Anticipation of Power Generated by Photovoltaic Panels Based on Artificial Neural Network and Matlab

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***Abstract*— This project is to design a feed forward multi-layer (MLP) neural network of PV panel by using artificial neural network (ANN) and Matlab application software. An approach based on artificial neural network (ANN) was developed in this project to anticipate the output power of photovoltaic (PV) panels. The Levenberg-Marquardt back propagation was used in the neural network as its learning algorithm. In this project, several sets of mono-crystalline historical data have been used to train and test the neural network in order to predict the performance mono-crystalline PV-panel. The inputs of the PV panels network are solar irradiance and ambient temperature of PV panels while the output is electrical power generated by the PV panels. Firstly, a dataset of 3x300 were used to train the network then another 3x165 data were used to test the trained network. The results of the trained and tested neural network based on Matlab were presented. The regression from data testing procedure shows that the use of ANN for performance prediction of mono-crystalline PV panels is acceptable.**

***Index Terms*—Artificial Neural Network (ANN), Photovoltaic (PV), Backpropogation (BP), mean squared error (MSE), Multi-layer Preceptron (MLP).**

I. INTRODUCTION

There are many types of renewable energy studied by many scientists such as micro hydro, solar, biomass, wind and wave. However, recent studies found that solar energy is the most feasible study to be proceeded with solar farm construction, because certain areas in Malaysia receive enough amount of solar irradiance. A study conducted by a group of researchers from University Malaysia Perlis (UniMAP) stated that Perlis receives 1019 W/m^2 on average in a year [1] which is considered as a big amount of solar irradiance. Plus, the electricity which is produced from the sun is cheap and clean energy source [2].

Therefore, to predict the performance of PV-panel is essential in order to carefully design the construction of solar farms. Normally, the performance of PV panel can be determined by using the experimental method or system monitoring, where all the data of solar irradiance, module temperature, ambient temperature of PV-panel and power generated by PV panels can be collected by means of experiment. Nevertheless, the experiment cannot be conducted if the weather is rainy and dark because the output of a PV panel is highly dependent on the environmental factors for instance solar irradiance and temperature of PV panels. Besides, it is very difficult to predict an accurate PV panel model based on numerical computation due to these uncertain factors. Photovoltaic panel is a combination of many photovoltaic cells. A PV cells generate direct current from sunlight, it converts light and heat energy into electrical energy, but the magnitude of generating electrical power depends on solar irradiation and temperature of PV panel [3].

Artificial Neural Network (ANN) model has received many attentions by researchers and this model is widely used in electronic applications. But the implementations of the ANN model in photovoltaic systems are very limited [4]. But there were several researches had been done in modeling a PV-system based on ANN [5-7]. The concept of ANN is inspired by our very own brain neural network to make a decision, recognition and prediction. Like our brain system, ANN needs to learn and be trained [8] before it can perform any of these jobs accordingly. Therefore, in this project the ANN was trained by using historical data of mono-crystalline PV panel. Nevertheless, the neural network of PV is developed for a specific condition of a certain area because the historical data used to train the network was taken from UiTM Green Energy Resource Center located in Shah Alam, therefore this project cannot predict the performance PV panels generally and accurately for other PV system at different locations in Malaysia.

The main objective of this project is to design a feed forward multi-layer neural network of PV panels by using artificial neural network (ANN) and using Matlab application software. Hence, to make this project usable in order to create a better "green environment" in the future. Because, generate electricity by burning fossil fuels will contribute to environmental pollution [9].

The outcomes of the project are expected to be able to show the output power generated by the photovoltaic panels. In practice, the input variables involved are solar irradiance, reflected solar irradiance, diffuse solar irradiance, tilt angle and temperature of photovoltaic panels. However, some of these data are difficult to obtain and some of them need to be purchased at an expensive price from the Malaysia meteorological department.

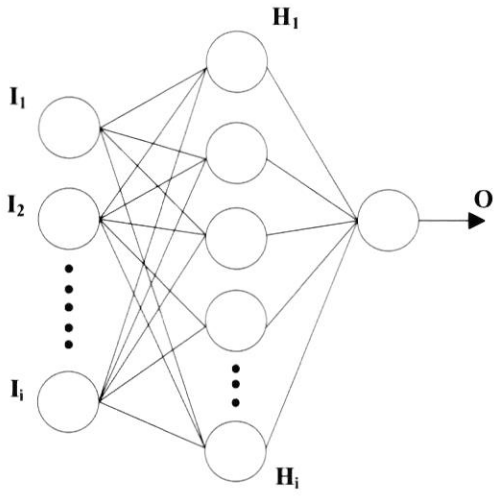

Fig. 1) Feed forward multi-layer (MLP) neural network

II. Methodology

The sequence of method as shown in Fig. 2 had been designed before the project was initiated.

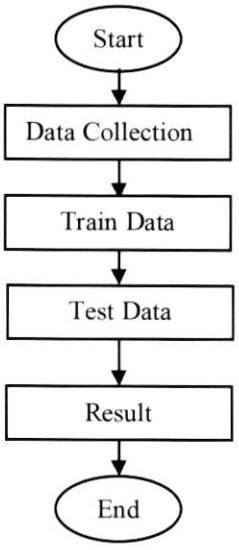

Fig. 2) Flow of project.

A. Data Collection

Before constructing the neural network by using Matlab, a set of mono-crystalline historical data need to be prepared and identified. For this project, the relevant historical data are solar irradiance and ambient temperature of PV panels as the input data variable. On the other hand, the output data variable is electrical power generated by PV panels.

TABLE I
Shows some of the collected historical data.

Mono-crystalline		
Input		Output
Solar irradiance (W/m2)	Ambient temperature (°C)	Power (W)
1	27.2	19
4	27.2	22
8	27.2	32
13	27.2	74
19	27.3	102
25	27.5	128
36	27.6	175
47	27.8	221
54	28.2	250
60	28.4	276
68	28.7	304
75	28.9	333
83	29.1	361
90	29.2	387
93	29.5	398
94	29.7	401
94	29.8	403
96	29.9	413
101	30.1	437
115	30.2	490
127	30.3	545
164	30.5	687
209	30.9	864
283	31.4	1193
332	32.1	1289
384	32.7	1371
349	33.9	1322
398	34.4	1628
435	34.9	1910
442	35.3	1929

B. *Train Data*

Once the network had been constructed for photovoltaic system application, that network is ready to be trained. To start this process some historical data for both input and output variables can be chosen randomly. Next, in order to get a better result these data need to be normalized [10,11]. Then, the training or learning process can be initiated. The training process must be repeated until its training performance converges, Fig 5 shows converges training performance. Refer to below flow chart (Fig. 3) for a clear picture of training process.

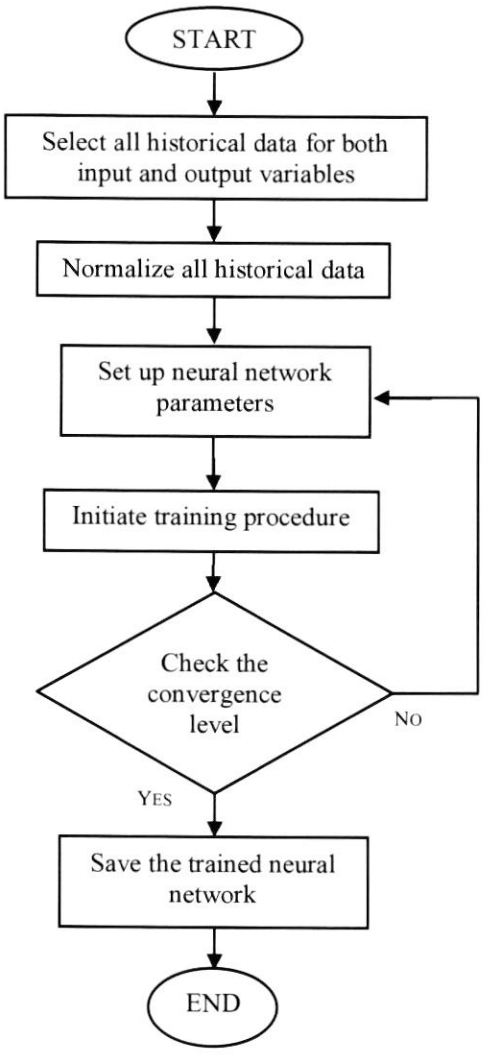

Fig. 3) Training procedure

C. *Test Data*

Once the training performance of the network achieved at the significant convergence level, now the trained network is ready to be tested to ensure whether or not the neural network has successfully been trained. For this process, some other historical data for both input and output variables of photovoltaic system application are chosen at random and had been normalized then the testing process can be initiated. This process is to ensure that the performance of the trained neural network is functioning accordingly. Fortunately, supervised learning method that had been used in this project allows us to physically compare the estimated output and the actual output (Fig. 8).For better illustration, flow chart below (Fig. 4) shows the data testing process.

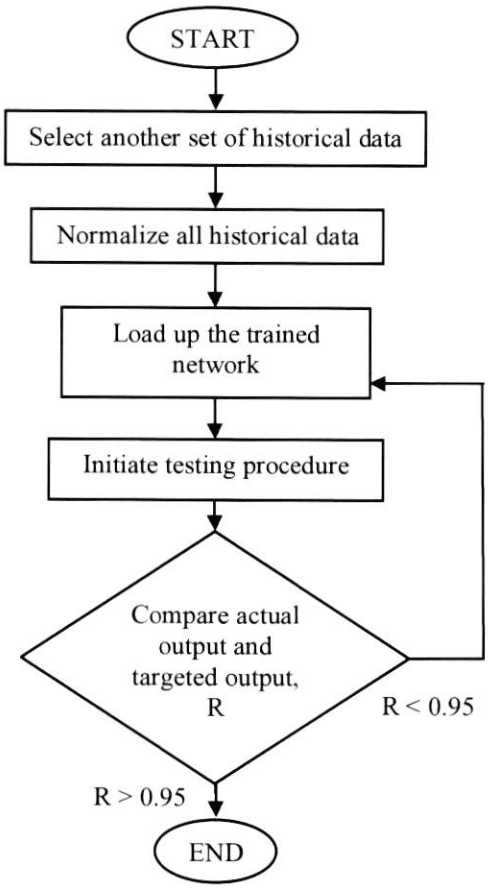

Fig. 4) Testing procedure

D. *Result*

The trained neural network is said to be a successful network only if its value of regression is close to 1. The closer the value of regression to 1 means the better artificial neural network has been designed. Therefore, in this paper the favored result is a regression line produced in the testing procedure.

III. RESULT AND DISCUSSION

Result of training process

Once the commands have been constructed by using Matlab, there are processes need to be done in order to determine the performance level of the network. First, "data training process" and the number of data were trained are around 300 data. The purpose of this process is to create so called brain or the artificial brain network. The artificial brain network needs to be trained until it is converges which can be determined by undergoing the data training procedure (Fig. 3).

In training procedure, the training performance will achieve the significant convergence level if the mean squared error(MSE) has achieved according to the training parameter that have been set.

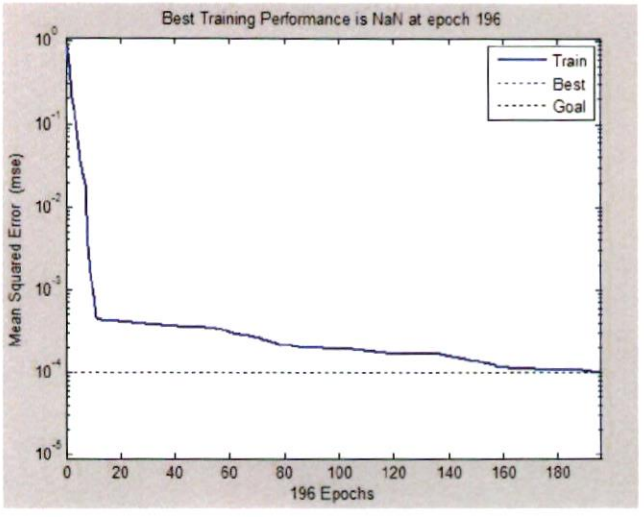

Fig. 5) Converges performance line

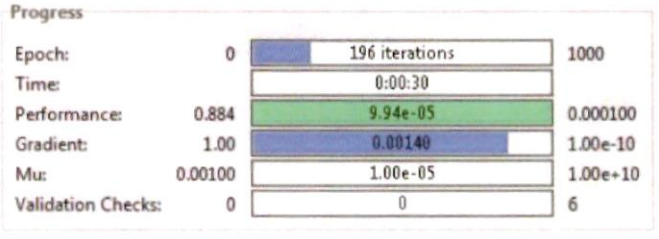

Fig. 6) MSE or Performance setting value (Green)

In this project, the learning method used is a supervised learning method and the learning algorithm used is Levenberg-Marquardt back propagation which is a network that updates weight and bias values. This learning algorithm is known as a successful learning rule [4] and the fastest back propagation (BP) algorithm in the Matlab software application.

For a supervised learning method, whenever the predicted output does not match the actual output, the weights are adjusted in order to minimize error. If the predicted output matches the actual output, then there is no adjustment need to be made. Refer equation (1).

$$W_{ij}^{K+1} = W_{ij}^{K} \qquad (1)$$

If the output is 1 but should have been 0, then the weights are decreased on the active input link by using equation (2).

$$W_{ij}^{K+1} = W_{ij}^{K} - \alpha.x_i \qquad (2)$$

If the output is 0 but should have been 1, then the weights are increased on the active input link by using equation (3).

$$W_{ij}^{K+1} = W_{ij}^{K} + \alpha.x_i \qquad (3)$$

Where,

W_{ij}^{K+1}	is the new adjustment weight
W_{ij}^{K}	is the old weight
x_i	is the input
α	is the learning rate parameter

the bigger the α, the faster learning process.

Figures below (Fig. 7) shows the result of data training procedure.

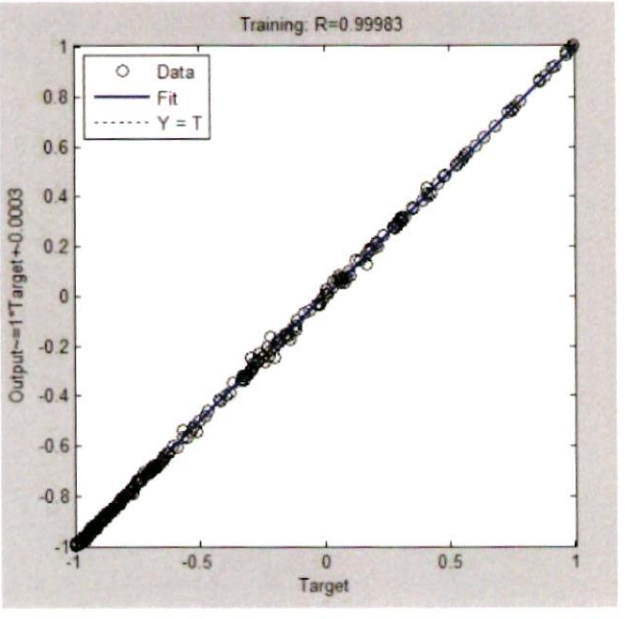

Fig. 7) Regression line for training procedure

From the result of training process (Fig. 7) the regression is extremely close to 1. Beside the estimated output is approximately the same with the actual output. In other word, the trained network is ready to be tested.

Result of testing procedure.

The presented result of testing procedure (Fig. 8) is a comparison between actual output and targeted output after using same neural network in training process but different set of historical data.

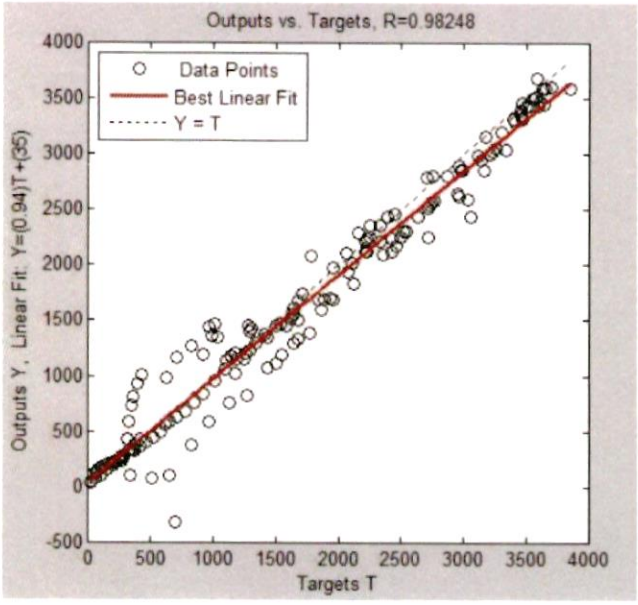

Fig. 8) Regression line of testing procedure

With reference to the above Fig. 8, the relationship between estimated output and actual output is directly proportional; specifically the regression is 0.98248 which is considered as a good result. In order to undergo the testing procedure, another set of 165 data was used to measure the performance of the trained artificial brain.

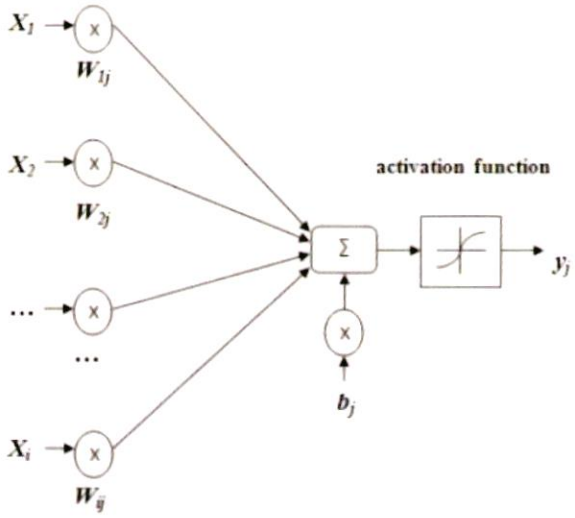

Fig 9) Processing unit

Fig. 9 shows processing unit of feed-forward for Multi-layer Preceptron (MLP) network that being used in this project. All these processing units perform the same basic computation (see equation 4). Then they apply the result to a non-linear function named activation function (sigmoid function) (see equation 5). Table 2 shows some result from testing procedure.

$$yj = f\left[(\sum_i Wij.Xij) - bj\right] \qquad (4)$$

Where,

W_{ij}	synaptic weight
X_{ij}	input
y_{ij}	output
b_j	bias

$$f(x) = \frac{1}{1+e^{-1}} \qquad (5)$$

TABLE 2
Result from testing procedure.

Estimated output, Y (Watt)	Actual output, T (Watt)
21.9	22
52.9	51
82.3	91
121.5	118
186.6	165
249.8	238
295.1	294
336.4	349
355.3	379
367.8	397
377.6	392

IV. Conclusion

In this paper, a mono-crystalline PV panel has been simulated based on ANN and Matlab. The precision of the modelled neural network is interpreted by comparing the estimated output data and the actual output data. The regression from data testing procedure shows that the use of ANN for performance prediction of mono-crystalline PV panel is acceptable. The benefit of implementing ANN technique in photovoltaic system is that it can be used to anticipate the generated electric power from the mono-crystalline PV panel based on its historical data economically. Therefore, the objective of this project has been achieved which is to design a feed forward multi-layer neural network of PV panel by using artificial neural network (ANN) and Matlab. Actually the neural network can be used to predict the performance of many types of PV panels simultaneously, but that will be the objective in the future paper.

Acknowledgment

Several sets of mono-crystalline PV panel historical data were taken from Green Energy Resource Center, UiTM Shah Alam.

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