
13-May-15	1115	1135	20	20	1.8%	1.8%	1.8%
14-May-15	1105	1140	35	35	3.2%	3.2%	3.1%
15-May-15	1002	1035	33	33	3.3%	3.3%	3.2%
16-May-15	845	855	10	10	1.2%	1.2%	1.2%
17-May-15	908	970	62	62	6.8%	6.8%	6.4%
18-May-15	996	965	-31	31	-3.1%	3.1%	-3.2%
19-May-15	965	965	0	0	0.0%	0.0%	0.0%
20-May-15	859	850	-9	9	-1.0%	1.0%	-1.1%
21-May-15	908	915	7	7	0.8%	0.8%	0.8%
22-May-15	909	925	16	16	1.8%	1.8%	1.7%
23-May-15	927	930	3	3	0.3%	0.3%	0.3%
24-May-15	967	940	-27	27	-2.8%	2.8%	-2.9%
25-May-15	908	940	32	32	3.5%	3.5%	3.4%
26-May-15	841	845	4	4	0.5%	0.5%	0.5%
27-May-15	848	830	-18	18	-2.1%	2.1%	-2.2%
28-May-15	858	845	-13	13	-1.5%	1.5%	-1.5%
29-May-15	913	900	-13	13	-1.4%	1.4%	-1.4%
30-May-15	866	865	-1	1	-0.1%	0.1%	-0.1%
31-May-15	813	805	-8	8	-1.0%	1.0%	-1.0%
Minimum	813	805	-38	0	-3.3%	0.0%	-3.5%
Average	988	998	10	21	1.0%	2.1%	0.9%
Maximum	1250	1255	75	75	7.2%	7.2%	6.8%

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.



2.2 May 6 and 7, 2015

On May 6 and 7, 2015, the forecast overestimated the peak load by 6.7% and 7.2%; in fact, the load was overestimated by a similar amount throughout the day. This is indicative of a period when one or more of the industrial loads is lower than expected.

The native load forecast for CBPP, which is supplied by its own generation and power on order from Hydro, is 107 MW. The minimum CBPP load on May 6 was 42 MW; the average was 83 MW. The minimum CBPP load on May 7 was 54 MW; the average was 79 MW. The Energy Control Centre Operators were aware of the reduced load and adjusted generation accordingly.

The accuracy of the Nostradamus utility peak in the 7:20 am forecast was 3.3% on May 6 and 3.7 % on May 7.

2.3 May 17, 2015

On May 17, the peak of the 7:20 am forecast was 970 MW; the actual peak was lower, at 908 MW. The absolute difference was 63 MW or 6.8% of the actual. Figure 3 includes an hourly plot of the load forecast for May 17 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. The forecast predicted a morning peak of 970 MW at 11:00 am. The actual peak was 908 MW at approximately 10:00 am.

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 is somewhat less, so error in the industrial forecast contributed to the discrepancy.

Figure 3(c) shows the actual temperature in St. John's compared to the forecast. Although Nostradamus uses weather data at four sites, the weather in St. John's tends to have the largest effect because of the concentration of customers in St. John's. The temperature was forecast to be up to three degrees warmer through the early part of the day, but was quite accurate for the hours close to the peak so the error in the temperature forecast did not contribute to the forecast error.

Figure 3(d) shows the actual cloud cover in St. John's compared to the forecast. Near the time of the peak the weather was slightly less cloudy than forecast so the error in the cloud cover forecast may have contributed somewhat to the over forecast.

Figure 3(e) shows the actual wind speed in St. John's compared to the forecast. For the full day, the wind speed was significantly lower than predicted, so the error in the wind speed forecast likely contributed to the over forecast of the peak.

The Nostradamus model runs every hour to use actual loads experienced that day to improve the estimate for the rest of the day. At 8:20 am, the forecast peak was only 4.4% above actual and at 9:20 am, the forecast was only 3.4% above actual. These within day updates are used by Energy Control Centre operators to manage spinning reserve.

Figure 3 Accuracy Analysis - May 17, 2015