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Predicting Power Consumption using Algorithm of artificial Neural networks; Case Study: Golestan Province

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Abstract

Today, using smart technologies for solving complex scientific problems in different industrial sectors have been significantly considered. The systems could achieve general facts through conducting calculations on empirical data. Hence, the systems can be called intelligent systems. Neural networks are kinds of these intelligent systems, which can transfer hidden knowledge beyond the data to structure of network through processing empirical data. The main objective of the present study is predicting power consumption using algorithm of artificial neural networks, which would be done as case study in Golestan province Iran. Generally, in order to predict future events, historical events and data would be considered. For this purpose, previous data would be processed, so that a generalized pattern for future can be achieved. In most methods of prediction, one can assume that relations among variables would be continued even in future. Information and data about demand for power consumption in each period is an essential issue in order to have exact planning and proper policy making. Hence, prediction of power consumption would be significant for different economic units. Obtained results from the study indicate that feed-forward neural network model has high validity level, comparing to routine prediction models for power consumption.

Keywords: Neural network, artificial neural network, prediction, power consumption, GDP.

Introduction

Application of neural networks in economic issues has been started since late 1990s through study of White (1998) in financial markets and prediction of stock prices of IBM Company[1]. Success of neural networks in relevant studies of financial domains has gained attention of many specialists in microeconomics and econometrics[2]. There are also several studies in regard with using artificial neural networks in order to predict demand for power through applying mentioned models[3].

Salama and George have considered prediction of short-term demand for power in Republic of Check[4]. Through comparing artificial neural network model and ARIMA model, they have suggested that neural networks cam provide better prediction than ARIMA model because of non-linear nature of demand for power[5]. Yaw et al have evaluated neural networks and wavelet transmission in short-term prediction of demand for power[6]. They have suggested that wavelet transmission can be applied as a useful device for prediction.

Steinrez et al have investigated application of artificial neural networks in prediction of demand for power[7]. The mentioned study has been in fact an overview and general evaluation for all conducted studies in regard with prediction of demand for power from 1991 to 1999. The study has referred also problems, weakness and power points of artificial neural networks against other models. Conducted study by Jang and Dong has applied wavelet transmission model for short-term prediction in Australia[8]. The study has indicated that it can present better results and outcomes than other relevant models.

Kim et al have applied neural networks and wavelet transmission for short-term prediction of demand for power in South Korea[9]. Obtained results from the mentioned study indicate that mentioned models are effective in short-term prediction. Hipret et al has applied neural network for prediction of daily power consumption in Brazil[10]. The mentioned study has been evaluated better than other relevant models through applying different 24-hour models.

Gilermo et al has conducted a study in order to evaluate power consumption prediction method of new neural network based on structural application[11]. The study has indicated that because of high costs of energy, it would be essential to find some methods and solutions in order to optimizing new energy resources and enabling consumers to have a good perception about pressure curve. The perception would help improvement of consumer flexibility and ability to respond prices or other signs of power selling[12]. One of the most important stages of conducting current calculations would be predicted consumption curve. Through having an exact curve, consumers would be able to attend responding programs and confirming of relevant activities[13].

Kong Gi Li et al has conducted a comparative study for prediction of power consumption in buildings using neural network and hybrid fuzzy-neural system[14]. Obtained results from the study indicate that Genetic Algorithm Model (GA) is able to predict energy consumption in buildings based on method of regular data on artificial neural networks[15]. In this model, regressive classification radiuses, which apply certain rules, have been optimized. Organizational hierarchy structure of ANFIS would regulate effective assumptions and parameters in order to optimize implementation of prediction. Liuki et al have conducted a study in order to investigate power energy consumption model based on neural network of GA-BP[16]. They have indicated that GA-BP method has been presented based on neural network in order to predict quantitative changes of investment in power industry. Basis of the method has been Sliding Window, which has applied power industry structure in order to form a part of successive constant linear capital structure.

Ping Jang and Hui Wang has conducted a study in international conference of 2012 on future electric energy and presented energy system, in order to investigate fuzzy violet neural networks for prediction of urban power consumption[17]. Obtained results from the mentioned study have indicated that just in fuzzy violet neural network method, prediction would be based on non-linear stages. In non-linear method, focusing on local strong stimulants and slow process of training would have the most effects on this method. Fuzzy violet neural network method would be presented for cities with high level of energy consumption[18].

Methodology

The present study has applied feed forward neural networks for prediction and post-distribution algorithm has been also applied for training networks. In order to investigate effects of social and economic criteria on demand for power energy consumption in Gorgan Iran, related data to GDP, population, and price of KWH from 2001 to 2011 have been considered[19]. Then, using artificial neural networks and considering social and economic criteria, power consumption of the city has been predicted between 2012 and 2021. Inputs have included neural network, GDP, population, and price per KWH; while output of neural network has been demand for power consumption in Gorgan province. For input data of the model from 2012 to 2021, neural network has been applied in order to predict the years. Finally, the data has been applied as main data to train the model[20].

Data collection method: Related data to GDP, population, and power consumption have been collected from Department of Energy.

Results and Discussion

Structure of artificial neural networks: Artificial neural networks have been created through inspiration from neural system and its components. The models have less capabilities and expansion than natural neural networks. However, it should be noted that, the network has calculative ability in conducting some activities such as approximation of a non-linear function[21]. Artificial equivalents for neural networks are some units, which a schematic of them has been presented in figure-1.

In artificial neural networks, synapses would be equaled with a unit weight, so that each input can be affected before entering body of processor unit. At the next stage, weighted inputs would be combined and finally, output amount of a neuron would be determined through a stimulant function based on its inputs. The first applied function in an artificial neuron has been stepwise function.

As it was indicated in fig.1, while using the function and after combining weighted inputs, the values would be compared with a threshold value. If output of neuron is smaller than its input, would be equal to 1; otherwise, it would be equal to 0. The term “network” would be applied for any system including artificial neurons. The network can be constructed from a neuron or a set of linked neurons.

Table-1
Input and output data of the model

Year	Input1	Input 2	Input 3	output
	Population (per 1000)	Price per KWh (Rials)	GD(billion Rials)	Power consumption (MWh)
2001	372,081	10.5	330,565	943‹3,160
2002	379,462	10.8	355,554	5,901,187
2003	387,053	11.2	379,838	6,302,271
2004	394,844	11.4	420,928	4,752,357
2005	402,845	11.4	446,880	7,469,357
2006	411,066	12.6	499,071	5,452,783
2007	419,514	20.2	501,000	2,574,367
2008	420,059	31.6	501,892	5,692,309
2009	428,189	37.6	502,897	4,712,835
2010	437,099	43.2	503,259	3,112,334
2011	441,075	43.2	504,009	6,455,718

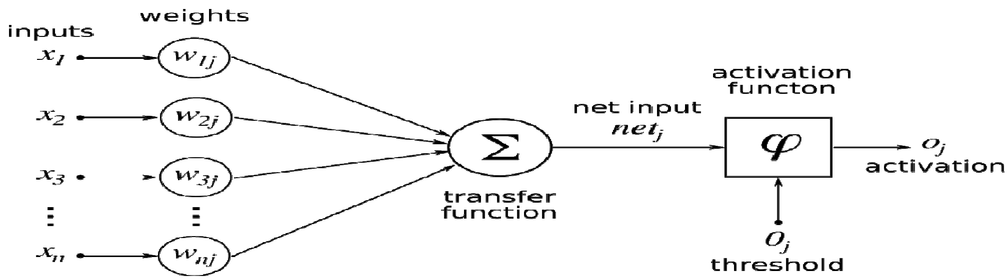

Figure-1
Schematic of a processor unit (artificial neuron)

In biological neurons, stability of synapses may be changed under special conditions in order to regulate and adjust behavior of a neuron against its input stimulus. In artificial neurons, equivalent of the process would be conducted through changing amount of weights in learning process of network. In data processing, process of weight regulation and desirable weight achievement would be known as network learning. Saved weights are in fact knowledge of the network. Process of weight changes would be continued until achieving sufficient accuracy in network's response.

Every specific instruction and method for weight regulation would create a learning algorithm. The process, which includes in general presentation style of teaching patterns, criteria for end of training process, and learning methods, would form training algorithm of a network[22]. In general, artificial neural networks include three main components as follows[23]:

Topology: structural properties of a neural network. Learning: method of saving information in the network. Anamnesis: method of recovering saved data in the network.

At the present study, relevant criteria of GDP, population, and price per KWH have been considered as input data. A significant issue in this regard can be normalizing applied data. Normalization of data in a range between 0 and 10 would be essential, so that greater data would not have higher value than smaller data as well as avoiding early satisfaction of hidden neurons, which can prevent learning of neural network. There is no standardized method to normalize input and output data. A method for normalization would be as follows:

$$x_i = \lambda_1 + (\lambda_2 - \lambda_1)\left(\frac{z_i - z_i^{min}}{z_i^{max} - z_i^{min}}\right) \quad (1)$$

Where; x_i is normalized value of z_i; z_i^{max} and z_i^{min} are maximum and minimum values of z_i.

Hence, before predicting input data, first data should be normalized and then other stages should be implemented.

Prediction of each input criterion using neural networks: In order to predict demand for energy using statistic methods such as regression model, auto regression, and moving average, at the first functional relation should be determined between dependent variable (energy consumption) and independent variables (population of state, GDP, and number of automobiles)[24]. Most of the time and for easiness, second degree or logarithmic linear relations would be assumed and the simplification may lead to incorrect results[25]. Determining functional relation between energy consumption and effective factors on it can be a complicated issue and would not be possible easily. Using intelligent systems such as neural networks, which has gained attention of many researchers recently, seems logical. In this section, each input criterion has been predicted for years from 2011 to 2025.

Table-2
Statistic of normalized population

Normalized values of population	Population (per 1000)	Year
0. 000000000000000000	372,081	2001
0. 085454526417188400	379,462	2002
0. 131348815781207500	387,053	2003
0. 247661926999350800	394,844	2004
0. 364414801164324800	402,845	2005
0. 481628379368835500	411,066	2006
0. 599323602705589200	419,514	2007
0. 617479530081880000	420,059	2008
0. 736138043683119000	428,189	2009
0. 863696521684501000	437,099	2010
0. 992343936506607000	441,075	2011

Table-3
Statistic of normalized price per KWh

Normalized values of population	Price per KWh (Rials)	Year
0. 000000000000000000	10.5	2001
0. 185454526412684500	10.8	2002
0. 231348815597864100	11.2	2003
0. 447545568542560800	11.4	2004
0. 466598421598625800	11.4	2005
0. 588955542855569500	12.6	2006
0. 698974656987452200	20.2	2007
0. 718954128552521000	31.6	2008
0. 834569875632854500	37.6	2009
0. 993895452785265000	43.2	2010
0. 992985645285887000	43.2	2011

Table-4
Statistic of normalized GDP

Normalized values of population	GDP (billion Rials)	Year
0. 000000000000000000	330,565	2001
0. 096422365426852500	355,554	2002
0. 138965423545654100	379,838	2003
0. 235648985458525800	420,928	2004
0. 356987456955233200	446,880	2005
0. 469875645965456500	499,071	2006
0. 589564556525222200	501,000	2007
0. 623698756456581000	501,892	2008
0. 712369854855865600	502,897	2009
0. 889654896542655500	503,259	2010
0. 975695547565255500	504,009	2011

A network with 3 hidden layers and mentioned inputs has been trained and its results have been presented in table5.

Table-5
Predicted outputs

Year	Predicting normalized data of power consumption	Data prediction in real scale of power consumption (MWh)
2012	1. 1459629317785100	4,856,987
2013	1. 2325533044703100	5,012,236
2014	1. 3175237575406000	5,232,253
2015	1. 3992369769881800	5,356,275
2016	1. 4761757579092700	5,402,221
2017	1. 5471201702524100	5,457,894
2018	1. 6112490069019100	5,501,435
2019	1. 6681634750786800	5,522,569
2020	1. 7178487175182100	5,856,254
2021	1. 7605971159156800	6,056,469

Conclusion

Despite the fact that Islamic Republic of Iran includes much potential for developing energy, development of power energy industry has slow process. According to available literature, the main barrier in regard with development of the power industry would be lack of efficient policies and imposing international sanctions. In fact, lack of a clear framework of effective factors in power consumption in Iran and its components has forced specialists to make decisions and policies based on unprofessional ideas. The present study, which has been designed based on a proper approach for relations among determination indices of power consumption, has tried to use systematic knowledge and identify effective factors in power consumption. For this purpose, the study has presented a model for prediction of power consumption in Iran, in order to making plans for the future. The pattern would determine effective factors in power consumption and the most common accelerative or limiting relations for it. Through completing and validating the model, it can be significantly effective in making production and export policies of power; social significance of power energy; its relation with other departments; and awareness of amount of power consumption in daily life in order to make required policies. The present study has considered comparative and non-linear study of artificial neural network for prediction of feed-forward neural network. Obtained results from the study indicate that feed-forward neural network includes low level of prediction error.

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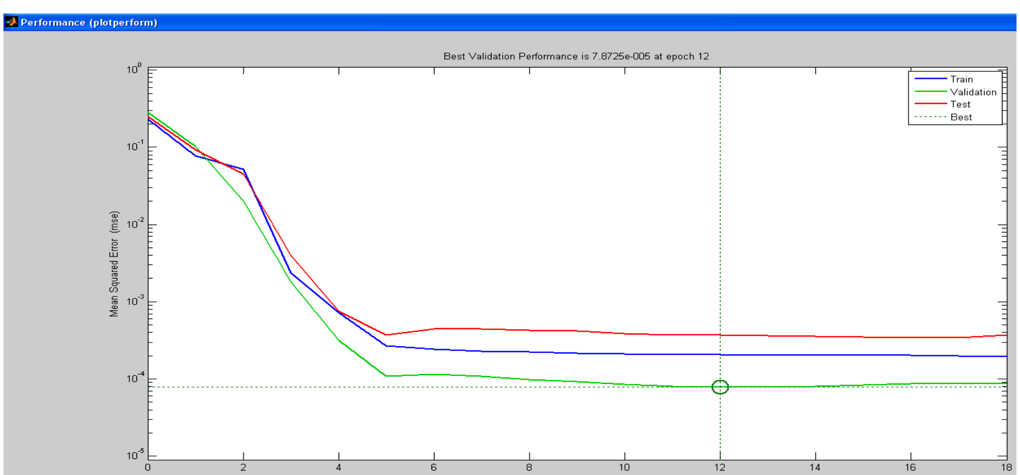

Figure-2
Schematic of general model's performance with MSE=7.85×10^{-5}

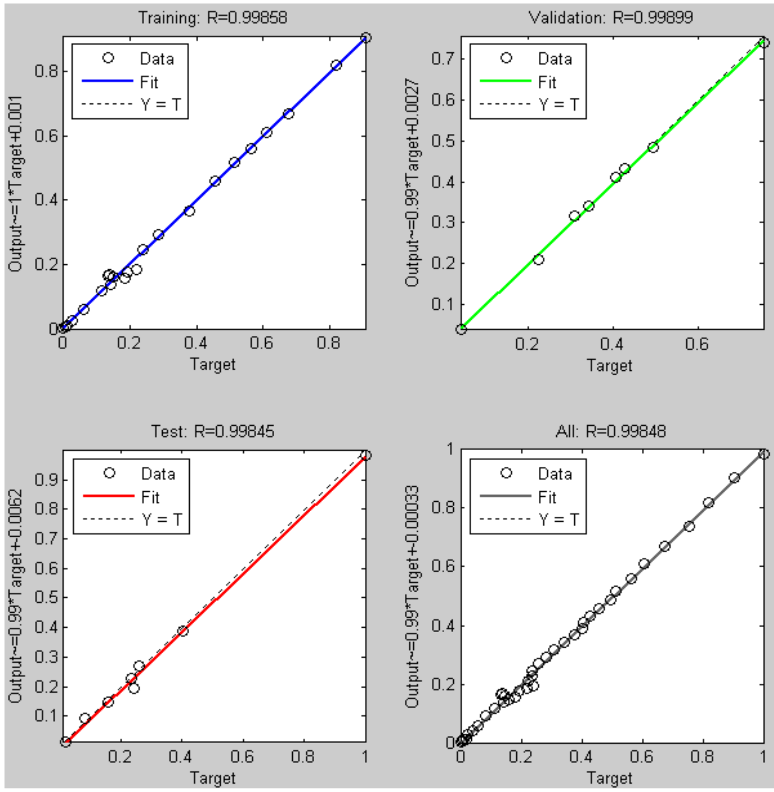

Figure-3
Diagram of regression

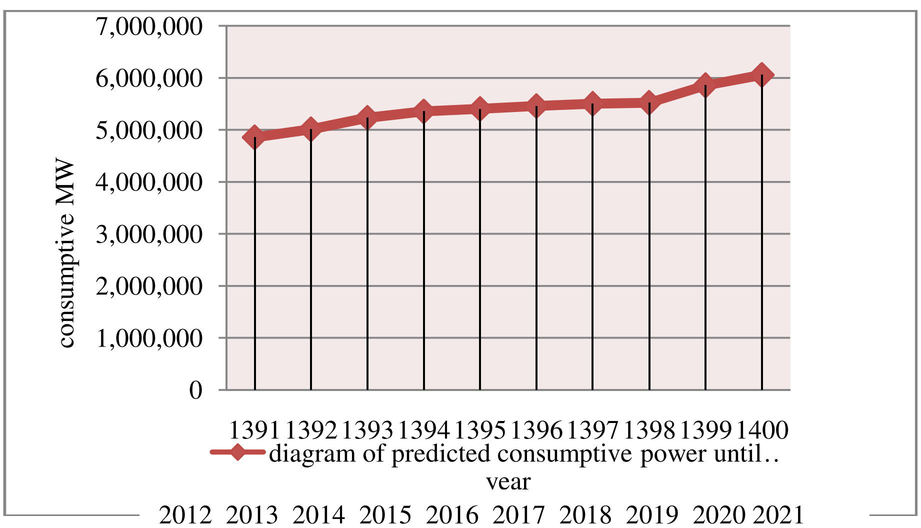

Figure4
Results of normalized prediction of power consumption until 2021

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