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ARIMAX Model for Short-Term Electrical Load Forecasting

Shilpa G N, G S Sheshadri

***Abstract:** The scope for ARIMAX approach to forecast short term load has gained a lot of significant importance.In this paper, ARIMAXmodel which is an extension of ARIMA model with exogenous variables is used for STLF on a time series data of Karnataka State Demand pattern. The forecasting accuracy of ARIMA model is enhanced by taking into consideration hour of the day and day of the week as exogenous variables for ARIMAX model. Forecasting performance is thus improved by considering these significant load dependent factors. The forecasted results indicate that the proposed model is more accurate according to mean absolute percentage error (MAPE) obtained during the testing period of the model. As the historical load data are available on the databases of the utility, researches in the areas of time series modelling are ongoing for electrical load forecasting. In the proposed paper real time demand data available on Karnataka Power Transmission Corporation Ltd. (KPTCL) website is taken to develop and test the proposedload forecasting model.The power utility system operational costs and its securitydepend on the load forecasting for next few hours. Regional load forecasting helps in the accurate management performance of generation of power plant. Today's deregulated markets have great demand for prediction of electrical loads, required for generating companies. There has been tremendous growth in electric power demand and hence it is very much essentialfor the utility sectors to have theirdemand information in advance.*

***Index Terms:**Artificial neural networks (ANN), autocorrelation, autoregressive integrated moving average with exogenous variables (ARIMAX),mean absolute percentage error, partial autocorrelation, short term load forecasting (STLF).*

I. INTRODUCTION

Among the different categories of load forecasting, short-term load prediction has gained importance andhas undoubtedly become an integral part in operational performance of any electric utility [1]. Some of the operational decisions namely economic scheduling of power station, fuel purchase schedule, energy transactionsplanningand power system security assessment[2]. In addition to power utilities other various firms likeelectricity marketers, traders and independent load system operators also need accurate load forecasts for their operations.

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* Correspondence Author
Shilpa G N*, Assistant Professor, Department of Electrical and Electronics Engineering, Sri Siddhartha Institute of Technology, Tumakuru, Karnataka, India.
Dr. G S Sheshadri, Professor, Department of Electrical and Electronics Engineering, Sri Siddhartha Institute of Technology, Tumakuru, Karnataka, India.

Hence, accurate and reliable electrical load forecasting can result in better financial rewards for all these entities.Accurate load predictions leads to great savings, as it improves economic load dispatch, unit commitment etc[3].Many nonlinear factors like weather variables, daily, weekly and seasonal etc. practically affect STLF[4].

Several electrical utilities have adopted the conventional methods of forecasting the future loads. In conventional techniques, the models are mainly designed with respect to the relationship between the load and factors that influence the load power [5]. Recently, many similarity based approaches have been studied and developed for load forecasting. These approaches rely on the load behaviourinformation of the similar days that improves the forecasting accuracy. Such methodologies have the ability to deal with the nonlinear nature of the load along withits behavioural pattern in weekdays, weekends and special days/holidays [6-7]. Many researches have been carried out in the field of short term load forecasting [8]. Time Series Models and Artificial neural networks (ANN)are the main methodologies [9]used for load forecasting. Autoregressive integrated moving average (ARIMA) modelis the best adopted procedure among various time series methods [10].The modified form of ARIMA model is autoregressive integrated moving average (ARIMAX) model with exogenous variables. This method is implemented by applying the difference operation to get stationary time series. Then, the preliminary model order is identified and confirmed by analyzing the plots of the autocorrelationand partial autocorrelation[11]. The proposed model parameter estimationis done by applying maximum likelihood or weighted least-square methods [12].As a result, electrical future load is forecasted based on intelligent projection of previous load and present loadwith greater reliability.The past load pattern of the power system and its constitution along with the distribution of region wiseload is essential to get an overall good behaviourof load pattern. This paper presents time series ARIMAX modeling for STLF which takes into account hour of the day and day of the week along with the load as the inputs to the model. Practically, load depends on the hour of the day, day of the week; these significant factors should be taken into account for further improvement of the forecasting accuracy.Similarly other exogenous variables (special days, temperature etc.) that affect the load pattern can be included in the proposed ARIMAX modeling. This approach is analysed and simulated on a set of real time load data of Karnataka State Demand (2016).

II. ARIMAXMODEL

The forecasting accuracy of ARIMA model is improved by addition of weekdays and weekends pattern that leads to ARIMAX model. Due to dynamic nature of the load,there exists a very strong correlation with the input variablesselected.As a result, the forecasting performance of the ARIMAX model strongly depends on the input variablesselected and the input variables are to be chosen in such a way that the forecasting error of the developed model is minimized.

Hourly load changes from one day to another day of the week affects the load pattern and hence becomes an importantfactorto be considered and included in the proposedARIMAX model.

The ARIMAX model equation is given by,

$A(q)y(t) = B(q)u(t) + C(q)e(t)$-----------------(1)

where,

A(q), B(q)&C(q)– Delay Polynomials
u(t) - Exogenous Input Variables
e(t) - Noise
y(t) -Output Load

Autoregressive integrated moving average model with exogenous variables (ARIMAX) model development is mainly classified into three steps:

1. Determination of model order
2. Estimation of model parameters
3. Output load forecasting

The present paper attempts to simulate and execute all the three phases of ARIMAX approach in STLF using real time load data of Karnataka Demand (2016). The proposed work is carried out using Mat lab software.Power griddemands accurate load forecasting that is essential for economic, stable and secure operation. It also helps in making proper necessary arrangements for planning the maintenance.

III. SIMULATION RESULTS

Statistical study of Karnataka State demand pattern is carried out for short term load forecasting. Analysis of simulation results & model development for accurate STLFcomprises of three major computational steps as explained below.

***1.Determination of model order*:**Model is developed using January load data and tested on February load data. Fig.1 shows the plot of ACF for the month of January 2016. ACF plotindicates that thenature of the load is oscillatory andnon-decaying.As a result, differencing of the load data is appliedin order to make the set of considered load series stationary. Fig.2 shows the resulting auto correlation and partial autocorrelationplots for differenced set of time series load data. The initial order of the ARIMAX model is determined by studying and analyzing autocorrelation and partial autocorrelation plots for differenced time series load data.

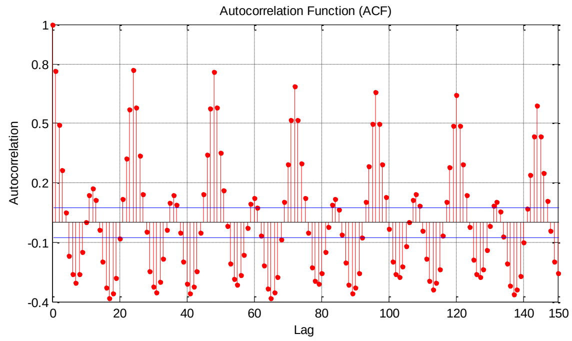

Fig.1. Plot of ACF for January load data.

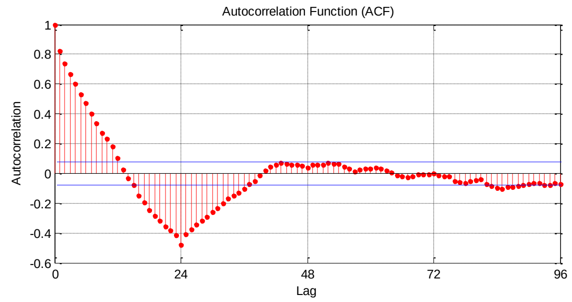

Fig.2. Plot of ACF for Differenced January load data

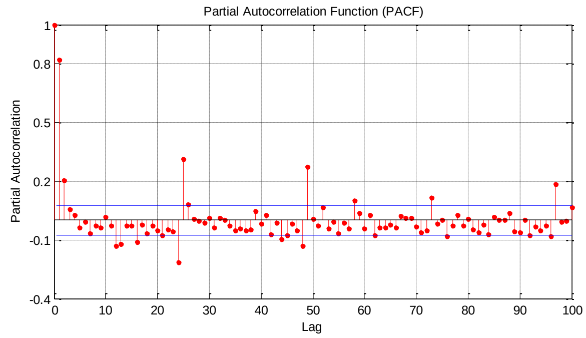

Fig.3. Plot of PACF for Differenced January load data

The ACF & PACFplots as shown in Fig.2 and Fig.3 suggesta model of order 2 i.e.autoregressive AR (2) and moving average MA (2).As a result, thedevelopedARIMAX (p,d, q)model takesthe form ARIMAX $(2, 1, 2)_{24}$.After determining the orders of the model, the next step is to estimate the model parameters.

***2.Estimation of model Parameters*:**In this phase, the proposedARIMAX $(2, 1, 2)_{24}$model estimates the values ofcoefficients of delay polynomialsstated in equation (1) in order to minimize the energy of the noise term e(t). Parameters are estimated by an efficient gradient based method known as theleast square method. After all the parameters of ARIMAX $(2, 1, 2)_{24}$model are estimated, the next step is to forecast the future valuesof the output load using this proposed model.

Figs.8-9 show load behaviour on weekdays and weekends. Monday through Saturday is taken as weekdays and Sunday is taken as weekend.The load pattern for weekdays and weekends of January/February month is analysed and it is observed that weekdays have similar pattern and weekends have similar pattern.

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Hence ARIMAX (2, 1, $2)_{24}$model is developed that takes into consideration day code, hour code, weekdays and weekends as exogenous variables along with January (2016) load data of Karnataka State.

***3. Output load forecasting*:**January load data is used to develop ARIMAX (2, 1, $2)_{24}$model and is applied to forecastthe next month i.e. February hourly load. In order to check the ARIMAX model forecasting performance, it is essential to calculate the output load forecasting errors.

Fig.10 shows the proposed and developed model withMean Absolute Percentage Error (MAPE) of 2.86%. The model outputs encouragingforecasting results with least forecasting errors.The forecastedresultsshown in Figs.4-7indicate that the model is most suitablefor short term load forecasting. Table I gives the weekly forecasted results (MAPE) for the month of February.

TABLE I ARIMAX Model Forecasted Results for February Month

WEEK	ARIMAX Model (Day code, hour code, weekends and weekdays) MAPE
1	3.48%
2	2.17%
3	2.38%
4	3.43%
Overall (February)	**2.86%**

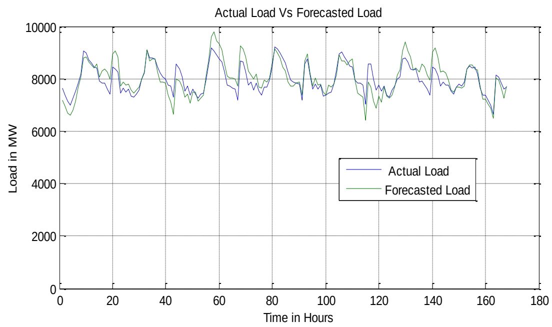

Fig.4 Forecasted result for 1st week (1/2 – 7/2 2016)

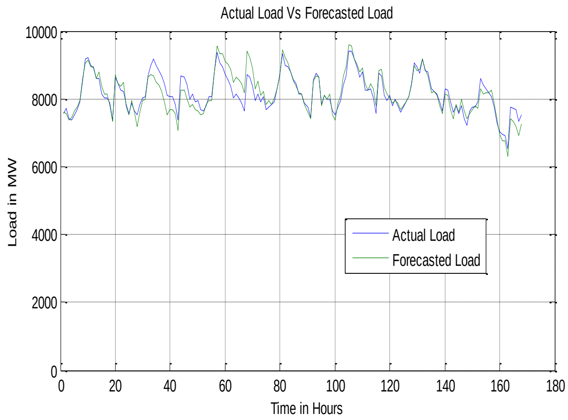

Fig.5 Forecasted result for 2nd week (8/2 – 14/2 2016)

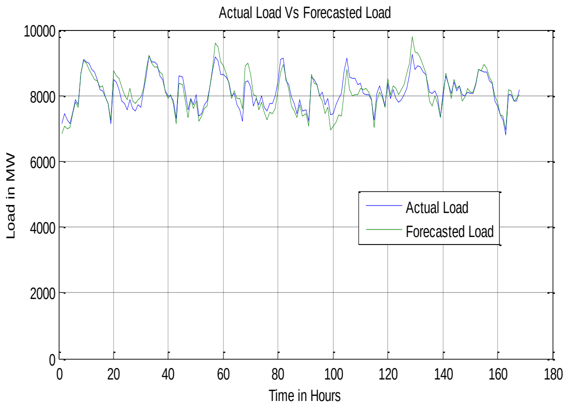

Fig.6 Forecasted result for 3rd week (15/2 – 21/2 2016)

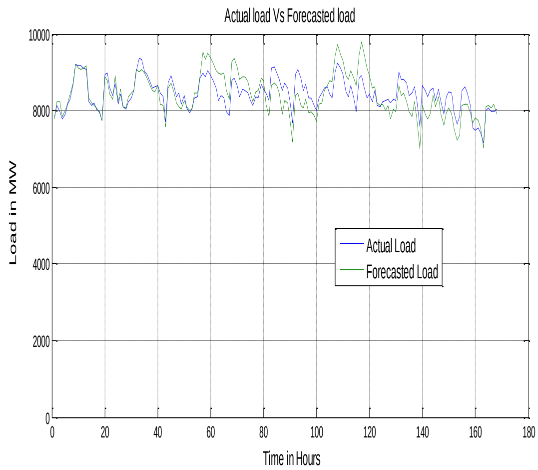

Fig.7 Forecasted result for 4th week (22/2 – 28/2 2016)

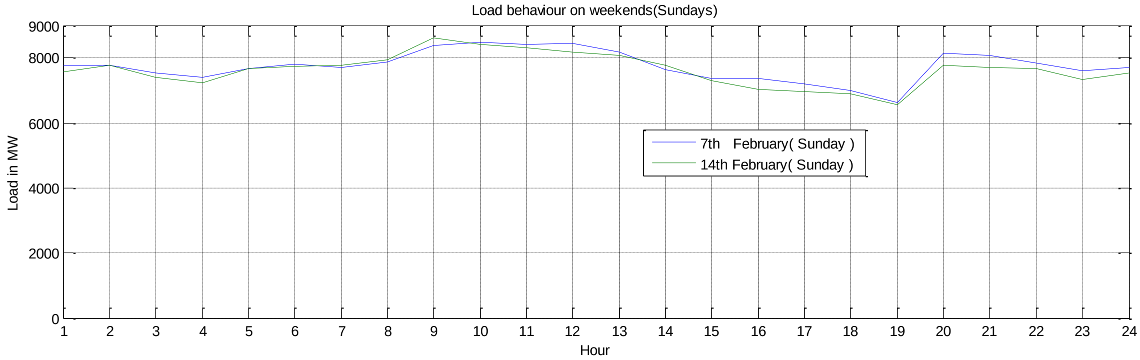

Fig.8 Load behaviour on weekends (Sundays) (07/2 &14/2 2016)

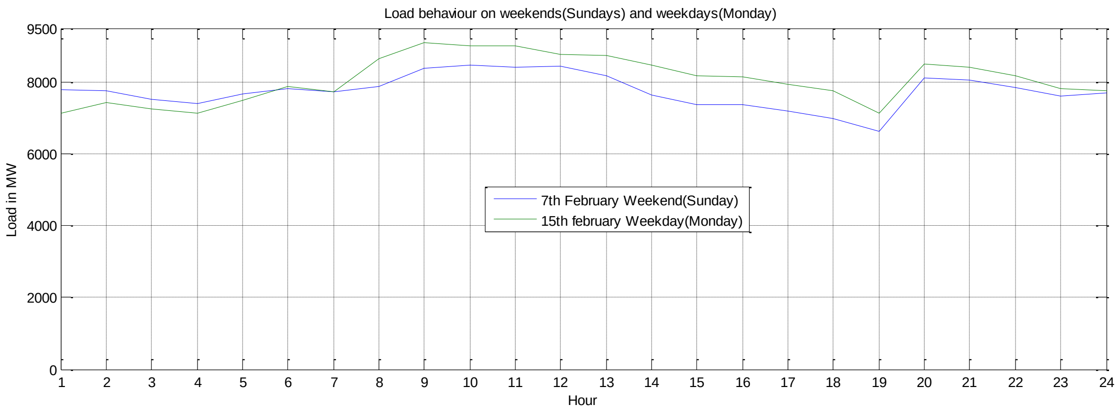

Fig.9 Load behaviour on weekends (Sundays) and weekdays (Monday) (07/2 &15/2 2016)

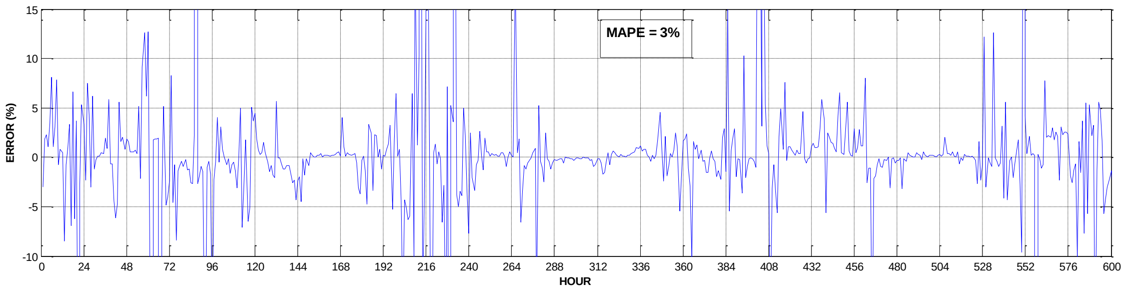

Fig.10 Mean Absolute Percentage Error (MAPE)

IV. CONCLUSION

The proposed ARIMAX model forecasts theelectric load by considering the correlation established to the data of the selected similar days.Initially differencing is applied to January load data to make it stationary as it was observed to be oscillatory and non-decaying. Later the differenced data is used to build the model. The model orders were determined to be AR(2) and MA(2) by plotting PACF and ACF of differenced data respectively. The load pattern for weekdays and weekends of January/February month is analysed and it is observed that weekdays have similar pattern and weekendshave similar pattern. Hence, the inputs chosen to build ARIMAX modelare January month differenced hourly load data, time of the day, exogenous variables like weekdays and weekends. The model parameters are then estimated and February month load is forecasted. The forecasted load is compared with the actual load and forecasting errors are calculated. The results forecasted show a mean absolute percentage error (MAPE) of 2.86%. Theresearch studies have reported that the load profile is dynamic in nature and hence the loads aresubjected totemporary and seasonal variations. Thus the electric load can be more accurately forecasted by consideringthese factors like temperature, humidity etc. that has major impact on the load.

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AUTHORS PROFILE

Shilpa G N received her B.E. Degree in Electrical and Electronics Engineering in 2003 from Visvesvaraya Technological University and M.E. in Power and Energy Systems from University Visvesvaraya College of Engineering, Bangalore University, Karnataka, India. From 2007 through 2009, she had been working as Assistant Professor in Bapuji Institute of Engineering and Technology, Davangere. Presently she is serving as Assistant Professor since September 2010 in the Department of Electrical & Electronics Engineering at Sri Siddhartha Institute of Technology, Tumakuru, Karnataka, India. She is also working toward the Ph.D degree in the research area Power and Energy Systems at Sri Siddhartha Academy of Higher Education, Sri Siddhartha University, Tumakuru, Karnataka, India. Her research interests include load forecasting, time series modelling and artificial neural network applications to power systems.

Dr. G. S. Sheshadri aged 56 years is presently serving as Professor at Sri Siddhartha Institute of Technology, Tumakuru, Karnataka. He has obtained B.E. in *Electrical and Electronics Engineering* from Bangalore University in the year 1987. He obtained his M.Tech. Degree from National Institute of Engineering, Mysore, in the year 1990, securing first rank. He has been awarded Ph.D from Visvesvaraya Technological University, Belagavi in the year 2011. His areas of interest are power systems, neural networks, Renewable energy sources, etc.