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Application of Artificial Neural Networks Model for Forecasting Consumption of Electricity in Gezira State, Sudan (2006-2018)

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Abstract: This paper aimed applying models of artificial neural networks to electricity consumption data in the Gezira state, Sudan for the period (Jan 2006- May 2018), and predicting future values for the period (Jun 2018- Dec 2020) by train a recurrent neural network using Quasi-Newton Sampling and using online learning. The study relied on data from the national control center. After applying artificial neural networks, The Thiel coefficient is used to confirm the efficiency of the model, and the paper recommends the use of artificial neural networks to various time series data due to their strength and Accuracy.

Keywords: Artificial Neural Networks, Thiel coefficient, electricity consumption.

تطبيقات الشبكات العصبية الاصطناعية للتنبؤ باستهلاك الكهرباء في ولاية الجزيرة، السودان (2006-2018)

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كلية العلوم || جامعة حفر الباطن || المملكة العربية السعودية

الملخص: هدفت هذه الورقة إلى تطبيق نماذج الشبكات العصبية الاصطناعية على بيانات استهلاك الكهرباء في ولاية الجزيرة، السودان للفترة (يناير 2006 – مايو 2018) والتنبؤ بالقيم المستقبلية للفترة (يونيو 2018 – ديسمبر 2020)، وقد اعتمدت الدراسة على البيانات التي كان مصدرها مركز التحكم القومي وبعد تطبيق الشبكات العصبية الاصطناعية عليها توصلنا إلى نتائج فعالة تم فحص فعاليتها باستخدام معامل ثايل لتقييم دقة التنبؤات التي تم التوصل إليها، وقد أوصت الدراسة باستخدام الشبكات العصبية الاصطناعية لنمذجة مختلف السلاسل الزمنية نظراً لقوتها ودقتها.

الكلمات المفتاحية: الشبكات العصبية الاصطناعية، معامل ثايل، استهلاك الكهرباء.

1. Introduction:

Forecasting electricity consumption is one of the most important factors affecting the success of investment in different sectors, as electricity is the main energy source in Sudan and in order to make any decision in any economic area must provide the power operating energy commensurate with the quantity and cost with the expected consumption of Electric power. The importance of forecasting also comes from the possibility of determining the expected changes to consumption negatively and positively depending on the factors affecting it. The method of analysis of time series is preferred for prediction purposes in two

cases, the first of which is when there are problems either in finding external factors affecting the phenomenon or problems in measuring the relationships that govern this behavior or both.

Second, when the primary objective of the prediction is to know the value of the phenomenon or the behavior of the phenomenon in the future only without the need to explain this behavior.

Neural network forecasting is more flexible than typical linear or polynomial approximations and is thus more precise. With neural networks an expert can discover and take into account non-linear connections and relationships between data and build a candidate model with high prediction strength

The most popular definition of artificial neural networks is a mathematical model that tries to simulate the structure and functionalities of biological neural networks

The Research problem:

Finding energy sources has become one of the most important problems facing most developing countries and since it is necessary to determine the volume of energy commensurate with the volume of demand, the best way to predict the amount of energy needed in general and the amount of electricity required in particular as electricity is considered one of the most important sources of energy Used in Sudan. The most immediate problem is lack of studies in delineating and forecast. The study fetches the most appropriate model to predict the consumption of electricity in Gezira state, where it gives more accurate results.

Research question:

What is the optimal appropriate and accurate statistical model in predicting the data of electricity consumption in Gezira state, Sudan?

Research hypothesis:

The basic assumption of this research is that the models of neural networks are the most appropriate and accurate model in predicting the data of electricity consumption in Gezira state, based on the value of the Thiel criteria obtained.

Research objectives

The Main objectives of this research is to find an effective or efficient model for studying monthly electricity consumption in Gezira state in Sudan and add a new stock of data. And the Sub objectives is:

1- To use the ANN model identified above to forecast precipitation.
2- To predict the behavior of electric power production.

Source of data

The source used in this research has been collected from national control center (Sudan).

research tools and methods:

In this research, two programs were used to analyze neural networks Alyuda NeuroIntelligence program 2.2(577) and GMDH Shell DS 3.8.9.

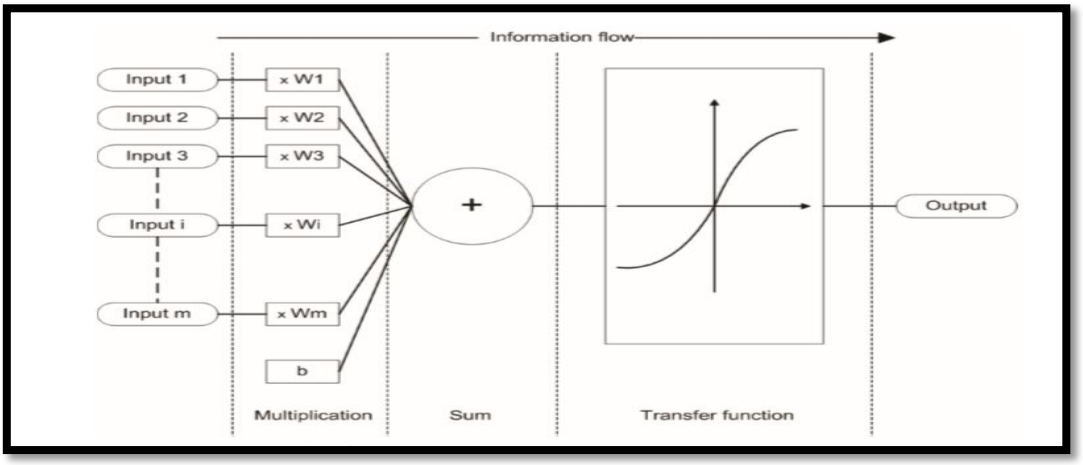
2. Theoretical framework

What Is a Neural Network?

It is a computational system inspired by the Structure, Processing Method Learning Ability of a biological brain.

Characteristics of Artificial Neural Networks:

- A large number of very simple processing neuron-like processing elements.
- A large number of weighted connections between the elements.
- Distributed representation of knowledge over the connections.
- Knowledge is acquired by network through a learning process.



Fig(1) Characteristics of Artificial Neural Networks

Steps to work on artificial neural networks:

1- Collecting the data needed for training, which is the most important step in neural networks that the data is accurate, the outputs are accurate and preferably the data is large and often taken for many years before, it contributes to significantly increasing the effectiveness of the network performance.

2- Develop the training plan and its main elements (number of training times, error rate or goal at which it can be stopped)

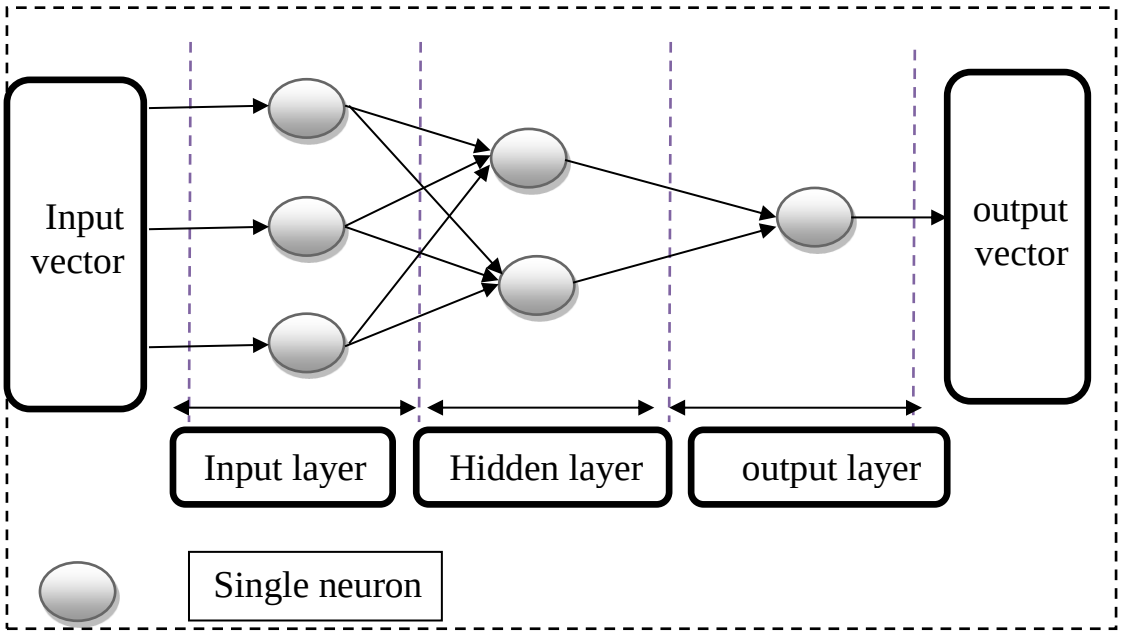
3- Build the structure of the network in terms of determining its type and the number of layers.

4- Processing data in a way that is acceptable to the network and equipping desired outputs in the same way.

5- Start the training process and then test the results and modify the previous hypotheses in case of not reaching the desired goal.

Definition of Topology: The way that individual artificial neurons are interconnected, architecture or graph of an artificial neural network. topologies are divided into two section

1- simple feedforward topology where information flows from inputs to outputs in only one direction.



Fig(2) Graph of an simple feedforward topology

Source: researcher own design

2- simple recurrent topology where some of the information flows not only in one direction from input to output but also in opposite direction[1].

Neural Network Structure:

Various architectures are available to approximate any nonlinear function and allow for generation of functions of different complexity and power:

1. Feedforward networks (FFNN):

In this type of network, neurons are usually connected so that each neuron in a layer is connected to all neurons in the next layer (the neurons of the same layer are not related to each other).

(1) Andrej Krenker1, Janez Bešter, and Andrej Kos, " Introduction to the Artificial Neural Networks "Consalta d.o.o., Faculty of Electrical Engineering, University of Ljubljana Slovenia

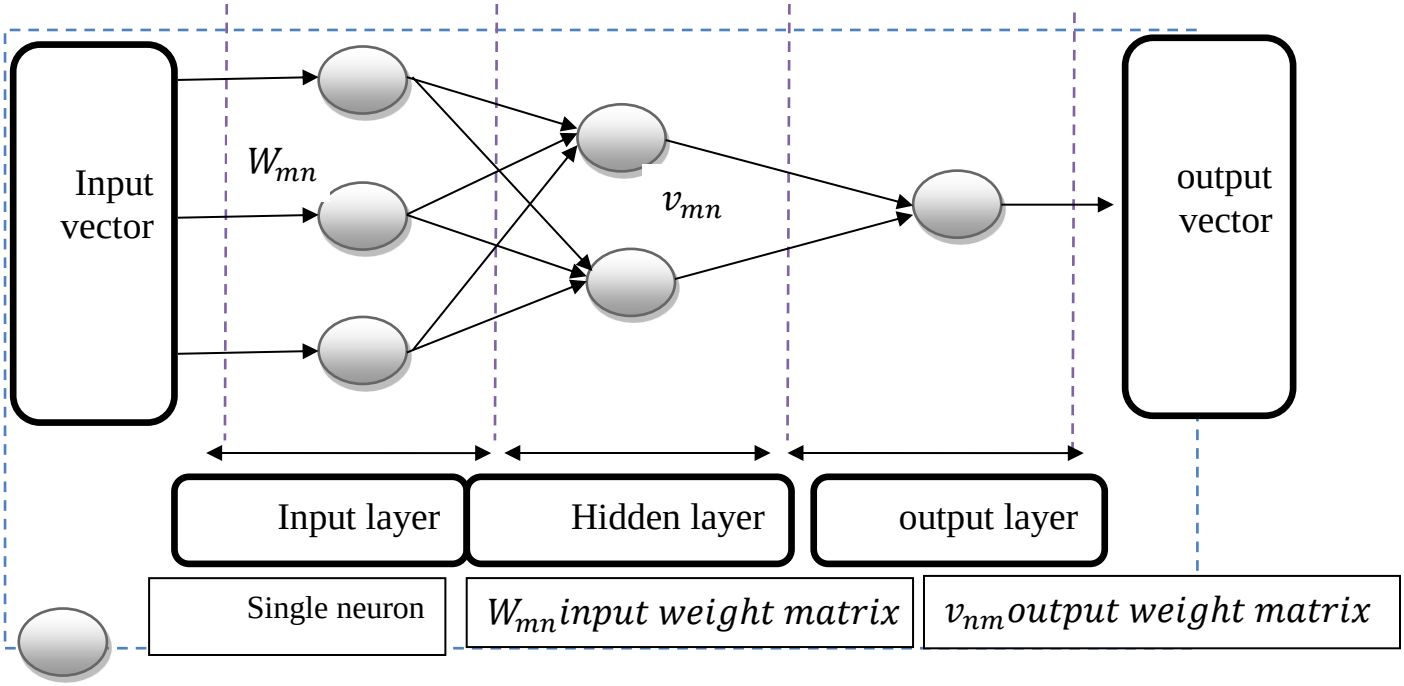


Fig (3) Feed forward net works

Source::researcher own design

Feedback networks(Recurrent Network):

neurons in this kinds of networks are feeding themselves or neurons of the preceding layers or neurons of same layer. Most popular types are:

- Elman Recurrent Network
- Jordan Recurrent Network
- Lateral networks

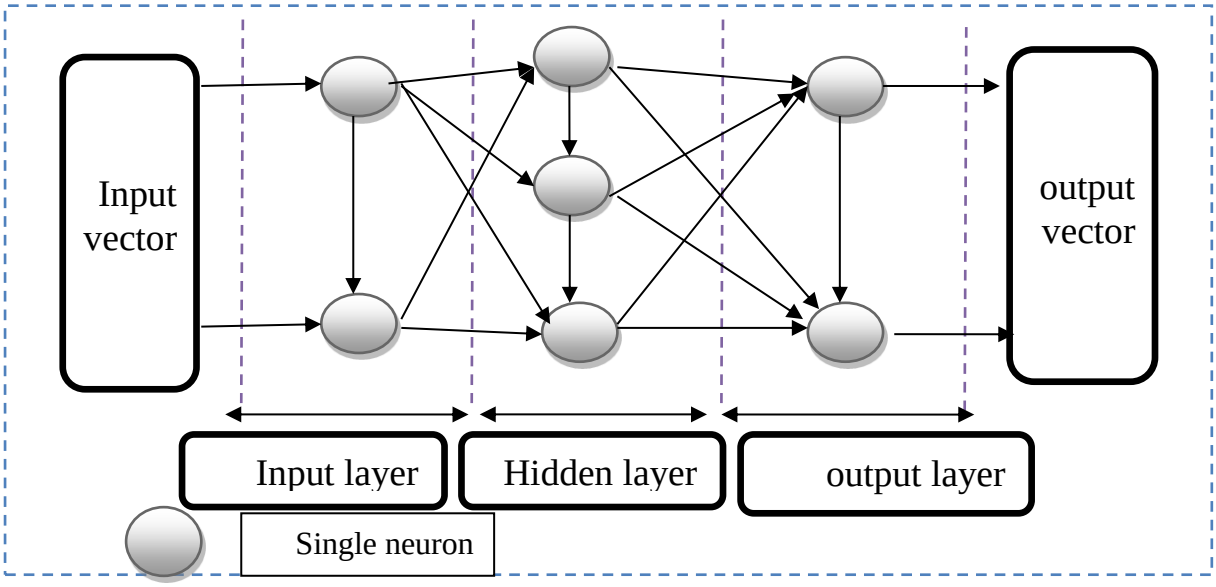


Fig (4) Feedback networks(Recurrent Network)

Source:researcher own design

Seasonal Artificial Neural Networks (SANN):

The SANN structure is produced by C. Hamzacebi to improve the forecasting performance of ANNs for seasonal time series data. The SANN model does not require any preprocessing of actual data. SANN can learn the seasonal trend in the series, without need to remove it, according to some other traditional models, such as SARIMA.

In this model, the seasonal parameter s is used to determine the number of input and output neurons. This consideration makes the model surprisingly simple for understanding and implementation. The ith and (i+1)th seasonal period observations are respectively used as the values of input and output neurons in this network structure. Each seasonal period is composed of a number of observations[(2)].

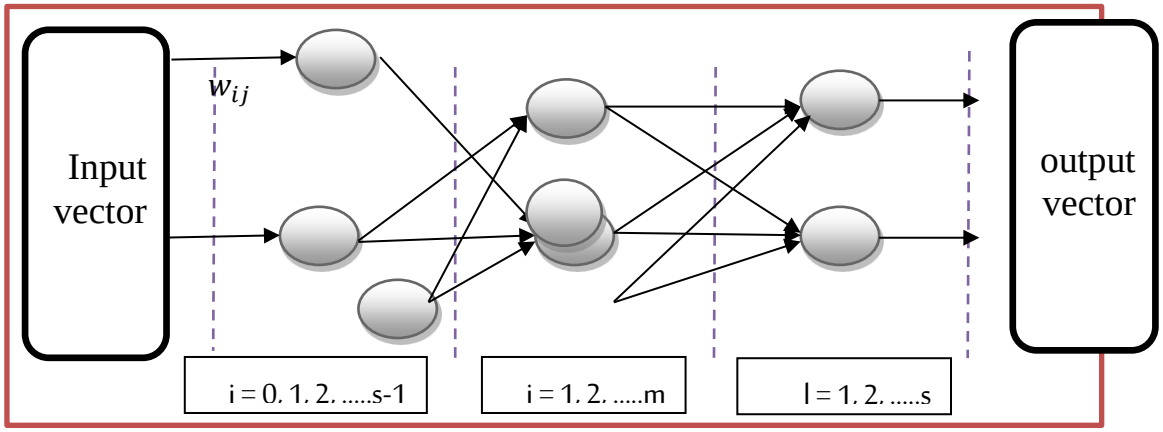


Figure (5) Seasonal Artificial Neural Networks (SANN)

Source: researcher own design

Mathematical expression for the output of the model is:

$$Y_{t+1} = \alpha_1 + \sum_{j=1}^{m} w_{ij}\ f(\theta_j + \sum_{i=1}^{s-1} v_{ij}\ y_{t-i})\ \forall t; i = 1, 2, 3, \dots \dots s$$

Learning method of Neural Networks:

- Supervised Learning.
- Unsupervised Learning.
- Hybrid Learning.

(2) Holger robert maier, Graeme clyde dandy, " Neural networks for the prediction and forecasting of water resources variables: A review of modelling issues and applications" university of Adelaide , Environmental Modelling and Software 15(1):101-124 · January 2000,

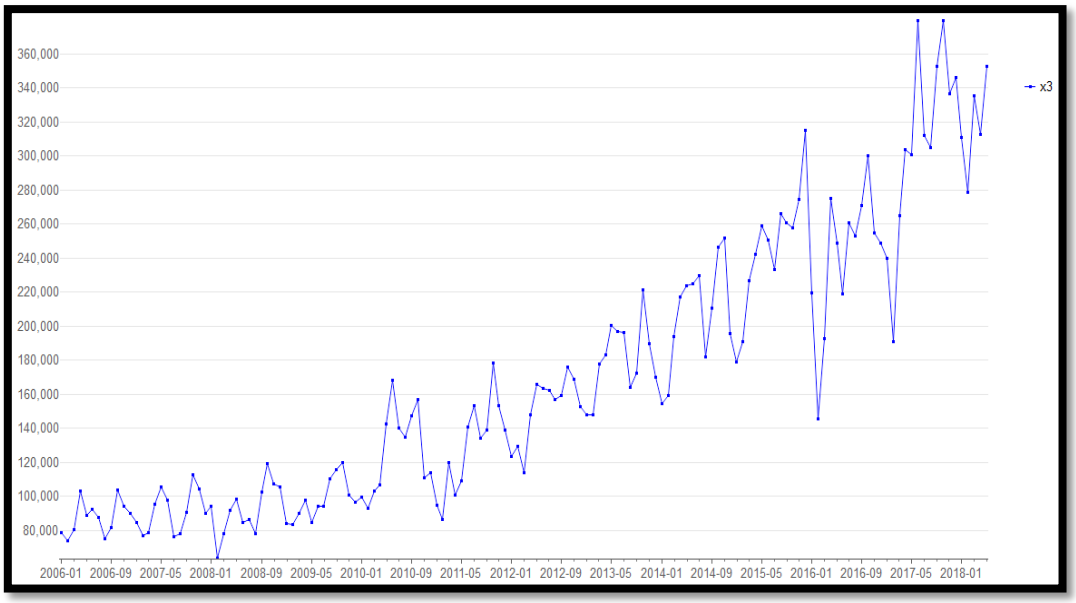
Results:

The average electricity consumption in The Gezira State, Sudan from January 2006 to May 2018 was found to be 168, 527.0281 and the standard deviation is 79, 477.11079.

The table below show the consumption of electricity in Gezira state forecasting for the period (Jun 2018-Dec 2020) produce by GMDH Shell **program.**

Time series plot: **Plot** is a time series chart used to analyze models visually,

it is the first step of analyzing, and after looking to the diagram aseasonal trend appear.ANN does not need to remove the seasonality of time series as in ARIMA model.



Figure(6) time series plot

Source: GMDH Shell program

Network proprieties:

The table below show the proprieties of the network taken by Alyuda NeuroIntelligence program

Table (1) ANN proprieties

No	Item	
1	Network architecture	[5-5-1]
2	Training algorithm	Quasi-Newton
3	Number of iterations	142
4	Number of retrains	2
5	Hidden layers activation function	Logistic
6	Error function	Sum-of-squares
7	Activation function	Logistic
8	Search Method	Heuristic search
9	Fitness criteria	Inverse Test error

Source: researcher own design

Logistic: This function has a sigmoid curve and is calculated using the following formula: $F(x) = 1/(1+e^{-x})$. Its output range is [0..1]. This function is used most often.

Actual vs. Output Graph:

This graph displays a line graph of the actual data and network output data. The Actual vs Output is marked on the graph with blue and red points. Horizontal axis displays the row number of the input dataset(149 point) and vertical axis displays the range of the output values (consumption point). The graph also displays a line graph of the network output values vs. one of input columns. Horizontal axis displays the selected input column values and vertical axis displays the network output.

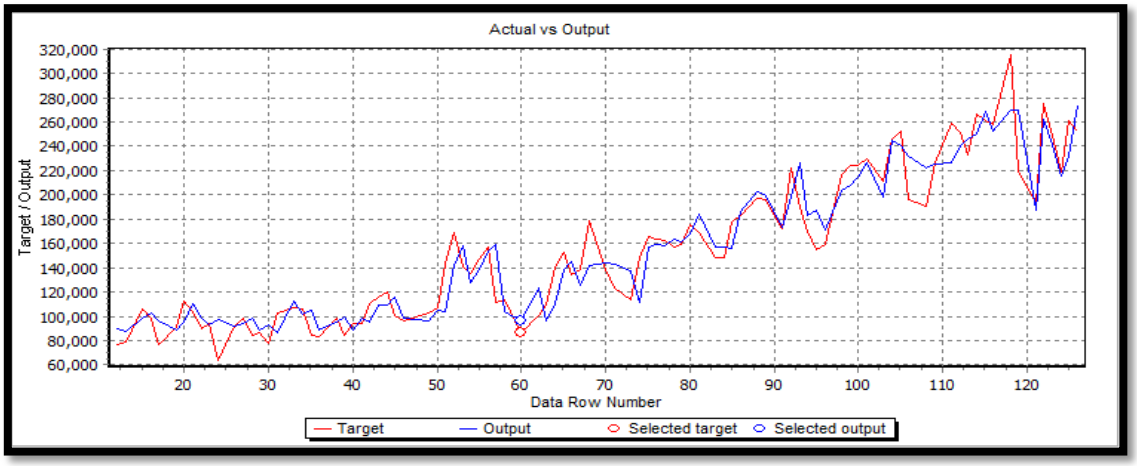


Figure (7) Actual vs. Output Graph

Source: Alyuda NeuroIntelligence program result

Error Dependence Graph displays the network error dependence on values of numerical input data. The Error Dependence Graph allows analyze which ranges of the selected input column tend to produce bigger or smaller network errors. As other testing graphs, the Error Dependence Graph curve can be plotted separately for training, test and validation set or for all of them, the graph show the network has small errors.

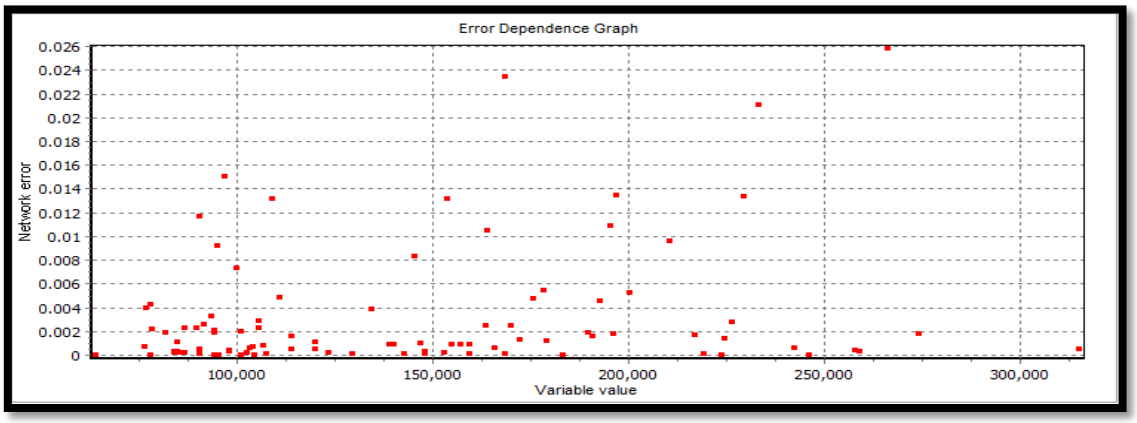


Figure (8) Error Dependence Graph

Source: Alyuda NeuroIntelligence program result

Autocorrelation charts:

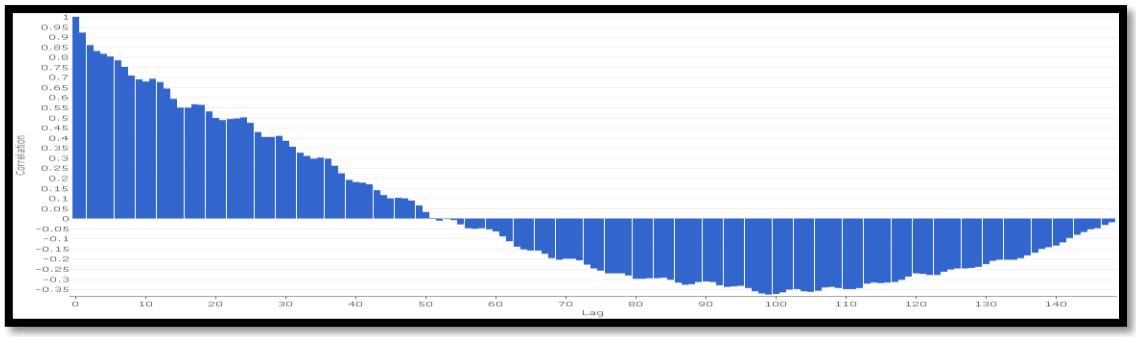


Figure (9) autocorrelation chart

Source: GMDH Shell program

Residual: Residuals is used to add differences between actual and model values.

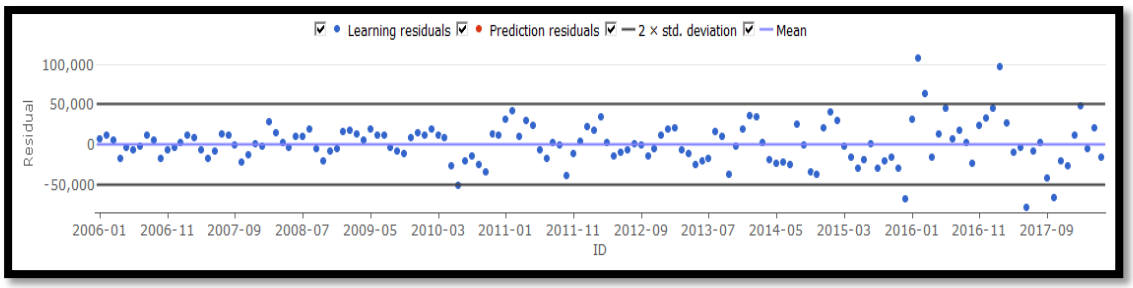


Figure (10) Residuals **chart**

Source: GMDH Shell program

consumption of electricity in Gezira state forecasting using NN model:

Table (2) consumption of electricity in Gezira state forecasting using ANN model:

Month	Predictions	Final forecast	Lower	Upper
2018-06	344544	344544	295591.2	393496.8
2018-07	332804	332804	283851.2	381756.8
2018-08	329219	329219	280266.2	378171.8
2018-09	344695	344695	295742.2	393647.8
2018-10	357483	357483	308530.2	406435.8
2018-11	356132	356132	307179.2	405084.8
2018-12	343544	343544	294591.2	392496.8
2019-01	318390	318390	269437.2	367342.8
2019-02	306703	306703	257750.2	355655.8
2019-03	329243	329243	280290.2	378195.8
2019-04	353526	353526	304573.2	402478.8
2019-05	357112	357112	308159.2	406064.8

Month	Predictions	Final forecast	Lower	Upper
2019-06	354858	354858	305905.2	403810.8
2019-07	342079	342079	293126.2	391031.8
2019-08	359645	359645	310692.2	408597.8
2019-09	337855	337855	288902.2	386807.8
2019-10	395344	395344	346391.2	444296.8
2019-11	355304	355304	306351.2	404256.8
2019-12	346358	346358	297405.2	395310.8
2020-01	371910	371910	322957.2	420862.8
2020-02	298071	298071	249118.2	347023.8
2020-03	359168	359168	310215.2	408120.8
2020-04	398890	398890	349937.2	447842.8
2020-05	398466	398466	349513.2	447418.8
2020-06	421295	421295	372342.2	470247.8
2020-07	419620	419620	370667.2	468572.8
2020-08	388500	388500	339547.2	437452.8
2020-09	408308	408308	359355.2	457260.8
2020-10	449630	449630	400677.2	498582.8
2020-11	406471	406471	357518.2	455423.8
2020-12	433033	433033	384080.2	481985.8

Source: GMDH Shell program

Chart below show **Predicted** model in red, **Model fit** in blue, **Actual data** is gray.

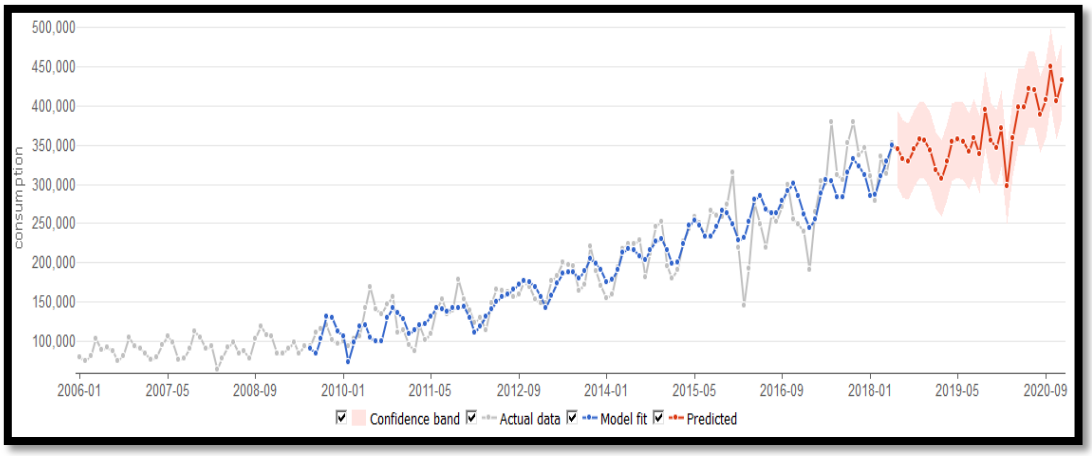


Figure (11) fit data **chart**

Source: GMDH Shell program

Scatter Plot displays a scatter plot of the actual and forecasted target values. Horizontal axis displays the actual values. Vertical axis displays the forecasted values.

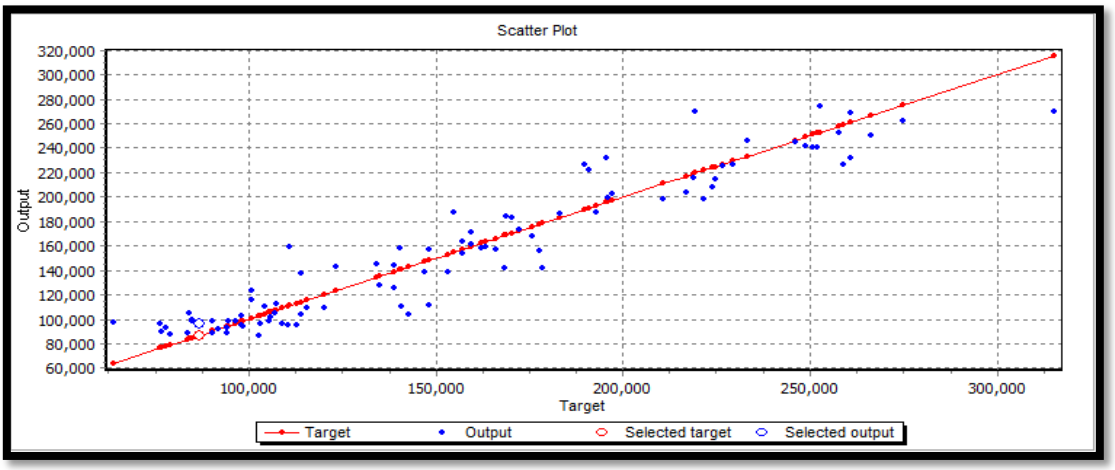


Figure (12) scatter plot

Source: Alyuda NeuroIntelligence program result

Discussion:

Time series will be treated with one variable as an input for neural networks, which is the amount of monthly consumption due to the difficulty of obtaining sufficient information about variables that are indicative or affect the volume of consumption.

The consumption of electricity data (Jan 2006- May 2018)149 point was split such that 70% of the data was used as training data set(about 104 point) while 30% was used as testing data set(45 point). The training set was used to optimize the weights and the bias of the network, while testing set was used to determine the generalization ability of the network. The transformed data was scaled Input columns scaling range: [-1..1]

Output column(s) scaling range: [0..1].

The quasi-newton method was used to train our model and validation of the model done using testing data set.

The Architecture Search table is filled parameters of the tested network architectures [5-5-1] architecture had the best fitness, that mean network had 5 input layer 5 hidden layer and one output layer is best neural network .

prediction of consumption of electricity in Gezira state using ANN:

Table (3) Consumption of electricity in Gezira state real data and forecasting using NN

month	Real value	forecasting
Jun 2018	350382	344544
Jul 2018	315642	332804
Aug 2018	377997	329219

Source: researcher own design

Thiel coefficient calculation:

Table (4) Thiel coefficient calculation

	x	y	x^2	y^2	x-y	$(x-y)^2$
jun	350382	344544	1.22767E+11	1.46018E+11	5837.91	34081193.17
jul	315642	332804	99629853857	1.19455E+11	-17162.03	294535239.4
aug	377997	329219	1.42882E+11	1.1577E+11	48777.94	2379287236
sum			3.65279E+11	3.81243E+11		2707903668
sum/3			1.2176E+11	1.27081E+11		902634556
sqr(sum/3)			348940.7886	356484.0979		30043.87718
U	0.042589761					

Source:EXCEL program result

As we see before when we use ANN model U = 0.043, The value of the Thiel coefficient is very small, which indicates the accuracy of the predictions reached by the neural network mentioned its characteristics previously.

Conclusions and recommendation:

There are many statistical methods that used time series in the forecasting process, but the best of these techniques in terms of accuracy are artificial neural networks and this has been proven by applying it to the practical of electricity consumption in Gezira state as we get a value that is considered small To apply the equation of Theil criteria.

The research recommended the following:

1- Use of artificial neural networks to predict the amount of electricity consumption as it is characterized by strength, accuracy and effectiveness, So it is strongly recommended to use artificial neural networks in data that show some difficulty.

2- It must be recognized that economic and social development around the world has been accompanied today by the availability of stable electricity services for all the economic, industrial and residential sectors consumed by them. The study shows the steady and seasonal increase in electricity consumption in the state, so it was necessary to be accurate in the forecasts obtained because of its significant impact on development and the economy.

3- Sudan in general and the Gezira state in particular need to build a large, basic and cheap production generating force that meets the growing demand, as the study showed in predictive values.

4- When the consumer reduces the rate of electricity consumption, it will not only save the value of its electricity bill, but will provide a surplus of electricity that the electricity company can deliver to

a new consumer, and reducing consumption reduces the construction of new power plants, so the government must raise awareness necessary to reduce consumption Electricity and finding an effective power resources.

References:

1- 3.PASW statistics 18 release 18.0.0. Jul 2009, User's Guide: The Neural Network Structure.

2- Andrej Krenker1, Janez Bešter, and Andrej Kos, " Introduction to the Artificial Neural Networks "Consalta d.o.o., Faculty of Electrical Engineering, University of Ljubljana Slovenia.

3- Bishop, C.M. "Neural Networks for Pattern Recognition" New York: Oxford University Press(1995) .

4- Box, G. P. and Jenkins, G. M. (1976), "Time Series Analysis, Forecasting and Control". Holden-Day. San Francisco. CA.

5- Holger robert maier, Graeme clyde dandy, " Neural networks for the prediction and forecasting of water resources variables: A review of modelling issues and applications" university of Adelaide , Environmental Modelling and Software 15(1):101-124 · January 2000

6- Hornik, K., M. Stinchcombe, and H. White (1989): "Multi-Layer Feed forward Networks are Universal Approximators, " Neural Networks, 2, 359—366.

7- Zhang, B. Eddy Patuwo, Michael Y. Hu, (1998) "Forecasting with artificial neural networks: The state of the art", International journal of forecasting, 14, 35–62.