POLİTEKNİK DERGİSİ

JOURNAL of POLYTECHNIC

ISSN: 1302-0900 (PRINT), ISSN: 2147-9429 (ONLINE)
URL: http://dergipark.gov.tr/politeknik

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Bu makaleye şu şekilde atıfta bulunabilirsiniz(To cite to this article): Ozden S., Dursun M., Aksoz A. ve Saygın A., "Prediction and modelling of energy consumption on temperature control for greenhouses", ***Politeknik Dergisi***, 22(1): 213-217, (2019).

Erişim linki (To link to this article): http://dergipark.gov.tr/politeknik/archive

DOI: 10.2339/politeknik.417757

Prediction and Modelling of Energy Consumption on Temperature Control for Greenhouses

Araştırma Makalesi / Research Article

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(Geliş/Received : 28.11.2017; Kabul/Accepted : 03.01.2018)

ABSTRACT

Prediction of the energy consumption is the most important topic for planning to build an energy power station. This energy power station can be non-renewable sources power plants or renewable power plants like wind and solar. Prediction of the energy consumption also figures out load modeling problem in new smart grid applications. In this study, energy consumption model is developed for temperature control of a greenhouse. Artificial Neural Network based modeling is advanced with temperature of inner, temperature of outer and temperature of soil. So, these temperatures are inputs in the ANN based model. In addition, the output of the ANN is energy demand that is strongly related with temperature data.

Keywords: Artificial neural network, greenhouse, modeling, temperature control, energy consumption.

Seralarda Enerji Tüketiminin ve Sıcaklık Kontrolünün Tahmini ve Modellenmesi

ÖZ

Bir enerji güç istasyonunun kurulması planlanırken en önemli konu enerji tüketiminin tahminidir. Bu enerji güç istasyonları yenilenemez kaynaklı güç sistemleri veya rüzgâr ve güneş gibi yenilenebilir kaynaklı güç sistemleri olabilirler. Üstelik enerji tüketiminin takibi yeni akıllı şebeke uygulamalarında yük modellemesi problemini çözerler. Bu çalışmada, enerji tüketim modeli sera sıcaklık kontrolü için geliştirilmiştir. Yapay sinir ağları(YSA) tabanlı model iç sıcaklık, dış sıcaklık ve toprak sıcaklığına göre geliştirilmiştir. Ek olarak, YSA nın çıkışı tamamen sıcaklık verilerine bağlı enerji talebidir.

Anahtar Kelimeler: Yapay sinir ağları, sera, modelleme, sıcaklık kontrolü, enerji tüketimi.

1. INTRODUCTION

In recent years, energy sources have been decreasing and demand for energy and its costs have been increasing. This is affects product cost. Moreover makes more efficient and positive use of climate resources together with global warming and drought. Since the sources utilized for producing electricity are limited and their prices gradually increased, researches for new alternatives for temperature control in greenhouse system.

Energy of heating systems pumps used for the agricultural irrigation is generally provided from electrical energy or fossil fuels. Since fossil fuels commence to annihilate besides its increasing of prices and hazards to environment alternative energy seeking efforts has become inevitable also in agricultural. Solar energy that is sensitive to environment, clean and requiring no maintenance is an alternative renewable energy source especially for countries like Turkey having a high amount of annual solar irradiation rate.

Dursun and Ozden have been studied optimal use of water resources especially in agricultural field. Soil measure sensors were used for measuring soil humidity. Optimum solar panels were selected according to calculated maximum power consumption of motors. The need of energy of BLDC Motors has been provided from solar panels and batteries [1], [2]. Zou et al studied a greenhouse climate controller for energy consumption under control. This controller is realized with participle swarm optimization for nonlinear greenhouse system in North of China [3]. Avila-Miranda et al. studied to ventilate a greenhouse during the day. Their intelligence technique combines of a neural network and the particle swarm optimization algorithm. In addition, Kalman Filter is used for predictions on the dynamic behavior of the system variables [4]. Guoqi Ma et al. studied auto regressive moving model for naturally ventilated greenhouse in autumn under east–central China conditions [5]. Liu et al investigated to microclimate controlling and monitoring in greenhouse. According to indoor temperature and humidity, a prediction is realized with neural network algorithm [6]. Yelmen et al. discussed on a model of prediction of greenhouse heating requirement climate models thanks to neural networks [7].

Yan and Yao aimed to predict building energy consumption at different climate zones using artificial

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neural network. Thanks to ANN, the building energy consumption predicted easily and quickly [8]. Yuce and Rezgui addressed to difference of energy performance in public buildings between predicted and actual. GA based artificial neural networks generated optimized energy saving [9]. Gezer et al studied artificial neural network based energy consumption for a smart grid application [10]. Ferlito et al compared to difference of actual and predicted building's energy demand at 3 month, 6 month and 12 month [11].

This study continues as follows: temperature control of greenhouse is described in Section II. Then, Section III provides artificial neural network and prediction of energy consumption with this method. In Section IV, the obtained results are discussed and are compared to actual energy values. Conclusion of paper describes error methods success of ANN in conclusion.

2. TEMPERATURE CONTROL OF GREENHOUSE

A temperature control of greenhouse system provides to prevent unnecessary energy losses, decrease harmful effect of greenhouse and maintain proper environment for crops. Thus, temperature of greenhouse has controlled with consummating necessary energy, which produce for demand of inner temperature make equal to desired temperature. In the real applications, energy consumption to keep desired temperature is related with many parameters as temperature, humidity, wind speed and irradiation of the sun. Developed model skipped all other parameters except temperatures of inner, outer and soil. In addition, this study focused only energy consumption for the temperature control unit as air conditioner.

The inner temperature, the outer temperature and the soil temperature of greenhouse obtained from sensors are used for prediction of necessary energy consumption. Table 1 shows to average of the inner temperature, the outer temperature and the soil temperature of greenhouse in a year. Average consummated energy from greenhouse temperature control in a year is given Table 1 too. In addition, desired temperature for crops is 20 °C.

Table 1. Average temperature values and average consummated energy

	Average values in a year
The inner temperature	16,31 C
The outer temperature	13,11 C
The soil temperature	17,06 C
Consumed energy	4300,24 W

When data in Table 1 is obtained from sensors, it can be seen to difference between the inner temperature and desired temperature. Thus, temperature control of greenhouse tries to make up the difference and to consume energy along all a year. Three temperature and desired temperature was used, because the energy consumption bases on all of them. Figure 1 show that the inner temperature changes daily. Horizontal axis of the temperature-changing figure is day of year.

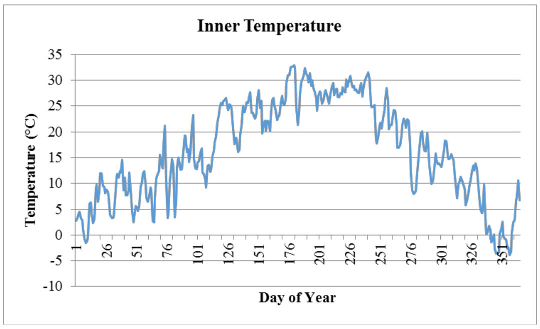


Figure 1. The Inner Temperature Changing

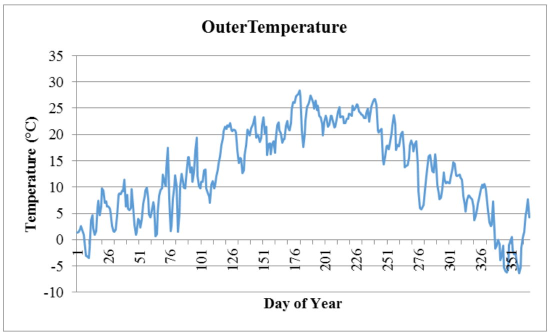


Figure 2. The Outer Temperature Changing

The outer temperature changing in all year is illustrated in Figure 2. The lowest temperature (around -5°C) was observed at the end of year. The highest temperature was measured in June around 30 °C. In addition, soil temperature changing is directly shown in Figure 3. The trend of the temperature is similar of the inner and outer temperature. In addition, it is higher than the others and more smoothed.

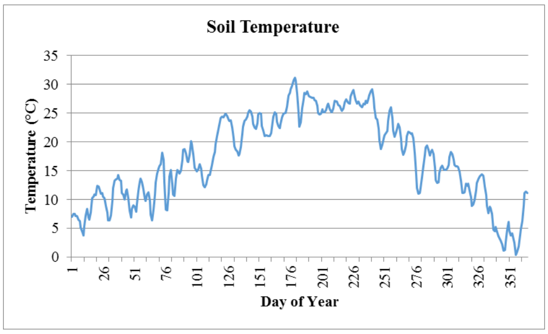


Figure 3. The Soil Temperature Changing

In addition, the energy consumption graphics in a year is given in Figure 4. Depending on temperatures of inner, outer and soil, energy consumption was fluctuated. Temperature control unit was kept 20°C that is optimum level of the plant. This value was defined by growers. Energy consumption during winter days is higher than summer days. The highest consumption was measured at the end of year and the temperature was under zero.

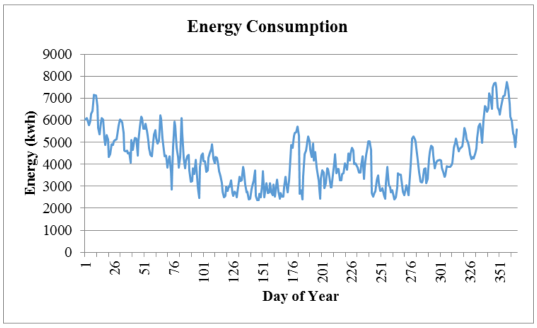


Figure 4. Energy Consumption Changing

Beside of these figures, actual temperature values and especially actual energy consumption values are given for a year. If these energy consumption values are known at one year ago, energy saving can be realized according to temperature values.

3. ANN (Artificial Neural Network)

ANNs are the most widely implemented methods in forecasting energy consumption. In last decades, ANN's have been used for load and consumption modeling, prediction and forecasting, because of their ability to learn complex, non-linear functions with memory.

They operate like a ''black box'' model, and require no detailed information about the system. Instead, they learn the relationship between the input parameters and the controlled and uncontrolled variables by studying previously recorded data, in a way similar to how a non-linear regression might be performed. Another advantage of using ANNs is their ability to handle large and complex systems with many interrelated parameters [12].

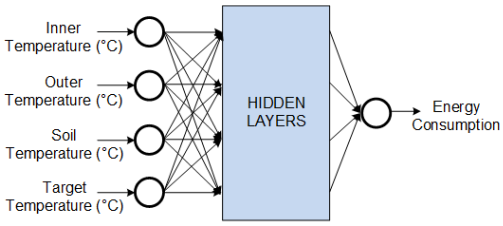


Figure 5. ANN architecture used in the proposed method

The proposed ANN architecture is given in Figure 5. The model has three layers as input, hidden and output. Inner, outer, soil and target temperatures were selected for input data. The output data is energy consumption for temperature control of greenhouse. Different algorithms and number of hidden layers were performed. The best results were obtained by ten hidden neurons with Levenberg–Marquardt algorithm.

The consumption of the temperature control units at the end of the day was measured and saved. Inner, outer and soil temperature were achieved by Turkish State Meteorological Service.

In this study, 365 experimental data sets were measured for the training and testing data. The ratio for training, validation and testing data was selected as 70%, 15% and 15%, respectively. The validation and testing data were selected randomly. The use of the proposed ANN has been implemented in MATLAB.

4. RESULTS

The overview of ANN are presented in Figure 6. The network structure of the ANN is 4-10-10-1. The training algorithm is Levenberg–Marquardt algorithm. The target error value is evaluated by Mean Squared Error (MSE). The number of the maximum algorithm for learning process is one thousand. The calculation formula of the MSE is given below.

$$MSE = \frac{1}{n}\sum_{k=1}^{n}\left|y_k - \hat{y}_k\right|^2 \qquad (1)$$

where, y_k and $\hat{y}_k$ represent actual and predicted kth value, respectively, in other words error of the ANN prediction. The MSE calculated squared error with dividing number of the samples.

The number of training, validation and test are 255, 55, and 55, respectively. The result assessments of the ANN with MSE and correlation coefficient (R) of training, validation and testing are given in Figure 7. The R-values for all data are close to one. The result of MSEs are around 22, 26 and 49 for training, validation and test, respectively. The output value of ANN is energy consumption and its maximum value is around 8000 kWh. These MSEs are expected range for this consumption data.

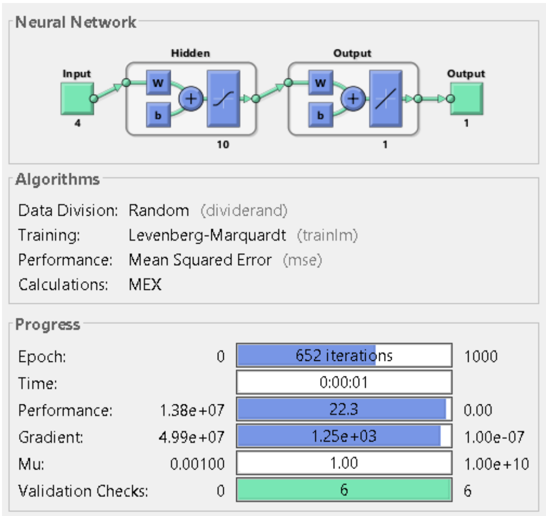
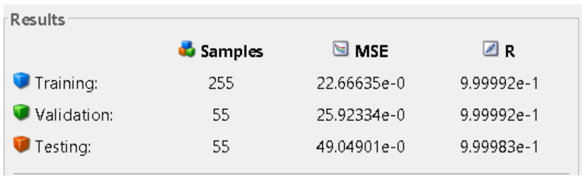


Figure 6. ANN results for proposed system



Results

	Samples	MSE	R
Training:	255	22.66635e-0	9.99992e-1
Validation:	55	25.92334e-0	9.99992e-1
Testing:	55	49.04901e-0	9.99983e-1

Figure 7. Error value of the ANN

In Figure 8, error-changing graph of the validation, train and test are given versus Epochs. The best results were kept at the epoch 646. The loop was stopped with evaluation of the validation data. After learning process, the performance of the ANN was calculated with 55 number of testing data. The learning loop of the ANN was stopped 652th iteration for the best validation performance.

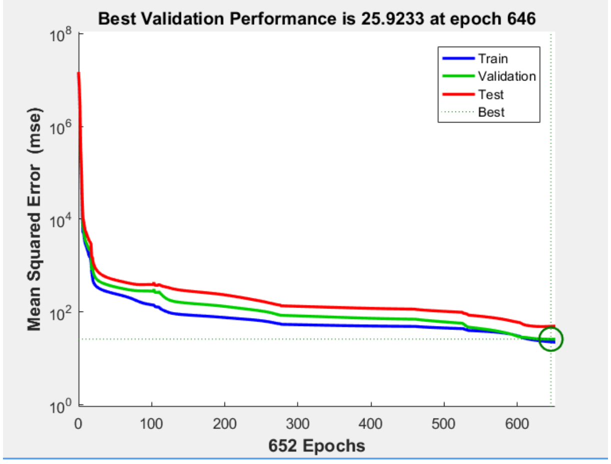


Figure 8. MSE value vs epochs

R-squared is a statistical measure of how close the data are to the fitted regression line. It measures the strength and direction of a linear relationship between actual and predicted. The result of R is very close to one means good prediction.

The graphs of (R) for training, validation, test and all are given in Figure 9. It is divided to four section for analysis of training, validation, test and all data. The graphs are obtained for output value is energy consumption. For per graphs, linear regression and Y=T line are graphed, predicted data are dotted. It is expected that predicted data be on the linear lines.

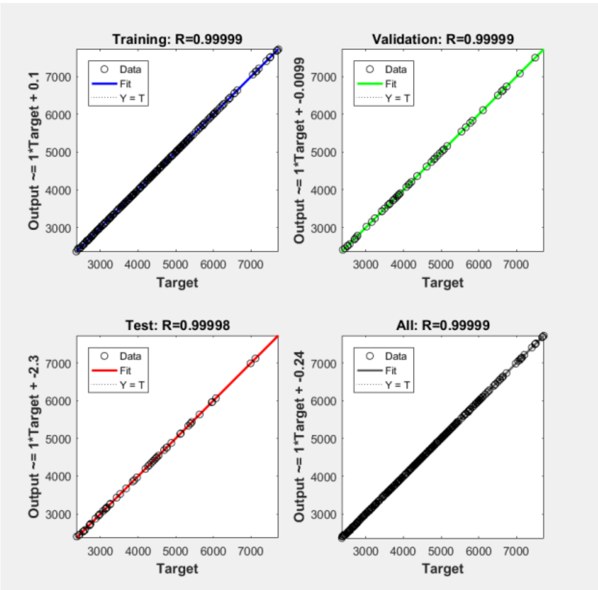


Figure 9. Result of the coefficient of determination

4. CONCLUSION AND FUTURE WORK

The most important part of the smart grid applications is prediction of energy consumption. In this study artificial neural network based, prediction of energy consumption was studied and modelled depending on temperature of inner, outer and soil. The data was measured and used for the temperature control of a greenhouse. The results show that energy load modeling has correlation with the temperature of inner, outer and soil was realized and R-values were very close to one. Temperatures and energy consumption are strongly correlated with developed model.

The main aim of the study is to find solution for the energy planning and organization for the next day. This model helps to predict energy demand at the rural (agricultural) area. In addition, it provides to predict energy demand of a greenhouse with temperature information for growers.

REFERENCES

[1] Dursun M. and Ozden S., "Optimization of soil moisture sensor placement for a PV powered drip irrigation system using a genetic algorithm and artificial neural network," ***Electrical Engineering***, 99: 407–419, (2017).

[2] Dursun M. and Ozden S., "An Efficient Improved Photovoltaic Irrigation System with Artificial Neural Network Based Modeling of Soil Moisture Distribution – A Case Study in Turkey", ***Computers and Electronics in Agriculture***, 102: 120-126, (2014).

[3] Zou Q., Ji J., Zhang S. and Shi M., "Model Predictive Control Based on Particle Swarm Optimization of Greenhouse Climate for Saving Energy Consumption," ***World Automation Congress (WAC)***, 123-128, (2010).

[4] Avila-Miranda R., Begovich O. and Ruiz-Leon J., "An optimal and intelligent control strategy to ventilate a greenhouse," ***Evolutionary Computation (CEC)***, 779-782, (2013).

[5] Ma G., Qin L., Chu Z. and Wu G., "Modeling greenhouse humidity by means of NNARMAX and principal component analysis," ***Control and Decision Conference (CCDC),*** 27th Chinese. IEEE, 2015, 4840–4845, (2015).

[6] Liu Q., Jin D., Shen J., Fu Z. and Linge N., "A WSN-based prediction model of microclimate in a greenhouse using extreme learning approaches," ***Advanced Communication Technology (ICACT)***, 2016 18th International Conference on. IEEE, (6): 730–735, (2016).

[7] Yelmen, B. And Çakir, M. T. "Yapay Sinir Ağları Kullanılarak Sera Isıtma İhtiyacının Tahmini", ***Politeknik Dergisi***, 14(4): 235-541, (2011).

[8] Yan C. W. and Yao J., "Application of ANN for the prediction of building energy consumption at different climate zones with HDD and CDD," ***Future Computer and Communication (ICFCC***), 2010 2nd International Conference on. IEEE, 2010, 3: 286–289, (2010).

[9] Yuce B. and Rezgui Y., "An ANN-GA semantic rule-based system to reduce the gap between predicted and actual energy consumption in buildings," ***IEEE Transactions on Automation Science and Engineering***, 1351-1363, (2017)

[10] Gezer G., Tuna G., Kogias D., Gulez K. and Gungor V. C., "PI-controlled ANN-based Energy Consumption Forecasting for Smart Grids," ***12th International Conference on Informatics in Control, Automation and Robotics (ICINCO),*** 110–116, (2015).

[11] Ferlito, S., Atrigna, M., Graditi, G., De Vito, S., Salvato, M., Buonanno, A. and Di Francia, G. "Predictive models for building's energy consumption: An Artificial Neural Network (ANN) approach". ***AISEM Annual Conference,*** 1-4, (2015).

[12] Kalogirou S. A., "Applications of artificial neural-networks for energy systems", ***Applied Energy***, 67: 17–35, (2000).