Int.J.HIT.TRANSC:ECCN.Vol.3: Issue 1A (2017) Page 48-57 ISSN: 0973-6875

Available Online at www.hithaldia.in/locate/ECCN

ORIGINAL CONTRIBUTION

A Forecasting Model for Relationship between Electricity Consumption and Ambient Temperature: A Case Study in Kolkata

Nimai Sundar Manna[1,*] and Binoy Krishna Choudhury[2]

[1] *SRF, CUCSE-CEFM and Ph.D. Scholar at Dept. of Business Management, University of Calcutta, West Bengal, India*
[2] *MBA Public Systems Management Department, IISWBM, India, E-mail: bkchoudhury@iiswbm.edu*

(Received Date: 10th November, 2016; Revised Date: 20th January, 2017; Acceptance Date: 10th February, 2017)

ABSTRACT

A forecasting model has been developed which identifies a weather-sensitive load component. Regression analysis of past load and weather data is used to identify the normal load model. A load forecasting system is presented here that includes weather sensitive features. The model intends to take into consideration of special event, random load component and holiday effect beside normal & weather load component. This paper estimates the temperature sensitivity of electricity consumption by investigating the impact of ambient temperature on the consumption of electricity in Kolkata using hourly data during the four years period between 01.04.2011 to 31.03.2015. A Panel Smooth Transition Regression model has been adopted to investigate the time varying impact of the temperature on the consumption of electricity in Kolkata. Results indicate that electricity demand is a function of temperature and temperature-electricity curve is becoming more pronounced over time indicating increasing cooling demand per unit increase in summer temperature. Therefore, this model helps electricity producer to plan for uninterrupted supply of electricity to the consumers.

KEYWORDS— electricity demand, ambient temperature, cooling load, weather-sensitive load, Panel Smooth Transition Regression models, forecasting of electrical demand

1. INTRODUCTION

Due to urbanization and elevation of the standard of living of the people has set an increasing trend in air-conditioning demand. As per estimate about 10386 GWh of electricity per year would be required to meet the air-condition and cooling load of the country as it is projected to increase by 40% in urban India and 21% in rural India by the year 2017 as compared to 2012. As the energy used in space cooling is double in past 5 years in India and due to hot & humid weather condition in Kolkata number of Air-Conditioning systems per family is rocketing high. So electricity supply companies (such as CESC) require system for forecasting electricity demand due to cooling load. Entropy of a system is always non-negative and the entropy of the world is increasing as we see the average increase in global temperature which results in global warming. On this context the increase in the Earth's mean temperature stimulates various possible impacts of such changes on different economic sectors. As major geographical portion of India is having a tropical weather condition and our focus of study Kolkata is one of the most populated city in India where yearly temperature varies from 11^0 c to 42^0 c and the monthly average Cooling Degree Days (CDD) is more than 260 therefore here is a growing demand of cooling need. To fulfill this HVAC need people consume more power i.e., electricity and as such this study focus on how temperature as part of weather condition affect the demand for electricity at Kolkata. During summer and wet rainy seasons temperature and humidity are very high and uncomfortable for people and as such cooling degree days increases so demand for electricity increases. We explore the effect of climate variable on energy demand by analyzing the direct impact of temperature on the electricity consumption in Kolkata. This choice

*Corresponding author: nsmanna@gmail.com

is motivated by the important share of energy to HVAC purpose and as per BEE (Bureau of Energy Efficiency) about 45% of peak load is shared by the Air-Conditioning load. Therefore temperature is a major determinant of electricity consumption. Global warming has already made the world 0.6^0 c warmer. Investigating the relationship between electricity consumption and temperature is important to assess the impact of climate change on energy demand. This study is complicated by the non-linear pattern of the relationship between electricity consumption and temperature. An increase in temperature leads to a higher use of air-conditioners and other cooling devices. Taking this into account the non-linearity requires a specific treatment in statistical analysis for establishing the relationship.

In analyzing the effect of temperature on electricity demand we extend the method used by Moral-Carcedo and Vicens-Otero (2005) a logistic smooth threshold regression model (LSTR) with temperature as threshold variable.

2. LITERATURE REVIEW

Angel Pardoa, Vicente Meneua, Enric Valorb(2002) in their paper 'Temperature and seasonality influences on Spanish electricity load' they found the influence of weather and seasonality was proved, and was significant even when the autoregressive effects and the dynamic specification of the temperature were taken into account. The estimated general model showed a high predictive power.

Marie Bessec and Julien Fouquau (2007) investigated the threshold panel approach to the non-linear link between electricity and temperature in European Union on 15 EU countries.

Moral- Carcedo and Vicens-Otero(2005) worked on effect of temperature on electricity demand in Spain using logistic smooth threshold regression model (LSTR).

O. Hyde and P.F. Hodnett (1997) worked on 'An Adaptable Automated Procedure for Short Term Electricity Load Forecasting' where they indicated four component of electricity demand –Basic load, Weather load, Normal load, Specific event based load.

Eshita Gupta 2011, in her working paper "Climate Change and the Demand for Electricity: A Non-Linear Time Varying Approach" studied the Electricity demand in Delhi as a U-shaped function of temperature.

Data and Methodology:

The data on daily electricity consumption at Kolkata has been collected at 15 minutes interval and the corresponding ambient temperature of Kolkata has been collected from the Regional Meteorological Centre, Kolkata of the India Meteorological Department for the period from 01.04.2011 to 31.03.2015. To study the impact of Temperature on the consumption of electricity we take care of the daytime and nighttime as well as weekdays and holidays effect. We assume that power consumptions due to lighting and ventilation remain the same devoid of temperature as HVAC effect is due to temperature and humidity.

The logistic smooth regression model allows the relationship between consumption and temperature to depend on the level of the threshold variable i.e., temperature. This approach has various advantages. Like it allows smooth transition from cold regime to the warm regime which is very relevant because there is a neutral zone for mild temperature where the demand is inelastic to the temperature. Moreover the impact of temperature can be assessed easily as the variable is treated as an explanatory variable in the model.

Here we use the statistical software package 'R' to analyze the various regression models like exponential smoothing and winter's model to investigate the relationship between Electricity consumption and Ambient Temperature of Kolkata, West Bengal, India.

Table 1: Empirical results and discussion

Week_avg_temp	Fri_day	Sat_day	Sun_day	Mon_day	Tue_day	Wed_day	Thur_day
25.5	956.3139	956.8462	986.951	913.7047	821.0583	843.4051	927.3362
25.38571	888.0862	886.0268	897.3639	843.9475	767.4695	785.5099	863.1151
25.27143	843.0927	847.2416	852.1404	799.4538	736.5298	751.3086	819.7936
25.05714	827.5667	836.3044	831.6356	785.8873	721.5462	724.8978	799.0139
24.9	807.5418	820.0911	817.0618	785.1974	713.2133	724.6729	788.5741
24.6	781.3234	792.1207	785.3399	763.1581	702.636	693.0334	757.8994
24.64286	803.2578	837.4666	794.5551	796.2721	767.8994	747.1172	800.4436
25.32857	882.4002	928.2985	831.2882	869.5335	859.5785	830.041	887.7638
27.24286	992.0423	1008.678	848.6888	969.8254	929.1483	930.0006	992.0248
28.82857	1119.205	1120.517	865.3595	1119.547	1049.273	1065.721	1136.715
30.48571	1260.401	1244.908	897.8462	1268.617	1183.106	1210.089	1264.373
31.84286	1346.245	1303.658	942.7723	1366.534	1270.121	1297.264	1347.254
32.48571	1357.034	1313.28	967.8634	1387.162	1290.731	1314.838	1374.09
32.7	1315.95	1250.524	960.3503	1342.668	1229.629	1272.023	1337.077
33.01429	1343.895	1226.897	975.7839	1367.309	1243.428	1290.804	1364.01
32.52857	1367.412	1201.396	978.0308	1395.107	1274.333	1318.542	1393.705
31.67143	1366.837	1167.827	972.0623	1400.758	1286.52	1310.356	1404.217
30.35714	1364.047	1156.398	1009.785	1436.464	1338.407	1341.131	1400.898
28.58571	1451.44	1282.003	1188.247	1515.149	1456.874	1468.671	1452.09
27.75714	1427.901	1264.678	1196.45	1326.057	1400.733	1403.38	1420.073
27.08571	1338.037	1233.238	1180.039	1210.072	1271.928	1319.049	1353.078
26.71429	1255.69	1178.767	1170.169	1132.429	1184.591	1244.568	1278.002
26.41429	1176.568	1101.469	1138.42	1044.256	1095.913	1143.661	1185.365
25.72857	1090.75	1046.688	1048.068	935.8341	966.0439	1032.257	1087.795

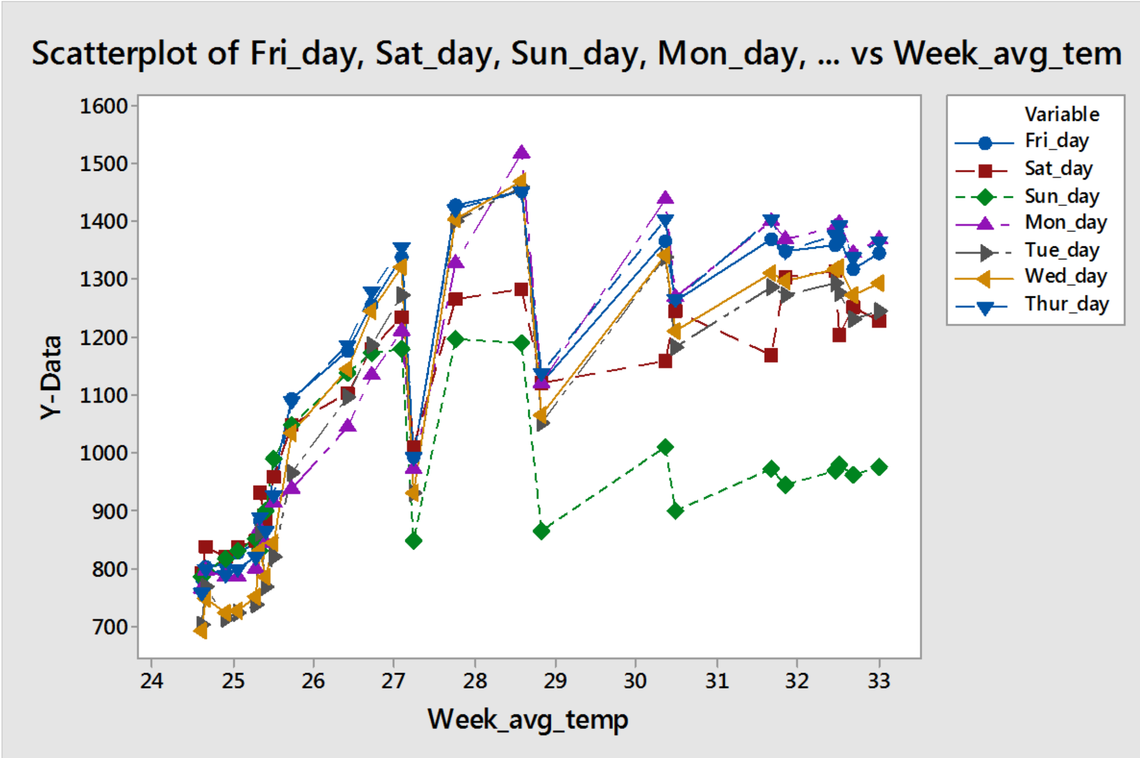


Figure 1: Scatter plot of days of week vs. weekly average temperature

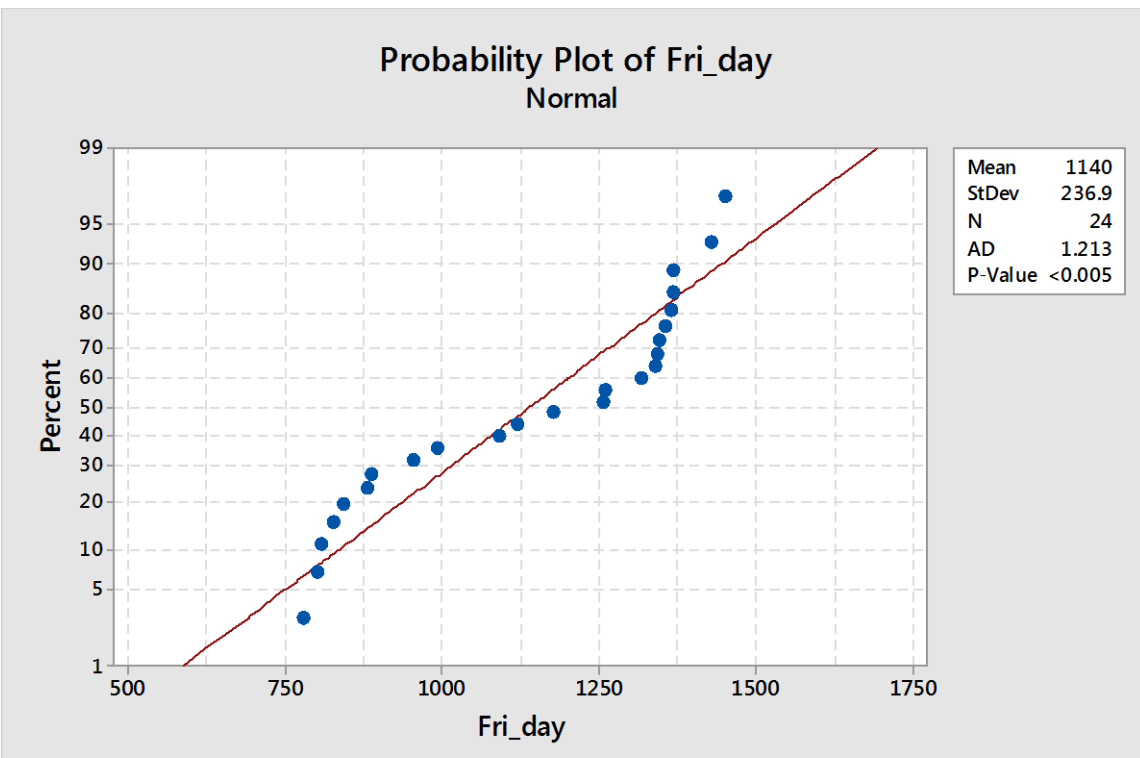


Figure 2: Probability Plot of Friday

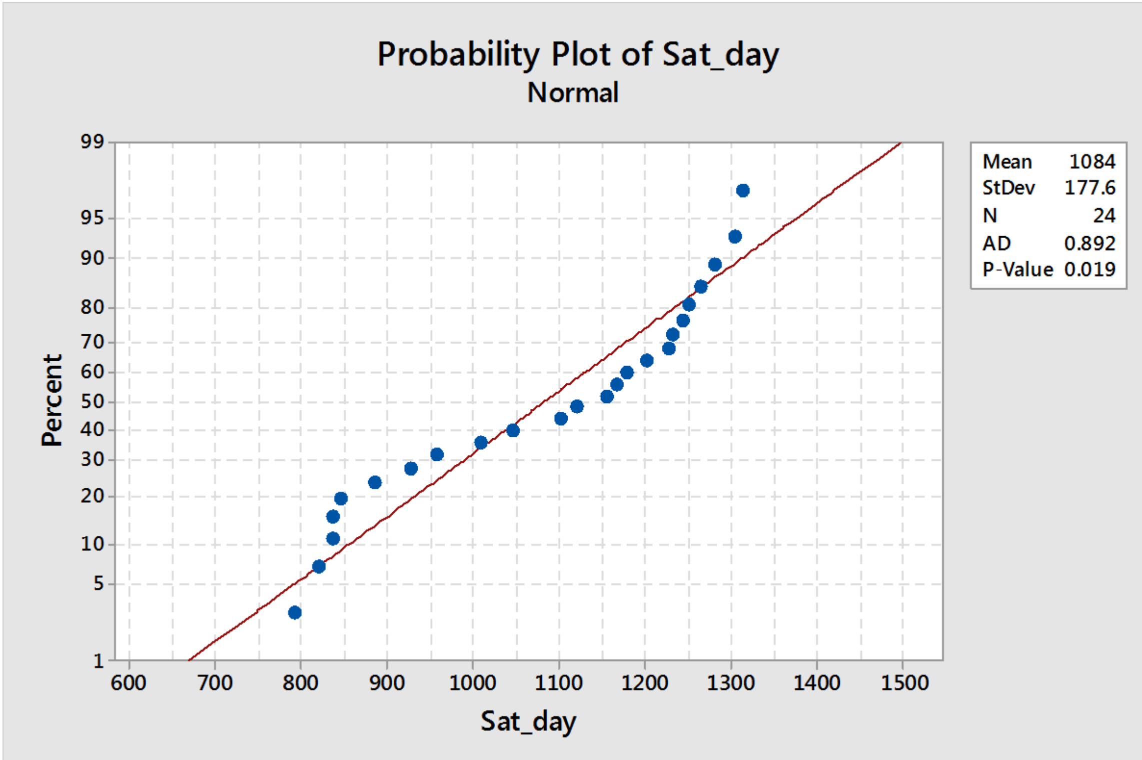


Figure 3: Probability Plot of Saturday

Regression Analysis: Electricity Consumption versus Temp

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	1	17995562	17995562	648.25	0.000
Temp	1	17995562	17995562	648.25	0.000
Error	718	19931832	27760		
Lack-of-Fit	127	6161458	48515	2.08	0.000
Pure Error	591	13770374	23300		
Total	719	37927394			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
166.614	47.45%	47.37%	47.16%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-241.1	54.3	-4.44	0.000	
Temp	47.14	1.85	25.46	0.000	1.00

Regression Equation

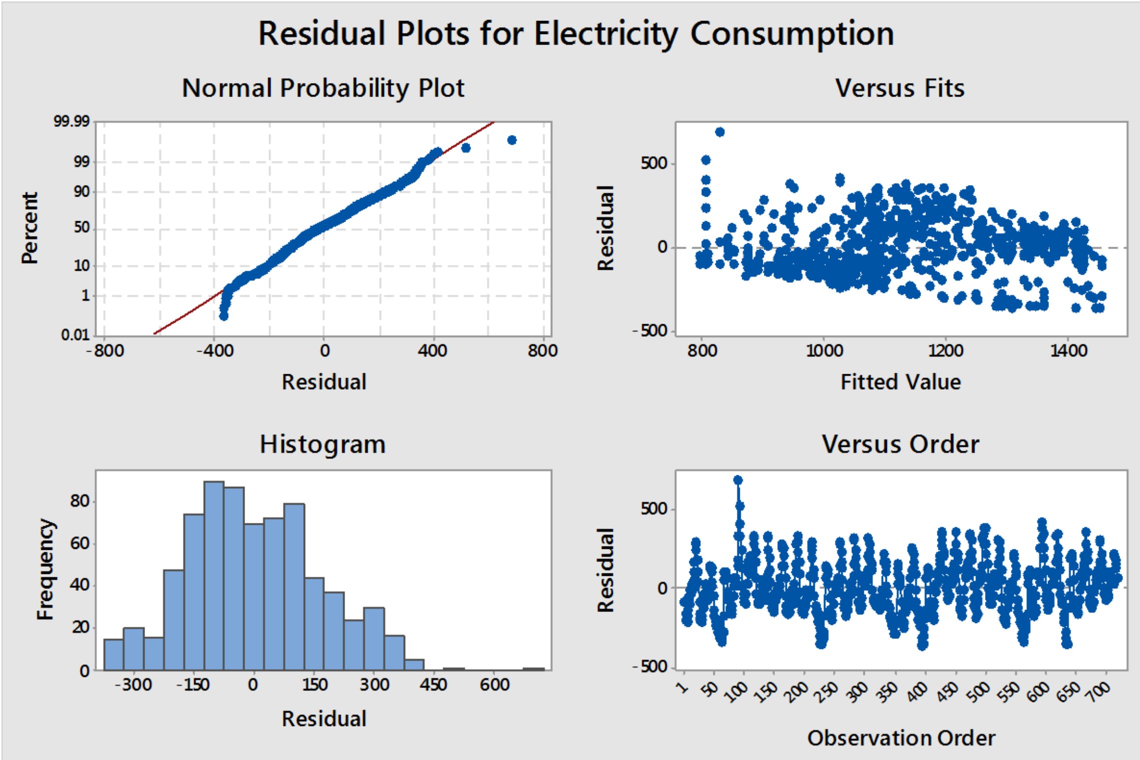
Electricity Consumption = -241.1 + 47.14 Temp

Fits and Diagnostics for Unusual Observations

Electricity Consumption

Sl.No.	Obs	Consumption	Fit	Resid	Std Resid	
1	62	960.4	1300.3	-339.9	-2.04	R
2	63	975.8	1319.1	-343.3	-2.06	R
3	91	1515.1	828.9	686.2	4.13	R
4	92	1326.1	805.3	520.7	3.14	R
5	93	1210.1	805.3	404.7	2.44	R
6	139	1468.7	1135.3	333.4	2.00	R
7	188	1447.0	1111.7	335.3	2.01	R
8	227	939.0	1290.8	-351.9	-2.11	R
9	228	980.1	1338.0	-357.8	-2.15	R
10	229	1006.7	1361.6	-354.9	-2.13	R
11	230	987.7	1338.0	-350.3	-2.11	R
12	395	994.3	1347.4	-353.2	-2.12	R
13	396	1050.6	1413.4	-362.8	-2.18	R
14	397	1084.9	1451.1	-366.2	-2.21	R
15	398	1084.9	1446.4	-361.5	-2.18	R
16	427	1581.7	1239.0	342.7	2.06	R
17	428	1530.4	1173.0	357.4	2.15	R
18	451	1554.8	1196.6	358.2	2.15	R
19	452	1516.8	1158.9	357.9	2.15	R
20	475	1500.6	1154.1	346.5	2.08	R
21	476	1451.7	1116.4	335.2	2.01	R
22	499	1515.0	1135.3	379.7	2.28	R
23	500	1474.7	1135.3	339.4	2.04	R
24	501	1321.5	942.0	379.5	2.28	R
25	564	1015.9	1361.6	-345.6	-2.08	R
26	595	1442.1	1026.9	415.3	2.49	R
27	596	1412.9	1026.9	386.1	2.32	R
28	597	1299.5	951.5	348.0	2.09	R
29	620	1422.7	1083.4	339.3	2.04	R
30	636	927.2	1281.4	-354.3	-2.13	R
31	637	948.9	1309.7	-360.8	-2.17	R
32	638	935.3	1286.1	-350.8	-2.11	R
33	667	1470.4	1116.4	354.0	2.13	R
34	668	1441.7	1088.2	353.5	2.12	R

R Large residual



Single Exponential Smoothing for Electricity Consumption

Data Electricity Consumption

Length 720

Smoothing Constant

α 1.64405

Accuracy Measures

MAPE 3.78; MAD 42.73; MSD 2866.01;

Forecasts

Period	Forecast	Lower	Upper
721	1166.48	1061.79	1271.16
722	1166.48	1061.79	1271.16
723	1166.48	1061.79	1271.16
724	1166.48	1061.79	1271.16

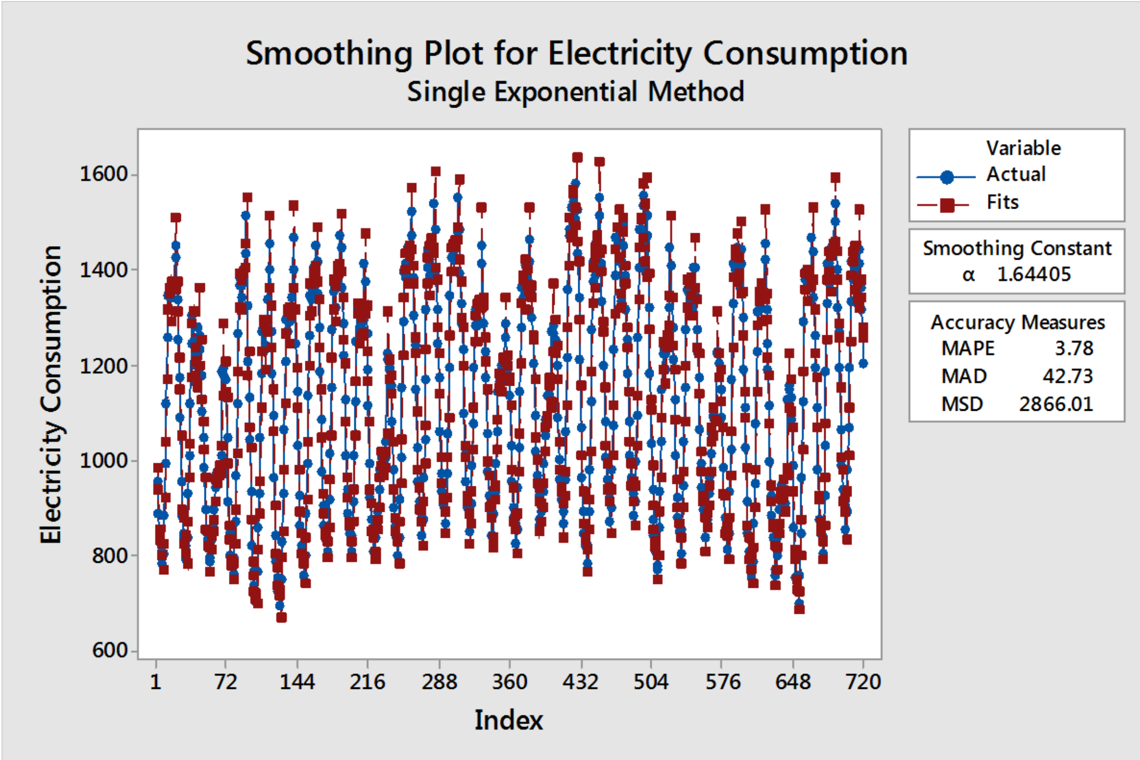


Figure 4: Smoothing Plot for Electricity Consumption (through Single Exponential Method)

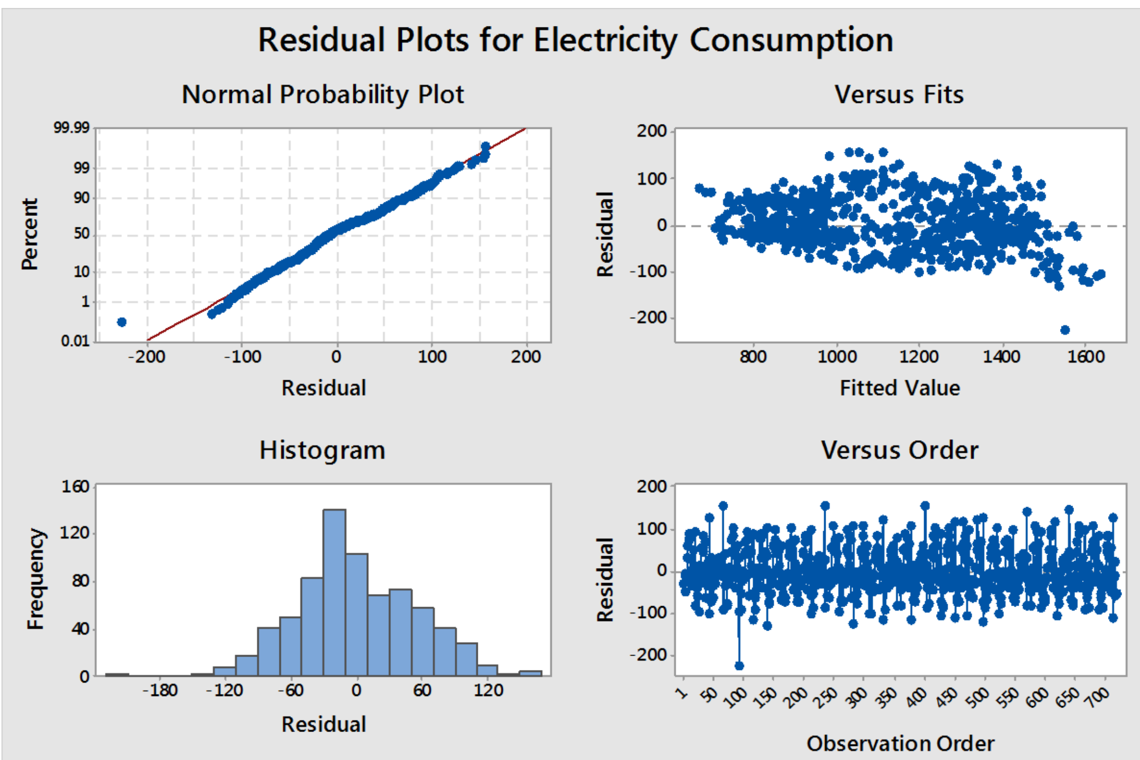


Figure 5: Residual Plots for Electricity Consumption

Winters' Method for Electricity Consumption

Multiplicative Method

Data Electricity Consumption

Length 720

Smoothing Constants

α (level) 0.2; γ (trend) 0.2 ; δ (seasonal) 0.2 ;

Accuracy Measures

MAPE 5.81; MAD 64.79; MSD 6956.58;

Forecasts

Period	Forecast	Lower	Upper
721	1051.05	892.320	1209.77
722	982.42	821.205	1143.63
723	937.44	773.455	1101.43
724	921.75	754.724	1088.79

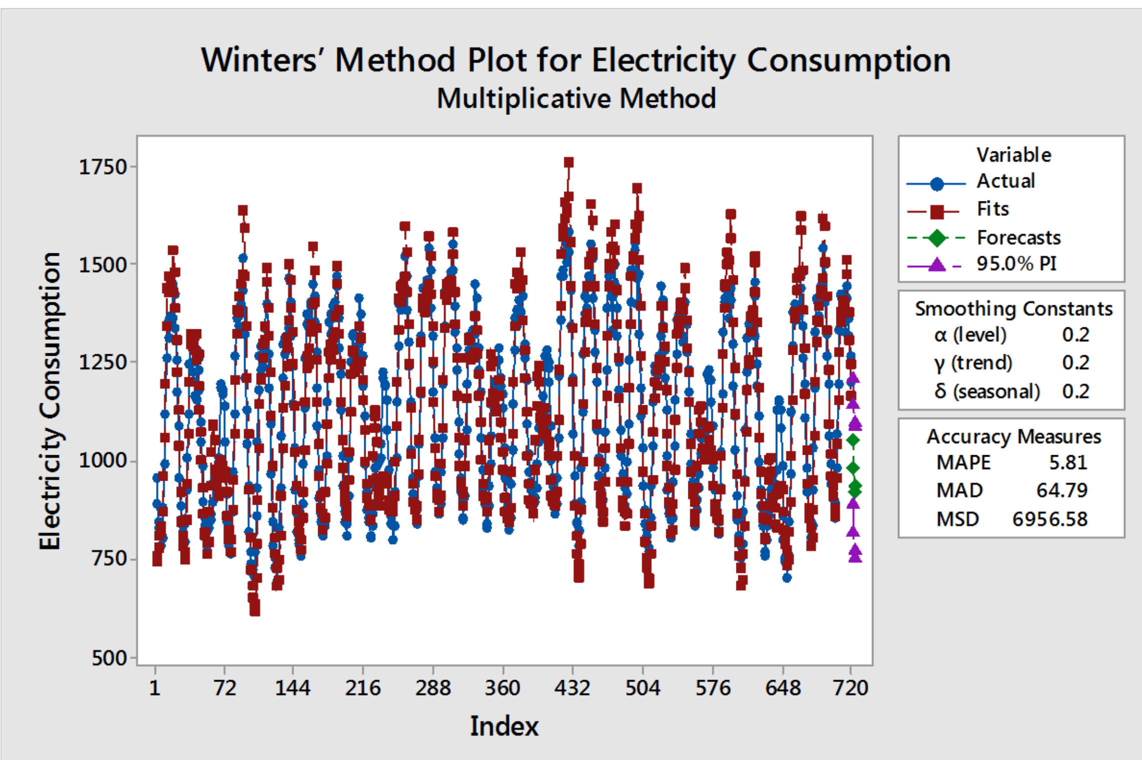


Figure 6: Winter's Method Plot for Electricity Consumption (through Multiplicative Method)

3. SUMMARY AND CONCLUSION

In this paper, we have investigated the relationship between electricity consumption and temperature in Kolkata, India. It is evident from the result that the non-linear pattern of this relationship exists in all the days of the week in Kolkata and the hourly variation of electricity demand with respect to the ambient temperature clearly indicates the implicit relationship between the two parameters.

This paper shows that temperature is a major determining factor of electricity consumption in cities like Kolkata and the relationship between the two variables is modified by the climate change as over the years the demand for electricity increases with the increase of the mean average temperature which is also evident from the study of the last 100 years climatology data of Indian cities. In line with the concern about global warming, these findings suggest that as the peak load demand is directly proportional to the maximum temperature of the daytime therefore plenty resources of solar energy can be harvested to meet the energy demand thereby to reduce the pressure on grid and to meet energy security of the nation. So this research supports the interests in energy related issues like, renewable energy, building integrated photo-voltaic (BIPV), solar air-conditioning systems, renewable energy policy and framework implementation at the state level etc.

References

[1] Angel Pardoa, Vicente Meneua, Enric Valorb 2002, “Temperature and seasonality influences on Spanish electricity load” Energy Economics 24(2002) 55_70

[2] Bessec, M. and J. Fouquau. 2007. "The Non-Linear Link between Electricity Consumption and Temperature in Europe: A Threshold Panel Approach." Energy Economics, 30(5), 2705-21.

[3] Eshita Gupta 2011, “Climate Change and the Demand for Electricity: A Non-Linear Time Varying Approach” Working Paper, Indian statistical Institute Delhi

[4] L S Rathore, S D Attri And A K Jaswal ‘State Level Climate Change Trends In India’ India Meteorological Department, Ministry Of Earth Sciences, Government Of India, 2013

[5] Moral-Carcedo, J. and J. Vicens-Otero. 2005. "Modelling the Non-Linear Response of Spanish Electricity Demand to Temperature Variations." Energy Economics, 27(3), 477-94.

[6] O. Hyde and P.F. Hodnett (1997) “An Adaptable Automated Procedure for Short-Term Electricity Load Forecasting”

[7] Monthly mean maximum & minimum temperature and total rainfall based upon 1901-2000 data: National Data Centre: ndc@imdpune.gov.in

Data source: for Electricity data of Kolkata, *CESC Ltd, Kolkata W.B., India, E-mail: rajib.das@rp-sg.in;*
Weather data are collected from IMD, Regional Meteorological Centre Kolkata.

Acknowledgement: Mr. Rajib Das, DGM (Planning) -*CESC Ltd, Kolkata*