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DEVELOPMENT OF ARTİFİCİAL NEURAL NETWORK MODELS TO PREDİCTİON OF NATURAL GAS CONSUMPTION İN SİİRT OF TURKEY

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ABSTRACT

Correct prediction of natural consumption is crucial for both gas distributors and consumers. By means of an accurate prediction, potential issues regarding natural gas distribution systems may be reduced, distribution limits may be planned properly. In this paper, an ampiric relation has been developed dependent on basic consumption indicators and meteorological data by making use of Artificial Neural Networks (ANN) which is used broadly in various disciplines and providing good prediction results in nonlinear multivariable models. With the proposed system, monthly natural gas consumption prediction study is implemented for Siirt which is one of the first-time users of natural gas in dwelling houses (share in total consumption 1.8 %, 2.5 % in terms of customer number). R^2=1 statistical error value is found for analytical expression of provided prediction model.

INTRODUCTION

In recent years, with the rapid increase of natural gas consumption the share of natural gas in energy production reached up to 55%. Natural gas, not only in energy field but an energy source also used in many fields such as dwelling houses, industry, school, residences, hotel and so forth and consequently with vital importance for economic, social and technical developments. For the countries dependent on 99% foreign sources, like Turkey as the allocation of natural gas over or below than the required volume shall cause severe economic loss, then appropriate prediction models usage for reducing the errors gain importance. In order to compensate the natural gas supply and demand imbalance especially arising in winter months, consumption volumes need to be correctly predicting. Until to the last years, natural gas supply has been seen as an public service and natural gas predictions are made for annually or for longer terms. Aim of these predictions are to determine primarily the long term natural gas price or to foresee the technological developments. However, in consequence of encountering with intense competitive environment in last years, making short term demand and price predictions to enhance the efficiency and quality became obligatory.

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Short term correct demand prediction studies be crucial for manufacturers and service providers to prevent the losses to arise as a result of both increasing the profit rates and imperfect demand predictions. First study where ANN is used for natural gas demand prediction is the daily gas consumption prediction made by Brown *et al.* (1996). In their works, Nguyen and Mandziuk (2003) implemented a natural gas demand prediction work in a specific region of Poland by using ANN and Fuzzy Logic Neural System techniques. Musilek *et al.* (2006), utilised ANN and statistical models together to define seasonal variability seen in natural gas consumption. Apart from these, Peharde *et al.* (2001) and Bakirtzis *et al.* (1995) made use of ANN method for short term, hourly prediction works. Alireza Khotanzad *et al.* (2000) performed natural gas consumption prediction in their works by combining different ANN methods. Additionally, Mamlook *et al.* (2009) successfully implemented ANN method in his work for prediction of short term electric energy. Çakır M.T. made use of ANN method and a case studied estımatıon of natural gas consumptıon usıng artıfıcıal neural network ın Ankara (?) In this paper, an empiric relation has been developed to be used in monthly natural gas consumption prediction by making use of Artificial Neural Networks (ANN) which is used broadly and providing good prediction results in nonlinear multivariable models. When monthly natural gas sales amount are examined, the affecting factors for utilisation of natural gas can be listed as: number of residential customers, number of industrial customers, natural gas sale price, monthly natural gas consumption amount, monthly average temperature, monthly average relative humidity, monthly average wind velocity, monthly total amount of rainfall. The results obtained have importance for further projections of natural gas consumption as tangible and empirically regarding sustainable natural gas supply in countries like Turkey which are 99% dependent on foreign sources.

Natural Gas Consumption (ngc)

Turkey has a stock capacity only for 5% of natural gas consumption and efforts for increasing stock up capacity is carried out by making new investments. Turkey as fully dependent on foreign sources, should make projections of demand, supply, transmission, distribution and pricing and implement them in order to maintain the sustainability in natural gas sector where its stock capacity is low. One of the important issue in projection works to be done is correct determination of natural gas demand amount.

When the distribution of natural gas consumption in Turkey is considered on provisional basis it is seen that the major part of the consuption is effectuated by the provinces where infrastructure works are completed and consuming natural gas for a long time. In 2008, 5 provinces which consume the highest amount of natural gas constituted more than 75% of residential consumption of the country. In total consumption, especially Istanbul and Ankara become prominent with 43,4% and 21,3% respectively. However, as the consumption in these provinces initiated long time ago, natural gas infrastructure is widespread when compared with other provinces (Çakır ?).

Development of main natural gas transmission lines in Turkey is a factor affecting the consumption directly. Main transmission line primarily brought to Ankara, conveyed to many other provinces by supplementing new natural gas pipe lines. During the construction of transmission lines, development levels of the provinces and population are also considered beside the geographical conditions. For example, despite Bursa city did not take place in physical route of primarily constructed pipe line, pipe line is made to pass from Bursa in order to provide natural gas for usage of the densely populated region. As a result of dense work on transmission infrastructure system implemented by Boru Hatları and Petrol Taşıma A.Ş. (Botaş), many other potentially low cities also included in the scope of natural gas transmission network beside dense populated and developed cities. That much widespread of transmission network shall seriously increase utilisation of natural gas in Turkey (Çakır ?). Natural gas consumption used in industry constitute 21,9% of total consumption of Turkey. Industrial sector with 14,6% annual consumption increase rate became most increasing natural gas utilisation field. Conveyance of natural gas to new industrial reagions and development of industry of the country is effective on industrial natural gas consumption increase in Turkey. Main transmission line routes constructed for conveyance of natural gas in Turkey affected natural gas consumption in industry directly. When Botaş designated the routes for main transmission lines elaborated to pass the lines primarily over industry dense regions. During the construction of Russia-West natural gas pipeline, line is conveyed to Ankara passing over by industry dense provinces such as Tekirdağ, Istanbul, Kocaeli, Sakarya, Yalova, Bursa and Eskişehir respectively. Following the construction of pipeline routes to provinces Botaş initiated the work for conveyance of natural gas to industry and industry started utlilizing natural gas densely in the provinces the line conveyed to. As industrial companies are the biggest natural gas consumers, they have initiated using natural gas long before the licenses are provided for natural gas distribution companies. When the costs of industrial sector is considered, conversion to natural gas occurred so fast and industrial customer numbers achieved satisfaction in short period of time. When considered the development of present pipelines, it is seen that natural gas transmission to all places where specific industries located is provided. Places where the natural gas not yet conveyed consists small part of the industry, however the works regarding the supply of natural gas to those places are continuing (Çakır ?). Siirt has the 1 billion metric cube annual natural gas consumption in Turkey. As the end of 2014 also at the top ranks in terms of customer density with its 15.124 active and 6.000 potential customers. when the geographic structure of the center and expansion of adjacent area is considered continuation of fast growth of customer number is expected. Each year estimated or about of 4.250 new customer can join the system (Siirt Belediyesi 2014). Residential customers constitute 95% of customer base in Siirt. As the end of 2014 there are total 95 thousand residential consumers. Industrial, official and free consumers consist 5% of total customer number. There are approximately 4 thousand industrial, official and free consumer customers as the end of 2014. Free consumers constitute 0,03 % of total customer number (Siirt Belediyesi 2014).

Between years 2012 and 2014, natural gas volume provided from Batman Refinery showed annual average increase of 3.7%. As per 2014, total natural gas supply amount of Siirt effectuated as 1.260.110 m^3 and total sale amount as 1.115.325 m^3. Natural gas supply and consumption accordingly, especially for residential customers, mostly dataize within a period between September and March. The gas from Iran to Turkey, Batman and Siirt access road to the resort there are Gokcebag. Gokcebag heading into the city from the town of Sirnak other is a line. However, geographical proximity to the sinking of the structure is more suitable siirt natural gas gained immediately. Siirt is given along with Kurtalan natural gas. That's because the town of Siirt, Batman is going through a rescue from natural gas. 6 months summer and 6 months winter passes in Siirt. A subscriber of the natural gas consumed in winter the average 2700 m^3 respectively. In summer, an average of 720 m^3 respectively. The number of years that a total of about 3500 m^3 respectively. 1 m3 of natural gas is considered equivalent to 1 kW of energy and is charged with 0.95 ₺ . Towards the end of 2020 year together with other towns and villages in Siirt all planned and is expected to be natural gass. 2,000 subscribers in 2012, reached 5,000 subscribers in 2013. In 2014, this will increase to 8,000 the number of subscribers up to öngörülmektedir.2020 maximum number of subscribers is assumed to be 30,000 in Siirt (2014).

Growth realised in industry is also a substantial factor on industry natural gas consumption rate increase. Growth in industry and increase of natural gas consumption showed parallelism with each other. Industrial growth rate on yearly basis from 1998 to 2003 remained limited with rate of 2% and natural gas consumption rate in industry became 7% in same period. As from 2003 the effects of rapid growth of industry on natural gas consumption is observed. From 2003 to 2008 industry has grown in an average annual rate of 8%, annual natural gas consumption has increased with a high rate of 18% in same period. Quick conclusion of distribution license tenders as from 2003 and increase of natural gas infrastructure dense works helped the growing industry to use required natural gas. By 2008 growth in industry eased down and parallel to this increase rate in industrial natural gas consumption also limited. Development levels of the provinces, potential number of customers in provinces and temperature parameters are important when determining the residence demand prediction. Development levels and the population of the provinces determine the total potential customer number to be reached. It is assumed that ten years following the gas distribution the provinces shall come at to a satisfaction level regarding the consumers. Income level of the provinces also affect per customer consumption. In the works performed for prediction, it is seen that there is a high corelation between the temperatures of the provinces and their average consumptions. While coastline provinces consume less natural gas, Central Anatolia and Eastern Anatolian provinces need higher volume of natural gas for heating (Kalogirou 2000).

After the natural gas reach to provinces, users quickly turn to natural gas utilisation. As natural gas is economic and easily used when compared with its alternatives become a substantial factor in its dense increase of utilisation. When the paid costs of fuels are compared to provide 1000 Kcal heat, cheapest fuel was the natural gas in 2009 for heating, however when evaluated by years, cost of coal and natural gas seem to be close to each other. But, utilisation of natural gas is much convenient than coal by its cleanness, not requiring preliminary preparation and storage and not leaving behind wastes such as ashes. These advantages cause new customers quickly start using natural gas in their residences.

Increase on income level beside the economic characteristic of natural gas is also a substantial factor on increase of the customers. Penetration rates in provinces according to income levels of residences show serious differences. While low-income family rate is 25% in total customer number, the penetration rate for high income families is 75%. Beside that, income per capita has increased fast by years in Turkey. National income in 2002 which was $ 3.492 increased to $10.276 in 2008. Increase of national income in Turkey, brought the natural gas cost to more convenient level for the residences. As the residence incomes increse by the years, number of natural gas customers shall also increase accordingly. Natural gas consumption used for electricity production in Turkey has the highest share rate of 54,6 % in annual consumption of 2008. Spended natural gas volume in this sector showed 13,6 % annual average increase between 1998-2008. First natural gas consumption in Turkey initiated at Hamitabat Trakya Kombine Çevrim Santrali in 1987 and later the consumption increased with parallel to the increased number of new constructed power plants (Kalogiro 2003).

MATERIALS AND METHODS

Material

In this study an empiric relation has been developed to predicting natural gas consumption. For the relation, inputs involving basic consumption and meteorological conditions effecting natural gas consumption directly are taken as bases. There are:

n_1: Monthly total rainfall (kg/m^2)
n_2: Monthly average temperature (^{o}C)
n_3: Monthly average wind velocity (m/sec)
n_4: Monthly average relative humidity (%)
n_5: Monthly natural gas consumption volume (m^3)
Used data are provided from Siirt Municipality SİBADAŞ (Official Corporation of gas distribution in Siirt Municipality) for 2014.

Method: Artificial neural network

The artificial neural networks (ANNs) are widely used in various fields of mathematics, engineering, meteorology, economics and in adaptive control and robotics, in electrical and thermal load predictions and many other. ANNs are information processing systems which have the ability to learn, recall and generalize from training data. In order to perform predictions, ANNs need given examples instead of conventional equations. ANNs have been used widely in many application areas. Researches have been applying the ANN technique successfully in various fields of mathematics, engineering, medicine, econom- ics and many other areas. ANNs have been trained to overcome the limitations of the conventional approaches to solve complex problems. This technique learns from given examples by constructing an input–output mapping in order to perform predictions (Sözen 2009). ANNs are modeled by using neurons resembling those of the human brain. A neuron, fundamental processing element of an ANN, is shown in Fig. 1.

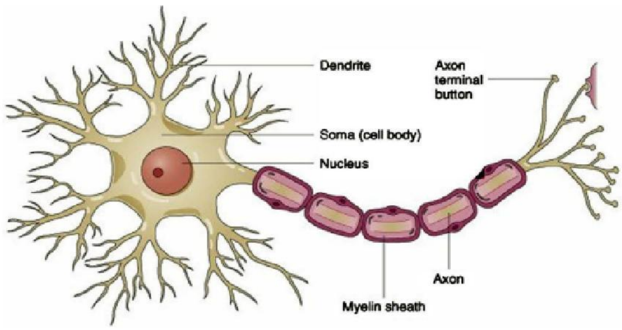

Fig. 1. A simplified model of a biological and artificial neuron (Sözen2009)

Initially, the data to be taught are entered into a program based on ANN system. Then, the program models these data through different neuron and network structure. It aims to produce values close to the value, which is targeted to be taught, by using neuron weights. Once lower error rates and high R^2 values have been obtained, data are entered through the mathematical model used in the program's substructure. Artificial intelligence (AI) systems are widely accepted as a technology offering an alternative way to tackle complex and ill- defined problems (Sözen 2009).

ANNs are attractive because of at least four reasons

1. They are weighted connection and massively parallel proces- sing with fault tolerance, so that they can automatically learn from experience.

2. They have the generalization capability to learn complex patterns of inputs and provide meaningful solutions to problems even when input data contain errors, or are incomplete, or are not presented during training.
3. They are distribution free because no prior knowledge is needed about the statistical distribution of the classes in the data sources in order to apply the method for classification. This is an advantage over most statistical methods that require modeling of data. Neural networks could avoid some of the shortcomings of the currently used statistically or empirically based techniques.
4. They take care of determining how much weight each data source should have in the classification, which remains a problem for statistical methods. The non-linear learning and smooth interpolation capabilities give the neural network an edge over standard computers and rule-based systems for solving certain problems.

Most applications use a feed forward neural network with back propagation training algorithm. The main advantage is that they possess inherent generalization ability. This means that they can identify and respond to patterns which are similar but not identical to the ones with which they have been trained. A learning algorithm is defined as a procedure that consists of adjusting the weights and biases of a network, to minimize an error function between the network outputs, for a given set of inputs, and the correct outputs. There are different learning lgorithms. A popular algorithm is the back propagation algorithm, which have different variants. Back propagation training algorithms gradient descent and gradient descent with momentum are often too slow for practical problems because they require small learning rates for stable learning (Sözen 2009).

Prediction and curve fit functions tend to converge to each other at a particular error value. This error value is denoted by the absolute fraction of variance (R^2) in scientific field. The absolute fraction of variance (R^2) and mean absolute percentage error is defined as follows:

$$R^2 = 1 - \left(\frac{\sum_j (t_j - o_j)^2}{\sum_j (o_j)^2} \right) \tag{1}$$

Where t is target value and o is output value.

Application and results

Methods of the algorithm used in the study is Levenberg Marquardth. Inputs and outputs are normalized in the (0-1) range. Neurons in input layer have no transfer function. Fermi transfer function has been used. In the simplest case, products and biases are simply summed, then transformed through a transfer function to generate a result, and finally the output obtained. Main natural gas consumption indicators are used in the input layer of the network. The ANN structure is shown in Fig. 2. The Natural Gas Consumption (ngc) is in the output layer for all models. The hidden layers have six neurons.

The new formulation dependent on main natural gas consumption indicators for the outputs is given with Eq. (4).

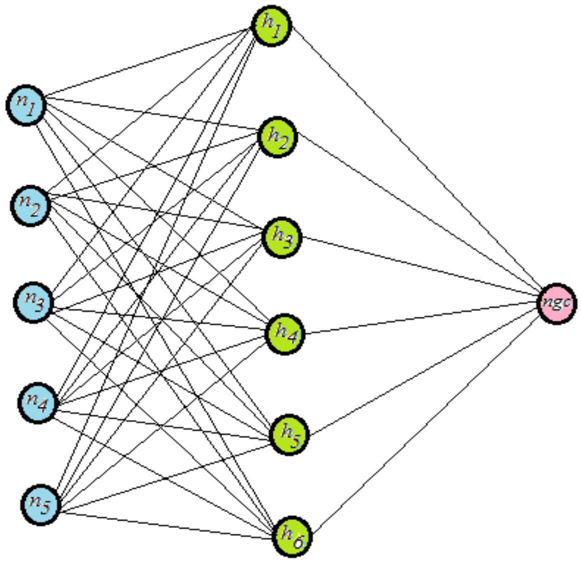

Figure 2. ANN architectures used for prediction of the ngc

The equation can be used for prediction of ngc in Siirt of Turkey using different natural gas consumption indicators.

$$ngc_{ann} = \frac{1}{1+e^{-4(-0{,}836435\, h_1 - 1{,}013923\, h_2 - 1{,}013909\, h_3 + 1{,}518842\, h_4 + 1{,}468854\, h_5 + 1{,}254133\, h_6 - 0{,}5)}} \quad \ldots\ldots\ldots\ldots \tag{2}$$

Here h_i $(i=1,2,\ldots,6)$ can be calculated by Fermi function according to Eq. (3). The formulation for the prediction of ngc in Siirt is dependent on basic meteorological and natural gas consumption indicators as seen in Eq. (4). In Eq. (3), c_i is given with Eq. (4). Matlab program was used in the present study. This program's ANN toolbox uses fermi function. w parameters are weights and n parameters are the inputs, which are required to be calculated. After $h_1, h_2, \ldots, h_6$ parameters found through the weights existing in the hidden layer have been calculated, the following equation is used for the value to be obtained as output. This function is seen in Equation (3).

$$hi = \frac{1}{1 + e^{-4(c_i - 0.5)}} \tag{3}$$

c_i parameters seen in Equation (3) according to this network structure is

$$c_i = w_{i1}\, n_1 + w_{i2}\, n_2 + \ldots\ldots + w_{i5}\, n_5 \tag{4}$$

The constants (W_{ij}) in Eq. (4) are given in Table 1.

Since the ngc parameters obtained by ANN is very close to the data parameters, they can not be shown together graphically. For this reason, the following Eq. (5) has been calculated as error rate in parameters, and these have been shown graphically.

$$E_{ngc} = \frac{ngc_{data} - ngc_{ann}}{ngc_{data}}$$

Table 1. Constants in Eq. (4).

n	W_{i1}	W_{i2}	W_{i3}	W_{i4}	W_{i5}
1	-0,507305	0,329602	-0,383784	0,583788	0,487875
2	0,041353	0,518208	0,911984	0,911996	-1,100270
3	-0,130026	0,254133	0,046631	-0,046633	0,065509
4	0,388918	-0,235102	1,518842	1,468854	-0,569824
5	0,470762	0,516424	-1,013909	-1,013923	0,718013
6	-0,836435	-0,504320	0,500917	0,500917	-0,196455

Table 2. ngc_{ann} parameters

Ann parameters	
Average error rate (%)	0,04
R^2	1

Obtained results for verification of provided empiric relation is submitted in Table 2. according to Table 2, rather a small value as 0.04 % for average error rate and a rather high value for verification as R^2=1 is obtained. According to Figure 3 showing the performance of ANN, with demand prediction empiric relation developed by prediction model shall provide highly accurate projections to be performed.

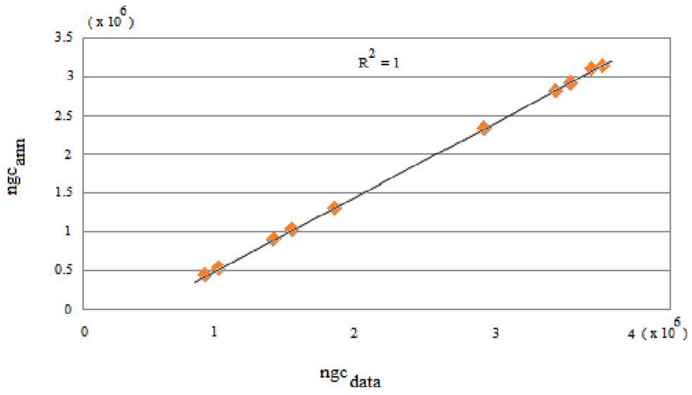

Figure 3. Comparison of correlations of ngc_{ann} and measured values ngc_{data}

When monthly dispersion of demand prediction error rates are considered, general dispersion is at ±1% border and error rate reaches up to ±4% (Fig.4).

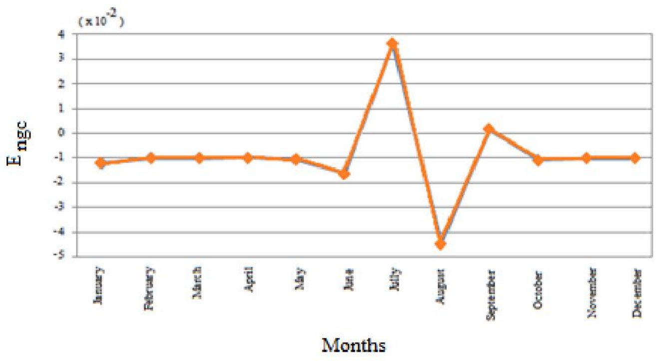

Figure 4. Changes of error rates in ngc_{ann}

In Figure 5, projection parameters are given for Siirt's monthly natural gas consumption until 2020 calculated in accordance with equality 2. Annually average of 4 % upward trend in consumption volume according to their parameters is seen in the prediction.

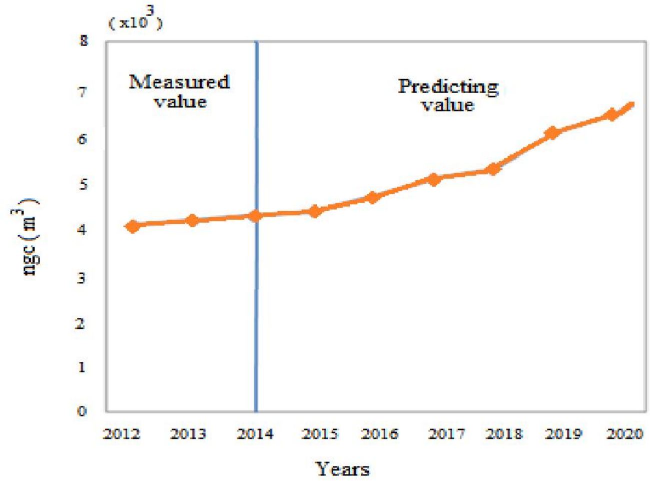

Figure 5. Projection parameters for ngc

Conclusion

Comparative studies on natural gas consumption forecasting in literature show that ann has high accuracy. Similarly, forecasting of ngc with high straightness has become possible. When the findings of this study are compared to the previous studies, ann approach can be used to predict the ngc based on meteorological and basic natural gas consumption indicators. According to results of Model, this study can be used to predict of ngc in Siirt from the meteorological and basic natural gas consumption indicators with high confidence (R^2 =1, average error rates 0.04%). The prediction models can be used effectively for the provision of supply-demand balance and the sustainability of gas consumption in Siirt. This analysis formed an uncomplicated analytical expression for the sustaining of the gas demand of gas distribution companies in the near future.

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