A comparison of ANFIS and ARIMA techniques in the forecasting of electric energy consumption of Tokat province in Turkey

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ABSTRACT

In this study, the electric energy demand of Tokat province was estimated by means of ANFIS and ARIMA techniques. Seven different forecasting experiments were implemented for the subscriber groups and the consumption of electric energy which is the dependent variable. The electric energy demand of the province for the first six months of the year 2011 was estimated by means of ANFIS and ARIMA techniques. The obtained results were compared and interpreted in order to illustrate the forecasting success of these techniques. We showed that the ANFIS is more appropriate than the ARIMA in point of the forecasting of electric consumption.

Keywords: *Electric energy consumption, Forecasting, ANFIS, ARIMA, and Tokat.*

Jel Codes: C22, C45, Q47

Introduction

Nowadays, energy is an important source of life. By entering into the life of mankind in 1880s, the electric energy gradually became an indispensable part of modern life and industry (Şekerci Öztura, 2007).

In order to generate the electric energy, which is a secondary energy source, the support of primary energy sources is needed. Electric energy is widely used in many fields, and a large part of energy resources for the benefit of the people are converted into electric energy (Demir, 1968). The electric energy demand has been continuously increasing in parallel with the growing population, urbanization, industrialization, technologic deployment, and enhancement of welfare.

The spread of the usage fields of electric energy which is one of the most important parts of all types of economic activities increases the electric energy demand. Also, since the distribution network provided a great deal of the electric energy of even the smallest residential areas, the share of electric energy in the total energy consumption increased (Kılıç, 2006).

The province of Tokat is geographically located between 39-51, 40-55 North latitudes and 35-27, 37-39 East longitudes, in the inner side of middle Black Sea part of Black Sea Region. Covering the 1.3% of mainland Turkey, elevation from the sea level of the province is 623m and surface area of it is 9.958km² (Governorship of Tokat, 2006). There are 12 districts of Tokat province including with the central district[1]. Historical periods of the province consist of Hattie, Hittite, Phrygian, Med, Persian, Alexander the Great, Roman, Byzantine, Arabian, Danishmend, Anatolian Seljuk, Mongolian, Ilkhanid, Ottoman Governments and Emperors (Provincial Department of Environment And Foresty of The Governorship of Tokat, 2007:1). The province of Tokat became a province with the proclamation of the republic in 1923 (Turkish Statistical Institute, 2010:10). By 2010 the population of the province is 550.703 (Turkish Statistical Institute, 2010).

The province has a wide potential of both agriculture and other sectors (such as tourism). In the economic structure of the industry, agriculture, livestock sector plays an important role. Particularly in the food industry, rock and land-based industries, forest products industry and in recent years, textile weaving and garment sector is the backbone of the economy in Tokat (Provincial Department of Environment And Foresty of The Governorship of Tokat, 2007:130).

Electric energy was firstly provided in the city center of Tokat in 1935 by the Hydroelectric power plant which was built on Aksu for the city lightening. This power plant consists of 2 tribunes with 175 horsepower (HP), and each tribune operates by 230 m^3 water passing through the water channel. The power plant provided electric energy of 135 kWh for 1580 subscribers. However, the electricity production was insufficient for the city. Because of Almus Hydroelectric power plant built in 1966, Tokat had continuously the electric energy, and still it provides the electric energy of the city. Besides, transmission lines were renewed and electric energy of every part of the city was provided by using 18 transformers (Governorship of Tokat, 2006). The installed power plant in Tokat consists of Almus, Köklüce, Ataköy Hydroelectric power plants within Tokat. Almus Hydroelectric power plant became operational in 1966 and Number of Unit – Power is 3X9 MW and its installed power is 27 MWAnnual production of the plant is 100 GWh. Köklüce entered service in 1998 and Number of Unit – Power is 2X46 MW and its installed Power is 90 MW. Annual production of the power plant is 588 GWh (Electricity Generation Corporation, 2011). The construction of Ataköy Hydroelectric power plant dam was completed in 1977. Having 5.5 MW Power, its annual production is 8 GWh (VIII. Regional Directorate of State Hydraulic Works, 2011).

In this study, electric energy demand are estimated by Adaptive Neuro-Fuzzy Inference System (ANFIS) and Autoregressive Integrated Moving Average (ARIMA) techniques by using the electric energy consumption data of Tokat province in the time of period between January 2002 and December 2010. Matlab 7.04 package program is used for the ANFIS model and Minitab 14.0 package program is used for the ARIMA model.

Aim

This study aims at contributing to the planning of supply by estimating electric demand in the future. The demand for electric energy was forecasted in Tokat province by means of the ANFIS and the ARIMA models. The generation planning of electric energy is very important because it cannot be stored, and therefore must be consumed shortly after its generation. If these kind local studies were generalized into all country, it helps the supply planning and provides a more effective usage of resources. Therefore we estimated the electric energy demand by ANFIS and ARIMA models for Tokat province.

Literature

Energy consumption and demand are among the most debated topics, and many studies have been made available in the literature. It is seen that the studies especially focused on the causality between the electricity consumption and economic growth and controversial results has been achieved. There are scarcely any studies on electric energy consumption and demand through ANFIS and ARIMA models. These models are often used in engineering studies.

There are many studies in various fields by using the fuzzy logic method. In one of them, Tufan and Hamarat (2003) analyzed the "Aggregation of The Financial Ratios of publicly-traded companies Through Fuzzy Logic Method".

The first detailed study examining the demand for electricity with the help of econometric models is the work of Houthakker (1951). The study includes the econometric analysis of the household electricity demand through cross-section data from the period of 1937-1938 for 42 residential center in England. Another study was conducted by Fisher and Kaysen. Fisher and Kaysen (1962) using time-series and cross sectional data, examined the demand for electricity with the help of multiple regression and analysis of covariance. Electric demand was taken up in four components, including electricity demand, household electricity demand, industrial electricity demand and the short and long period determinant of them. Accordingly, short run is in question if the stock of electric appliances is fixed and long run is in question if the stock is variable. In the case of industry, short run is in question if there is an assumption that technology is invariable and long run is in question if there is an assumption that technology is variable (Tak, 2002).

Al-Garni and Javeed Nizami (1995) developed a model of artificial neural networks for electric energy consumption with the data from seven years such as temperature, moisture, solar radiation and population. After the comparison of the model of artificial neural networks with the regression model, it was revealed the model of artificial neural networks was a better forecasting model.

Al-Garni and Abdel-Aal (1997) estimated the Electric Energy consumption for five years on the east of Saudi Arabia for the consumption on the sixth year, developing monthly ARIMA models by using the univariate and Box-Jenkins time-series analysis. When ARIMA models are compared to the abductive network machine-learning models, it is seen that ARIMA models needs less data and coefficient and give better results as well.

Brown and Koomey (2002) examined the increase in electric demand in their work named "Electric Use in California: Past Trends and Present Usage Patterns. They took sector (settlement, commercial, industrial, agricultural and other) of electric consumption from the previous period as data. They brought forward that there had been a great increase in the electric demand in 1990, compared to 1980 and that it stems from the increase in buildings and the tendencies in the building sector (Enduse Forecasting and Market Assessment, 2011).

It can be seen that the studies on the modeling of the energy consumption and demand, which is also crucial for the economy of Turkey, accelerated in 2000s. There are not many studies, done widely on the provincial (regional) electricity consumption and demand. State institutions and organizations of which subject of activity is electricity became obliged to state the electricity consumption of the provinces on their annual report on the basis of subscriber groups after "Legislation On The Annual Reports Drawn Up By The Public Administrations" were published by the Ministry of Finance on the Official Gazette dated 17.03.2006 and became effective on 01.01.2006 (Official Gazette, 2006). These institutions conduct studies also on the monthly and yearly electric data which must be sent to Turkish Statistical Institute (TÜİK) and Ministry of Energy and Natural Resources (ETKB) by these institutions even though these data changes in the ensuing years.

In the work of Terzi (1998) which analyzes the relationship between the electric consumption and economical growth for the period of 1950-1991, the relationship between the electricity consumption and of the commerce house, industry and household and economical growth; the long period relationship between the variables were determined through the Engle-Granger cointegration method and the short run dynamics were analyzed through the debugging tool. It was determined through this econometric method that the income and price elasticity were in fact inelastic. A meaningful and two-way relationship between electricity consumption and economical growth came along in the business and industry sector.

Sarı and Soytaş (2004) employed the technique of generalized forecast error variance decomposition and came to the conclusion that the electricity demand and variance in national income growth are as important as employment (Lise & Van Monfort, 2005).

Çebi and Kutay (2004) used artificial neural networks while estimating the long run electric energy consumption and compared the results to the Box-Jenkins models and regression technique. The results revealed that using artificial neural networks was a good forecasting method for electric energy consumption.

In addition, we must specify the MAED (Model for Analysis of Energy Demand) model study of Ministry of Energy and Natural Resources, the most important study that was conducted in our country, which reveals the medium and long run general energy demand and electric energy demand in this demand.

Research Method

In this study, monthly electricity consumption data of Tokat province was used. This data covers the period between January 2002 and December 2010. The subscriber groups consist of private houses, industry, business firms, government agencies and other subscribers. The total electricity used in agricultural irrigation, fresh water, work-sites, temporary activities, state-owned enterprises, municipalities, internal activities, prefectures, sanctuaries, and local government lightening systems was also included in these groups. Seven different experiments were implemented for investigating the success of the ANFIS and the ARIMA models in the forecasting of the total electric energy consumption of all subscriber groups.

Time Series and Box-Jenkins Forecasting Model

Time Series

A time series is simply a sequence of numbers collected in regular intervals (as day, month and year) over a period of time (Dikmen, 2009: 227). Time series monitors the motion of a variable in a time sequence. For example, monthly unemployment ratio, monthly increase ratio of money supply, annual inflation ratio, monthly electric use, etc. Time series can be also used as a resource of knowledge acquisition and a method for forecasting the future. While in the evaluation process, analysis is important in degrading the trend, growth trend, seasonality, cyclical, and irregular fluctuations (Bozkurt, 2007). The selection of method used for forecasting the future values depends on the estimation of purpose, type and elements of time series, amount of data, and the length of the estimation period (Asilkan & Irmak, 2009).

Box-Jenkins Forecasting Model

Box-Jenkins method is the most widely used model for stationary time series modeling. For the implementation of Box- Jenkins method, the time series must be stationary (with constant mean, variance and autocorrelation). If the series is not stationary, it should be made stationary by taking the difference of a few times (Gujarati, 2009).

Box-Jenkins method is based on the principle that each time series is a function of past values and may only be explained by means of them. Some assumptions cannot be applied based on the econometric models, but there is not any restrictive assumption for Box-Jenkins method (Bircan & Karagöz, 2003). In this method;

- In contrast to the regression models that explain y_t with a k number of explanatory variables of $x_1, x_2, x_3, \ldots, x_k$,
- The dependent variable Y_t can be explained by its own past or lagged values and stochastic error terms.

The most important stage of the Box-Jenkins method is the selection of the appropriate ARMA (p, q) model by examining the autocorrelation and partial autocorrelation coefficients. Experience of the researcher is very important because of this phase is not able to determine mechanically. If the time series is not stationary, artificial autocorrelations will prevent the model to determine. Non-stationary time series is transformed stationary time series by logarithmic transform or taking differences.

Autocorrelation and partial autocorrelation coefficients of the distribution can be examined with the help of graphs (autocorrelation function (ACF) and partial autocorrelation function (PACF). When the autocorrelation coefficients are seen to be approaching zero exponentially, AR model must be applied; while the partial autocorrelation coefficients are realized to be approaching the same level mentioned above, then MA model must be used; if both of these approach zero exponentially; ARMA model must be applied in this situation.

In ARMA model, the degree of AR is determined by the number of partial autocorrelation coefficients (p), while the degree of MA is determined by the number of autocorrelation coefficients (q) (Önder & Hasgül, 2009: 65–66).

ARMA models consists of four models, these are AR, MA, ARMA and ARIMA. These models will be explained in the following: (Demirel & et al., 2010).

AR (p) Model

In AR (p) model, Y_t value is the linear function of stochastic error term and weighted aggragates of past values in p period of the series. AR (p) model is shown as follows:

$$Y_t = \Phi_1 Y_{t-1} + \Phi_2 Y_{t-2} + \ldots + \Phi_p Y_{t-p} + \delta + at$$
(1)

In the above model, Y_{t-1}, Y_{t-2},..., Y_{t-p} is the values of past observation, Φ_1, Φ_2,..., Φ_p is the coefficients for the values of past observation, δ is the constant value and at is the error term.

MA(q) Model

In MA (q) model, Y_t value is the linear function of average past error terms in q period backwards. MA (q) model is shown as follows:

$$Y_t = \mu + at - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \ldots - \theta_q a_{t-q} \qquad (2)$$

In the above model a_t, a_{t-1}, a_{t-2},……, a_{t-q} is the error terms, θ_1, θ_2, … , θ_q is the coefficients of error terms and μ is the average of the series.

ARMA (p,q) Model

ARMA model, the most stochastic preocess models, is the linear function of past observations and error terms. ARMA (p,q) model is generally shown as follows:

$$Y_t = \Phi_1 Y_{t-1} + \Phi_2 Y_{t-2} + \ldots + \Phi_p Y_{t-p} + \delta - at + \theta_1 a_{t-1} - \theta_2 a_{t-2} - \ldots - \theta_q a_{t-q} \qquad (3)$$

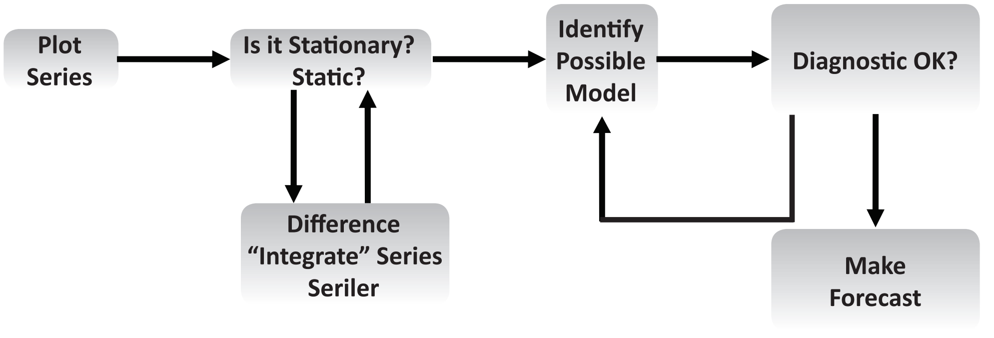
In third equation, Y_{t-1}, Y_{t-2}, ..., Y_{t-p} is the past observation values, Φ_1, Φ_2 ,..., Φ_p is the coefficient for past observation values, δ is the constant, a_t, a_{t-1}, a_{t-2}……, a_{t-q} is the error terms and θ_1, θ_2, … , θ_q is the coefficients of error terms.

ARIMA (p,d,q) Model

To make a non-stationary time series stationary, one or two times the difference-making process is carried out and the result are shown with d. The model that is applied to the series stationary by differencing is called as non-stationary linear stochastic model or integrated model shortly (Bircan & Karagöz, 2003).

Figure 1. Box-Jenkins Procedure

Box-Jenkins process operates as follows: (Dobre & Alexandru, 2008: 157).



Adaptive Neuro-Fuzzy Inference System (ANFIS)

Fuzzy Inference System (FIS) consists of three conceptual components: fuzzy rule base, data base and inference. In this system, the fuzzy rules and membership functions of input and output variables are determined by the user. The most important step is to set the membership degrees of input and output variables. FIS techniques aim at providing of significant inferences by using the linguistic rules (Ross, 2004).

Fuzzy systems do not have the skill to learn things, so they heavily depend on expert opinion. Adaptive Neuro-Fuzzy Inference System (ANFIS), a hybrid model, was first developed by Jang in 1993 in order to overcome this problem. This system has combined the learning skill by artificial neural networks with inference skill of expert opinion based FIS models (Jang, 1993). It adjusts the membership functions of input and output variables and generates the rules related to input and output, automatically. ANFIS can produce all the rules by using the dataset and enables the researchers to interpret these rules. Therefore, it is the widely used model in the studies of classification and estimation.

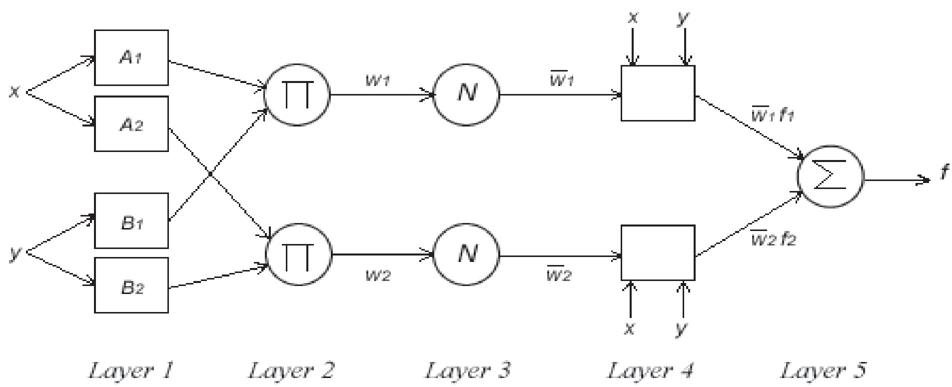
In an ANFIS model consisting of two inputs and one output, the set of rules is as follows (Jang, 1993):

$Rule\ 1$: If x is A_1 and y is B_1, then $f_1 = p_1 x + q_1 y + r_1$

$Rule\ 2$: If x is A_2 and y is B_2, then $f_2 = p_2 x + q_2 y + r_2$

where x and y are the inputs, A_i and B_i are the fuzzy sets, f_i are the outputs within the fuzzy region specified by the fuzzy rule, and parameters p_i, q_i and r_i are the design parameters that are determined during the training process. The ANFIS architecture to implement these two rules is shown in Figure 2, in which a circle indicates a fixed node, whereas a square indicates an adaptive node (Jang, 1993).

Figure 2. Structure of an ANFIS.



In the first layer, each node produces membership grades to which they belong to each of the appropriate fuzzy sets using membership functions. The outputs of this layer are the fuzzy membership grade of the inputs, which are given by

$$O_i^1 = \mu A_i(x) \tag{4}$$

$$O_i^1 = \mu B_{i-2}(y) \tag{5}$$

Where, x and y are the crisp inputs to ith node, A_i and B_i (small, large, etc.) are the linguistic labels characterized by appropriate membership functions μA_i and μB_i, respectively.

In the second layer, every node multiplies the incoming signals and sends the product out. Each node output represents the firing strength of a rule.

$$O_i^2 = w_i = \mu_{A_i}(x) \times \mu_{B_i}(y) \tag{6}$$

In the third layer, the main objective is to calculate the ratio of each *i*th rule's firing strength to the sum of all rules' firing strength. Consequently, $\overline{w}_i$ is taken as the normalized firing strength

$$O_i^3 = \overline{w}_i = \frac{w_i}{w_1 + w_2} \tag{7}$$

In the fourth layer, the nodes are adaptive nodes. The output of each node in this layer is simply the product of the normalized firing strength and a first order polynomial (for a first order Sugeno model). Thus, the outputs of this layer are given by

$$O_i^4 = \overline{w}_i f_i = \overline{w}_i (p_i x + q_i y + r_i) \tag{8}$$

where $\overline{w}_i$ is the *i*th node's output from the previous layer. Parameters p_i, q_i and r_i are the coefficients of this linear combination and are also the parameter set in the consequent part of the Sugeno fuzzy model.

In the fifth layer, there is only one single fixed node. This single node computes the overall output by summing all the incoming signals as follows

$$f = \sum_i \overline{w}_i f_i = \frac{\sum_i \overline{w}_i (p_i x + q_i y + r_i)}{\sum_i w_i} \tag{9}$$

Accordingly, the defuzzification process transforms each rule's fuzzy results into a crisp output in this layer.

In this study, the ANFIS was trained by hybrid learning algorithm which is highly efficient in training the ANFIS. This learning algorithm adjusts all parameters $\{a_i, b_i, c_i\}$ and $\{p_i, q_i, r_i\}$ to construct the ANFIS output match the training data. When the premise parameters a_i, b_i and c_i of the membership functions are fixed, the output of the ANFIS becomes as follows:

$$\begin{aligned} f &= \overline{w}_1 f_1 + \overline{w}_2 f_2 \\ &= \overline{w}_1 (p_1 x + q_1 y + r_1) + \overline{w}_2 (p_2 x + q_2 y + r_2) \end{aligned} \tag{10}$$

Where, p_1, q_1, r_1, p_2, q_2 and r_2 are the adjustable resulting parameters? The least squares method is widely used to easily identify the optimal values of these parameters (Jang, 1993).

ARIMA and ANFIS Applications

We benefited from autocorrelation and partial autocorrelation functions of the related series in order to obtain ARIMA models. The appropriate models for applications were investigated based on the monthly electric data between years 2002–2010. After choosing the models, the monthly electric values pertaining to the period between the first half of 2010 and second half of 2011 were estimated by the models. Then, the forecasting values relating to the second half of 2010 were compared with the real values of the same period.

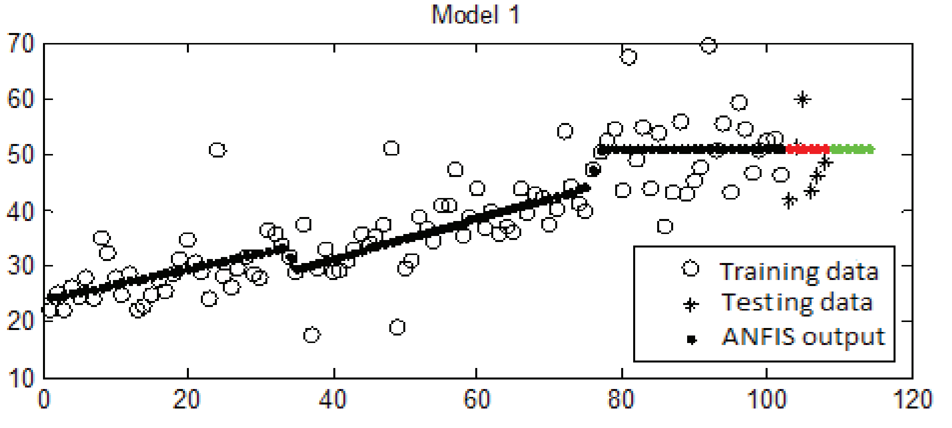
Seven different models based on the subscriber groups were tested for the investigations. They are total electric use (Model 1), electric use in private houses (Model 2), electric use in industrial organizations (Model 3), electric use in business firms (Model 4), electric use in government agencies (Model 5), electric use in other subscriptions (Model 6), and electric use in business firms-government agencies-other subscriptions (Model 7). In the implemented experiments, we observed that there is no ARIMA model appropriate for Model 1 and 7.

Experiment 1.
Analysis of total energy use (Model 1)

In the construction stage of an appropriate ARIMA model related to the consumption of total energy use, we determined that the change of energy consumption versus months is non-stationary. The difference of the monthly energy series was taken once in accordance with the autocorrelation and partial autocorrelation function graphs. When the difference was once taken, the series had got stationray character in model validation stage. However, the ARIMA techniques generated through tests are to pass the suitability test in order to be used for future forecastings. Thus, it is indicated that the autocorrelation coefficients of the forecastings generated through the ARIMA techniques show a trend of systematicity in the suitability test. Despite all those efforts put forward, no model was detected as appropriate for this purpose.

When the ANFIS model was trained by the training dataset for 1000 iterations, it found three rules for this experiment. The results obtained by ANFIS model are shown in Figure 3, where the test result of the model is red line and the forecasting of the next six month period is green line as follows:

Figure 3. The ANFIS output for Model 1.



As seen in Figure 3, there is a small decrease possibility, but the stationary case will be lasting in the next six months. The comparative results of ARIMA and ANFIS techniques are given in Table 1:

Table 1. Forecasting of total electric use (Model 1)

Month	Real	ARIMA		ANFIS	
		Forecasting	MSE	Forecasting	MSE
Jul.10	42,0229	No appropriate model has been found		50,9282	40,4117
Aug.10	51,4488			50,9275	
Sep.10	59,9116			50,9268	
Oct.10	43,4847			50,9261	
Nov.10	46,3052			50,9254	
Dec.10	48,5912			50,9247	
Jan.11				50,9240	
Feb.11				50,9233	
Mar.11				50,9226	
Apr.11				50,9219	
May.11				50,9212	
Jun.11				50,9205	

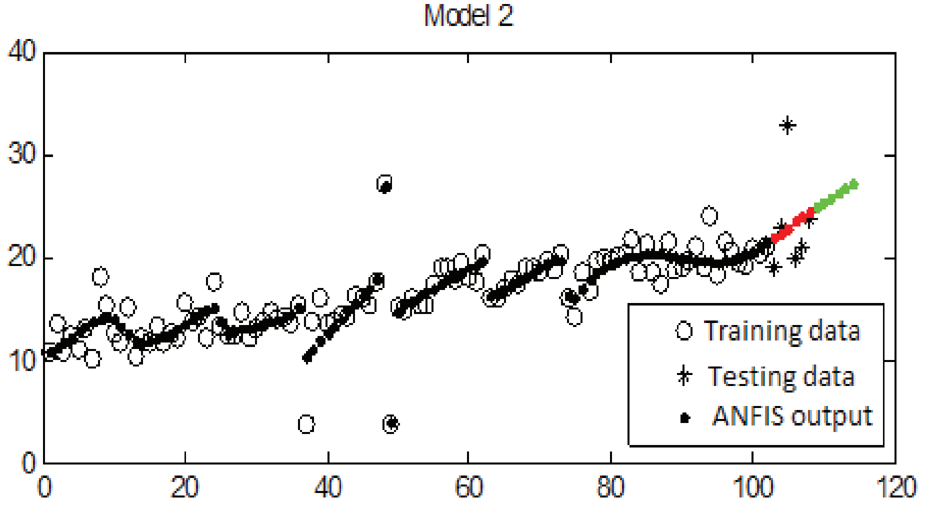
As seen in Table 1, the ARIMA could not achieve any forecasting result. However, when the ANFIS was tested by six-month testing dataset, its mean square error (MSE) ratio was 40.4117. The forecasting obtained by the ANFIS for the next six months was close to the obtained test results of the ANFIS, so it can be observed that there was approximately a stationary case.

Experiment 2.
Analysis of the electric use in private houses (Model 2)

In the construction stage of an appropriate ARIMA model related to the consumption of electric energy use in private houses, we determined that the change of energy consumption versus months is non-stationary. The difference of the energy series is once taken in accordance with the autocorrelation and partial autocorrelation function graphs. When the difference taken, the series showed stationary haracter in the model validation stage. As a result of the tests, ARIMA(1,1,2) was chosen as the model.

When the ANFIS model was trained by the training dataset for 4000 iterations, it found eight rules for this experiment. The results obtained by ANFIS model are shown in Figure 4, where the test result of the model is red line and the forecasting of the next six month period is green line as follows:

Figure 4. The ANFIS output for Model 2.



As seen in Figure 4, there is a constant increase in the next six months in Model 2. The comparative results of ARIMA (1,1,2) and ANFIS techniques and the real values for the period between 2002-2010 are given in Table 2:

Table 2. Forecasting of the electric use in private houses (Model 2)

Month	Real	ARIMA(1,1,2)		ANFIS	
		Forecasting	MSE	Forecasting	MSE
Jul.10	18,9146	21,1999	24,0842	22,0048	21,3410
Aug.10	22,9082	21,3377		22,4716	
Sep.10	32,8206	21,4178		22,9416	
Oct.10	19,9593	21,5264		23,4125	
Nov.10	20,9913	21,6209		23,8837	
Dec.10	23,7073	21,7224		24,3547	
Jan.11		21,8205		24,8256	
Feb.11		21,9202		25,2962	
Mar.11		22,0191		25,7668	
Apr.11		22,1184		26,2372	
May.11		22,2175		26,7077	
Jun.11		22,3167		27,1781	

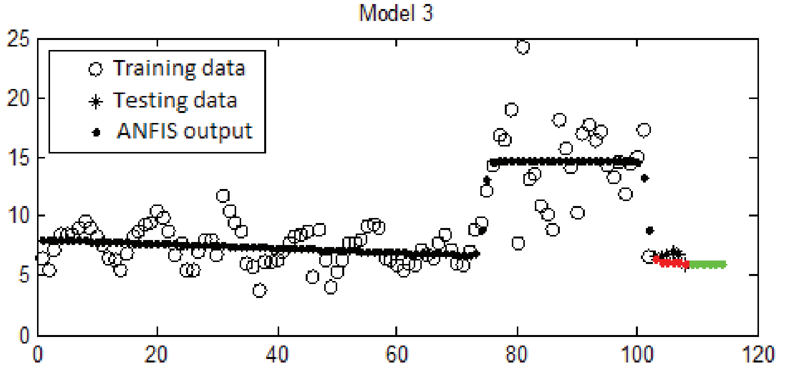
As seen in Table 2, the MSE ratio was 24.0842 for ARIMA (1,1,2) and 21.3410 for ANFIS in the result of forecasting implemented by the six-month testing data for Model 2. Thus, it can be said that the ANFIS provided a more successful forecasting than the ARIMA.

Experiment 3.
Analysis of the electric use in industry (Model 3)

We experienced that the monthly energy change is originally unsuitable for the validation of a model in the set stage of an appropriate ARIMA model to be applied in electric use in industry. After the analysis on the autocorrelation and partial autocorrelation function graphs of the series employed in industrial electric use, the difference was taken twice. Then, the series was made suitable for the analysis. After a few testing, the model was selected as ARIMA (1,2,1).

When the ANFIS model was trained by the training dataset for 1500 iterations, it found two rules for this experiment. The results obtained by ANFIS model are shown in Figure 5, where the test result of the model is red line and the forecasting of the next six month period is green line as follows:

Figure 5. The ANFIS output for Model



As seen in Figure 5, the next six months is constantly stationary for Model 3. The comparative results of the real values in the period between 2002-2010 and ARIMA (1,2,1) and ANFIS techniques are given in Table 3.

Table 3: Forecasting of the electric use in the industry (Model 3)

Months	Real	ARIMA(1,2,1) Forecasting	ARIMA(1,2,1) MSE	ANFIS Forecasting	ANFIS MSE
Jul.10	6,5457	11,1835	6,1138	6,4739	0,3079
Aug.10	6,6035	8,3942		6,1838	
Sep.10	6,7541	9,1898		6,1471	
Oct.10	7,0919	8,2417		6,1275	
Nov.10	6,7017	8,1281		6,1088	
Dec.10	5,9649	7,6015		6,0901	
Jan.11		7,2656		6,0714	
Feb.11		6,8283		6,0527	
Mar.11		6,4308		6,0340	
Apr.11		6,0049		6,0153	
May.11		5,5836		5,9967	
Jun.11		5,1508		5,9780	

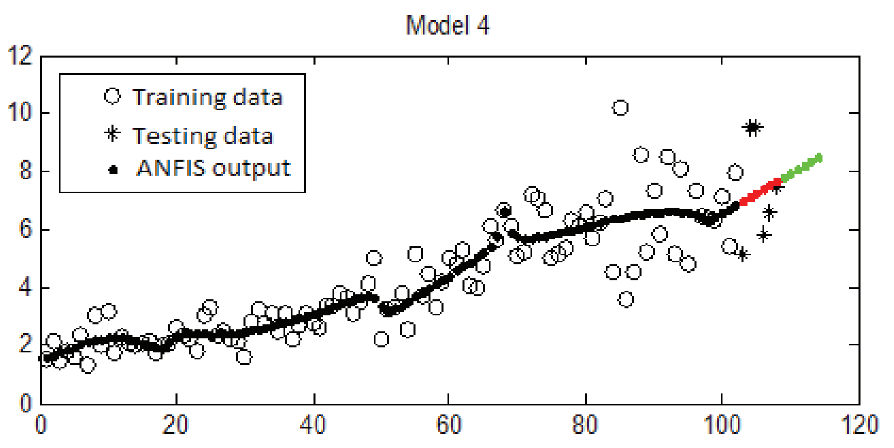
As seen in Table 3, the MSE ratio is 6.1138 for ARIMA (1,1,2) and 0.0379 for ANFIS in the result of forecasting made through the six-month testing data for Model 3. Thus, it can be said that ANFIS provided a more successful forecasting than the ARIMA.

Experiment 4.
Analysis of the electric use in business firms (Model 4)

While a model related to the electric use in business firms was constructed, monthly energy change was analyzed. But, it was determined that the series was originally unsuitable to construct an appropriate model. After the analysis on the autocorrelation and partial autocorrelation function graphs, the series was observed to be appropriate for an analysis stage when the difference was once taken. After a few testing, ARIMA(1,1,1) was determined to be the most appropriate model for this experiment.

When the ANFIS model was trained by the training dataset for 3600 iterations, it found four rules for this experiment. The results obtained by ANFIS model are shown in Figure 6, where the test result of the model is red line and the forecasting of the next six month period is green line as follows:

Figure 6. The ANFIS output for Model 4.



As seen in Figure 6, there was very quickly rise in the next six months for Model 4. The comparative results of the real values in the period between 2002-2010 and ARIMA(1,1,1) and ANFIS techniques are given in Table 4.

Table 4: Forecasting of electric use in business firms (Model 4)

Months	Real	ARIMA(1,1,1)		ANFIS	
		Forecasting	MSE	Forecasting	MSE
Jul.10	5,1655	6,6010	2,6646	6,9789	2,8888
Aug.10	9,5100	7,1028		7,1073	
Sep.10	9,4926	7,0126		7,2370	
Oct.10	5,8424	7,1121		7,3683	
Nov.10	6,5950	7,1508		7,5016	
Dec.10	7,4564	7,2089		7,6370	
Jan.11		7,2608		7,7745	
Feb.11		7,3147		7,9142	
Mar.11		7,3680		8,0561	
Apr.11		7,4215		8,2001	
May.11		7,4749		8,3462	
Jun.11		7,5283		8,4943	

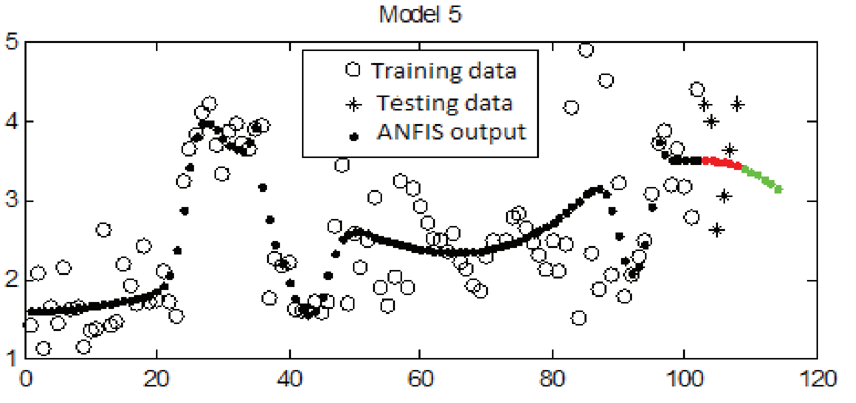
As seen in Table 4, the MSE ratio is 2.6646 for ARIMA (1,1,1) and 2.888 for ANFIS as a result of the forecasting through the six month testing data for Model 4. Thus, it can be said that ARIMA is little more successful in the implemented experiment when compared to ANFIS.

Experiment 5.
Analysis of the monthly electric use in government agencies (Model 5)

While constructing a model for the electric use in government agencies, the graphs of monthly energy change were used in hand as a basis. It was determined that the series was originally unsuitable for model validation. After the analysis on the autocorrelation and partial autocorrelation function graphs, the series was, then, found to be suitable for an analysis stage when the difference was once taken. After a few testing, the model was selected as ARIMA (2,1,1).

When the ANFIS model was trained by the training dataset for 5000 iterations, it found four rules for this experiment. The results obtained by ANFIS model are shown in Figure 7, where the test result of the model is red line and the forecasting of the next six month period is green line as follows:

Figure 7. The ANFIS output for Model 5.



As seen in Figure 7, there is a constant decrease in the next six months for Model 5. The comparative results of ARIMA (2,1,1) and ANFIS techniques and the real values in the period between 2002-2010 are given in Table 5.

Table 5: Forecasting of the electric use in government agencies (Model 5)

Month	Real	ARIMA(2,1,1)		ANFIS	
		Forecasting	MSE	Forecasting	MSE
Jul.10	4,2125	3,3762	0,3909	3,5093	0,3841
Aug.10	3,9930	3,6692		3,5053	
Sep.10	2,6223	3,4032		3,4961	
Oct.10	3,0580	3,4401		3,4812	
Nov.10	3,6314	3,3647		3,4604	
Dec.10	4,2085	3,3635		3,4337	
Jan.11		3,3431		3,4011	
Feb.11		3,3429		3,3627	
Mar.11		3,3415		3,3184	
Apr.11		3,3467		3,2686	
May.11		3,3531		3,2131	
Jun.11		3,3620		3,1522	

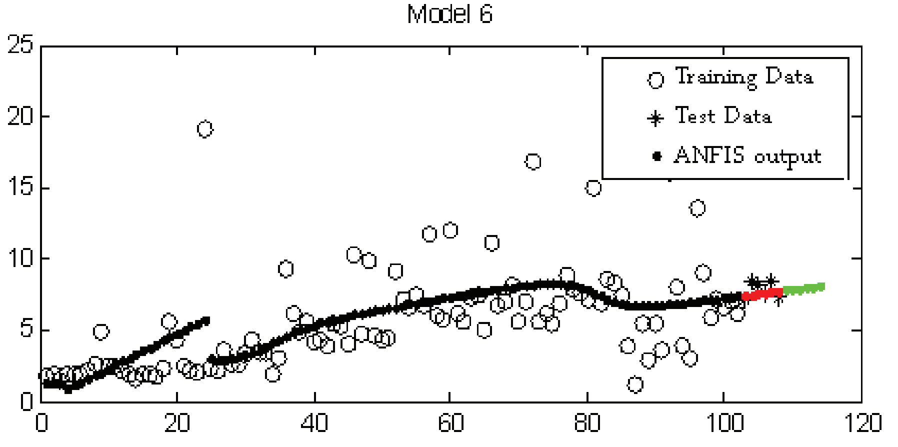
As seen in Table 5, the MSE ratio is 0.3909 for ARIMA(2,1,1) and 0.3841 for ANFIS in the result of the forecasting made through the six month testing data for Model 5. Thus, it can be said that ANFIS is little more successful in the forecasting when compared to ARIMA.

Experiment 6.
Analysis of electric consumption of the others (Model 6)

Model testing named the others about the electric consumption of the subscriber groups for six months was done. It was determined that the series was not appropriate to construct a model in its original. Thus, the series became appropriate after the difference was once taken through the autocorrelation and partial autocorrelation function graphs. After several tests, the model were determined as ARIMA (1,1,1).

When the ANFIS model was trained by the training dataset for 5000 iterations, it found three rules for this experiment. The results obtained by ANFIS model are shown in Figure 8, where the test result of the model is red line and the forecasting of the next six month period is green line as follows:

Figure 8. The ANFIS output for Model 6.



As seen in Figure 8, there will be a little increase in the next six months for Model 6. In Table 6, there are comparative results of the real values from the period of 2002-2010 and the techniques of ARIMA (1,1,1) and ANFIS in Model 6.

Table 6: Electric Consumption Forecasting of the Others (Model 6)

Months	Real	ARIMA(1,1,1)		ANFIS	
		Forecasting	MSE	Forecasting	MSE
Tem.10	7,1845	8,1967	0,5540	7,4670	0,3401
Ağu.10	8,4338	8,2828		7,5274	
Eyl.10	8,2217	8,3353		7,5877	
Eki.10	7,5329	8,3873		7,6481	
Kas.10	8,3855	8,4392		7,7085	
Ara.10	7,2539	8,4912		7,7689	
Oca.11		8,5431		7,8293	
Şub.11		8,5951		7,8897	
Mar.11		8,6470		7,9501	
Nis.11		8,6990		8,0104	
May.11		8,7509		8,0708	
Haz.11		8,8029		8,1312	

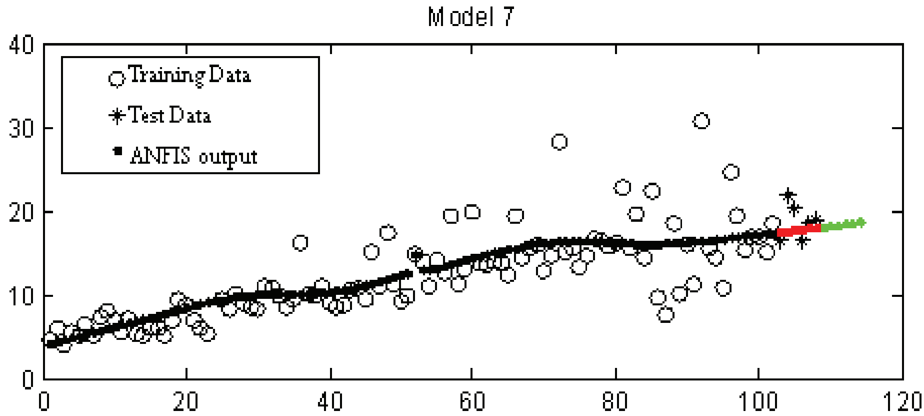
As seen in Table 6, MSE ratio is 0.3401 for ANFIS whereas it is 0.5540 for ARIMA (1,1,1) as a result of the forecasting which was done by using test data for six months for Model 6. Thus, ANFIS provided a more successful forecasting than ARIMA for Model 6.

Experiment 7.
The analysis of electric consumption of the Business firm, State office and others (Model 7)

It was determined in the forecasting of modeling about the electric consumption of the business firm, state office and others that consumed energy is non-stationary. The series became stationary by taking the difference for once according to the autocorrelation and partial autocorrelation function graphs of the related series. The ARIMA techniques which are obtained through several experiments must pass the compliance test to be used as an forecasting model regarding the future. In the compliance test which was done for this reason, it was determined that the autocorrelation coefficients of the forecasting errors of the forecastings obtained through the ARIMA techniques shows a systematic tendency. The appropriate model could not be determined.

When the ANFIS model was trained by the training dataset for 5000 iterations, it found three rules for this experiment. The results obtained by ANFIS model are shown in Figure 8, where the test result of the model is red line and the forecasting of the next six month period is green line as follows:

Figure 9. The ANFIS output for Model 7.



As seen in Figure 9, there will be a linear increase in the next six months for Model 7. In Table 7, there are the results of ANFIS model for Model 7.

Table 7: Electric Consumption Forecasting of the Commerce Houses, State Offices and Others (Model 7)

Months	Real	ARIMA Forecasting	ARIMA MSE	ANFIS Forecasting	ANFIS MSE
Tem.10	16,562	No appropriate model has been found		17,5558	4,8571
Ağu.10	21,937			17,6570	
Eyl.10	20,336			17,7583	
Eki.10	16,433			17,8599	
Kas.10	18,612			17,9616	
Ara.10	18,918			18,0636	
Oca.11				18,1660	
Şub.11				18,2690	
Mar.11				18,3730	
Nis.11				18,4789	
May.11				18,5878	
Haz.11				18,7017	

As seen in Table 7, there is not any forecasting through ARIMA for Model 7. MSE ratio became 4.8571 as a result of the forecasting through ANFIS which was done by using test data for six months. The estimated results of the next six months are similar to the results obtained through ANFIS but there has been an increase at the least.

Conclusions

We implemented different seven experiments for estimating and analyzing electric energy consumption in order to plan the production, transmission and distribution of electric energy and to determine the consequences of the events occurring in the electric market. These experiments focus on the electric energy consumption forecasting implemented by using ANFIS and ARIMA techniques including the analyses of total energy consumption, household electric consumption, industrial electric consumption, commerce house electric consumption, monthly electric consumption in state offices, electric of the others and the electric consumption of the commerce houses, state offices and the others. This is especially guiding key for the investors planning the investments in the electric sector.

There has been a preparatory work for the necessary precautions regarding the electric in Tokat, revealing the electric consumption structure of Tokat province. The electric demand structure of Tokat regarding the previous consumption of Tokat province and the estimated electric energy for the future has been revealed. Although the study which was conducted through ANFIS and ARIMA techniques in the field of electric energy consumption was conducted on regional basis, it can be a pilot study for the extensive national and international studies on the energy consumption.

Electric energy demands for the tested periods and the first six months of the year 2011 were estimated by using the ARIMA and the ANFIS techniques. Every forecasting experiment related to the electric consumption performed by ANFIS and ARIMA showed that ANFIS is more successful estimator. The ARIMA was more successful in only an forecasting experiment. In addition to this, an appropriate ARIMA model could not have been found for two forecasting experiments. As a result, the ANFIS is more appropriate than the ARIMA in the forecasting studies regarding the electric consumption.

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