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December 15, 2015

The Board of Commissioners of Public Utilities
Prince Charles Building
120 Torbay Road, P.O. Box 21040
St. John's, NL 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: November 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: November 2015

Newfoundland and Labrador Hydro

December 15, 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 (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, and the expected owned generation from Corner Brook Pulp and Paper (CBPP), are used for the industrial load forecast unless System Operations engineers modify the forecast based on some knowledge of customer loads, for instance a decrease due to planned 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 day 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 November 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 November 2015. The data are also presented in Figure 1. The actual peaks, as reported to the Board, varied from 1017 MW on November 7 to 1534 MW on November 30.

The available capacity during the month was between 1520 MW on November 4 and 1995 MW on November 28. Reserves were sufficient throughout the period.

Table 2 presents error statistics for the peak forecasts during the month of November 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 November the forecast peak was in a range between 3.5% below the actual peak and 9.1% 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 93 MW too high. On average, the forecast peak was 28 MW different than the actual peak, or 2.4% of actual.

In the review of forecast accuracy statistics for November 2015 in Table 2, Hydro offers further detail on the difference found between forecast and actual peak for November 5, November 7, and November 15.

Table 1 November 2015 Load Forecasting Data

Date	Forecast Peak, MW	Actual Peak, MW	Available Island Supply, MW	Forecast Reserve, MW
1-Nov-15	1075	1037	1620	545
2-Nov-15	1145	1102	1665	520
3-Nov-15	1215	1216	1540	325
4-Nov-15	1260	1248	1520	260
5-Nov-15	1360	1284	1545	185
6-Nov-15	1235	1214	1540	305
7-Nov-15	1110	1017	1575	465
8-Nov-15	1225	1221	1580	355
9-Nov-15	1290	1270	1600	310
10-Nov-15	1185	1160	1615	430
11-Nov-15	1220	1184	1670	450
12-Nov-15	1275	1263	1585	310
13-Nov-15	1225	1227	1695	470
14-Nov-15	1160	1184	1665	505
15-Nov-15	1245	1178	1790	545
16-Nov-15	1330	1326	1805	475
17-Nov-15	1315	1275	1710	395
18-Nov-15	1310	1293	1700	390
19-Nov-15	1290	1295	1800	510
20-Nov-15	1265	1260	1815	550
21-Nov-15	1230	1209	1805	575
22-Nov-15	1205	1153	1795	590
23-Nov-15	1185	1133	1990	805
24-Nov-15	1180	1170	1915	735
25-Nov-15	1325	1314	1960	635
26-Nov-15	1325	1319	1935	610
27-Nov-15	1225	1192	1800	575
28-Nov-15	1280	1236	1995	715
29-Nov-15	1335	1319	1960	625
30-Nov-15	1480	1534	1990	510
Minimum	1075	1017	1520	185
Average	1250	1228	1739	489
Maximum	1480	1534	1995	805

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).

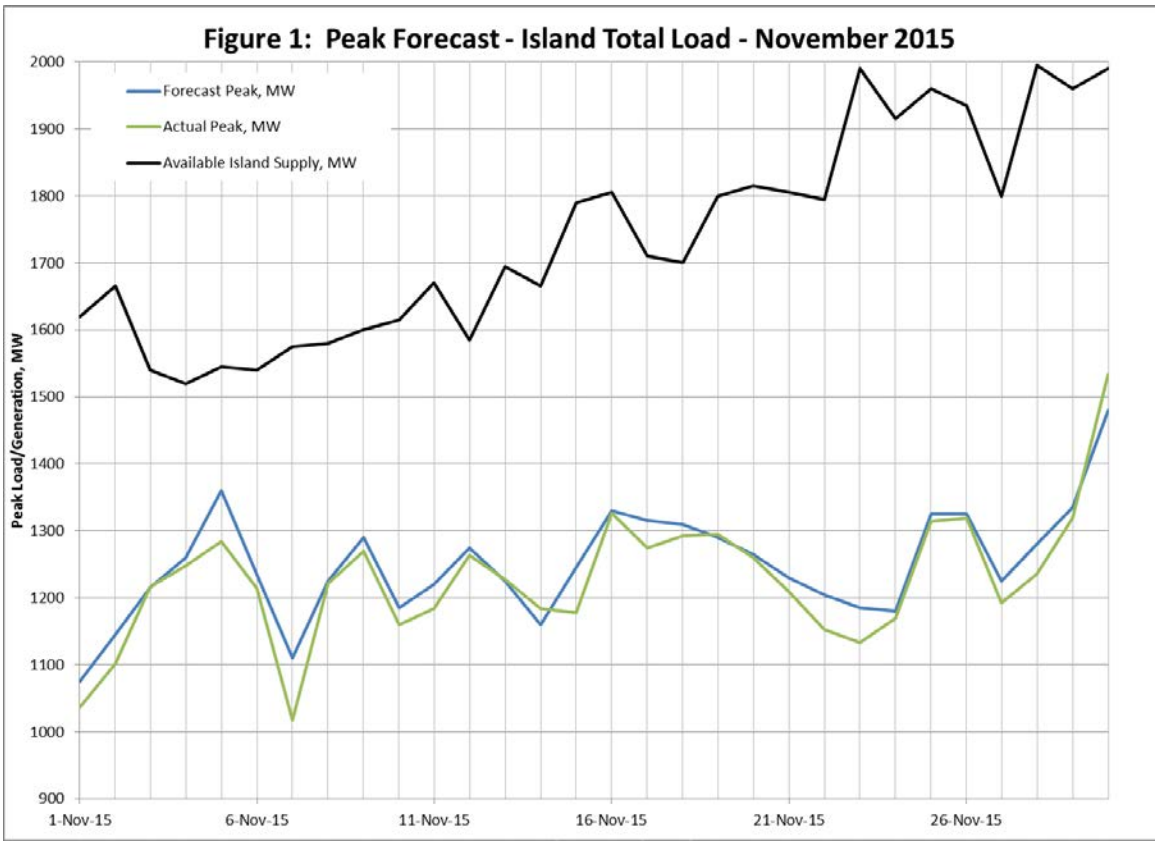


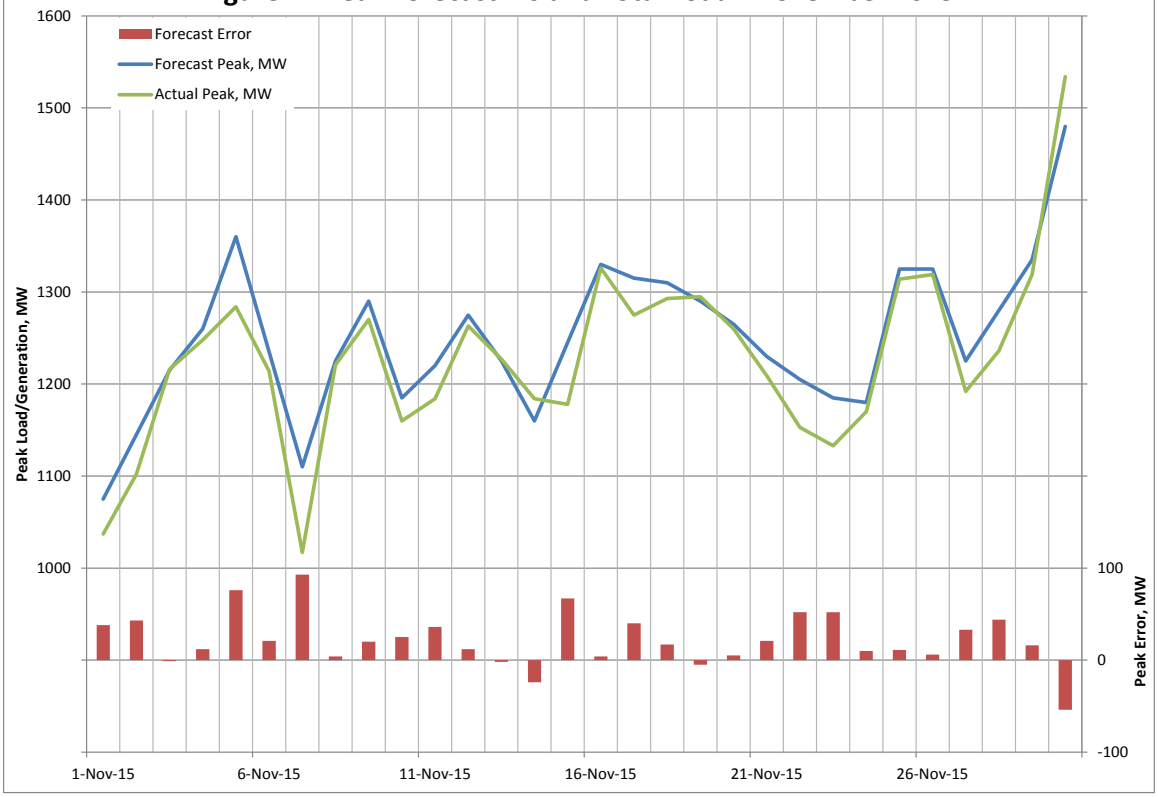
Figure 1: Peak Forecast - Island Total Load - November 2015
Forecast Peak, MW
Actual Peak, MW
Available Island Supply, MW
Peak Load/Generation, MW
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
1-Nov-15
6-Nov-15
11-Nov-15
16-Nov-15
21-Nov-15
26-Nov-15

Table 2 November 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-Nov-15	1037	1075	38	38	3.7%	3.7%	3.5%
2-Nov-15	1102	1145	43	43	3.9%	3.9%	3.8%
3-Nov-15	1216	1215	-1	1	-0.1%	0.1%	-0.1%
4-Nov-15	1248	1260	12	12	1.0%	1.0%	1.0%
5-Nov-15	1284	1360	76	76	5.9%	5.9%	5.6%
6-Nov-15	1214	1235	21	21	1.7%	1.7%	1.7%
7-Nov-15	1017	1110	93	93	9.1%	9.1%	8.4%
8-Nov-15	1221	1225	4	4	0.3%	0.3%	0.3%
9-Nov-15	1270	1290	20	20	1.6%	1.6%	1.6%
10-Nov-15	1160	1185	25	25	2.2%	2.2%	2.1%
11-Nov-15	1184	1220	36	36	3.0%	3.0%	3.0%
12-Nov-15	1263	1275	12	12	1.0%	1.0%	0.9%
13-Nov-15	1227	1225	-2	2	-0.2%	0.2%	-0.2%
14-Nov-15	1184	1160	-24	24	-2.0%	2.0%	-2.1%
15-Nov-15	1178	1245	67	67	5.7%	5.7%	5.4%
16-Nov-15	1326	1330	4	4	0.3%	0.3%	0.3%
17-Nov-15	1275	1315	40	40	3.1%	3.1%	3.0%
18-Nov-15	1293	1310	17	17	1.3%	1.3%	1.3%
19-Nov-15	1295	1290	-5	5	-0.4%	0.4%	-0.4%
20-Nov-15	1260	1265	5	5	0.4%	0.4%	0.4%
21-Nov-15	1209	1230	21	21	1.7%	1.7%	1.7%
22-Nov-15	1153	1205	52	52	4.5%	4.5%	4.3%
23-Nov-15	1133	1185	52	52	4.6%	4.6%	4.4%
24-Nov-15	1170	1180	10	10	0.9%	0.9%	0.8%
25-Nov-15	1314	1325	11	11	0.8%	0.8%	0.8%
26-Nov-15	1319	1325	6	6	0.5%	0.5%	0.5%
27-Nov-15	1192	1225	33	33	2.8%	2.8%	2.7%
28-Nov-15	1236	1280	44	44	3.6%	3.6%	3.4%
29-Nov-15	1319	1335	16	16	1.2%	1.2%	1.2%
30-Nov-15	1534	1480	-54	54	-3.5%	3.5%	-3.6%
Minimum	1017	1075	-54	1	-3.5%	0.1%	-3.6%
Average	1228	1250	22	28	2.0%	2.4%	1.9%
Maximum	1534	1480	93	93	9.1%	9.1%	8.4%

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 - November 2015



2.2 Data Adjustment

Problems with Hydro's PI database first experienced after a software upgrade in October continued into November and influenced the load data being imported to Nostradamus on November 7 and November 21 (the problematic process is run automatically early on Saturday mornings). The PI server stopped archiving new data so the midnight load value was imported to Nostradamus as the 'actual' data for the early hours of November 7 and November 21 until Hydro's on-call Energy Systems staff person took corrective action later those mornings. Archiving on November 14 worked as it should; the intermittent nature of this situation makes it particularly difficult to troubleshoot.

The hours of erroneous data were used by Nostradamus for the forecasts on November 7 and 8, 21 and 22. The impact of the bad data on the load forecasts is difficult to

determine. It would be a function of the time of the peak and of how different the midnight load value was from the actual values in the following hours.

Hydro's troubleshooting continues but, to date, the exact source of the problem has not been determined. In the meantime, a temporary fix has been instituted to automatically restart the errant process several times on Saturday mornings. This fix was implemented in the week of November 23 and the data problem has not occurred during the three weekends since.

Once the problem was identified, the erroneous actual data from November 7 and 21 was replaced with the last reliable forecast values for the affected hours to prevent the poor data being used in future Nostradamus training.

2.3 November 5, 2015

On November 5, the forecast peak at 7:20 am, as reported to the Board, was 1360 MW; the actual reported peak was 1284 MW. The absolute difference was 76 MW, 5.9% of the actual. Figure 3 includes an hourly plot of the load forecast for November 5 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 lower. The forecast predicted a 5:00 pm peak of 1358 MW. The actual hourly peak was 1274 MW at 6:00 pm.

Figure 3(b) shows the hourly distribution of the utility load forecast only, i.e., the load forecast with the industrial component removed. The forecast utility load is closer to actual than the forecast total load, so a discrepancy in the industrial forecast did contribute somewhat to the variance in the peak.

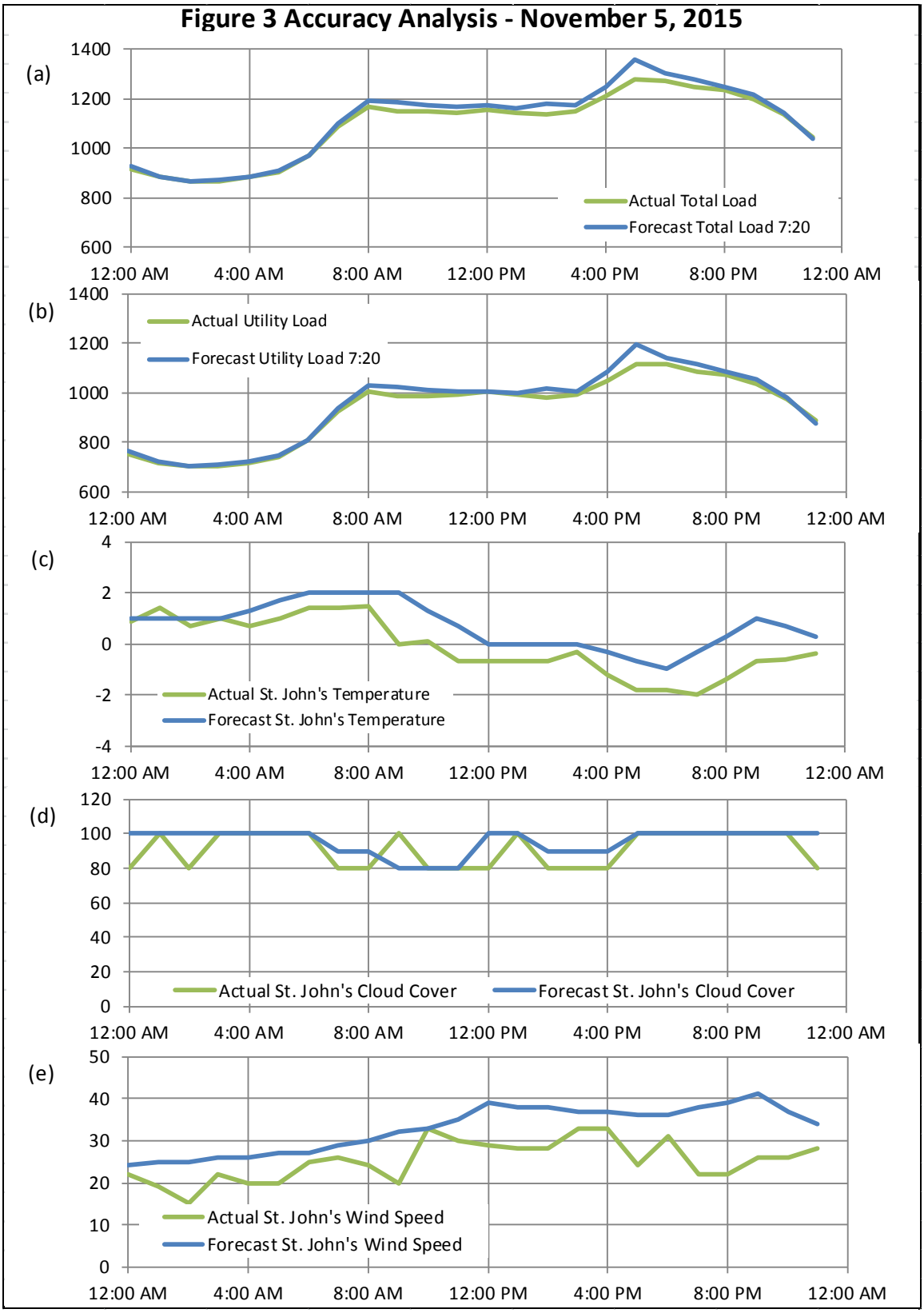
Figure 3(c) shows the actual temperature in St. John's compared to the forecast. Although Nostradamus uses weather data at four sites, the weather in St. John's tends to have the largest effect because of the concentration of population in St. John's. The actual temperature was approximately 1 degree colder than forecast for most of the day which would have resulted in a higher than anticipated load, so the error in the temperature forecast does not explain the error in the load forecast.

Figure 3(d) shows the actual cloud cover in St. John's compared to the forecast. The cloud cover forecast was quite accurate for most of the day. The forecast was for 80% to 100% cloud cover all day, which is what actually occurred, so cloud cover did not contribute to the variance 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 may have contributed to the over forecast of the peak.

The discrepancy between actual and forecast load for November 5 was likely a result of multiple factors, including errors in the industrial load and wind forecasts but also by non-uniform customer behaviour which results in unpredictability in the load. By midday, the forecast had improved and was within 3% of the actual. The hourly within day updates are used by Energy Control Centre operators to manage spinning reserve. An overestimate of the peak results in more than enough spinning reserve.

Figure 3 Accuracy Analysis - November 5, 2015



2.4 November 7, 2015

On November 7, the forecast peak at 7:20 am was 1110 MW; the actual reported peak was 1017 MW. The absolute difference was 93 MW, 9.1% of the actual. Figure 4 includes an hourly plot of the utility and total load forecasts for November 7. Figure 4(a) shows the hourly distribution of the load forecast compared to the actual load. The forecast predicted a 6:00 pm peak of 1110 MW. The actual peak was at 6:20 pm, but was lower, at 1017 MW (the plot shows a peak of 1009 MW as it was created with data from Nostradamus which is input on the hour only).

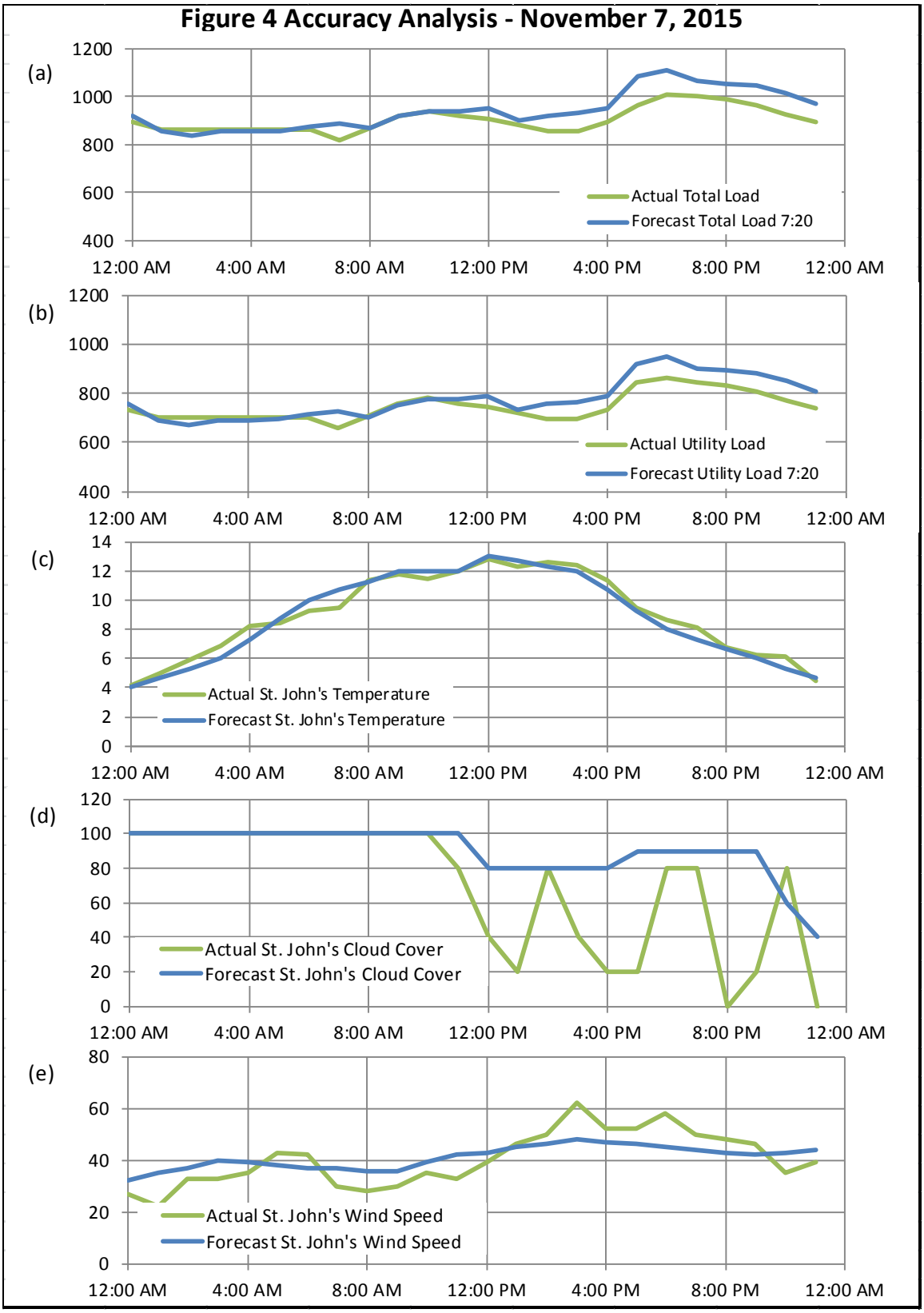
November 7 was one of the days identified earlier in this report as having been affected by the PI server problems. The server stopped archiving new data so the midnight load value was imported to Nostradamus as the 'actual' data for the hours between 1:00 am and 7:00 am (note the horizontal line in the plot). This error in actual load data likely hindered the accuracy of the peak forecast made at 7:20 am, though the error cannot be quantified.

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 closer to the actual than the total load. As in previous months, some of the error in the total load forecast is attributable to a lower than forecast load at CBPP.

Figures 4(c) through 4(e) show comparisons of the weather conditions to the weather forecasts. The temperature forecast was very accurate. The cloud cover forecast overestimated the percent of cloud cover which could have contributed to the over forecast. The actual wind speed, however, was generally higher than forecast which would have made the load forecast prone to under forecast rather than over forecast.

The discrepancy between actual and forecast load for November 7 was a result of multiple factors, including lower than forecast industrial load and errors in the wind forecast. Data input problems likely also contributed. By midday, the forecast had improved and was within 4% of the actual. The hourly within day updates are used by Energy Control Centre operators to manage spinning reserve. An overestimate of the peak results in more than enough spinning reserve.

Figure 4 Accuracy Analysis - November 7, 2015



2.5 November 15, 2015

On November 15, the forecast peak at 7:20 am was 1245 MW; the actual reported peak was 1178 MW. The absolute difference was 67 MW, 5.7% of the actual. Figure 5 shows hourly plots of the load forecast for November 15.

Figure 5(a) shows the hourly distribution of the load forecast compared to the actual load. The forecast predicted a 5:00 pm peak of 1246 MW. The actual peak, based on hourly data only, was 1172 MW at 5:00 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 actual utility load was much closer to forecast; a 30 MW lower than forecast load at CBPP explains most of the error in the total forecast. Energy Control Centre operators were aware of the lower CBPP load and adapted generation accordingly. An overestimate of the peak results in more than enough spinning reserve.

Figure 5 Accuracy Analysis - November 15, 2015