Time Series Modelling approach for forecasting Electricity Demand in Sri Lanka

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Abstract— *Both of the electricity production and consumption are playing a significant role in their national economy. To forecast the efficient electricity production and consumption in Sri Lanka, the current study is proposed a systematic and iterative methodology based on the time series modelling approach. Furthermore, the proposed methodology was successfully applied to the data related to the gross electricity generation and total electricity usage in Sri Lanka over the past fifty years from the year 1970 to 2014.*

The Box-Jenkins and Autoregressive Integrated Moving Average (ARIMA) based empirical results suggested that ARIMA (3, 1, 1) and ARIMA (1, 1, 1) are suitable and more appropriate for predicting the future demands of electricity in Sri Lanka.

Keywords—**Box-Jenkins, ARIMA, MAPE, Electricity Production, Electricity Consumption, Forecast, Sri Lanka**

I. INTRODUCTION

Both of the electricity production and consumption are playing a significant role in goods and services. According to the literature, different types of factors are directly affected on the electricity demand of the country. Some of them are; the growing populations, extensive urbanization, industrialization of economies and increasingly greater use of electrical appliances in daily life have been contributed directly to increase the electricity demands.

Generally, the electricity demand in Sri Lanka is fulfilled based on the three primary sources. They are; thermal power (which includes energy from biomass, coal, and all other fuel-oil sources), hydro-power (including small hydro), and other non-conventional renewable energy sources (solar power and wind power) (CEB Statistics). According to financial reports in 2014, the total electricity generation and total electricity consumption in Sri Lanka is over the 12848.88 GWh (Giga Watts per hour) and 10996.92 GWh respectively, whereas those for the year 1970 is, 785.7 GWh and 619.51 GWh respectively (CEB Statistics, 2014). Furthermore, the statistics suggested that, both of the total electricity generation and total electricity consumption have been increasing rapidly. As a result of these circumstances, forecasting efficient electricity production and consumption in Sri Lanka is playing a significant for their future development.

According to the literature, studies related to the electricity production and consumptions are extremely limited. Furthermore, most of the available studies also have done based on the foreign literature. The study by Amarawickrama and Hunt (Amarawickrama & Hunt, 2007) estimated electricity demand functions for Sri Lanka using six econometric techniques. By upgrading Amarawickrama & Hunt (2007) methodology, Silva & Samaliarachchi carried out a different study to identify sensitive elements which affect the daily peak demand of Sri Lanka power systems. According to their findings, they developed two forecasting models, based on the multiple linear regression and feed-forward Artificial Neural Network to estimate demands of Sri Lanka from the year 2008 to 2011. The empirical findings with the lowest Mean Absolute Percentage Error (MAPE) concluded that an Artificial Neural Network model is the best fit model for predicting daily peak demand of Sri Lankan power system (Silva & Samaliarachchi, 2013).

In the same period of time, Cooray & Peiris developed a state space based on structural time (SSST) series model to forecast day and night peak values of electricity demand in Sri Lanka for week-days and week-ends (Cooray & Peiris, 2012). In an another study, Dissanayake & Perera fitted an Autoregressive Integrated Moving Average (ARIMA) model to forecast for future domestic electricity demand for Sri Lanka by using quarterly data of Electricity demand from 1997 to 2013 (Dissanayake & Perera, 2013).

According to the foreign literatures which are related to electricity demand, production and consumption, Makukule et.al contribution is significant. They have investigated the impact of day of the week, holidays and other seasonal effects on daily electricity demand in South Africa for the period 2001 to 2009 (Makukule, Sigauke, & Lesaoana, 2012). In the same period of time, Yasmeen & Sharif, used ARIMA, SARIMA, and ARCH/GARCH models to evaluate the monthly electricity consumption in Pakistan for the period of January 1990 through December 2011 and concluded that, ARIMA (3,1,2) model is the most appropriate model to forecast electricity consumption in Pakistan (Yasmeen & Sharif, 2014). In 2009, Abosedra et.al (2009) estimated the demand for electricity in Lebanon by employing three modeling techniques namely OLS, ARIMA and exponential smoothing for the time span January 1995 to December 2005. The empirical findings with respect to the lowest RMSE, MSE and MAPE criteria of this study suggested that, the ARIMA (0,1,3) (1,0,0)12 is superior for forecasting under the unstable manner (Abosedra, Dah, & Ghosh, 2009). Kandananond (2011) carried out a same type of study and utilized different forecasting methods such as ARIMA, ANN and multiple linear regressions to formulate prediction models of the electricity demand in Thailand. Based on these error measures they found that, the ANN approach outperformed the ARIMA and MLR methods (Kandananond, 2011, Seneviratna et.al, 2013).

The current study focuses on analyzing and forecasting the efficient electricity production and consumption in Sri Lanka over the past 50 years' worth of data. The rest of the paper is organized as follows: Section II explains about the brief overview of the methodologies. Sections III analyze and compare Sri Lankan electricity consumption results and section IV end up with the conclusion and future work.

II. MATERIALS AND METHODS

The Demand for electricity exceeds its supply which is called epileptic problem facing by most of the developing countries including Sri Lanka. The average rate of electricity demand for Sri Lanka has gone over 6.7% last three decades. According to the financial reports in 2015, so many modifications have been done in Sri Lankan energy production. Data for this study was extracted from the database of Sri Lanka Sustainable Energy Authority ("Sri Lanka Energy Balance"); especially, Gross Electricity Generation (GWh) and Total Electricity Use in Sri Lanka (GWh) from the year 1970 to 2014 were considered.

A. Data pre-processing and stationary/non-stationary checking

As an initial step, stationary and non-stationary conditions were measured based on three different unit root statistics, namely, Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski – Phillips – Schmidt - Shin (KPSS) test statistics. If series not stationary then regular differencing will be applied.

B. Time series methods of forecasting

The Autoregressive integrated moving average (ARIMA) models have been successfully applied today in wide areas for predicting future movements of non-stationary data patterns. ARIMA model is a generalization of an Autoregressive moving average model. Basically, it consists three parts (Rathnayaka et.al, 2014, Rathnayaka et.al, 2015, Seneviratna et.al, 2013). They are; the auto regressive parameter (p), the number of differencing passes (d) and moving average parameter (q). The moving average process and the auto regressive process can be written as follows. The autoregressive process of order p is denoted AR (p), and defined by

$$X_t = \sum_{r=1}^{p} \varphi_r X_{t-r} + \varepsilon_t \qquad (1)$$

Where $\phi 1$. …. ϕr are fixed constants and {εt} is a sequence of independent (or uncorrelated) random variables with mean 0 and variance $\sigma 2$. The moving average process of order q is denoted MA (q) and defined by

$$X_t = \sum_{s=0}^{q} \theta_s €_{t-s} \qquad (2)$$

Where $\theta 1. . . \theta q$ are fixed constants, $\theta 0 = 1$, and {€t} is a sequence of independent (or uncorrelated) random variables with mean 0 and variance $\sigma 2$.

If we combine differencing with auto regression and a moving average model, we obtain a non-seasonal ARIMA model. The full model can be written as

$$X'_t = \sum_{s=0}^{q} \theta_s €_{t-s} + \sum_{r=1}^{p} \varphi_r X'_{t-r} + \varepsilon_t \qquad (3)$$

Where X'_t is differenced series.

The methodology of this study is carried under the three main phases as follows. They are; data analysis, model identification and model validation and forecasting; especially, for, Box Jenkins methodology based ARIMA fitting approach is used. Furthermore, the best model is selected by using Akaike Information Criterion (AIC) value and Schwarz's Bayesian Information Criterion (SBC) value (Rathnayaka et.al, 2016, Rathnayaka et.al, 2014).

C. Time series methods of forecasting

As a next step, the diagnostic checks are performed on the residuals to see if they are randomly and normally distributed. Furthermore to check the normality of results, the Jarque-Bera test and Heteroskedasticity ARCH test were used.

If the residuals series of selected model passed diagnostic checking, then the model could be used in predicting future values. The accuracy of forecast error of fitted model is measured by MAPE (mean absolute percentage error). The mean absolute percentage error is given by:

$$\text{MAPE} = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{e_t}{y_t}\right| \times 100 \quad (4)$$

III. RESULTS AND DISCUSSION

As an initial step, stationary conditions of both electricity consumption and electricity production were measured using Unit Root test methods named ADF and PP tests and Schwarz Info Criterion as the selection criteria. The estimated results are presented in Table 1 as follows.

Table 1: Test results of unit root test

Data Set	Level Data		First Differenced Data	
	ADF Test	PP Test	ADF Test	PP Test
Electricity Production	1.0000	1.0000	0.0002	0.0002
Electricity Consumption	1.0000	1.0000	0.0031	0.0036

As a result of the original data of Electricity Production and Electricity Consumption is not stationary, the first differenced data were considered. According to the Table 1 results, first differenced data of Electricity Production and Electricity Consumption were stationary under the 0.05 level of significance.

As the next step, time series plots of Electricity Consumption and Electricity Production were constructed.

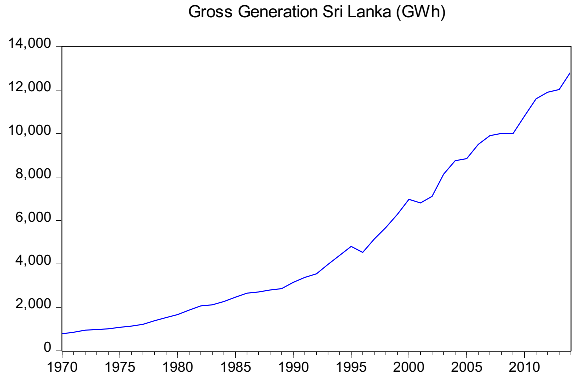

Figure 1: Electricity Production in Sri Lanaka

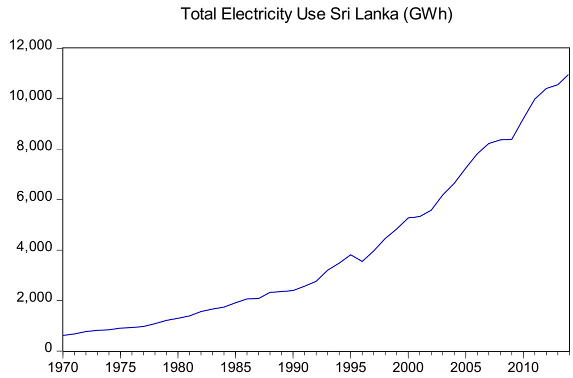

Figure 2: Electricity Consumption in Sri Lanaka

Data patterns in Figure illustrate that Electricity Production and Electricity Consumption has quadratic trend during the past 30 years. Furthermore, from year 1970 to 1995, Electricity Production and Consumption in Sri Lanka, shows a smooth quadratic trend, but after year 1995 it has slight fluctuations.

Table 2: Information criterions for various iterations of ARIMA (p,1,q) for Electricity Production

ARIMA(p,1,q)		q-(MA) 0	1	2	3
p-(AR)	0		14.542 14.623 14.572	14.559 14.680 14.604	14.586 14.748 14.646
	1	14.461 14.542 14.491	14.188 14.310 14.233	14.230 14.392 14.290	14.052 14.255 14.128
	2	14.493 14.615 14.538	14.395 14.395 14.293	14.797 14.999 14.871	14.097 14.341 14.188
	3	14.244 14.406 14.304	14.036 14.238 14.111	14.061 14.305 14.152	14.101 14.385 14.206

Table 3: Information criterions for various iterations of ARIMA (p,1,q) for Electricity Consumption

ARIMA(p,1,q)		q-(MA) 0	1	2
p-(AR)	0		14.053 14.134 14.083	13.967 14.088 14.012
	1	13.774 13.855 13.804	13.593 13.715 13.638	13.606 13.768 13.666
	2	13.793 13.915 13.838	13.621 13.783 13.681	14.266 14.469 14.341

Among the above information criterions, the models with the lowest AIC value were chosen as the most suitable models. The best model chosen for Electricity Production was an ARIMA (3,1,1) model (Table 2) and for Electricity

Consumption was an ARIMA (1,1,1) model (Table 3). The coefficients, standard errors and probabilities of parameters of the fitted models were described in Table 4 and Table 5. Since the probability value for each parameter is less than 0.05, we may conclude that the fitted models were consistent with the data for both Electricity Production and Consumption.

Table 4: Fitted ARIMA model for Electricity Production

Variable	Coefficient	Std. Error	t-Statistic	Prob.
AR(1)	0.884860	0.144372	6.129045	0.0000
AR(2)	-0.410534	0.183455	-2.237793	0.0310
AR(3)	0.513916	0.135292	3.798569	0.0005
MA(1)	-0.722975	0.129369	-5.588483	0.0000
SIGMASQ	54654.40	12365.56	4.419890	0.0001

Table 5: Fitted ARIMA model for Electricity Consumption

Variable	Coefficient	Std. Error	t-Statistic	Prob.
AR(1)	0.991153	0.029226	33.91281	0.0000
MA(1)	-0.806450	0.142199	-5.671290	0.0000
SIGMASQ	39217.12	9593.670	4.087812	0.0002

As the next stage of this study, diagnostic checking was carried out for all selected models. Jarque-Bera test was used to check normality and Heteroskedasticity ARCH test was used to check for ARCH effect. The results are shown in Table . The Jarque-Bera test results indicated that, the residuals are independently distributed. Furthermore, the Heteroskedasticity ARCH test results indicated that both models have an ARCH effect.

Table 5: Results of Jaque-Bera test and Heteroskedasticity ARCH test

Data Set	Jarque-Bera test		Heteroskedasticity ARCH test	
	Test Statistic	p-value	Test Statistic	p-value
Electricity Production	2.0669	0.3557	8.9182	0.0047
Electricity Consumption	1.9008	0.3865	5.9660	0.0190

IV. CONCLUSION AND RECOMMENDATIONS

In this paper, we developed a systematic and iterative methodology of Box-Jenkins ARIMA forecasting for Electricity Consumption and Electricity Production. After the test of stationary, we conclude that the data is stationary at first difference, E-views software is used for fitting the coefficient of the model, using graphs, statistics, ACFs and PACFs of residuals and after several iterations, the models selected are ARIMA (1,1,1) for Electricity Consumption and ARIMA (3,1,1) for Electricity Production.

The empirical results suggest that ARIMA (1,1,1) model can be used for Electricity Consumption and ARIMA (3,1,1) model can be used for Electricity Production for short term forecasting. In this study we identified that both ARIMA (3,1,1) and ARIMA (1,1,1) models has an ARCH effect, hence it can be improved in the future, by moving to a higher model, such as ARCH model, for both Electricity Production and Consumption.

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