PARAMETERS ESTIMATION OF LINEAR, QUADRATIC AND EXPONENTIAL MODELS FOR ENERGY DEMAND FORECASTING BY USING ABC ALGORITHM

[1]SEMIH ÖZDEN, [2]YUSUF SÖNMEZ, [3]AHMET MAVI, [4]VEYSEL ÖZDEMIR

[1,3]Gazi University, Technical Sciences Vocational College, Electronics and Automation Department,
[2]Gazi University, Technical Sciences Vocational College, Electrical and Energy Department,
[4]Gazi University, Technology Faculty, Department of Industrial Design Engineering
E-mail: [1]sozden@gazi.edu.tr, [2]ysonmez@gazi.edu.tr, [3]amavi@gazi.edu.tr, [4]vozdemir@gazi.edu.tr

A**b**stract - The accurate energy demand forecasting is important issue for energy supplier companies. Especially, the electrical energy price is defined one day ago depending on energy demands. Developed accurate model increases management capacity and efficient usage of power plants. Despite the fact that, In Turkey, transformer based energy measurement for a specific region is still developing topic and application, the consumption data for a specific region can be very limited. In cases where there is limited data, modeling is a difficult task to perform. Although there are several methods have been proposed before, they suffers from forecasted values close to real ones efficiently. In this study, a model was developed to forecast electrical energy consumption in a specific industrial region in Turkey. In the model, the energy consumption of an industrial region between years of 2014 – 2016 was considered as output values and temperature and energy consumption values belonging one day ago are defined as input values. The output values were estimated by giving input values to the model, which is based on linear, quadratic and exponential functions. In the study, parameters of these functions were defined by Artificial Bee Colony Algorithm (ABC) by minimizing the error value between predicted and real values. Results obtained from three different functions were compared with each other and shown as graphically. Results show that the ABC algorithm can define the parameters of functions very accurately by decreasing the error value very close to zero.

Index Terms - Energy demand forecasting, Artificial Bee Colony, parameter estimation, linear regression

I. INTRODUCTION

The electrical energy is major, critical and important issue for country and especially its management and planning has key role. Electrical energy management consists of price and planning energy source. Countries have to plan their energy needs a day ahead. This requires accurate estimation of energy need. It also secure for the efficient and reliable operation of modern electricity network [1]. Many models/algorithm/methods have been developed for estimation of electric energy and the effect of various independent variables on prediction have been examined. Moreover, in all of the simple or complex models developed depending on the source of consumption, the main aims of the studies are to predict energy consumption in the future with the least amount of error.

Huang et al developed hybrid algorithm (combining an adaptive genetic algorithm and a cointegration analysis) to optimize the coefficients of linear and quadratic forms of the AI-based model. Historical annual data of China's electricity usage over the period of 1985–2015 was used. The results of this study show that the developed model provided greater accuracy and reliability [2]. Holt-Winter and Autoregressive Integrated Moving Average (ARIMA) models on time series was studied to estimated energy consumption by sectors (household, industrial, agriculture, streetlight, commercial, traction). 1980 – 2011energy consumption data in Pakistan was used. The authors found that the Holt-Winter forecasting model is more appropriate to forecast the total electricity consumption [3]. Hassan et al described an electricity load demand-forecasting problem and a chaotic data modeling. They developed a combined algorithm that fuzzy logic trained using extreme learning machine for modelling and solving problems in forecasting [4]. Time series and historical data have been used by researcher to figure out trend of the energy consumption. Another important parameter for Mediterranean countries is weather conditions especially during summer days. In these regions, a dramatic increase of demand and peak loads due to air conditioning and refrigeration emerges. The effectiveness of seasonal climate forecasts for electricity demand forecasting was studied and analyzed both considering deterministic and probabilistic approaches [5].

Kaytez et al performed three different approaches as least squares support vector machines, traditional regression analysis and artificial neural networks for the prediction of electricity energy consumption of Turkey. Gross electricity generation, installed capacity, total subscribership and population are used as independent variables using historical data from 1970 to 2009 [6]. Another regression (simple and multiple linear regression analysis) study was realized to forecast residential energy consumption. Outdoor temperature and solar radiation was considered to improve coefficient of determination. The performance assessment and comparing of the models were evaluated root mean square error [7]. In this study, very simple model were developed with limited

data. ın Turkey, total consumption data are well known, however local consumption data is missing. Especially, industrial and residential area for a region in a city have very limited data. Therefore, in this study focused on developing a model for an industrial area in the capital city of Turkey, Ankara. Linear, quadratic and exponential linear regression model parameters were predicted to achieve minimum error.

II. ARTIFICIAL BEE COLONY(ABC)ALGORITHM AND MODELLING OF THE PROBLEM

The Artificial Bee Colony Algorithm (ABC) was developed and described by Karaboga and it is based on discovering and finding of honeybees' food. In the ABC, three types of bee as scout, onlooker and employed search and find food source depending on amount of nectar. When the highest amount of nectar was achieved, the loop stops. In the first step of the algorithm, employed bees search and evaluate food source. Then, this information is shared with onlookers' bees and they evaluate nectar amount at the selected locations food source. Scout bees search possible new food sources [8, 9]. General steps of the ABC algorithm is given in Figure 1. In this study, three linear regression approaches were studied to forecast electrical energy demand for an industrial area in Turkey. The parameters of the models were optimized by ABC with minimum error. Previous studies used many variables and many historical data to increase accuracy of the models. Here, only temperature and previous energy consumption data were used for three years. The independent variables of the models are temperature and average of last three days' power consumption. The mathematical equations of the proposed models are presented as linear, quadratic and exponential in Equation 1, 2 and 3, respectively.

$$P_{predicted} = \omega_0 + \omega_1 P_{prv} + \omega_2 T \quad (1)$$

$$P_{predicted} = \omega_0 + \omega_1 P_{prv} + \omega_2 T + \omega_3 P_{prv}{}^2 + \omega_4 T^2 + \omega_5 P_{prv} T \quad (2)$$

$$P_{predicted} = e^{\omega_0 + \omega_1 P_{prv} + \omega_2 T} \quad (3)$$

Here, ω_i are coefficient of the models, T is temperature and $P_{predicted}, P_{prv}$ are predicted and average of last three days' power consumption. Totally, 650 and 113 number of data was used as training and test, respectively.

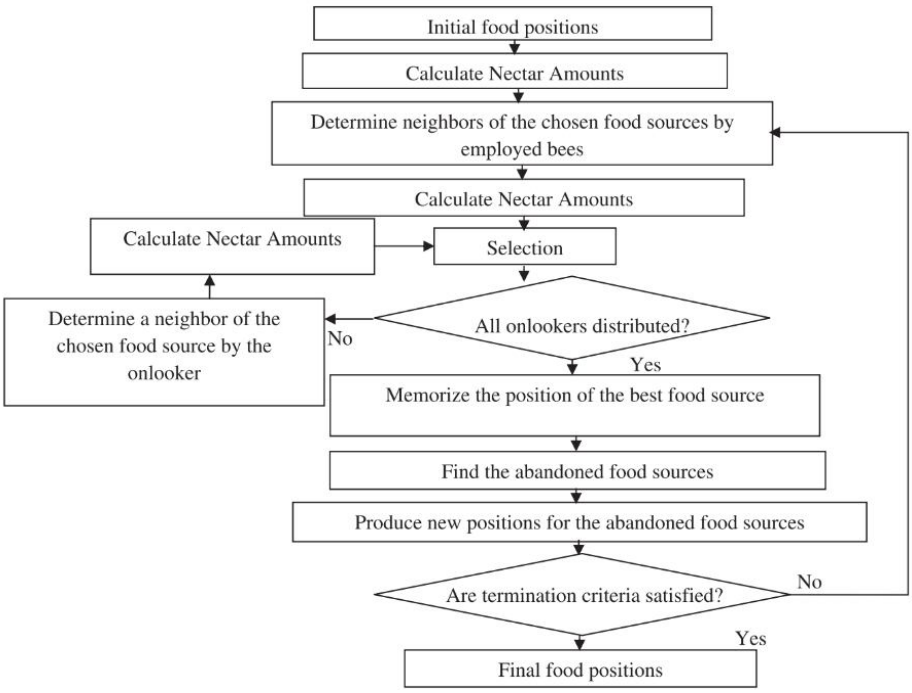


Figure 1. Flow chart of the ABC a lgorithm [10].

III. EXPERIMENTAL RESULTS

The accuracy of the models was evaluated three statistical merits. In literature commonly, Mean Absolute Error (MAE), Mean Squared Error (MSE), Root Mean Squared Error (RMSE) and correlation coefficient (R) have been selected by researchers. In Table I and II, the results of the merits are given both training and test. It could be seen from graphs and results that linear approach is more accurate model.
The R graphs of the proposed linear, quadratic and exponential approach models are given both training and test results in the Figure 2, 3 and 4, respectively.

Table I. The statistical assessment of the models for training data

	TRAINING			
	MAE	MSE	RMSE	R
Linear	0,02988	0,00190	0,04363	0,96880
Quadratic	0,02987	0,00189	0,04351	0,96882
Exponential	1,30774	1,74080	1,31939	0,96849

Table II. The statistical assessment of the models for test data

	TEST			
	MAE	MSE	RMSE	R
Linear	0,01877	0,00078	0,02800	0,93763
Quadratic	0,01877	0,00078	0,02785	0,93756
Exponential	1,37969	1,90894	1,38165	0,93618

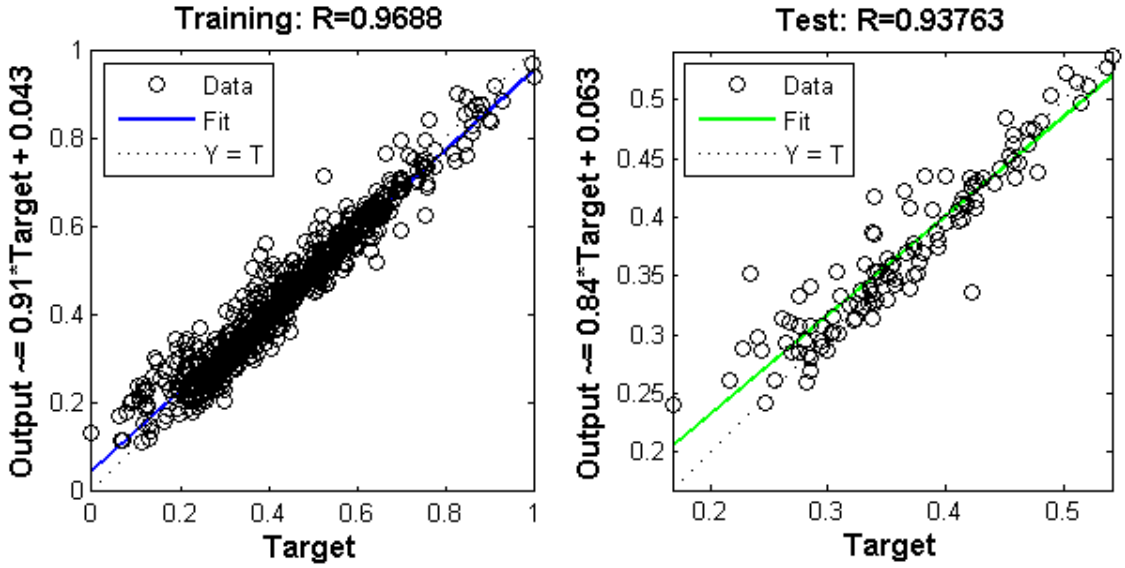


Figure 2. Regression analysis of the linear model

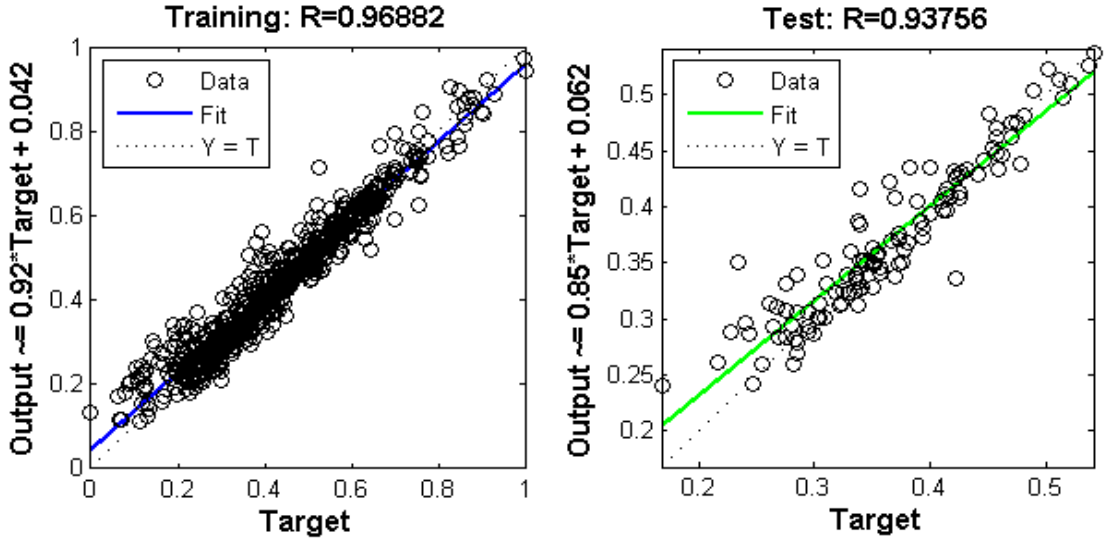


Figure 3. Regression analysis of the quadratic model

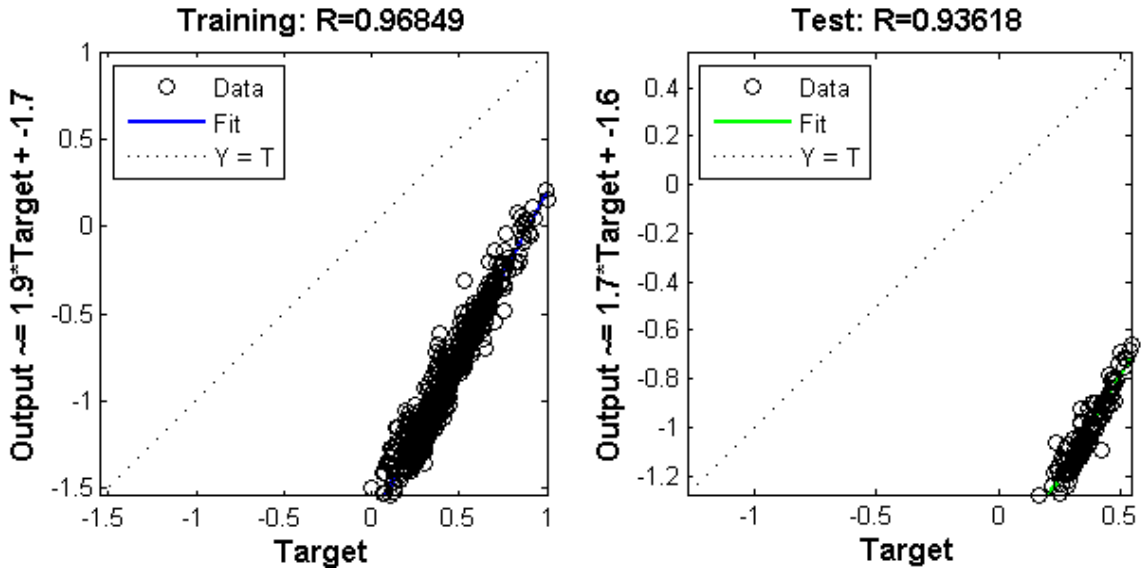


Figure 4. Regression analysis of the exponential model

CONCLUSION

In this study, prediction models were studied for energy consumption of an industrial region in Turkey. The parameters of the linear, quadratic and exponential models were defined and optimized by artificial bee colony algorithm. Inputs of the model equations are previous energy consumption and temperature. The results were evaluated well-known statistical merits. The result show that the best model (means highest R and lowest MAE, RMSE and MSE) is linear for test data. For training data, linear and quadratic results are very close to other one. Thus, the electrical energy demand forecasting was realized. It is clear that more input parameters and previous data could increase accuracy of the models.

REFERENCES

[1] M. Rana and I. Koprinska, "Forecasting electricity load with advanced wavelet neural networks,"Neurocomputing, vol. 182, pp. 118-132, Mar 19 2016.

[2] J. B. Huang, Y. Tang, and S. X. Chen, "Energy Demand Forecasting: Combining Cointegration Analysis and Artificial Intelligence Algorithm," Mathematical Problems in Engineering, vol. 2018, pp. 1-13, 2018.

[3] A. Hussain, M. Rahman, and J. A. Memon, "Forecasting electricity consumption in Pakistan: the way forward," Energy Policy, vol. 90, pp. 73-80, Mar 2016.

[4] S. Hassan, A. Khosravi, J. Jaafar, and M. A. Khanesar, "A systematic design of interval type-2 fuzzy logic system using extreme learning machine for electricity load demand forecasting," International Journal of Electrical Power & Energy Systems, vol. 82, pp. 1-10, 2016.

[5] M. De Felice, A. Alessandri, and F. Catalano, "Seasonal climate forecasts for medium-term electricity demand forecasting," Applied Energy, vol. 137, pp. 435-444, 2015.

[6] F. Kaytez, M. C. Taplamacioglu, E. Cam, and F. Hardalac, "Forecasting electricity consumption: A comparison of regression analysis, neural networks and least squares support vector machines," International Journal of Electrical Power & Energy Systems, vol. 67, pp. 431-438, 2015.

[7] N. Fumo and M. A. Rafe Biswas, "Regression analysis for prediction of residential energy consumption," Renewable and Sustainable Energy Reviews, vol. 47, pp. 332-343, 2015.

[8] D. Karaboga and B. Akay, "A comparative study of Artificial Bee Colony algorithm," Applied Mathematics and Computation, vol. 214, no. 1, pp. 108-132, 2009.

[9] D. Karaboga and B. Basturk, "A powerful and efficient algorithm for numerical function optimization: artificial bee colony (ABC) algorithm," Journal of Global Optimization, vol. 39, no. 3, pp. 459-471, November 2007.

[10] A. F. Mohamed, M. M. Elarini, and A. M. Othman, "A new technique based on Artificial Bee Colony Algorithm for optimal sizing of stand-alone photovoltaic system," Journal of Advanced Research, vol. 5, no. 3, pp. 397-408, 2014.

★★★