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August 10, 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: July 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/bs

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: July 2015

Newfoundland and Labrador Hydro

August 10, 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 currently uses: 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 April 1, 2012 to March 31, 2015 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;
- 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);
- 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;
- Move to two weather forecasts per day and an update of observed weather data midday; and
- Version 8.2.4 of the Nostradamus software was installed on Production in mid-July 2015. Implementation of the new version had no noticeable effect on the forecasts.

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. 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 JULY 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 July 2015. The data are also presented in Figure 1. The actual peaks, as reported to the Board, varied from 711 MW on July 4 to 895 MW on July 24.

The available capacity during the month was between 1240 MW on July 12 and 1455 MW on July 18. Reserves were sufficient throughout the period.

Table 2 presents error statistics for the peak forecasts during the month of July 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 July the forecast peak was in a range between 3.9% below the actual peak and 8.3% 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 60 MW too low. On average, the forecast peak was 16 MW different than the actual peak, or 2.1%.

In the review of forecast accuracy statistics for July 2015 in Table 2, Hydro offers further detail on the difference found between forecast and actual peak for July 4 and July 15, two days on which the peak load was overestimated.

Table 1 July 2015 Load Forecasting Data

Date	Forecast Peak, MW	Actual Peak, MW	Available Island Supply, MW	Forecast Reserve, MW
1-Jul-15	750	751	1405	655
2-Jul-15	780	771	1405	625
3-Jul-15	795	786	1390	595
4-Jul-15	760	711	1290	530
5-Jul-15	775	745	1400	625
6-Jul-15	855	870	1390	535
7-Jul-15	860	850	1310	450
8-Jul-15	800	784	1300	500
9-Jul-15	775	735	1375	600
10-Jul-15	765	758	1365	600
11-Jul-15	805	783	1255	450
12-Jul-15	795	767	1240	445
13-Jul-15	815	834	1400	585
14-Jul-15	770	757	1355	585
15-Jul-15	785	725	1360	575
16-Jul-15	780	780	1325	545
17-Jul-15	780	757	1445	665
18-Jul-15	772*	763	1455	683
19-Jul-15	807*	806	1390	583
20-Jul-15	851*	844	1415	564
21-Jul-15	860	870	1380	520
22-Jul-15	845	857	1400	555
23-Jul-15	845	835	1410	565
24-Jul-15	860	895	1450	590
25-Jul-15	850	854	1425	575
26-Jul-15	855	851	1425	570
27-Jul-15	810	833	1395	585
28-Jul-15	805	796	1385	580
29-Jul-15	790	792	1370	580
30-Jul-15	800	818	1400	600
31-Jul-15	810	813	1415	605

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 forecast peaks on these three days were not rounded on the daily reports to the Board, so are not rounded here, for consistancy.

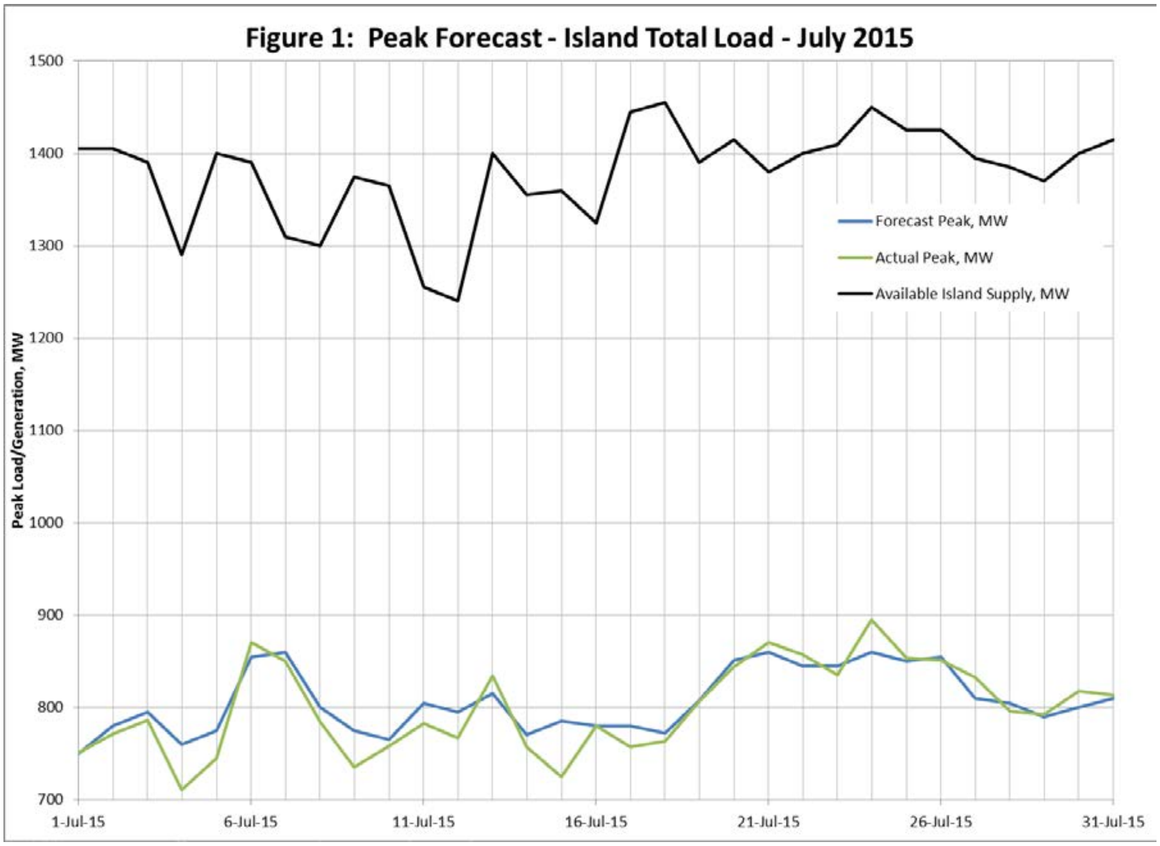


Figure 1: Peak Forecast - Island Total Load - July 2015
Peak Load/Generation, MW
1500
1400
1300
1200
1100
1000
900
800
700
1-Jul-15
6-Jul-15
11-Jul-15
16-Jul-15
21-Jul-15
26-Jul-15
31-Jul-15
Forecast Peak, MW
Actual Peak, MW
Available Island Supply, MW

Table 2 July 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-Jul-15	751	750	-1	1	-0.1%	0.1%	-0.1%
2-Jul-15	771	780	9	9	1.2%	1.2%	1.2%
3-Jul-15	786	795	9	9	1.1%	1.1%	1.1%
4-Jul-15	711	760	49	49	6.9%	6.9%	6.4%
5-Jul-15	745	775	30	30	4.0%	4.0%	3.9%
6-Jul-15	870	855	-15	15	-1.7%	1.7%	-1.8%
7-Jul-15	850	860	10	10	1.2%	1.2%	1.2%
8-Jul-15	784	800	16	16	2.0%	2.0%	2.0%
9-Jul-15	735	775	40	40	5.4%	5.4%	5.2%
10-Jul-15	758	765	7	7	0.9%	0.9%	0.9%
11-Jul-15	783	805	22	22	2.8%	2.8%	2.7%
12-Jul-15	767	795	28	28	3.7%	3.7%	3.5%
13-Jul-15	834	815	-19	19	-2.3%	2.3%	-2.3%
14-Jul-15	757	770	13	13	1.7%	1.7%	1.7%
15-Jul-15	725	785	60	60	8.3%	8.3%	7.6%
16-Jul-15	780	780	0	0	0.0%	0.0%	0.0%
17-Jul-15	757	780	23	23	3.0%	3.0%	2.9%
18-Jul-15	763	772*	9	9	1.2%	1.2%	1.2%
19-Jul-15	806	807*	1	1	0.1%	0.1%	0.1%
20-Jul-15	844	851*	7	7	0.8%	0.8%	0.8%
21-Jul-15	870	860	-10	10	-1.1%	1.1%	-1.2%
22-Jul-15	857	845	-12	12	-1.4%	1.4%	-1.4%
23-Jul-15	835	845	10	10	1.2%	1.2%	1.2%
24-Jul-15	895	860	-35	35	-3.9%	3.9%	-4.1%
25-Jul-15	854	850	-4	4	-0.5%	0.5%	-0.5%
26-Jul-15	851	855	4	4	0.5%	0.5%	0.5%
27-Jul-15	833	810	-23	23	-2.8%	2.8%	-2.8%
28-Jul-15	796	805	9	9	1.1%	1.1%	1.1%
29-Jul-15	792	790	-2	2	-0.3%	0.3%	-0.3%
30-Jul-15	818	800	-18	18	-2.2%	2.2%	-2.3%
31-Jul-15	813	810	-3	3	-0.4%	0.4%	-0.4%
Minimum	711	750	-35	0	-3.9%	0.0%	-4.1%
Average	800	806	7	16	1.0%	2.1%	0.9%
Maximum	895	860	60	60	8.3%	8.3%	7.6%

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 forecast peaks on these three days were not rounded on the daily reports to the Board, so are not rounded here, for consistancy.

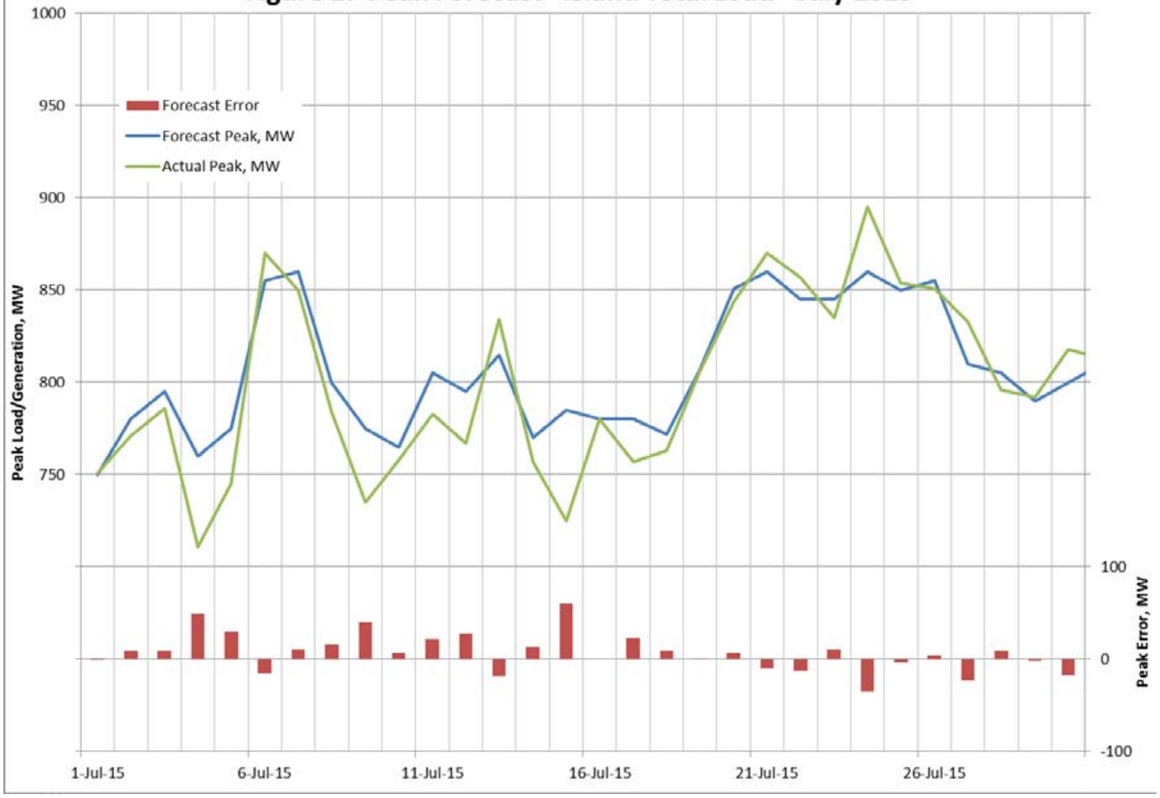


Figure 2: Peak Forecast - Island Total Load - July 2015

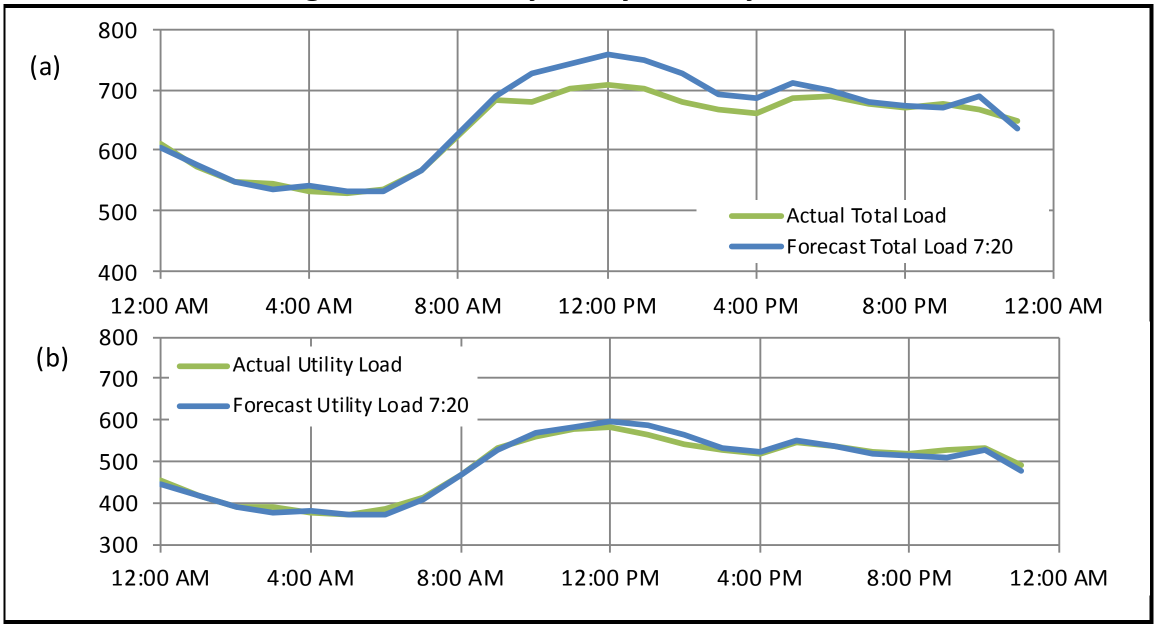
2.3 July 4, 2015

On July 4, the peak of the 7:20 am forecast was 760 MW; the actual peak was lower, at 711 MW. The absolute difference was 49 MW or 6.9% of the actual. The forecast was accurate in predicting that the peak would fall at mid-day.

Figure 3a plots the forecast and actual total load through the day and Figure 3b plots the forecast and actual utility load. The difference shows clearly that the error in the forecast was not in the Nostradamus portion of the forecast; it was in the forecast of industrial load.

Most of the error in the peak on July 4 can be attributed to a lower than forecast demand at Corner Brook Pulp and Paper. The default forecast for the Kruger Mill is 107 MW. The average demand on July 4 was approximately 97 MW and the demand was approximately 77 MW at the time of the peak. The demands at Teck and Vale were both also approximately 5 MW below forecast. The Energy Control Centre Operators would have been aware of the lower than usual industrial demand and adjusted generation accordingly.

Figure 3 Accuracy Analysis - July 4, 2015



2.4 July 15, 2015

On July 15, the peak of the 7:20 am forecast was 785 MW; the actual peak was lower, at 725 MW. The absolute difference was 60 MW or 8.3% of the actual. The forecast predicted a late afternoon peak; the actual peak occurred at mid-day. There was a large discrepancy between the forecast and actual load throughout the day.

Figure 4a plots the forecast and actual total load through the day and Figure 4b plots the forecast and actual utility load. The difference shows that most of the error in the forecast throughout the day was in the forecast of industrial load. The default forecast for the Kruger Mill is 107 MW. The average demand on July 15 was approximately 50 MW and demand was as low as 25 to 30 MW through most of the peak period. The Energy Control Centre Operators would have been aware of the lower than usual industrial demand and adjusted generation accordingly.

There is also an error in the peak of the utility load at mid-day. Figures 4c through 4e compare the forecast and actual weather parameters, but other than the wind speed being slightly lower than forecast, the weather forecast was accurate. It would appear that something not forecast by Nostradamus increased utility load for a short period on July 15.

Figure 4 Accuracy Analysis - July 15, 2015