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Forecasting Electricity Consumption with Neural Networks and Support Vector Regression

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Abstract

Energy strategy is extremely important for developing countries. As the economy of these countries grow rapidly, their energy consumptions increase substantially. Turkey's high growth rate in the last decade resulted with significant increase in energy consumption. Policy makers should give critical decisions and develop new strategies for meeting this growing energy demand. Apparently, accurate predictions of the future energy consumption are vital for developing such strategies. In this study, we have used the state of the art computation methods to forecast the electricity consumption of Turkey. The forecast results are compared with real consumption values to measure the performance of the methods.

Keywords: Electricity consumption; Forecasting, Artificial neural networks, Support vector regression.

1. Introduction

Energy demand forecasting is one of the most important tools that decision makers use (Ediger and Akar, 2007). It is a very attractive area for researchers and there are various models generated for energy

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demand forecasting. Techniques used in energy demand forecasting studies are mainly composed of Box-Jenkins models, regression models, econometric models and neural networks (Jebaraj and Iniyan, 2006).

Turkey's energy demand forecasting studies dates back to 1960s where State Planning Organization realized a demand forecast study based on simple regression. After that Ministry of Energy and Natural Resources of Turkey also continued studies on Turkey's energy demand. These early forecasts consistently predicted much higher values than the consumptions that actually realized. The model generated by the Ministry, Model of Analysis of the Energy Demand (MAED), is used currently for official prediction. Not only the public enterprises but also academicians developed models on Turkey's energy demand. In the study of Unler (2008) in which GDP (Gross Domestic Product), population, import and export amounts are used as basic energy indicators and hybrid model is used which is composed of Particle Swarm Optimization and Ant Colony Algorithm. Autoregressive Integrated Moving Average (ARIMA) and seasonal ARIMA (SARIMA) methods are used in the study of Ediger, Akar (2007) and they generated a demand forecast model till 2020.

In the studies of forecasting electric energy demand, there are many methods used in the literature including autoregressive integrated moving average (ARIMA), artificial neural networks ANN, time series methods, support vector machines and fuzzy logic method. In the study of Abraham and Nath (2011) Box-Jenkins autoregressive integrated moving average method is used. Abdel-Aal and Al-Garni (1997) generated Autoregressive integrated moving average (ARIMA) models and used Univariate Box-Jenkins time-series analysis for monthly electrical energy demand forecasting. Azadeh, Ghaderi, and Sohrabkhani (2007) used Artificial Neural Network (ANN) approach based on supervised multi layer perception (MLP) network for electricity demand and results are compared with time-series methods by using analysis of variance (ANOVA) technique.

There are also many studies on Turkey's electricity demand forecasting. Kucukali and Baris (2010) generated fuzzy logic approach by using GDP parameter. Akay and Atak (2007) used grey prediction with rolling mechanism (GPRM) technique and compared their results with the results of Ministry of Energy and Natural Resources of Turkey and concluded that their method is more reliable. The study of Erdogdu (2007) which uses autoregressive integrated moving average (ARIMA) modeling is one of the other studies that make comparison with results of Ministry of Energy and Natural Resources of Turkey. They also showed that their model gives better results than results of the Ministry. Toksarı (2007) generated a model for estimating the net electricity energy generation and demand. In the study, GDP, population, import and export based ant colony optimization model is proposed. They also compared their work with the results generated from MAED model of the Ministry and concluded that they have come up with better solutions. The work of Kavaklioglu, Ceylan and Ozturk (2009) was used ANN as a tool for Turkish electricity consumption forecast.

Support Vector Machine (SVM) is a new and promising technique for data classification and regression (Vapnik, 1998). There exist studies on energy in which SVM is used as the methodology. For instance Chen, Chang and Lin (2004) considers the problem of load forecasting which includes predicting maximum electricity load values of each day for the next 31 day period and they used SVM for this purpose. In his paper, Kavaklioglu (2011) considers Turkey's electricity consumption forecast and used SVM for regression as the tool. He formulated electricity consumption as a function of socio-economic indicators like population, imports, exports and Gross National Product. In order to generate a forecast till 2026, consumption data between 1975 and 2006 is used and as a result it is stated that consumption in year 2026 is predicted to be about twice the 2006 consumption.

Electricity demand forecast will provide guidance in strategic management and future demands will give a road map during strategy formulation and implementation processes. Deciding on the forecasting model and methodology for demand prediction is a valuable asset for companies in the energy sector. Based on this research, companies acting in the energy market can set their strategic goals and have the chance to achieve better performance.

Electrical energy is not storable therefore it is a vital need to make a good electricity demand forecast. The main purpose of this study using monthly based consumption data is to develop an accurate forecasting model for predicting electricity consumption in Turkey.

2. Methodology

2.1. Artificial Neural Networks

Artificial neural networks (ANN) are computational techniques modeled on the learning processes of the human cognitive system and the neurological functions of the brain. Recently, there has been considerable interest in the development of artificial neural networks for solving a wide range of problems from different fields. Neural networks are distributed information processing systems composed of many simple computational elements interacting across weighted connections. Inspired by the architecture of the human brain, neural networks exhibit certain features such as the ability to learn complex patterns of information and generalize the learned information. Neural networks are simply parameterized non-linear functions that can be fitted to data for prediction purposes.

Artificial neural networks (ANN) can be classified into several categories based on supervised and unsupervised learning methods and feed-forward and feedback recall architectures. A back propagation neural network (BPNN) uses a supervised learning method and feed-forward architecture. A BPNN is one of the most frequently utilized neural network techniques for classification and prediction (Pankratz, 1983).

The main appeal of neural networks is their flexibility in approximating a wide range of functional relationships between inputs and output. Indeed, sufficiently complex neural networks are able to approximate arbitrary functions arbitrarily well. One of the most interesting properties of neural networks is their ability to work and forecast even on the basis of incomplete, noisy, and fuzzy data. Furthermore, they do not require a priori hypothesis and do not impose any functional form between inputs and output. For this reason, neural networks are quite practical to use in the cases where knowledge of the functional form relating inputs and output is lacking, or when a prior assumption about such a relationship should be avoided.

The success of the NN models depends on properly selected parameters such as the number of nodes (neurons) and layers, the nonlinear function used in the nodes, learning algorithm, initial weights of the inputs and layers, and the number of epochs that the model is iterated

In ANN methodology, the sample data often is divided into two main sub-samples which are named as training and test sets. During the training process, the neural network learns the relationship between output and input criteria, while in the testing process; test set is used to assess the performance of the model.

2.2. Support Vector Machine

Vapnik (1995) developed Support Vector Machine (SVM) which constitutes one of the most robust and accurate methods in data mining algorithms. Its theoretical foundation derived from statistical learning theory. Statistical methods and machine learning methods are combined with SPV method. SVM is a supervised learning method that generates input-output mapping functions from a set of training data.

Observations constitute source of SVM learning process. There is an input space and output space and a training set. The nature of the output space decides the learning type. Learning types can be of any kind including type of binary or multiple classification problems. The standard SVM formulation solves only the binary classification problems.

Predicted value in SPM methodology represents “attribute” where transformed attribute defines “feature”. Hyperplane is defined by the transformed attribute. The task of selecting the most appropriate representation is known as “feature selection”. A set of features that describe one case is called a “vector”.

Mapping data to a high dimensional feature space is the working manner of SVM where the mapping functions can be either classification or regression function. SVM methodology is among maximal margin classifier types. There are four kernel functions (linear function, polynomial function, and radial based function, sigmoid function) to be used in classification problems when the input data is not easily separable.

Optimal hyperplane is found by SVM which separates the clusters of vector in such a way that cases with one category of the target variable on one side of the plane and cases with the other category are on the other side of the plane. Support vectors are the ones near the hyperplane. A separator which is drawn as a hyperplane is found between the separated classes.

The ultimate aim of SVM is to establish a maximal margin between the separated classes. Establishing a maximal margin between the separated classes will enable to have a good classification performance on the training data as well as to provide high predictive accuracy for the future data from the same distribution. The characteristic of new data after separation can be used for prediction. SVM’s learning ability is independent of the dimensionality of the future space and that situation leads to SVM providing good performance (Cristianini and Shawe, 2000).

In the support vector machine (SVM) technique described above only applies to classification and output variables are restricted to take only binary values. However, the SVM models have been extended for general estimation and prediction problems, including a version of SVM for regression, which is known as support vector regression (SVR) technique. Usage of support vector regression (SVR) technique eliminates this restriction since SVR methodology allows use of nonlinear functions.

3. Forecasting Monthly Electric Energy Consumption of Turkey

In this section first we have examined the structure of the monthly consumption data, and then we have forecasted monthly consumption values of 2010 and 2011 with using different artificial neural network algorithms.

3.1. The Data: Monthly Electricity Consumption of Turkey

The monthly electricity consumption data of Turkey from January 1970 to December 2011 were obtained from EUAŞ (Electricity Generation Company of Turkey). The time series plot of the consumption data is given in Figure 1. It is obvious that the data is non-stationary. There is clear increasing nonlinear trend and the variance of the data is also not constant. These suggested that regular time series methods cannot be applied this data without making transformation and differencing to remove unconstant variance and trend.

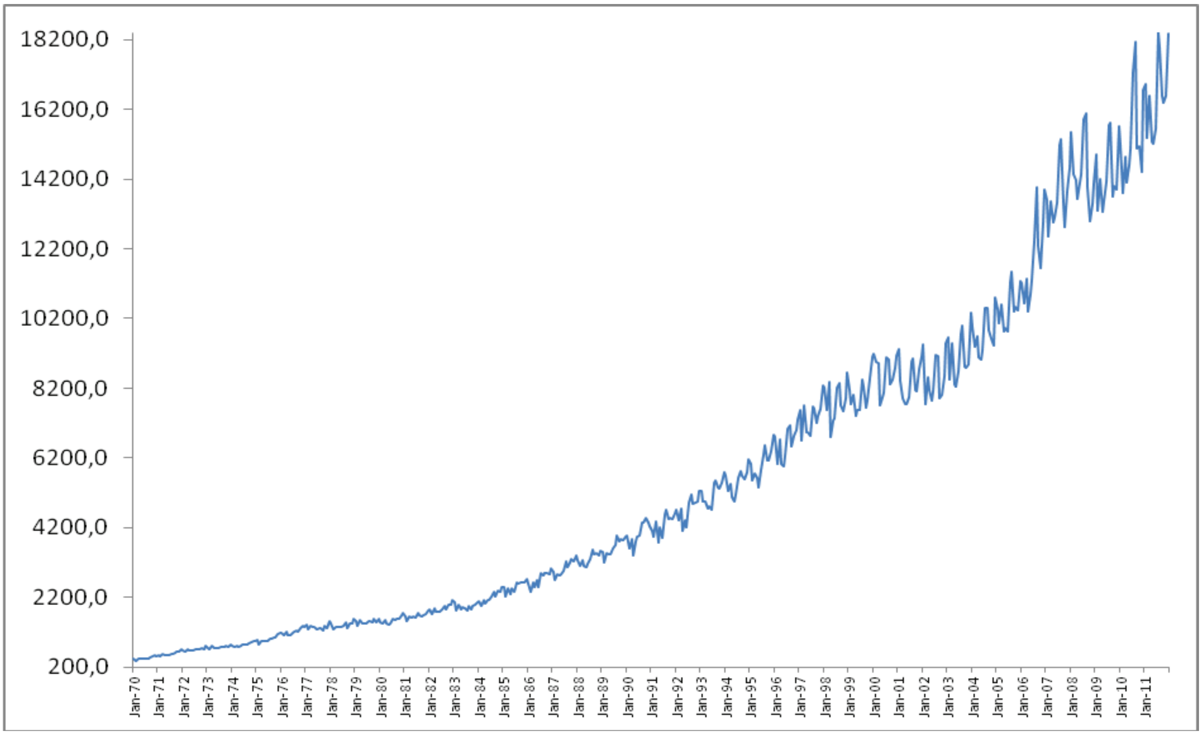

Fig. 1. Turkey's Monthly Electricity Consumption from January 1970 to December 2011

As the data period is long it is not clear from the time plot that whether there is seasonality or not. To reveal this issue we have plotted in Figure 2 last five years of consumption on the same plot where the y axis is 12 months. Again it is clear that there is seasonality in the consumption values: summer and winter months have high consumption values whereas spring and fall months have lower ones. This also suggested that to apply time series method we should take the seasonal differences of the data.

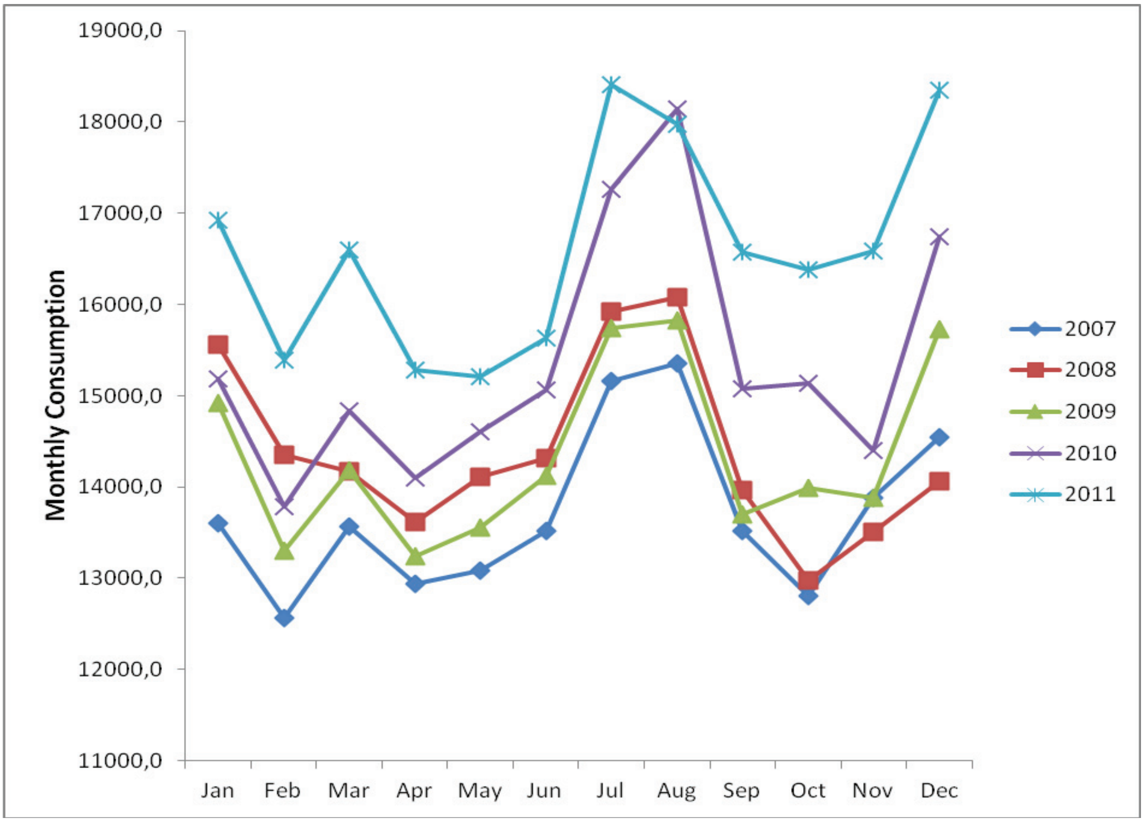

Fig. 2. Turkey's Consumption Values of Each Month at Last 5 Years

Though the plot in Figure 1 shows that the variance of the data is changing with time, it is not very clear. We have removed the trend by taking first differences and the seasonality by taking seasonal differences. The resulted data is plotted in Figure 3. Now it is clear that the variance of the data is increasing with time and to apply a regular method we need to make transformation.

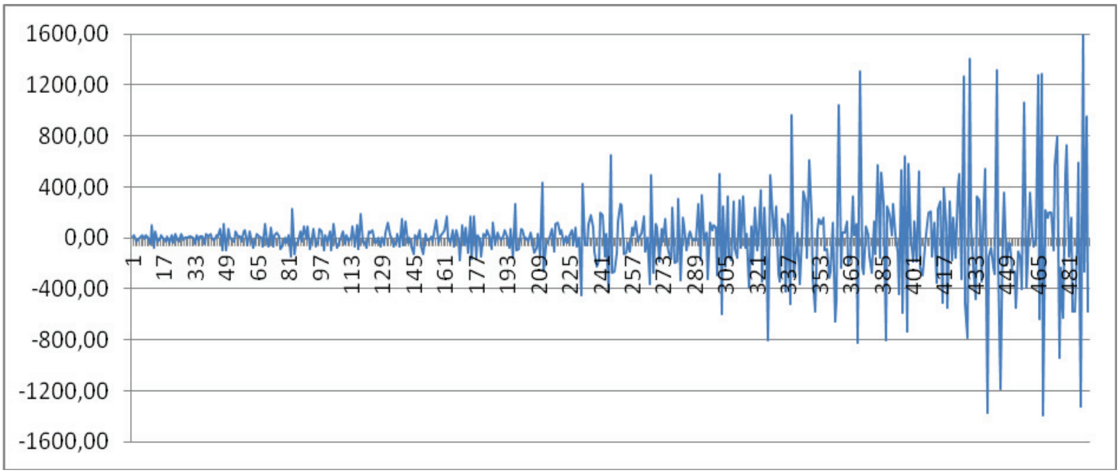

Fig. 3. Trend and seasonality removed consumption data

All these examinations suggested that this data is a good candidate to apply artificial neural networks (ANN) and support vector regression (SVR) that both can be applied to forecast nonlinear and non-stationary data.

3.2. Forecasting Using ANN and SVR

The dataset covers the time period 1 January 1970 through 31 December 2011. In our study like traditional univariate time series methods for forecasting we have only used the consumption data. However in literature the forecasting electricity consumption studies using either ANN or SVR always used multivariate data where the consumption data is the dependent (output) variable and some other variables such as economic variables are inputs.

In our study, total five inputs and one output were employed where all derived from the consumption data. These inputs are 'lag 12', lag 24', 'seasonal index', 'time index', and "month index". Output of the study is electricity consumption.

Monthly electricity consumption and all independent variables used in the analysis are normalized to the 0-1 range. ANN and SVR algorithms are designed to pick nonlinear patterns in the data. In artificial models, normalization makes it easy to compare weights of links between neurons. The reason behind using SVR rather than SVM is that SVR fits more to our problem since electricity consumption is a continuous variable and SVR is able to use nonlinear functions.

The data set was partitioned into training and testing data sets. The model is initially trained using data from 1 January 1970 to 31 December 2009 period, i.e. "training sample" which consists of 480 months. Then forecasting performance of each model is evaluated by conducting out-of-sample tests on the 24 months between 2010 and 2011, called the "test sample". For performance analysis, the test data sets were used for assessment.

Table 1 is the demonstration of errors of training data based on two methods. Training data is composed of electricity consumption values between years 1970-2009. In order to measure the performance of the methods MAPE (Mean Absolute Percentage Error) is used. MAPE is calculated as the following equation

$$MAPE = \left(\frac{1}{n} \left(\sum_{t=1}^{n} \left| \frac{A_t - F_t}{A_t} \right| \right) * 100 \right) \tag{1}$$

where A_t is the actual value and F_t is the forecast value and n is the number of forecasted points in time.

Table 1. Model Performance Based on MAPE Results

	ANN	SVR
Training Data	13.8%	11.0%

In order to make a comparison between the forecasted values of ANN and SVR methods, error values based on MAPE are used. Results based on test data which includes the two years period of 2010-2011 showed that SVR has a lower MAPE value (see Table 2).

Table 2. Forecasting Performance Based on MAPE Results

	ANN	SVR
Test Data	3.9%	3.3%

In Figure 4, electricity consumption values generated by ANN and SVR methods and also the real consumption values are represented. As can be seen from the figure, both of the methods are capable of tracking the actual trend in electricity consumption. However SVR forecasts catches the real consumption better than ANN, which is consistent with MAPE results.

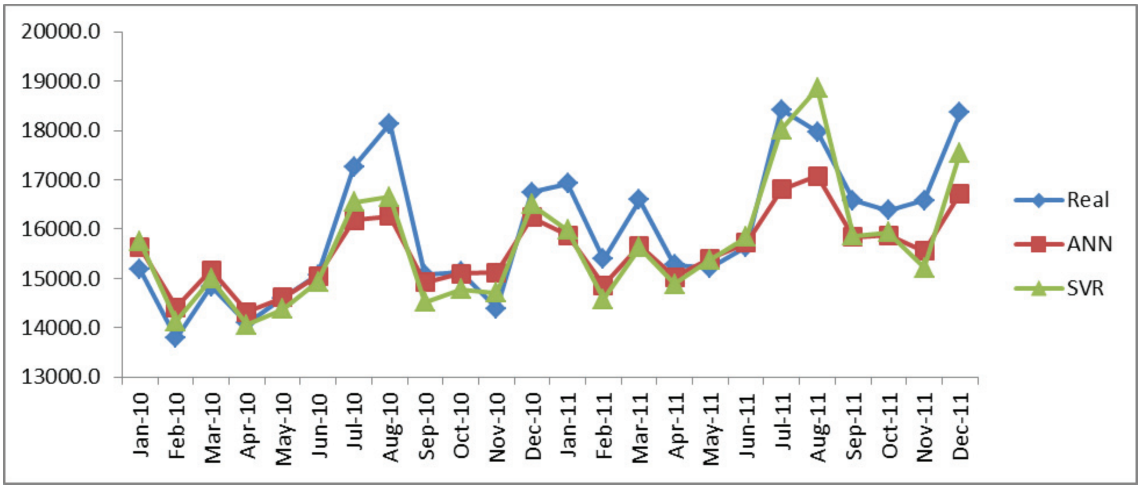

Fig. 4. The Plot of 2010-2011 Real Consumption Values and Predictions from ANN and SVR

Though both methods perform well and have less than 5% of error for predicting the real consumption values, support vector regression performs slightly better than neural networks. Only using univariate consumption data and forecasting with 3.3% error is a good achievement. As a result we can suggest SVR confidently for the energy planners for predicting future electricity consumption of Turkey.

4. Conclusions & Future Research

With a rapidly growing economy Turkey has become one of the fastest growing energy markets in the world. Today, Turkey's total installed power generation capacity exceeded 50,000 megawatts (MW). According to Turkish Electricity Production Company (TEİAŞ) and Energy Market Regulatory Agency (EPDK), of this capacity, 64.3 percent was attributable to thermal power plants and another 32.8 percent to hydroelectricity power plants. Most of the remaining 2.9 percent capacity was attributable to windmills. Installed power generation capacity in Turkey is expected to become approximately 100,000 MW in 2023. Turkey is presently dependent on foreign energy supply but desires to become self-sufficient by 2023. Therefore prediction of electricity demand in Turkey becomes very important.

In this study SVR and ANN models were employed to develop the best model for predicting electricity output within 2010 and 2011. SVR models have been successfully used in time series forecasting problems, but they have not been widely explored in seasonal time series prediction. This study proposed a seasonal SVR model for forecasting seasonal time series data. The study indicates that seasonal SVR model outperforms the ANN model. The results of the study provided empirical evidence that electricity consumption in Turkey will be increased in the near future therefore energy sector will be the most important investment area for both local and foreign companies.

This model can be extended in the future. First, the wavelet algorithm and SVR model can be combined. Another future research direction could consider hybrid model using heuristic techniques such as genetic algorithm and particular swarm optimization techniques for improvement in the forecasting accuracy of the SVR model in a seasonal time series data.

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