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Forecasting Renewable Energy Potential of Turkey Using Artificial Neural Network up to 2030

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Abstract. All over the world, oil based energy sources have many problems for nature and moreover oil has finite volume. All countries deal with renewable energy sources to reduce the energy spending and to improve their freedom on energy dependency. Every renewable energy sources has its own characteristics and applicability. According to latitude and longitude, wind or sun powered energy plants can be chosen and photovoltaic or wind powered power plants may be chosen together or not. According to demands and present request may require some forecasts about energy demands in the future. In future percentage of green energy level gives hints for government to support investment or decide to energy policies. The presented trends and future forecasts of the electricity demand, and how photovoltaic and wind power may grow in percentage of the total demand. Artificial intelligences are very common to solve nonlinear problems in many areas such as biomedical, construction computing etc. Artificial neural network is one of the famous artificial intelligence methods in literature. In this study, artificial neural network is used to forecast wind based energy percents in energy demands through the years up to 2030. One percent increasing in renewable energy amount leads to save money, time and open a gate to powerful economy. Abilities, possibilities and targets in renewable energy sources must be observed and forecasted strictly. Near the year of 2030, Turkey's renewable energy demand will reach estimated target according to artificial neural network. The results showed that renewable energies would not only provide economic and environmental benefits but also improve living standards and a clean world. The presented trends and future forecasts of the electricity demand, and how solar and wind power may grow in the total demand. Artificial neural network is used to forecast renewable energy percentage in total energy demands. Artificial intelligence results are evaluated mean absolute error R^2 statistical validation. Mean absolute error and R^2 method are common ways to evaluate the results in literate. Mean absolute error and mean R^2 validation were obtained as 7.651MW and 0.9999, respectively. Mean absolute error is just 0.035118% percentage mean renewable energy demand.

Keywords: Artificial neural network, renewable energy source, mean absolute error, R^2 validation.

1. Introduction

As energy shortage and environmental impact caused by using fossil fuel get more attention, renewable energy has become a worldwide focus [1]. New technological advances are the most important driving force behind growth and renewal in such fields as information technology, energy supply and genetic engineering that are predicted to provide increasing quality of life [2]. The electricity supply sector, a major source of CO2 emissions in the world, accounts for about 37% of global CO2 emissions, which may continuously increase in the future [3].

Renewable energy is very important by a resource that is sustainable in economic, social and environmental terms. It is usually defined by the fuel source, for example, solar, wind, biomass, tidal, etc., but it has other relevant features that are important. Most of the present demand in the world is met by fossil and nuclear power plants. A small part is met by renewable energy technologies, such as the wind, solar, biomass, geothermal and the ocean. Among the renewable power sources, wind and solar have experienced a remarkably rapid growth in the past 10 years. Both are pollution free sources of abundant power. Additionally, they generate power near the load centers hence eliminate the need of running high voltage transmission lines through rural and urban landscapes [4].

Wind or air motion comes from temperature gradient between two or more regions. Application of wind energy goes back to thousands of years, but its application to generate electricity was made prevalent in the last century. Turkey is situated at the Southeastern Europe and Eastern Mediterranean region with a population of about 73 million. Turkey has experienced rapid economic growth since 1980s and today Turkey ranks among the fastest growing energy markets in the world [5]. Turkey's total national installed capacity is about 44.761 MW by the end of 2009, while it was 16.318 MW in 1990 with the average annual growth rate of 5%. As its economy expands, Turkey can expect a very large growth in energy demand especially that produced from natural gas and electricity. However, since Turkey has very rich renewable energy sources, this potential should be considered as a solution to the future energy problem. Hence, wind energy holds great importance [6]. Currently, the largest share of the installed capacity in Turkey is still attributable to thermal power plants. As of the end of 2008, 66 percent of the total installed capacity consists of thermal power plants, 33 percent of hydro power plants, 0.1 percent of geothermal and 0.9 percent of wind power plants. Although there is currently a low level of non-thermal installed capacity, there is an environment conducive to renewable investments due to substantial renewable energy resources and recent developments in renewable legislation and liberalization in the electricity market [7]. In order to forecast the participation rate of renewable energy, especially wind energy, by both investors and customers is a preparatory study to the future. Many researchers [8-9] have made some important contributions to renewable energy technology foresight studies.

Artificial intelligences are so common techniques to solve nonlinear problem that artificial intelligence are used in many areas from forecasting to generate real time values in many areas [10-12]. Artificial neural network (ANN) is one of the famous artificial intelligence method in literature [13-15]. For training and testing of ANN, real data set was used. For time based data sets, the values flows and change in time. Thus preparing of the data set was in need careful and true outlet. After arranging the data set, data set was divided into three groups as training, testing and validation.

This study was arranged as follows. Energy data structure and re-arranging data structure, the proposed method and ANN were explained in material and methods section. Performance criteria and its results was explained and listed in experimental results. Conclusion was addressed in the last section. In this study, ANN is used to forecast green energy level percentage up to 2030 using official values for Turkey.

2. Material and Methods

Forecasting is a famous problem in electric distributing and power plant managements. In addition to this, many observations are in need to make any forecast or any decision. In this study, ANN is used to forecast green energy percentage in total demand up to 2030. Data structure has 27 attributes and 3 features. Used data includes maximum power demand in an hour, years, total wind and solar power level in total demand and total energy level explained as gig watt hour (GWh). Data structure was created from two sources, Turkish Electricity Transmission Company (TEIAS), and Solar Energy Industrialist and Industry Association (GENSED) [16,17]. In order to obtain more accuracy, data structure re-arranged as time-series structure using backward data. Using backward data leads to improve resolution and decrease number of nodes in the structure for ANN [18,19].

2.1. Data structure and data arranging

Raw data set has three features and 27 attributes. Raw data were re-generated on time axis as four years attributes. Windowed data structure includes past four years, present year and future year. After arranging data set new structure turned into 10 features and 24 attributes. Table 1 shows raw data structure. From the table, past year energy demand was written as observed data and future year energy demand written from official government predicted energy demand through the years.

After arranging the data, the aim is to improve the inherencies from backward data structure for ANN application [18]. Converted data structure was shown in Figure 1 after re-arranging.

Arranged data includes four years packages as two years backward, one year present year and next year. Target is arranged as energy demand for next year green energy level as GWh in total.

Table 1: Raw data structure and data features

Years	Peak load (MW)	Solar and wind based power (MW)	Energy demand (GWh)
2004	23485	19	150018
2005	25174	76	160794
…	…	…	…
2009	29870	380	194079
2010	32170	757.9	209000
…	…	…	…
2030	80132	23500	520643

Year-2			Year-1	Present Year	Target (Future)
Peak load (MW)	Solar and wind based power (MW)	Energy demand (GWh)			
18.938	63.366	118.485			
19.39	64.259	128.276			
…	…	…			
30.982	71.897	200.137			
68.547	72.698	202.368			

Fig. 1: After arranging, raw data turn to time series data structure.

2.2. Artificial neural networks (ANN)

Artificial neural network (ANN) is an emulation of biological neural system based on the operation of biological neural networks. An ANN has lots of paralleled interconnected computational unit which are connected as a hierarchical structure. The elementary of this unit is called as neuron which has computational ability. Learning ability of ANN is hidden in its weights and bias values. A multi layer perceptron (MLP) ANN structure is shown in Fig. 2.

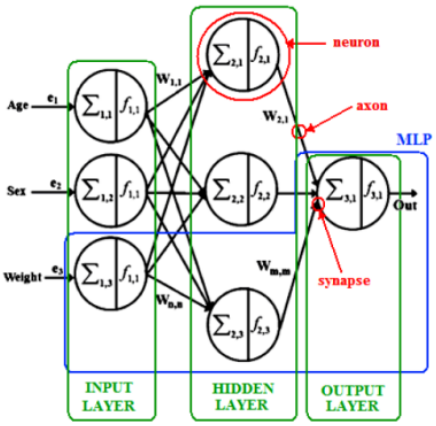

Fig. 2: MLP-ANN structure

ANN learns by examples like human through the learning process [20,21]. An ANN structure consists of an input layer with three neurons, a hidden layer with three neurons, and an output layer. ANN can generate a valid solution for any kind of nonlinear problems [13-15,22]. This problem can be related to pattern recognition, predictions or data classification and so on. For an ANN, one input, one hidden and one output layer are called MLP and this configuration is common [23]. This is miniature of an ANN. The back propagation is widely used to adjust connection weights and bias values using training. Each MLP layer is formed by a number of predefined neurons. The neurons in the input layer can be explained as a buffer which distributes the input signals x_i to next neurons in the hidden layer without humiliating the signal. Each neuron j in the hidden layer sums the input signals x_i after weighting them with the strengths of the respective connections w_{ij} from the input layer, and computes its output y_j as a function f of the sum (Eq. 1):

$$y_i = f(\sum w_{i,j} x_i) \quad (1)$$

where, f is the activation function which is needed to transform the weighted sum of all signals influence a neuron. Although there are many activation function for ANN application due to different data set groups, logsig is very common activation function. All activation functions have different transfer curve that may be threshold, linear tangent etc. In the end, the output neuron in the output layer can be calculated similarly. The training parameters and structure of the MLP was set as 40% training, 30% validation and 30% testing. In this study, the experimental studies were performed on MATLAB(™) 6.5 environment.

2.3. Performance measurement methods

Performance measurement is a way to compare and present for any implementation. Every measurement method has its own characteristic and implementation method. Mean absolute error and R^2 are famous methods of success measurement for any implementation.

Mean absolute Error: Mean absolute error is one of the simplest ways to evaluate any success and depends on mean of difference among observations and real values [24-25]. Mean absolute error is shown in Eq. 2.

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\frac{\left|x_{im} - x_{ip}\right|}{x_{im}} \quad (2)$$

where x_{im} is the i^{th} measured value and x_{ip} is the forecasted value.

R^2 Validation: R^2 is one of the very common statistical performance evaluating methods. R^2 closes to one as long as predicted and measured values are close to each other [26,27]. R^2 value can be calculated by Eq. 3.

$$R^2 = \frac{\sum_{i=1}^{n}(T - T)^2}{\sum_{i=1}^{n}(T - \overline{T})^2} \quad (3)$$

Here, P symbolizes predicted and T symbolizes measured value. For good fitting, R^2 values must be close to one.

3. Material and Methods

In this study, next years of renewable energy increasing were evaluated using ANN and real data structure. ANN is a very common and fast artificial intelligence method. Firstly, in order to improve the inference, data set was re-arranged. Data structure was divided as 40% training, 30% validation and 30% testing. MSE error list is given in Table 2. From the table especially testing error is significantly low and obtained MSE is 7.651 and only 0.000977% of mean renewable energy demand.

Table 2: Obtained MSE and R2 validation for ANN

ANN	MSE	R^2
Training	0.3396	0.9999
Validation	714.87	0.9997
Testing	7.651	0.9999

R^2 presents forecasted values and target values at x and y axises. Closer the obtained and target values, closer the R^2 to1. Fig. 3 shows training validation and test results of R^2 and all of them together.

In this study, a low node size MLP structure and Levenberg-Marquardt training algorithm were preffered. Two hidden nodes were used. Low structure leads to inrease in speed and decrease complexity of the structure. So any re-calculation and applicability are increased.

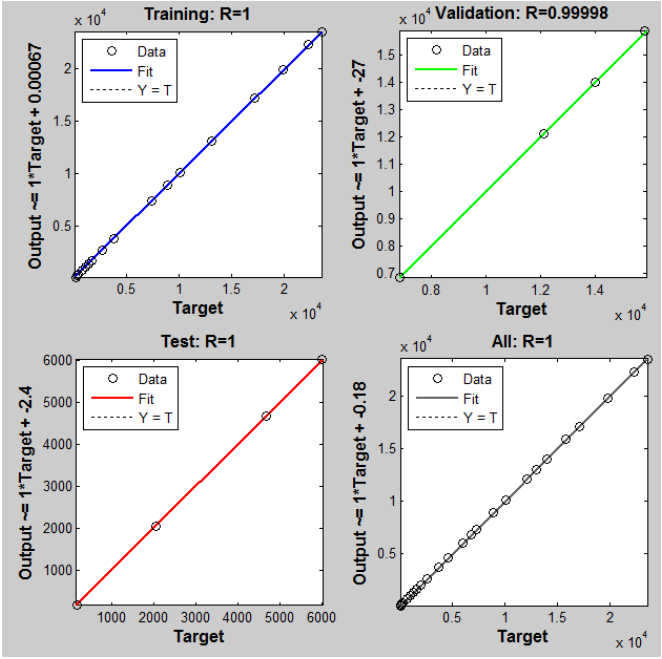

Fig. 3: R^2 validation results for training, validation, testing and all.

4. Conclusion

This study introduces the development status and forecasts on renewable energy power generation suitable for the power industry, in view of the current situation in Turkey. The usage of renewable energy resources shows a promising expectation in Turkey in the future as an alternative to the conventional energy.

This paper was the first attempt to provide an ANN approach of the Turkish renewable energy. Turkey's renewable energy demand will increase through the demand and this study confirms official forecast only 0.3396MW as MSE and 0.9999 resolutions as R^2 validation. Further forecasting is a very difficult problem for energy estimating because of the many kinds of variables. This study can reach same resolution only using backward re-arranged data and ANN. Consequently, the renewable energies will bring not only economic and environmental benefits but also improved living standards a clean world.

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