

Forecasting electricity consumption: A comparison of regression analysis, neural networks and least squares support vector machines



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ABSTRACT

Accurate electricity consumption forecast has primary importance in the energy planning of the developing countries. During the last decade several new techniques are being used for electricity consumption planning to accurately predict the future electricity consumption needs. Support vector machines (SVMs) and least squares support vector machines (LS-SVMs) are new techniques being adopted for energy consumption forecasting. In this study, the LS-SVM is implemented for the prediction of electricity energy consumption of Turkey. In addition to the traditional regression analysis and artificial neural networks (ANNs) are considered. In the models, gross electricity generation, installed capacity, total subscribership and population are used as independent variables using historical data from 1970 to 2009. Forecasting results are compared using diverse performance criteria in this study with each other. Receiver operating characteristic (ROC) analysis is realized for determining the specificity and sensitivity of the empirical results. The results indicate that the proposed LS-SVM model is an accurate and a quick prediction method.

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Introduction

Long term electricity consumption forecasting is the basis for energy investment planning and plays a vital role in developing countries for governments. Overestimation of the consumption would lead to superfluous idle capacity which means wasted financial resources, whereas underestimation would lead the higher operation costs for energy supplier and would cause potential energy outages. Therefore, modeling electricity consumption with good accuracy becomes vital in order to avoid costly mistakes.

Electricity forecasting models are developed specific to a nation or utility depending on market conditions prevailing. Each country has a specific consumption model to its own conditions. A few important points need to be considered in order to model the electricity consumption accurately. First, the parameters affecting electricity consumption for the country should be well defined. Usually historical data and the independent indicators considered to be influential on this consumption need to be used in the model. The second consideration is to choose a methodology suitable for the consumption model. Traditional methods such as time series, econometric models, regression as well as soft computing

techniques such as artificial intelligence, fuzzy logic and genetic algorithms are being broadly used for electricity consumption forecasting. Ant colony optimization, particle swarm optimization and support vector regression are emerging techniques in electricity demand modeling. Moreover, an applied model should allow for the next step into the future computations.

Electricity market in Turkey has a rapidly developing structure due to industrialization, rapid urbanization and growing population for last two decades. The average annual increase in total electricity consumption in Turkey is about 4–5%, which is far above the average of many countries in Europe and throughout the world [1,2]. However, energy sources in Turkey are quite scarce. Turkey's extensive dependence on import sources for its energy supply creates some economic and political negative effects, making authorities necessary to estimate future electricity consumption accurately by using the accurate models.

Estimates of long-term energy consumption in Turkey are carried out officially by the Ministry of Energy and Natural Resources (MENR) and the Ministry of Development (MD). Official estimation results are higher than actual consumption values in general, and the Ministry of Energy and Natural Resources revises these results every six months. For this reason, it is necessary to use reliable methodologies and to develop new and alternative techniques for the estimation of future electricity consumption in Turkey properly.

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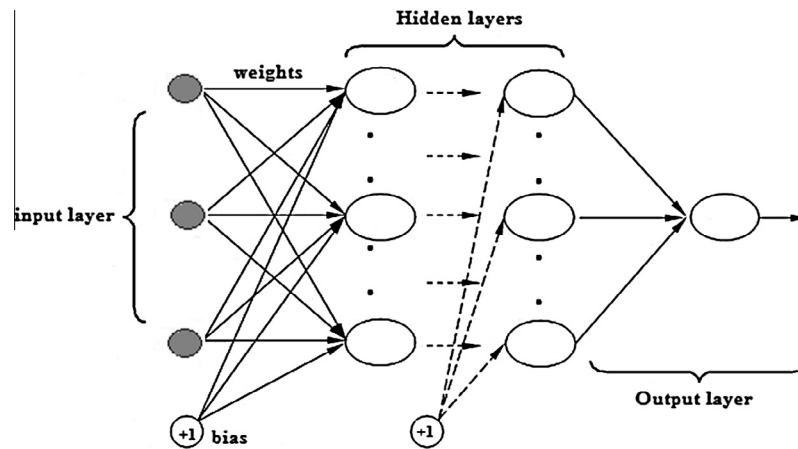


Fig. 1. MLP feed forward ANN.

The main objective of this manuscript is to develop an accurate and optimal LS-SVM model and to propose applicable models for forecasting net electricity consumption in Turkey. In recent years, the least squares formulation of SVM, called LS-SVM has been used in various energy research, such as forecasting, classification, and power engineering [3–6]. The literature review reveals that the LS-SVM technique has not been used for forecasting electricity energy consumption previously. Therefore, this study will provide important contributions to the literature of electricity demand forecasting.

In the literature, there are a number of important studies on electricity consumption and demand estimation. In these studies, some of commonly used methods are time series models, regression models, Box–Jenkins models, econometric models, neural networks, ant colony optimization, genetic algorithms and statistical learning models. Traditionally, regression analysis and time series have been the most popular modeling techniques in electricity consumption predicting [7–9]. The use of neural networks (NNs) has become increasingly popular in many forecasting models. Some researchers have proposed different models to improve the prediction performance using neural networks [10,11]. Artificial neural networks (ANNs) have also been used for the prediction of electricity consumption [12–16]. The following studies were selected from the literature in order to present the variety of the methods. By using genetic algorithms; Ceylan and Ozturk [17] have conducted an estimation study up to the year 2025 in Turkey's long-term energy demand forecasting. By using particle swarm optimization (PSO); Unler [18] has carried out the long-term demand forecast of Turkey up to the year 2025. By using ant colony optimization algorithm (ACO); Toksari [19] has predicted the Turkey's long-term demand under the effect of selected economic and demographic variables. By using an optimized grey modeling; Hamzacebi and Es [20] have forecasted the annual electricity consumption in Turkey. Finally electricity consumption forecasting and robust forecasting modeling have been proposed using the support vector regression model [21] and singular value decomposition [22].

Studies on the relationship between GDP and consumption are increasingly common [23–26]. Karagol et al. [27] investigated the relationship between Turkey's GDP and electricity consumption. They found a negative relationship through cointegration analysis between the variables. Altinay and Karagol [28] showed that there is a unidirectional relationship between electricity consumption and GDP. It is a common hypothesis that energy consumption has a positive effect on economic growth in Turkey. The reverse of this hypothesis is controversial. Especially in Turkey, an increase

in electricity consumption is observed even in periods of low GDP. Turkey's yearly energy consumption was affected by the economic crisis especially. It is difficult to predict or detect economic crises in advance. Therefore, GDP is not used as an independent variable in the model. This study compares mainly the accuracy in predicting long-term electricity consumption in Turkey among three different approaches: regression analysis, neural networks and support vector machines. When comparing accuracy in predicting electricity energy consumption, it is found that the LS-SVM model perform better than other models. The background of the study is described in the following section. Methodologies and results are described in Sections 'Methods' and 'Experimental results', respectively. Comparative advantages of the different data analysis approaches in application to electricity energy consumption and conclusions of results are given in Sections 'Results and sensitivity-specificity analyses' and 'Conclusion', respectively.

Methods

Artificial neural network approach

ANNs have been trained to overcome the restriction of the traditional methods to solve complex problems. This technique learns from given examples by constructing an input–output mapping in order to perform estimations. Neural networks consist of an interconnection of a number of neurons. There are many varieties of connections in literature. However, this study focuses only one type of network, which is called the multi-layer perceptron (MLP) which is shown in Fig. 1.

ANNs use different learning algorithms. A learning algorithm is described as a procedure that consists of adjusting the weights and biases of a network, to minimize an error function between the network output and sample output data for a given set of inputs [29,30]. The backpropagation algorithm (BP) is one of many learning algorithms used to train neural networks and is widely used in solving many practical problems. However, BP has the disadvantage of slow convergence and long training time. Additionally, success of BP algorithm depends on the user-dependent parameters learning rate momentum constant. The Levenberg–Marquardt (LM), scaled conjugate gradient (SCG) and Quasi-Newton algorithms are faster than BP algorithm and use standard numerical optimization methods. The Levenberg–Marquardt (LM) algorithm is an alternative to backpropagation for use in training feedforward neural networks based on a nonlinear optimization. LM algorithms use an approximation of second-order derivatives of the objective

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