International Journal of Computer Applications (0975 – 8887)
Volume 124 – No.7, August 2015

Functional Time series (FTS) Forecasting of Electricity Consumption in Pakistan

Farah Yasmeen
Department of Statistics
University of Karachi

Muhammad Sharif
Department of Statistics
University of Karachi

ABSTRACT
Electricity is one of the most important sources for economic and social development of a country. The growth in energy consumption is basically linked with the growth in economy. Energy demand increases due to different reasons, including higher Gross Domestic Product (GDP) growth, higher per capita consumption, the population growth and rapid development of industrial & commercial sectors.

In this study, the monthly electricity consumption for the period of January 1990 through December 2011 in Pakistan is analysed using functional time series (FTS) technique. Electricity consumption model reveals a significant trend due to socio-economic factors. The monthly behavior of forecast values reveals that the electricity consumption is more for summer season and this demand will be increased in future. Forecast model and the forecast values show that the electricity consumption is increasing with the passage of time. The growing energy consumption in the country may be due to economic growth, urbanization process in the region, population growth and industrialization.

Keywords
Functional Time Series, Functional Data, Electricity Consumption, Principal Component, forecast

1. INTRODUCTION
Electric energy consumption is the form of energy consumption that uses electric energy. Energy is the basic building block of economic development and the most flexible form of energy that constitutes one of the vital infra-structural inputs in socio-economic development. In Pakistan, electric power is becoming the main energy form relied upon in all economic sectors of the country. Also, the time series of electrical energy consumption in Pakistan is unique due to irregular power outages and increasing demand. It is therefore desirable to consider the future pattern, or to forecast the series.

The electric power sector in Pakistan is operated by the Water and Power Development Authority (WAPDA),with additional generation contribution from Independent (private) Power Producers (IPPs). WAPDA is key responsible department for power management in Pakistan, with the exception of Karachi, which is supplied by KESC.. The National Electric Power Regulatory Authority (NEPRA) regulates the power sector in Pakistan, which includes power generation, transmission and distribution. NEPRA is also responsible for determining electricity rates in Pakistan.

Forecasting electricity consumption with high accuracy is essential to prevent energy wasting and system failure. Electricity consumption forecasting is one of the most significant challenges in dealing supply and demand of the electricity, since the electricity demand is volatile in nature; it cannot be stored and has to be consumed immediately. Electricity consumption forecast are generally divided in two categories: short term and long term. Short term forecast are useful in daily operations of a utility companies whereas long term forecast are needed for strategic planning

This paper is organized as follows: section 1 is introductory, while some previous literature is reviewed in section 2. Section 3 describes the forecasting method. Finally, some concluding remarks are given in section 4.

2. LITERATURE REVIEW
Ali et al [1] studied the relationship between extreme temperature and electricity demand in Pakistan. The results show that there is significant linear correlation coefficient (0.412) between extreme temperature and electricity demand in Pakistan. The power demand is maximum in summer season and will be highest (6785.6 (GWh)) in July, 2020 due to increase in temperature.

Khan and Ahmed [2] reported that the current electricity production of Pakistan is around 11,500 MW per day. The economy's electricity jumped to around 20,000MW per day by 2010. This gap between the supply and demand in the energy sector suggests the magnitude of the energy crisis the economy faces. To fulfill increased electricity demand, planning and investment in infrastructure development is necessary. The unplanned outages may negatively affect economic growth. The government should adopt a policy so that a sustainable electricity supply may be ensured. There is abundant potential capacity of hydroelectricity in the country that can be tapped by constructing dams.

Khan and Qayyum [3] justified that Pakistan has been facing severe imbalance between energy demand and energy supply. During the past 25 years, energy supply in Pakistan has been increased by around 40 times, but still the demand outstrips supply.

According to research of Alter and Shabib [4], current electricity crisis has influenced the whole economy of Pakistan. Electricity crisis has mainly affected the industries, exports and employment. Where industrial losses have reached to 157 billion rupees, unemployment losses are about 400,000. Currently Pakistan is going through the worst energy and electricity crisis of its history. Electricity shortfall has increased about 5000 Mw, load shedding has increased from 8 to 14 hours daily, industrial growth has declined, and ultimately the whole economy has suffered.

Zachariadis and Pashourtidou [5] used models based on econometrics method for forecasting electricity demand in Bangladesh. The forecasts of the electricity demand with respect to the GDP data were obtained. The results show that keeping pace the electricity demand and energy generation can successfully avoid the burden of load-shedding.

Zahang et al [6] studied on forecasting with artificial neural networks (ANNs). ANNs are universal functional approximates. ANN technique assumes a few priori assumptions about the models for problems under observation. ANNs have more flexible and general functional forms than the traditional statistical methods which we use for modeling and forecasting can. In fact most of the real world systems are nonlinear (Granger [7]). ANN models give better results for such nonlinear time series data.

Yasmeen and Sharif [8] analyzed the monthly electricity consumption in Pakistan for the period of January 1990 through December 2011 and obtained the forecast of electricity consumption in Pakistan using linear and non linear modeling technique, they include ARIMA, Seasonal ARIMA (SARIMA) and ARCH/GARCH model. The results of the study conclude that ARIMA (3,1,2) model is the most appropriate model for forecasting electricity consumption of Pakistan. The results reveal that the electricity consumption is continuously increasing with the passage of time. This suggests that the government of Pakistan must take effective steps to increase the electricity production through different energy sources to restore the economical status of the country by meeting the demand of electricity in the country.

Mati et al [9] employed multiple regression time series modeling approach to model the electricity demand in Nigeria for the period of 1970 to 2005. The standard root mean square error has been used to evaluate model accuracy. The study used annual increment and connectivity variables as independent variable to define annual consumption. The data analysis shows that the highest demand will be 5222 MW by 2003. The overall installed capacity of the country as at that year was around 5600MW, which shows that the demand can only be met if all plants were functioning at 95% capacity factor.

Aman et al [10] discussed modeling and forecasting electricity consumption of Malaysian large steel mills by using multiple linear regression method. Electricity consumption depends on steel production, steel consumption, Gross Domestic Product (GDP) and electricity price. Several statistical tests these include the adjusted R^2 test, the t-test, the F-test and the Durbin-Watson test are used to validate the model. The significance of the variables was evaluated at 95% level of confidence. For modeling and forecasting electricity consumption Aman et al[10] worked on two functional data techniques, functional analysis of variance (FANOVA) and functional autoregressive (FAR) model. The FANOVA analysis is useful for studying the seasonal patterns of consumption and the FAR analysis is shown to improve univariate forecasts.

3. MODELING ELECTRICITY CONSUMPTION

3.1 Data Description

A series of monthly electricity consumption (EC) of Pakistan in million kilo watt hour (kwh), January 1990 through December 2011, has been used in this study (figure 1). The data were recorded by Department of Federal Bureau of Statistics, Pakistan. It consists of electricity consumption in all economic sectors (industrial, residential, and commercial) of Pakistan, because regional or sectoral disaggregated data were not available.

3.2 Forecast Accuracy Measurement

In previous studies, different criteria are used for evaluating the accuracy of time series forecasting. Let consider $f_{t,s}$ as the forecast made at time 't' for 's' steps ahead and y_{t+s} as the realised value of 'y' at time $t+s$. Here, the Mean Absolute Percentage Error (MAPE) is used to check the forecasting performance of the models. Mean Absolute Percentage Error (MAPE) is defined as;

$$MAPE = 100 \times \frac{1}{N} \sum_{t=1}^{N} \left| \frac{y_{t+s} - f_{t,s}}{y_{t+s}} \right| \quad (1)$$

Where 'N' shows total number of values in the data.

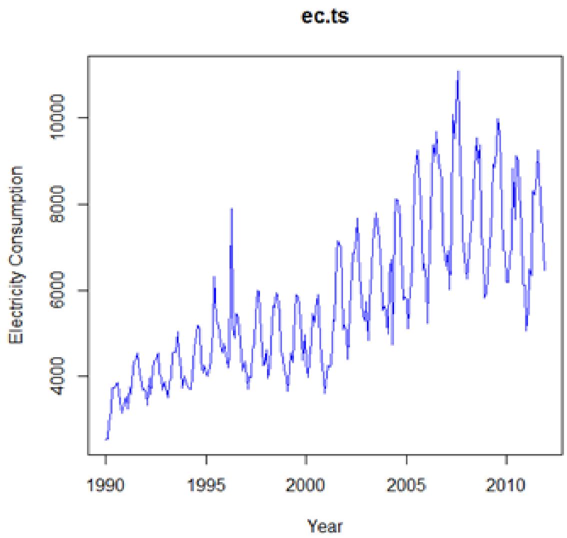

Figure 1: Monthly electricity consumption in Pakistan (million kwh) from January 1990 through December 2011.

3.3 Functional Data Analysis (FDA)

FDA provides information about surfaces, curves varying over time or a continuum. For example, measurements of electricity consumption over time and measurements of the weights of children over a wide range of ages. The analysis of such type of data is called functional data analysis (FDA). The ultimate goal of the analysis of functional data is the same as those of the most conventional statistics: to formulate the problem; to develop ways of presenting the data; to investigate variability; to build models and forecasting.

FDA is infinite-dimensional, an important factor distinguishing it from the multivariate vector case is smoothness (Hall et al[11]). Functional data analysis is a branch of statistics concerned with analyzing data in the form of functions.

3.4 Functional Time Series (FTS) Modeling

Hyndman and Ullah [12], Erbas et al [13] and Yasmeen et al [14] used functional time series (FTS) for forecasting purposes. In recent times, functional time series models have been applied for demographic forecasting and for mortality forecasting. Also these models are used in forecasting the mortality rates of chronic diseases such as breast cancer. The reader is referred to [15-17] for more applications of FTS models.

Using an FTS model, the interest lies in forecasting a series of functional data observed over time. The functions are observed (with error) at times $t = 1, 2, \ldots\ldots, m$ and we wish to forecast the functions for time $t = m+1, m+2, \quad m$. Let $[g_t(x_j)]$ denote the observed data, where $j = 1,2, \ldots\ldots p$. We assume that there are underlying L_1 continuous and smooth functions [f_t (x)] such that:

$$g_t(x_j) = f_t(x_j) + \delta_t(x_j)e_{t,j} \qquad (2)$$

where [$e_{t,j}$] are independent and identically distributed variables with zero mean and unit variance, and $\delta_t(x_j)$ allows for heteroskedasticity.

The FTS technique of Hyndman and Ullah [12] uses nonparametric smoothing on each curve $g_t(x)$ separately to obtain estimates of the smooth functions $[f_t(x)]$. Panelized regression splines are used for smoothing, and then a functional principal component approach is used to decompose the time series of functional data into a number of principal components and their scores.

The functional time series (FTS) model can be written as follows:

$$f_t(x) = \mu(x) + \sum_{k=1}^{K} \alpha_{t,k}\psi_k(x) + e_t(x) \qquad (3)$$

where $\psi_k(x)$ is the k^{th} principal component, the set of coefficients $[\alpha_{1,k,}, \alpha_{2,k,} \ldots\ldots\ldots, \alpha_{m,k,}]$ are the corresponding scores, $e_t(x)$ denote independent and identically distributed random functions with zero mean, and $k < m$ is the number of principle components to be used.

The h-step-ahead Forecasts

The h-step-ahead forecasts of $Y_{n+h}(x)$ can be obtained as:

$$\hat{Y}_{n+h/n} = \hat{f}(x) + \sum_{k=1}^{K} \hat{\alpha}_{n+h/(n,j)}\, \hat{\psi}_k(x) + e_t$$

Where $\hat{\alpha}_{n+h/(n,j)}$ shows the h-step-ahead forecasts of $\alpha_{n+h/(n,j)}$ using univariate time series and $\hat{\psi}_k(x)$are the estimated basis function, obtained by functional principal component analysis. The reader is referred to Hundman and Ullah [12] for detailed description of the method.

4. RESULTS

Figure 2 depicts the electricity consumption series in the form of sliced functional time series. The entire series of Figure 1 is sliced/divided into a number of curves, each corresponds to a year (22 curves in total). The curves are represented in the rainbow order, i.e red for the early year (1990) and violet for the most recent year (2010).

Next, a functional time series model is applied to these curves. The mean function and the components of FTS model are plotted in figure 3. The plot shows that on the average, the values are higher for August for each year. The first function shows that the months July and August are more responsible for the variation and their forecast shows increasing trend in future. Next function represent the month April and it forecasts shows steady behavior. Other functions and their forecasts are not presented here, as their functions are more complicated and relatively less important.

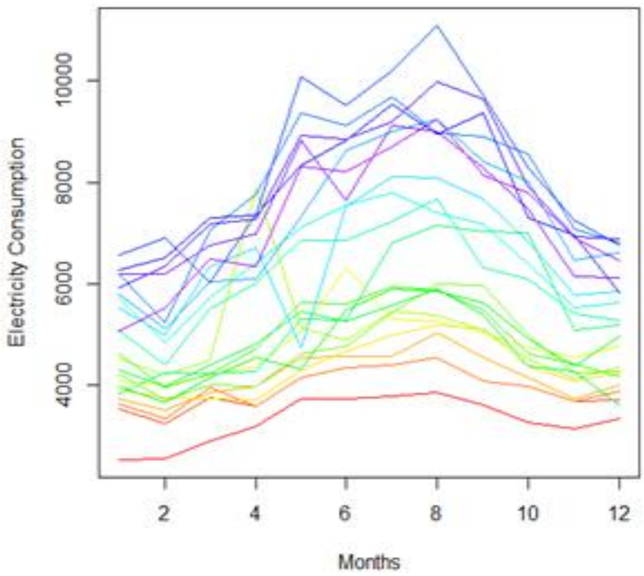

Figure2: Monthly Electricity Consumption Series as Sliced Functional Time Series. The years are plotted in rainbow order, with earlier year (1990) is represented by red, whereas the most recent year (2010) is represented by violet colour.

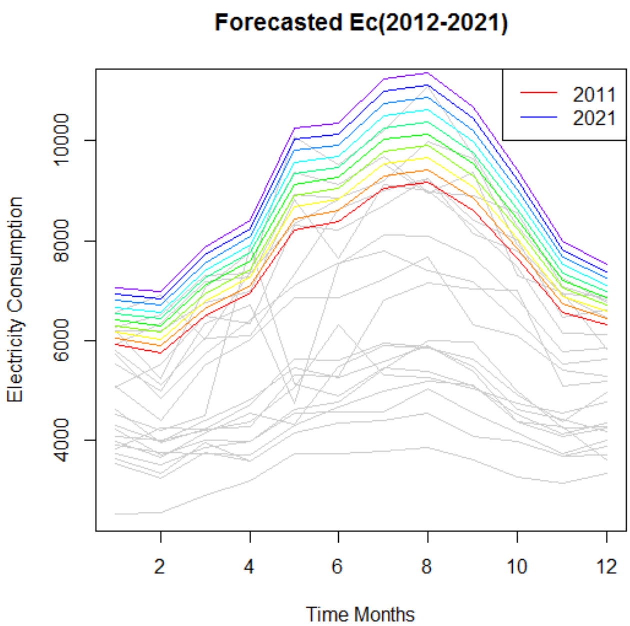

Figure 4: Forecasts for 2011 and 2021 using FTS Model

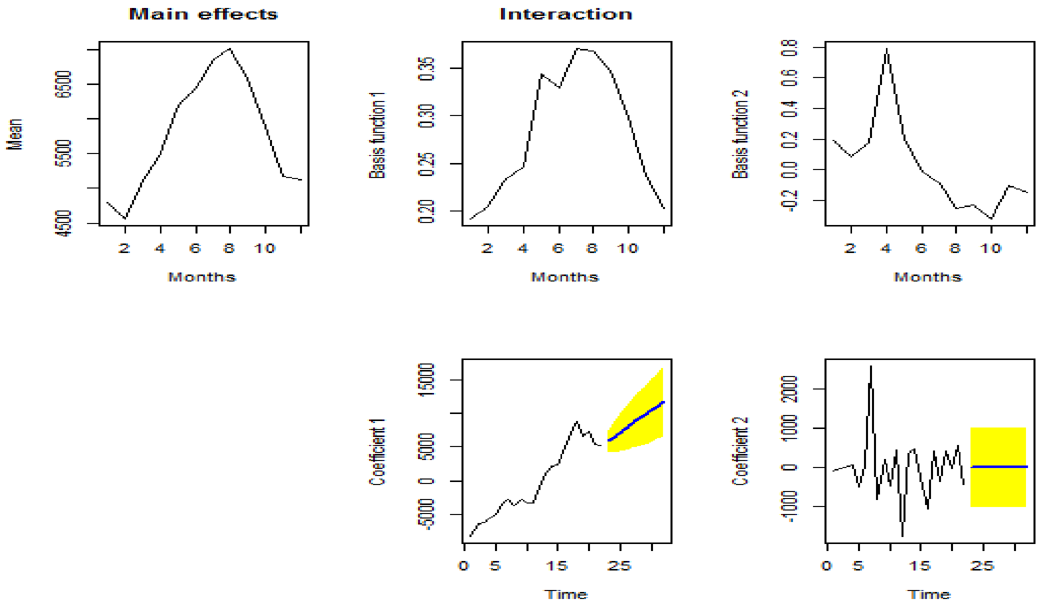

Figure3: Different components of FTS Model for electricity consumption series, the mean component $\mu(x)$ and the first two basis functions are plotted on the top panel, whereas the first two time series coefficients, along with their forecasts and 80% prediction intervals are plotted at the bottom.

Forecasts for 2011 and 2021 are plotted in Figure 4. This graph shows that future consumption will be relatively lower in the months of January till April, then higher in the months of May, June and July. The most highest values correspond to the month August for each year. After that, the values will start to decline till December. Again, the rainbow colors are used to represent the forecasts with red color is used for the early year (2011) and violet color is used for the year (2021).

5. CONCLUSION

In this paper, the monthly electricity consumption in Pakistan is analyzed and 10-year forecasts (January 2012-December 2021) are obtained using functional time series (FTS) models. The continuously rise in demand of electricity in the country indicates the importance and need of more electricity production in future. The monthly behavior of forecast values illustrate that the electricity consumption is more for summer season and this demand will be highest (11281 million kwh) in August 2021. The average consumption in future will be at least 8229 million kwh. Forecast model and the forecast plot describe that the electricity consumption is continuously increasing with the passage of time. The growing energy consumption in the country may be due to economic growth, urbanization process in the region, population growth and industrialization.

To balance the demand and supply of electricity in future, the government of Pakistan must take effective steps. They include launching different types of energy projects, building dams and using solar energy, hydel power and atomic energy to restore the economical status of the country.

6. REFERENCES

[1] Ali, M, Iqbal, J.M. and Sharif, M. 2013, Relationship between extreme temperature and electricity demand in Pakistan, International Journal of Energy and Environmental Engineering (IEEE), pages 4-36.

[2] Khan, A.M., Ahmed, U. 2009, Energy Demand in Pakistan: A Disaggregate analysis, Pakistan Institute of Development Economics, Islamabad. Available at athttp://mpra.ub.uni- muenchen.de/15056.

[3] Khan, M.A. and Qayyum, A. 2009, The Demand for Electricity in Pakistan. OPEC Energy Review, pages 70-96.

[4] Alter,N. and Shabib, H.S. 2011, An Empirical Analysis of Electricity Demand in Pakistan" International Journal of Energy Economics and Policy 1(4), 2011, pages 116-139 ISSN: 2146-4553.

[5] Zachariadis,T. and Pashourtidou,N. 2006, An Empirical Analysis of Electricity Consumption in Cyprus, Economics Research Centre University of Cyprus, Discussion Paper .

[6] Zahang.G.,Patuwo,E.B. and Hu,Y.M. 1998, Forecasting with artificial neural networks:The state of the art",International Journal of Forecasting Vol.14 , pages 435–62 .

[7] Granger,C.W.J. 1993, Strategies for modelling nonlinear time series relationships, The Economic Record 69 (206), pages 233–238.

[8] Yasmeen, F. and Sharif, M. 2014, Forecasting Electricity Consumption for Pakistan, International Journal of Emerging Technology and Advanced Engineering (IJETAE) 4(4).

[9] Mati,A.A.,Eng,M.,Gajoga,G.B.,Jimoh,B.,Adegobye,A. and Dajab,D.D. 2009, Electricity Demand Forecasting in Nigeria using Time Series Model, The Pacific Journal of Science and Technology 10(2). pages 479- 485.

[10] Aman,S., Ping,W.H. and Mubin,M. 2011, Modelling and forecasting electricity consumption of Malaysian large steel mills, Scientific Research and Essays 6(8), pages 1817-1830.

[11] Hall,P.B., Muller,G.H. and Wang,L.J .2006, Properties of Principal Component Methods For Functional and Longitudinal Analysis, Institute of Mathematical Statistics, The Annals of Statistics, Vol. 34(3), pages 1493–1517.

[12] Hyndman, R.J. and Ullah, M. S. 2007, Robust forecasting of mortality and fertility rates: A functional data approach, Computational Statistics & Data Analysis 51 , 4942 – 4956.

[13] Erbas, B., Hyndman, R.J and Gertig, D.M., 2007, Forecasting age-specific breast cancer mortality using functional data models, Statistics in Medicine 26, 458-470.

[14] Yasmeen, F., Hyndman, R. J. and Erbas, B. 2010, Forecasting age-related changes in breast cancer mortality among white and black US women: A functional data approach, Cancer Epidemiology 34(5), pages 54F.

[15] Yasmeen, F. and Zaheer, S. 2014. Functional time series models to estimate future age-specific breast cancer incidence rates for women in Karachi, Pakistan, Journal of Health Science, 2 David Publishing Company, pages 213-221.

[16] Yasmeen,,F and Mughal, S. 2014, Functional Time Series Models and t.he APC models: A comparative study on the lung cancer incidence rates in Denmark Journal of US-China Medical Science, David Publishing Company, 11 (3) pages. 121-128

[17] Yasmeen,F. Fatima, H. and Mahmood, Z. 2014, An FDA approach to forecast age-specific fertility rates of Pakistan region-wise, Computer Science and Applications, Ethan Publishing Company 1(6) pages. 341-348 www. ethanpublishing.com