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November 16, 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: October 2015.*

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

Yours truly,

NEWFOUNDLAND AND LABRADOR HYDRO

Jennifer M. Williams, P. Eng.
Manager, Regulatory Engineering

JMW/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: October 2015

Newfoundland and Labrador Hydro

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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 (Amec) to provide the weather parameters in the form of twice daily hourly weather forecasts for a seven-day period. At the same time as the weather forecast data are provided, Amec also provides recent observed data at the same locations. 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. Preliminary training has been done on the Development system using data up to September 2015, but that has not been moved to Production yet.

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 forecast 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 period are input at approximately 5:00 am and again at mid-day (1:00 pm or 2:00 pm depending on Daylight Saving Time). Nostradamus is run every hour of the day and the most recent load 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 load 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); 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.
- Version 8.2.4 of the Nostradamus software was installed on Production in mid-August 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 OCTOBER 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 October 2015. The data are also presented in Figure 1. The actual peaks, as reported to the Board, varied from 797 MW on October 1 to 1193 MW on October 28.

The available capacity during the month was between 1365 MW on October 4 and 1635 MW on October 31. Reserves were sufficient throughout the period.

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

As in August and September, there were times during October when the CBPP load was below the default forecast of 107 MW which led to significant apparent error (overestimate) in the forecast. The average load during the month was approximately 95 MW, but was significantly below the forecast between October 6 and October 14 and again for several days in the middle of the month. Because the load forecast is a total of the utility and industrial load forecasts, the result of the industrial load being lower than forecast is additional reserves available to the system.

Through the month of October the forecast peak was in a range between 6.8% below the actual peak and 10.2% 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 96 MW too high. On average, the forecast peak was 29 MW different than the actual peak, or 2.9% of actual.

In the review of forecast accuracy statistics for October 2015 in Table 2, Hydro offers further detail on the difference found between forecast and actual peak for October 4, October 6, October 30 and October 31.

Table 1 October 2015 Load Forecasting Data

Date	Forecast Peak, MW	Actual Peak, MW	Available Island Supply, MW	Forecast Reserve, MW
1-Oct-15	795	797	1370	575
2-Oct-15	910	901	1375	465
3-Oct-15	925	962	1455	530
4-Oct-15	895	952	1365	470
5-Oct-15	960	959	1420	460
6-Oct-15	870	809	1540	670
7-Oct-15	875	889	1505	630
8-Oct-15	875	828	1395	520
9-Oct-15	875	874	1385	510
10-Oct-15	905	929	1490	585
11-Oct-15	1040	994	1480	440
12-Oct-15	945	934	1475	530
13-Oct-15	910	874	1460	550
14-Oct-15	820	804	1475	655
15-Oct-15	855	829	1480	625
16-Oct-15	880	872	1460	580
17-Oct-15	880	897	1465	585
18-Oct-15	1000	967	1460	460
19-Oct-15	1060	1025	1480	420
20-Oct-15	1070	1057	1460	390
21-Oct-15	1000	1045	1505	505
22-Oct-15	1105	1084	1440	335
23-Oct-15	1000	997	1575	575
24-Oct-15	1060	1063	1500	440
25-Oct-15	1060	1056	1480	420
26-Oct-15	1060	1002	1600	540
27-Oct-15	1140	1165	1605	465
28-Oct-15	1180	1193	1610	430
29-Oct-15	1220	1186	1575	355
30-Oct-15	1035	939	1600	565
31-Oct-15	1025	1100	1635	610
Minimum	795	797	1365	335
Average	975	967	1488	513
Maximum	1220	1193	1635	670

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).

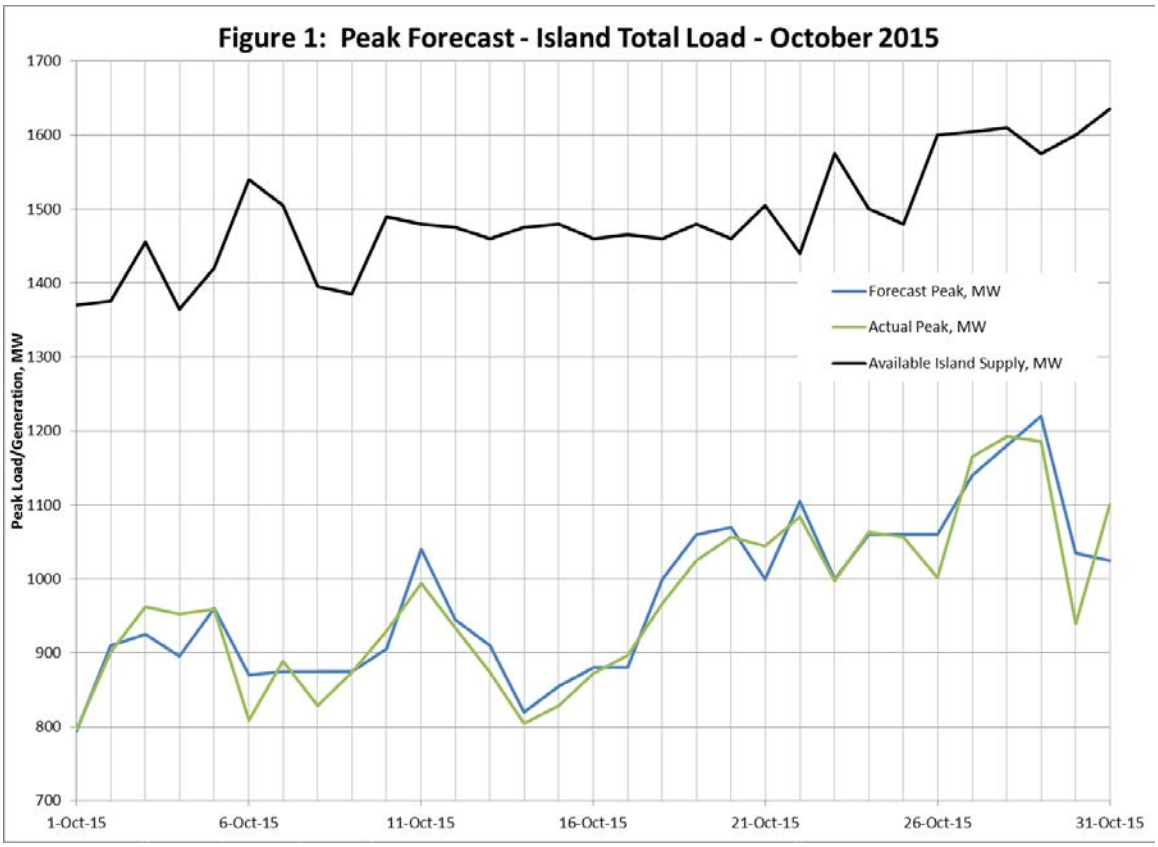
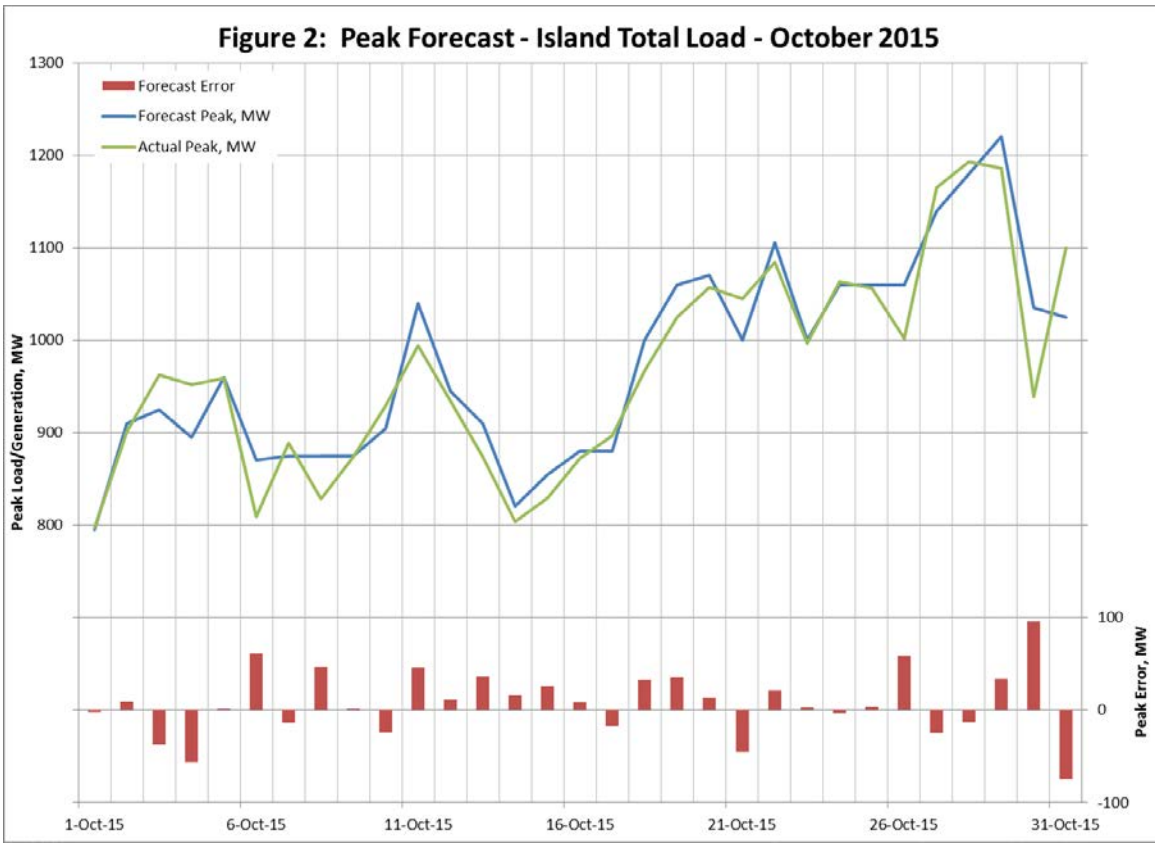


Figure 1: Peak Forecast - Island Total Load - October 2015
Peak Load/Generation, MW
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
1-Oct-15
6-Oct-15
11-Oct-15
16-Oct-15
21-Oct-15
26-Oct-15
31-Oct-15
Forecast Peak, MW
Actual Peak, MW
Available Island Supply, MW

Table 2 October 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-Oct-15	797	795	-2	2	-0.3%	0.3%	-0.3%
2-Oct-15	901	910	9	9	1.0%	1.0%	1.0%
3-Oct-15	962	925	-37	37	-3.8%	3.8%	-4.0%
4-Oct-15	952	895	-57	57	-6.0%	6.0%	-6.4%
5-Oct-15	959	960	1	1	0.1%	0.1%	0.1%
6-Oct-15	809	870	61	61	7.5%	7.5%	7.0%
7-Oct-15	889	875	-14	14	-1.6%	1.6%	-1.6%
8-Oct-15	828	875	47	47	5.7%	5.7%	5.4%
9-Oct-15	874	875	1	1	0.1%	0.1%	0.1%
10-Oct-15	929	905	-24	24	-2.6%	2.6%	-2.7%
11-Oct-15	994	1040	46	46	4.6%	4.6%	4.4%
12-Oct-15	934	945	11	11	1.2%	1.2%	1.2%
13-Oct-15	874	910	36	36	4.1%	4.1%	4.0%
14-Oct-15	804	820	16	16	2.0%	2.0%	2.0%
15-Oct-15	829	855	26	26	3.1%	3.1%	3.0%
16-Oct-15	872	880	8	8	0.9%	0.9%	0.9%
17-Oct-15	897	880	-17	17	-1.9%	1.9%	-1.9%
18-Oct-15	967	1000	33	33	3.4%	3.4%	3.3%
19-Oct-15	1025	1060	35	35	3.4%	3.4%	3.3%
20-Oct-15	1057	1070	13	13	1.2%	1.2%	1.2%
21-Oct-15	1045	1000	-45	45	-4.3%	4.3%	-4.5%
22-Oct-15	1084	1105	21	21	1.9%	1.9%	1.9%
23-Oct-15	997	1000	3	3	0.3%	0.3%	0.3%
24-Oct-15	1063	1060	-3	3	-0.3%	0.3%	-0.3%
25-Oct-15	1056	1060	4	4	0.4%	0.4%	0.4%
26-Oct-15	1002	1060	58	58	5.8%	5.8%	5.5%
27-Oct-15	1165	1140	-25	25	-2.1%	2.1%	-2.2%
28-Oct-15	1193	1180	-13	13	-1.1%	1.1%	-1.1%
29-Oct-15	1186	1220	34	34	2.9%	2.9%	2.8%
30-Oct-15	939	1035	96	96	10.2%	10.2%	9.3%
31-Oct-15	1100	1025	-75	75	-6.8%	6.8%	-7.3%
Minimum	797	795	-75	1	-6.8%	0.1%	-7.3%
Average	967	975	8	28	0.9%	2.9%	0.8%
Maximum	1193	1220	96	96	10%	10%	9%

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 Data Adjustment

Problems with Hydro's PI database on October 28, 29 and 31 resulted in erroneous records of actual load being automatically input into Nostradamus. In each case, the calculated values of load were below the actual load. For short periods of the day on October 28 and 29 generation from Grand Falls and Bishop's Falls was not included in the total generation values; this was corrected on the days it occurred by simply adding the known Exploits generation value (40 MW) to the actual load on the hours when it was required. This problem did not affect the load forecasts reported to the Board.

Early in the morning on October 31 (a Saturday) a problem occurred with the PI server such that no new total load values were calculated between 1:00 am and approximately 8:00 am; the automatic input for those hours would have used the value at midnight. Those incorrect values would have been used by Nostradamus for the forecasts (including those sent to the Board) on October 31 and November 1. The on-call Energy

Systems staff person rebooted the server at approximately 8:00 am on October 31, which corrected the situation. On November 2 (Monday) the erroneous actual data was replaced with the forecast values for the missing seven hours; this prevents the poor data being used in future Nostradamus training.

2.3 October 4, 2015

On October 4, the forecast peak at 7:20 am was 895 MW; the actual reported peak was 952 MW. The absolute difference was 57 MW, 6.0% of the actual. Figure 3 includes an hourly plot of the load forecast for October 4 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 shape of the actual load was similar to forecast but was generally higher. The forecast predicted a 10:00 am peak of 895 MW. The actual peak was close to 10:00 am but was 952 MW.

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 similar to that of the total load, so a discrepancy in the industrial forecast does not explain the variance in the peak.

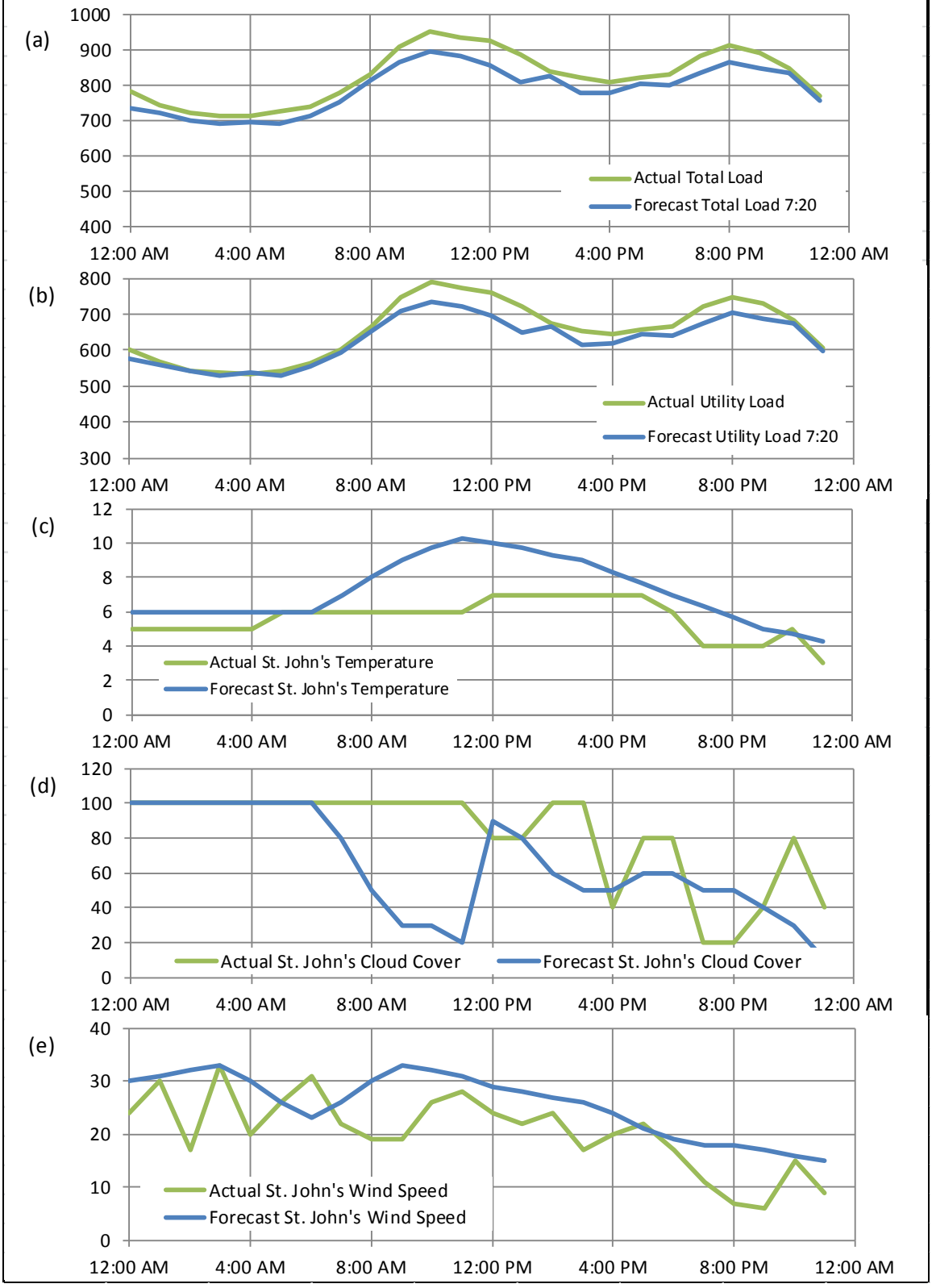
Figure 3(c) shows the actual temperature in St. John's compared to the forecast. Although Nostradamus uses weather data at four sites, the weather in St. John's tends to have the largest effect because of the concentration of customers in St. John's. The temperature forecast was poor for most of the day. At the time of the peak the actual temperature was approximately 4 degrees below the forecast, which explains some of the error in the forecast.

Figure 3(d) shows the actual cloud cover in St. John's compared to the forecast. For most of the morning, the forecast was for clear weather but in fact there was 100% cloud cover up until mid-day. This error in the cloud cover forecast likely contributed to the error in the load forecast.

Figure 3(e) shows the actual wind speed in St. John's compared to the forecast. For most of the day the actual wind speed was lower than predicted so the error in the wind speed forecast did not contribute to the under forecast of the peak.

The discrepancy between actual and forecast load for October 4 was a result of colder and cloudier weather than forecast. By 9:00 am, the forecast had improved and was only 2.5% below actual.

Figure 3 Accuracy Analysis - October 4, 2015



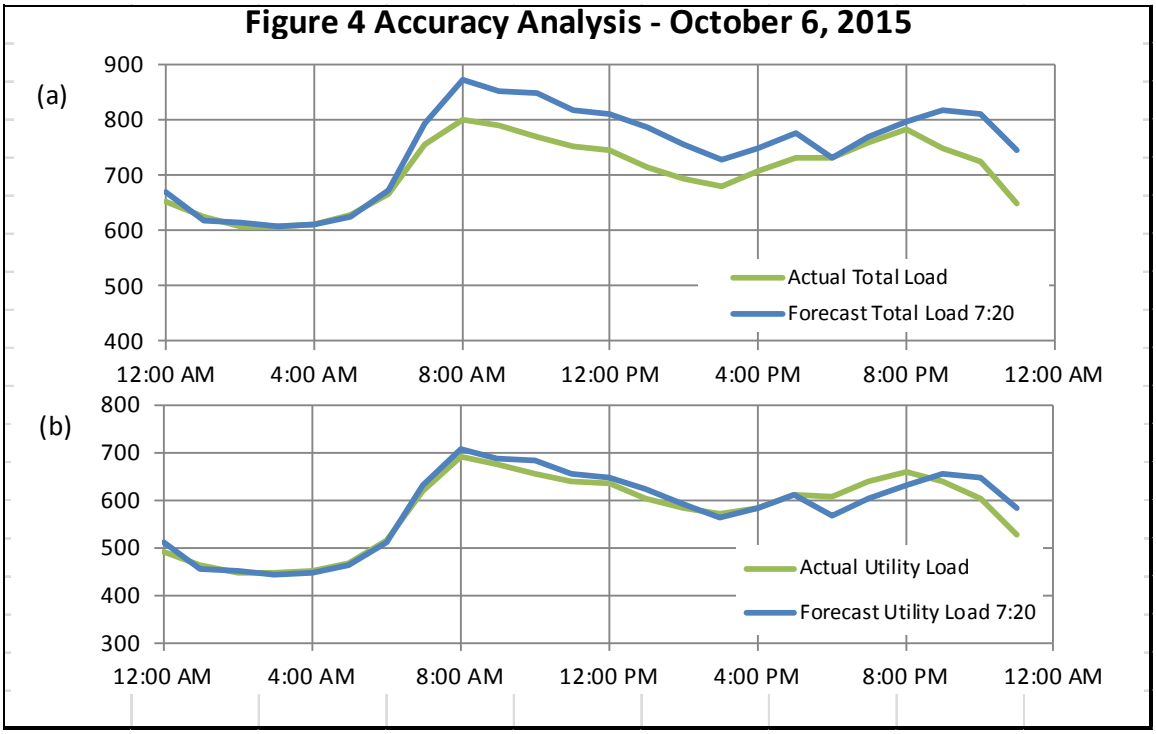
2.4 October 6, 2015

On October 6, the forecast peak at 7:20 am was 870 MW; the actual reported peak was 809 MW. The absolute difference was 61 MW, 7.5% of the actual. Figure 4 includes an hourly plot of the utility and total load forecasts for October 6.

Figure 4(a) shows the hourly distribution of the load forecast compared to the actual load. The forecast predicted an 8:00 am peak of 870 MW. The actual peak was 809 MW at 8:00 am (the plot shows a peak of 800 MW as it was created with data from Nostradamus which is input on the hour only).

Figure 4(b) shows the hourly distribution of the utility load forecast only, i.e., the load forecast with the industrial component removed. It shows that the utility forecast produced by Nostradamus was close to the actual. As with errors in August and September, the error in the total load forecast is attributable to a lower than forecast load at CBPP. The CBPP load at 8:00 am was 57 MW, approximately 50 MW below the forecast.

Figure 4 Accuracy Analysis - October 6, 2015



2.5 October 30, 2015

On October 30, the forecast peak at 7:20 am was 1035 MW; the actual reported peak was 939 MW. The absolute difference was 96 MW, 10.2% of the actual. Figure 5 includes an hourly plot of the load forecast for October 30 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 5(a) shows the hourly distribution of the load forecast compared to the actual load. The forecast predicted a 7:00 pm peak of 1035 MW. The actual peak was 939 MW at 7:00 pm.

Figure 5(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 similar to that of the total load, so a discrepancy in the industrial forecast does not explain the variance in the peak.

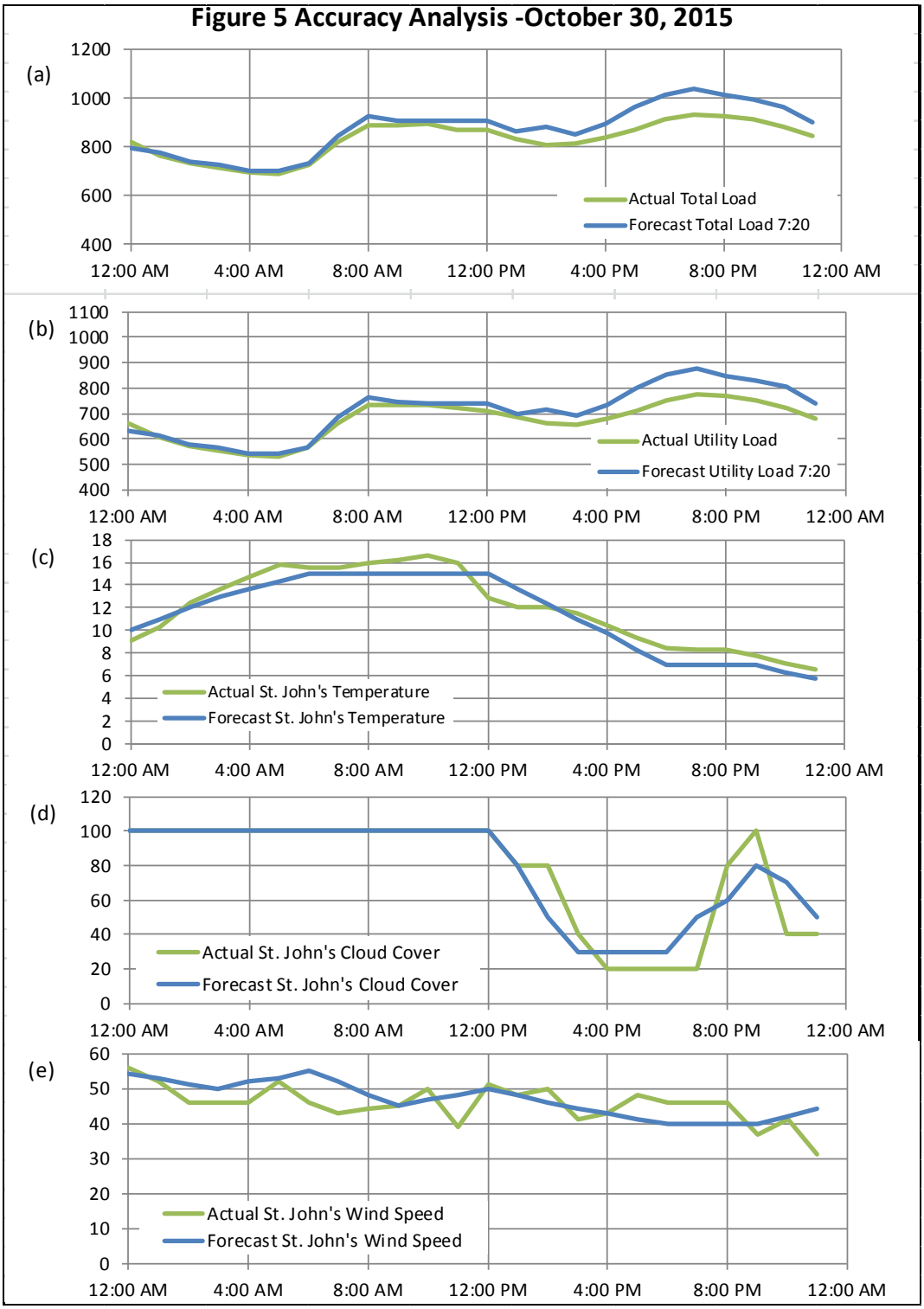
Figures 5(c) through 5(e) show comparisons of the temperature, cloud cover and wind forecasts and actual for St. John's. The weather forecast was quite accurate for October 30, so the discrepancy in the weather forecast was not the cause of the load forecast error.

It is difficult to ascertain why Nostradamus underestimated the load for most of October 30. As noted in the September report, peaks late in the day are relatively unusual, so Nostradamus would not have had as many examples of load patterns like this on which to base its estimate.

The Nostradamus model runs every hour to use actual loads experienced that day to improve the estimate for the rest of the day. On October 30 the forecast was within 2% of actual by 3:20 pm. These with-in day updates are used by Energy Control Centre

operators to manage spinning reserve. An overestimate of the peak results in more than enough available reserve.

Figure 5 Accuracy Analysis -October 30, 2015



2.6 October 31, 2015

On October 31, the forecast peak at 7:20 am was 1025 MW; the actual reported peak was 1100 MW. The absolute difference was 75 MW, 6.8% of the actual. Figure 6 shows the hourly utility and total load forecasts for October 31.

Figure 6(a) shows the hourly distribution of the load forecast compared to the actual load. The forecast predicted 12:00 pm peak of 1025 MW. The actual peak was 1100 MW at 11:00 am. As noted earlier, there was a problem with Hydro's PI server on the morning of October 31 which resulted in erroneous low values of actual load being input to Nostradamus. These low actual values would have resulted in a lower forecast going forward, including for the time of the peak on October 31. The server was rebooted at approximately 8:00 am.

Figure 6(b) shows the forecast of total load produced at 9:20 am, by which time an accurate load would have been recorded and the forecast peak is improved to 1077 MW, only 1.6% from actual. The Nostradamus model runs every hour to use actual loads experienced that day to improve the estimate for the rest of the day. These with-in day updates are used by Energy Control Centre operators to manage spinning reserve.

Figure 6 Accuracy Analysis -October 31, 2015