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Forecasting of Electricity Demand in Libya using Economic and Demographic Variables

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***Abstract*—The forecasting of Electricity demand plays a vital role in the electric power industry, as it offers the foundation of decisions making in power system operation and planning. The aim of this paper is to investigate the influence of demographic and economic variables on the annual electricity consumption in Libya. The study uses the gross domestic product and population of Libya for the period of 2008–2021 as the main drivers of electricity consumption. Two models have been developed by means of multiple regression analysis and trend method techniques. It was found that electricity consumption has a good correlation with both variables. The resulting models using both forecasting techniques are compared through a few statistical measures and the most accurate model was selected.**

Keywords— demand, Forecasting, modeling, demographic, Electricity.

I. INTRODUCTION

Energy demand, and in particular electricity demand has been growing rapidly over the world, playing an essential role in social and economic development, mostly in developing countries. Uncertainty is a particular characteristic of the energy sector. Even though decisions in this sector are usually not built on foreseeable outcomes, some variables that affect decision-making be able to be forecasted, with a specific degree of certainty, using data from various sources[1, 2]. The rapid increases in demand need to be assessed properly to have proper planning for this key infrastructure, in order that society gets the desired growth rate.

Many factors such as the type of customers, demographic conditions, population, GDP growth, and social activities etc. could influence the load demand considerably. The effects of all these factors need to be investigated in order to improve the accuracy of the load forecasted model.

Over the years several studies have previously looked into the characteristics and factors affecting domestic energy consumption in order develop electricity demand forecasting models [3-13]. In [3] a long-term forecasting of the two electricity suppliers in Bonny Island - Nigeria LNG Ltd (NLNG) and Shell Petroleum Development Company (SPDC) was carried out. A recorded load data of 34 months was collected and used to forecast the load of both Finima and Bonny towns for a period of 10 years using the linear regression methodology. In [4] an econometric model with log linear demand function was used to investigate the monthly electricity consumption for domestic consumers through the summer season, for the period from 1972 to 1975. The results presented that the factors influencing electricity consumption were weather, the real price of electricity, and needs for energy conservation. Even though this reference is long-standing, it is still applicable to work with traditional modeling. In [5] three econometric models were applied to investigate determinants of electrical energy consumption in post-war Lebanon. Electricity demand varies during different periods of the year. During the hot and humid summer, considerable use of air conditioning equipment is required in the coastal and heavily populated areas to keep comfortable indoor spaces. In [6] the influence of selected economic and demographic variables on the annual electricity consumption in New Zealand was investigated. Gross domestic product (GDP), population and average price of electricity throughout the period 1965–1999 were used as the inputs of the model. The multiple linear regression analysis was used to develop the models. An effective correlation between electricity consumption and the three independent variables was found. In [7] a knowledge-based expert system to support the option of the utmost appropriate demand forecasting model with practical application was implemented. However, traditional forecasting methods are disapproved for their weakness of non-linear fitting ability. In AI-based techniques, artificial neural network was one of the utmost common models. In [8] an econometric methods and statistical datasets about changing socioeconomic factors and their influence on the Ukrainian electricity market were presented as the instrument for forecasting electricity demand. A linear multiple regression equation was selected as the main method and changes in gross domestic product (GDP), the average price for electricity and the population the correlation between the exploring variable factors and the demand for electricity was found to be close (for the period 2000-2017). In [9] Long-term demand forecasts has been developed using regression and end-use models. Simulation was carried out to determine the load demand of the Maluku-Papua system through 2050. The variables that have the greatest influence on demand forecasting, according to data analysis, were gross regional domestic product (GRDP), population, electrification ratio, and electricity price. In [10] the concept of long-term load forecasting was demonstrated reasonably and also presents recent development within electric power industry. In [11] the multiple linear regression was used to study the influence of economic variables on the annual electricity consumption in Northern Cyprus for the duration of 1988–1997. It was found that the number of consumers, the electricity price and the tourists' number correlate with the annual electricity consumption. in [12] it was presented that the end use model is much more detailed than econometric model; however, their analytical formulation can be quite simple. The end use technique is very well suited in the case of energy efficiency forecasting because it is possible to clearly consider changes in service levels and technology. The electricity demand in the domestic sector is made as a function of the number of electric appliances, usage hours, households' number, and capacity of electric appliances. The paper in [13] dealt with an econometric model to forecast future electricity requirements for numerous sectors of Indian economy. Following the analysis of time series of sectoral GDPs, number of consumers in several sectors and price indices of electricity, a multiple logarithmic linear regression model was developed to predict long-term electricity demand up to 2045.

In this paper the influence of demographic and economic variables on the annual electricity consumption in Libya is to be investigated. The study uses the gross domestic product and population to forecast the electricity demand in Libya for the period of 2008–2021. Two models will be developed by means of multiple regression analysis and trend method techniques

II. METHODOLOGY

In this paper two models have been used, trend and econometric methods. Firstly, the explanatory variables such as population and GDP have been forecasted using statistical analysis. After forecasting the explanatory variables, a multiple regression model has been developed to forecast electricity consumption in Libya.

A. Forecasting of Population using Logistic Model

The annual statistical data which is available in public reports and statistics are used as input data when modelling of population of Libya. The forecast of population of Libya is based on the data from 1990 to 2020 which is available at the World Bank Data website [14]. The Logistic model used to forecast the population is expressed as:

$$P(t) = \frac{KP_0}{P_0+(K+P_0)e^{-rt}} \qquad (1)$$

Where: P (t) is the population as a function of time, P_0 is the initial value of population, K is the carrying capacity (limited size of population), and r is the growth rate. The model involves two unknown parameters growth rate (r) and the limited size of the population (K) The value of growth rate (r) was found directly from the equation (r= birth rate – death rate); however, the value of parameters K was estimated by substituting of the value of population P (t) which is available in the historical data into equation (1), (K was calculated and found to be equal 3455×10^3). Figure 1 shows forecasting of population in Libya using the logistic curve model.

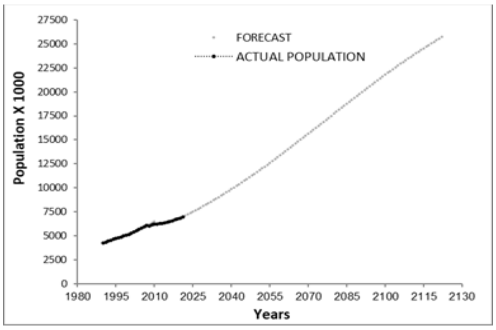

Fig. 1. Forecasting of Population using logistic curve model

B. Forecasting of Gross Domestic Product (GDP)

The fitted equation of Gross Domestic Product (GDP) is based on the data published by The Institute for Security Studies (ISS) African Futures on April 2021 which is available online at [5]. Figure 2 shows the GDP per capita in CP and Stability scenario in Libya, 2019 – 2043 [15].

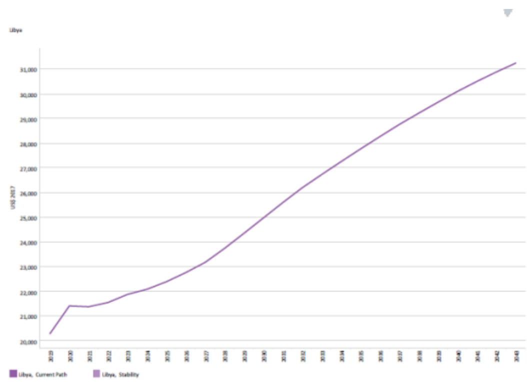

Fig.2. GDP per capita in CP and Stability scenario in Libya, 2019 – 2043 [7]

The Minitab statistical software was used as a tool to forecast the fitted regression equation of GDP. Figure 3 shows the fitted line plot of the Gross Domestic Product (GDP).

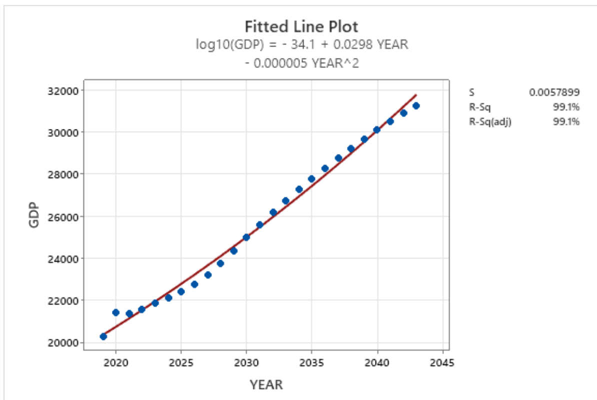

Fig.3. Forecasting of GDP per capita model based on (ISS) data

The fitted regression equation of GDP is:

$$\log10(GDP) = - 34.1 + 0.0298\ YEAR - 0.000005\ YEAR^2 \qquad (2)$$

C. Forecasting of Electricity Demand Model

Modelling of electricity demand is usually based on historical consumption data and the relationship of this consumption to other relevant variables such as economic, demographic, etc [16]. There are many methods that are available today for forecasting electricity demand. A suitable chosen method is based on the nature of the data obtainable and the desired nature and level of aspect of the forecasting. The forecasters used to use more than one method and then compare the forecasts to get more accurate forecasts. In this paper, the trend and econometric methods have been used to develop the electricity demand model.

C.1 Trend method

In this method, the historical data of electricity consumption has been expressed as a function of time rather than by relating it to other economic, demographic, policy, and technological variables. Trend extrapolation assumes that things will maintain changing in the future in the same way they have been changing in the past. The regression model used in quadratic regression follows:

$$ED = a + bt + bt^2 + \varepsilon \qquad (3)$$

Where ED is the electricity demand, t is the year, a and b are referred to as the parameters of the model, and e is a random variable referred to as the error term. The error term accounts for the variability in ED that cannot be described by the linear relationship between t and ED. Minitab statistical software package has been used to predict the fitted regression equation. The regression equation of the electricity demand is:

$$ED = -284528 + 282.0\ YEAR - 0.06985\ YEAR^2 \qquad (4)$$

Table I shows the Minitab output regressing ED (electricity consumption) on time (year),

TABLE I. REGRESSION ANALYSIS RESULTS

Model Summary

S	R-sq	R-sq (adj)
1.59401	74.84%	70.27%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	2	83.142	41.5708	16.36	0.00
Error	11	27.950	2.5409		
Total	13	111.091			

Figure 4 shows forecasting of electricity demand (ED) in Libya using the trend method.

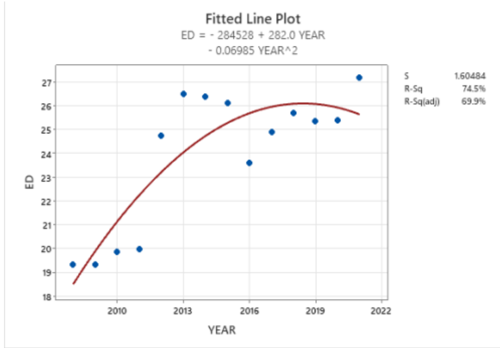

Fig. 4. Forecasting of electricity demand using trend method

C.1 Econometric method

The electricity demand is assumed to be a function of GDP, population, and the year. The regression model used in a multiple regression follows

$$ED = f(GDP, POP, YEAR) \qquad (5)$$

Where: ED represents the electricity demand. (GWh), GDP represents the Gross Domestic Product per capita, and POP represents population.

The electricity consumption data is obtained from the annual report published online by U.S. Energy Information Administration (EIA) [17]. Each of the explanatory variables GDP and POP are obtained from the regression applied to data sets of these variables over time (t).

A variety of statistical tests were used to verify the model. These tests are the coefficient of determination R squared (R^2), the adjusted coefficient of determination R^2 to indicate how much of the total variation in the consumption (dependent variable) can be accounted for by the regression function, an F-test for overall significance of the model and a t-test for testing the strength of each of the individual coefficients of the model.

TABLE II. CORRELATION MATRIX

	GDP	**ED**
ED	0.614	1.0
POP	0.650	0.783
YEAR	0.996	0.865

The strength of the linear relationship between these variables (electricity demand, GDP and population) is shown by the correlation matrix. The correlation matrix for the explaining variables used in the multiple regression analysis for modeling the annual electricity consumption in Libya from 2008 to 2021 has been shown in Table II. All the explaining variables are good correlated to the dependent variable (ED) and therefore are significant in their use in the forecasting model. The correlation coefficient for population vs. GDP is 0.65, this is due to of violence since 2011.

The multiple regression model achieved reasonably for the given data, therefore, it was decided to include these two variables in the model. Attempting to remove GDP might generate a better model. The fitted regression that represents the electricity demand are obtained by multiple regression using 14 years of data from 2008 to 2021 for each of the variables. The resulting model is:

ED=-22383 + 0.000319 GDP + 11.40 YEAR - 0.0796 POP (6)

The independent variables GDP and population are estimated using simple regression mentioned in equations 1 and 2. The regression analysis results are listed in Table III.

Where, S is the standard deviation and R^2 is the determination coefficient. analysis results are listed in table III.

TABLE III. REGRESSION ANALYSIS RESULTS

Regression Equation

ED = -22383 + 0.000319 GDP + 11.40 YEAR - 0.0796 POP

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.61026	76.66%	69.66%	51.30%

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value	T-Value
Regression	3	85.162	28.387	10.95	0.002	
GDP	1	4.945	4.945	1.91	0.197	1.38
YEAR	1	16.792	16.792	6.48	0.029	2.54
POP	1	15.332	15.332	5.91	0.035	-2.43
Error	10	25.929	2.593			
Total	13	111.091				

The *F*-test (*F*=10.95, *p*=0.002) indicates that the model as a whole reflects a real association between the dependent variable (ED) and the independent variables (GDP & population) as a group. The *t*-test for each coefficient indicate that population and GDP make a good contribution to the model (*t*=-2.43, *p*=0.035 for population and t=-1.38, *p*=0.197 for GDP).

The developed electricity consumption model is good with adjusted coefficient of determination R2 of 0.6966, but better models may exist as the adjusted R2 is less than 0.69. Figure 5 shows the actual electricity consumption along with the estimated values using the developed model. As can be seen from the figure, appropriate fit of the historical data is provided by these models. The residuals produced by these models are also well behaved.

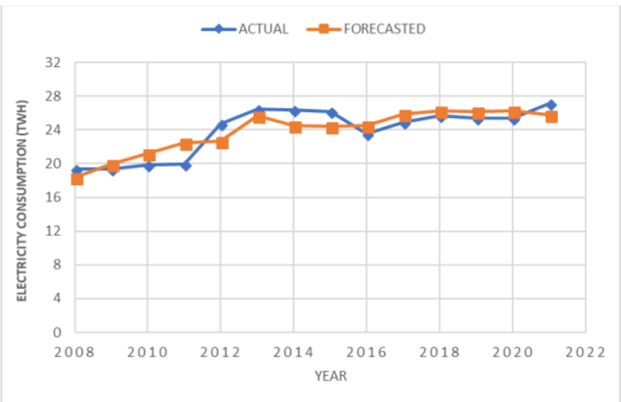

Fig. 5. Actual and estimated electricity consumption using econometric model

III. CONCLUSION

Forecasting of Electricity power demand is a key process in the electric power industry, as it provides the foundation for making decisions in electric power system operation and planning. Long-term electricity demand forecasting in power systems is a complicated task because it is affected directly or indirectly by various factors primarily associated with the economy and the population. In this paper, two methods to of forecasting of Electricity power demand have been applied, first is the trend method and second is multiple regression model. The two models attained well in the statistical tests conducted, indicating their significance in forecasting electricity demand using the explanatory variables considered. The two models have been compared. The comparison exposed that the forecasts made by the econometric model follows the actual electricity demand reasonably, however the trend model is characterized by some little higher deviations. The results clearly indicate that the proposed econometric model forecasts the electricity demand with more accuracy than the trend model for a long period. The accuracy of the forecasts made by these models depends strongly on the accuracy of forecasts made for the explanatory variables.

Further investigation on the use of artificial intelligence for this work could be used to get more accurate electricity demand forecast.

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