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The estimation of the electricity energy demand using particle swarm optimization algorithm: A case study of Turkey

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Abstract

Energy is the most important factor in improving the quality of life and advancing the economic and social progress. Demographic changes directly affect the energy demand. At present the world's population is growing quickly. As of 2015, it was estimated at 7.3 billion. The population and the export of Turkey have been increasing for two decades. Consequently, electricity energy demand of Turkey has been increasing rapidly. This study aims to predict the future electricity energy demand of Turkey. In this paper, the prediction of the electricity demand of Turkey is modeled by using particle swarm optimization algorithm. The data of the gross domestic product, population, import and export are used as input data of the proposed model in the experiments. The GDP, import and export data are taken from the annual reports of the Turkish Ministry of Finance. The population data are taken from the Turkish Statistical Institute. The electricity demand data are taken from the Turkish Electricity Transmission Company. The statistical method R^2 and adjusted-R^2 are used as the performance criteria. The experimental results show that the generated model is very efficient.

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*Keywords:*Electricity energy estimation; particle swarm optimization; prediction of the future electricity demand.

1. Introduction

Energy is the most important factor in improving the quality of life and advancing the economic and social progress. Demographic changes directly affect the energy demand. At present the world's population is growing

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quickly. As of 2015, it was estimated at 7.3 billion. According to the report of the International Energy Agency[1], it is expected that the world's population will increase to 9 billion in the year 2040. The urbanization rate of the world's population is 52% in 2011, 53% in 2012. It is expected that the urbanization rate of the world's population will increase to 64% in 2040. But, approximately 1.3 billion people, namely 18% of the world population still remain without access to electricity. These people are mainly in either developing Asia or sub-Saharan Africa, and in rural areas[1]. According to the New Policies Scenario of the International Energy Agency, this situation will continue for a very long time and close to 1 billion people will still be without electricity in 2030. These people will be mainly in Southern Africa, India and Asia. In the world, the proportion of the energy covered by the electricity energy was 18.2% in 2012 and it is expected that the proportion of the energy covered by the electricity energy will be 19.9% in 2020 and 23.8% in 2040[2].

According to the report published by U.S. Energy Information Administration in 2012[3], the world top 20 countries with highest electricity generation in 2012 are shown in Fig. 1(a). China, The U.S., and India are the top producers. Turkey is at 20th rank in the list. Turkey's electricity generation was 246 TW h in 2013. The electricity generation in terms of sources is shown in Fig. 1(b). 48.1% of the electricity was produced by natural gas, 29.2% by coal, 16.1% by hydro, 3.3% by wind and the remaining 3.3% by other sources. According to the Turkish Ministry of Finance[4] and Turkish Statistical Institute[5], the population and the export have been increasing for two decades. Consequently, electricity energy demand of Turkey has been increasing rapidly. Therefore, this study aims to predict the future electricity energy demand of Turkey.

Many researchers have been working about energy demand estimation. Ozturk et al. developed two different non-linear estimation models using GA[6]. One of them is in a quadratic form and the other is in an exponential form. They used the basic indicators of the gross national product, population, import and export figures as the input data of model. They validated the developed models with actual data and estimated the future electricity demand until 2025. Hamzaçebi predicted the net electricity energy consumption of Turkey on sectorial basis until 2020[7]. He used artificial neural networks as prediction tool because ANN has an ability to predict future values of more than one variable concurrently and to model the nonlinear relation in the input data. Three different ANN models were developed. The models are changed depending on the number of the input neurons. The developed models are run in matlab neural network tool box for 1000 epoch. Mean absolute errors, root mean square errors, absolute percentage error and mean absolute percentage error are used as performance criterion. The founded results are compared with official forecasts. Kavaklioglu et al. proposed also a method based on ANN to model and forecast electricity consumption of Turkey[8]. The input data of ANN are population, gross national product, imports and exports. The proposed model was compared with different models using absolute and percentage mean square error. Electricity consumption of Turkey was predicted until 2027 using data from 1975 to 2006. In another research of Kavaklioglu[9], support vector regression was used to model and estimated the electricity consumption of Turkey. Toksari proposed a method based on ant colony optimization algorithm to predict the electricity demand[10]. Ünler proposed also a method based on particle swarm optimizer[11]. Kıran et al. generated a model based on artificial bee colony with neighborhood mechanism[12]. Recently, Kaytez et al. produced a model based on least squares support vector machines[13]. They compared the model with the models based on the traditional regression analysis and artificial neural networks.

This article is organized as follows: Section 2 gives the background information on the PSO algorithm. The model of the electricity energy demand estimation is presented in Section 3. Section 4 reveals the experimental results and analysis of the proposed model. Finally, the article is concluded in Section 5.

2. Particle swarm optimization

The Particle Swarm Optimization (PSO) algorithm that was developed by James Kennedy and Russell Eberhart in 1995[14] was inspired by collective behavior of a bird swarm. It has been widely used to solve the optimization problems in various fields.The advantages of PSO are that it has only few parameters that need to be controlled and its implementation is very simple and easy.

PSO starts with a population of particles randomly positioned in a d-dimensional search space. Each particle in the population has two vectors: a velocity vector and a position vector. To discover the optimal solution, each