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ARIMAX models for predicting electrical energy consumption in Samawah city

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Abstract

In this paper, the aim was to develop an ARIMAX model to predict electricity consumption until 2030 using the population growth rate as an external variable (X) in the city of Samawah. The proposed models were compared, and the best prediction model was selected based on the Mean Average Percent Absolute Error (MAPE) criterion. Therefore, forecasting performance is improved by taking into account these important factors dependent on electricity consumption. The predicted results indicate that the proposed model is more accurate according to the mean absolute percentage error (MAPE) obtained during the model testing period. Given the availability of historical load data on utility databases, research is underway in the field of time series modeling for electricity load forecasting. Forecasting electricity consumption helps improve performance and accurate planning to determine the amount of energy a city needs.

Keyword: *ARIMAX, Forecasting, population growth & MAPE*

1. INTRODUCTION

Electricity is a fundamental pillar of modern life, as various industrial, service, and residential sectors depend on it. With the increasing demand for electrical energy due to population growth, urban development and expansion of economic activities, Especially as it directly impacts human development indicators such as health, education, agricultural productivity and industrial production, which underlines the vital role of energy access in improving the quality of life [1]. Recent years have witnessed a significant increase in global demand for energy, which poses obstacles to achieving sustainable economic and social development. [2]. On the other hand, electrical load forecasting helps accurately manage power generation performance. There is a high demand for electrical load forecasting, which is essential for power generation companies [3]. Demand for electricity has grown tremendously, so it is crucial for utilities to have advance demand information.

Samawah, the capital of Muthanna Governorate in southern Iraq, is one of the cities experiencing an annual population growth rate of 2%. The significant rise in temperatures in recent years due to climate change has had a direct impact on electricity consumption patterns, posing significant challenges to relevant authorities in the areas of planning, distribution, and maintenance. In this context, forecasting electricity consumption emerges as an effective tool for supporting decision-making and providing future insights that help improve energy management efficiency and avoid problems of interruptions or waste [4]. In addition, this situation emphasizes the urgent need to implement strong energy management practices to reduce the increasing consumption, highlighting the urgent need for sustainable energy solutions such as electricity demand forecasting models [5].

To achieve highly efficient results, the process of predicting the future behavior of the studied phenomenon is important in many fields such as commercial, industrial, and governmental. Forecasting has gained importance and has undoubtedly become an integral part of the operational performance of any vital facility [7]. Some operational decisions, such as economic scheduling of power plant, fuel procurement schedule, power transaction planning, and power system security assessment [8]. In addition to power utilities, various other businesses such as electricity marketers, merchants, and independent load-shedding system operators also need accurate consumption forecasts for their operations. Therefore, accurate and reliable forecasting of electricity consumption can lead to improved consumption, unit commitment, etc. [9]. Many non-linear factors, such as daily, weekly, and seasonal weather variables, also affect electricity demand.

This paper presents ARIMAX time series modeling of electricity consumption data, which considers power supply hours in addition to consumption as model inputs. These important factors should be considered to further improve forecast accuracy. Similarly, external variable, population

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growth that influence consumption patterns can be included in the proposed ARIMAX model. This approach was analyzed using a set of electricity consumption data for the city of Samawah.

2. The methodology of ARIMAX

ARIMAX is a time series-forecasting model that combines the ARIMAX model and the influence of exogenous variables. The ARIMAX model is a popular method for modeling time series to capture the autocorrelation and moving average properties of time series.

The ARIMAX model is a variant of the autoregressive integrated moving average (ARIMA) model. By introducing exogenous variables, the ARIMAX model allows for the consideration of other factors affecting the time series, which is necessary to adjust for non-stationary time series in the ARIMA model to create an ARMA model. The ARMA model is a comprehensive model that combines the autoregressive (AR) model and the moving average (MA) model.

Because this forecasting is based on a time series dataset with an annual time unit, this paper does not consider seasonal factors.

2.1 Autoregressive model: AR (p)

The current value of the time series (Y_t) it is written as a weighted sum of the previous values of the time series $(Y_{t-1}, Y_{t-2}, \dots)$ plus the current error value(b_t) .
The formula model as the following (p):

$$Y_t = \alpha + \eta_1 Y_{t-1} + \eta_2 Y_{t-2} + \cdots + \eta_p Y_{t-p} + b_t \quad \dots\dots (1)$$

Where:
$\eta_1, \dots, \eta_p$: Parameters of the model
t: Time
b_t: Random error

2.2 moving average model :MA(q)

The current value of the time series (Y_t) in terms of weighted sum of the previous values of the random error$(b_t, b_{t-1}, \dots)$.
The formula model as the following (q):

$$Y_t = \alpha + b_t - \delta_1 b_{t-1} - \delta_2 b_{t-2} - \cdots - \delta_q b_{t-q} \quad \dots\dots (2)$$

Where:
α: Constant
$\delta_1, \dots, \delta_q$: Parameters of the model
t: Time

2.3 Mixed model

In this step the forms are mixed above (MA (P) , MR (q)) for analysis of time series data.

The formula model as the following (ARMA (p,q))

$$Y_t = \alpha + \eta_1 Y_{t-1} + \eta_2 Y_{t-2} + \cdots + \eta_p Y_{t-p} + b_t - \delta_1 b_{t-1} - \delta_2 b_{t-2} - \cdots - \delta_q b_{t-q} \quad \dots\dots (3)$$

Where:
α: Constant
$\eta_1, \dots, \eta_p$ & $\delta_1, \dots, \delta_q$: Parameters of the model
t: Time

2.4 Autoregressive Integrated Moving Average (ARIMA)

ARIMA models are the most usually used time series models these models consist of the above steps, where AR (p) , MA(q) & (d) represents the differences required by time series to be stable then the model turns into (p,d,q) .

2.5 The ARIMAX model equation is given by,[6].

$$(q)y(p) = (q)u(p) + (q)e(p) \quad \dots\dots (4)$$

where,
(q): Delay Polynomials
$u(p)$: Exogenous Input Variables
$e(p)$: Noise
$y(p)$: Output Load

3. Forecasting Performance Measure

In this paper we will based on the criterion of the mean absolute percentage error (MAPE), for comparison between models whichever is more accurate in prediction. The formula as the following:[10].

$$MAPE = \frac{\sum_{t=1}^{n} |b_t| / Y_t}{n} * 100 \quad \dots\dots (5)$$

4. Data Analysis and Results

Electricity consumption data (kilowatt-hours per capita) were collected from the World Bank Group's website for the period 2002 to 2022. This period was chosen due to the changes that occurred in Iraq, particularly after 2003, and the significant changes that occurred in all aspects of social and economic life in the country.

Figure 1 shows that the time series for electricity consumption is unstable and highly volatile, indicating variations in the time series. This is due to instability in electricity supply and peak loads, especially in the summer, which led to instability in the electricity consumption series.
https://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC

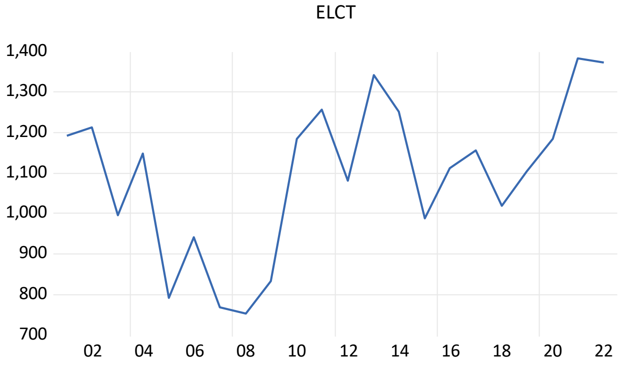

Figure 1. Time series chart of electricity consumption from 2002 to 2022

Figure 2 shows after taking the first-order difference the results indicate the time series that the time series for electricity consumptiondoes not include a unit root after taking the first difference for series (ΔS1).

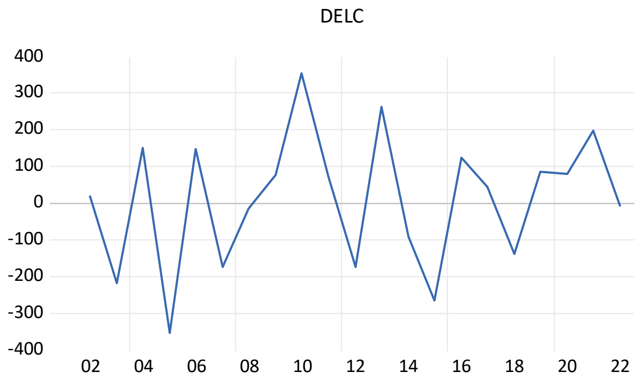

Figure 2. The plot of time series for electricity consumption after taken the first-order difference (ΔS1)

4.1 Data analysis

When analyzing experimental data using the Eviews and by drawing Autocorrelation Function (ACF) vs. Partial Autocorrelation Function (PACF) Figure 2 and figure 3 show that time-series data can follow one of the Autoregressive Integrated Moving Average (ARIMA).

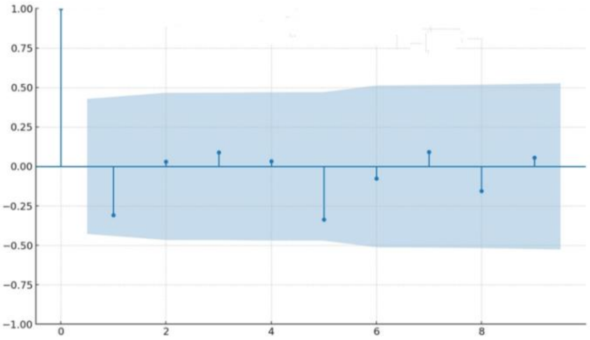

Figure (3) curve of the Autocorrelation Function (ACF)

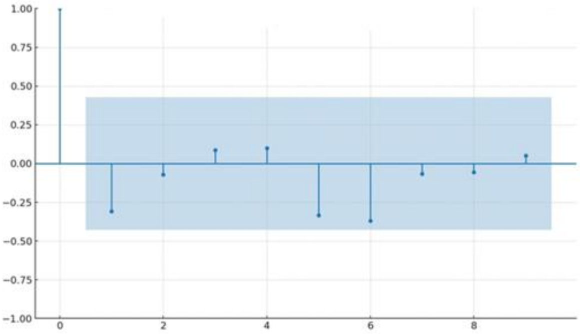

Figure (4) curve of the Partial Autocorrelation Function (PACF)

After drawing Autocorrelation Function (ACF) vs. Partial Autocorrelation Function (PACF). We start by selecting the best model from a set of proposed models for ARIMA models, based on the mean absolute percentage error.

Table (2) suggested ARIMA models

The Model	MAPE
ARIMA(0,1,1)	4.329
ARIMA(1,1,1)	3.95
ARIMA(0,1,2)	4.029

Through the comparison between the proposed models, it was found that the model (ARIMA (1, 1, 1)) It is preferable because the criteria for differentiation for it were lower than the rest for other models. Note that the rest of the models were not mentioned and were neglected because their parameters were not significant.

4.2 Forecast

According to Figure 5, the forecasting of the electricity consumption does within the sample for the next eight years, using a model, ARIMAX (1,1,1) for forecasting, shows that the electricity consumption does will rise in the coming days, due to an increase in the external variable, which is the increase in population growth in the city of Samawah.

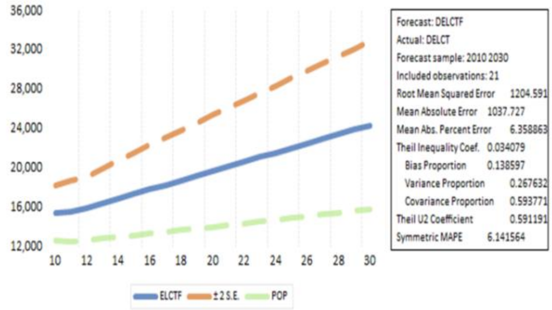

Figure (5) represents the graph of the iterative curve of the original and estimated values and the prediction values.

5. Conclusions

A standard model was built to predict the electricity consumption in Samawah city until 2030. The rate of electricity consumption is not stable during the studied period, because the correlation coefficients function plot showed that because of the loads in the consumption rate due to the external variable in energy consumption, which is the population growth rate, the best model among the proposed models for predicting electricity consumption is ARIMAX (1, 1, 1). It is expected that there will be a higher energy consumption in the coming years due to the increase in the population growth rate by 2%, through the proposed model. There is also another variable that can be studied as an external variable, which is the temperature, as we notice from the data that the loads increase in the summer, which increases the demand for electricity.

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