Forecasting Uncertainty of Thailand's Electricity Consumption Compare with Using Artificial Neural Network and Multiple Linear Regression Methods

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***Abstract*— In this paper, the accurate electricity consumption forecasting has become important decisions in the energy planning of the developing countries. Last decade has several new techniques are used for electricity consumption forecasting to accurately predict the future demand. The considerable amount of electricity consumption modeling was efforts. This research approach to develop electricity models, statistical approach is a good to engineering approaches when observed and measured data is available. The statistical models, linear regression analysis has shown promising results because of the reasonable accuracy and relatively simple implementation which compared to other methods. In this study, artificial neural network and multiple linear regression analysis were performed data from Electricity Generating Authority of Thailand. In the models, gross electricity generation, installed capacity, gross domestic products (GDP) and population are used as independent variables using historical data from 1993 to 2015. Forecasting results are compared using MAPE and RMSE for the test period data. The results indicate electricity consumption model are accurate and minimum cost for electricity generation in Thailand.**

Keywords—Artifical neural network; Operation research; Thailand electricity consumption forecasting; Multiple linear regression analysis

I. INTRODUCTION

There has been an enormous increase in the demand for electricity since the middle of the last century as a result of industrial development and population growth. The electricity consumption forecasting has become important decision planning in developing countries for government policy. Consequently, the development of new and renewable source of electricity generation has become a matter of priority in many countries all over the world. Electricity is conceivably the most multipurpose in economic development and population growth. In many studies found a correlation between electricity consumption and economic growth. (1) The causal relationship between electricity consumption and economic growth are important for decision making of government energy policy.

Thailand has the demand of electricity consumption increasing every year. The main of electric generated by combined thermal process mostly with natural gas. The natural gas is imported from neighboring countries and electric generation capacity insufficient for demand consumption in country. The electric generated by Electricity Generating Authority of Thailand (EGAT) and private power plants. It is uncertainty of electricity with respect to stability in the country.

In this study was focused on a load forecasting and optimization the manufacturing in electric generation. Load forecasting helps an electric utility to make important decision including decisions on purchasing and generating electric power. The forecasting has been in existence for decades to forecast the future demand. Traditional methods such as operation research (OR), time series, regression analysis as well as computing techniques, artificial intelligence (fuzzy and neural network) are being used for electricity consumption forecasting. In this research used multiple linear regression (MLR) and artificial neural network (ANN) for electricity consumption forecasted and optimization with solver in Excel software to find optimal production with minimal cost in electric generation. Load forecasting using a back propagation neural network (2-3). A neural network was used to train and test the developed model. The capacity installed of Thailand which fuel type shown in the Table 1. The economic data, electric demand and climate data recorded for 23 years between 1993 and 2015 were used as inputs 18 years in a neural network for developed model and verification 5 years.

In this paper, electricity consumption of Thailand is forecasting by using multiple linear regression (MLR) and ANNs, which consider two input variables GDP per capita and population. Finally find the optimize solution for production planning with Solver in Excel program.

II. LITERATURE REVIEW

The Artificial Neural Network (ANN) has proposed since 1980s, it powerful computational tool to solve the forecasting problem (4). ANN is able to give better performance in dealing with nonlinear relationships among input variables (5). The ANN and Regression Analysis for Iran is annual electricity, using GDP and population variables (6). The multilayer perception with back propagation algorithm and regression analysis for long term forecast using GDP and population variables and comparing two methods is using MAPE to measure the forecasting accuracy (7)The

relationship between electricity consumption and economic growth has been widely discussed in many studies. (8-9) In electric generation used various types of manufacturing such as hydropower, thermal, combined thermal, gas turbine, etc. Their results disclose that electricity consumption can influence economic growth. (10-11)
The electricity consumption and GDP have long term equilibrium relationship. The GDP were found to be connected with electric production and electricity consumption. (12)

In addition, economic growth and electricity consumption can be used a tool for planning and policy in development country. In Thailand GDP, population and electricity data shown in figure.1

TABLE I. PRODUCTION CAPACITY BY TYPE OF THAILAND

UNIT IN MEGAWATT

Year	Hydropower	Thermal	Combined Thermal	Gas Turbine	Diesel	Import	Renewable	Total
1993	2,422.76	6,101.50	3,423.60	224.00	13.60	90.00	0.41	12,185.87
1994	2,531.06	6,101.50	4,099.60	210.00	13.60	166.00	0.39	12,956.15
1995	2,690.06	6,701.50	3,093.60	928.00	13.60	1,232.00	0.39	14,659.15
1996	2,861.06	6,517.50	3,311.60	872.00	16.60	2,146.00	0.53	15,725.29
1997	2,873.66	6,517.50	4,392.60	886.00	16.60	2,280.00	0.53	16,966.89
1998	2,873.66	6,517.50	4,817.60	886.00	6.00	2,834.00	0.53	17,935.29
1999	2,873.66	6,517.50	5,074.60	886.00	6.00	3,739.40	0.53	19,097.69
2000	2,879.96	7,227.50	5,074.60	656.00	6.00	5,229.40	0.53	21,073.99
2001	2,886.26	6,255.00	5,318.60	534.00	6.00	7,004.40	0.53	22,004.79
2002	2,886.26	6,255.00	5,074.60	778.00	6.00	8,754.40	0.53	23,754.79
2003	2,921.66	6,370.00	5,074.60	778.00	6.00	10,611.20	0.53	25,646.99
2004	3,421.68	6,370.00	4,694.30	858.00	6.00	10,618.00	1.03	25,969.01
2005	3,424.18	6,370.00	5,146.95	847.00	5.40	10,655.60	1.03	26,450.16
2006	3,424.18	6,370.00	5,146.95	847.00	5.40	11,312.64	1.03	27,107.20
2007	3,424.18	6,370.00	5,146.95	847.00	5.40	12,736.69	1.03	28,530.25
2008	3,424.18	5,258.00	5,482.00	805.10	4.40	14,866.19	1.03	29,840.90
2009	3,424.18	4,699.00	6,196.00	805.10	4.40	14,883.89	4.55	29,212.02
2010	3,424.18	4,699.00	6,866.00	805.10	4.40	15,921.89	4.55	30,920.02
2011	3,424.18	4,699.00	6,866.00	805.10	4.40	16,448.59	4.55	31,446.72
2012	3,436.18	4,699.00	6,866.00	805.10	4.40	17,590.09	4.55	32,600.22
2013	3,436.18	4,699.00	6,866.00	805.10	4.40	18,670.89	4.55	33,681.02
2014	3,443.74	3,647.00	8,382.00	805.10	4.40	19,185.90	4.99	34,668.03
2015	3,454.18	3,647.00	8,382.00	805.10	30.40	23,296.82	4.55	38,814.95

ELECTRICITY GENERATING OF THAILAND (WWW.EGAT.CO.TH)

In the Table 1 can be converse unit in Megawatt to Kilowatt and constrain as follow:

- Hydropower have limit in a season for 4 month or 120 days and 24 hours' work time.

$$\text{Production Capacity} = \frac{\text{Production Capacity Install} \times 1{,}000 \times 24 \times 120}{1{,}000}$$

- Thermal, Combine Thermal, Gas Turbine, Diesel and Import have 300 days only work time.

$$\mathrm{Pr}\,oduction\,\text{Capacity} = \frac{\mathrm{Pr}\,oduction\,\text{Capacity Install} \times 1{,}000 \times 24 \times 300}{1{,}000}$$

- Renewable have limit in an uncertainty thus only 150 days and 8 hours' work time.

$$\mathrm{Pr}\,oduction\,\text{Capacity} = \frac{\mathrm{Pr}\,oduction\,\text{Capacity Install} \times 1{,}000 \times 8 \times 150}{1{,}000}$$

III. METHODOLOGY

A. Multiple Linear Regression (MLR) Analysis

In this part, Thailand's electricity consumption has been modeled with the multiple linear regression models.

The model can be summarized as:

$$Y_{(t)} = a_t x_1 + b_t x_2 + e_t \tag{1}$$

Where Y represents the estimated electricity consumption, $a_{(t)}$, $b_{(t)}$ and $e_{(t)}$ are the regression coefficients.

The x_1 value is population and x_2 value is GDP per capita for the two independent variables used as the predictors of estimated electricity consumption, $Y_{(t)}$. The regression coefficients were obtained by computer aided solution of the regression equation (1), are show as:

$$Y_{(t)} = 5{,}980.156x_1 + 0.821x_2 - 334{,}031 \quad (2)$$

$$Y_{(2011)} = (5{,}980.156 \times 64.08) + (0.821 \times 129{,}471.74) - 344{,}031$$
$$= 145{,}473.70$$

$$Y_{(2012)} = (5{,}980.156 \times 64.46) + (0.821 \times 138{,}015.33) - 344{,}031$$
$$= 154{,}760.44$$

$$Y_{(2013)} = (5{,}980.156 \times 64.79) + (0.821 \times 141{,}022.70) - 344{,}031$$
$$= 159{,}202.95$$

$$Y_{(2014)} = (5{,}980.156 \times 65.12) + (0.821 \times 141{,}455.27) - 344{,}031$$
$$= 161{,}531.54$$

$$Y_{(2015)} = (5{,}980.156 \times 65.72) + (0.821 \times 144{,}166.01) - 344{,}031$$
$$= 167{,}345.15$$

B. *Artificial Neural Network (ANN)*

A multi-layer feed-forward back propagation neural network model was used for the estimation of electricity consumption in Thailand. The two independent parameters analyzed in the MLR section represents inputs to our ANN model, and the electricity consumption represents the output are show in figure 2.

The MATLAB® neural network toolbox was used to train the developed network models. In this study used the multi-layer feed-forward back propagation consists of two input layer, hidden layer (2, 4, 6 and 8) and output layer The ANN can be trained to perform particular input leads to a specified target output are show in figure 3.

TABLE II. ECTRICITY CONSUMPTION, POPULATION AND GDP PER CAPITA OF THAILAND (13-15)

Year	Electricity Consumption (Million Kilowatt hour)	Population (Million)	GDP per Capita (Million Baht)
1993	64,822.35	58.44	74,281.18
1994	74,165.28	59.24	79,138.03
1995	82,152.89	59.28	85,506.51
1996	84,886.99	59.90	89,404.59
1997	82,672.77	60.50	86,080.51
1998	83,566.15	61.20	78,599.93
1999	89,861.03	61.80	81,395.76
2000	93,296.41	61.88	84,912.57
2001	100,684.30	62.31	87,231.01
2002	107,171.40	62.80	91,872.26
2003	114,541.11	63.08	98,040.14
2004	117,853.49	61.97	106,072.70
2005	124,483.46	62.42	109,718.12
2006	130,364.02	62.83	114,417.28
2007	132,882.14	63.04	120,234.11
2008	133,829.35	63.39	121,633.63
2009	147,720.59	63.53	120,469.56
2010	147,227.81	63.88	128,803.27
2011	158,153.16	64.08	129,471.74
2012	159,265.90	64.46	138,015.33
2013	127,375.84	64.79	141,022.70
2014	163,552.79	65.12	141,455.27
2015	164,345.35	65.72	144,116.01

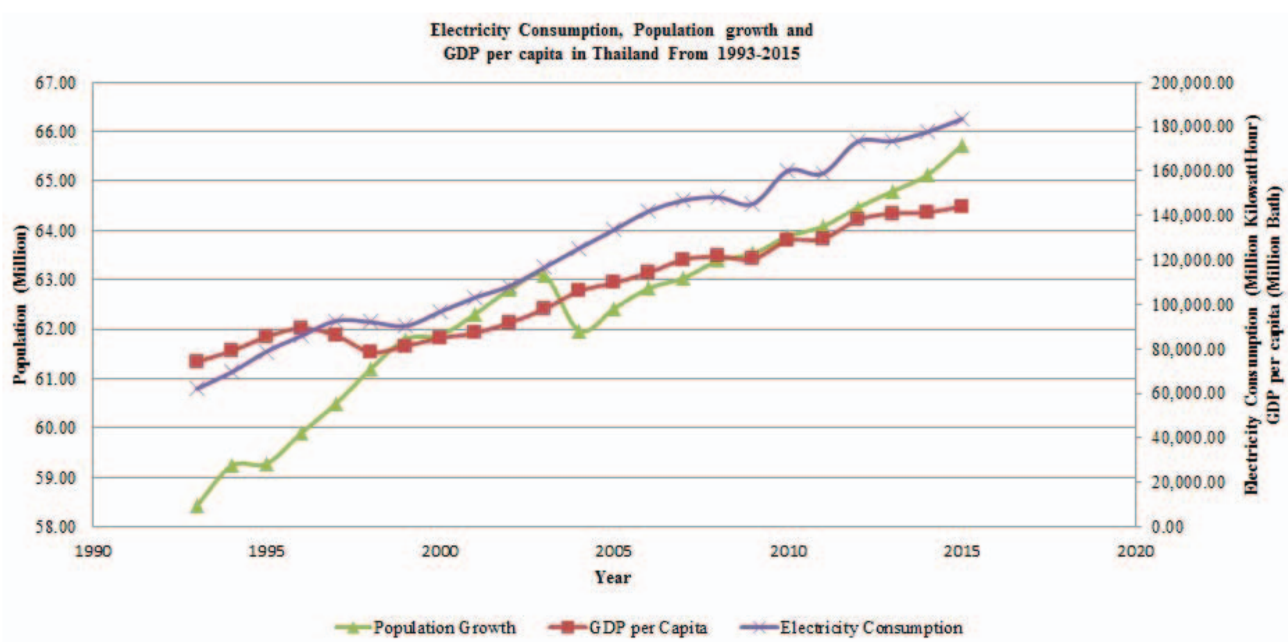

Fig. 1. Electricity Consumption, Population Growth and GDP per capita vs. Year

TABLE III. PRODUCTION CAPACITY AND MANUFACTURING BY TYPE OF THAILAND

Year	Production Capacity and Manufacturing by Fuel Type														NET TOTAL	
	Hydropower		Thermal		Combined Thermal		Gas Turbine		Diesel		Import		Renewable		Capacity	Manufacturing
	Capacity	Manufacturing	Capacity	Manufacturing	Capacity	Manufacturing	Capacity	Manufacturing	Capacity	Manufacturing	Capacity	Manufacturing	Capacity	Manufacturing	(Million Kilowatthours)	
1993	6,977.55	3,826.66	43,930.80	37,975.03	24,649.92	18,667.34	1,612.80	1,126.36	97.92	13.85	650.00	570.02	0.49	1.46	77,919.48	62,180.71
1994	7,289.45	3,431.39	43,930.80	39,194.58	29,517.12	25,084.94	1,512.00	1,085.27	97.92	9.08	1,200.00	844.90	0.47	0.98	83,547.76	69,651.14
1995	7,747.37	6,684.58	48,250.80	42,391.13	22,273.92	20,400.73	6,681.60	1,687.48	97.92	2.53	8,870.40	7,712.87	0.47	1.04	93,922.48	78,880.37
1996	8,239.85	7,233.81	46,926.00	45,310.49	23,843.52	19,204.85	6,278.40	2,704.95	119.52	4.75	15,451.20	11,463.98	0.64	1.30	100,859.13	85,924.12
1997	8,276.14	7,055.47	46,926.00	44,818.44	31,626.72	21,863.14	6,379.20	2,554.73	119.52	3.37	16,416.00	16,427.98	0.64	1.53	109,744.22	92,724.66
1998	8,276.14	5,881.87	46,926.00	42,147.35	34,686.72	24,323.31	6,379.20	1,566.02	43.20	4.15	20,404.80	18,210.36	0.64	1.39	116,716.70	92,134.44
1999	8,276.14	3,433.46	46,926.00	38,374.52	36,537.12	25,379.07	6,379.20	1,252.01	43.20	3.39	26,923.68	21,969.80	0.64	1.74	125,085.98	90,413.99
2000	8,294.28	5,296.03	52,038.00	36,151.92	36,537.12	25,556.71	4,723.20	1,153.32	43.20	2.63	37,651.68	28,618.29	0.64	1.82	139,288.12	96,780.72
2001	8,312.43	6,310.55	45,036.00	31,617.50	38,293.92	22,685.58	3,844.80	1,138.15	43.20	2.37	50,431.68	41,409.31	0.64	1.74	145,962.66	103,165.20
2002	8,312.43	6,480.87	45,036.00	30,127.44	36,537.12	23,529.74	5,601.60	1,117.89	43.20	5.15	63,031.68	47,126.34	0.64	1.81	158,562.66	108,389.24
2003	8,414.38	7,741.42	45,864.00	30,826.61	36,537.12	19,346.69	5,601.60	1,084.65	43.20	4.15	76,400.64	57,738.13	0.64	1.80	172,861.58	116,743.45
2004	9,854.44	5,915.47	45,864.00	31,538.05	33,798.96	20,652.56	6,177.60	1,090.26	43.20	2.32	76,449.60	66,118.10	1.24	2.03	172,189.03	125,318.79
2005	9,861.64	5,845.49	45,864.00	33,570.52	37,058.04	23,534.78	6,098.40	1,315.78	38.88	2.09	76,720.32	69,350.64	1.24	2.30	175,642.51	133,621.60
2006	9,861.64	7,950.05	45,864.00	33,648.81	37,058.04	25,137.01	6,098.40	1,088.63	38.88	1.25	81,451.01	74,176.36	1.24	2.57	180,373.20	142,004.68
2007	9,861.64	7,960.62	45,864.00	32,146.45	37,058.04	24,762.91	6,098.40	901.32	38.88	1.23	91,704.17	81,150.32	1.24	2.64	190,626.36	146,925.49
2008	9,861.64	6,950.72	37,857.60	29,128.68	39,470.40	27,209.42	5,796.72	675.05	31.68	2.37	107,036.57	84,297.95	1.24	2.00	200,055.84	148,266.20
2009	9,861.64	6,941.71	33,832.80	23,463.69	44,611.20	33,164.46	5,796.72	306.77	31.68	1.44	107,164.01	81,403.53	5.46	4.70	201,303.51	145,286.31
2010	9,861.64	5,325.20	33,832.80	27,289.03	49,435.20	38,338.03	5,796.72	275.55	31.68	3.98	114,637.61	88,950.64	5.46	7.10	213,601.11	160,189.53
2011	9,861.64	7,912.97	33,832.80	24,996.71	49,435.20	37,211.11	5,796.72	338.34	31.68	0.28	118,429.85	88,496.04	5.46	7.85	217,393.35	158,963.30
2012	9,896.20	8,408.36	33,832.80	26,168.43	49,435.20	42,551.79	5,796.72	370.31	31.68	0.38	126,648.65	95,747.44	5.46	3.57	225,646.71	173,250.28
2013	9,896.20	5,390.33	33,832.80	25,732.64	49,435.20	40,531.46	5,796.72	453.21	31.68	0.78	134,430.41	101,421.51	5.46	5.52	233,428.47	173,535.45
2014	9,917.97	5,141.09	26,258.40	24,764.11	60,350.40	43,052.39	5,796.72	370.82	31.68	1.25	138,138.48	104,244.68	5.99	6.13	240,499.64	177,580.47
2015	9,948.04	3,724.16	26,258.40	20,560.05	60,350.40	45,225.25	5,796.72	308.55	218.88	0.06	167,737.10	113,627.84	5.46	21.45	270,315.00	183,466.84

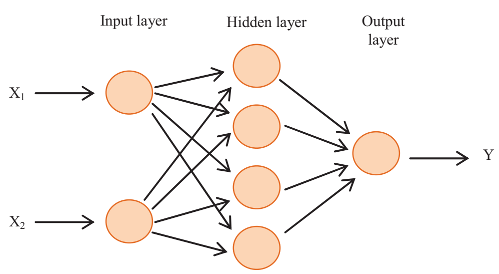

Fig. 2. Artificial Neural Networks Structure

C. *Minimum cost production planning*

$$\text{Min } Z = \sum c_i x_i$$

Subject to

$$\sum x_i \le D$$

$$x_i \le I_i$$

$$x_i \ge 0$$

Notes: definitions of notation

c_i = Cost by type of process (fixed all year)

x_i = Manufacturing by type of process per year

I_i = Production capacity installed per year

D = Demand of electricity consumption per year

Z = Total cost of manufacturing electricity per year

$$\text{Min } Z = 2.41x_1 + 5.57x_2 + 3.09x_3 + 6.00x_4 + 10.20x_5 + 4.50x_6 + 6.50x_7$$

D. *Performance criterion*

Mean absolute percentage error (MAPE), mean square error (MSE), root mean square error (RMSE) and sum square error (SSE) are used as performance measures in our model comparison. Performance criteria are defined as:

$$MAPE(\%) = 100 \times \frac{\sum_{k=1}^{N} \left| \frac{y_r - y_f}{y_r} \right|}{N} \quad (3)$$

$$MSE = \frac{1}{N} \sum_{k=1}^{N} \left(y_r - y_f \right)^2 \quad (4)$$

$$RMSE = \sqrt{\frac{\sum_{k=1}^{N} \left(y_r - y_f \right)^2}{N}} \quad (5)$$

$$SSE = \sum_{k=1}^{N} \left(y_r - y_f \right)^2 \quad (6)$$

where y_r denotes the realized consumption values, y_f shows the forecasted values for kth year and N shows number of years.

The square of Pearson product-moment correlation coefficient (R^2) is an important tool in determining the degree of linear correlation of variables in regression analysis. It is also known as the correlation coefficient. The adjusted- R^2 is a modified version of R^2 that has been adjusted for the number of predictors in the model and should always be used with models with more than one predictor variable. R^2 and adjusted R^2 are defined as follows respectively:

$$R^2 = \frac{SSR}{SST} = 1 - \frac{SSE}{SST} \tag{7}$$

$$\text{Adjusted } R^2 = 1 - \left(\frac{n-1}{p-1}\right)\frac{SSE}{SST} \tag{8}$$

$$SST = \sum_{t=1}^{n} (y - \hat{y})^2 \tag{9}$$

Where SSR is the sum of squared regression, SST is the sum of squared total, SSE is the sum of squared error, p is the number of regression coefficients and n is the number of observations. R^2 and MSE were used to evaluate the prediction capability of proposed models.

IV. Results and Evaluation

The prediction of the electricity consumption based on the two input variables population and GDP per capita. To evaluate the performance of MLR and ANN method are compare. The Excel software was used for applying MLR and the computer program written using MATLAB was used to implement ANN model. The simulation result of MLR shown in Table 4.

The capacity installed by type from computed shown in table 5.

TABLE IV. Coefficients of MLR Method by Excel

Regression Statistics	
	Coefficients
Intercept	-344031.0723
Population	5980.164749
GDP/Capita	0.82063392

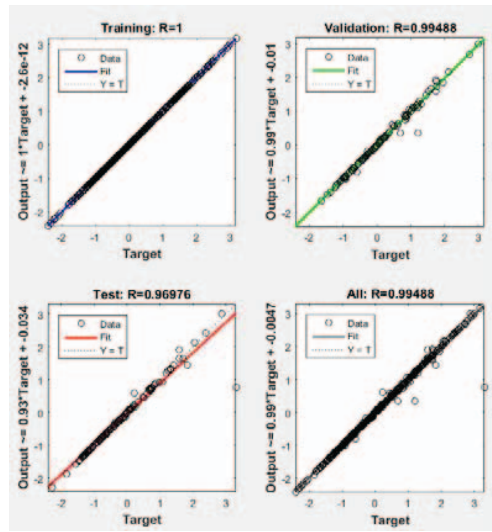

Fig. 3. Trained Artificial Neural Networks

The result computed optimal production compare with EGAT manufacturing electric shown in table 6. The details of simulation result are compared with electricity consumption, MLR and ANN shown in Table 7.

TABLE V. Process Capacity Installed by Type

Year	2011	2012	2013	2014	2015
Manufacturing Process by Type	Capacity installed (Million kilowatt hours)				
Hydropower (x_1=2.41)	9,861.64	9,896.20	9,896.20	9,917.97	9,948.04
Thermal (x_2=5.57)	33,832.80	33,832.80	33,832.80	26,258.40	26,258.40
Combined Thermal (x_3=3.09)	49,435.20	49,435.20	49,435.20	60,350.40	60,350.40
Gas Turbine (x_4=6.00)	5,796.72	5,796.72	5,796.72	5,796.72	5,796.72
Diesel (x_5=10.20)	31.68	31.68	31.68	31.68	218.88
Import (x_6=4.50)	118,429.85	126,648.65	134,430.41	138,138.48	167,737.10
Renewable (x_7=6.50)	5.46	5.46	5.46	5.99	5.46

V. Discussion

Although the artificial neural network method has the best performance in this study, the difference between the errors of each method tested. The decision should depend on criterion in scenarios.

The MLR method, its accuracy lowest but it is simplest one. As a result, in selected a method need to evaluate the trade-off between forecasting accuracy and limitation of the method.

TABLE VI. THE COMPARISON OF FORECASED AND EGAT MANUFACTURING

	Manufacturing (Million kilowatt hours)									
Year	2011		2012		2013		2014		2015	
Type	Opt	Egat	Opt	Egat	Opt	Egat	Opt	Egat	Opt	Egat
x_1	9,861.64	7,912.97	9,896.20	8,408.36	9,896.20	5,390.33	9,917.97	5,141.09	9,948.04	3,724.16
x_2	-	24,996.71	33,832.80	26,168.43	-	25,732.64	-	24,764.11	-	20,560.05
x_3	49,435.20	37,211.11	49,435.20	42,551.79	49,435.20	40,531.46	60,350.40	43,052.39	60,350.40	45,225.25
x_4	-	338.34	5,796.72	370.31	-	453.21	-	370.82	-	308.55
x_5	-	0.28	31.68	0.38	-	0.78	-	1.25	-	0.06
x_6	98,853.16	88,491.04	60,277.40	95,747.44	68,048.60	101,421.51	93,281.63	104,244.68	94,051.56	113,627.84
x_7	-	7.85	-	3.57	-	5.52	-	6.13	-	21.45
Cost (Million bath)	621,360.54	673,600.36	671,405.06	730,619.75	482,823.31	740,723.60	630,152.38	754,736.58	633,689.53	776,557.34
Save (Million bath)	52,239.82		59,214.69		257,900.29		124,584.20		142,867.81	
Save (%)	7.76				34.28		16.51		18.40	

TABLE VII. ELECTRICITY CONSUMPTION: ACTUAL VS FORECASTING

Actual Electricity Consumption		Forecast Electricity Consumption Method	
Year	Unit in Million kwh	Multiple Linear Regression	Artificial Neural Networks
2011	158,153	145,246	158,150
2012	159,265	154,710	159,270
2013	127,375	159,151	127,380
2014	163,552	161,480	163,550
2015	164,345	167,251	164,350

TABLE VIII. THE COMPARISON OF ERRORS FROM THE METHODS

Statistic	**%Error**	
	ANN	**MLR**
MAPE	0.002645	7.801003
SSE	88	1,209,790,870
RMSE	4.195	15,555
r^2	0.000000093	4.455

VI. CONCLUSION

In this paper, we forecast and predict the electricity consumption of Thailand with multiple linear regressions and ANN. Nowadays, the forecasting of electricity consumption is very important for economic development. Thailand is very uncertainty in used the energy and unstable in the resource of electricity. Most of all the electricity used for import from neighbor. It is a big problem for stability energy in Thailand. These studies can helpful planning and policy to find alternative energy resources with under demand uncertainty. In the result showed artificial neural network more accuracy and can solved production in minimum cost.

REFERENCES

[1] Ferguson RW, Wiklinson, Hill R. “Electricity use and economic development.” *Energy Policy* 2000;28:923-34.

[2] Panklib, Thakrit, C. Prakasvudhisarn, and D. Khummongkol. "The potential of biomass energy from agricultural residues for small electricity generation in Thailand." *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects* 36.8 (2014): 803-814

[3] Hsu, Che-Chiang, and Chia-Yon Chen. "Regional load forecasting in Taiwan—applications of artificial neural networks." *Energy conversion and Management* 44.12 (2003): 1941-1949.

[4] Mohamed, Zaid, and Pat Bodger. "Forecasting electricity consumption in New Zealand using economic and demographic variables." *Energy* 30.10 (2005): 1833-1843.

[5] Hippert, Henrique Steinherz, Carlos Eduardo Pedreira, and Reinaldo Castro Souza. "Neural networks for short-term load forecasting: A review and evaluation." *IEEE Transactions on power systems* 16.1 (2001): 44-55.

[6] A.Kazemi et al.," A Multi-level Artificial Neural Network for Gasoline Demand Forecasting of Iran," in Second international Conference on computer and Electrical Engineering, 2009, pp. 61-64.

[7] A. Ghanhari, A. Naghavi, S.F. Ghaderi, and M. Sabaghian, "Artificial Neural Networks and regression approaches comparison for forecasting Iran's annual electricity load," Proceeding International Conference on Power Engineering Energy and Electrical Drives. pp. 675-679, Mar 2009.

[8] Belke, Ansgar, Frauke Dobnik, and Christian Dreger. "Energy consumption and economic growth: New insights into the cointegration relationship." Energy Economics 33.5 (2011): 782-789.

[9] Ji, Yimo, Xiaoliu Shen, and Qun Liu Acheng. "Effect of energy consumption to economic growth in Beijing and its sensitivity analysis." Electronics, Communications and Control (ICECC), 2011 International Conference on. IEEE, 2011.

[10] D.B.L. Bong, J.Y.B. Tan, and K.C. Lai, "Application of Multilayer Perceptron with Back propagation Algorithm and Regression Analysis for Long-Term Forecast of Electricity Demand: A Comparison," ICED International Conference on Electronic Design, pp. 1-5, December 2008.

[11] Hong, C. "The Analysis Model of Co-integration on Economic Growth." 2nd Conference on Environmental Science and Information Application Technology. 2010.

[12] Ji, Yimo, Xiaoliu Shen, and Qun Liu Acheng. "Effect of energy consumption to economic growth in Beijing and its sensitivity analysis." Electronics, Communications and Control (ICECC), 2011 International Conference on. IEEE, 2011.

[13] Electricity Generating of Thailand (www.egat.co.th)

[14] Bank of Thailand (www.bot.or.th)

[15] National Statistic Office of Thailand (www.nso.go.th)