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Forecasting Short-Term Peak Load Demand in the Libyan Power Grid using Multiple Regression Model

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A B S T R A C T

The demand for energy, particularly electricity, has been rising rapidly around the world and plays an important role in socio-economic development, especially in developing countries. Electricity load forecasting is a key task in power plant planning, as well as in efficient operation and sustainable growth of modern electricity distribution networks. This is to make Balancing the relationship between electricity demand and supply. The main purpose of this study is to investigate the impact of meteorological factors such as temperature, relative humidity and wind speed on short-term electricity demand forecasts in Libya. A model has been developed by means of multiple regression analysis and trend method techniques. It was found that there is a good correlation between the factors and electricity use. Since the final model exhibits some little deviation, this approach has proven to be helpful for predicting Libya's electricity consumption. The findings are analyzed and discussed in order to offer recommendations for using this approach for forecasting the short-term demand of electricity.

التنبؤ بالحمل الذروي قصير الأجل في شبكة الكهرباء الليبية باستخدام نموذج الانحدار المتعدد

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الكلمات المفتاحية:
الطلب
الطاقة الكهربائية
التنبؤ
العوامل المناخية
الانحدار المتعدد

الملخص

يتزايد الطلب على الطاقة ولا سيما الطاقة الكهربائية بسرعة في جميع أنحاء العالم ، ويلعب دورًا مهمًا في التنمية الاجتماعية والاقتصادية خاصةً في البلدان النامية. يعد التنبؤ بالاحمال الكهربائية مهمة أساسية في تخطيط محطات الطاقة ، وكذلك في التشغيل الفعال والنمو المستدام لشبكات توزيع الكهرباء الحديثة لتحقيق التوازن في العلاقة بين العرض والطلب على الطاقة الكهربائية. تهدف هذه الورقة الى دراسة تأثير العوامل المناخية مثل درجة الحرارة والرطوبة النسبية وسرعة الرياح على التنبؤ في المدى القصير بالطلب على الطاقة الكهربائية في ليبيا. في هذه الورقة تم تطوير نموذج عن طريق تحليل الانحدار المتعدد وتقنيات طريقة الاتجاه للتنبؤ بحمل الذروة اليومي ، و وجد أن استهلاك الطاقة الكهربائية له علاقة جيدة بالمتغيرات. نظرًا لأن النموذج النهائي يُظهر بعض الانحراف الطفيف ، فقد أثبتت هذه الطريقة أنها مفيدة في التنبؤ باستهلاك الطاقة الكهربائية. في ليبيا. وأخيراً تم تحليل النتائج ومناقشتها من أجل تقديم توصيات لاستخدام هذه الطريقة للتنبؤ في المدى القصير على الطلب على الطاقة الكهربائية في ليبيا.

Introduction

Electricity load forecasting is a key task in power plant planning, as well as in efficient operation and sustainable growth of modern electricity distribution networks. Forecasting short-term power demand is also of great interest to power supply companies as it helps ensure a balance between supply and demand**.** Short-term load forecasting is a critical component of an energy management systems.

The precision of the predicted system load has a direct impact on the outcomes of a short-term operation planning process and security analysis. In other words, the Forecast of short-term load demand significantly affects the reliability and economics of power system operations. Uncertainty is a unique feature of the electric energy sector. Decisions are not usually based on predictable outcomes, but

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some factors that influence decision making can be predicted with some degree of confidence using data from a variety of sources [1, 2]. In order for society to properly plan this critical infrastructure to achieve the desired growth rate, a rapid increase in demand needs to be properly recognized.

Many factors such as customer type, demographics, population, GDP growth, and social activity can have a significant impact on load demand. The impact of all these factors should be studied to improve the accuracy of the load forecasting model. Over the years, several studies have investigated the characteristics and factors affecting energy consumption in order to develop electricity demand forecasting models [3-13]. Reference [3] used an econometric model with a log-linear demand function to study the monthly electricity consumption of private customers during the summer months from 1972 to 1975. As a result, it was found that the factors affecting power consumption are the weather, the actual price of power, and the need to save energy. Although this reference is old, it is still applicable to traditional modeling tasks. In [4] a detailed comparison of numerous practical algorithms (sinusoidal regression, polynomial regression, ANNs and machine learning) for short-term demand forecasting was provided. the electric load was displayed in terms of two variables: temperature and calendar days. Case studies were presented. In [5], four different methods for short-term load forecasting applications were considered. The SARIMAX and SARIMA models achieved poorly as compared to the ensemble model. The results were reasonable because SARIMA failed to record the different seasonality of the data. Furthermore, using temperature as an exogenous variable did not appear to significantly improve predictions. As an alternative, ensemble methods, especially GBRT, provided more accurate predictions. GBRT achieved better forecasting compared to other models due to easy control over the bias-variance trade-off in estimating the given predictive data. According to results of earlier studies [6-8]., there are numerous variables that affect power demand, including population density, economic structure, season, month, day, time of day, and climate change Temperature was measured in [9,10]. Included as an exogenous predictor. In both cases, temperature acted as a contributing factor to model performance.

The main purpose of this study is to investigate the impact of meteorological factors such as temperature, relative humidity and wind speed on short-term electricity demand forecasts in Libya.

In this paper the impact of meteorological factors such as temperature, relative humidity and wind speed on short-term electricity demand forecasts on the Libyan Power Grid has been investigated using multiple regression approach.

Methodology and Assumptions

In this paper a multiple regression analysis and trend techniques have been used. The multiple regression model input dataset used to forecast the peak load demand includes historical load and weather data, which are described as follows.

1. peak load

a. The electricity peak load data are obtained from General Electricity Company of Libya (GECOL), including historical peak load of the Libyan electric network with an hourly basis for about 12 months starting from January 2017.

2. Weather data

The weather datasets are obtained from the Weather and Climate - The Global Historical Weather and Climate Data [11]. The raw weather data include temperature, wind speed, and humidity, with a daily Observations for about 12 months starting from January 2017 to December 2017.

The methodology followed in this study to perform the short term forecasting of the peak load can be summarized as follows:

1- Getting the historical data of peak load and weather data (T, H and W), for each month of the year 2017.
2- Calculating the average monthly maximum hourly basis demand (peak load) of twelve months hourly basis of the Libyan electric network with an hourly basis for about 12 months.
3- The proposed model for one month for each season will be tested, namely January 2017, April 2017 August 2016, October 2017, , and April 2017 which represent the winter spring, summer and autumn respectively.
4- Perform the multiple regression analysis by using Minitab statistical software package to describe the relationship of statistics between dependent variable and the explanatory variables
5- determine the multiple regression model for the first week of January 2017, which represents the relation between PL with respect to explanatory variables (T, H , W).
6- A regression model obtained from past dates from week 1 of January 2017 will be used in week 2 of January 2017 to predict daily peak loads given the predictable weather data for that week (T, H, W).
7- A diversity of statistical tests will be used to verify the developed model.
8- Conclusions will be drawn from the work. finally, suggestions for a future work have been presented.

Results and Discussion

The performance of the proposed technique is evaluated on the collected datasets. Fig. 1 presents one week of Libya's historical hourly load data from, 1st January 2017 to 7th January 2017. We can clearly see that the load series exhibits daily seasonality

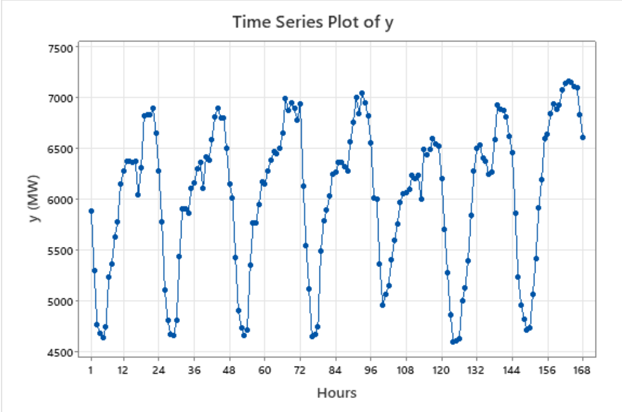

Fig. 1.: Libya's hourly load time series for 1 week from, 1st January 2017 to 7th January 2017

A multiple regression model proposed to predict peak load power consumption using meteorological data is:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \varepsilon \quad (1)$$

Where:

y is the dependent variable. $\mathbf{x_1, x_2, x_3}$ are the explanatory variables. The parameters β_1, β_2 and β_3 are the parameters relating x's to dependent variable (y), denoted by x_1, x_2 and x_3 respectively (regression coefficients), β_0 is the y-intercept, and $\boldsymbol{\varepsilon}$ is a random error component that reflects the difference between the observed linear relationship and the fitted linear relationship.

In our model, *y* represents the peak load of electricity consumption (PL), and x_1, x_2 and x_3 represent temperature T, humidity H and wind speed respectively.

A regression model obtained from past dates from the 1st week of January 2017 can be used in week 2 of January 2017 to estimate daily peak loads given the expected weather data for that week (T, H, W). The daily peak load (PL) and the explanatory variables (weather data T, H, and W) for the first week of January 2017 are shown in Table (1).

The electricity demand is assumed to be a function of a weather data. The regression model used in a multiple regression follows

$$\text{PL} = f(T, H, W) \quad (2)$$

Where: PL represents the electricity peak load. (MW), T represents the temperature, H represents relative humidity and W represents wind speed.

Table 1: First week of august 2017 data

Day	Peak Load MW	Temperature C^{O}	Humidity %	Wind speed km/hr
1	5943.79	12	70	8
2	5973.75	12	59	14
3	6075.5	12	50	21
4	6103.5	13	44	22
5	5979.92	13	44	23
6	5952.58	12	57	35
7	6247.54	12	61	32

Forecasting of Population using Logistic Model

The fitted regression that represents the electricity peak load demand are obtained by multiple regression using the first week of January 2017 data. The multiple regression equation of peak load demand is presented in equation (2). The Minitab output for a multiple regression is shown below in Table (2).

$$Y = 7386 - 10.3\,T - 32.8\,H + 43.8\,W \quad (3)$$

Table 2: The Minitab output for a multiple regression

Regression Equation

$$Y = 7386 - 10.3\,T - 32.8\,H + 43.8\,W$$

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
91.0348	85.88%	71.76%	0.00%

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value	T-Value
Regression	3	151192	50397.2	6.08	0.048	12.02
T	1	644	644.4	0.08	0.798	-0.28
H	1	80084	80084.0	9.66	0.053	-3.11
W	1	74232	74232.1	8.96	0.057	2.99
Error	3	24862	8287.3			
Total	6	176054				

The values of S and R^2 in Table II represent the standard deviation and is the determination coefficient respectively.

The F-test (F=6.08, p=0.048) shows that the model as a whole reflects the true association between the dependent variable y (PL) and the independent variables (T, H and W) as a group. A t-test for each coefficient indicates that temperature T, humidity H and the wind speed W contribute well to the model (t=-3.11, p=0.053 for H and t=-2.99, p=0.057 for W). The power consumption model developed is good with an adjusted R^2 of 0.859, but a better model may exist as the adjusted R^2 is less than 0.717 as shown in Table (2). The coefficient of determination R^2 is 0.8588 which indicates that 85.88% of the variation in peak load is around its mean, explained by explanatory variables.

1. Weather Data Forecasting

In order to forecast the peak load for the second week of the same month, the weather data will be forecasted using trend method, The peak load can then be estimated by inserting the forecast weather data from Table (3) into the regression model of (2). The Minitab output for the regression equation of temperature is presented in equation (3).

$$T = 16.86 - 6.524\,D + 2.024\,D^2 - 0.1667\,D^3 \quad (4)$$

The model summary for the regression equation of temperature for the second week is shown in table (4)

Table 3: Data forecast for the second week of January2017

Day (D)	Temperature C^O	Humidity %	Wind speed km/hr
1	12	65	26
2	11	65	26
3	11	61	22
4	12	55	17
5	14	52	13
6	15	54	12
7	13	65	18

Table 4: Model summary

S	R-sq	R-sq(adj)
0.471405	95.14%	90.28%

The steps performed in the second week of January 2017 can be consistently applied in the next few weeks of the same month by incorporating the Week 2 model into Week 3, Week 3 into Week 4, and so on. In other words, with this approach, the daily demand for day j is predicted using the demand for day j- 1.

The coefficient of determination R^2 is 0.9514 which indicates that 95.14% of the variation in the temperature is around its mean, explained by explanatory variable (D). Figures 2, 3, 4 and 5 show results of the Month of January, April, and November of the year 2017 respectively.

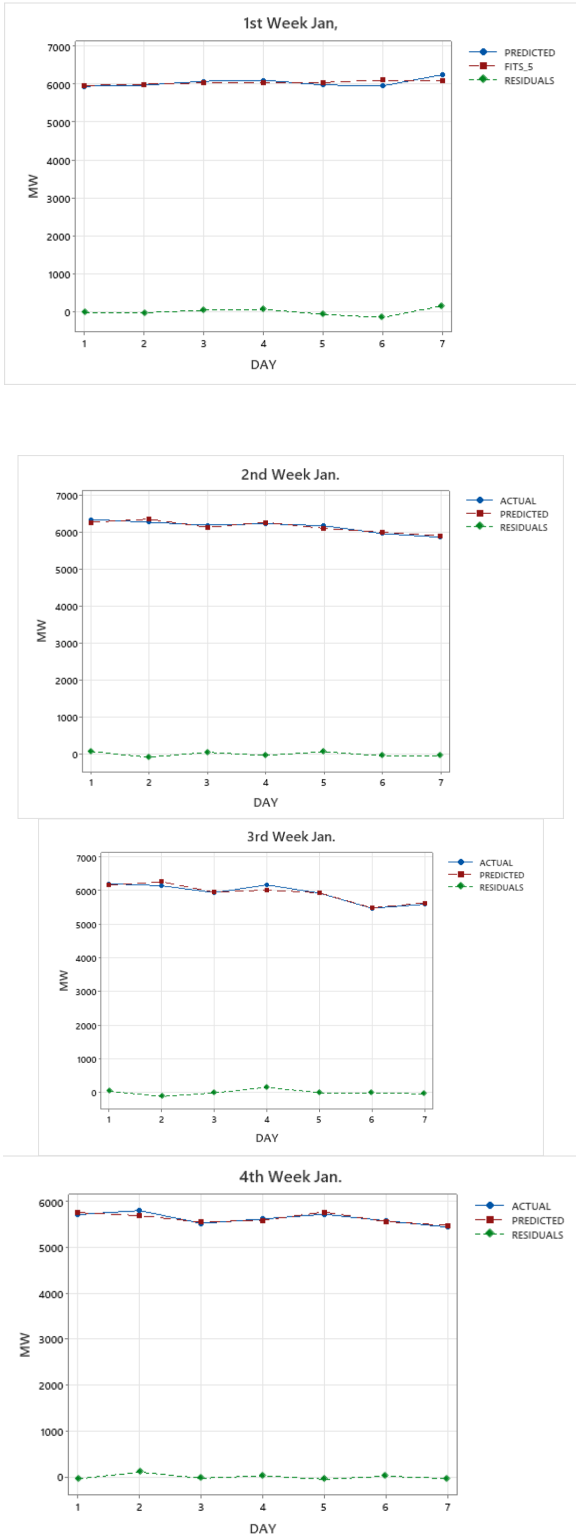

Fig. 2.: Actual and Predicted Peak load for 4 Weeks of Jan. 2017

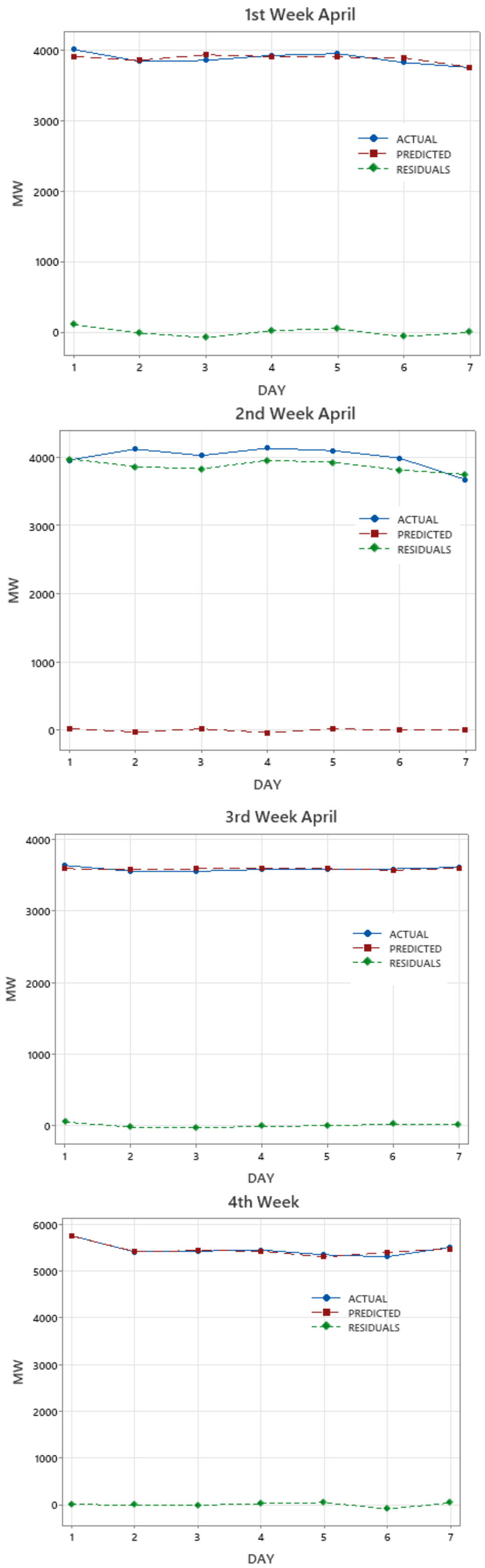

Fig. 3.: Actual and Predicted Peak load for 4 Weeks of Aug. 2017

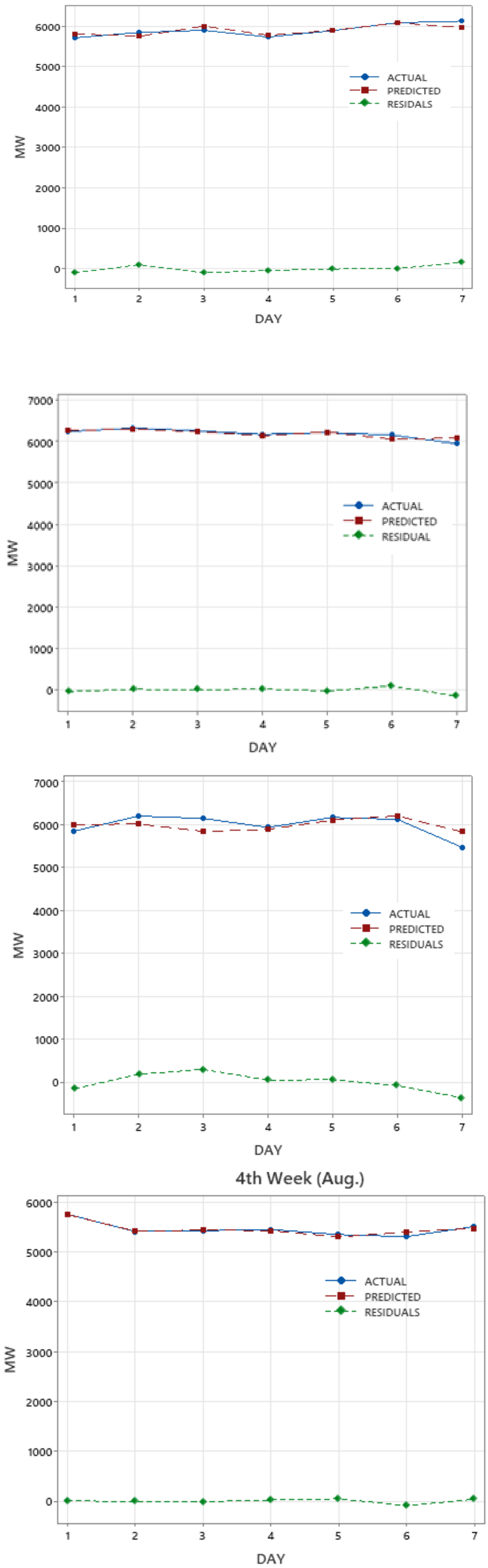

Fig. 4.: Actual and Predicted Peak load for 4 Weeks of Aug. 2017

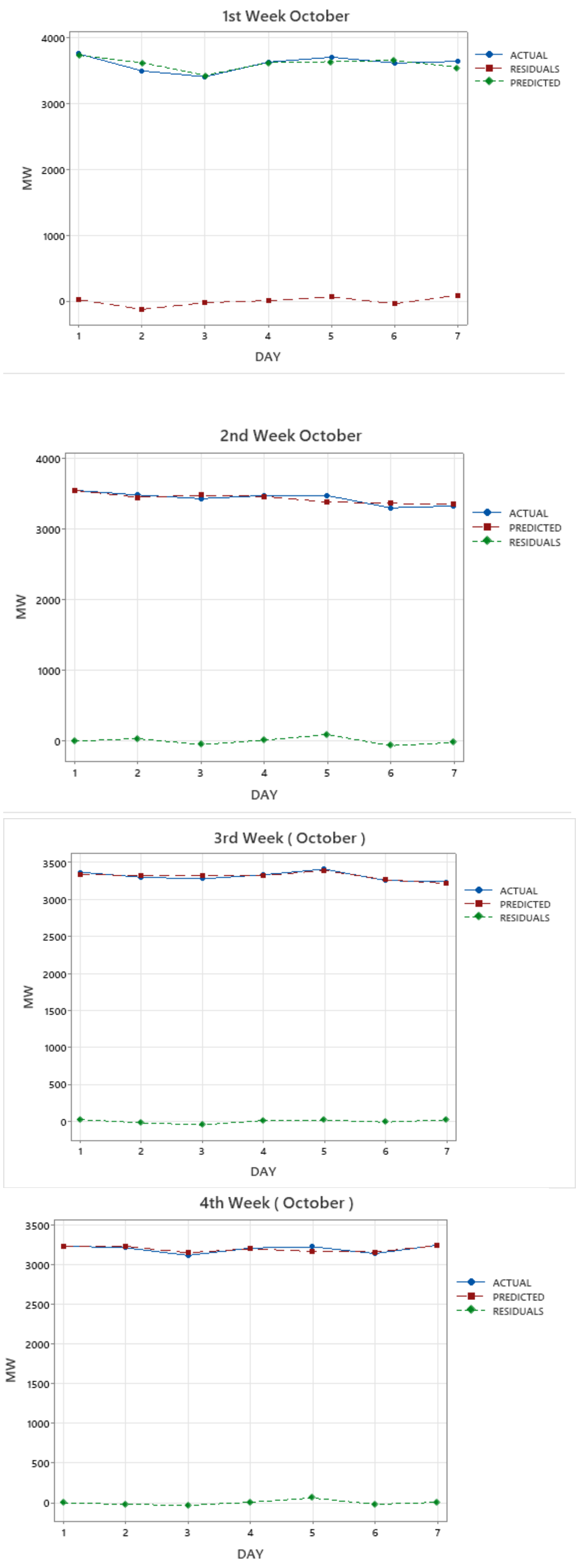

Fig. 5.: Actual and Predicted Peak load for 4 Weeks of Oct. 2017

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. short-term electricity peak load forecasting in power systems is a complicated task because it is affected directly or indirectly by various factors primarily associated with the meteorological factors such as temperature, relative humidity and wind speed. This study looked into how weather variables affected forecasts for Libya's short-term peak load electricity consumption. The multiple regression analysis and trend techniques over a period of a week have been used to develop the model. with this method, the daily demand for day j is predicted using the demand for day j- 1. The findings of the daily peak load forecasting clearly indicate that the weather is a significant factor affecting the demand of the electric system. Further studies on the application of artificial intelligence for this task might be used to forecast electricity demand with greater accuracy.

References

[1]- A. Diniz and *et al*, "Short/mid-term hydrothermal dispatch and spot pricing for large-scale systems-the case of Brazil," in *2018 Power Systems Computation Conference (PSCC)*, Dublin, Ireland, , 2018 pp. 1-7.

[2]- L. Resende, M. Soares, and P. Ferreira, "Electric power load in Brazil: View on the long-term forecasting models," *Production*, vol. 28, October 8 2018.

[3]- J. M. Walker, "The residential demand for electricity: Further empirical evidence," Resources and Energy, vol. 2, pp. 391-396, 1979.

[4]- M. Atanasovski, M. Kostov, G. Veljanovski and P. Popovski, "Short-Term Load Forecast in Power Systems: A Comparison of Different Practical Algorithms," 2022 18th International Conference on the European Energy Market (EEM), Ljubljana, Slovenia, 2022, pp. 1-5, doi: 10.1109/EEM54602.2022.9921172.

[5]- S. Papadopoulos and I. Karakatsanis, "Short-term electricity load forecasting using time series and ensemble learning methods," 2015 IEEE Power and Energy Conference at Illinois (PECI), Champaign, IL, USA, 2015, pp. 1-6, doi: 10.1109/PECI.2015.7064913.

[6]- T. W. S. Chow and C. T. Leung, "Neural network based short-term load forecasting using weather compensation," in *IEEE Transactions on Power Systems*, vol. 11, no. 4, pp. 1736-1742, Nov. 1996, doi: 10.1109/59.544636.

[7]- James W. Taylor, Roberto Buizza,"Using weather ensemble predictions in electricity demand forecasting",International Journal of Forecasting,Volume 19, Issue 1,2003,Pages 57-70,

[8]- M. O. Oliveira, D. P. Marzec, G. Bordin, A. S. Bretas and D. Bernardon, "Climate change effect on very short-term electric load forecasting," *2011 IEEE Trondheim PowerTech*, Trondheim, Norway, 2011, pp. 1-7, doi: 10.1109/PTC.2011.6019249.

[9]- N. Liu, V. Babushkin, and A. Afshari, "Short-term forecasting of temperature driven electricity load using time series and neural network model," Journal of Clean Energy Technologies, vol. 2, no. 4, 2014.

[10]-S. Bercu and F. Pro¨ıa, "A sarimax coupled modelling applied to individual load curves intraday forecasting," Journal of Applied Statistics, vol. 40, no. 6, pp. 1333–1348, 2013

[11]-Weather and Climate - The Global Historical Weather and Climate Data, available at: https://tcktcktck.org/tripoli/august-2017.