ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645
Indian Journal of Science and Technology, *Vol 12(30), DOI:10.17485/ijst/2019/v12i30/140861, August 2019*

Control of Power in Photovoltaic cell Using Artificial Neural Networks (NARMA Controller)

Ali Abdyasser Kadhum, and Suham Abdulhussein Albderi

Al-Furat Al–Alawsat Technical University, 31003, Al-Kufa, Iraq; Kin.ali1@atu.edu.iq, Kin.shm@atu.edu.iq

Abstract

Objectives: To derive suitable simulation model to improve the performance of PV cell. **Methods/Statistical analysis:** Artificial Neural Networks (ANN) is one of these techniques that applied to present important tasks encounter in Photovoltaic systems. This work presents a MATLAB-based modeling and simulation scheme suitable for studying the I–V and P–V characteristics of PV cell by Select and collect a data from PV panel for developing a simulink model in Matlab program with different values of the main parameters such as solar radiation, temperature. **Findings:** The results are illustrated the simulation model of PV cell with NARMA controller gave good agreement results which exhibit the advantages of using ANN techniques in Renewable Energy Systems. **Application/Improvements:** Artificial Intelligence technique (AI) plays an important role in various applications due to its capability of solved complex problem of systems.

Keyword: NARMA controller, Neural Networks, I-V and P-V characteristics, PV

1. Introduction

A Power generation from renewable energy sources plays an important role because of growing demand of electric energy[1]. Photovoltaic (PV) is one of renewable energy sources[2], so the photovoltaic cells represent a solar radiation converted by semiconductor device to electricity. This type of energy source reduces emissions of carbon[3].

Artificial Neural Networks Technique (ANN) is to control power that produces from PV cell. Many researchers studied the PV cells; as[4] applied different techniques to tracking maximum powerpoint of (PV). These techniques have taken at least 19 different with much variation on implementation. In[5] studied the effect of temperature, solar insolation, shading, and cell Configuration on performance of (PV) using a MATLAB modeling and studied the I–V and P–V characteristics of a PV under a nonuniform insolation due to partial shading. The results showed that the configuration of cell affects the maximum power under partially shaded conditions.

In[6] illustrates artificial neural networks of photovoltaic (PV) to obtain power. This power obtained by three types of ANNs as : the first using Multilayer perceptron (MLP), a recursive neural network , and a gamma memory trained with the back propagation. ANNs were trained using air temperature, solar irradiance, and wind speed. The results revealed on the suitability of power output forecasting problem and identified the best topology.

2. Photovoltaic (PV) Principles

Photovoltaic (PV) is a system to generate electrical power using semiconductors by converting solar radiation into electricity. Photovoltaic cell is a simple design and must be of low maintenance, and they can work as stand-alone systems to produce outputs from microwatts to megawatts according to the application. The request of photovoltaic is increasing all over the world and has started to become economically competitor with conventional energy sources.

**Author for correspondence*

The photovoltaic cell consists of layers of semiconductor material, first layer is positive charge and the second layer is negative charge. Photons absorbed from sunlight directed on the surface by the semiconductor atoms and cause freedom of electrons from the cells. The liberty of electrons that flow through a circuit and lastly back to the positive layer to complete the circuit. A diagram of generating power in photovoltaic cell is shown in Figure 1 where set of PV cells is close electrically in series / parallel circuits to generate higher voltage, current and power values[7].

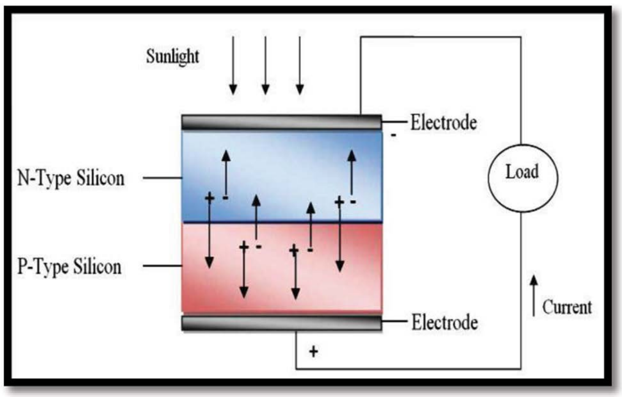

Figure 1. Diagram of photovoltaic cell.

3. Artificial Neural Networks Technique (ANN)

Artificial neural networks Technique (ANN) is a mathematical model try to simulink the construction of the biological brain[8]. A simple model of artificial neural network consists of three simple sets of rules: multiplication, summation and activation. All neuron inputs are multiplied by weight and combined with basis where the network outlet is the sum of the mixture multiplied by weights with the transient through transfer function[9-10].

4. Feedback Linearization Control (NARMA Controller)

The Nonlinear Autoregressive Moving Average (NARMA) is a model that's apply to present input-output performance of nonlinear systems. The NARMA model is represents by the formula[11]:

$$y\,(k+d) = Nf\,[y\,(k), y(k-1), \ldots\, y\,(k-n+1), u\,(k), u(k-1), u(k-n+1)] \quad (1)$$

Where:

u(k), (k) are is an input and output of structure. ANNs are required training to guess the nonlinear purpose. Nf is the system identification. Figure 2 shows a block controller of (NARMA) with estimated nonlinear purpose (f and g), (TDL) is time shifting, implemented in the NARMA. Controller is a multi-layer feed forward network applied successfully in the identification and control of dynamic systems[12].The most important at the rear the NARMA is converting nonlinear structures to linear in dynamic systems.

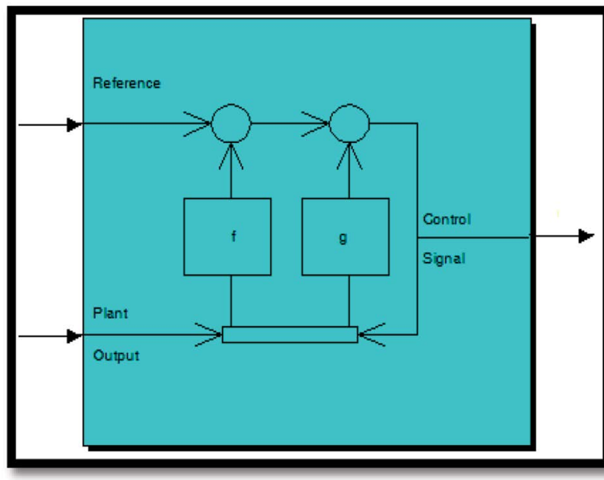

Figure 2. Block controller of NARMA

Design of NARMA in PV Panel has been applied using Matlab program. There are two most important steps in the use of NARMA that contains a control identification system and design.

5. Mathematical Formulation of PV Module

The mathematical equation of PV performance has been simulated in MATLAB Simulink for estimating the current-voltage characteristic.

The equivalent circuit of PV cell contains of current source connected in parallel with a diode and two resistors shunt and series to appear the losses[13] as shown in Figure 3.

The mathematical description of the current-voltage output characteristics for PV cell can be calculate by

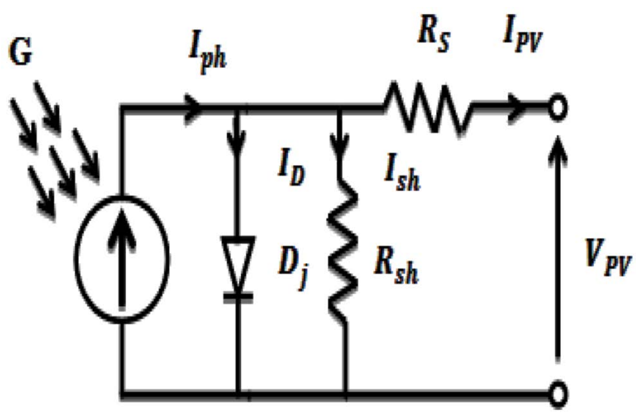

Figure 3. PV equivalent circuit.

applying =Kirchhoff's current law in the circuit above, which yields eq. (2)

$$I_{PV} = I_{ph} - I_D - I_{sh} \quad (2)$$

The internal diode diffusion current is calculated as:

$$I_D = I_S . [\exp\left(\frac{q.(Vpv + Ipv\,Rs)}{N.K.T}\right) -1] \quad (3)$$

The photocurrent calculates from:

$$I_{ph} = \left[I_{sc} + K_i\left(T - T_n\right)\right] \frac{G}{Gref} \quad (4)$$

The open circuit voltage can be given by [14]:

$$V_{OC} = V_{OCS} + K_V (T - T_n) \quad (5)$$

The saturation current of the diode is described as

$$I_S = I_{RS} \left(\frac{T}{Tn}\right)^3 exp\ [\frac{q\,Eg}{N.K}\left(\frac{1}{Tn} - \frac{1}{T}\right)] \quad (6)$$

The reverse saturation current of cell at reference temperature can be calculated as[14-15]:

$$I_{rs} = \frac{Isc}{exp(\frac{qVoc}{N\,K\,T}) - 1} \quad (7)$$

The current of PV and shunt current determine as:

$$I_{PV} = I_{ph} - I_S[exp\ (\frac{q}{N.K.T}\left(V_{PV} + I_{PV}R_S\right) - 1\ - I_{sh} \quad (8)$$

$$I_{sh} = \frac{V + I.Rs}{Rsh} \quad (9)$$

A specification of PV model

6. Simulation Model of Photovoltaic Cell

The Simulation model of PV applied MATLAB Simulink from equations from (2 to 9) shown in Figures 4 to 10.

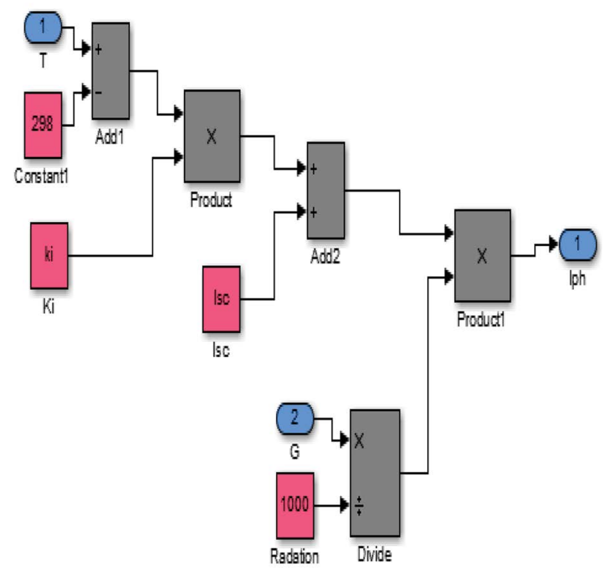

Figure 4. Model of shunt current.

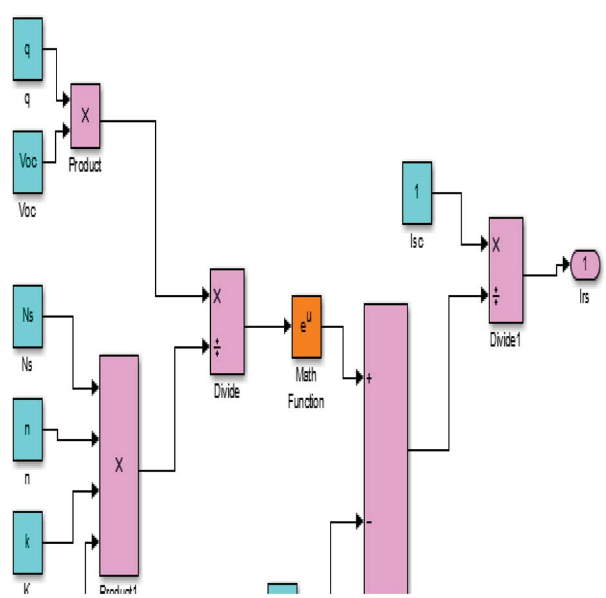

Figure 5. Model of photo current.

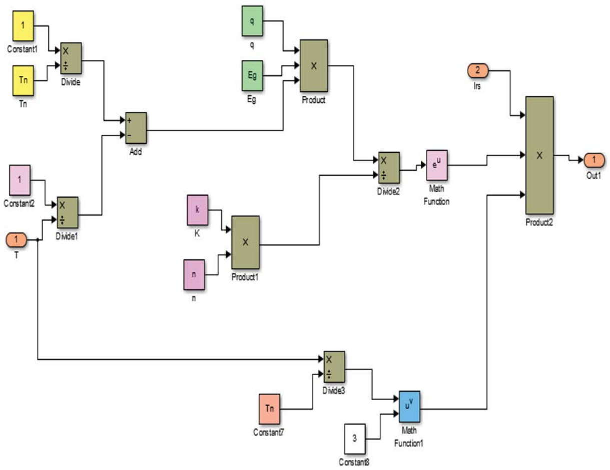

Figure 6. Model of saturation current.

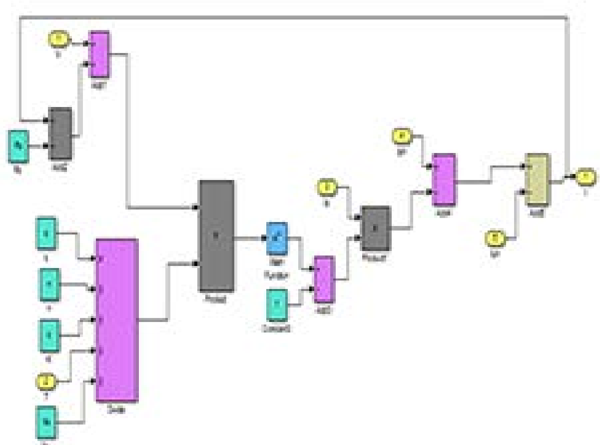

Figure 7. Model of PV current.

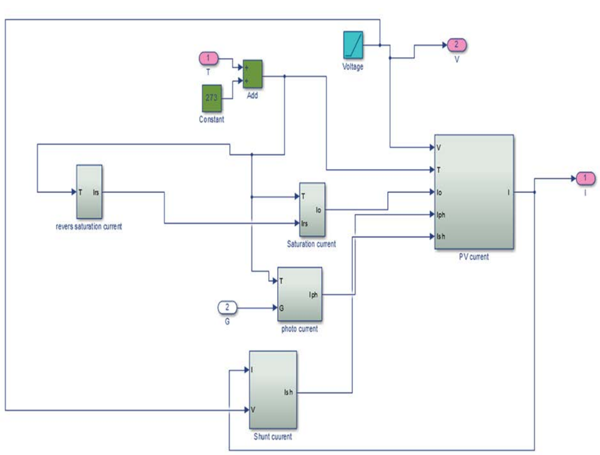

Figure 8. PV model.

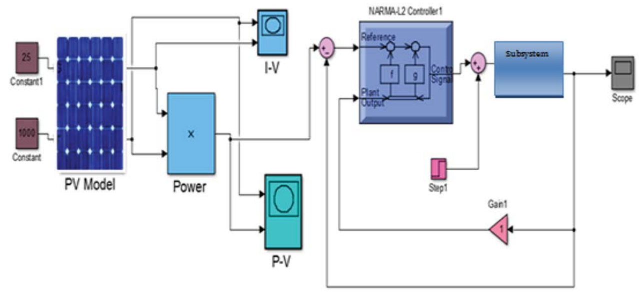

Figure 9. PV model with NARMA controller.

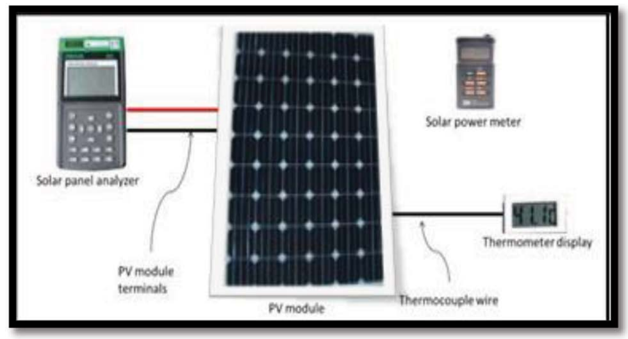

Figure 10. Experimental setup of PV module.

7. Experimental Setup

A mono-crystalline silicon solar PV module is used with electrical specification listed in Figure 11 which illustrated the PV module. Solar power meter is used to measure irradiation in W/m² and thermometer to measure temperature of the PV module.

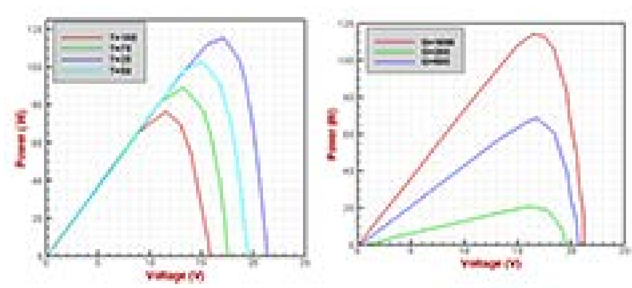

Figure 11. Power with voltages at varying value of irradiance and temperature.

8. Results and Discussion

The plots of I-V and P-V characteristic curves have been varying with solar irradiance value and temperature. Figure 12 describes maximum power point with voltages at varying value of irradiance and temperature. These curves show the increase in irradiance and decrease in temperature values which caused increased power production from cell. Figure 13 shows the relation between voltage and current of cell at varying value of irradiance and temperature.

The results of experimental set up of PV (Figure 14) exhibited maximum power in two month (Feb, June). The power in long a day and months are different, so it needs for control to reach optimum power. The results of NARMA controller reaches power at nominal point at STC (T=25C, G=100W\m^2.

9. Conclusion

The results illustrated that the simulation model of PV cell with NARMA controller gave good agreement results which exhibit the advantages of using ANN techniques in Renewable Energy Systems. NARMA Controller is a best controller of Power and this technique improves the performance of PV at Abnormal condition.

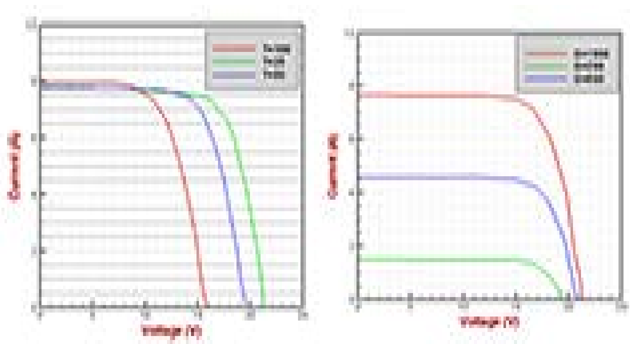

Figure 12. The relation between voltage and current of cell at varying value of irradiance and temperature.

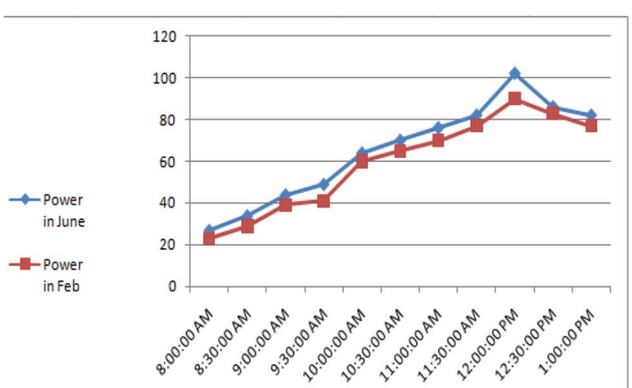

Figure 13. maximum power at deferent time in 27 Feb, 15 June.

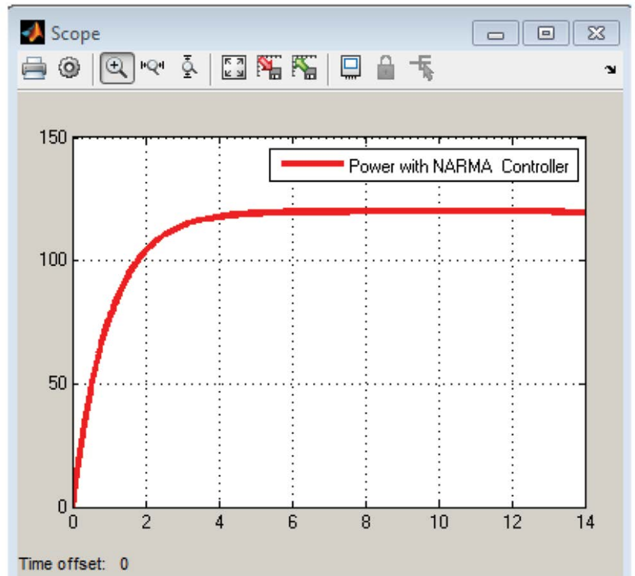

Figure (14). Power with NARMA controller at T=25, G=1000W\m.

10. References

1. Kalogirou S. Solar thermal collectors and applications. Progress in Energy and Combustion. 2004; 30(12): 231–255. https://doi.org/10.1016/j.pecs.2004.02.001.
2. Bevrani H, Ghosh A, Ledwich G. Renewable energy sources and frequency regulation: survey and new perspectives. IET Renewable Power Generation. 2010; 4(5): 438–457. https://doi.org/10.1049/iet-rpg.2009.0049.
3. Steven K. Raising Efficiency in Photovoltaic Systems: High Resolution Monitoring and Performance Analysis, Thesis, De Montfort University. 2006.
4. Esram T, Chapman PL. Comparison of photovoltaic array maximum power point tracking techniques. IEEE Transactions on Energy Conversion. 2007; 22(2): 439–449. https://doi.org/10.1109/TEC.2006.874230.
5. Patel H, Agarwal V. MATLAB-Based Modeling to Study the Effects of Partial Shading on PV Array Characteristics. IEEE Transactions on energy conversion. 2008; 23(1). https://doi.org/10.1109/TEC.2007.914308.
6. Brano VL, Ciulla G, Falco MD. Artificial Neural Networks to Predict the Power Output of a PV Panel. Int. j. photoenergy. 2014. https://doi.org/10.1155/2014/193083.
7. Hamidreza N. Evaluation of Alternative Cooling Techniques for Photovoltaic Panels. Thesis, University of Alabama. 2012; 89.

8. Burns RS. Advance Control Engineering. Butterworth-Heinemann, Published. 2001.
9. Krenker A, Bester J, Kos Consalta A. Introduction to The Artificial Neural Networks. Published by In Tech, Janeza Trdine, Croatia. 2011; 3–18. https://doi.org/10.5772/15751.
10. Churchland PS, Sejnowski TJ. The Computational Brain, Computational Neuroscience Series, 25th Anniversary Edition, MIT Press, Cambridge. 1992
11. Narendra KS, Mukhopadhyay S. Adaptive Control Using Neural Networks and Approximate Mode Ls. IEEE Transactions on Neural Networks. 1997; 8(3): 475–485. https://doi.org/10.1109/72.572089.
12. Beale MH, Hagan MT, Demuth HB. Neural Network Toolbox User's Guide, R2011b Ed., Natick, Ma: Mathworks. 2011; 404.
13. Rekioua D, Matagne E. Optimization of Photovoltaic Power Systems Medialization, Simulation and Control. Springer-Verlag London Limited. 2012. https://doi.org/10.1007/978-1-4471-2403-0_7.
14. Xiao W, Dunford WG, Capel A. A Novel Modeling Method for Photovoltaic Cells. Annual IEEE Power Electronics Specialists Conference. 2004; 1950–1956.
15. Jayashri V. Mathematical Modeling and Experimental Validation of Performance Characteristics of Solar Photovoltaic Modules. IJAIEM. 2013; 2: 295-301.