Univariate Time Series Forecasting of Monthly Peak Demand of Electricity in Haryana

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Abstract

Electricity being the most commonly used form of primary energy is a matter of prime concern. Today, it is one of the critical ingredients of socio-economic development of modern society. Its' uses all over the world are being augmented by leap and frog. The unique feature of electricity is that it can not be stored for future use. Its generation, transmission and distribution have to be simultaneous and instantaneous. This unique feature of electricity as a commodity or service makes the dynamics of its demand and supply very complex to manage. Moreover, there have been significant seasonal and diurnal variations of demand. Therefore, its precise and accurate forecasting is a great challenge for the planners so that they may be able to deploy the existing facilities in an optimum way as well as arranging new infrastructure in advance. The present paper considers three techniques namely- ordinary least square, auto regressive integrated moving average and exponential smoothing to forecast the monthly peak demand for electricity in Haryana. This uses the data for the time span January 1998 to December 2008. Considering different criteria such as root mean square error, mean square error and mean absolute percentage error, paper concludes that ARIMA (0,1,3) $(1,0,0)^{12}$ reveals much better forecasts than remaining two techniques. Finally, this suggests that in the present circumstances planners in Haryana could use linear univariate time series models to predict future peak demand for electricity. However, they may go for any other superior forecasting method if meet with detailed data on various socio-economic variables.

1.0 Introduction

Electricity is the basic building block of socio-economic development. Today, a nation's ability to register robust economic growth can crucially be affected due to inadequate supply of electricity. For many sectors like manufacturing and agriculture sector, electricity is the most critical input which in turn facilitates the use of other factors of production. Therefore, adequate availability of quality and reliable electricity is the crying need of hour. At present, demand for electricity is increasing rapidly, particularly in the developing countries. This increasing demand needs to be assessed properly to have a proper planning for this key infrastructure, so that the desired growth rate can be achieved in an effective manner.

The nature of electricity differs from that of other commodities since electricity is a non-storable good and there have been significant seasonal and diurnal variations of demand. Under such conditions, precise forecasting of demand for electricity must be an integral part of planning process as it enables the planners to provide directions on cost-effective investment and on scheduling the operation of the existing and new power plants so that the supply of electricity can be made adequate enough to meet the future demand and its fluctuations. Typically, demand forecasting can be long term, medium term and short term depending upon the purpose of forecasting.

One of the realities that plague Indian power sector is that electricity demand has seldom been scientifically estimated. The basic reasons for this are poor data management by State Electricity Boards (Chattopadhyay, 2004) and inappropriate techniques for forecasting demands. Central Electricity Authority, India (CEA), in its 16th Electric Power Survey (EPS), used trend method to forecast demands for different consumer categories. Sixteenth EPS also forecasted state-wise and all India level peak load demand on yearly basis.

Forecasts made by CEA have found to be overestimated demand. No reviews were made till the next forecast (five years later). No attempt was made there to estimate demand elasticities and the likely effect of more remunerative tariffs to suppliers and the control of theft and subsidies (Rao, 2002). Besides, there has not been any monthly demand forecasting that is very important for maintenance planning and fuel scheduling.

In this study, an attempt has been made to forecast monthly demand for electricity in Haryana using three benchmarks namely- ARIMA, OLS and exponential smoothing. A sample size for the time span January 1998 to December 2008 has been considered. The main objective is to compare the accuracy of these models. Utilizing several performance criteria such as root mean square error (RMSE), mean square error (MSE) and mean absolute percentage error (MAPE), the forecasting performance of these three models is compared and finally the best one is identified. This will help the policy makers in Haryana, on making investment decisions and on scheduling the operation of the existing and new power plants so that the supply of electricity can be made adequate enough to meet the future demand and its variations in a cost effective manner.

Forecasting the demand for electricity in Haryana appears to be very important as, a robust forecast of electricity demand is necessary; as over estimation of demand could result in unnecessary huge investments in electric generations and transmission assets. Such a result would create more financial burdens in a state like Haryana that is already struggling financially and under a heavy debt of over Rs.10,000 crores (Statistical abstracts of Haryana, 2009). Alternatively, under estimation of the demand for electricity would lead to further future shortage of supply of electricity, a situation from which Haryana has already been suffering. It is very important, therefore, to select an appropriate demand estimation model that will provide precise estimates of future demand of electricity in Haryana.

The rest of paper is organized as follows. In section-2, we review the literature on various techniques of forecasting the demand for electricity. Section-3 describes the data used in the study. Section-4 presents the econometric methodology used in the study. Results obtained from different models are also shown the same section. Finally, section-5 contains the comparative analysis of different techniques and concluding remarks.

2.0 Review of Literature

Many studies in the literature have examined electrical energy consumption forecast and related topics, [Bernard et al., 1996; Hsing, 1994; Al-Faris, 2002; Nasr et al., 2000], among others, estimated demand for electricity for various countries using different modeling techniques. Most such studies have investigated the impact of real income, price of electricity, price of substitute source of energy, population, temperature and other related variables, on the consumption of electricity.

Houri and Korfali (2005) used a sample of 509 households in Lebanon to study the residential energy consumption patterns in the country in relation to income, price, area of residency and number of occupants. Nasr and Badr (2000) investigated the determinants of electricity consumption (Imports and Degree Days) in Lebanon for the period 1993-1997. Co integration analysis for the two sub-periods 1995-97 and 1996-97 revealed the existence of a long run relationship between the variables.

In another study, Bader and Nasr (2001) investigated co integrating relationship between electricity consumption and climate factors, temperature, relative humidity and clearness index for the period 1992 – 1999. Saab and Badr (2001) used three univariate models namely autoregressive (AR), autoregressive moving average (ARMA) and an AR (1)/high pass Filter model to forecast electricity consumption in Lebanon using sample size Jan 1990 – May 1999. The study finds that the AR (1)/high pass Filter model produced the best forecast.

According to Chow and Leung (1996) & Taylor and Buizza (2003), weather related variation is critical in predicting electricity demand. There are many studies which show that the stochastic nature of demand as a function of time has frequently been modeled with seasonal ARIMA. According to Infield and Hill (1998), seasonal ARIMA is the most attractive model due to greater performance and computational efficiency. Studies made by Abraham and Nath (2001) and Charytoniuk and chen (1998) advocate the superiority of general exponential smoothing methods as small number of parameters are required with this approach.

This review has enabled the researcher to understand the various variables of electricity demand and the methods to be used in predicting the demand.

3.0 Description of Data Used

The study uses the monthly data for Haryana covering the period January 1998 to December 2008. Monthly electricity consumption figures (in MWH) were obtained from the reports of various utilities including Haryana Power Genartion Corporation Limited (HPGCL), Haryana Vidyut Prasaran Nigam Limited (HVPNL) and Haryana Electricity Regulatory Commission (HERC) for different years. Due to unavailability of monthly data on GDP or index of industrial production (IIP), monthly expenditure made on purchases and imports, as a proxy of economic activity, were collected from the various monthly statistical abstracts of government of Haryana.

According to Nasr, Badr and Dibeh (2000), expenditure made on purchases and imports is a good proxy of GDP. These figures were then deflated using monthly CPI figures obtained from Reserve Bank of India (RBI) to show real purchases/ imports. Given the unavailability of data for an index of import prices, this was regarded as a good proxy. Relative humidity figures for the same time span are taken from various issues of the statistics bulletins of metrological agency.

Finally, data for degree days were calculated from temperatures figures for Chandigarh's (Capital) airport which were obtained from the office of the Directorate General of Civil Aviation. The concept of degree days is used to evaluate energy demand for cooling and heating services as it measures of the average temperature's departure from a human comfort level .Using a base temperature of 31.2°C, heating degree days (HDDs) are defined as 31.2 – T, where T is the average temperature of a given day. Cooling degree days (CDDs) are calculated in a similar fashion with a base of 18.6. DD figures are then calculated as the sum of HDD and CDD.

4.0 Econometric Methodology Used

4.1 Regression Analysis

Firstly, demand for electricity in Haryana is estimated using ordinary least square (OLS) technique, where electricity consumption has been regressed on real purchase/import, relative humidity and monthly degree-days. The regression equation can be written as;

$$E_t = a + bI_t + cH_t + d\,DD_t + u_t \quad \text{———— (1)}$$

Where E_t, I_t, H_t and DD_t are electricity consumption, real import, relative humidity and degree-days respectively at time t and u_t is the error term. a, b, c, d are the parameters to be estimated. The Durbin-Watson D-W test is used to check for serial correlation of the error terms. A first order autoregressive term can be added as a correction measure, in case of rejection of the null hypothesis of no serial correlation that can be represented as

$$u_t = ru_{t-1} + e_t \quad \text{———— (2)}$$

In Eq. 2, u represents the unconditional residuals, e is the innovation in the disturbance and r is an estimate of the first-order autocorrelation coefficient. Results of the regression analysis are shown in Table 1. t-statistics show that all the explanatory variables are statistically significant at 10% level. We have introduced AR (1) term in order to get rid of serial correlation and is found to be statistically significant.

Table- 1. Summary of Regression Analysis

Variable	*Coefficient*	*Std. error*	*t-statistics*	*Prob.*
C	356.188	90.2356	4.9658	0.0000*
I	0.19856	0.0689	2.4598	0.0120*
H	2.7956	0.8965	2.7854	0.0049*
DD	0.1256	0.0698	1.7589	0.0589
AR (1)	0.75468	0.0295	23.5684	0.0000*
R- squared		0.82308	**AIC**	10.0956
Adjusted R-squared		0.81742	**SBC**	10.2284
Durbin Watson stat		2.2456	**F- stat**	145.236

Source: Self computed. *statistically significant at 10% level of significance.

4.2 Univariate Time-Series Forecasting: To take into account the effect of trend and seasonal fluctuations of a time series; general multiplicative seasonal model i.e. ARIMA (p, d, q) $(P, D, Q)_s$ model is considered. It can be expressed as-

$$Ö_p(L^S)\,\varnothing_p(L)\,(1-L^s)^D(1-L)^d X_t = È_Q(L^s)\,è_q(L)\,u_t \quad \text{———— (3)}$$

Where X_t is the original series, L is the backward shift operator, ∅ and θ are autoregressive (AR) and moving average (MA) parameters while Φ and È are seasonal AR and MA parameters. D & d represent order of seasonal and non-seasonal differencing.

In order to identify the most appropriate ARIMA model, Box–Jenkins methodology has been exploited which considers model building as an iterative process to be separated into four stages: identification, estimation, diagnostic checking and forecasting.

The sample autocorrelation function and partial autocorrelation function have been used to identify the possible values of the regular part of the model, i.e., autoregressive order p and moving average order q in a univariate ARMA model along with the seasonal part, which has then been estimated by maximum likelihood. The residuals are inspected for any remaining autocorrelation and as shown in Table 2, the residual series appears to be purely random.

Table-2. Confirmatory for Randomness of Residual Series

Lag	*AC*	*PAC*	*Q-stat*	*Prob.*
5	0	0.002	0.4789	0.475
6	0.08	0.089	1.4956	0.470
7	0.13	0.126	3.2956	0.325
8	0.017	0.024	3.2546	0.489
9	0.069	0.079	4.0547	0.534
10	0.091	0.092	5.1463	0.513
11	-0.014	-0.018	5.2345	0.623
12	-0.141	-0.135	7.8456	0.398
13	0.059	0.0215	8.4568	0.501
14	0.036	-0.002	8.5016	0.620

Source: Self computed

It has been found that ARIMA $(0, 1, 3)(1, 0, 0)^{12}$ is the best fitted model in terms of smallest Akike Information Criterion (AIC) and Schwarz Bayesiam Criterion (SBC) to explain the electricity consumption in Haryana. The estimated parameters with their standard error, t statistics and probability values are summarised in table 3.

Table-3. Estimated Parameters of ARIMA $(0,1,3)(1,0,0)^{12}$ model

Variable	*Coefficient*	*Std. error*	*t-statistic*	*Prob.*
SAR (12)	0.5743	0.03765	11.3452	0.0005*
MA (1)	-0.3987	0.07297	-3.9851	0.0003*
MA (2)	-0.2987	0.08087	-3.4875	0.0039*
MA (3)	-0.1934	0.09087	-1.8740	0.0246*
AIC	**9.61**			
SBC	**10.19**			
DW-statistics	**1.98**			

Source: Self computed. *significant at 10% level of significance.

4.3 Exponential Smoothing: Exponential smoothing methods are relatively simple but robust approaches to forecasting. Three basic variations of exponential smoothing are commonly used: simple exponential smoothing (Brown, 1959); trend-corrected exponential smoothing (Holt, 1957); and Holt–Winters' method (Winters', 1960). In this study, Holt-Winters-Multiplicative method has been considered as this method is appropriate for series with a linear time trend and seasonal variations. The smoothed series is given by

$$\hat{x}_{t+k} = (a + bk)c_{t+k} \qquad (4)$$

Where a,b and c are intercept, trend and multiplicative seasonal coefficients, which are defined as following -

$$a(t) = \alpha \frac{y_t}{c_t(t-s)} + (1-\alpha)(a(t-1) + b(t-1))$$

$$b(t) = \beta(a(t) - a(t-1)) + (1-\beta)b(t-1)$$

$$c_t(t) = \gamma \frac{y_t}{a(t)} + (1-\gamma)c_t(t-s)$$

Where 0<α, β, γ<1 are dumping factors and s is the seasonal frequency. Forecasts are computed by-

$$\hat{x}_{T+k} = [a(T) + b(T)k]c_{T+k-s} \qquad (5)$$

Results of the smoothing procedure are shown in Table 4. Part 1 shows the estimated parameter values. Zero values for â and ã mean that the trend and seasonal components are estimated as fixed and not changing. Part 2 of the table displays the mean (á) and trend (â) at the end of estimation period that are used for post-sample smoothed forecasts along with seasonal factors (ã).

Table- 4. Results of smoothing process

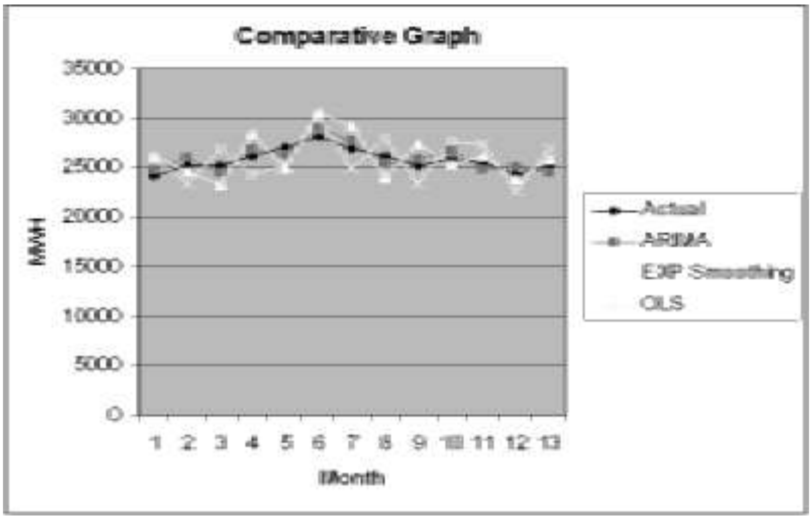
	á		0.69
	â		0
Part-1:	ã		0
	Mean		798.2587
	Trend		4.13859
	Seasonals:	2006M12	0.09874
		2007M01	1.08760
		2007M02	0.95439
		2007M03	1.09682
		2007M04	0.87371
Part-2:		2007M05	0.91437
		2007M06	0.98143
		2007M07	1.07853
		2007M08	1.08346
		2007M09	0.89542
		2007M10	0.91693
		2007M11	1.00785

Source: Self computed

5.0 Comparison of Models and Conclusion

In order to compare all three techniques/ models in terms of their ability to make an accurate forecast for the demand for electricity, in-sample forecasts of electricity consumption calculated by these techniques along with actual consumption data ranging from December 2007 to December 2008 have been plotted on a graph as shown.

It has been found that in-sample forecasts made by ARIMA $(0, .1, 3)(1, 0, 0)^{12}$ is superior in terms of smallest RMSE criteria (39.05) followed by exponential smoothing (RMSE = 53.26) and OLS (RMSE = 78.19). Other diagnostic criteria like AIC, SBE etc. also indicate the superiority of ARIMA model.



Conclusion: To meet the consumer's demand for electricity timely and effectively, a precise and accurate forecasting is imperative. This issue becomes more significant in Haryana where most of the revenues are generated by agricultural and secondary sector which electricity is a critical input for. The present study considers three models namely-ARIMA, OLS and exponential smoothing to forecast the demand for electricity in Haryana, utilizing monthly data from January 1998 to December 2008. Such an investigation seems to be useful to provide an accurate, robust and understandable forecast for electricity demand in the state. In-sample forecasts reveal that the forecasts made by ARIMA (0,1,3) $(1,0,0)^{12}$ is superior in terms of lowest RMSE, MSE and MAPE criteria, followed by exponential smoothing and the OLS. The results produced are satisfactory given the unavailability of data on the price of electricity, real GDP and price of substitute source of energy. Therefore, the policy makers in Haryana could utilize linear univariate time-series models for forecasting future peak demand of electricity until detailed data on various socio-economic variables are available.

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