Estimated the amount of energy production of dams using artificial neural networks: Oymapinar example

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Abstract

The demand of energy is rapidly growing in today's world, the energy production and the efficient use of energy is as important as never before. For this reason, the feasibility study of new projects should be carried meticulously out and the optimum way of use of existing projects should be searched. Optimum energy usage is possible with predicting the amount of energy production. In this study, the capacity of energy production of Oymapinar Hydroelectric Station in Turkey's Mediterranean region is tried to forecast using artificial neural networks. The inputs are the elevation of surface of lake, the lake volume, the charging flow rate and the amount of water to produce energy. As output, the energy production amounts are approximately given.

Keywords: Oymapinar, hydroelectric station, ANN, forecast;

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1. Introduction

In today's rapid population growth and high industrialization rate conditions, the demand for hydroelectric stations is getting increased. The efficient ways of use of resources are crucial since the resources are limited. To get these ways, some programs and models are built up. The model of artificial neural networks (ANN) is just one of them.

ANN models are the models which are used for actualizing one or many processes of learning, relationship, classification, generalization and optimization benefitting from the obtained data (Sen, 2004). People have studied on human brain for thousands of years and these processes have gained speed with the advance of modern electronics. The first study related with neural network was done by McCulloch and Pitts (1943). In their study, simple neural network is modeled on with electrical cycles. In 1950s, with the advent of the computer technology, the developments on artificial neural has gained speed. Firstly, with the leadership of IBM research laboratory, Nathanial Rochester tried to simulate a simple neural network. Although he could not achieve on first try, he succeeded in his later attempts (Wang, 2006). Widrow and Hoff (1960) developed ADALINE and MADALINE methods. MADALINE is the first neural network model which was adapted from the existed problems in the world. This model was used to prevent the echoes which occurred in phone lines and the model has still been commercially used. Subsequently, it is cited that the network structures can be used in the devices which are used in our daily life (Hopfield, 1982). In 1985, American Physics Institution proved that neural network can be used for computer technology (Wang, 2006). Today, ANN is used every part of engineering and the comments on the model is still continued. Today, companies commonly study on 3 type neurons which are defined as digital, analog and visual. ANN network may be inspected in two parts and one of which is about its structure and the other is about mathematical functions. In general, ANN structure is formed by the neural cells in the input, hidden and output layers and is formed in according with the linkage among them. In hidden cells, there is an internal processor or a trigger processor, called precisely as processor (activation function). Processing of ANN can be thought as internal and external processors which has two mathematical functions. An internal process of ANN is carried out by processors in the hidden layers. External process occur with the application of the relationship among layer cells randomly and the reduction of errors with the help of some processes such as feedback of output prediction error etc. These mathematical operations take on the task of ANN for learning, being trained, recall, recognition of new information and refreshing the network connections (Sen, 2004). The aim of all the learning algorithms is to obtain the weight of connection which will provide the most appropriate relationship between input and output data. According to the single layer sensor network, the two layers feed forward networks can eliminate many limitations. However, the problems are emerging about how to change the sheets among the weight connections. In this context, the back propagation algorithm contains a powerful learning process which can be used for ANN models. The essence of back propagation algorithms working process depends on fully and effectively calculations of the changes in ANN which generally occur in sub-systems. This provides the use of the ANN in the learning of information in the complex and nonlinear structure and the relationship among the processor parameters. A back propagation algorithm on network system which has the topology as in Figure 1, is performed step by step as follows (Sen, 2004).
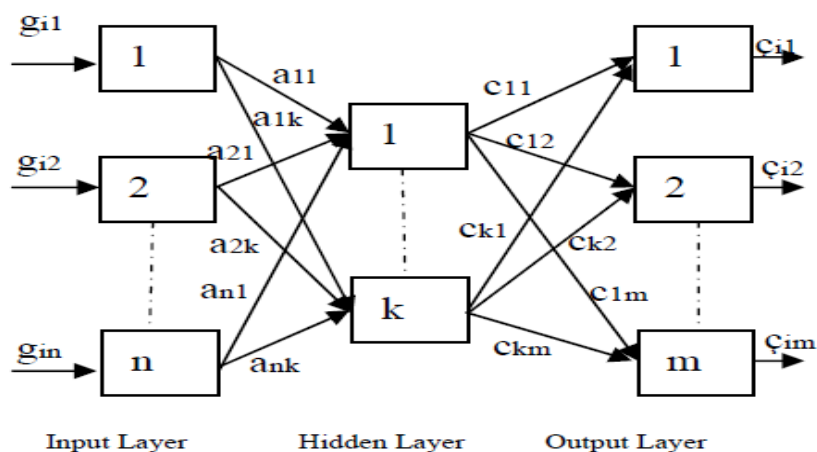
Figure 1. General ANN structure

- First, the layers and the number of cells in all layers are determined for the purpose of determining ANN's topological structure.

- At the later stages, the values of constant parameters are assigned.

- The weight connections between layers are determined.

- Using the connection weights assigned with the symbol "n", measurement number, output vector is obtained for all input vector.

- Firstly aij values are renewed and its starting point is the weight connection between output layer and hidden layer for the purpose of the reversal of the spread of the errors.

- For the renewal of the aij values, weight coefficients, firstly, it is required the calculation of the error value and derivatives on the basis of aij weight connection.

- Total error value is calculated by using the output values which are given by ANN and expected values.

- It is necessary that the derivatives must be taken again according to error relations with the basis of their weights for the purpose of renewal in every weight coefficient.

ANN has many applications on hydrology field. There are many successful examples especially on rainfall and runoff models (Fernando & Jaywardena, 1998; Cigizoglu & Alp, 2004; Tokar & Johnson, 1999). Additionally, ANN model is started to be used frequently to determine quality of the water parameters (Newham et al., 2003), to determine evapotranspiration quantity (Keskin & Terzi, 2006), to predict the sediment quantity in recent years (Cigizoglu, 2004; Kisi, 2004; Agarval et al., 2005).

In this study, the data are used which are the elevation of surface of lake, the lake volume, the charging flow rate and the amount of water to produce energy belonging to Oymapinar Hydroelectric Station in Mediterranean region of Turkey in between December of 1998 and January of 2008. As the data set, 55 of 69 are used for training the models and the rest of them (E.İ.E., 2011) are used for testing the models. These data are used to build the ANN models and in the stage of tests.

2. Study Area and Method

Oymapinar Hydroelectric Station is located on Manavgat River in the Mediterranean Region of Turkey. The station was started up in 1984, and its mean annual energy generation is 1620 GWh. The height of water surface from river bed is 185 m and the volume of lake at regular level is 236 hm³.
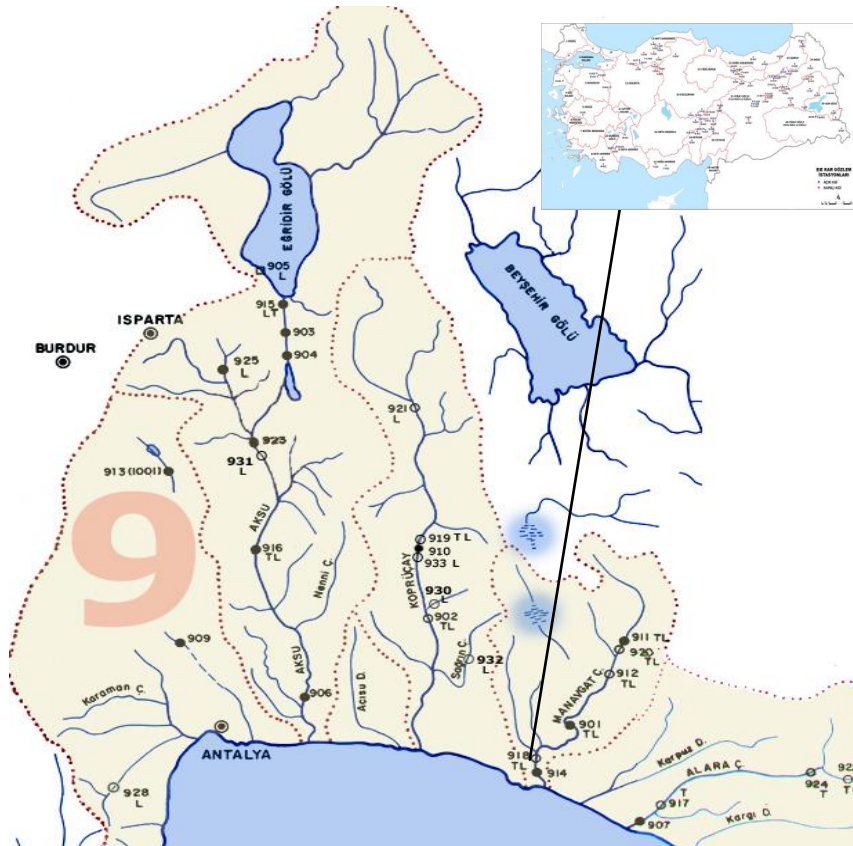

Figure 1. The map of the Middle Mediterranean Basin of Turkey [14]

In the study, artificial neural networks models are built. In these models, 1 hidden layer is used and the peak point is looked for with increasing the number of neurons. As function, the logarithmic sigmoid function is chosen and the training is done by feedforward backpropagation. As inputs, the elevation of surface of lake, the lake volume, the charging flow rate and the amount of water to produce energy are selected. As output, the energy production is given. Besides, these data are normalized in the range of 0-1 before modelization.

1. Results and Discussions

The neuron numbers are always tried to increase in this study with 4 inputs, 1 hidden and 1 output layers. From all 69 data, 55 of them are used for training and the 14 of them are used for testing the models. The training and the testing data of ANN models are statistically tested. These tests are

regression test and mean square error test. In addition to this, the distance of regression test values from 45 angled line is evaluated. And the results are summarized in Table 1.

Table 1. Statistical analysis of artificial neural networks

Neuron Numbers	Training			Testing		
	R²	MSE%	a	R²	MSE%	a
1 Neuron	0,9681	0,012	0,9887	0,6892	0,3256	0,8251
2 Neurons	0,9719	0,0113	0,9894	0,7124	0,3027	0,8448
3 Neurons	0,9736	0,0105	0,9902	0,7357	0,2799	0,8645
4 Neurons	0,9764	0,0098	0,9909	0,7589	0,2570	0,8842
5 Neurons	0,9891	0,0081	0,9927	0,7822	0,2341	0,9039
6 Neurons	0,9819	0,0084	0,9924	0,8054	0,2112	0,9236
7 Neurons	0,9846	0,0076	0,9932	0,8287	0,1884	0,9734
8 Neurons	0,9874	0,0069	0,9939	0,8519	0,1655	0,9631
9 Neurons	0,9801	0,0062	0,9947	0,8752	0,1426	0,9628
10 Neurons	0,9929	0,0055	0,9954	0,8984	0,1197	1,0925
11 Neurons	0,9956	0,0047	0,9962	0,9217	0,0969	1,0622
12 Neurons	0,9984	0,004	0,9969	**0,9449**	**0,074**	**1,0419**
13 Neurons	**0,9986**	**0,004**	**0,9970**	0,9338	0,079	1,0525

According to the results by Table 1, the best result of the training column is obtained with 13 neurons while the best result of the testing column is with 12 neurons. Since the testing models give generally more consistent outputs, the one with 12 neurons is taken into account to predict energy production (Figure 2). Besides, the possibility of prediction becomes very low when the neuron numbers are very low.
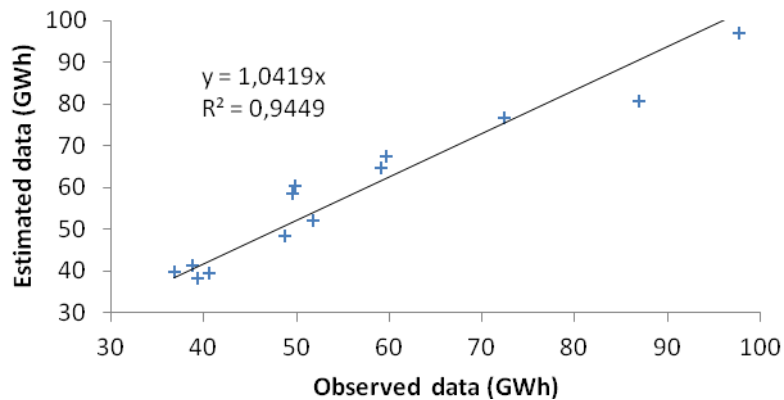

Figure 2. Testing column results of ANN model with 12 neurons

Saplioglu, K., Kilit, M. & Yavuz K., B., Estimated the amount of energy production of dams using artificial neural networks: Oymapinar example, *AWERProcedia Information Technology & Computer Science*. [Online]. 2013, 3, pp 1099-1104.Available from: http://www.world-education-center.org/index.php/P-ITCS

2.   Conclusion

In this study, the data belonging The Oymapinar Barrage located on Manavgat River are used. The ANN models are built by these data and the best model is selected to forecast energy production. The best model is considered as the one with 12 neurons among all the models with 4 inputs, 1 hidden and 1 output layers. With this model which gives regression test value of 92%, energy generation can be predicted with accuracy over 90% inputting the elevation of lake surface, the lake volume, the charging flow rate and the amount of water for producing energy. In this way, the water is consumed in a more controlled way to generate energy in a running barrage. Moreover, a model with enough data, similar to the ANN model built in this study, can be used for all hydroelectric stations.

It is observed that the prediction ability of ANN models is decreased when the number of neurons is low, and vice versa. However when the neuron numbers exceed a certain amount, the contribution of neurons diminishes; even more there becomes negative effect.

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