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July 14, 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: June 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: June 2015

Newfoundland and Labrador Hydro

July 14, 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 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;
- 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 will be implemented on the Production environment in July. Implementation of the new version had no noticeable effect on the forecasts generated by the software on the Development 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. 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 JUNE 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 June 2015. The data are also presented in Figure 1. The actual peaks, as reported to the Board, varied from 755 MW on June 21 to 971 MW on June 2.

The available capacity during the month was between 1220 MW on June 11 and 1625 MW on June 4. Reserves were sufficient throughout the period.

Table 2 presents error statistics for the peak forecasts during the month of June 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 June the forecast peak was in a range between 6.5% below the actual peak and 4.8% 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 56 MW too low. On average, the forecast peak was 17 MW different than the actual peak, or 2.0%.

In the review of forecast accuracy statistics for June 2015 in Table 2, Hydro offers further detail on the difference found between forecast and actual peak for June 13.

Table 1 June 2015 Load Forecasting Data

Date	Forecast Peak, MW	Actual Peak, MW	Available Island Supply, MW	Forecast Reserve, MW
1-Jun-15	930	933	1605	675
2-Jun-15	1000	971	1595	595
3-Jun-15	960	916	1580	620
4-Jun-15	960	926	1625	665
5-Jun-15	930	925	1605	675
6-Jun-15	850	869	1610	760
7-Jun-15	875	887	1445	570
8-Jun-15	970	959	1435	465
9-Jun-15	880	880	1410	530
10-Jun-15	820	816	1240	420
11-Jun-15	830	808	1220	390
12-Jun-15	800	810	1270	470
13-Jun-15	800	856	1255	455
14-Jun-15	920	946	1290	370
15-Jun-15	975	952	1340	365
16-Jun-15	875	855	1330	455
17-Jun-15	885	913	1400	515
18-Jun-15	845	843	1410	565
19-Jun-15	775	765	1385	610
20-Jun-15	775	765	1420	645
21-Jun-15	765	755	1420	655
22-Jun-15	800	788	1400	600
23-Jun-15	850	830	1400	550
24-Jun-15	885	900	1340	455
25-Jun-15	900	922	1395	495
26-Jun-15	905	908	1395	490
27-Jun-15	895	872	1385	490
28-Jun-15	800	773	1390	590
29-Jun-15	795	809	1385	590
30-Jun-15	810	803	1400	590

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).

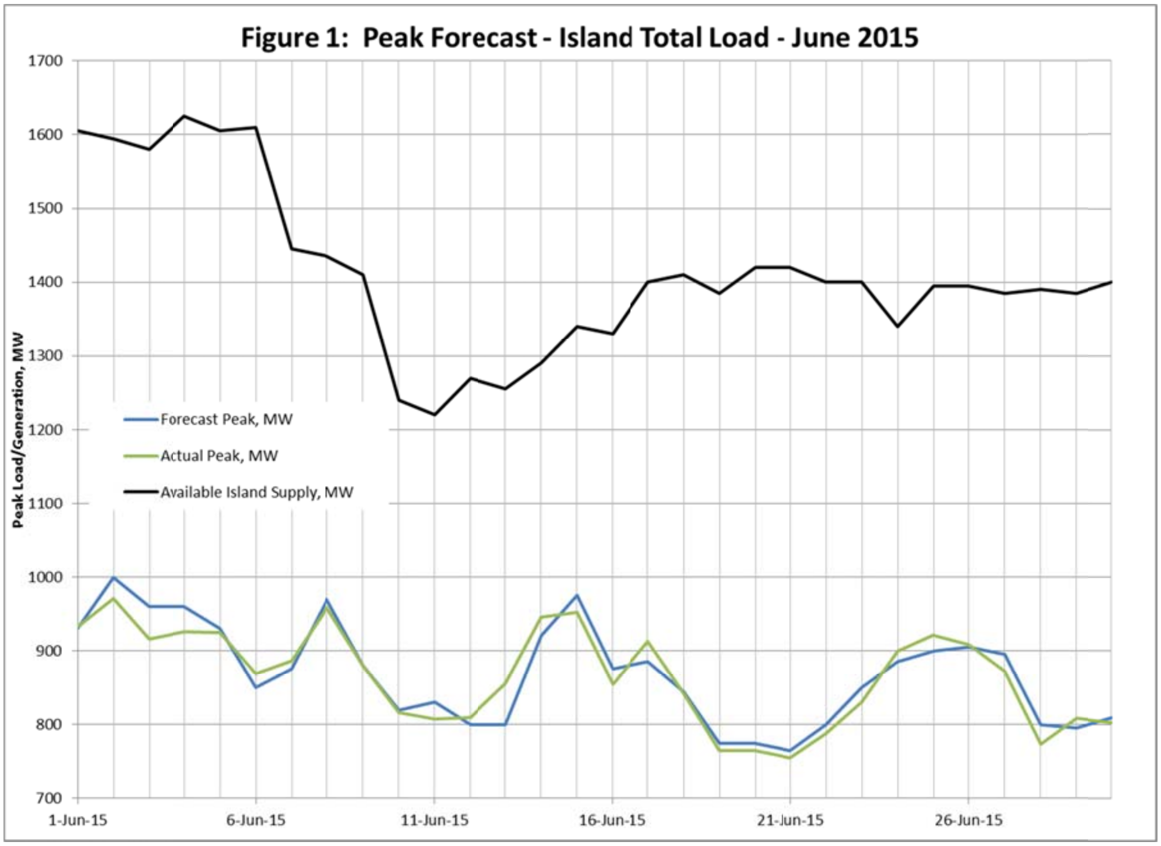
Figure 1: Peak Forecast - Island Total Load - June 2015
Peak Load/Generation, MW
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
Forecast Peak, MW
Actual Peak, MW
Available Island Supply, MW
1-Jun-15
6-Jun-15
11-Jun-15
16-Jun-15
21-Jun-15
26-Jun-15

Table 2 June 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-Jun-15	933	930	-3	3	-0.3%	0.3%	-0.3%
2-Jun-15	971	1000	29	29	3.0%	3.0%	2.9%
3-Jun-15	916	960	44	44	4.8%	4.8%	4.6%
4-Jun-15	926	960	34	34	3.7%	3.7%	3.5%
5-Jun-15	925	930	5	5	0.5%	0.5%	0.5%
6-Jun-15	869	850	-19	19	-2.2%	2.2%	-2.2%
7-Jun-15	887	875	-12	12	-1.4%	1.4%	-1.4%
8-Jun-15	959	970	11	11	1.1%	1.1%	1.1%
9-Jun-15	880	880	0	0	0.0%	0.0%	0.0%
10-Jun-15	816	820	4	4	0.5%	0.5%	0.5%
11-Jun-15	808	830	22	22	2.7%	2.7%	2.7%
12-Jun-15	810	800	-10	10	-1.2%	1.2%	-1.3%
13-Jun-15	856	800	-56	56	-6.5%	6.5%	-7.0%
14-Jun-15	946	920	-26	26	-2.7%	2.7%	-2.8%
15-Jun-15	952	975	23	23	2.4%	2.4%	2.4%
16-Jun-15	855	875	20	20	2.3%	2.3%	2.3%
17-Jun-15	913	885	-28	28	-3.1%	3.1%	-3.2%
18-Jun-15	843	845	2	2	0.2%	0.2%	0.2%
19-Jun-15	765	775	10	10	1.3%	1.3%	1.3%
20-Jun-15	765	775	10	10	1.3%	1.3%	1.3%
21-Jun-15	755	765	10	10	1.3%	1.3%	1.3%
22-Jun-15	788	800	12	12	1.5%	1.5%	1.5%
23-Jun-15	830	850	20	20	2.4%	2.4%	2.4%
24-Jun-15	900	885	-15	15	-1.7%	1.7%	-1.7%
25-Jun-15	922	900	-22	22	-2.4%	2.4%	-2.4%
26-Jun-15	908	905	-3	3	-0.3%	0.3%	-0.3%
27-Jun-15	872	895	23	23	2.6%	2.6%	2.6%
28-Jun-15	773	800	27	27	3.5%	3.5%	3.4%
29-Jun-15	809	795	-14	14	-1.7%	1.7%	-1.8%
30-Jun-15	803	810	7	7	0.9%	0.9%	0.9%
Minimum	755	765	-56	0	-6.5%	0.0%	-7.0%
Average	865	869	4	17	0.4%	2.0%	0.4%
Maximum	971	1000	44	56	4.8%	6.5%	4.6%

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.

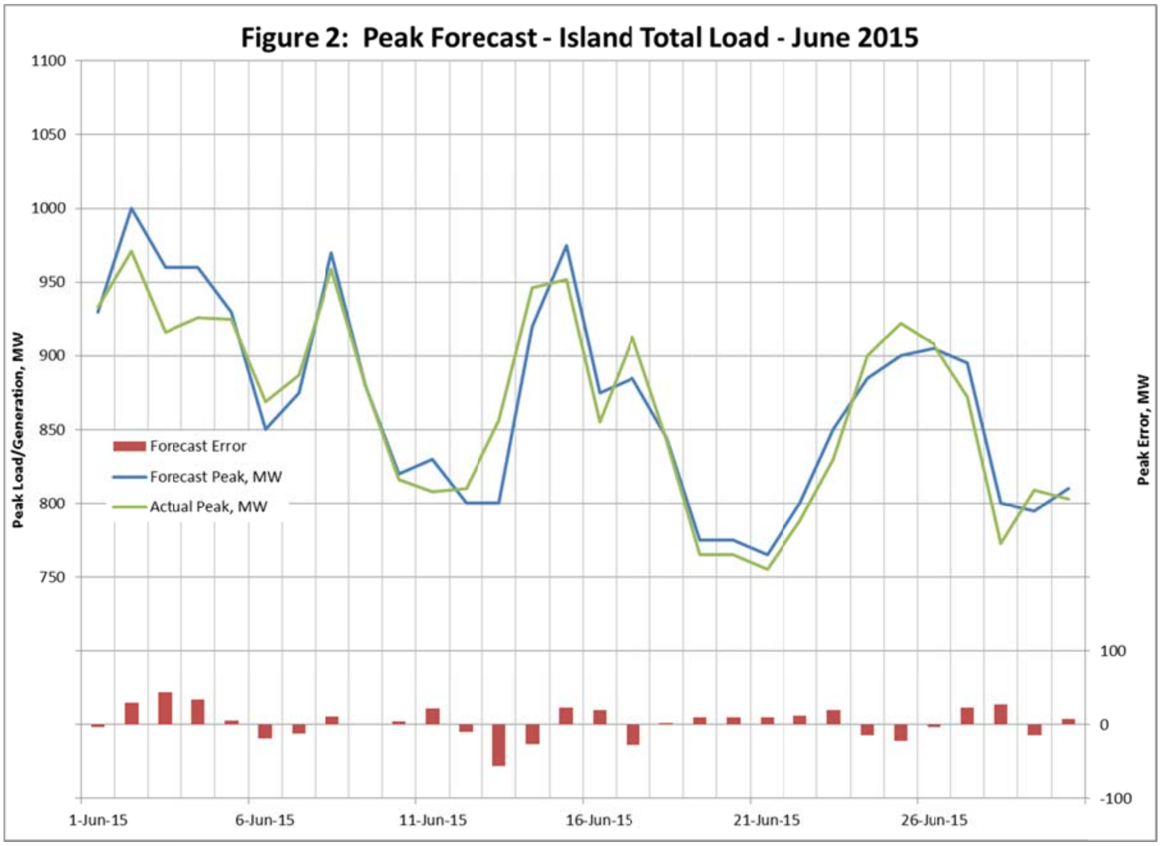

Figure 2: Peak Forecast - Island Total Load - June 2015

2.3 June 13, 2015

On June 13, the peak of the 7:20 am forecast was 800 MW; the actual peak was higher, at 856 MW. The absolute difference was 56 MW or 6.5% of the actual. Figure 3 includes an hourly plot of the load forecast for June 13 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 800 MW at 11:00 am. The morning peak was 800 MW at approximately 11:00 am, but the afternoon peak was higher, 856 MW at approximately 5:00 pm.

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

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 forecast was relatively accurate for the first half of the day, but was forecast to be up to eight degrees warmer through the afternoon so the error in the temperature forecast likely contributed significantly to the forecast error.

Figure 3(d) shows the actual cloud cover in St. John's compared to the forecast. The forecast was quite accurate, especially for the afternoon.

Figure 3(e) shows the actual wind speed in St. John's compared to the forecast. The accuracy of the wind forecast was mixed; the wind speed was overestimated for parts of the day and underestimated for the reminder. The error in the wind speed forecast may have contributed somewhat to the under forecast of the peak, but the main error was likely due to the error in the temperature forecast.

Figure 3 Accuracy Analysis - June 13, 2015