Forecasting Hourly Electricity Demand in Egypt

Using Double Seasonal Autoregressive Integrated Moving Average Model

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***Abstract*—Egypt has faced a major problem in balancing electricity produced and electricity consumed at any time in the day. Therefore, short-term forecasts are required for controlling and scheduling of electric power system. Electricity demand series has more than one seasonal pattern. Double seasonality of the electricity demand series in many countries have considered. Double seasonality pattern of Egyptian electricity demand has not been investigated before. For the first time, different double seasonal autoregressive integrated moving average (DSARIMA) models are estimated for forecasting Egyptian electricity demand using maximum likelihood method. $\boldsymbol{DSARIMA}\ (\mathbf{3,0,1})\ (\mathbf{1,\ 1,\ 1})_{\mathbf{24}}\ (\mathbf{2,\ 1,3})_{\mathbf{168}}$ model is selected based on Schwartz Bayesian Criterion (SBC). In addition, empirical results indicated the accuracy of the forecasts produced by this model for different time horizon.**

Keywords-multiple seasonality pattern; post-sample forecasts; Double Seasonal ARIMA models.

I. Introduction

Electricity is one of the ordinary life necessities, and a major driving force for economic growth and development. The unstorable nature of electricity means that the supply of electricity must be always available to satisfy the growing demand. Therefore, electricity utilities throughout the world have given a remarkable interest for forecasting electricity demand. Decision makers around the world widely use energy demand forecasting as one of the most important policy making tools. An accurate hourly demand forecasting up to one day ahead is a vital process in electricity industry planning. It is critical for nations in order to balance electricity produced and electricity consumed at any time in the day, to increase the reliability of power supply, to minimize costs and to provide correct decisions for future development [1][2] .

Electricity demand is mainly influenced by seasonal effects (daily and weekly cycles, calendar holidays). A within-day seasonal cycle is apparent if similarity of the hourly demand from one day to the next exists, while a within-week seasonal cycle is apparent if similarity of the daily demand exists week after week. Therefore, using a forecasting method that is able to capture both seasonal patterns (daily and weekly) is mandatory.

Seasonal Autoregressive integrated moving average (SARIMA) model is used for time series data with single seasonal pattern. However, SARIMA model can be extended to cope with multiple seasonal cycles [3]. SARIMA model that includes two cycles is known by DSARIMA model. DSARIMA was used by many authors for forecasting electricity demand. In [4], DSARIMA model was used for forecasting hourly electricity load in England and Wales and was compared with single seasonal Holt-Winters exponential smoothing method and with a double seasonal Holt-Winters exponential smoothing method. The forecasts produced by the DSARIMA model were well and outperformed those from Holt-Winters exponential smoothing method that considered only single seasonal pattern but were outperformed by those from double seasonal Holt-Winters method. In [5], six forecasting methods including DSARIMA, double seasonal exponential smoothing, a method based on the principal component analysis (PCA), artificial neural network (ANN), a random walk model and a seasonal version of the random walk were considered for forecasting hourly electricity demand for the state of Rio de Janeiro in Brazil and half-hourly electricity demand for England and Wales. Among those forecasting methods, DSARIMA model was competitive and performed well for Rio data and England and Wales data. The same pervious methods were also applied on ten European countries and the same conclusion was reached [6].

In a recent study [7], the DSARIMA model was investigated for forecasting the double seasonal (daily and weekly) Malaysian electricity demand series. In (2011), it was compared with SARIMA model and concluded that DSARIMA model outperformed the SARIMA model [8]. Therefore, our target is to investigate DSARIMA model in forecasting Egyptian electricity demand series.

The rest of this paper is organized as follows. Section II describes the Egyptian electricity demand series. Section III describes DSARIMA model. Section IV discusses the results. The conclusion and future work close the article.

 ISBN: 978-1-61208-445-9

II. EGYPTIAN ELECTRICITY DEMAND SERIES

The Egyptian electricity demand series consists of hourly time series data of Egyptian electricity demand measured in Megawatt (MW) for a one year starting on Saturday 7 January 2012 and ending on Friday 28 December 2012. All the data is used to estimate parameters except for the last 4 weeks that are put aside to evaluate post-sample accuracy of forecasts.

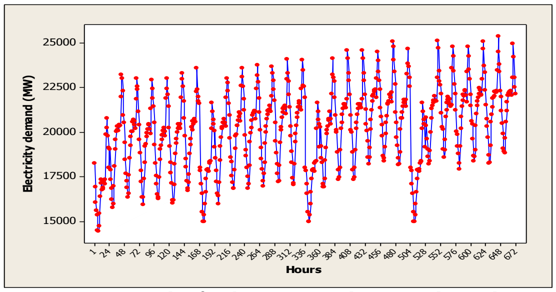

Figure 1. Time plot for the Egyptian electricity demand series from Friday 1 June 2012 to Thursday 28 June 2012

Figure 1 shows a time series plot covering the period from Friday 1 June 2012 to Thursday 28 June 2012. In the figure, the first day is represented by hours from hour 1 till hour 24, while from hour 24 till hour 48 represents the second day and so on. Figure 1 shows a within-day seasonal cycle and a within-week seasonal cycle. A within-day seasonal cycle is apparent from the similarity of the demand from one day to the next. A within-week seasonal cycle is also apparent from comparing the demand on a certain day of different weeks. It is clear that the weekdays show similar patterns of demand, while the weekend days, which have the lowest peak of electricity demand, have a different electricity demand pattern.

III. DSARIMA MODELS

A multiplicative SARIMA model has introduced by [9] to analyze single seasonal pattern time series data. SARIMA model is denoted as $\mathrm{ARIMA}\,(p,d,q)\,(P,D,Q)_s$ where p and P are the orders of nonseasonal and seasonal autoregressive terms, respectively, d and D are the orders of nonseasonal and seasonal differencing, respectively, while q and Q are the orders of nonseasonal and seasonal moving average terms and s is the seasonal period. SARIMA can be expressed as

$$\emptyset_p(B)\Phi_P(B^s)\,\nabla^d\,\nabla_s^D\,y_t = \theta_q(B)\,\Theta_Q(B^s)\,\varepsilon_t, \qquad (1)$$

where ∇^d and ∇_s^D are the nonseasonal and seasonal differencing operators, respectively ; B is the backward shift operator; $\{\varepsilon_t\}$ is a white noise process with mean zero and a constant variance; $\emptyset_p(B)$ *and* $\Phi_P(B^s)$, are polynomials of order p and P, represent the nonseasonal and seasonal autoregressive terms, respectively; $\theta_q(B)$ and $\Theta_Q(B^s)$ are polynomials of order q and Q, represent the nonseasonal and seasonal moving average terms, respectively.

SARIMA model can be extended for DSARIMA model [3]. DSARIMA model has been expressed by [4] to capture two seasonality cycles (within-day and the within-week seasonal cycles). The multiplicative DSARIMA model, which is denoted as $\mathrm{ARIMA}\,(p,d,q)\,(P_1,\,D_1,\,Q_1)_{s_1}\,(P_2,\,D_2,\,Q_2)_{s_2}$, can be written as

$$\emptyset_p(B)\,\Phi_{P_1}(B^{s_1})\,\Omega_{P_2}(B^{s_2})\,\nabla^d\,\nabla_{s_1}^{D_1}\,\nabla_{s_2}^{D_2}\,y_t = \theta_q(B)\,\Theta_{Q_1}(B^{s_1})\,\Psi_{Q_2}(B^{s_2})\,\varepsilon_t, \qquad (2)$$

where $\nabla_{s_1}^{D_1}$ is the daily seasonal differencing operator; $\nabla_{s_2}^{D_2}$ is the weekly seasonal differencing operator; s_1 *and* s_2 are the two seasonal periods which are 24 and 168, respectively in our Egyptian electricity demand data set series; $\Phi_{P_1}(B^{s_1})$ and $\Omega_{P_2}(B^{s_2})$ are polynomials of orders P_1 and P_2, respectively; and $\Theta_{Q_1}(B^{s_1})$ and $\Psi_{Q_2}(B^{s_2})$ are moving average polynomials of orders Q_1 and Q_2, respectively.

Stationarity of the Egyptian electricity demand series is investigated in the next section. If the data series is nonstationary, suitable differences and/or transformations should be made to render stationarity.

IV. EMPIRICAL RESULTS

Different DSARIMA models are used for forecasting Egyptian electricity demand. At first, in order to identify a suitable DSARIMA model and check whether the series is stationary, we plotted the autocorrelation function (ACF) and the partial autocorrelation function (PACF) of the Egyptian electricity demand series. Figure 2 shows the ACF and PACF of the hourly Egyptian electricity demand series. It is clear from the ACF the presence of daily seasonal pattern. A daily seasonal differencing $(D_1 = 1, s_1 = 24)$ is considered to convert the nonstationary series that results from the daily pattern into a stationary series. Plotting the ACF and PACF after the daily seasonal differencing, Figure 3 shows another seasonal pattern which is the weekly seasonal pattern; therefore the weekly seasonal differencing $(D_2 = 1, s_2 = 168)$ is also considered.

The ACF and PACF after daily and weekly seasonal differencing, as shown in Figure 4, indicate that the series becomes stationary after eliminating the daily and weekly patterns. Lag polynomials up to order three was considered for the seasonal autoregressive polynomials and seasonal moving average polynomials. Different double seasonal ARIMA models have been estimated by maximum likelihood method using SAS software. All the data is used to estimate parameters except for the last 4 weeks that are put aside to evaluate post-sample accuracy of forecasts. The Schwartz Bayesian Criterion (SBC) for the different models was calculated and compared. By choosing the model corresponding to the minimum value of SBC, one is attempting to select the model corresponding to the highest Bayesian posterior probability. $DSARIMA\,(3,0,1)\,(1,\,1,\,1)_{24}\,(2,\,1,3)_{168}$ model was selected with the lowest SBC.

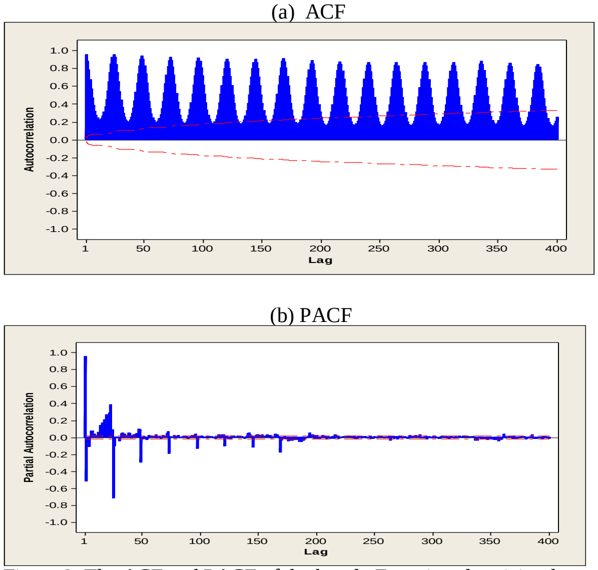

Figure 2. The ACF and PACF of the hourly Egyptian electricity demand

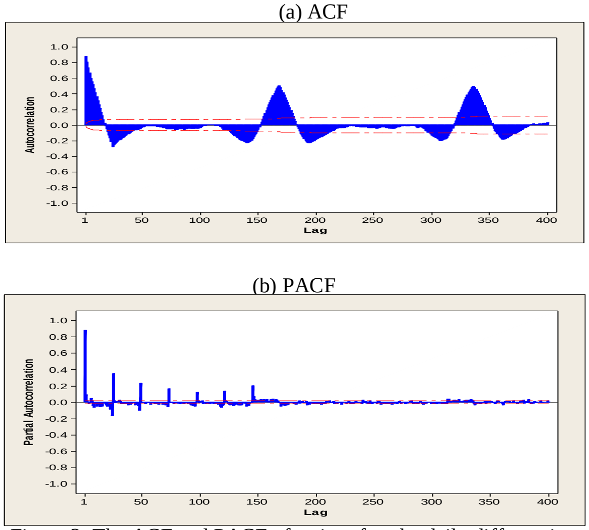

Figure 3. The ACF and PACF of series after the daily differencing

The selected model is estimated using the maximum likelihood method. The fitted model is given by:

$$(1 - 1.68\,B + 0.63\,B^2 + 0.06\,B^3)(1 - 0.12\,B^{24})(1 + 0.30\,B^{168} - 0.62\,B^{336})\,\nabla^0\,\nabla_{24}^1\,\nabla_{168}^1\,y_t = (1 - 0.92B)(1 - 0.77B^{24})(1 - 0.56B^{168} - 0.93B^{336} + 0.49\,B^{504})\varepsilon_t\,, \qquad (3)$$

Forecasts are obtained for the last 4 weeks of our data set from the above fitted model.

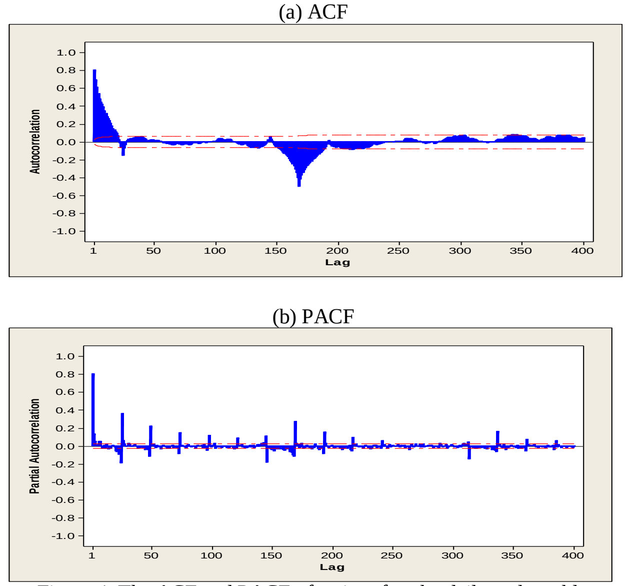

Figure 4. The ACF and PACF of series after the daily and weekly differencing

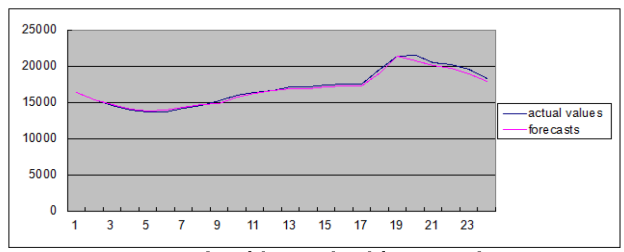

Figure 5. Time plot of the actual and forecasts values

The actual values of the Egyptian electricity demand series and its forecasts up to a day ahead are represented in Figure 5. It is observed that the forecasts are close to the actual values. In addition, the mean absolute percentage error (MAPE) is calculated for different time horizons to evaluate the accuracy of the selected model. The MAPE is the average of the absolute percentage prediction error. Low values of this statistic are preferred. The MAPE of the forecasts produced by the selected DSARIMA model up to one week horizon, two weeks horizon, three weeks horizon and a month horizon are 1.32%, 1.79%, 2.58% and 3.73%, respectively. Although, forecasting accuracy is less accurate for longer horizons, the selected model provides accurate forecasts for the Egyptian electricity demand.

 ISBN: 978-1-61208-445-9

V. CONCLUSION AND FUTURE WORK

In this paper, the DSARIMA model was investigated for forecasting Egyptian electricity demand. Different DSARIMA models were estimated. Forecasts produced by the selected model were accurate for different time horizons. The results agree with those reported in the literature for other countries. Different techniques and methods, such as exponential smoothing method and artificial neural networks, may be used and compared with DSARIMA model in forecasting the Egyptian electricity demand series. Obtained results would be of a great importance for policy makers.

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