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Short-Term Load Forecasting Using ARIMA Model For Karnataka State Electrical Load

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ABSTRACT: Short-term load forecasting is a key issue for reliable and economic operation of power systems. This paper aims to develop short-term electric load forecasting ARIMA Model for Karnataka Electrical Load pattern based on Stochastic Time Series Analysis. The logical and organised procedures for model development using Autocorrelation Function and Partial Autocorrelation Function make ARIMA Model particularly attractive. The methodology involves Initial Model Development Phase, Parameter Estimation Phase and Forecasting Phase. To confirm the effectiveness, the proposed model is developed and tested using the historical data of Karnataka Electrical Load pattern (2016). The forecasting error of ARIMA Model is computed and results have shown favourable forecasting accuracy.

Index Terms: Autocorrelation Function (ACF), Autoregressive Integrated Moving Average (ARIMA), Mean Absolute Percentage Error (MAPE), Partial Autocorrelation Function (PACF), Short-Term Load Forecasting (STLF), Stochastic Time Series.

I. INTRODUCTION

Short-term load forecasting has been essential for reliable power system operation. The operational decisions in power systems such as unit commitment, economic dispatch, automatic generation control, security assessment, maintenance scheduling and energy commercialization depend on the future behaviour of the loads [1]. Also, with the rise of deregulation and free competition of the electric power industry all over the world, load forecasting has become more important than ever before. Load forecasts plays vital role for any energy transactions in the competitive electricity markets [2]. In order to provide substantial amount of electric energy to grow the economy progressively, load forecasting is required by the electrical power producers. As a result, the accuracy of the forecasts has significant effect on economy and control of power systems operations. Hence, more sophisticated forecasting tools with higher accuracy are necessary for modern power system [3], [4]. Owing to the importance of short-term load forecasting (STLF), research in this area during the past few decades has resulted in the development of numerous forecasting methods. Most of the methods are based on time series analysis. Time series models mainly include approaches based on statistical methods [1],[3]-[7],[8]. The statistical models are hard computing techniques that forecast current value of the variable by using mathematical combination of the previous values of that variable.

This paper presents ARIMA model for STLF wherein for each day of a week or a month, 24 load forecasts are computed based on time series analysis. Given set of time series load data, it is possible to produce accurate short-term forecasts and extract information on overall demand structure. Description of the proposed model order determination and parameter estimation is provided to achieve minimum MAPE and thus accurate short-term load forecasts. This methodology is implemented on a set of time series of Karnataka Electrical Load pattern.

II. DESCRIPTION OF THE PROPOSED ARIMA APPROACH

Various time series approach such as Box-Jenkins time series models have been presented for STLF [5]. Here, the time series model of Auto Regressive Integrated Moving Average, ARIMA has been used. The input series for ARIMA Model needs to be stationary. However, if the time series is non-stationary i.e. when its statistical properties such as mean and variance change over time, differencing is required to transform the series into a stationary one. Therefore, usually the series first needs to be differenced until it is stationary.

By introducing the ▼ operator, a differenced time series of order 1 can be written as,

$$\blacktriangledown y(t) = y(t) - y(t-1) = (1-B)\, y(t) \qquad (1)$$

Where,
y(t) – output or the load at time ‘t’
B – Backshift operator and
B y(t) = y(t-1);

Consequently, an order'd' differenced time series is written as,

$$\nabla^{d} y(t) = (1-B)^{d} y(t) \quad (2)$$

Here the differenced stationary series can be modelled as an AR, MA or an ARMA to yield an ARIMA time series processes. For a series that needs to be differenced 'd' times and has the orders 'p' and 'q' for AR and MA components respectively i.e. ARIMA (p, d, q) model is written as,

$$A(q)\ \nabla^{d} y(t) = C(q)\, a(t) \quad (3)$$

Where,
A(q) & C(q) – delay polynomials
p & q – Orders of the delay polynomials A(q) & C(q) respectively.

The purpose of this ARIMA model is forecasting the value of y(t). Here, the forecasting methodology involves three phases:

a) Initial Model Development Phase
b) Parameter Estimation Phase
c) Forecasting Phase

The three phases are explained in the following section.

III. IMPLEMENTATION OF PROPOSED APPROACH FOR THE STLF

To implement the proposed ARIMA model using time series analysis for STLF, the hourly load demand of Karnataka for the months of January and February 2016 has been statistically studied. Initially for determining the order of the model and to estimate the parameters of the model, the load demand of January is used. Further, the developed ARIMA model is used to predict the loads for February. This forecast is compared with the existing load data of February 2016 and hence the forecasting errors are computed. This novel approach for STLF incorporates three main phases and is explained as follows:

A. Initial Model Development Phase: Identification of the model usually relies on analysis of autocorrelation function (ACF) and partial autocorrelation function (PACF). The load data of January 2016 is used in this analysis. The oscillatory and non-decaying nature of ACF indicates a non-stationary series as shown in Fig.1. Hence differencing is needed to obtain a stationary series. The resulting ACF and PACF plots for differenced time series load data are shown in Fig.2.

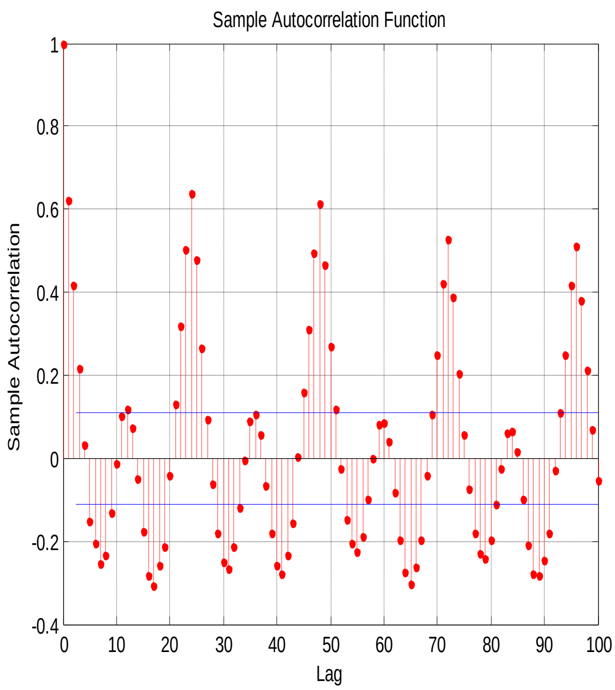
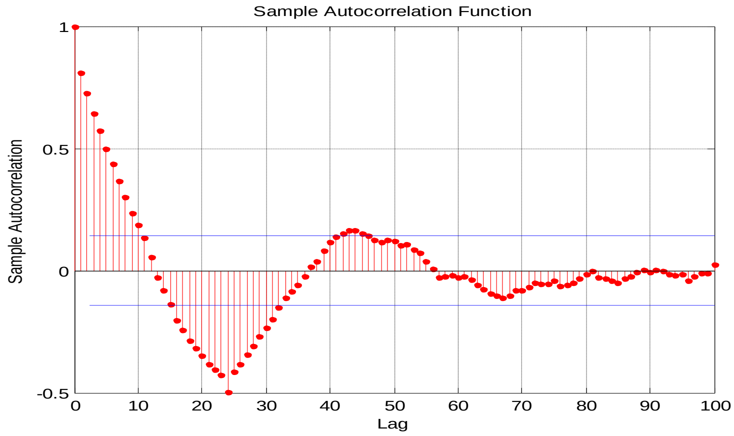


Fig.1. ACF of January 2016 Data



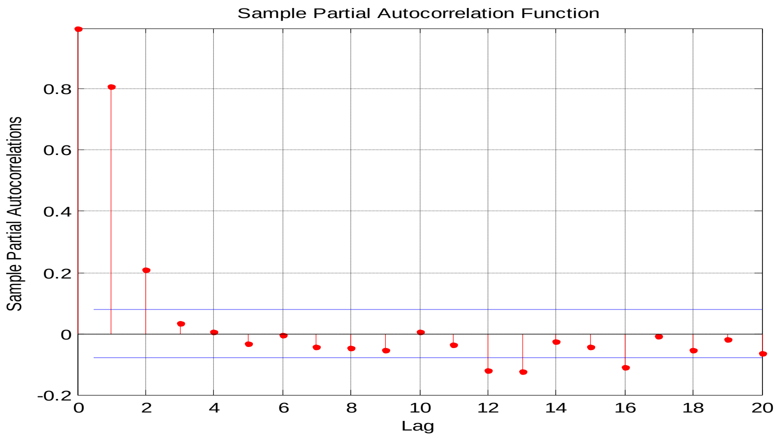


Fig.2. ACF and PACF of Differenced January 2016 Data

With a large spike at lag of 24 on ACF and at lag of 1 on PACF in Fig.2 suggest AR(1) and MA(1) components. Hence the overall ARIMA(p,d,q) model takes the form ARIMA$(1,1,1)_{24}$. To continue with the forecasting process, the model parameters are to be estimated as explained in the next phase.

B. Parameter Estimation Phase: In this phase, using Least Square method the model ARIMA$(1,1,1)_{24}$ estimates the coefficients of the delay polynomial A(q) and C(q) of equation (3) so that the energy of the noise term is minimized. Hence the estimated values of A(q) and C(q) are,

A(q) = 1 - 0.8922 q^-1 (4)

C(q) = 1 - 0.249 q^-1 (5)

Having estimated the model parameters, ARIMA$(1,1,1)_{24}$ model can be used to forecast the future values.

C. Forecasting Phase: By using the proposed statistical forecasting approach the developed ARIMA$(1,1,1)_{24}$ model is used to forecast the hourly load data for next month i.e. February 2016. The prediction errors are then calculated. The Autoregressive Integrated Moving Average, ARIMA$(1,1,1)_{24}$ model has consistently shown satisfactory performance with Mean Absolute Percentage Error (MAPE) of 4.46%.

In order to further minimize the prediction error, some exogenous variables such as the day type, environment temperature, humidity, wind speed etc. should be taken into account in the load forecasting. As further improvements Autoregressive Integrated Moving Average with exogenous variables (ARIMAX) model should provide more accurate forecasts.

IV. NUMERICAL RESULTS

The time-series approach ARIMA$(1,1,1)_{24}$ for STLF is developed using the Karnataka load data of January 2016 and this model is further used to forecast the demands for February 2016. The prediction errors are calculated and shown in Table I.

Table I Results Obtained For February With Arima Model

TIME PERIOD	MAPE
February 1-7	4.74%
February 8-14	4.20%
February 15-21	4.69%
February 22-28	4.85%
Overall(February)	4.46%

The forecasted results as well as the real load demand of February 2016 are plotted and compared in Fig.(3)-(7).

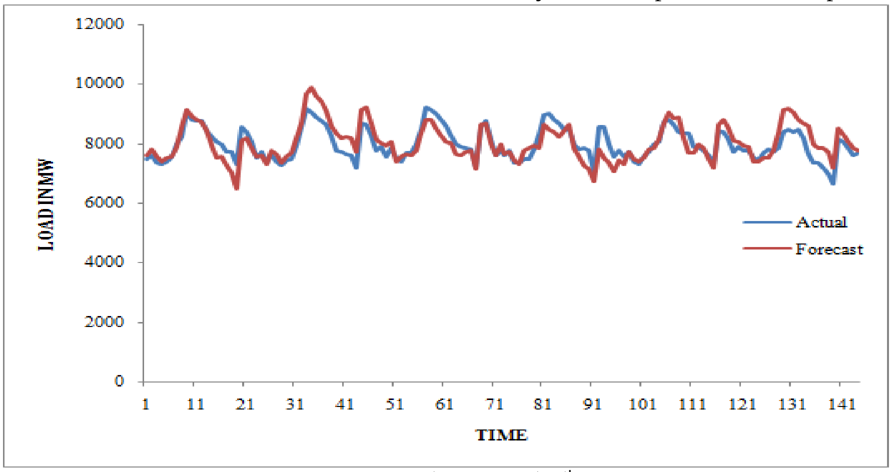


Fig.3 Forecasted results for 1st week (1st-7th) of February 2016

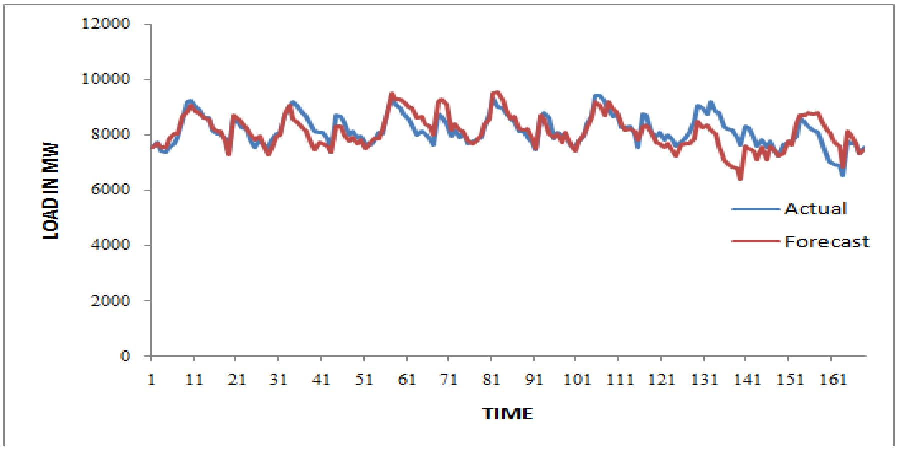


Fig.4 Forecasted results for 2nd week (8th-14th) of February 2016

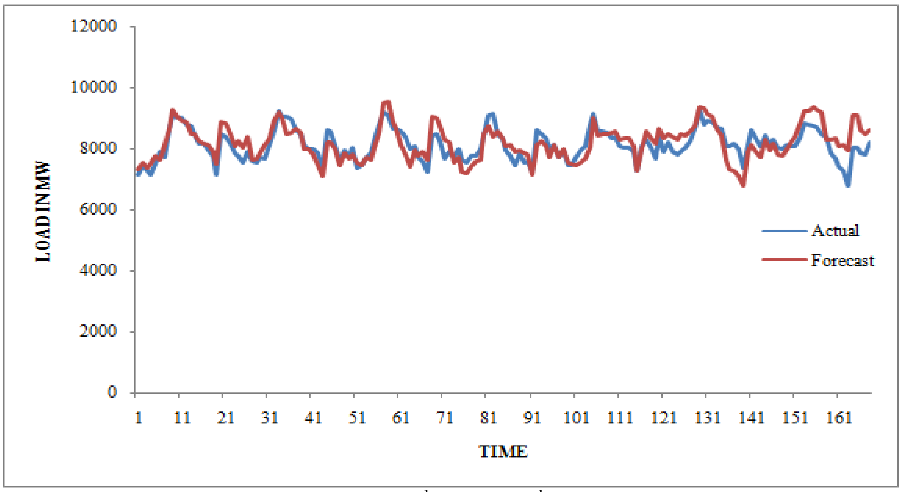


Fig.5 Forecasted results for 3rd week (15th-21st) of February 2016

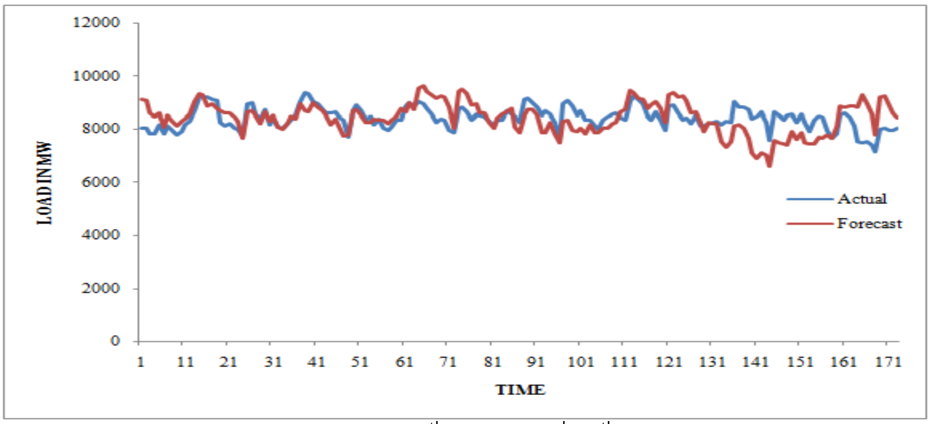


Fig.6 Forecasted results for 4th week (22nd-28th) of February 2016

V. CONCLUSION

Electricity demand forecasting has significant implications on the costs and security of the energy supply. Accurate forecasting models are needed for secure and reliable energy system operation. In this paper, a novel approach for STLF has been developed which incorporates the ARIMA time series modeling. To implement this ARIMA approach, we statistically studied the load demand, including hourly loads of Karnataka Electrical Load pattern. The model has shown favourable load forecasting accuracy. Although in the present work only load data is incorporated in the ARIMA model, the forecasting accuracy can be further improved by including more exogenous variables such as the day type, temperature, humidity etc. Research work is under way in order to develop Auto Regressive Integrated Moving Average with Exogenous variables (ARIMAX) model.

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