The Forecasting of Iran Natural Gas Consumption Based On Neural-Fuzzy System Until 2020

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Abstract

In this paper, an Adaptive-Network-based Fuzzy Inference System (ANFIS) is used for forecasting of natural gas consumption. It is clear that natural gas consumption prediction for future, surly can help Statesmen to decide more certain. There are many variables which effect on gas consumption but two variables that named Gross Domestic Product (GDP) and population, are selected as two input variables. The input variables data and output variable (gas consumption) data are collected in years 1993 till 2012. Pre-process is done on the primary data to obtain better results then finally our outputs are post-processed. In this paper, many fuzzy models are applied and the results and error of every model are investigated. All ANFIS outputs are compared with real output by considering Mean Absolute Percentage Error (MAPE). The best model, which has the lowest MAPE, is chosen for forecasting gas consumption. In this paper, the values of gas consumption are forecasted from 2013 to 2020.

Keywords: (ANFIS), Natural Gas Consumption, GDP.

1. Introduction

The close relation between energy and international issues in the last two centuries has created its own paradigm of international and put national security with international affairs in indisputable link. So both the energy and national security are interlinked. At the end of the twentieth century and early twenty-first century a new paradigm is emerging on energy that is affected by technological and environmental changes and also the amount of fossil fuel resources and global demand.

Natural gas is almost clean energy source, abundant and inexpensive that already is used for domestic and industrial purpose largely and its operation will be expanded during the coming decodes. So the growing share of natural gas in the energy basket from %23.7 in 2011 to %28 in 2030, indicate the growing importance of natural gas.

In Iran, natural gas consumption rate comparisons show this fact that Iran despite having many gas resources and a high share of production is not the gas exporter, even has become a gas importer. According to the future plan of gas industry in Russia and Qatar, the main Iran's competitor countries, checking program and perspective is very important in this industry.

Considering that natural gas is a kind of non-renewable fuels and population is increasing in Iran, indicate the importance of research in the field of the topics related to gas economy and especially a model which can forecast the gas consumption.

Nowadays, there is a great interest in the use of intelligent systems to improve the quality of financial decisions. Intelligent systems combined of artificial intelligence that simulates skills, knowledge and power of analysis of an expert. In fact, intelligent systems try to simulate the human brain. Neural networks, fuzzy systems and genetic algorithm are among intelligent systems. In this paper, neural-fuzzy systems are chosen to predict the natural gas consumption. There are numerous models that have been used to forecast the future energy demand.

Chaves et al. predicted the energy production and consumption in Asturias, Northern Spain by Box-Jenkins time-series analyses (ARIMA) [1]. Kadoshin et al. checked the effect of two factors which named increasing population and economic development, on future energy consumption [2]. The combination of artificial neural-network forecasters for prediction of natural gas consumption has been done by Khotanzad et al. [3]. Chow has studied the sectoral energy consumption in Hong Kong from 1984 to 1997 with special emphasis on the household sector [4]. Three univariate models has been used for the forecasting of monthly electric energy consumption in Lebanon by Saab et al. which named autoregressive, autoregressive integrated moving average (ARIMA) and a novel configuration combining an AR with a high pass filter [5]. Ediger and Tatlldil have forecasted the primary energy demand in Turkey and analysis of cyclic patterns [6]. Simek et al. has estimated natural gas consumption based on the logistic-curve interpretation in Poland [7]. Robby and Balachandra has investigated various factors which effect on energy demand in India [8]. Gorucu et al. has used artificial neural network for forecasting the gas consumption for short-term applications [9]. Gorucu and Gumrah have predicated gas consumption by multivariable regression analysis in Ankara [10]. Gutierrez et al. has forecasted total natural gas consumption by using the stochastic gompertz innovation diffusion model in Spain [11]. Modelling and forecasting industrial end-use natural gas consumption has been done by Sanchez-ubeda and berzosa [12]. Parikh et al. has investigated demand projections of petroleum products and natural gas in India [13]. Azadeh et al. has forecasted electrical consumption by integration of neural network time series and ANOVA [14]. Estimating the residential demand function for natural gas in Seoul with correction for sample selection bias has been done by Yoo et al. [15]. Azadeh et al. has proposed a hybrid simulation adaptive-network-based fuzzy inference system for improvement of electricity consumption estimation [16]. In this paper, adaptive network fuzzy inference system is used to forecast long-term natural gas consumption.

2. Adaptive Network Fuzzy Inference System.

Intelligent systems try to simulate the human brain. Neural networks, fuzzy systems and genetic algorithm are among intelligent systems. Which are used to forecast energy consumption in different parts, but each of them has its own advantages and disadvantages. Neural networks given a good result where there is a large number of training data but because natural gas consumption data is mostly annual and its number is limited in Iran, so neural networks aren't suitable for this purpose. Since the fuzzy systems are not able to train from the collected data in the past singly so in this paper, neural fuzzy systems combines is used until covers the disadvantages of both of them.

Adaptive network fuzzy inference systems are able to train by neural networks and also they can deal with unknown data and conclude by fuzzy systems.

In fact, ANFIS is a fuzzy inference system that developed in the framework of neural networks. This method was presented by Jang. The ANFIS algorithm can be trained with gradient descent method in combination with the least squares method. The general structure of ANFIS with two input variables is shown in fig.1.

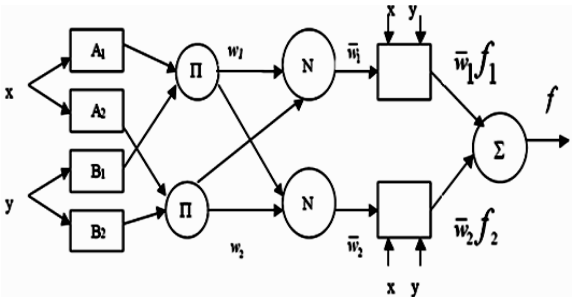

Fig.1. the general structure of ANFIS with two input variables

3. Method

Different variables effect on natural gas consumption such as population, temperature, Gross Domestic Product (GDP), the amount use of other energy and etc. In this paper, population and Gross Domestic Product (GDP) are considered as the most important factors and also as the input variables of ANFIS. Collecting a data set is the main step in prediction process so two input variables data (population and GDP) and output variables data (gas consumption) are gathered from 1993 to 2012 as shown in table.1. Also all of inputs and output data are pre-processed by normalization method as shown in table.1. This is very important phase because the quality of the response of the model directly depends

on quality and care of the data and although the model care is high, if data gathered doesn't have necessary care the final response of model won't be reliable [17]. The data are collected from British Petroleum and World Bank.

All the data set are divided into two sets, one for estimating the models called train data set and the other for evaluating the validity of the estimated model called test data set [18]. Usually train data set contains 70% to 90% of all data and remained data are used for the test data set [18]. In this study, the data from 1993 to 2007 are considered as training data and the data from 2008 to 2012 are considered as test data.

All plausible ANFIS models are run according to two main parameters. Type of membership function and number of linguistic variables are two important parameters. Numbers for linguistic variables are considered between 2 and 20. Many ANFIS models with eleven membership functions are run that just the models with six membership functions have an acceptable response. The membership functions are named Generalized bell-shaped built-in membership function (gbell), Gaussian curve built-in membership function (gauss), Gaussian combination membership function (gauss2), Difference between two sigmoidal membership functions (dsig), Product of two sigmoid membership functions (psig) and π-shaped built-in membership function (pi).

To select the best acceptable ANFIS model should find the Mean Absolute Percentage Error (MAPE) criterion for each model with each membership function and each linguistic variable. The MAPE criterion is calculated in (1) as follows:

$$MAPE = \frac{\sum_{t=1}^{n} \left| \frac{x_t - x'}{x_t} \right|}{\mathrm{n}} \quad (1)$$

As shown in table.2. the model with Gaussian curve built-in membership function (gauss) has minimum MAPE among other models so the best ANFIS model has three linguistic variables and its membership function is gauss.

There is a need to predict the input variables (population and GDP) from 2013 to 2020 by using autoregressive model which is one of main models in time series area [18]. Autoregressive model is considered as time series model because of the shortage of annual data [18]. So by using a and b coefficients and the previous year amount, the next year amount can be forecasted. Time series model for independent variable Xi is shown in (2)

$$\mathrm{X}_i = a\,\mathrm{X}_{i-1} + \mathrm{b} \quad (2)$$

a and b coefficients for population and GDP are shown in table.3.

The earned values for population and GDP, which predicted by using autoregressive model, are given to the best ANFIS model as inputs and then the values of gas consumption are obtained from 2013 till 2020 as outputs. Naturally the amounts of gas consumption are normalized so they must be post-processed and returned to their original scale. The amount of predicted population, GDP and gas consumption are shown in table.4.

Table. 2

MF Type	Number of linguistic variables	MAPE
Gbell mf	3	0.061275051
Gauss mf	3	0.033848387
Gauss2 mf	9	0.12083731
Dsig mf	3	0.081028047
Psig mf	3	0.08103009
pi mf	2	0.150463804

Table.3
a and b coefficients for population and GDP

	a	b
POP	0.983919	0.026494468
GDP	1.091009	0.008549621

Table.4
The amount of predicted population, GDP and gas consumption

Year	POP (million)	GDP$US	Gas consumption(Billion cubic meters)
2013	76386003	486304521324.56	182.4448661
2014	77160611	534343702117.91	197.9051851
2015	77922764	586754863836.45	214.724833
2016	78672660	643935894556.00	233.0839618
2017	79410498	706320893608.47	253.0808363
2018	80136471	774383467119.36	274.879231
2019	80850769	848640323467.60	298.626543
2020	81553581	929655195963.43	324.5356793

4. Conclusion

As mentioned earlier, natural gas is a kind of non-renewable fuels and population is increasing in Iran so the importance of research in the field of the topics related to gas economy and especially a model which can forecast the gas consumption, is clear.

There are lots of variables that effect on gas consumption but two main variables are considered that named population and Gross Domestic Product (GDP). Population, GDP and gas consumption data are gathered from 1993 till 2012.

Many fuzzy models are trained and the results and error of every model are investigated so the model with Gaussian curve built-in membership function and three linguistic variables is the best among other model because has the lowest MAPE.

Population and GDP values from 2013 to 2020 are predicted by using autoregressive model. They are fed to the best ANFIS model as inputs and then the values of gas consumption are calculated from 2013 till 2020 as outputs. The increase process of natural gas consumption is shown in fig.2. It is clear that it is increasing sharply. So our statesmen should take it seriously.

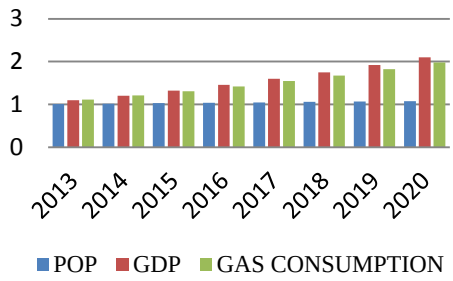

Fig.2. the process of natural gas consumption

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Table. 1
All inputs and outputs data set

Year	POP(Million)	GDP $US	GAS (Billion cubic meters)	POP (Normalized)	GDP (Normalized)	Gas consumption (Normalized)
1993	57,940,444.00	60,088,309,490.62	26.56	0.766421	0.135863	0.162147
1994	58,808,655.00	67,128,216,022.67	31.80	0.777905	0.15178	0.194169
1995	59,757,114.00	90,829,495,171.44	35.20	0.790451	0.20537	0.21493
1996	60,815,686.00	110,573,439,131.01	38.90	0.804454	0.250012	0.237522
1997	61,955,730.00	105,298,720,965.10	47.10	0.819534	0.238086	0.28759
1998	63,133,032.00	102,661,888,397.34	51.75	0.835107	0.232124	0.315983
1999	64,278,307.00	104,656,040,167.70	58.36	0.850256	0.236632	0.356343
2000	65,342,319.00	101,286,514,977.46	62.89	0.864331	0.229014	0.384003
2001	66,313,553.00	115,438,386,681.93	70.09	0.877178	0.261012	0.427966
2002	67,212,850.00	116,420,833,373.68	79.23	0.889074	0.263233	0.483775
2003	68,061,695.00	135,409,681,532.11	82.90	0.900302	0.306168	0.506184
2004	68,893,323.00	163,226,579,221.10	86.54	0.911303	0.369063	0.528409
2005	69,732,007.00	192,014,940,324.05	104.98	0.922396	0.434155	0.641003
2006	70,582,086.00	222,880,533,511.29	108.70	0.933641	0.503944	0.663717
2007	71,435,498.00	286,057,933,325.52	113.04	0.94493	0.646791	0.690217
2008	72,289,291.00	338,187,289,004.76	119.29	0.956224	0.764658	0.728379
2009	73,137,148.00	331,014,973,186.14	131.36	0.967439	0.748441	0.802078
2010	73,973,630.00	364,921,462,057.40	144.58	0.978504	0.825105	0.882799
2011	74,798,599.00	401,913,734,660.54	153.34	0.989416	0.908747	0.936287
2012	75,598,734.23	442,272,624,002.97	163.77	1	1	1