Prediction Output Current and Output Power of Photovoltaic System Using Artificial Neural Network

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***Abstract*— This paper presents an application of Artificial Neural Network (ANN) for prediction of output from Photovoltaic (PV) system. The output current and output power is predicted from PV system from Green Energy Research Centre (GERC) in Uitm Shah Alam. DC input current and voltage from two strings A and B is sets as input data in ANN program in order to predict the output current and output power from PV system. The performance of the system is measured by its regression value. The best performance of the system is when regression value is equal to 1. Usually, ANN will run heuristically for its parameter and in this paper ANN program is set to generate automatically random parameter. The purpose of prediction output current and output power from PV system using ANN is to evaluate the performance of PV system by using historical data from GERC. The results show that ANN program gives an accurate prediction.**

***Index Terms*—Photovoltaic (PV), Green Energy Research Centre (GERC), Artificial Neural Network (ANN), prediction output current and output power automatically**

I. INTRODUCTION

An increase in price of fossil fuel, air pollution and many more are the reasons why renewable energy is needed at this time. Conventional energy sources based on oil, coal and natural gas keep on increasing the economic cost, produce polluted environment and giving risk to human life. Renewable energy are used nowadays, as it can reduce the dependency on fossil fuels and drive clean technology to the market. There are many types of renewable energy in the market such as biomass, biogas but PV is a popular renewable energy sources in our country.

PV is an item that converts solar irradiation to power energy. Solar energy can be obtained freely at any places most of the time. Solar energy is a clean, pollution free and the energy source is renewable. That's why PV became alternative renewable energy sources and getting more important to electric sources. PV system can be connected to national grid or can be stand alone. In solar energy the irradiation is fluctuations and this is a weakness of PV. PV system use an input like DC current and DC voltage from PV panel, to determine the output current and output power. The performance of PV system is not known so to estimate the system performance a program like ANN is used to estimate their performance and operation[1] [2].

In Artificial Intelligence (AI) there are many methods such as Evolutionary Programming (EP), Fuzzy Logic and ANN is one of them. Based on training experience, ANN has the ability to learn from example and also has the capability to implement pattern recognition and forecasting task[3]. When the relationship is nonlinear and not well determine, ANN can adjust the relationship itself so that it can give a good representation of the relationship[3]. If the trend are too complex to be realized by human or other prediction technique, ANN can obtain the pattern and detect trends[3]. Besides that, ANN method did not use any mathematical equation, because it is hard to obtain the result and sometimes not accurate for nonlinear systems. The training process using onsite measurements adapts ANN automatically by minimizing mean square error [3].

A similar analysis has been used to predict output from PV such as Optimizing Three-layer Neural Network Model for Grid-connected Photovoltaic System Output Prediction by Shahril Irwan, Titik Khawa Abdul Rahman and Ismail Musirin [4]. In this paper is to predict the energy output of a grid connected photovoltaic system installed at Malaysian Energy Centre (PTM) Bangi. Other paper is Simulation of Photovoltaic Power Systems and Their Prediction by Saifur Rahman [9]. However this paper is to test photovoltaic performance analysis model for their ability to estimate the AC power output. And other paper is Artificial Neural Network Versus Linear Regresion for Predicting Grid-Connected Photovoltaic System Output by Shahril Irwan Sulaiman, Titik Khawa Abdul Rahman and Ismail Musirin [6]. This paper shows how to predict the output by using Multi-Layer Feedfoward Neural Network (MLFNN).

The objective of this project is to predict output current and output power from photovoltaic system using ANN from historical data. Several ANN model will be constructed and the performance of each model will be evaluated. The data is taken from GERC and the best results are chosen according to the value of regression.

II. THEORETICAL BACKGROUND

A. *Photovoltaic (PV)*

PV are semiconductor devices or known as solar cells that convert sunlight into direct-current (DC) electricity. When PV module receives solar irradiance, this electrical field provide momentum and direction to light-stimulated electrons, resulting in a flow of current when the cell is connected to an electrical load. Efficiency, size and the intensity of sunlight striking surface is the factor that contributing the amount of current generated by PV module.

Generally, there are 4 types of PV module technology. Monocrystalline, Polycrystalline, HIT (hybrid technology combination crystalline and thin film) and Thin Film. At GERC, they use Monocrystalline PV module from Yingli Solar. The type of module is YL 250 C-30B. The classification of PV module is shown in Table 1 and the characteristic of PV module at GERC is shown in Table 2.

PV Module	Output Capacity
Small (domestic usage)	1 - 10k Wh
Medium (building integrated)	10 - 100k Wh
Large (electric companies)	500k Wh - M Wh

Table 1: Classification of PV Module output capacity

Type of PV Module	Monocrystalline
Maximum Power, Pmax	250 W
Short Circuit Current, Isc	7.02 A
Open Circuit Voltage, Voc	35.1 V
Module Efficiency	15.3%
Type of Inverter	STP 8000TL-10

Table 2: Characteristic of PV system at GERC

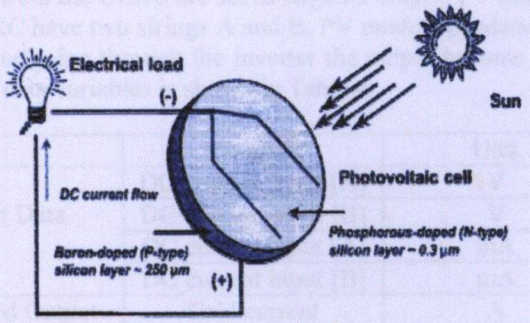

Figure 1: Photovoltaic Cell

B. *ANN*

ANN is a mathematical model that consist of an interconnected group of artificial neurons inspired in natural neurons. The number of inputs is called neurons and neurons is the basic processing unit of an ANN[4]. Input neurons and output neurons is fully connected by hidden neuron, input and output neurons were determined as set of input and targeted output of ANN. The ANN model is shown in Figure 2. The Figure 3 show the Biological Neural Network that has been adapt to ANN. Table 3 is show the comparison terms between ANN and Biological Neural Network.

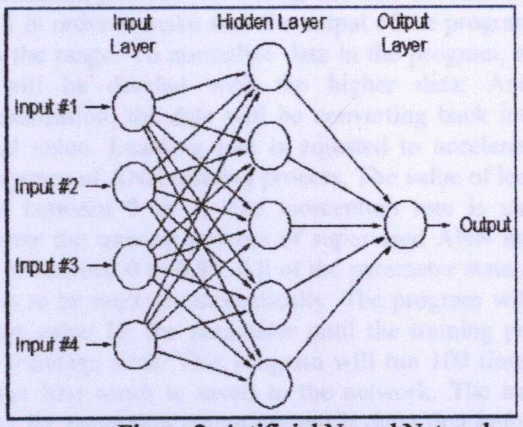

Figure 2: Artificial Neural Network

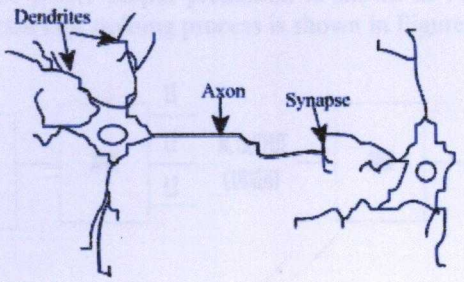

Figure 3: Biological Neural Network

Biological Neural Network	Artificial Neural Network
Soma	Neuron
Dendrite	Input
Axon	Output
Synapse	Weight

Table 3: Terms use in Biological and Artificial Neural Network

Generally, to transform input neurons to output neurons a transfer function is used in hidden layer [4]. The neurons is organized in layers and Back-Propagation (BP) is used since this ANN is in layered feed-forward and the errors are propagated backwards. BP is a supervised

learning and to compute the network the set of input and output is provided, so the difference between actual and targeted results are calculated. Error in the network can be reduce with the idea of BP until ANN learns the training data

III. METHODOLOGY

In general, prediction for PV performance can be divided into two stages, data collection and development of ANN. The development of ANN consist of training and testing process. Normally, the process of training and testing is done separately but in this paper this two process are combined. There are 4 different ANN program, three program for three output line current and one program for output power. The flowchart of the project is shown in Figure 4.

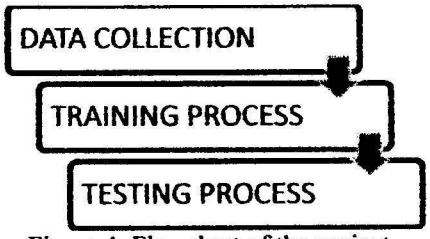

Figure 4: Flowchart of the project

A. Data collection

Data for this project is taken from GERC in UiTM Shah Alam. The data are different for inverter SB 5000TL-20 and STP 8000TL-10 and the data from inverter STP 8000TL-10 is selected. Data is taken from 1 January until 7 January 2013, the data is collected for 24 hours per day and the data pattern obtain are based on 5 minute interval. There are 4 variable input data and the output current and output power from the GERC are set as targeted output. PV module in GERC have two strings A and B. PV module produce DC and after going through the inverter the output become AC. List of data variables is shown in Table 4.

	Variables	Unit
Input Data	DC voltage input [A]	V
	DC voltage input [B]	V
	DC current input [A]	mA
	DC current input [B]	mA
Targeted Output	Grid current	A
	Power	W

Table 4: List of data variables

Average data taken for 1 day is 137, so the total input data for 1 week is 962. At GERC, the output current is measured after going through inverter and the output power is measured before connected to the grid system.

B. Development of ANN

I. *Training Process*

In ANN program, it will learn from historical data and improved its performance by learning the data. Targeted output will be the guideline for the ANN program to train the data, so the results for the training process will reach the convergence state. Each data used in ANN program must be normalized and will be denormalized back.

This process is to make the program more efficient after the preprocessing steps are performed [5]. Normalization process will change the data between range -1 and 1 in order to make sure the output of the program will lies in the range. To normalize data in the program, all the data will be divided with the higher data. And for denormalization, the data will be converting back into the original value. Learning rate is adjusted to accelerate the convergence of ANN training process. The value of learning rate is between 0 to 1. The momentum rate is used to accelerate the training process of supervised ANN and the value is between 0 to 0.95. All of the parameter state above are sets to be random automatically. The program will find the best value for the parameter until the training process reach converge state. This program will run 100 times and only the best result is saved to the network. The training process for prediction output current is done first before the training process for prediction output power is run. The process for power output prediction is shown in Figure 5. The flowchart for training process is shown in Figure 6.

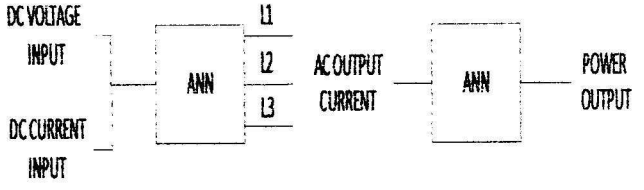

Figure 5: Flowchart of the project using ANN

From flowchart, AC output current has 3 different values. So, three different ANN program are developed to predict the output current for Line 1, 2 and 3. The AC output current are used to predict the output power using another ANN program.

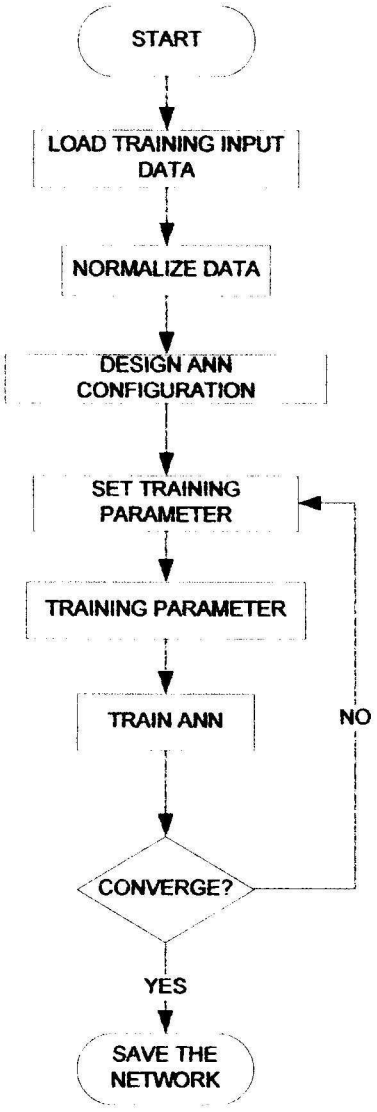

Figure 6: Flowchart for training process

II. *Testing Process*

In training process, the step 'save the network' is called as a brain. For training process, the brain will be called to run the program. From previous process, the output is already converge and the testing process will run on data collection to get the regression coefficient, R. the value of R will represent the relation between output and targeted output. If the regression is close to 1, that indicate the strong relation between output and targeted output. If the regression is close to 0, there is no relation or the relation is low. For output power prediction, the data will load the output current prediction from previous ANN. If the regression value from testing process is very far from 1, training process is needed to run again with the changes in training parameter so that regression value will be close to 1. The flowchart for training process is shown in Figure 7.

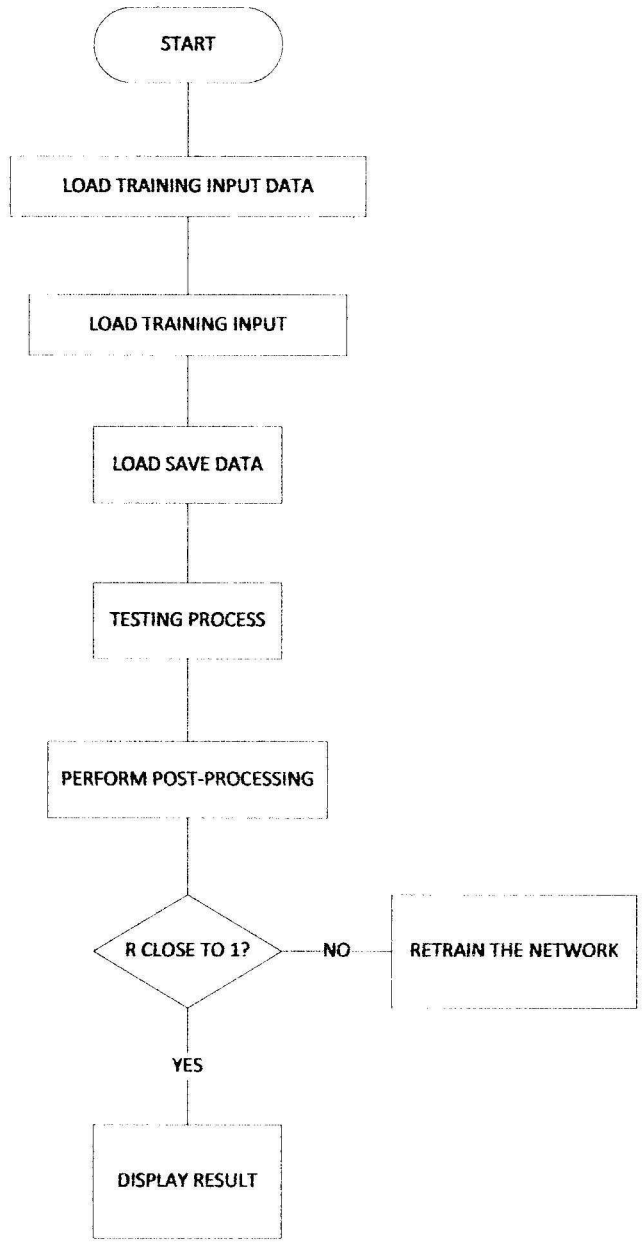

Figure 7: Flowchart for testing process

IV. Results and Discussion

ANN program used in this paper to predict AC output currents and output power. There are four ANN program. First, three ANN program is use to predict AC output currents for three different line and the other one is to predict output power based on AC output currents. Each ANN program have two different program training and testing. For training and testing process output current and output power prediction the results is shown in Table 5. The regression value from testing process is shown in Figure 8, 9, 10 and 11. For output current prediction there is 3 different value for each line 1, 2 and 3.

The purpose of doing the second part of ANN program is to determine whether the output current prediction is correct and can be used to determine the output power. The regression results, r is equal to 0.96969 show that ANN program give accurate prediction. For output power prediction, the parameter in ANN program are set manually. ANN program will give a different results when it run, so the parameter did not have to change every time when ANN program need to be run.

Parameters	Result			
	L1	L2	L3	Power
Network configuration	[50,18,1]	[50,18,1]	[20,5,1]	[5,3,1]
Momentum Rate	0.094	0.74	0.94	0.85
Learning Rate	0.6622	0.0541	0.5998	0.0.85
Epoch	87	92	421	3
Regression	0.99964	0.99963	0.9999	0.96969

Table 5: ANN Parameters and Regression

Table 5 show that the parameter use in ANN program. Each ANN program use a different parameter in order to get the best results. Regression value for L1, L2 and L3 is very close to 1, it means the prediction value is close to the actual value. Regression value for output power prediction is 0.96969, it show that the strong relationship between inputs use in ANN program. Figure 12 shows the comparison between actual value and predict value for output power. There are slight different between these two data, the regression value indicates the prediction accuracy that will affect the graph.

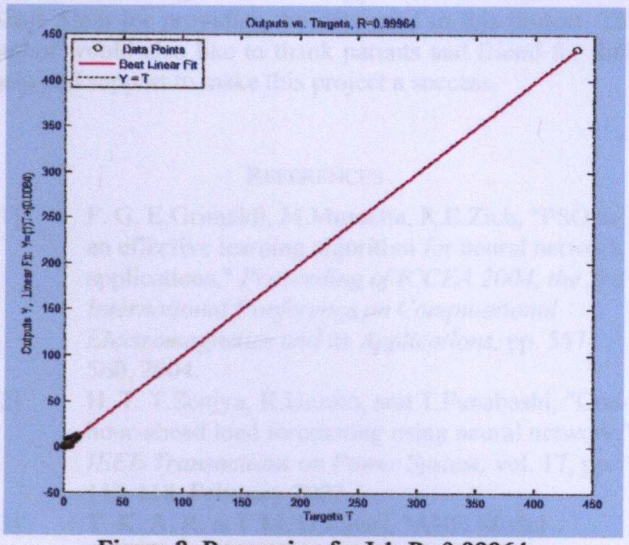

Figure 8: Regression for L1, R=0.99964

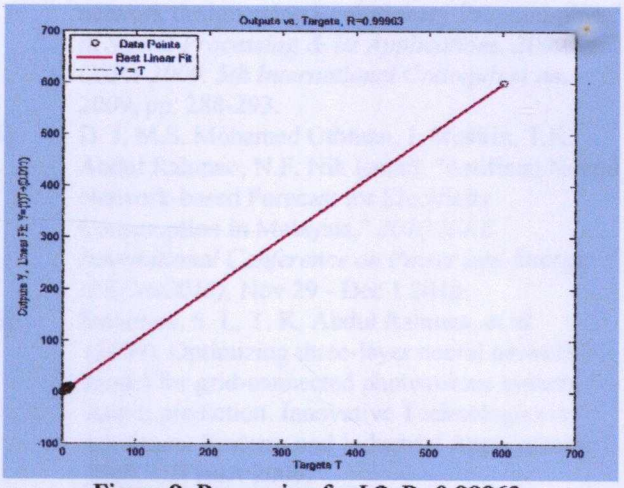

Figure 9: Regression for L2, R=0.99963

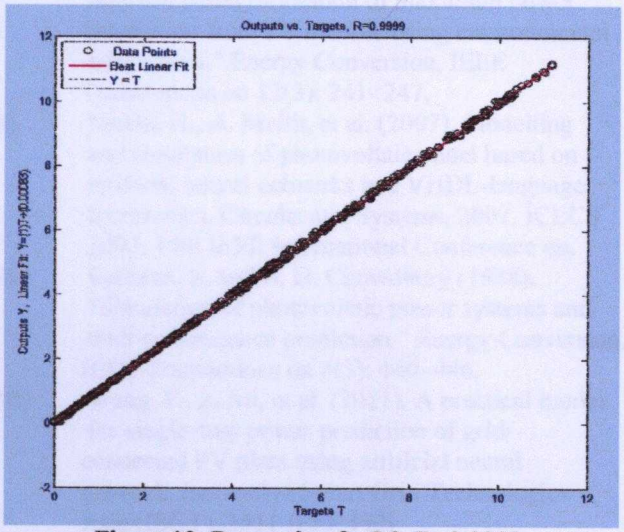

Figure 10: Regression for L3, R=0.9999

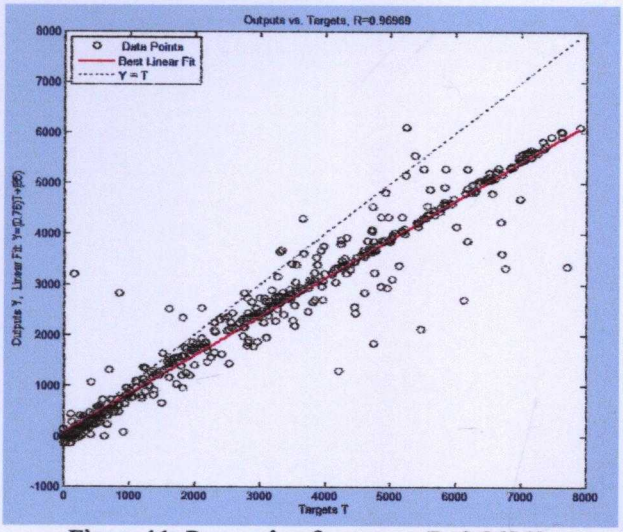

Figure 11: Regression for power, R=0.96969

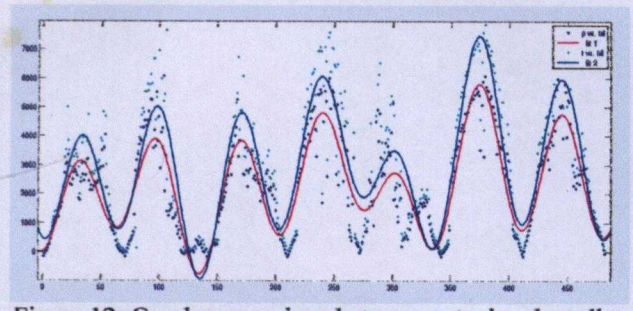

Figure 12: Graph comparison between actual and predict output power

V. Conclusion

From the result obtained it can be seen that the output from PV system at GERC at UiTM Shah Alam can be predicted. ANN is an alternative method to predict output current and output power. Output current and output power result from ANN are more accurate compare to other prediction methods. The regression value for PV system is close to 1 showing the accuracy prediction using ANN.

For future works, the ANN program that had been created can be used to calculates the output power, output current, efficiency, total lost based from the historical data.

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