Forecast of Electricity Consumption in Malaysia using Artificial Intelligence

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Abstract— **This paper present on forecast of electricity consumption in Malaysia using artificial intelligence. From the world market, electricity consumption depends on the electrical usage of a group of society. Electricity consumption should correspond to the current demand because the production of excess electricity and the reduction of electricity can cause economic loss. It is impossible to do complete inspection because the time and cost increases drastically with increase in number of samples. This has created a need for a system that can inspect the components automatically with less cost and less time. The ANN will generate the pattern and predict the future pattern of electricity consumption. To improve the result of ANN model, the optimization method was used to optimize the forecast. As the result, the range of electricity consumption is obtained.**

Keywords— ***Electricity consumption; Artificial neural network; Evolutionary programming; Forecasting; Optimization***

I. INTRODUCTION

The electricity consumption is an important data in establishing a planning for electricity, so the forecast study and analysis must have strong factors and theoretical significance[1]. The different factors affect the electricity consumption in different degree[2]. The electricity consumption can be obtained periodically whether daily, monthly, or yearly. This consumption data periodically were followed by factors that might be affected electricity consumption which is 1-Economic factors (GDP, NI, Investment), 2-Social factors (Population, Demand, Utility, etc) and 3-environment factor (Temperature, Pollution, Geography Zone, etc)[3].

Artificial Neural Network (ANN) were used because the objective of this Artificial Intelligence was to predict[4]. Furthermore, ANN has already been successfully applied in the thousands of real life applications[5]. ANN is a data processing system that was generated by elements that manipulated the results. Its design is similar with the architecture of the cerebral of the brain. Thus, artificial neural network was capable to do what a human brain can do[6]. However, one of ANN disadvantages is it applied the heuristic method. The determination of an appropriate ANN architecture is always a challenging task for the ANN designers[5].

Lately, there are some researches that have been using the numerical modeling and quantitative evaluation to optimize the output results. The modeling forecast of electricity consumption can be formulated as a mathematical problem, which can be numerically solved by optimization algorithms. In engineering field, optimization algorithms has been approved and used to find the optimum method to fulfill condition of the design. For certain circumstances, evolutionary computations can be regarded the best method of optimization [7, 8]. Evolutionary computation was consists of different method such as evolutionary programming (EP), evolutionary strategy (ES), genetic programming (GP), genetic algorithm (GA), particle swarm optimization (PSO), and etc. The problem of this method needs to develop programming codes to optimize the output results.

Nowadays, electricity consumption are rapidly increasing due to population growth, economic growth, social lifestyle improvement, urbanization and developing industrial sectors[9].This paper had forecast electricity consumption in Malaysia. The ANN were generated the data of electricity consumption by using historical data that has been research. To improve the result of ANN model, the optimization method will be used to optimize the forecast.

From this result, the forecast of electricity consumption in Malaysia were generated. The result from this project can be used to develop further research such as renewable energy; capacitive bank and factor can support the future planning of electricity consumption.

II. METHODOLOGY

Basically, the methodology for forecast electricity consumption can be divided into three parts which are data collection, development of ANN and lastly evolutionary computation process. The process of the forecast is shown in Figure 1.

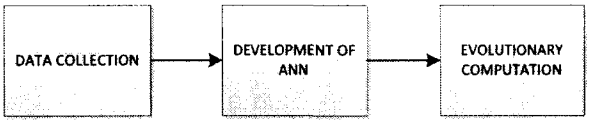

Figure 1: Process of Forecast

A. Data Collection

The data were collected from the Malaysia Energy Commission. The data were obtained annually and tabulated in Table I. The input and output variables were taken from year 1990 until 2010. The input variables were selected because the data can manipulate the electricity

consumption in every country[10]. The target output variable which is electricity consumption annually becomes dependent variable[11]. The data which is input data and target output were used in ANN training and ANN testing[11].

In Figure 2, input data represent the independent variable of ANN such as population, number of electricity consumer, peak demand, Gross Domestic Product at 2000 prices and electricity demand per capita. On the other hand, target output represents dependent variable which is total electricity consumption annually.

The description the input variables selected are shown below.

1) Population

Population has a relationship associated with electricity consumption. The population used in this project is a population of Malaysia. The population growth will cause the increasing electricity consumption. Growing population consume more energy. When the population increases, the energy uses will be increase in public places such as shopping malls, public departments, public transportation centers, hospitals and etc.

2) Number of electricity consumer

Number of electricity consumer can increase the electricity consumption. The number of electricity consumer used is the total of combination electricity consumer of Tenaga Nasional Berhad (TNB), Sabah Electricity Sdn. Bhd (SESB), and Sarawak Energy Berhad(SEB).When electricity consumers increase, the electricity consumption also indirectly increases.

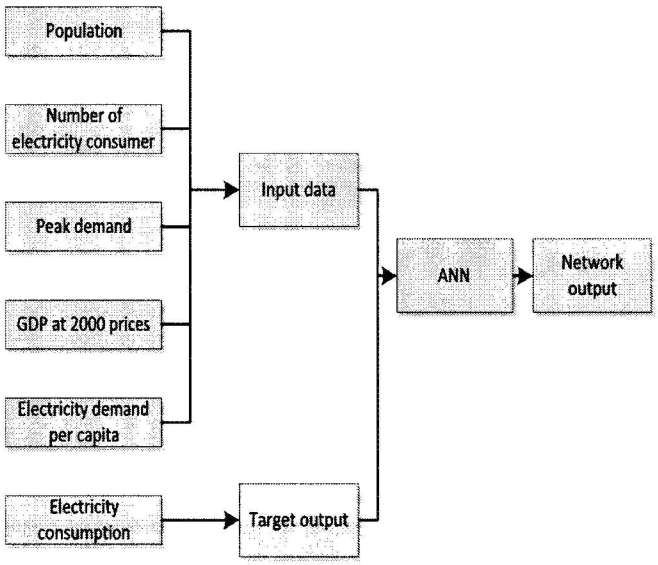

Figure 2: Architecture of the developed ANN

3) Peak Demand

Peak demand is amount of electricity consumed at peak time and the unit in watt. When the number of consumer increased, the peak demand also increases. So, the relations between electricity consumption are linear between the peak demands of electricity.

TABLE I. DATA ELECTRICITY CONSUMPTION OBTAINED ON MALAYSIA ENERGY COMMISSION (1990-2010)

Year	Population (million)	Number of electricity consumer				Peak Demand (MW)				GDP at 2000 Prices (RM million)	Electricity Demand per Capita (kWh/person)	Electricity Consumption (GWh)			
		TNB	SEB	SESB	Total	TNB	SEB	SESB	Total			TNB	SEB	SESB	Total
1990	18.102	2903271	175183	158116	3236570	3447	204	194	3845	179383	1101	17394	836	877	19107
1991	18.547	3103767	186728	167595	3458090	3990	213	239	4442	196506	1206	19538	949	929	21416
1992	19.068	3320521	200487	190335	3711343	4498	240	242	4980	213966	1352	22712	1091	1144	24947
1993	19.602	3533951	214661	192690	3941302	4971	250	274	5495	235137	1453	25579	1259	1270	28108
1994	20.142	3748730	230196	203474	4182400	5610	276	312	6198	256798	1692	29201	1494	1319	32014
1995	20.682	3995445	245327	223147	4463919	6381	310	343	7034	282039	1897	33689	1686	1422	36797
1996	21.223	4196455	260214	234841	4691510	7413	327	394	8134	310251	2068	38174	1943	1569	41686
1997	21.769	4337617	277283	250154	4865054	8302	349	352	9003	332970	2341	44285	2327	1792	48404
1998	22.334	4669289	294041	262696	5226026	8470	372	462	9304	308465	2382	46566	2386	1884	50836
1999	22.909	4902346	309166	270672	5482184	8819	381	490	9690	327397	2443	49952	2538	1777	54267
2000	23.495	5027128	324173	290412	5641713	9712	373	554	10639	356401	2603	54261	2874	1913	59048
2001	24.013	5223890	341224	302981	5868095	10060	366	574	11000	358246	2707	57927	3066	2005	62998
2002	24.527	5481674	361545	313381	6156600	10783	391	604	11778	377559	2806	60054	3248	2182	65484
2003	25.048	5750976	385003	318615	6454594	11329	448	643	12420	399414	2929	64484	3471	2332	70287
2004	25.581	6010087	400348	335800	6746235	12023	481	685	13189	426508	3018	69570	3678	2557	75805
2005	26.128	6253239	414767	349757	7017763	12493	548	743	13784	449250	3089	74796	3942	2769	81507
2006	26.64	6477281	433401	366380	7277062	12990	594	773	14357	475526	3175	77771	4045	2969	84785
2007	27.174	6688426	447750	383716	7519892	13620	625	834	15079	506341	3286	82052	4272	3317	89641
2008	27.729	6932329	466404	401590	7800323	14007	673	860	15540	530683	3347	85616	4421	3475	93512
2009	28.307	7177443	483571	420178	8081192	14245	719	996	15960	522001	3402	82500	4540	3856	90896
2010	28.251	7429437	505205	440526	8375168	15072	780	1091	16943	559554	3700	89621	5727	4127	99475

4) GDP at 2000 Prices

Gross Domestic Product (GDP) is an indicator that be affected with final goods and service produced of a country at one time. It can be indicator of country standard of living[12]. When the GDP at the country changes, it can be affected the electricity consumption. GDP can be divided into two parts which are real GDP and nominal GDP. Real GDP were manipulating by current currency but nominal GDP manipulate by selected year currency. For this project, the data nominal GDP are GDP at 2000 prices. This factors selected because the changes of currency. All GDP value of each year was determined using the currency on year 2000. For a few countries where the official exchange rate does not reflect the rate effectively applied to actual foreign exchange transactions, an alternative conversion factor is used.

5) Electricity Demand per Capita

Electricity demand per capita also causes the changes of electricity consumption. When the electricity demand per capita which is electricity consumption of each person increase, the electricity consumption of country also increase.

B. Development of ANN

1) Normalization

To be more efficient in network training, pre-processing steps need to be performed [11]. This process was called normalization. This process made ANN to be more efficient. Normalization is of process that scaling the input and output within specific range [5]. Usually, normalization data was used to indicate the data from -1 to 1. So, when the data falls between these ranges, the forecast process will be more precise.

2) Training Algorithm

Training process is the ability to learn from the historical data and improve its performance by learning the data. At this stage, the ANN are adjusted or trained to perform the specific targeted output until it reach convergence on the output. The targeted output is important because it will be the lead or the guide for the ANN to achieve their target. In this training process, 11 data were selected as the training data. The general steps in training process are:

i. Design ANN configuration
ii. Set training parameters
iii. Train the ANN
iv. Save the network if converge

3) Testing Algorithm

After the training process was converging, the next process is testing process. In this section, the rest of the collected data which is 10 patterns will be test. The regression coefficient, R value represents the relation between output and targeted output. Values close to one indicate that there is a strong correlation between the output and the targeted output while if the correlation is close to zero, vice versa. Figure 3 shows the ANN algorithm which are combination of training and testing steps.

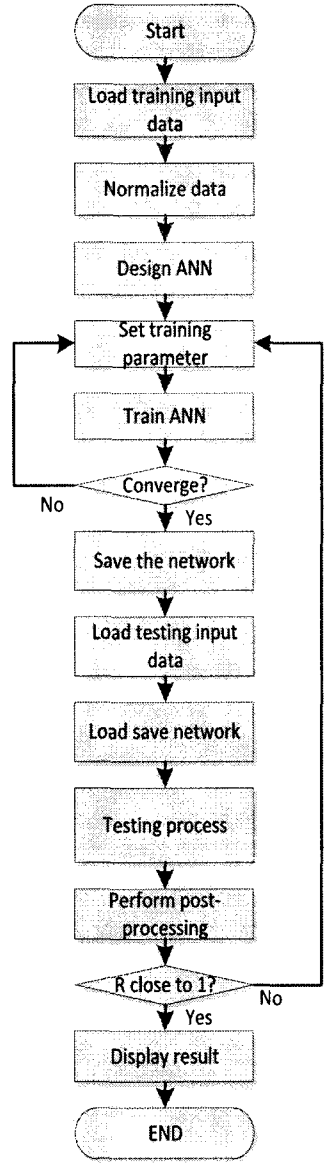

Figure 3: ANN Algorithm

C. Evolutionary Computation

There are many types of evolutionary computation and one of them is evolutionary programming. This project is using EP as optimization technique to maximize the regression. Objective EP is to optimize any fitness which can be represented using mathematical equation or any network. There are eight steps in EP and all these processes are showed in Figure 4.

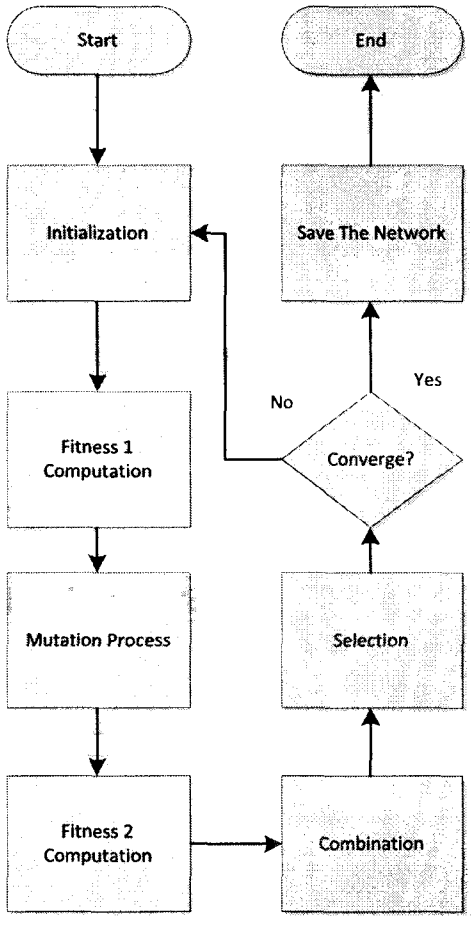

Figure 4: EP Algorithm

1) Initialization

Basically, initialization is a process to generate random numbers which represent the variables which control the objective function. In this project, random numbers generated from the program start from 0 up to 1. The values were randomly generated on the value of learning rate of ANN. From the process, x1 represent the variation value of learning rate in set training parameter in ANN. This step was collect 20 networks which has regression exceed 0.99.

2) Fitness 1 calculation

Fitness is the equation or function or subroutine to be optimized. It can be a single mathematical equation or a long subroutine. In this case, ANN will be a modeling mathematical equation. In the function, the training and testing are generating the data in order to get the value of regression.

Learning rate randomly generated will be used in the ANN programming to define the best regression or the best network. The best regression can be acceptable when the value of regression is close with 1. Then the regression calculated will be compared with the base case regression value which is 0.99 and if the value is higher, the value of learning rate generated will be selected. Only 20 values will be select by the constraints.

3) Mutation Process

Mutation process is an operation to breed offspring. To generate the offspring, Gaussian mutation technique will be applied. From the previous values from step fitness 1 calculation, it will create another value that is close to the previous values but a little bit different. Previous values of step fitness 1 calculation are the parenting for the offsprings.

4) Fitness 2 calculation

Fitness 2 calculation is the next process after mutation. This process will generate new maximum regression from the offsprings values. The offsprings act as the new control variable for the fitness 2 which is x1_new. Coding for fitness 2 calculations is the same with the fitness 1 calculation which is ANN programming but the different is fitness 2 calculation use new control variables.

5) Combination

Combination is a process to combine the parents and offsprings in series. From this process, number of rows will be doubled. In this project, the combination is to combine between step fitness 1 calculations with step fitness 2 calculations.

6) Selection

Selection is to select the survival of the fittest. From the combination process, the selection will arrange the regression. It will select the highest value at the first row and slowly decrease the value to the lowest row.

7) Convergence test

Convergence test is a process to determine the stopping criterion. Minimum fitness and maximum fitness must be identified. Accuracy of convergence test is 0.01 which is the difference between the minimum regression value and the maximum regression value is less than 0.01.

III. Result And Discussions

The annual data of electricity consumption were collected from the Malaysia Energy Commission. The data were divided into training and testing part. To improve efficiency of training and testing, the data were normalized in the range of 0 to 1. The data of eleven years were used in training data and the remaining years were used in testing data. From the tabulated data, there were 5 input variables and 1 target output was tabulated.

To develop ANN model in order to forecast the electricity consumption through the input variables, the value of regression, R is the important value. From the ANN model, the best regression obtained is 0.99973. This is the nearest value to 1 which is the best regression using ANN method.

The properties of ANN model for the forecasting electricity consumption can be summarized. The possible network configuration used is [5, 7, 1] with *logsig, logsig, purelin*. The types of ANN learning algorithm is *trainlm*. The learning rate is variable. The program runs until 1000 times and the learning rate was changed until the regression was optimized until close to 1.

The second method forecast is using combination of ANN with EP. The reason of this combination is to optimize the regression near to 1. The ANN were using the heuristically method. The properties ANN used were same with first method which is [5,7,1] configuration used with *logsig, logsig, purelin*. The types of ANN learning algorithm used *trainlm*.

Using this combination method, the EP program stop executed when the regression were achieved with the desired convergence test. For this project, the convergence test was set to 0.01. The network that has regression the closest to 1 was chosen as the best network. From the ANN-EP model, the best regression obtained is 0.99955.

The results were compared between ANN and ANN-EP method in term of regression value. The regression value that was close to 1 showed the strong relationship between input variable and target output.

Figure 5 and Figure 6 below show the result from testing process. The result by using ANN found that the regression value was 0.99973 when learning rate was set to 0.7678. Meanwhile the ANN-EP method showed the result of regression value of 0.99955 when learning rate was set to 0.6995.

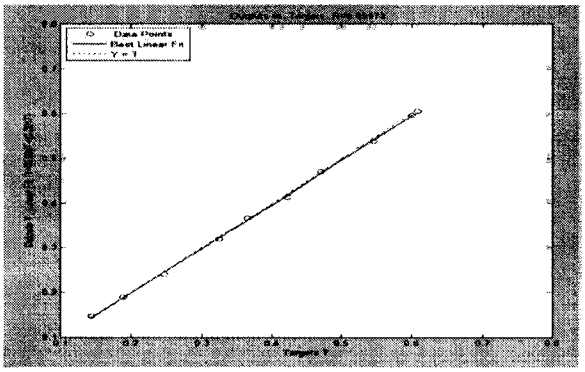

Figure 5: Regression from ANN method, R=0.99973

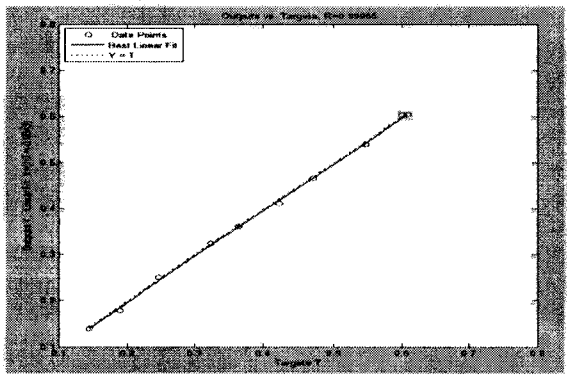

Figure 6: Regression from ANN-EP method, R=0.99955

From the result of the comparison between these two methods, the value of ANN method and ANN-EP method are very close. The different between methods ANN and ANN-EP is nearest to 0. ANN programming runs in 715.42 seconds while the combination of ANN with EP runs in 92.96 second. The combination of ANN and EP used the short time compare to ANN programming. Figure 7 shows comparison actual data value, ANN predicted values and the combination ANN with EP values for the electricity consumption.

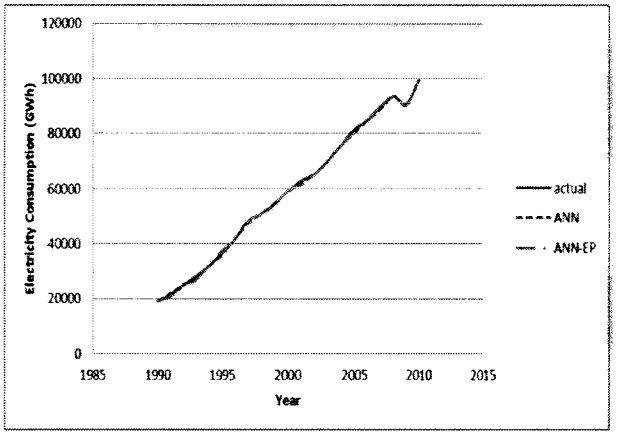

Figure 7: Comparison actual data value, ANN predicted values and ANN-EP predicted values for the electricity consumption

The properties and the result of the best ANN model and ANN-EP model for the forecasting electricity consumption can be summarized in Table II.

IV. Table II: ANN Properties And Result

configuration	***ANN***	***ANN-EP***
Network configuration	[5,7,1]	[5,7,1]
Transfer function	Logsig, logsig, purelin	Logsig, logsig, purelin
Learning rate	0.7678	0.6995
Momentum rate	1	1
Epochs	1000	1000
Time	715.42	92.96
Regression	0.99973	0.99955

V. CONCLUSION

An artificial neural network forecast of electricity consumption based on historical data was presented. The construction of ANN model included the ANN and combination of ANN with EP. From the result, the regression between combination models is close enough with ANN model. In Figure 7, the graph plotted the value between actual, predicted of ANN and predicted ANN-EP are exactly same. As a conclusion, the forecast of electricity consumption was successfully executed. The network ANN-EP were selected to forecast electricity consumption because the regression are close to 1 and the programming runs are faster than ANN model. Consequently, forecast of the electricity consumption can be successfully done.

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