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A Parameter based New Approach for Short Term Load Forecasting using Curve-fitting and Regression line method

M. Babita Jain is Professor and Dean at Rungta Engineering College, Raipur, CG, India

Manoj Kumar Nigam, Reader in Electrical Engineering Department at RITEE Raipur (C.G.), India

Prem Chand Tiwari, is M.E. Student at RITEE Raipur (C.G.) India,
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Abstract—**Short term load forecasting in this paper is done by considering the sensibility of the network load to the temperature, humidity, day type parameters (THD) and previous load and also ensuring that forecasting the load with these parameters can best be done by the regression line and curve fitting methods .The analysis of the load data recognize that the load pattern is not only dependent on temperature but also dependent on humidity and day type. A new norm has been developed using the regression line concept with inclusion of special constants which hold the effect of the history data and THD parameters on the load forecast and it is used for the STLF of the test dataset of the used data set. A unique norm with a, b, c and d constants based on the history data has been proposed for the STLF using the concept of curve fitting technique. The algorithms implementing this forecasting technique have been programmed using MATLAB. The input data of each day average power, average temperature , average humidity and day type are used for prediction of power, in the case of the regression line method and the forecast previous month data and the similar month data of the previous year is used for the curve fitting method. The simulation results show the robustness and suitability of the proposed norm for the STLF as the forecasting accuracies are very good and less than 3% for almost all the day types and all the seasons. Results also indicate the curve fitting method out passes the regression technique w.r.t forecasting accuracy and hence it the best suitable method for accurate short term loads forecasting.**

Index Terms-- Short term load forecasting, THD (tempreture, humidity, day type), curve fitting, regression line.

I. INTRODUCTION

Load forecasting is an important component for power system energy management system. Precise load forecasting helps the electric utility to make unit commitment decisions, reduce spinning reserve capacity and schedule device maintenance plan properly. Besides playing a key role in reducing the generation cost, it is also essential to the reliability of power systems. The system operators use the load forecasting result as a basis of off-line network analysis to determine if the system might be vulnerable. If so, corrective actions should be prepared, such as load shedding, power purchases and bringing peaking units on line.

With the recent trend of deregulation of electricity markets, STLF has gained more importance and greater challenges. In the market environment, precise forecasting is the basis of electrical energy trade and spot price establishment for the system to gain the minimum electricity purchasing cost. In the real-time dispatch operation, forecasting error causes more purchasing electricity cost or breaking-contract penalty cost to keep the electricity supply and consumption balance. There are also some modifications of STLF models due to this implementation of the electricity market. Weather is defined as the atmospheric condition existing over a short period in a particular location. It is often difficult to predict and it can vary significantly even over a short period. Climate also varies with time: seasonally, annually and on a decade's basis [1]. The relationship between demand and temperature is non linear with the demand increasing for both low and high temperature [2]. The range of the possible approaches to the forecast is to take a microscopic view of the problem and try to model the future load as a reflection of previous [3]. In the case of large variation in the temperature compared to that of the previous year, the load also changes accordingly. In such cases there would be the shortage of similar days' data and the task of the forecasting load is very difficult [4].

II. DATA ANALYSIS

A. Load Curves

For the analysis and implementation of load forecasting, data is taken from EUNITE network that was provided to participants for a competition many years ago (see acknowledgement). In the data analysis part we are going to analyze load variation with respect to day type, weather condition such as seasonal variation of load with temperature and humidity. Analyzing the monthly and yearly load curves given in Fig.1 and Fig.2 and also load variation with respect to temperature and humidity given in Fig.3 and Fig.4 the following observations are made:

- The load curve patters of two consecutive years is similar
- The load curves of similar months of two consecutive years is also similar
- The load curves are having different pattern in weekdays and weekend days in the month.
- The load curves on the weekends are similar.
- Taking in consideration the above observations the days of the week are classified based on the following categories:

a. Normal week days (Tuesday - Friday)

b. Monday

c. Sunday

d. Saturday

Monday is accounted to be different to weekdays so as to take care for the difference in the load because of the previous day to be weekend.

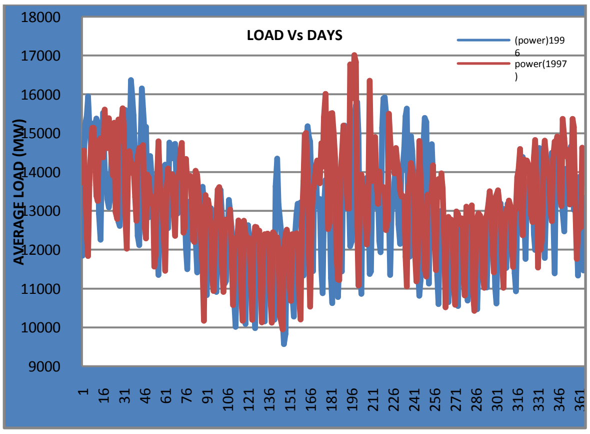

Fig.1 Yearly Load variation of 1996 and 1997

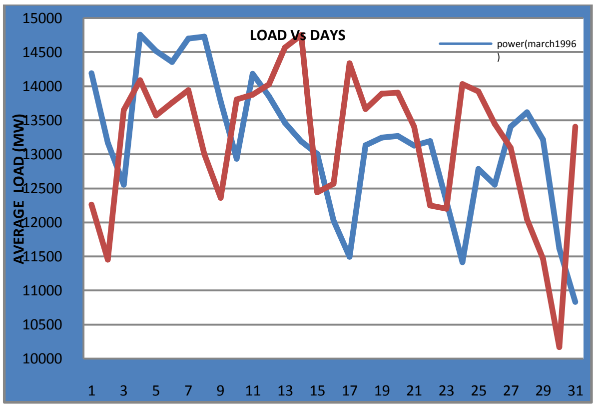

Fig. 2 Monthly Load variation of Mar'96 and Mar'97

B. Variation of Load with Temperature

The variation of the temperature variable results in a significant variation in the load. Fig 3 shows a plot between the maximum temperatures versus average demand. In Fig. 3 the dots represent the actual values and the solid line is the best fitted curve. The graph shows a positive correlation between the load and temperature i.e. demand increases as the temperature increases.

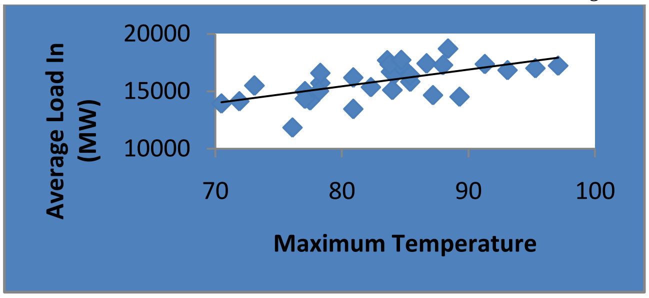

Fig.3 Monthly Load variation with Temperature

C. Variation of Load with Humidity

Fig 4 shows the plot between the average humidity versus average demand. From the graph it can be seen that there exists a positive correlation between load and humidity i.e. demand increases as the humidity increases.

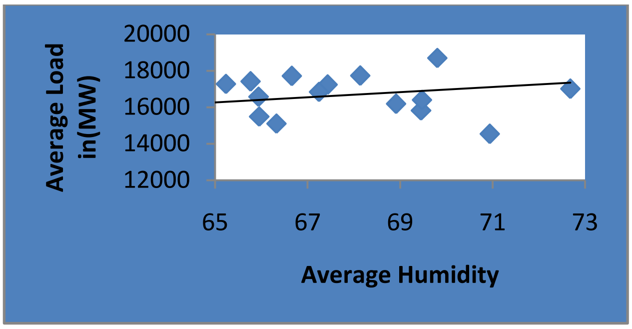

Fig.4 Monthly Load variation with Humidity

D. Autocorrelation of Load

It is seen from the plots that the load pattern of the present year is similar to the load pattern of previous year and also the load curve of a given month is similar to the load curve of the previous years' same month. Hence it can be considered that the load of similar month of previous year can greatly help in load forecasting along with the THD parameters.

III. Short Term Load Forecasting using Regression Line

This section deals with the details of the concept and implementation of regression line method and its implementation to STLF. The relation between load and the THD parameters is defined as they have direct impact on the load as seen in the earlier section. Regression is the study of the relationship among variables, a principle purpose of which is to predict, or estimate the value of the one variable from known or assumed values of other variables related to it .For electric load forecasting regression methods are usually used to model the relationship of load consumption and other factors such as weather and day type [4]-[10].

As it is clear from the data analysis that the load is totally dependent on the temperature, humidity and day type parameters, hence regression is used to obtain the relationship between load and these parameters. The method is basically divided into three parts as follows:

- Load variation with respect to temperature

- Load variation with respect to temperature and humidity
- Load variation with respect to temperature, humidity and day type.

Since it is clear from data analysis that all the three THD parameters affect the load forecast the regression line method is used to find the relation between load and all these three parameters.

Regression line (THD): The regression line equation for load forecast dependent on the temperature, humidity and day type parameters is given as follows:

$$P_{forecasted} = P_{avg} + \frac{(\mathrm{R}.\sigma_p.(T_f - T_{avg}).(H_f - H_{avg}).(D_f - D_{avg}))}{(\sigma_T.\sigma_H.\sigma_D)} \quad (1)$$

Where $P_{forecasted}$ = forecaste day power

P_{avg}= Previous year average power .

R = coefficient of co relation of load power with temperature and humidity of previous year .

T_{avg}, H_{avg}, D_{avg} = average temperature ,humidity and day type previous year.

σ_p, σ_T σ_H σ_D = standard deviation of power, temperature ,humidity and day type of previous year

- ALGORITHM:-

Step:-1.Calculation of previous year $P_{forecasted}$ T_{avg}, H_{avg}, and D_{avg}

Step:-2. calculation of coefficient of co relation R

$$R = (c_1 - c_2)/(c_3.c_4.c_5 c_6) \quad (2)$$

$$c_1 = \sum dPdTdHdD$$

$$c_2 = \frac{\sum dPdTdHdD}{N},$$

$$c_3 = \sqrt{(\sum dP^2 - ((\sum dP)^2/N))}$$

$$c_4 = \sqrt{(\sum dT^2 - ((\sum dT)^2/N))}$$

$$c_5 = \sqrt{(\sum dH^2 - ((\sum dH)^2/N))}$$

$$c_6 = \sqrt{(\sum dD^2 - ((\sum dD)^2/N))}$$

Where the value of $-1 \le R \le 1 - 1 \le R \le 1$

Step:-3. Taken the value of the forecast day temperature, humidity and day type.

Step:-4 writing the relation between load power and the parameters

$$P_{forecasted} = P_{avg} + \frac{(\mathrm{R}.\sigma_p.(T_f - T_{avg}).(H_f - H_{avg}).(D_f - D_{avg}))}{(\sigma_T.\sigma_H.\sigma_D)}$$

Step:-5.Calculating MAPE(mean absolute percentage error)of power.

$$MAPE = \sum_{i=1}^{N} \frac{|P_A^i - P_F^i|}{P_A^i} * 100$$

Step:-6. For next day load forecasting go step 1 to step 5.

Step:-7.Result analysis.

Step:-8. End

From the above algorithm we are easily calculating the load power. This method using the previous year load data including the temperature, humidity and the day type .It finding the variation of the load with respect to the parameters which is mention above.

IV. SHORT TERM LOAD FORECASTING USING CURVE FITTING

The methodology that is developed for the short term load forecasting of load using the curve fitting method would mainly focus on the variation of power with the three main parameters we have already mentioned i.e. Temperature, Humidity and the particular Day Type[11]-[14].

The first two parameters, quite evidently come under the weather changing phenomenon, but considering the time dependent variation of the load, the data that is available could not only be classified into a particular day type but it also follows a similar month pattern which implies that, for example, if we take the data of January of one particular year, there are steep chances that it is almost identical to the one we had in the same month of its previous year under a similar working environment. As from previous method similarly we are using the all three factors for the forecasting the power .It is explain in the algorithm.

- Algorithm (THD)

Step1.Write the equestions between power and its parameters using curvefitting .

$$P = a + b.T + c.H + d.D \quad (3)$$

$$\sum P = a.N + b.\sum T + c.\sum H + d.\sum D \quad (4)$$

$$\sum PT = a.\sum T + b.\sum T^2 + c.\sum HT + d.\sum DT \quad (5)$$

$$\sum PTH = a.\sum TH + b.\sum T^2 H + c.\sum H^2 T + d.\sum DTH \quad (6)$$

$$\sum PTHD = a.\sum THD + b.\sum T^2 HD + c.\sum H^2 TD + d.\sum D^2 TH \quad (7)$$

Step 2: Using privious year data of similar month calculate cofficent of a,b,c &d.

$$\begin{bmatrix} \sum P \\ \sum PT \\ \sum PTH \\ \sum PTHD \end{bmatrix} = \begin{bmatrix} N & \sum T & \sum H & \sum D \\ \sum T & \sum T^2 & \sum HT & \sum DT \\ \sum TH & \sum T^2 H & \sum H^2 T & \sum DTH \\ \sum THD & \sum T^2 HD & \sum H^2 TD & \sum D^2 TH \end{bmatrix} . \begin{bmatrix} a \\ b \\ c \\ d \end{bmatrix}$$

$$\begin{bmatrix} a \\ b \\ c \\ d \end{bmatrix} = \begin{bmatrix} N & \sum T & \sum H & \sum D \\ \sum T & \sum T^2 & \sum HT & \sum DT \\ \sum TH & \sum T^2 H & \sum H^2 T & \sum DTH \\ \sum THD & \sum T^2 HD & \sum H^2 TD & \sum D^2 TH \end{bmatrix}^{-1} \begin{bmatrix} \sum P \\ \sum PT \\ \sum PTH \\ \sum PTHD \end{bmatrix}$$

Asuming the cofficents

$$\begin{bmatrix} a \\ b \\ c \\ d \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{bmatrix}$$

Step 3: Cofficent subsitution in the equestion(3)

$P_{forecast} = a_1 + a_2.T_{forecast} + a_3.H_{forecast+}a_4D_{forecast}$

Step 4: Calculating the forecasting power of each day in present month

Step 5: Calculating MAPE(mean absulute percentage error)of power.

$$MAPE = \sum_{i=1}^{N} \frac{|P_A^i - P_F^i|}{P_A^i} * 100$$

Step 6: For next month forecasting of power repeat steps 2 to step 5.

Step 7: Result analysis

Step 8: End.

From the above algorithm the forecasting of the load power with respect to the parameters are easily calculated .this method is very simple and having less complex as compared to the regression line method .

V. SUMMARY OF THE METHODTHOLOGY

In this part we are discussing the summery of the methods which are used in this paper, regression line and the curve fitting are the same steps to follow and hence we draw the methodology in the same flow diagram.

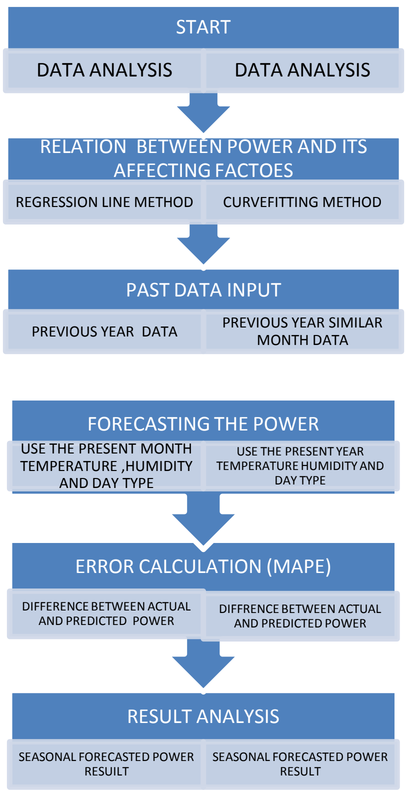

FIG. 5 SUMMARY OF MATHEDOLOGY.

VI. RESULT ANALYSIS

The result analysis of the simulation performed on the power variation with respect to its corresponding parameters clearly suggests the dependency of the load power on the main three factors that were considered in this paper, namely Temperature, Humidity and the Day Type. To understand this, we have tabulated the individual variation of power with temperature taken separately, power with temperature and humidity taken together and finally the power variation along with day type also. Based on the tabular data of the readings obtained, we also plotted the individual graphs each showing the variation of power with respect to its parameters separately and also when considered together. In this analysis part separate method results are tabular form shown and the graphical analysis is given below.

Table: I
Parameters of the regression line and curve fitting algorithms

PARAMETERS	VALUES
$P_{AVERAGE}$	13053.34
R	0.0014
$T_{AVERAGE}$	48.6190
$H_{AVERAGE}$	38.2240
$D_{AVERAGE}$	3.1448
σ_P	13608.54
σ_T	17.4668
σ_H	19.3137
σ_D	1.227
a	11279.72
b	3.71783
c	-29.0868
d	760.9079

Table: II
Comparative STLF of Saturday, Sunday, Monday and Tuesday Load

SN	**DATE**	**Actual** Load	**REGRESSION** Forecast Load	**CURVEFITTING** Forecast Load
1	1/11/97	11674.79167	12250.324	11720.18706
2	2/11/97	11021.91667	11561.25783	10929.62926
3	3/11/97	12754.66667	13080.58321	12495.5655
4	4/11/97	13030.375	13123.7481	13190.33612

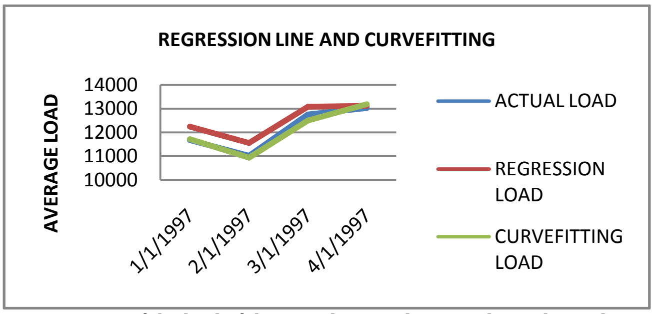

Fig.6 Curve of the load of the Saturday, Sunday, Monday and Tuesday Load

Table: III
Comparative STLF MAPE Saturday , Sunday , Monday and Tuesday Load

DATE	THD(MAPE)	
	REGRESSION LINE	CURVEFITTING
1/11/97	4.9297	0.388832548
2/11/97	4.893351854	0.837308176
3/11/97	2.555272922	2.031422499
4/11/97	0.716580306	1.227601821

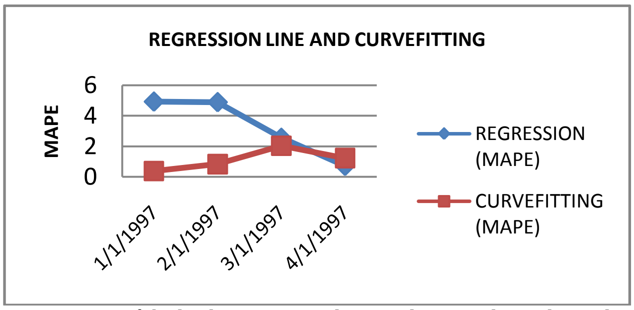

Fig. 7 MAPE of the load MAPE Saturday, Sunday, Monday and Tuesday Load

Table: IV
Comparative STLF of Sunday, Monday, Tuesday, Wednesday, Thursday, Friday and Saturday forecasted Load

DATE	ACTUAL LOAD	THD	
		REGRESSION LINE	CURVEFITTING
2/11/97	11021.91667	11561.25783	10929.62926
3/11/97	12754.66667	13080.58321	12495.5655
4/11/97	13030.375	13123.7481	13190.33612
5/11/97	13077.625	13134.87086	13355.7966
6/11/97	13264.5	13152.6676	13402.55266
7/11/97	13129.41667	13079.46963	13343.56988
8/11/97	12054.45833	13149.77202	12057.19216

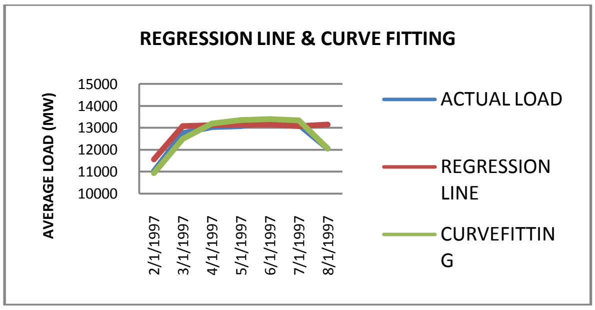

Fig. 8 curve of the load of Sunday, Monday, Tuesday, Wednesday, Thursday, Friday and Saturday forecasted Load

Table V
Comparative STLF MAPE Sunday, Monday, Tuesday, Wednesday, Thursday, Friday and Saturday forecasted Load

DATE	THD(MAPE)	
	REGRESSION LINE	CURVEFITTING
2/11/97	4.893351854	0.837308176
3/11/97	2.555272922	2.031422499
4/11/97	0.716580306	1.227601821
5/11/97	0.437738972	2.127080421
6/11/97	0.843095478	1.040767906
7/11/97	0.380420849	1.63109466
8/11/97	9.086378284	0.022678997

Table II,III,IV and V present the day wise load forecast for the selected days obtained by the two different methodology which are Regression line (THD)and the curve fitting (THD).

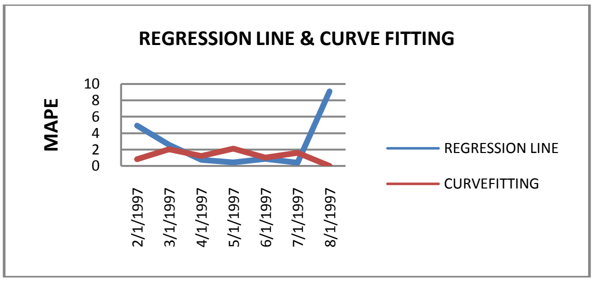

Fig. 9 Comparative MAPE of the entire week forecasted load

From the above analysis it is clear that both the regression line and the curve fitting methods are quite suitable for the short term load forecasting giving very good forecasting accuracies with MAPE's of most of the cases quite less than 3%. Results also indicate that the curve fitting method is better compared to the regression line method for short term load forecasting. The curve fitting method is simple and robust in comparison to the regression line method. The method yields very good results for days of all types and all around the year as the weekly result values clearly indicate.

VII. CONCLUSION

Accurate load forecasting is very important for electric utilities in a competitive environment created by the electric industry deregulation. In this paper, we have presented the regression line and curve fitting methods for short term load forecasting. The following are the conclusions derived from the proposed methods:

- In this paper, regression and curve fitting methods have strongly proved the impact of THD parameters in the STLF using the relation between input and output variable through the systematic rule. In the regression method input data is previous year's data and for the curve fitting method data input is previous year's similar month's data.
- The simulation results have shown that the both the proposed methodologies are quite good and completely suitable for STLF of all types of the days and for all

months round the year giving the MAPE for most of the cases quite less than 3%.

- Results also indicate that the curve fitting method has an edge over the regression line method. The efficiency of the curve fitting method is due to the consideration of the previous years' similar month as the training data set for the calculation of the constants. The data analysis part of Section II indicates the strong impact of the previous year similar month load on the present month. This impact of previous year similar month goes very well with the curve fitting method.

VIII. ACKNOWLEDGMENT

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IX. REFERENCES

1. Weather Gross,G,galiana ,F.D.,"Short term load forecasting "proceding of IEEE,December 1987
2. O.A. Alsayegh, "Short-Term Load Forecasting Using Seasonal ArtificialNeural Networks",*International Journal of Power and Energy Systems*, vol. 23,2003.
3. M. O. Oliveira and D. P. Marzec "Climate Change Effect on Very Short-Term Electric Load Forecasting"IEEE ,2011.
4. Ibrahim Moghram, SaifureRahman, "Analysis Evaluation of Five Short Term Load Forecasting Techniques", *IEEETransactions on Power Systems*, vol. 4, 1989.
5. K.Lru, S.Subbarayan, R.R.Shoults, M.T.Manry, C.Kwan, F.L.lewis and J.Naccarino, "Comparison of very short term load forecasting techniques",*IEEETransactions on Power Systems*, vol. 11, 1996
6. K.Lru, S.Subbarayan, R.R.Shoults, M.T.Manry, C.Kwan, F.L.lewis and J.Naccarino, "Comparison of very short term load forecasting techniques",*IEEETransactions on Power Systems*, vol. 11, 1996.
7. Eugene A. Feinberg and Dora Genethliou,"Applied Mathematics for Power Systems: Load Forecasting"..
8. T. Senjyu, Mandal. P, Uezato. K, Funabashi. T, "Next Day Load Curve Forecasting using Hybrid Correction Method," *IEEETransactions on Power Systems*, vol. 20, pp. 102-109, 2005.
9. S.M.Moghaddas-Tafreshi and Mahdi Farhadi "A linear Regression –based study for Temperature sensitivity analysics of the Iran Electriccity load",IEEE,2008.
10. Mrs. J.P.Rothe and Dr.A.K.wadhani"Short term Load forecasting using Multi parameter regression",IJCSIS ,2009.
11. M.A.Farahat and M.Talaat ,"A New Approch For short term load forecasting using curve fitting prediction optimized by geneticalgorithm"MEPSC.,Cario University ,Egypt,December 19-21,2010
12. Hiroyuki Mori and Noriyuki Kosemura "optimal regression Tree based rule Discovery for short term loadforecasting ",IEEE,2001.
13. N.Amral,C.S.Ozveren and D king ,"Short Term Load forecasting using Multiple Regression regression"University of Abertay Dundee,UK,UPEC 2007
14. Tao Hong and H. Lee Willis" A Naïve Multiple Linear Regression Benchmark for Short Term Load Forecasting", IEEE ,2011.

X. BIOGRAPHIES

M Babita Jain is PhD student at the International Institute of Information Technology, Hyderabad, India since 2006. The areas of interest include IT Applications to Power Systems, Load forecasting and Multi Agent Systems. She has actively involved in establishing IEEE student branch and Women in engineering affinity group activities.

Manoj Kumar Nigam is Reader in Electrical Engineering Department at RITEE Raipur (C.G.) India. He is completed his ME in Industrial systems & drives from MITS Gwalior, his area of interest is electrical drives & power electronics.

Prem chand Tiwari is the ME student at RITEE Raipur (C.G.) India since 2010. The area of interest is electronic devices and circuits and power electronics.