newfoundland labrador hydro
a nalcor energy company

Hydro Place. 500 Columbus Drive.
P.O. Box 12400. St. John's. NL
Canada A1B 4K7
t. 709.737.1400 f. 709.737.1800
www.nlh.nl.ca

January 13, 2016

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: December 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/cp

cc: Gerard Hayes – Newfoundland Power
Paul Coxworthy – Stewart McKelvey Stirling Scales
Sheryl Nisenbaum – Praxair Canada Inc.
ecc: Roberta Frampton Benefiel – Grand Riverkeeper Labrador
Thomas Johnson – Consumer Advocate
Thomas O' Reilly – Cox & Palmer
Danny Dumaresque

Accuracy of Nostradamus Load Forecasting at Newfoundland and Labrador Hydro

Monthly Report: December 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, 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);
- 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-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 DECEMBER 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 December 2015. The data are also presented in Figure 1. The actual peaks, as reported to the Board, varied from 1226 MW on December 12 to 1698 MW on December 29.

The available capacity during the month was between 1785 MW on December 10 and 2035 MW on December 25. Reserves were sufficient throughout the period.

Table 2 presents error statistics for the peak forecasts during the month of December 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 December the forecast peak was in a range between 5.5% below the actual peak and 7.7% 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 28 MW different than the actual peak, or 2.0% of actual.

In December 2015 there were peaks above 1600 MW, which would be considered a high demand, on three days: December 28 to December 30. The peak forecast was below actual on all three days, but by less than 4.0%.

In the review of forecast accuracy statistics for December 2015 in Table 2, Hydro offers further detail on the difference found between forecast and actual peak for December 3 and 4.

2.2 Data Adjustment

On December 3, maintenance work at the Massey Drive Terminal Station in Corner Brook meant that the load at the Kruger Mill was not properly represented in Hydro's Energy Management System between approximately 9:30 am and 4:30 pm. With an incorrect value for the industrial load, Hydro's system was unable to calculate the utility load, as that is calculated as the difference between the total load and the industrial load. System Operations was aware of this problem on the day, and hourly estimates of the actual utility load were made using the last unaffected forecast, which was at 9:20 am. The available and spinning reserves were strong throughout the day.

On December 29, Newfoundland Power requested a short-term voltage reduction during the expected peak demand period in order to reduce the peak. Therefore, System Operations increased the Avalon and Island utility load values in Nostradamus at 5:00 pm and 6:00 pm by 10 and 20 MW, respectively (estimated from the observed decrease in the load when the voltage reduction was put in place). These adjustments were made to the Nostradamus data so that in the future, when December 2015 is used in training, Nostradamus will use a value that is not affected by the requested voltage reduction.

The temporary fix applied to prevent the PI data archiving problem experienced in October and November prevented any such problems occurring in December.

Table 1 December 2015 Load Forecasting Data

Date	Forecast Peak, MW	Actual Peak, MW	Available Island Supply, MW	Forecast Reserve, MW
1-Dec-15	1480	1478	1950	557
2-Dec-15	1320	1310	1850	615
3-Dec-15	1335	1239	1890	641
4-Dec-15	1395	1476	2000	691
5-Dec-15	1435	1398	1955	607
6-Dec-15	1340	1363	1965	711
7-Dec-15	1310	1319	1880	655
8-Dec-15	1350	1318	1860	596
9-Dec-15	1365	1318	1855	576
10-Dec-15	1340	1293	1785	531
11-Dec-15	1240	1246	1820	664
12-Dec-15	1230	1226	1845	699
13-Dec-15	1305	1267	1990	770
14-Dec-15	1465	1482	2005	627
15-Dec-15	1420	1425	1815	482
16-Dec-15	1430	1467	1810	467
17-Dec-15	1455	1512	1960	592
18-Dec-15	1415	1402	1965	637
19-Dec-15	1285	1283	1985	795
20-Dec-15	1420	1447	2025	702
21-Dec-15	1450	1468	1970	617
22-Dec-15	1515	1523	2010	593
23-Dec-15	1475	1494	1990	612
24-Dec-15	1505	1500	1990	583
25-Dec-15	1250	1233	2035	880
26-Dec-15	1325	1323	2020	790
27-Dec-15	1490	1508	2030	637
28-Dec-15	1630	1660	1975	444
29-Dec-15	1630	1698	2015	484
30-Dec-15	1555	1612	1990	533
31-Dec-15	1500	1552	2000	598
Minimum	1230	1226	1785	444
Average	1408	1414	1943	625
Maximum	1630	1698	2035	880

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).

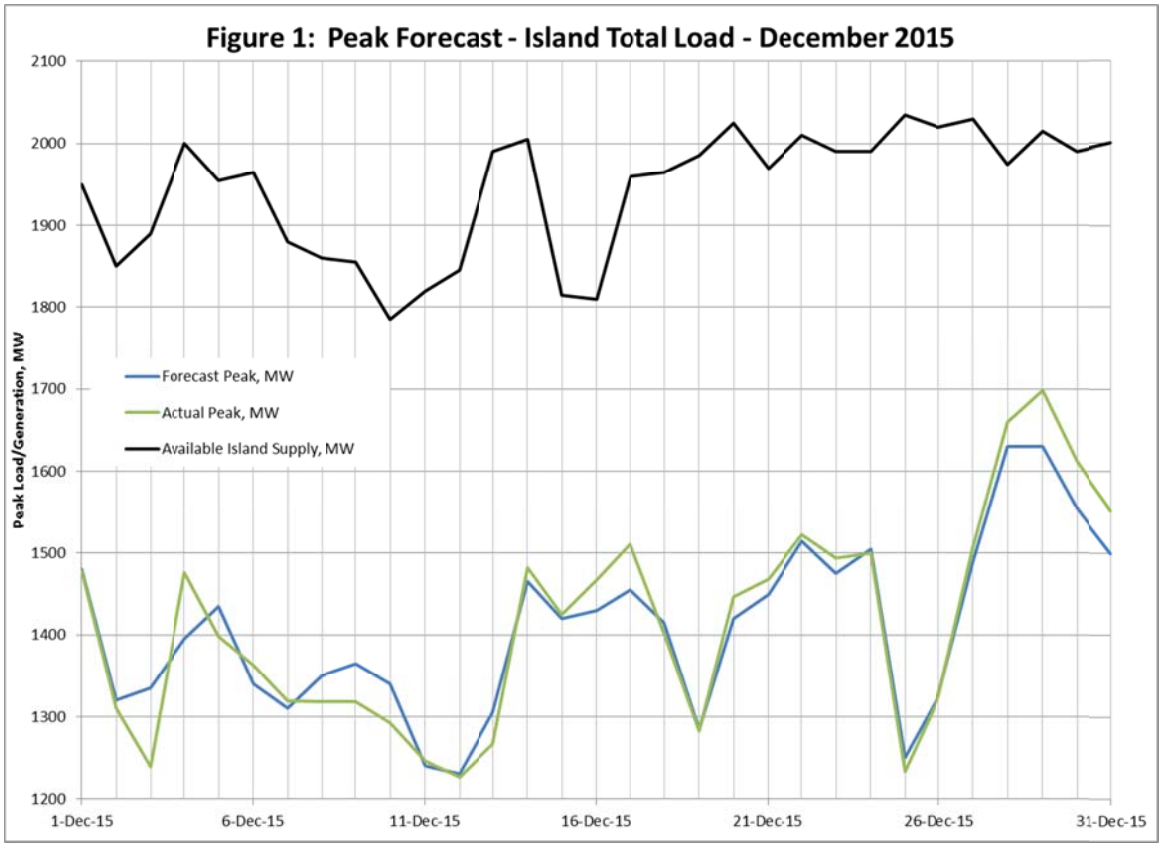
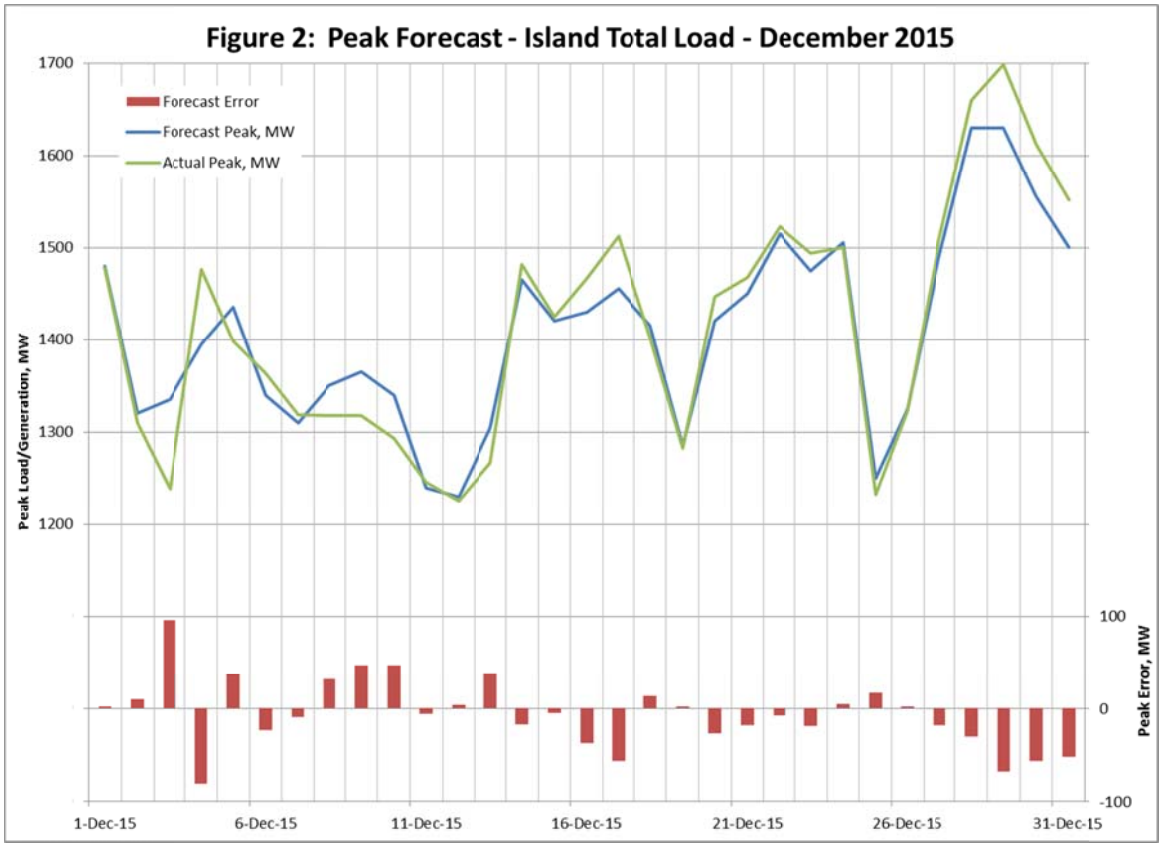


Figure 1: Peak Forecast - Island Total Load - December 2015
Peak Load/Generation, MW
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1-Dec-15
6-Dec-15
11-Dec-15
16-Dec-15
21-Dec-15
26-Dec-15
31-Dec-15
Forecast Peak, MW
Actual Peak, MW
Available Island Supply, MW

Table 2 December 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-Dec-15	1478	1480	2	2	0.1%	0.1%	0.1%
2-Dec-15	1310	1320	10	10	0.8%	0.8%	0.8%
3-Dec-15	1239	1335	96	96	7.7%	7.7%	7.2%
4-Dec-15	1476	1395	-81	81	-5.5%	5.5%	-5.8%
5-Dec-15	1398	1435	37	37	2.6%	2.6%	2.6%
6-Dec-15	1363	1340	-23	23	-1.7%	1.7%	-1.7%
7-Dec-15	1319	1310	-9	9	-0.7%	0.7%	-0.7%
8-Dec-15	1318	1350	32	32	2.4%	2.4%	2.4%
9-Dec-15	1318	1365	47	47	3.6%	3.6%	3.4%
10-Dec-15	1293	1340	47	47	3.6%	3.6%	3.5%
11-Dec-15	1246	1240	-6	6	-0.5%	0.5%	-0.5%
12-Dec-15	1226	1230	4	4	0.3%	0.3%	0.3%
13-Dec-15	1267	1305	38	38	3.0%	3.0%	2.9%
14-Dec-15	1482	1465	-17	17	-1.1%	1.1%	-1.2%
15-Dec-15	1425	1420	-5	5	-0.4%	0.4%	-0.4%
16-Dec-15	1467	1430	-37	37	-2.5%	2.5%	-2.6%
17-Dec-15	1512	1455	-57	57	-3.8%	3.8%	-3.9%
18-Dec-15	1402	1415	13	13	0.9%	0.9%	0.9%
19-Dec-15	1283	1285	2	2	0.2%	0.2%	0.2%
20-Dec-15	1447	1420	-27	27	-1.9%	1.9%	-1.9%
21-Dec-15	1468	1450	-18	18	-1.2%	1.2%	-1.2%
22-Dec-15	1523	1515	-8	8	-0.5%	0.5%	-0.5%
23-Dec-15	1494	1475	-19	19	-1.3%	1.3%	-1.3%
24-Dec-15	1500	1505	5	5	0.3%	0.3%	0.3%
25-Dec-15	1233	1250	17	17	1.4%	1.4%	1.4%
26-Dec-15	1323	1325	2	2	0.2%	0.2%	0.2%
27-Dec-15	1508	1490	-18	18	-1.2%	1.2%	-1.2%
28-Dec-15	1660	1630	-30	30	-1.8%	1.8%	-1.8%
29-Dec-15	1698	1630	-68	68	-4.0%	4.0%	-4.2%
30-Dec-15	1612	1555	-57	57	-3.5%	3.5%	-3.7%
31-Dec-15	1552	1500	-52	52	-3.4%	3.4%	-3.5%
Minimum	1226	1230	-81	2	-5.5%	0.1%	-5.8%
Average	1410	1405	-4	28	-0.1%	2.0%	-0.2%
Maximum	1698	1630	96	96	7.7%	7.7%	7.2%

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.



2.3 December 3, 2015

On December 3, the forecast peak at 7:20 am, as reported to the Board, was 1335 MW; the actual reported peak was 1239 MW. The absolute difference was 96 MW, 7.7% of the actual. Figure 3 includes an hourly plot of the load forecast for December 3 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.

As noted in Section 2.2 above, some load data is missing for December 3 because of the metering interruption at the Kruger Mill, so the 'actual' data was approximated using the forecast for a portion of the day. The data for the time of the peak was not affected.

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 1335 MW. The actual hourly peak was 1235 MW at 5:00 pm.

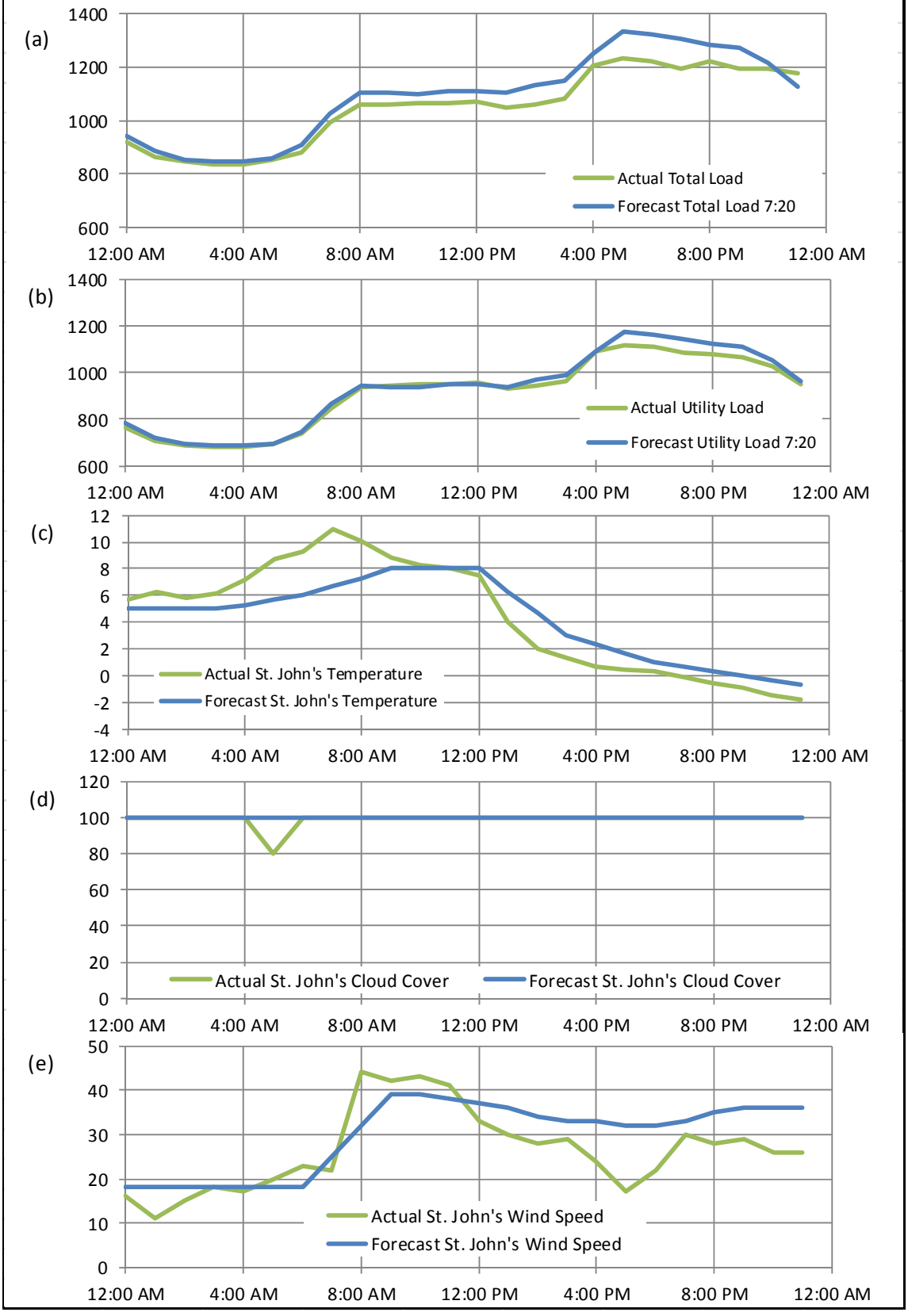
Figure 3(b) shows the hourly distribution of the utility load forecast only, i.e., the load forecast with the industrial component removed. The forecast utility peak of 1173 MW load was closer to the actual utility peak of 1117 MW so a discrepancy in the industrial forecast contributed significantly 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 between one and three degrees lower 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 overestimate 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 accurate for most of the day. Figure 3(e) shows the actual wind speed in St. John's compared to the forecast. The wind speed was somewhat higher than forecast in the early part of the day but for most of the afternoon the actual wind speed was lower than predicted, especially so in the peak period so the error in the wind speed forecast likely contributed to the load forecast error.

The discrepancy between actual and forecast load for December 3 was likely a result of errors in both the industrial load and wind speed forecasts. Energy Control Centre operators were aware of the situation and managed the reserves accordingly.

Figure 3 Accuracy Analysis - December 3, 2015



2.4 December 4, 2015

On December 4, the forecast peak at 7:20 am was 1395 MW; the actual reported peak was 1476 MW. The absolute difference was 81 MW, 5.5% of the actual. Figure 4 includes an hourly plot of the load forecast for December 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 4(a) shows the hourly distribution of the load forecast compared to the actual load. The 7:20 am forecast predicted a 5:00 pm peak of 1395 MW. The actual peak was 1476 MW at 4:55 pm.

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 error in the utility forecast was greater than the error in the total forecast, so error in the industrial forecast did not contribute to the error in the total load forecast.

Figures 4(c) through 4(e) show comparisons of the weather conditions to the weather forecasts. Figure 4(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 between one and three degrees lower than forecast for most of the day which would have contributed to the underestimate in the load forecast. In addition, the temperature pattern during the day was somewhat unusual. Typically the temperature rises during the day and then lowers again in the evening. On December 4 the temperature was approximately -2° C at midnight, gradually lowered as the day went on, and was -4° C by 11:00 pm. It has been noted in the past that unusual temperature patterns tend to lead to more error in the Nostradamus forecast.

Figure 4(d) shows the actual cloud cover in St. John's compared to the forecast. The cloud cover forecast was accurate during the daylight hours of the day, so the inaccuracy late in the day would not have had an effect on the load forecast. Figure 4(e) shows the actual wind speed in St. John's compared to the forecast. The actual wind speed was somewhat lower than forecast so the error in the wind speed forecast did not contribute to the load forecast error.

The discrepancy between actual and forecast load for December 4 was likely a result of error in the temperature forecast and the unusual temperature pattern through the day. By midday, the forecast had improved and was within 2% of the actual. The hourly, within day, updates are used by Energy Control Centre operators to manage spinning reserve.

Figure 4 Accuracy Analysis - December 4, 2015