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Design and Simulation of a Predictive System to Determine the Basic Factors of Solar Cells Using Neural Networks

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ABSTRACT

There are different sustainable energy sources in the word. The solar energy is the most global source that contains an enormous of energy. The Photovoltaics (PV) is a tool that converts the sunlight into electrical power to supply different types of buildings. In this paper, a proposed Neural Networks (NN) tool is used to determine the main parameters and required equipment of the PV system to produce the power for a given building or city. Fives input are chosen for NN which are: the load of the building, sunlight intensity, mean time of available sunlight per day, dust ratio and the air humidity. The input parameters were chosen for its effectiveness on the PV capabilities, the numerical values of the input are normalized to unity number and general use of the proposed method. The response of the NN will determine the required PV no. and its connection type in addition to the size of batteries that will save the produced power and finally the main mechanical variables of the PV installation. The error ratio of the work was 7*10-3 mean about 100 Epoch of each input pattern. The test and validation were held by using MATLAB 2012a which reached the validity of "0.034", zero is optimum value, after nearly 16 Epoch. The flexible treatment and simple construction are the main things of choosing NN in the design and control systems.

Keyword: Sustainable Energy, Photovoltaic (PV), Neural Network and Power Control

1. INTRODUCTION

Renewable energy systems operating solar collectors, including photovoltaic (PV) or thermal panels, are being one of the important technologies in supplying electric, heating and cooling energy for power systems and buildings (Herrando et al. 2014; Fang et al. 2013; Cao et al. 2014). In fact, in 2007, global renewable power accounted for 18% of the total power generation in the world. The entire operating capacity of solar PV power and solar thermal power was 10 GW and 425 MW respectively (Hussein 2015). Solar cells have non-linear properties due to the semiconductor structure inside them (Xin et al. 2004). A perfect solar cell can be represented by a current source connected in parallel with a rectifying diode; (Figure 1) shows the equivalent circuit for solar cell. The conforming I-V characteristic is described by the Shockley solar cell equation (Khalid et al. 2012):

$$I = I_{ph} - I_{sa}(e^{\frac{qv}{kT}} - 1) \qquad \dots 1$$

where I_{sa} is the diode saturation current, I_{ph} is the photo generated current, k is the Boltzmann constant, T is the absolute temperature, q is the electron charge, V is the cell voltage terminals.

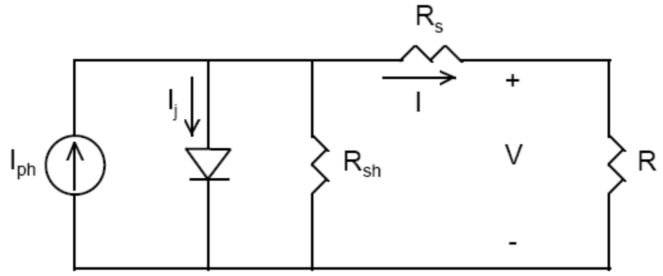

Figure 1: Equivalent circuit for solar cell.

The approximate power density of the insolation on a sunny day is around 1000W/m2. In combination with solar cell efficiencies between 15% and 17%, this yields a maximum possible power output between 150W/m2 and 170W/m2 (Mahmoud 2014). The intensity (radiation) of total solar radiation incident on inclined plane by δ angle calculated using the following formula (Omer 2014):

$$I_o = I_{DN} * [\cos(\theta) + C * \frac{(1+\cos(\delta))}{2} + s * (C + \sin(\beta) * \frac{(1-\cos(\delta))}{2})] \quad \ldots 2$$

where I_{DN} represents the amount of direct radiation incident on the perpendicular surface, s the amount of reflective ground known as (Alpedo) with an estimated value equal to 0.25 in most situation, β is the sun altitude angle calculated per hour, C is the sky-diffused factor calculated from the following formula:

$$C = 0.0965 * \left[1 - 042 * \cos\left(\left({}^{360}\!/_{370}\right) * ND\right)\right] - 0.0075 * [1 - \cos(1.95 * ND)] \quad \ldots 3$$

θ is the incidence angle calculated from the following relationship:

$$\cos(\theta) = (\sin(\beta) * \cos(\delta) \pm \cos(\beta) * \cos(\emptyset) * \sin(\delta)) \ldots 4$$

This research aim to pre-determine required materials, cost for the proposed solar system by means of NN, and how to real time maintain the daily and monthly weather changes.

1.1 The Photovoltaic Cells System

In recent years the demand for sustainable energy is increased and needs to well managed and designed for better use. The solar cell installation is needs to specific mechanical and physical given parameters for optimum power generator. The solar radiation and his angle are the most effective factors for well system configuration in solar cells field. For each region in the word there is a different value of solar radiation, which can be computed by Equation 2. In addition to the solar radiation, the time of available sun light, dust ratio and humidity are minor factors for the energy generation in solar cell system. Now in this section are some of records that computed for Iraq country (Kirkuk-city), as mean of four months (5-8) and will used in this work to compute the main solar cell components (Ahmed 2016, Omer et al 2017).

Solar radiation = 7114.44 MJ/ (m2.year).

Mean of sun light time = 9 hours.

Humidity = 44.6 %.

Dust ratio = 3.4 gram/m2.

These records will be included in this proposed system to manage and determine the required solar cell components for a given building. All the variables have a direct proportion with respect to number of cells except that the radiation intensity, which has opposite proportion.

2. METHOD AND MATERIALS

In this paper a novel method for predicting the main component for a solar cell system to a given place or building. The Neural Network (NN) was used in this work to manage and determine the exact parameters required for the sustainable energy needed for the project. There are many types of NN training; the Back Propagation Neural Network (BBNN) was the tool in this work. In NN; the inputs and the corresponding targets are must be well determined for a better response of the output and final system decision. A normalized data for the system treatments are used in both input and hidden layers neurons that deals with limited types of numbers.

All the possible values for the input factors are re-arranged to values between 0 & 1. The activation function is a mathematical process that permit or not the data to activated at the end of neuron and normally has a three state: low, medium and high. The sigmoid activation function was used in the proposed method for better response in the nonlinear systems. There are multi-layers of neurons in the BPNN: input, hidden and output in addition to the hidden layer which may be 2 or 3 layers. 12-neurons are determined for the hidden layer that reached after a set of try and error iteration and give more stable and less time to decide the desired output and its response. As mentioned earlier; each layer consist of a set of neurons and each one has its own weight that will leads to the true solution with smallest error rate and nearest choice to exact answer.

The NN learning algorithms depends on the input and hidden layer with types of training method and the activation function for each neuron. In this work; there are five inputs which are: (Actual Load, Light Radiation Intensity, Mean of Available light Time, Dust ratio and Humidity). 10 random different values are prepared for train the NN in this work, to get on the desired weights and right configuration for any incoming input data. These values of input data are normalized and saved inside a given variables then after that called by the NN package inside the MATLAB software. The Epoch or the iteration number for the algorithm to stop, if there is no any appropriate solution, is determining at first of execution program. The default value for the Epoch is 500; while the maximum number was reached by the proposed algorithm is 16 Epoch with nearly $7*10^{-3}$ of error rate.

In some input parameters only 3 Epoch was enough to satisfy the learning goal and well ratio of error rate with a validation and test success. The hidden layer neurons are determined by try and error with time of execution and error ratio monitor until fixed to 12 neurons that give the system more reliability and speed of decision maker. The main factors which are needed to design a solar cell system are the same tacked as output for the NN. The output of NN contains on: (Number of Cells, Cell Connection Type, Maintenance Period, Batteries Connection and Cells Direction). All these parameters needed to design and implement a solar cell system, instead of manually computation. The proposed system gives the exact set of requirements and optimizes the existing worked ones. Finally; the response of the system has been validated and tested by the software algorithm and show that the error was in optimum case comparing with other conventional method. In addition to NN curve result that translate the validity and test response of the proposed method; a numerical records are also fixed to guarantee the standard condition of the predicted system. In the NN the strategy is differs from the last learning ways; by selecting the best solution and validate it with the test response. The result shows that the proposed method satisfies the predefined problem key and fixed it in a novel way to predict any future work.

2.1 Flowchart Method

The flowchart for the NN and its operation in the solar cell system prediction is shown in (Figure 2), clear to see the process steps when agree the condition will stop directly, while if there is no solution the next iteration will be come.

Through the flowchart in (Figure 2); any designer can easily determine the required components and the cost for a given solar cell system. The input data in addition to the well-chosen target; the output will be in better situation and optimized the future system for sustainable energy. The load for the solar system will be determined through the situation of the building, if the inputs data are for house the load will be approximately 50A (11000 KW). The offices buildings or a manufacturer will needs more amounts of power supply, therefore the PV will not a good solution for this type of building.

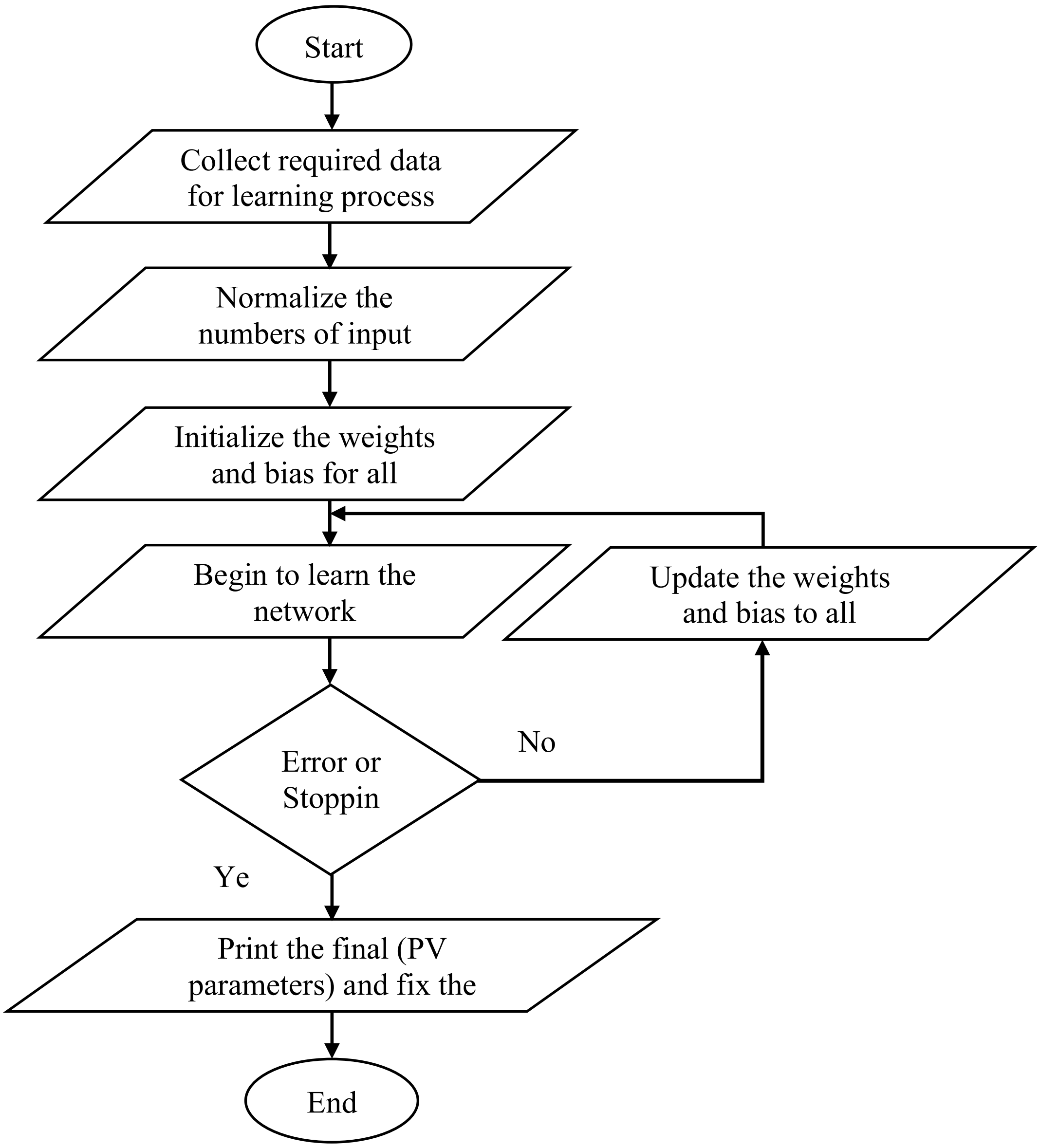

Figure 2: System flowchart and the main process points.

3. RESULTS AND DISCUSSION

This work are recorded via the NN response and the mathematical model of the solar cell. The main factors of the NN which must be recorded for each work are the response for the training, test and validation that must be have a consecutive ratio for more stable system response. The (Figures 3 and 4); show the result curves for the training, test and validation with respect to the Epoch number, this figures related to two different input set parameters, and there are different numbers of Epoch reached for each one. The relation between the mentioned factors translates the system stability and its validation to manage and predict the main component for future word of sustainable energy.

The error is the first stopping condition and its values make the system more reliable if reached to very low ratio; while if the error ration begin to increase toward positive direction that means the system begin to un-response for the input data and must update the weight matrix of the network. (Figure 5) shows the error ratio which is reached during the learning of the proposed method.

In addition to the NN response curves; the numerical statistical records are also included for more reliability of the work, the (Figure 6), show the transition that has been changed when the amount of load increased and the number of corresponding cells doubled with the same ratio of NN output.

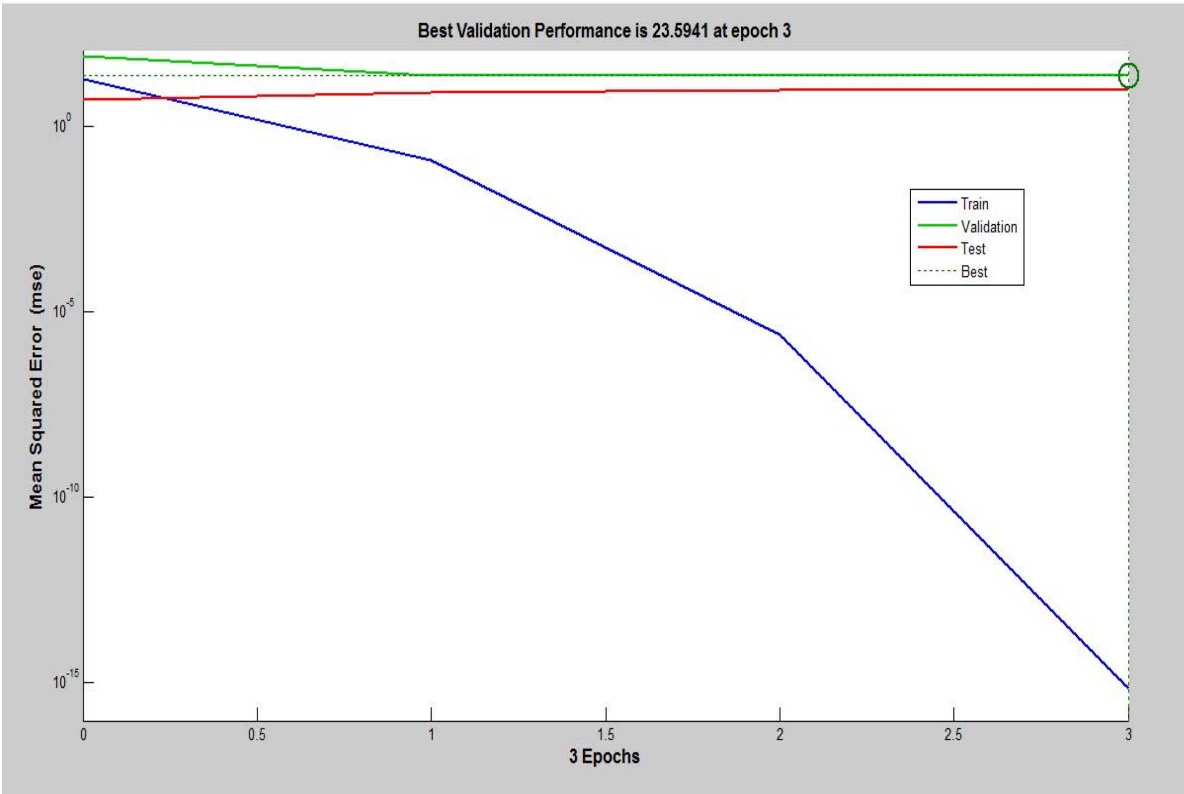

Figure 3: The train, validation and test curves response with respect to Epoch number, the goal was satisfied at 3'rd Epoch.

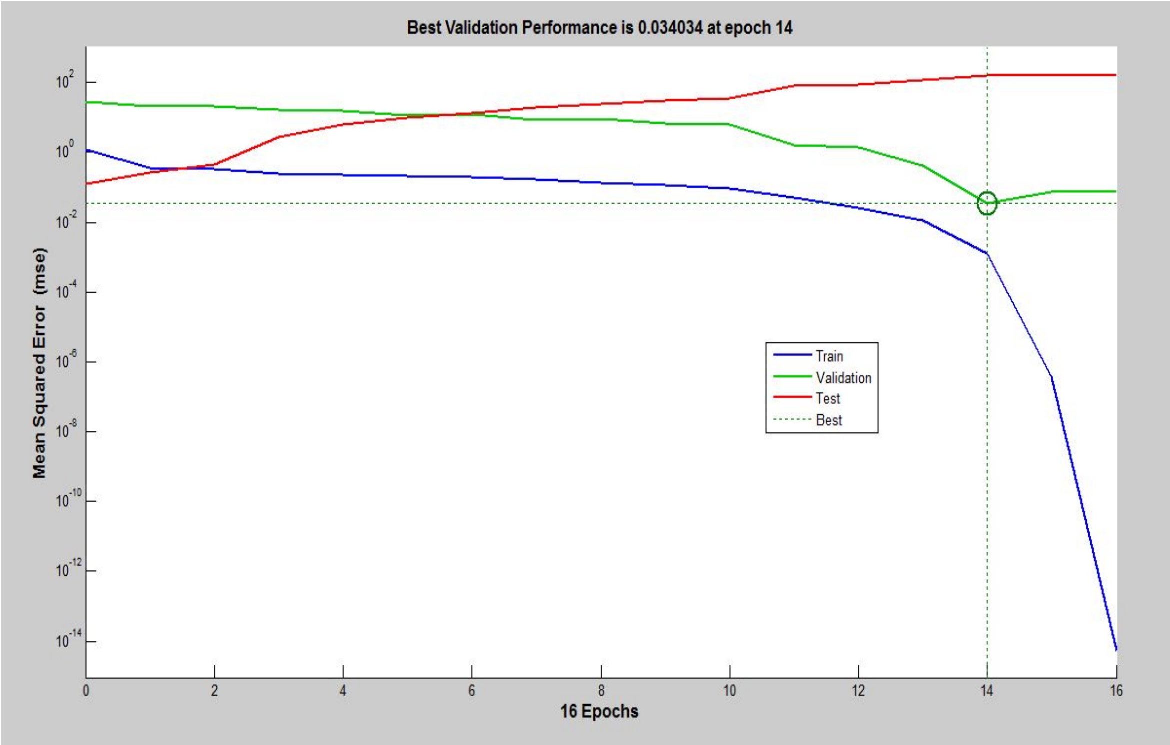

Figure 4: The train, validation and test curves response with respect to Epoch number, the goal was satisfied at 14'Th Epoch.

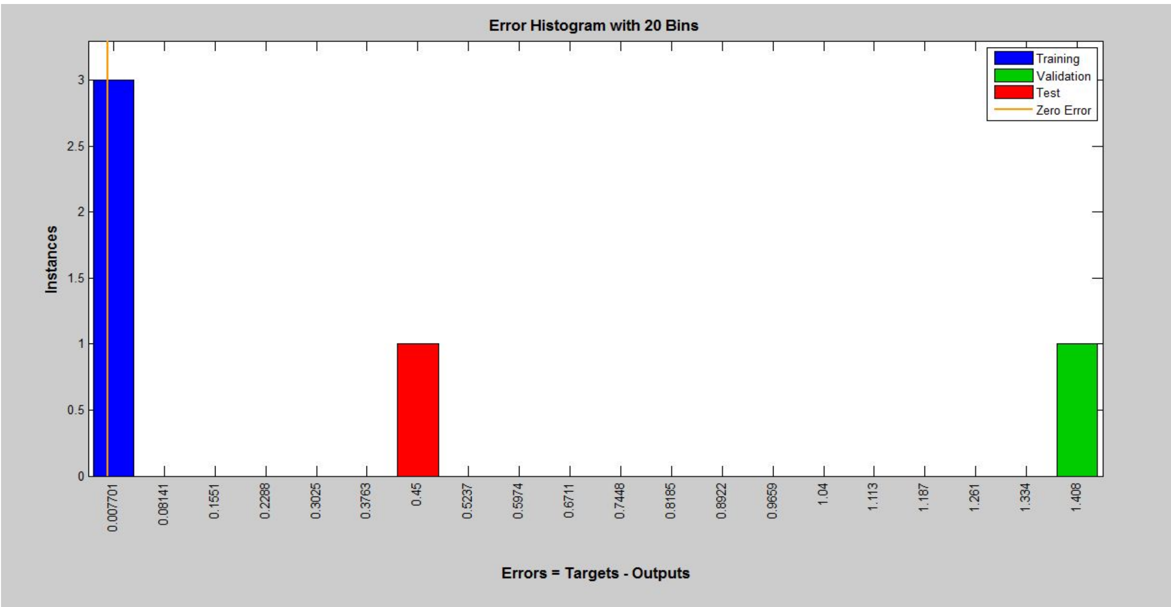

Figure 5: The error ratio for a given input pattern, record at 0.007707.

Due to the data in (Figure 6); clear to see the response of the NN, when the test values has been used to validate the proposed work the desired cell which is the target and the NN-Outputs are the same. According to (Equation 2) the radiation intensity fixed numerically for the Kirkuk city and after the training process the comparing with the proposed system output gives a unique response as shown in (Figure 6).

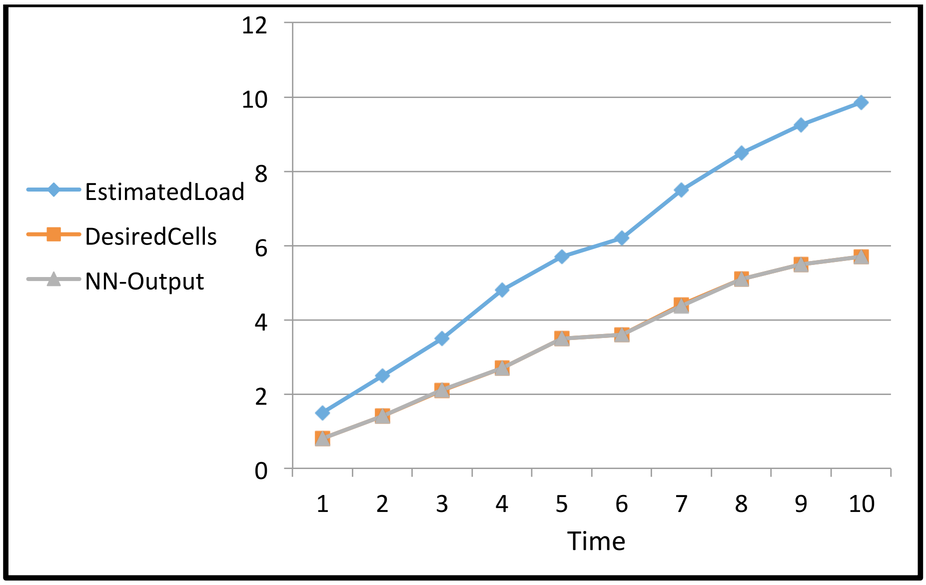

Figure 6: The relation between estimated load and No. of cell required.

The relation between the radiation intensity and the No. of cells are walk in different direction, when the intensity increased the cells decreased and vice versa, see (Figure 7).

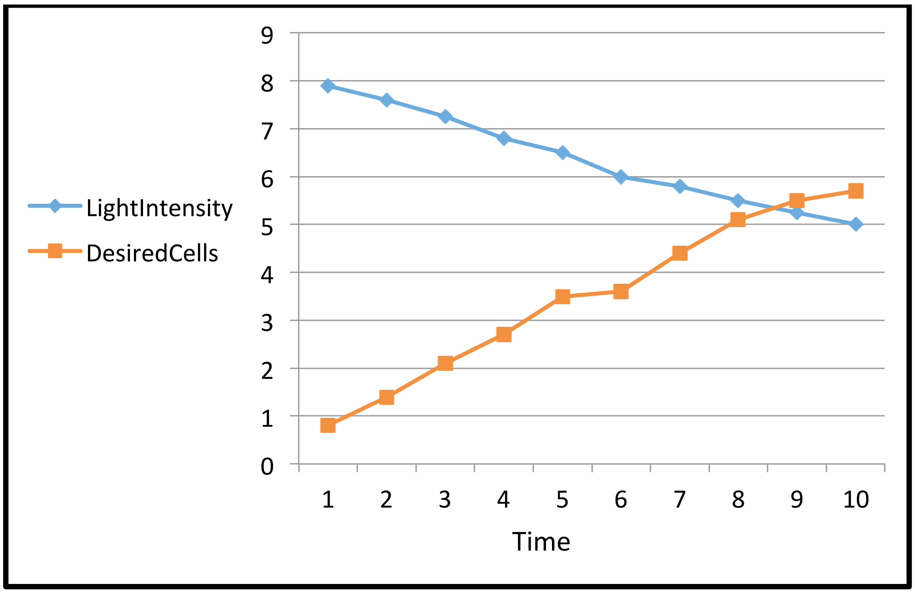

Figure 7: The light intensity with the number of cells required.

(Figure 8) show the relation between the estimated load and light intensity with respect to the number of required cells. As mentioned earlier when the radiation intensity increased the number of cell will decreased in unique form to satisfy the well power output; this situation well controlled by the proposed method.

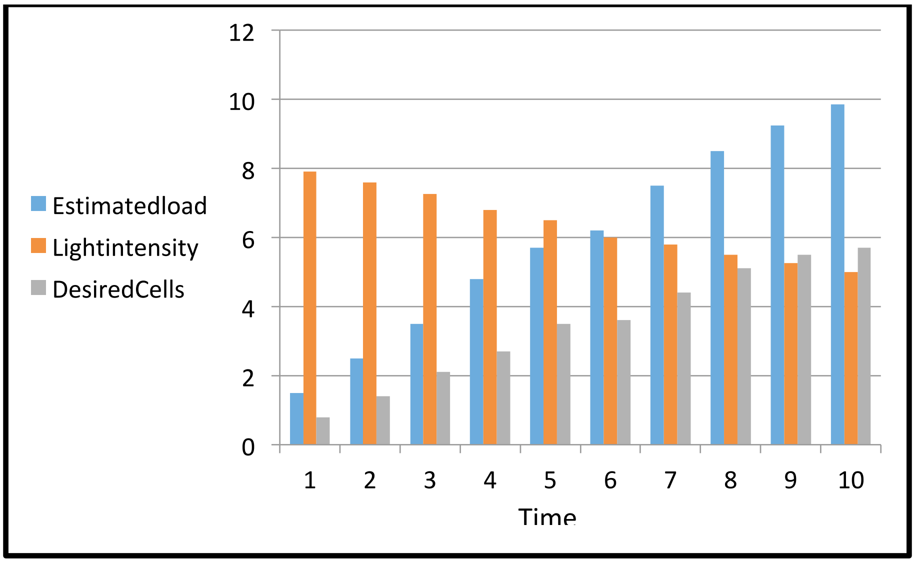

Figure 8: The relation between the estimated load and light intensity with respect to the number of required cells.

The batteries required for the energy storage after the solar cells are begins to receive the sun radiation depend on the load required and the light intensity. (Figure 9) show the relation between the light intensity and battery size in addition to NN output that learned to give the desired batteries required. The number of energy storage device (batteries) depends on the real amounts of load; so, when the load increased the number of batteries must be increased.

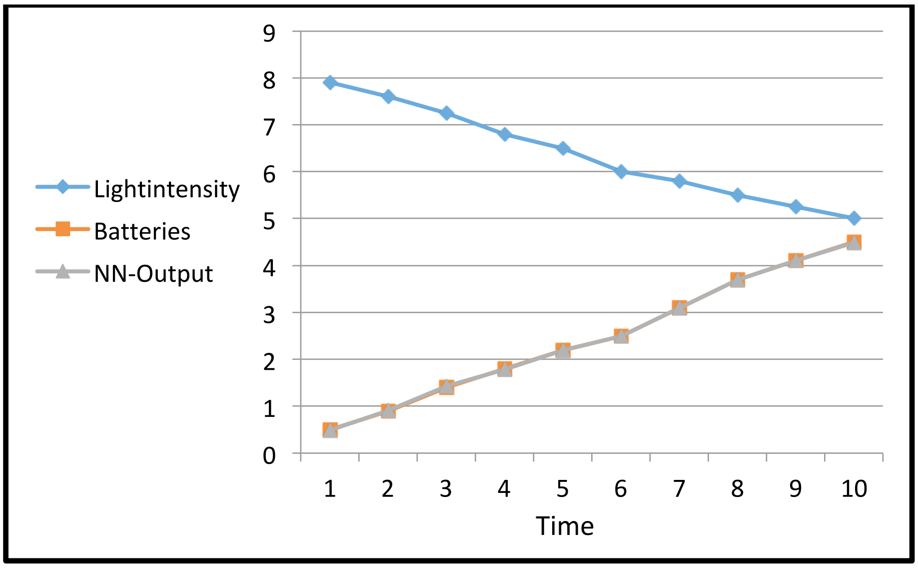

Figure 9: The relation between the light intensity and battery size in addition to NN output.

4. CONCLUSION AND RECOMMENDATIONS

The predetermined parameters for solar system are a novel thing to know the system components and the size of the PV with the corresponding number required. In this work the exact parameters for the solar energy supply are determined for a given building through collecting set of input factors that directly effect on the required system such as (solar radiation, time of available sun light … etc.). The flexible use and simple to change input variables are very useful factors to optimize the solar systems to get on smart sustainable source. The NN train the neurons in all layers (input, hidden and output) by a set of input parameters then the final weights can be used to predict any demand components for the solar cell system. Fast to decide and low error rate are the main benefits of the artificial intelligent systems that produced to manage and control the today projects. As shown in the numerical result the desired output and the real NN output are the same value. This work can developed to include the other sustainable energy sources such as wind turbine or others, to control their outputs and well power saver strategy reached.

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