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Day Ahead Load Forecast in ISO New England Market and Ontario Market using a Novel ANN

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ABSTRACT

Accurate short term load forecasting is an essential task in power system planning, operation, and control. This paper discusses significant role of artificial intelligence (AI) in short-term load forecasting (STLF). A new artificial neural network (ANN) has been designed to compute the forecasted load. The ANN model is trained on hourly data from the ISO New England market and Ontario Electricity Market from 2007 to 2011 and tested on out-of-sample data from 2012. Simulation results obtained have shown that day-ahead hourly forecasts of load using proposed ANN is very accurate with very less error in both the markets. However load forecast for ISO New England market & Ontario market is much better with temperature data as input than without taking it. This is due to the fact that temperature and weather data are having high degree of correlation with load of that particular region. This indicates that temperature data is a very important parameter for load forecasting using ANN.

Keywords —Mean Absolute Percentage Error, Mean Absolute Error, Neural Network, Power System, Short-Term Load Forecasting and Electricity Market.

1. INTRODUCTION

With an introduction of deregulation in power industry, many challenges have been faced by the participants of the electricity market. Forecasting electricity parameters such as load and energy price have become a major issue in power systems [1]. The fundamental objective of electric power industry deregulation is to maximize efficient generation and consumption of electricity, and reduction in energy prices. To achieve these goals, accurate and efficient electricity load forecasting is becoming more and more important [2].

Load forecasting is a key task for the effective operation and planning of power systems. Inaccurate forecasting of electricity demand will either lead to the startup of too many units supplying an unnecessary level of reserve or excessive energy purchase, as well as substantial wasted investment in the construction of excess power facilities or may result in a risky operation and unmet demand, persuading insufficient preparation of spinning reserve, and causes the system to operate in a vulnerable region to the disturbance [3].

Load forecasting is categorized as short-term, medium-term, and long-term forecasts, depending on the time scale. The forecasting of hourly-integrated load carried out for one day to week ahead is usually referred to as short-term load forecasting. Short-term load forecasting plays an important role in power systems since the improvement of forecasting accuracy results in the reduction of operating costs and the reliable power system operations [4].

The load at a given hour is dependent not only on previous loads but also on much important weather related variables.

Effective integration of various factors into the forecasting model may provide accurate load forecasts for modern power industries.

Various techniques have been developed for electricity demand forecasting during the past few years. Several research works have been carried out on the application of AI techniques to the load forecasting problem as AI tools have performed better than conventional methods in short-term load forecasting. Various AI techniques reported in literatures are expert systems, fuzzy inference, fuzzy-neural models, neural network (NN). Among the different techniques on load forecasting, application of NN technology for load forecasting in power system has received much attention in recent years [5]-[8]. The main reason of NN becoming so popular lies in its ability to learn complex and nonlinear relationships that are difficult to model with conventional techniques [9].

This paper discusses significant role of artificial intelligence in day-ahead load forecasting, that is, Day-Ahead hourly load forecast over a day, week & month. In this paper, artificial neural network designed using MATLAB R13 has been used to compute the day-ahead hourly load forecast in ISO New England market and Ontario electricity market. Both the hourly temperature and hourly electricity load historical data have been used in forecasting. The temperature variable is included in forecasting of load because temperature has a high degree of correlation with electricity load. The neural network models are trained on hourly data from the ISO New England market, Ontario electricity market from 2007 to 2011 and tested on out-of-sample data from 2012. The simulation results obtained have shown that artificial neural network (ANN) is able to make very accurate short-term load forecast with average errors around 0.85%-3.85% in ISO New England market and 1.07%-3.85% in Ontario electricity market. A box plot [10] of the error distribution of forecasted load has been plotted as a function of hour of the day, day of the week.

This paper has been organized in five sections. Section II presents the overview of neural network used. Section III discusses the selection of various data and model of ANN for day-ahead forecast. Results of simulation are presented and discussed in Section IV. Section V discusses the conclusion and future work.

2. ARTIFICIAL NEURAL NETWORK FOR LOAD FORECASTING

Neural networks are composed of simple elements called neuron, operating in parallel. A neuron is an information processing unit that is fundamental to the operation of a neural network. The three basic elements of the neuron model are (i) set of weights, (ii) an adder for summing the input signals and (iii) activation function for limiting the amplitude of the output of a neuron. A neural network can be trained to perform a particular function by adjusting the values of the connections (weights) between elements. In load forecasting, typically, many input/ target pairs are needed to train a neural network. Neural network is mapped between data set of numeric inputs and a set of numeric targets. The neural network consists of two-layer feed-forward network with sigmoid hidden neurons and linear output neurons. It can fit multi-dimensional mapping problems arbitrarily well, given consistent data and enough neurons in its hidden layer. The neural network is trained with Levenberg-marquardt back propagation algorithm.

3. DATA INPUTS AND ANN MODEL

The models are trained on hourly data from the ISO New England market & Ontario market from 2007 to 2011 and tested on out-of-sample data from 2012. The data used in the ANN model are both the temperature and electricity load hourly historical data. The temperature variable is included because temperature has a close relationship with electricity load. The relationship between demand and average temperature is shown in Fig. 1, where a nonlinear relationship between load and temperature can be observed. For the load forecast, the input parameters include followings.

- Dry bulb temperature
- Dew point temperature
- Hour of day
- Day of the week
- Holiday/weekend indicator (0 or 1)
- Previous 24-hr average load
- 24-hr lagged load
- 168-hr (previous week) lagged load

4. SIMULATION AND RESULTS

In this paper hourly day-ahead load forecasting has been done for sample of each day, week & month of data of year 2012 using neural network tool box of MATLAB R13a. The ANNs are trained with data from 2007 to 2011 and tested on out-of-sample data from 2012. The test sets are completely separate from the training sets and are not used for model estimation or variable selection.

The model accuracy on out-of-sample periods is computed with the Mean Absolute Percent Error (MAPE) metrics. The principal statistics used to evaluate the performance of these models, mean absolute percentage error (MAPE), is defined in eq. 1 below.

$$MAPE\ [\%] = \frac{1}{N}\sum_{i=1}^{N}\frac{|L_A^i - L_F^i|}{L_A^i} \times 100 \qquad (1)$$

Where LA is the actual load, LF is the forecasted load, N is the number of data points.

Various plots of the error distribution as a function of hour of the day, day of the week are generated. Also, the various plots comparing the day ahead hourly actual and forecasted load for every weeks for the year 2012 are also generated. Simulation results of Ontario and ISO New England market are discussed below.

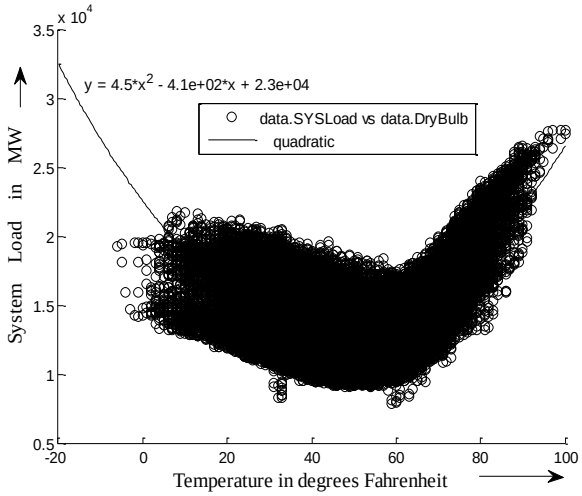

Fig. 1. Scatter plot of system load vs. temperature (degrees Fahrenheit) for ISO England market for year 2007 to 2012 with fitting equation of quadratic.

4.1 Ontario Electricity Market without Considering Temperature Effect

The ANN & improved ANN model used in the forecasting has input, output and one hidden layers. Hidden layer has 50 neurons in ANN, whereas improved ANN consists of a hybrid of 46 & 50 neurons in its hidden layer. Inputs to the input layer are as listed above for load forecast. After simulation the MAPE obtained is 2.90% & 2.85 % for load forecasting for the year 2012 by using ANN & improved ANN respectively as shown in Fig. 2.

The box-plot of the error distribution of forecasted load as a function of hour of the day is presented in Fig. 3. It shows the percentage error statistics of hour of the day in year 2012. It is also evident that the maximum error is for the 6th hour of the day and minimum error for 21th hour of the day in year 2012. The box-plot of the error distribution of forecasted load as a function of day of the week is evaluated in Fig. 4 which shows the percentage error statistics of day of the week in year 2012. The maximum error is for the Monday and minimum error for Friday in year 2012.

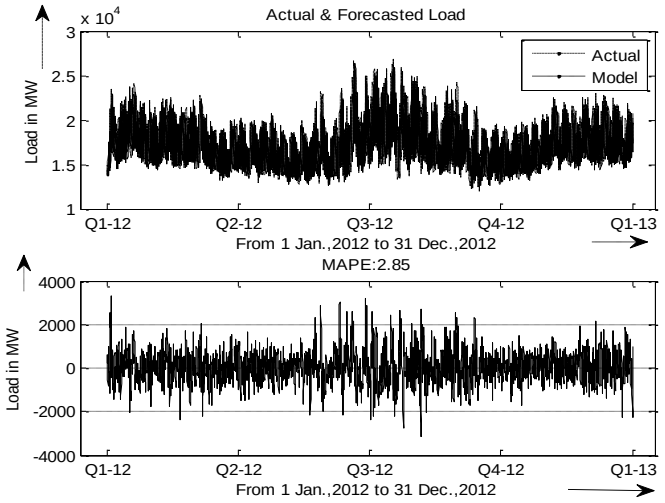

Fig. 2. Multiple series plot between actual load & forecasted load by improved ANN in year 2012 for Ontario electricity market.

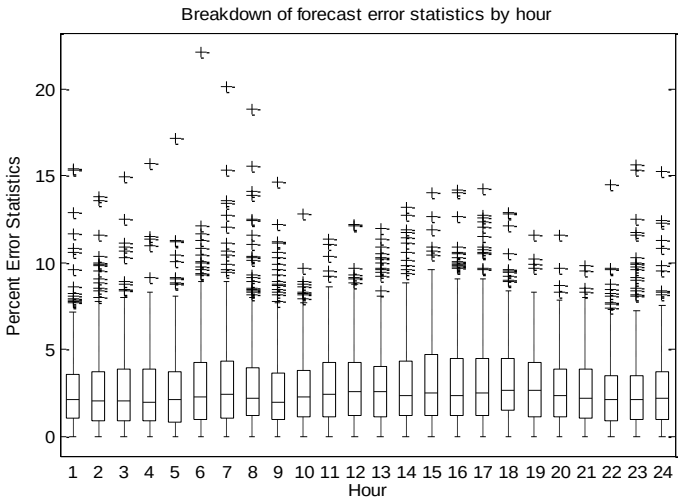

Fig. 3. Error distribution of forecasted load as a function of hour of the day in the year 2012 Ontario electricity market by improved ANN.

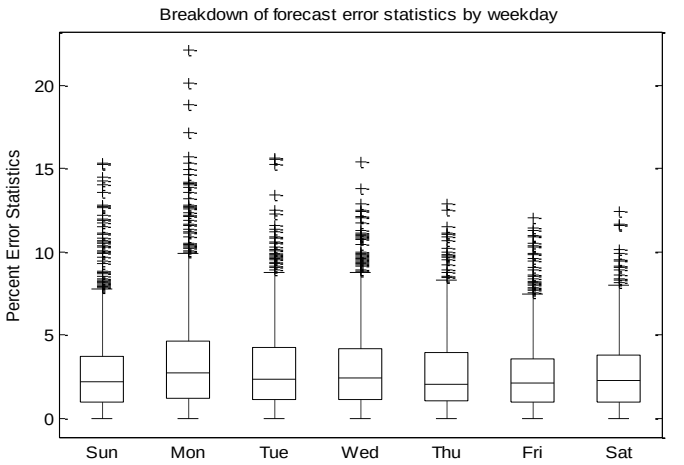

Fig. 4. Error distribution for the forecasted load as a function of day of the week in the year 2012 for Ontario electricity market by improved ANN.

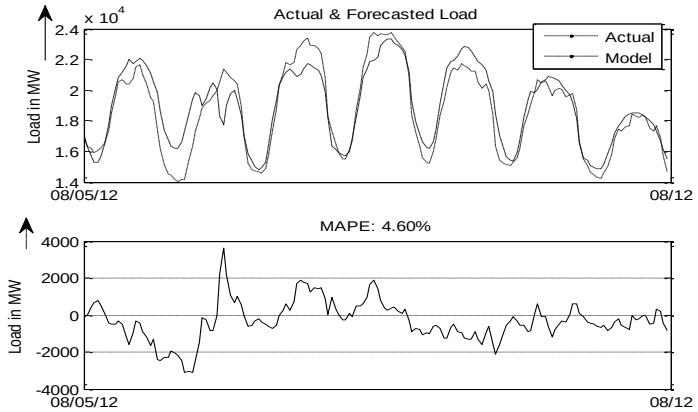

Fig. 5. Maximum MAPE is 4.60 % for the forecast of 05 -11 Aug., 2012 in year 2012 for day ahead hourly weekly forecast by using ANN.

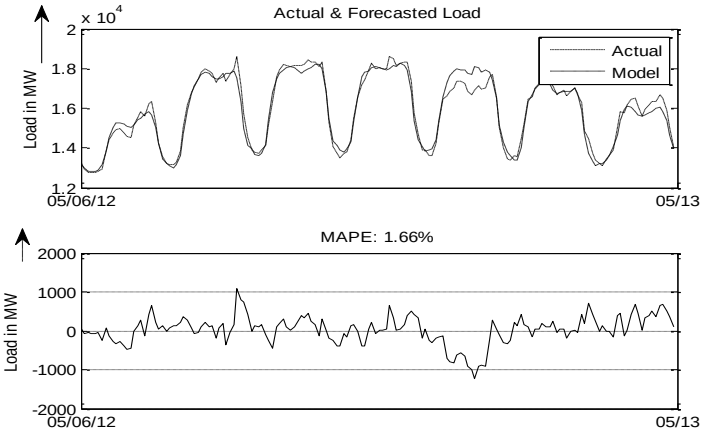

Fig. 6. Minimum MAPE is 1.66% for the forecast of 06-12 May, 2012 for day ahead hourly weekly forecast in the year 2012 by using improved ANN.

Multiple series plots between actual load & forecasted load from 05-11 Aug., 2012 & from 06-12 May, 2012 for Ontario electricity market and also plots of MAPE with maximum error (4.60%) and minimum error (1.66%) for day ahead hourly weekly forecast in year 2012 have been shown in Fig. 5 and Fig. 6 by ANN & improved ANN respectively.

4.2 ISO New England Market

The ANN & improved ANN model used in the forecasting has input, output and one hidden layers. Hidden layer has 52 neurons in ANN, whereas improved ANN has hybrid of 52 & 48 neurons in its hidden layer. Inputs to the input layer as listed above for load forecast with considering temperature data. After simulation the MAPE obtained is 1.55 % & 1.50 % for load forecasting for the year 2012 by ANN & improved ANN respectively.

The box-plot of the error distribution of forecasted load as a function of hour of the day is presented in Fig. 7. It shows the percentage error statistics of hour of the day in year 2012. It is also evident that the maximum error is for the 21st hour of the day and minimum error for 14th hour of the day in year 2012. The box-plot of the error distribution of forecasted load as a function of day of the week is evaluated in Fig. 8 which shows the percentage error statistics of day of the week in year 2012. The maximum error is for the Monday and minimum error for Thursday in year 2012.

Multiple series plots between actual load & forecasted load from 06-12 May, 2012 & from 28 October, 2012 to 03 November, 2012 for ISO New England market and also plots of MAPE with maximum error (3.85%) and minimum error

(0.85%) for day ahead hourly weekly forecast in year 2012 have been shown in Fig. 9 and Fig. 10 by using improved ANN.

Also, an ANN & improved ANN model for forecasting has been developed without considering temperature data (dry bulb & dew point) as an input to input layer. This ANN & improved ANN model used in the forecasting has input, output and one hidden layers. Hidden layer has 38 neurons in ANN, while the improved ANN has hybrid of 42 & 50 neurons in its hidden layer. After simulation the MAPE obtained is 2.90 % & 2.81 % for load forecasting for the year 2012 by using ANN & improved ANN respectively. The MAPE obtained between actual load & forecasted load from 17-23 June & from 06-12 May, 2012 for ISO New England market shows maximum error (5.13%) & minimum error (1.19%) for day ahead hourly weekly forecast in year 2012 by using ANN & improved ANN respectively.

The MAPE & MAE between the forecasted and actual loads for each day, week & month has been calculated and presented from Table I-VI in the year 2012, with & without considering temperature data for both the power market. From the results of Table I-VI it is observed that MAPE & MAE for ISO New England market (with temperature data) is much better than MAPE & MAE for Ontario electricity market. This is due to the fact that temperature and weather data is not been taken as input in Ontario electricity market but it is considered for input in ISO New England market. This indicates that temperature data is a very important parameter for load forecasting using ANN. Also, the MAPE & MAE from Table I-VI of ISO New England market with considering temperature data is much better than without considering temperature data as input to ANN in same market. From the results obtained from Table III, it is clear that maximum MAPE (3.85%) is for July & minimum MAPE (2.17%) is for November, 2012 for Ontario electricity market. Also, it is clear that maximum MAPE (2.02%) is for Dec., 2012 and minimum MAPE (1.4%) is for July, 2012 for ISO New England market (with temperature data),as soon in Fig. 11.

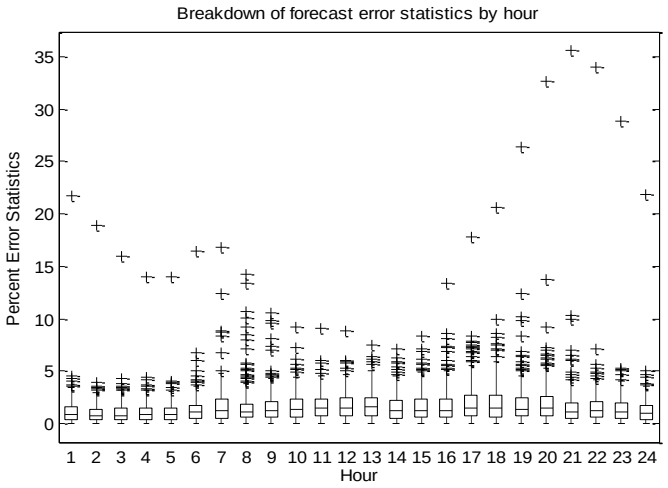

Fig. 7. Error distribution of forecasted load as a function of hour of the day in year 2012 for ISO New England market by improved ANN.

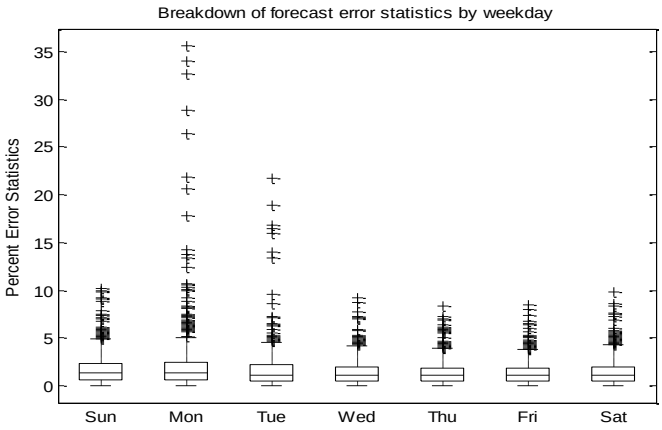

Fig. 8. Error distribution for the forecasted load as a function of day of the week in the year 2012 for ISO New England market by improved ANN.

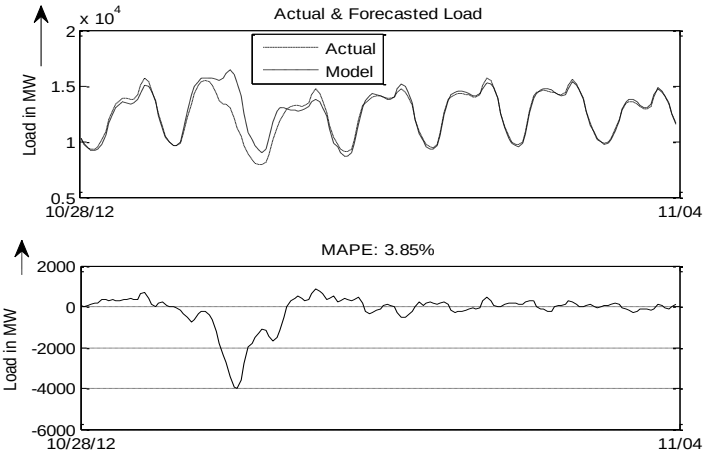

Fig. 9. Maximum MAPE is 3.85% for the load forecast of 28 October, 2012 to 03 November, 2012 for day ahead hourly weekly forecast for year 2012.

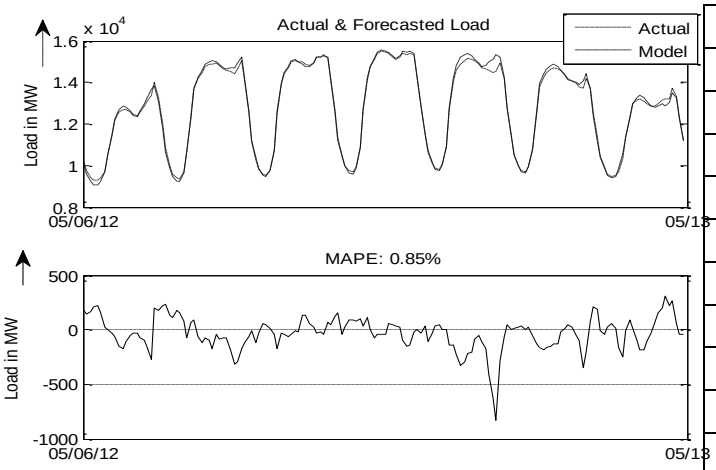

Fig. 10. Minimum MAPE is 0.85% for the load forecast of 06-12 May, 2012 for day ahead hourly weekly forecast for the year 2012.

TABLE I

RESULTS FOR OUT-OF-SAMPLE TEST FOR YEAR 2012

S. N.	Duration (Year 2012) mm/dd - mm/dd	MAPE (%)					
		ISO New England Market				Ontario	
		With Temp. Data		Without temp. data		Without temp. data	
		ANN	Imp. ANN	ANN	Imp. ANN	ANN	Imp. ANN
1	01/01-01/07	2.16	2.04	4.03	3.9	3.9	3.85
2	01/08-01/14	1.32	1.23	2.57	2.45	2.59	2.55
3	01/15-01/21	1.47	1.37	4.13	4.05	2.99	2.86
4	01/22-01/28	1.86	1.8	3.11	3.05	2.07	2.02
5	01/29-02/04	0.9	0.86	2.21	2.02	2.33	2.37
6	02/05-02/11	1.28	1.21	2.62	2.51	2.82	2.82
7	02/12-02/18	1.12	1.08	2.41	2.27	2.77	2.7
8	02/19-02/25	1.47	1.37	2.75	2.58	2.92	2.98
9	02/26-03/03	1.66	1.55	2.85	2.71	2.69	2.64
10	03/04-03/10	1.51	1.52	2.86	2.71	3.43	3.43
11	03/11-03/17	1.94	1.87	2.78	2.76	2.84	2.8
12	03/18-03/24	1.68	1.65	1.57	1.61	2.64	2.61
13	03/25-03/31	1.49	1.28	2.95	2.97	2.43	2.38
14	04/01-04/07	1.58	1.47	2.53	2.44	2.74	2.68
15	04/08-04/14	1.22	1.23	1.99	1.87	2.25	2.3
16	04/15-04/21	1.63	1.65	2.29	2.11	2.4	2.37
17	04/22-04/28	1.32	1.38	2.26	2.12	2.48	2.49
18	04/29-05/05	1.35	1.33	1.55	1.45	2.16	2.1
19	05/06-05/12	0.92	0.85	1.23	1.19	1.68	1.66
20	05/13-05/19	0.99	0.93	1.61	1.59	2.52	2.5
21	05/20-05/26	0.91	0.94	2.06	2.01	2.96	2.96
22	05/27-06/02	1.72	1.71	3.75	3.68	4	3.95
23	06/03-06/09	1.14	1.17	1.96	1.82	2.42	2.27
24	06/10-06/16	0.97	0.92	1.93	1.88	4.21	4.29
25	06/17-06/23	1.84	1.61	5.13	5.38	3.83	3.78
26	06/24-06/30	1.86	1.7	3.96	3.81	3.49	3.38
27	07/01-07/07	2.07	1.8	4.12	4.07	4.34	3.83
28	07/08-07/14	1.26	1.27	3.29	3.51	3.37	3.26
29	07/15-07/21	1.25	1.22	4.46	3.95	4.31	4.27
30	07/22-07/28	1.34	1.27	4.1	3.65	4	4.05
31	07/29-08/04	1.34	1.21	3.11	3.15	3.24	3.27
32	08/05-08/11	1.53	1.53	3.7	3.89	4.6	4.63
33	08/12-08/18	1.54	1.5	3.48	3.17	3.01	2.99
34	08/19-08/25	1.37	1.25	2.61	2.73	2.8	2.74
35	08/26-09/01	1.46	1.49	4.27	4.14	3.71	3.68
36	09/02-09/08	1.71	1.54	3.55	3.57	3.61	3.52
37	09/09-09/15	1.78	1.91	3.84	3.83	4.1	4.06
38	09/16-09/22	1.59	1.58	2.83	2.79	2.25	2.15
39	09/23-09/29	1.26	1.23	1.52	1.48	2.25	2.29
40	09/30-10/06	1.18	1.23	1.42	1.25	1.93	1.89
41	10/07-10/13	1.41	1.44	2.03	2.05	2.95	2.91
42	10/14-10/20	1.5	1.58	1.98	1.89	2.16	2.09
43	10/21-10/27	1.24	1.24	1.32	1.42	1.88	1.87
44	10/28-11/03	3.89	3.85	4.08	4.65	2.23	2.25
45	11/04-11/10	1.96	1.83	3.82	3.86	2.11	2.11
46	11/11-11/17	1.7	1.61	2.57	2.39	1.94	1.91
47	11/18-11/24	1.92	2.04	3.14	2.6	2.17	2.16
48	11/25-12/01	1.19	1.2	3.11	3.07	2.61	2.64
49	12/02-12/08	1.93	1.79	3.58	3.42	2.45	2.43
50	12/09-12/15	1.81	1.76	3.01	2.68	2.74	2.72
51	12/16-12/22	1.77	1.78	2.27	2.24	2.54	2.6
52	12/23-12/29	2.58	2.53	3.89	3.75	3.45	3.46
53	Average	1.55	1.50	2.90	2.81	2.90	2.85

TABLE II

RESULTS FOR OUT-OF-SAMPLE TEST FOR YEAR 2012

SN	Duration (Year 2012) mm/dd-mm/dd	MAE (MW)					
		ISO New England Market				Ontario	
		With Temp. Data		Without temp. data		Without temp. data	
		ANN	Imp. ANN	ANN	Imp. ANN	ANN	Imp. ANN
1	01/01-01/07	321.3	303	606.4	588.2	719.8	709.3
2	01/08-01/14	202.2	187	391.5	368.6	486.3	478.9
3	01/15-01/21	239.6	224	649.8	631.7	589.9	564.3
4	01/22-01/28	287.4	277	457.8	452	382.2	373.7
5	01/29-02/04	134.1	129	330.8	299.2	418.8	424.8
6	02/05-02/11	192.4	183	380.2	366.4	532.1	533.4
7	02/12-02/18	170.4	166	357	335.6	510.8	497.7
8	02/19-02/25	218.3	200	389.5	364.8	530.6	542.1

9	02/26-03/03	248.6	231	408.3	389.3	498.2	488.2
10	03/04-03/10	219.2	222	402.4	378.4	625.4	625.2
11	03/11-03/17	263.9	255	362.5	361.4	467	460.7
12	03/18-03/24	226.2	221	205.6	209	420.3	415.7
13	03/25-03/31	203.8	174	391.5	393.6	415	407.1
14	04/01-04/07	210.5	198	333.7	319.2	470.2	458.7
15	04/08-04/14	155.1	156	255.1	243	382.7	390
16	04/15-04/21	217.5	218	310.9	287.8	400.1	396.4
17	04/22-04/28	172.6	181	290.6	273.1	426.8	427.9
18	04/29-05/05	181.3	177	203.4	188.1	344.6	335.6
19	05/06-05/12	119.4	110	163.5	157.4	272	267.2
20	05/13-05/19	132.4	123	219.6	215	423.1	419.3
21	05/20-05/26	131.1	135	308.9	300.3	525	526.3
22	05/27-06/02	261.1	258	571.8	561.7	713.9	704.6
23	06/03-06/09	158.5	163	271.9	252.2	413.7	391.3
24	06/10-06/16	139.7	131	279.2	270.7	773.6	789.6
25	06/17-06/23	328.9	279	974.1	1008	783.1	774.9
26	06/24-06/30	295.5	272	633.3	605.1	671.1	649.5
27	07/01-07/07	361.8	315	709	692.5	883.5	788.1
28	07/08-07/14	225.7	225	559.8	596.9	644.1	625.1
29	07/15-07/21	227.6	222	772.2	680.4	837.2	829.6
30	07/22-07/28	233.5	218	675.3	615.5	786.4	799
31	07/29-08/04	234.5	212	551	562.3	657.4	665.4
32	08/05-08/11	276	273	675.1	721.1	835.8	843.9
33	08/12-08/18	263.5	255	575.7	526.7	551	547.1
34	08/19-08/25	218.8	199	383.6	396.5	536.8	525.4
35	08/26-09/01	243.7	246	676.1	649.8	700.7	695.1
36	09/02-09/08	273.9	251	545.9	554.5	621.4	604
37	09/09-09/15	255.7	275	520.8	524.1	645.4	643.5
38	09/16-09/22	213.5	213	381.6	369	368	352.2
39	09/23-09/29	167	163	201.5	195.7	360.4	365.6
40	09/30-10/06	164	172	194.2	171	312.7	306.5
41	10/07-10/13	180.8	186	263.4	267.4	475.3	469.8
42	10/14-10/20	202.6	212	271.3	258.1	365	353.6
43	10/21-10/27	164.1	164	174.9	188.9	311.4	309.9
44	10/28-11/03	448.4	444	483.1	555.1	384.2	388.1
45	11/04-11/10	285.3	262	537.7	542.2	392.7	392.9
46	11/11-11/17	239.8	226	354.9	327.8	352.3	347.1
47	11/18-11/24	264.6	279	428.6	355.3	387.4	386.5
48	11/25-12/01	182.7	185	458	454.9	493.7	499
49	12/02-12/08	285.2	266	499.6	472.9	446.2	442
50	12/09-12/15	275.6	269	442.9	391.7	515.5	510.2
51	12/16-12/22	279.2	281	352	343.2	472.4	481.9
52	12/23-12/29	395.5	386	576.8	558.8	613.7	617.5
53	Average	230.6	222	431	419.1	522	516.1

From the results obtained from Table IV-VI, it is clear that highest MAPE (9.14%) is on 06 August & least MAPE (1.01%) is on 26 July, 2012 in Ontario electricity market for day ahead hourly forecast in testing year-2012 & also multiple series plots between actual load & forecasted load with plot of MAPE on 06 August is shown in Fig. 12. Multiple series plots between actual load & forecasted load on 09 May, 2012 for ISO New England market and also plots of MAPE with least error (0.45%) for day ahead hourly forecast in year 2012 have been shown in Fig. 13. Also the highest error for daily forecast is on 29 Oct., 2012 in the year 2012 with MAPE (11.35%) for ISO New England market is presented in Table VI

TABLE III

RESULTS FOR OUT-OF-SAMPLE MONTHLY TEST IN YEAR 2012 BY USING IMPROVED ANN

S.N.	Month	MAPE (%)			MAE(MW)	
		Ontario (Without temp. data)	ISO New England		ISO market (With Temp. data)	Ontario (Without temp. data)
			Without Temp.	With Temp.		
1	Jan	2.86	3.25	1.56	239.03	535.93
2	Feb	2.67	2.47	1.17	175.06	494.5
3	March	2.79	2.52	1.63	226.27	475.86
4	April	2.47	2.11	1.41	186.09	417.56
5	May	2.63	1.91	1.14	160.19	455.23
6	June	3.34	3.17	1.33	207.72	629.5
7	July	3.85	3.84	1.4	243.82	761.38
8	August	3.49	3.41	1.4	240.33	660.34
9	Sept	2.95	2.86	1.54	221.14	481.79
10	Oct	2.22	2.29	1.98	249.9	367.85
11	Nov	2.17	2.88	1.62	229.91	397.61
12	Dec	2.89	3.03	2.02	309.32	527.38

TABLE IV

RESULTS FOR OUT-OF-SAMPLE DAILY TEST FROM JANUARY-APRIL, 2012 BY IMPROVED ANN

Day	MAPE (%) In Different Months of Year 2012							
	Ontario Electrcity Market Without Temp. Data				ISO New England Market With Temp. Data			
	Jan.	Feb.	Mar.	April	Jan.	Feb.	March	April
1	2.29	1.66	1.68	3.56	4.51	0.83	1.18	1.73
2	4.9	1.71	2.83	3.2	2.5	0.71	2.08	1.25
3	7.46	1.07	2.15	1.52	2.43	0.89	2.39	1.62
4	2.96	1.8	2.4	3.13	1.44	0.48	0.79	1.15
5	4.07	1.39	4.61	2.69	1.35	1.64	1.73	0.78

6	2.2	2.32	2.67	2.13	0.97	1.68	1.3	2.63
7	3.09	2.93	6.08	2.51	1.11	0.55	2.36	1.14
8	2.95	3.69	2.68	2.97	1.93	1.06	2.61	2.5
9	2.32	3.05	2.31	1.82	1.2	1.54	0.81	1.5
10	3.36	2.53	3.27	2.34	0.87	1.13	1.06	1.02
11	1.93	3.84	5.04	2.19	1.2	0.84	2.07	0.68
12	1.46	3.44	2.12	2.68	1	0.98	3.2	0.8
13	2.78	4.13	5.31	2	1.28	1.98	2.28	1.13
14	3.06	2.69	1.37	2.11	1.13	1.17	0.8	1
15	3.07	2.92	1.51	2.91	0.73	0.89	1.03	1.07
16	4.32	1.74	1.67	2.42	1.43	0.63	1.38	1.5
17	3.41	2.59	2.56	1.94	1.86	0.99	2.37	2.14
18	2.8	1.39	2.04	2.02	1.41	0.94	2.2	3.54
19	3.42	2.11	3.66	1.77	1.29	1.55	1.91	1.05
20	1.77	5.24	2.4	1.59	1.17	2.07	1.28	1.09
21	1.26	2.73	3.34	3.96	1.7	0.93	0.96	1.15
22	2.63	2.57	2.14	2.13	3.32	1.95	1.78	1.69
23	2.71	1.97	2.88	2.34	2.54	1.05	1.93	1.91
24	1.63	3.77	1.8	2.47	2.34	1.02	1.47	2
25	2.14	2.51	2.56	4.1	0.68	1.02	1.53	1.19
26	1.45	2.89	2.95	2.6	1.17	1.35	1.04	0.59
27	2.21	2.96	2.46	1.74	1.15	1.6	1.77	1.4
28	1.4	2.11	1.5	2.06	1.37	1.47	1.05	0.9
29	3.56	3.86	2.5	3.03	1.15	0.77	0.68	1.46
30	3.16	----	2.08	2.11	0.97	-----	2.01	1.23
31	3.61	-----	2.61	-----	1	------	0.91	-----

TABLE V

RESULTS FOR OUT-OF-SAMPLE DAILY TEST FROM MAY-AUGUST, 2012 BY IMPROVED ANN

Day	MAPE (%) In Different Months of Year 2012							
	Ontario Electrcity Market Without Temp. Data				ISO New England Market With Temp. Data			
	May	Jun.	July	Aug.	May	Jun.	July	Aug.
1	2.99	2.17	2.16	3.89	1.13	1.57	0.96	0.93
2	1.54	2.27	4.81	3.92	1.44	0.71	2.55	1.1
3	1.23	1.09	3.96	2.89	1.33	0.94	1.73	1.08
4	1.49	1.72	6.58	2.64	0.87	1.28	1.69	1.05
5	2.28	2.69	1.44	5.28	1.85	1.85	1.47	1.51
6	1.39	2.59	3.48	9.14	1.16	1.27	1.45	1.02
7	1.49	3.1	4.39	4.27	0.93	1.16	2.75	2.08
8	1.16	2.64	4.6	2.54	0.49	0.82	1.11	1.48
9	1.36	2.07	2.63	5.72	0.45	0.87	1.27	1.15
10	3.06	6.54	2.58	2.65	1.3	1.29	1.77	1.47
11	1.16	2.85	3.09	2.83	0.77	1.01	1.1	1.98
12	1.97	4.83	4.01	1.58	0.88	0.72	0.97	1.26
13	1.94	5.01	3.03	2.84	0.89	0.82	1.27	1.53
14	3.03	2.73	2.89	2.91	0.62	0.83	1.38	1.28
15	2.32	5.78	2.09	3.2	0.66	0.89	0.9	1.06
16	3.58	2.32	4.21	3.26	0.65	0.87	0.67	1.02
17	2.11	2.21	3.47	3.15	1.29	1.11	0.72	1.61
18	2.27	3.4	3.89	4.01	1.02	1.39	1.91	2.71
19	2.21	5.75	6.6	1.26	1.36	1.15	1.12	1.48
20	1.97	4.75	5.27	2.11	0.93	3.23	2.2	1.45
21	4.16	2.68	4.36	2.34	0.96	1.37	1.04	1.27
22	1.75	4.78	6.85	2.91	0.77	1.03	1.21	1.17
23	1.84	2.9	4.76	3.9	0.72	2	1.37	1.24
24	5.07	1.6	5.34	3.32	0.8	1.79	1.21	1.18
25	3.56	4.55	6.06	3.3	1.05	2.71	2.18	0.96
26	2.36	4.09	1.01	2.81	1.35	1.64	1.1	1.69
27	2.39	2.06	2.52	2.63	2.24	1.46	1	1.2
28	6.81	4.8	1.79	3.72	1.03	1.86	0.79	1.53
29	5.27	3.5	2.49	5.07	2.84	1.1	1.01	1.64
30	4.92	3.05	3.63	4.54	2.11	1.36	1.18	1.44
31	3.83	----	3.44	4.06	1.44	-----	2.09	1.65

TABLE VI

RESULTS FOR OUT-OF-SAMPLE DAILY TEST FROM SEPT.-DEC., 2012 BY IMPROVED ANN

Day	MAPE (%) In Different Months of Yaer 2012							
	Ontario Electrcity Market With Temp. Data				ISO New England Market With Temp. Data			
	Sep.	Oct.	Nov.	Dec.	Sep.	Oct.	Nov.	Dec.
1	2.9	2.42	2.74	3.57	1.27	1.35	1.32	1.12
2	3.62	2.44	1.45	1.52	1.49	0.87	1.13	2.76
3	4.94	2.13	2.34	3.12	1.52	1.04	0.85	2.51
4	2.97	1.52	1.23	1.71	1.41	1.3	2.73	1.18
5	3.16	1.6	2.91	3.24	1.78	1.33	1.59	1.79
6	2.01	1.52	2.38	2.7	1.6	1.78	1.13	1.97
7	3.95	2.13	2.9	2.35	1.29	2.27	2.95	1.18
8	3.95	4.47	1.93	2.38	1.72	2.58	0.84	1.15
9	5.19	3.49	1.6	3.44	1.92	1.12	1.7	1.46
10	2.44	2.36	1.81	3.77	2.39	0.87	1.87	1.42
11	3.83	1.52	2.04	2.78	2.04	1.31	2.2	2.03
12	4.49	2.2	1.95	2.46	1.52	0.86	2.66	1.93
13	3.42	4.21	1.99	2.97	1.34	1.09	0.95	1.67
14	3.77	2.14	1.72	1.9	1.83	1.8	1.39	1.96
15	5.25	4.37	2.33	1.73	2.35	2.21	1.28	1.87
16	2.46	1.74	1.4	1.84	2.19	1.69	1.13	2.5
17	2.4	1.34	1.93	3.9	0.99	0.58	1.66	1.37
18	2	1.55	1.39	2.52	1.2	1.22	1.96	1.67
19	2.39	2.02	1.7	2.91	2.23	1.22	1.55	1.53

20	1.98	1.51	1.72	1.92	2.47	2.3	1.04	1.69
21	1.85	2.71	2.56	2.31	0.89	1.96	1.18	1.42
22	1.97	1.44	1.19	2.77	1.1	1.45	2.91	2.28
23	2.72	1.1	2.67	2.62	1.31	0.85	3.54	1.43
24	1.78	2.08	3.88	6.73	1.64	0.79	2.09	6.26
25	3.5	1.79	1.96	2.1	1.73	0.76	2.2	2.71
26	1.86	2.1	2.34	4.2	0.96	1.59	1.3	3.02
27	2.4	1.87	2.29	3.65	1.18	1.3	0.6	1.4
28	1.6	2.88	2.08	2.31	0.56	2.07	0.8	1.67
29	2.14	3	2.74	2.62	1.27	11.35	1.25	1.2
30	1.64	2.28	3.48	2.2	0.96	8.08	1.16	1.28
31	-----	1.07	-----	5.26	-----	2.15	------	4.62

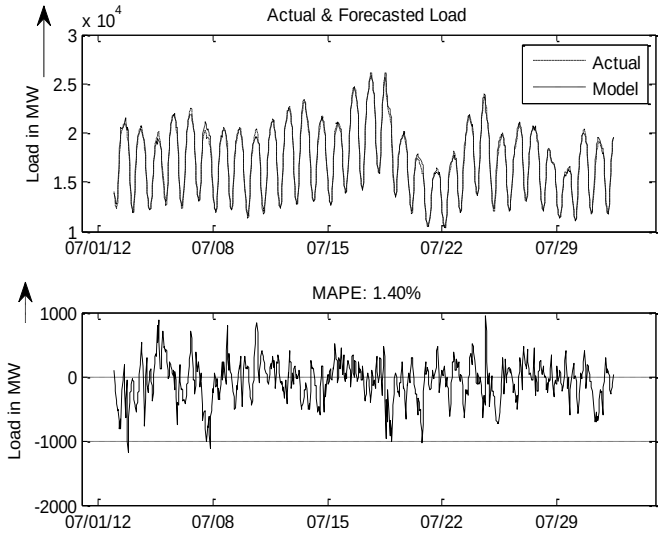

Fig. 11. MAPE is least (1.40%) for day ahead hourly-monthly forecast of July, 2012 of ISO New England market in year 2012.

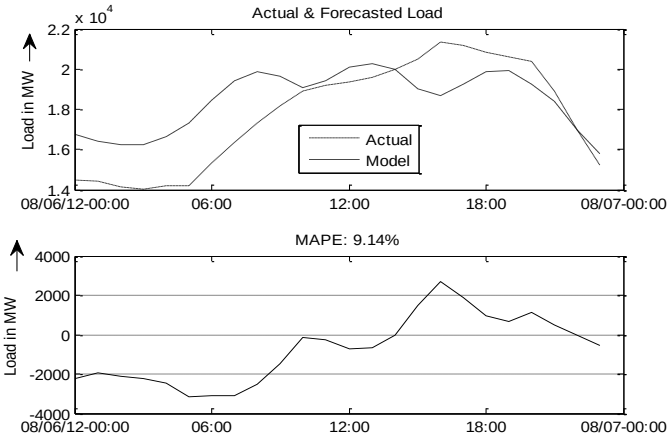

Fig. 12. MAPE is highest (9.14%) for the day ahead hourly forecast on 06 August 2012 in Ontario electricity market in year 2012 by improved ANN.

4.3 For Ontario Electricity Market Considering Temperature Effect

The ANN model used in the forecasting has input, output and one hidden layers. Hidden layer has 56 neurons. Inputs to the input layer as listed above for load forecast. Here temperature & load data of Toronto of Ontario Electricity Market has been considered. After simulation the MAPE obtained is 1.80% for load forecasting for the year 2012. Multiple series plots between actual load & forecasted load from 12-18 February, 2012 and also plots of MAPE with least error (1.07 %) for day ahead hourly weekly forecast in year 2012 have been shown in Fig. 14. The Mean Absolute Percentage Error (MAPE) & Mean Absolute Error (MAE) between the forecasted and actual loads for each week & month has been calculated and presented in the Table VII & Table VIII respectively for the year 2012. From the results obtained from Table VIII, it is clear that maximum MAPE (2.35%) is for July, 2012 and minimum MAPE (1.43%) is for February, 2012. It has been observed that load forecasting of 1-7 July has maximum error with MAPE of 3.85%. From the results obtained in Table I-VIII, it is observed that MAPE in load forecasting for Ontario Electricity Market with temperature data is much better than MAPE without considering it. This is due to the fact that temperature and weather data are having high degree of correlation with load of that particular region. This indicates that temperature data is a very important parameter for load forecasting using ANN.

TABLE VII

RESULTS FOR OUT-OF-SAMPLE TEST FOR YEAR 2012 BY IMPROVED ANN

S. N.	Duration (Year 2012) mm/dd/yy -	Ontario Electricity Market	
		MAPE (%)	MAE(MW)
1	01/01/12-01/07/12	2.92	169.5
2	01/08/12-01/14/12	1.37	83.8
3	01/15/12-01/21/12	1.3	80.73
4	01/22/12-01/28/12	1.16	70.68
5	01/29/12-02/04/12	1.34	81.22
6	02/05/12-02/11/12	1.32	80.52
7	02/12/12-02/18/12	1.07 (min.)	64.62
8	02/19/12-02/25/12	1.87	111.1
9	02/26/12-03/03/12	1.79	107.55
10	03/04/12-03/10/12	1.68	99.33
11	03/11/12-03/17/12	2.07	111.78
12	03/18/12-03/24/12	1.59	88.7
13	03/25/12-03/31/12	1.92	109.57

14	04/01/12-04/07/12	1.6	84.11
15	04/08/12-04/14/12	1.45	77.44
16	04/15/12-04/21/12	1.46	81.3
17	04/22/12-04/28/12	1.34	76.27
18	04/29/12-05/05/12	1.19	65.29
19	05/06/12-05/12/12	1.09	57.08
20	05/13/12-05/19/12	1.23	65.93
21	05/20/12-05/26/12	2.26	125.1
22	05/27/12-06/02/12	2.1	135.3
23	06/03/12-06/09/12	1.51	83.85
24	06/10/12-06/16/12	1.83	115.04
25	06/17/12-06/23/12	1.97	138.06
26	06/24/12-06/30/12	1.73	111.4
27	07/01/12-07/07/12	3.85 (max.)	252.43
28	07/08/12-07/14/12	1.89	130.96
29	07/15/12-07/21/12	1.89	132.6
30	07/22/12-07/28/12	2.22	156.99
31	07/29/12-08/04/12	1.89	132.71
32	08/05/12-08/11/12	3.41	202.7
33	08/12/12-08/18/12	1.44	85.52
34	08/19/12-08/25/12	1.47	93.12
35	08/26/12-09/01/12	1.74	112.72
36	09/02/12-09/08/12	2.6	156.89
37	09/09/12-09/15/12	1.74	103.58
38	09/16/12-09/22/12	1.64	89.74
39	09/23/12-09/29/12	1.27	68.13
40	09/30/12-10/06/12	1.38	76.67
41	10/07/12-10/13/12	2.49	129.27
42	10/14/12-10/20/12	1.59	86.96
43	10/21/12-10/27/12	1.61	89.42
44	10/28/12-11/03/12	3.12	176.45
45	11/04/12-11/10/12	1.42	82.18
46	11/11/12-11/17/12	1.76	98.59
47	11/18/12-11/24/12	1.93	110.94
48	11/25/12-12/01/12	1.23	76.55
49	12/02/12-12/08/12	1.66	97.77
50	12/09/12-12/15/12	1.7	104.64
51	12/16/12-12/22/12	1.81	107.46
52	12/23/12-12/29/12	3.03	162.55
53	Average	1.80	113.90

TABLE VIII

RESULTS FOR OUT-OF-SAMPLE MONTHLY TEST IN YEAR 2012 BY IMPROVED ANN

S.N.	Month	Ontario Electricity Market	
		MAPE (%)	MAE(MW)
1	January	1.65	98.95
2	February	1.43 (min.)	86.39
3	March	1.87	105.22
4	April	1.44	78.6
5	May	1.63	93.67
6	June	1.76	110.87
7	July	2.35 (max.)	161.91
8	August	2.02	125.9
9	September	1.8	104.19
10	October	2.15	118.2
11	November	1.57	90.64
12	December	2.13	122

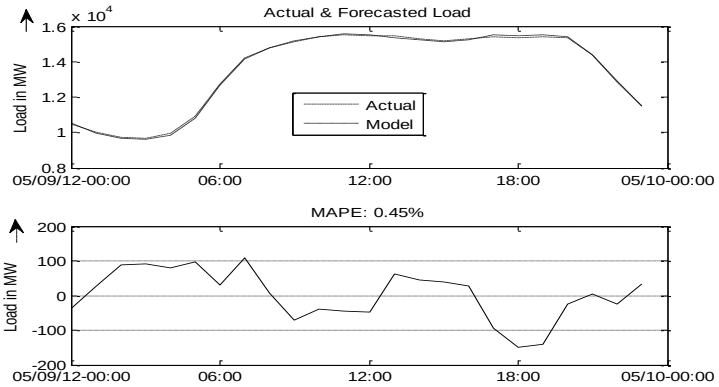

Fig. 13. MAPE is least (0.45%) for day ahead hourly forecast on 09 May, 2012 for ISO New England market in year 2012.

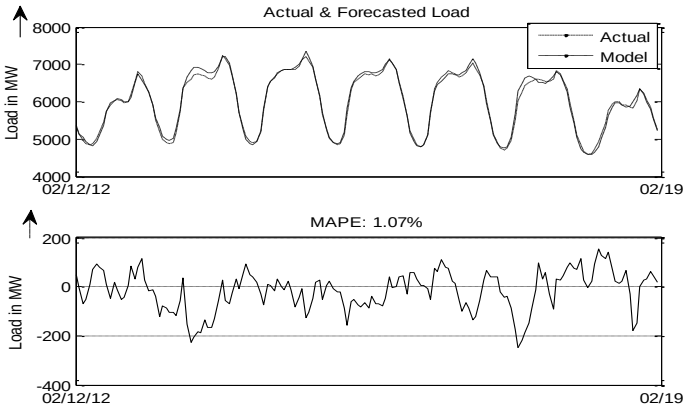

Fig. 14. MAPE is minimum (1.07%) for the load forecast of 12-18 February, 2012 for day ahead hourly weekly forecast.

5. CONCLUSION AND FUTURE WORK

This paper presents an ANN & improved ANN model for day-ahead short-term electricity loads forecasting in ISO New England market and Ontario market. Its forecasting reliabilities were evaluated by computing the MAPE & MAE between the exact and predicted electricity load values. We were able to obtain an MAPE 1.80% for Ontario market and

MAPE 1.50% for ISO New England market in the year 2012 by using improved ANN. The results suggest that improved ANN model with the developed structure can perform well in day ahead load forecasting with least possible error. It has been observed that temperature plays an important role in electricity load forecasting. In future effect of other weather parameters like humidity, precipitation, and wind velocity on short-term load forecasting may be worked out.

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