Day Ahead Forecasting and Peak Load Management using Multivariate Auto Regression Technique

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***Abstract*— One of the most important commodity of today's world is energy. Energy utilization depends upon several factors such as variation in temperature, seasons, humidity, day of the week, special holidays etc. and the most efficient utilization of energy requires delivery of uninterrupted good quality power. Tariff plays a vital role here. Tariff can be used to create favorable electricity trading conditions in peak demand hours. Therefore, we must have a judicious and proper planning for daily load profile forecasting and in specific peak load demand forecasting. There are numerous methods of Load Forecasting and in specific peak load forecasting. In recent days, Auto Regression technique (ARIMAX) has proved itself a successful tool for future data prediction. In order to find the best application of ARIMAX to get optimum results in peak load forecasting and load management a case study has been done for an urban city in this paper.**

Keywords*— *Load forecasting, Peak load forecasting, ARIMAX, MAE.

I. INTRODUCTION

The development of a country is identified by its per capita electricity consumption. The per capita consumption of energy of a country reflects the overall infrastructural growth. Therefore, load forecasting is important to ensure the efficient supply of energy to the consumers and minimize losses of the service provider. Load forecasting and peak load management are two indispensable part of demand side management. A model of high accuracy is very essential for peak load management. To operate efficiently, a system must adjust the load curve to the available generation capacity, as fast as possible without bringing down the system. Load forecasting can be divided into three categories: Short Term Forecasts, which are usually from one hour to one week, find its application in generation and transmission planning. Medium Forecasts, which are usually from a week to a year, are solely applied in maintenance scheduling, fuel supply planning. Long Term Forecasts, which are longer than a year, are used in Unit Commitment, Economic dispatch, Cost effective scheduling of resources and security analysis studies [1]. A review of load forecasting methods by using artificial intelligence techniques, hybrid techniques and knowledge based expert systems was given by Srivastava et al. [2]. An ARIMA model for forecasting the load based on different time of the year has been proposed Using ARIMA by Amjady et al [3]. An hourly load model using ARIMA has been proposed by Juberias et al [4]. On the other hand, for four types of customer in Taiwan power (Taipower) system, residential load, commercial load, office load and industrial load customers, the summer ARIMA model transfer function model have been derived to proceed the short-term load forecasting during one week by M.Y. Cho et al [5]. In this paper we have done the similar with different approach for urban city. In another application [6], the authors used both univariate and multivariate time-series models in daily and monthly snow water equivalent (SWE) forecasting in Ontario, Canada. In the paper, the effect of weather data in load forecasting has clearly been explained by Jonathan el at [7]. The hourly load data of the Californian Electricity market was used for training and testing purposes. The efficiency of a load forecasting model using ARIMA and Box-Jenkins model is based on the power market of Iran
[8]. Here we have done the same with an advanced multivariate technique and concluded with its significance in Indian Power market. Load and price forecasts are key information in the electricity market for the participants. Therefore, tariff can be used as a useful parameter to take various decisions in electricity trading. Numerous concepts for price forecasting has been proposed in last few decades [9-10].

II. AUTO REGRESSIVE INTEGRATED MOVING AVERAGE WITH EXOGENOUS VARIABLES

This section elaborately discusses about ARIMAX and its statistical background.

A. ARIMAX using Transfer Function Model

To built ARIMAX model for forecasting Y_t and X_t have been assumed two stationary time series. The TFM can be written as,

$$Y_t = C + \nu(B)X_t + N_t \tag{1}$$

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where,
Y_t is response series,
X_t is predictor data series,
C is constant term,
N_t is the stochastic disturbance,
$\nu(B)X_t$ is the transfer function,
B is back shift operator.

$$\nu(B)X_t = (\nu_0 + \nu_1 B + \nu_2 B^2 + \dots\dots + \nu_K B^K)X_t \quad (2)$$

In ARIMAX, we work with two different time series X_t and Y_t. Therefore, it differs from ARIMA or any other univariate method.
The Transfer Function $\nu(B)X_t$ can be written as,

$$\nu(B)X_t = [w_h(B)B^b / \delta_r(B)]X_t \quad (3)$$

Theoretically, $\nu(B)X_t$ has infinite number of coefficients. where,

$$w_h(B) = w_0 + w_1 B + \dots\dots + w_h B^h \quad (4)$$

$$\delta_r(B) = 1 - \delta_1(B) - \dots\dots - \delta_r B^r \quad (5)$$

where,
h is the number of terms plus one of the independent variable.
r is the number of terms plus one of the dependent variable.
b is the dead time.
N_t can be written as

$$N_t = [\, \theta(B)\, \Theta(B^s) / \Phi(B)\, \Phi(B^s)\, (1-B)^d\, (1-B^s)^D \,].a_t \quad (6)$$

where, a_t is zero mean and normally distributed white noise. Therefore, TFM can be finally expressed as,

$$Y_t = C + (\nu_0 + \nu_1 B + \nu_2 B^2 + \dots\dots + \nu_K B^K)X_t + [\theta(B)\, \Theta(B^s) / \Phi(B)\, \Phi(B^s)\, (1-B)^d\, (1-B^s)^D\,].a_t \quad (7)$$

First, we need to specify the value of K and N_t must be specified to find out (b,r,h). To represent TFM (b,r,h) can also be identified by visually comparing the estimated inpulse response function with some common theoretical functions. Several diagnostic checks are involved to conclude whether the model is adequate based on residuals. AIC (Akaike Information Criterion) is one of them. A forecasting model is considered good enough if the value of AIC is small. BIC and SIC can be used to choose the accurate model also.

Based on this, ARIMAX model can be built to have an efficient enough load forecast tool for Demand Side Management. The overall process to build ARIMAX model for load forecasting has been briefly explained using the flowchart shown in Fig. 1.

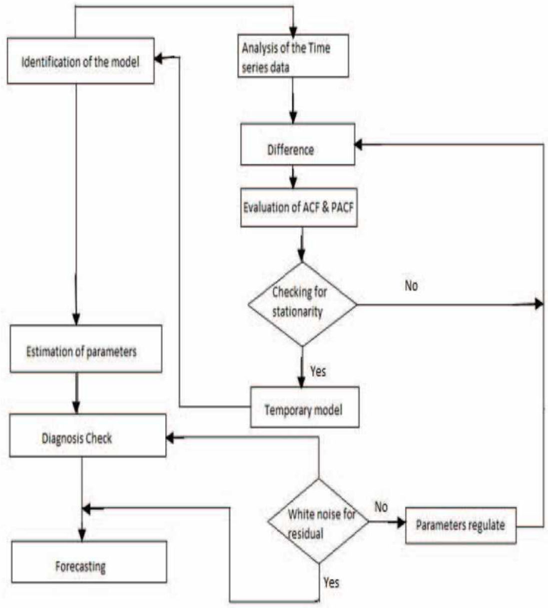

Fig. 1. Flow chart to establish ARIMA model.

The input time series consists of the load demand previous of three to four similar days. To make the time series stationary differencing process is performed. Then the input series has been tested for statistical stationarity. Auto Correlation Factor (ACF) and Partial Auto Correlation Factor (PACF) have been evaluated, based on which the value of p and q is selected, where p and q represents the order of AR and MA process respectively. The value of p and q can be evaluated using PACF and ACF plot respectively. The diagnostics checks are performed through residual analysis to and finally forecasting is done and accuracy is measured. The best fit ARIMA model would be used to forecast the load demand for a particular day. For the model selection use of AIC and BIC is the general approach.

III. Result Analysis And Discussion

To implement the proposed approach, we have considered the load demand of West Bengal's power network in Eastern Regional Load Dispatch Center (ERLDC). This study includes hourly load and peak load from January, 2017 to December, 2017.

Here, we have performed day ahead forecasting for different consumers of Kolkata, West Bengal. The order of the ARIMA model and ARIMAX model, have been chosen on the basis of Auto Correlation Factor (ACF) and Partial Auto Correlation Factor (PACF) and TFM respectively.

ISBN: 978-1-5386-6686-9

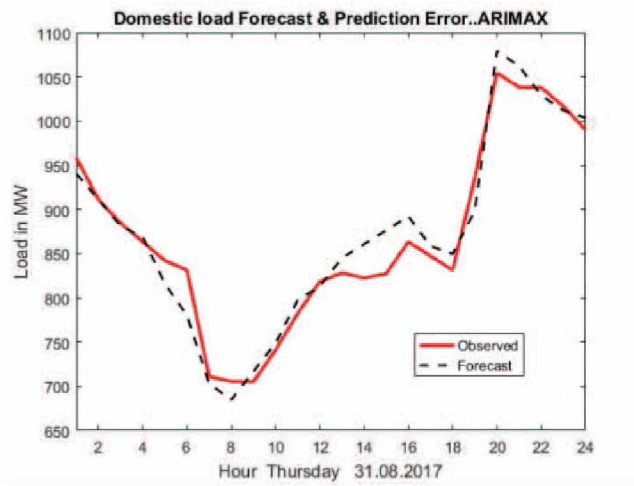

Fig. 2. Domestic Load Profile curve for 31.08.2017 (Thursday) using ARIMAX.

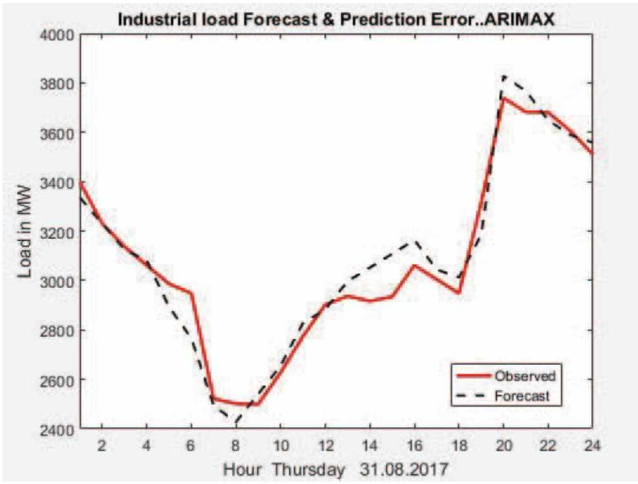

Fig. 3. Industrial Load Profile curve for 31.08.2017 (Thursday) using ARIMAX.

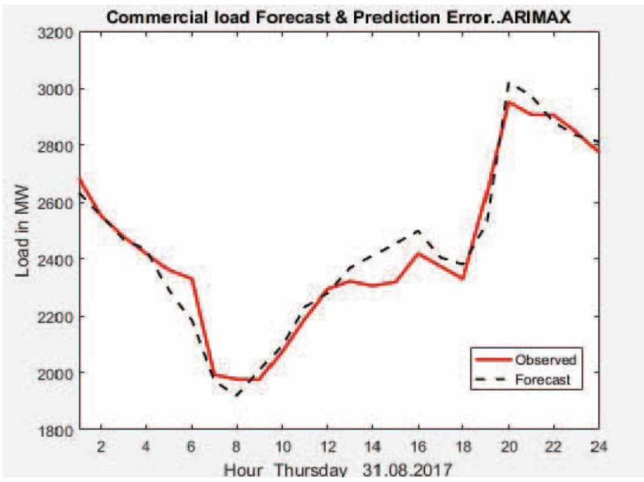

Fig. 4. Commercial Load Profile curve for 31.08.2017 (Thursday) using ARIMAX.

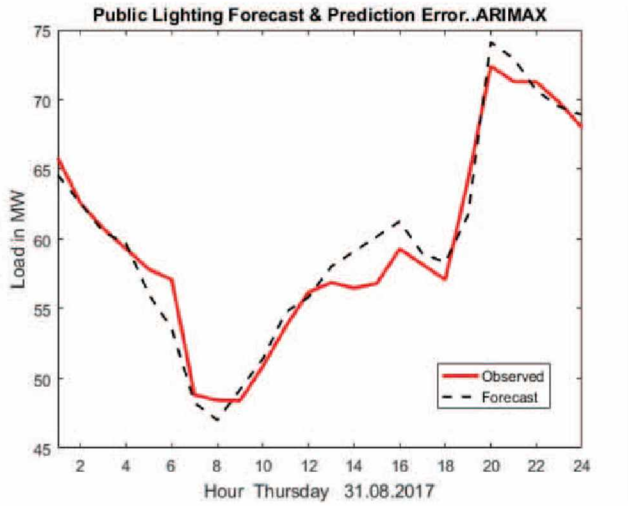

Fig. 5. Public lighting Load Profile curve for 31.08.2017 (Thursday) using ARIMAX.

In Fig. 2, Fig. 3, Fig. 4 and Fig. 5 the prediction error has been focused using ARIMAX method for domestic, industrial, commercial and public lighting respectively. It can be said that in case of STLF, ARIMAX gives more accuracy than other conventional techniques as because we are able to consider different predictor variables, like temperature, humidity, public holidays, industrial growth, and population etc, based on their influence on the response variable for that particular case using the multivariate technique.

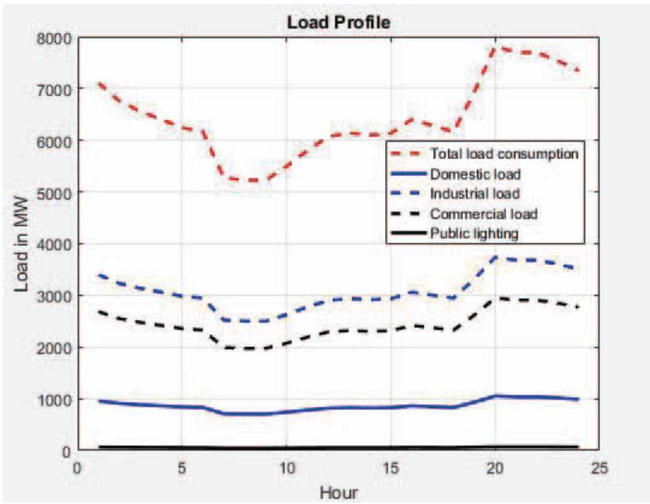

Fig. 6. Load Profile curve for different type consumer.

In Fig. 6, we have shown the influence of different consumers in daily load profile individually.

We have also calculated MAE (Mean Absolute Error).

$$MAE = \sqrt{\left(\frac{\text{Actual value} - \text{Forecasted value}}{\text{Actual value}}\right)^2}$$

Mean Absolute Error (MAE) is the measure of difference between two continuous variables. MAPE (Mean Absolute Percentage Error) is also an effective measurement of the same.

The following table shows the different forecasting errors for different consumer sectors. From the acquired data we were able to measure the contributions of Domestic, Industrial, Commercial consumers on daily load profile and also we have determined the accuracy of the model in terms of MAE (Mean Absolute Error).

TABLE I. OBTAINED RESULTS FOR DIFFERENT TYPE CONSUMERS

Type of consumers	*% share of loads under Daily Load Profile*	*Prediction Error (MAE) using ARIMAX*	*Actual % share of loads in Peak Load Demand Hours*	*Forecasted % share of loads in Peak Load Demand Hours*
Domestic	13.486 %	2.178%	13.71 %	13.49 %
Industrial	47.819 %	2.176 %	47.69 %	47.86 %
Commercial	37.769 %	2.181%	37.76 %	37.72 %
Public Lighting	0.926 %	2.175 %	0.68 %	0.93 %

ARIMAX method has been implemented using MATLAB. The above table shows a comparative result between actual and predicted values of load of different types. It is found that the predicted value and the actual value differ by an error of 2% – 2.5% error. This error using ARIMAX can be further minimized by introducing different parameters which includes humidity, wind speed, tariff, occasional spikes etc. ARIMAX is more reliable than other univariate methods as we are able to consider more than one predictor variables to find out their correlation with the input series and the predicted demand also. By this method, minute ahead forecasting is also possible which may help in Real Time Load Forecasting.

IV. CONCLUSION

Forecasting the electrical load data is an inevitable process for the efficient operation and control of the electrical power supply. The requirement of a highly efficient forecasting tool is increasing day by day. This paper has made an attempt to introduce a model of ARIMAX to forecast electrical load data. Our research reveals that ARIMAX achieves good accuracy in Peak load forecasting as well as forecasting of daily load profile. For ARIMAX, the order of prediction model depends on the Auto-correlation and Partial Auto-Correlation function of past and present data. In this paper, we have seen that the daily load profile is greatly influenced by Industrial, Commercial and Domestic consumers. The variation in load demand with temperature is predominant for Domestic and Commercial users. Therefore, they play a major role in Peak load hours also. Though industrial consumers play major role in peak load hours, they remain almost ineffective in temperature variation. Public lighting also has considerable influence in festive season. Therefore, different tariff frame can be designed for different users according to their contribution in daily load profile for favourable electricity trading conditions.

ACKNOWLEDGMENT

The authors wish to thank Eastern Region Load Dispatch Centre for providing the daily load profile. The authors also thank Jadavpur University and its digital library, with the help of which, the quality of this manuscript has been enhanced.

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