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Development of Neural Network Approach towards MPPT Optimization

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Abstract

This main aim of this paper is to provide a detailed survey of three maximum power tracking techniques: Perturb and Observe (P&O), Incremental Conductance (InC) and A.I. powered solution which uses an ANN (Artificial Neural Network) to predict current and voltage values. The main drawback of P&O and InC method is oscillation of point of operation in steady state, leading to reduced efficiency. The benefit of using an ANN powered system is that it can provide a stable point of operation and reach it faster as compared to traditional techniques. All the simulation results are performed in MATLAB/Simulink

Keywords: *earthquake detection, shaking, vibrations, timely warning*

1. Introduction

The rapid increase in global energy demand is leading to crisis, which is leading to environmental damage due to rampant use of traditional sources of energy like crude oil, coal and natural gas. The combustion of these fossil fuels is leading to an increased emission of greenhouse gases, which are largely responsible for global warming and climate change.

The question of sustainability is paramount given the adverse effects of climate change, which are leading to even extreme weathers, and extinctions of natural habitats all around the globe. In order, to tackle the present situation, our reliance on renewable sources has to increase in order to reduce the use of fossil fuels. In order to achieve this, the efficiency of renewable systems has to increase to reduce their operating cost.

Our paper aims at providing a viable solution to this problem by improving the overall efficiency of a PV array. The technique under study is called Maximum Power Point Tracking or MPPT.MPPT technique is used for obtaining the maximum possible power from the solar PV module. Main reason behind using MPPT is varying solar radiation and temperature conditions, which effect the nonlinear voltage current relationship of the PV array.

Our paper compares the traditional methods and proposes a better neural network based strategy to achieve faster and more stable system performance. We have taken up three different techniques to contrast between these methods to develop techniques that are even more efficient. The first two techniques are classical core approaches to solve this problem. They have been tried and tested for decades now. Perturb and Observe Method and Incremental Conductance Method are circuital approaches and have limitations that we have discussed. The third intelligent approach is to use Artificial Neural Network to achieve higher efficiencies. The sections ahead discuss these methods in detail.

2. Power electronics Involved

Power electronics is the field of electrical engineering that aims at developing efficient wide-bandgap-based power electronic systems such as the newly developed inverter and DC-DC converters.

The key function of these circuits is usage of semiconductor devices like switches to control or modify a voltage or current.

There are widespread applications of power electronics, from high-power conversion tools to everyday home appliances. The range of operation is vast as circuits can operate at mill watts or megawatts.

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The thing that makes it a complicated field is the application of many disciplines from electrical engineering. It encompasses fields like circuit theory, control theory, electronics, thermal design and microprocessors. Due to ever decreasing semiconductor size and increasing requirement to make efficient electrical components, power electronics is at the frontier of research in electrical engineering.

In our research effort, we have tried to use a boost converter, which is responsible for switching operation in our experimental setup. The sole reason to use it is to simplify the MPPT explanation and algorithm simulation.

A boost converter is a simple power circuit, which steps up the voltage, which means it produces an output voltage that is greater than or equal to the input voltage.

3. PV System Configuration

When the sunlight falls on the array, it is converted into electrical energy from solar energy. The electric energy is then fed into the DC/DC converter, which adjusts it to a value corresponding to the maximum deliverable power. The MPPT unit is the control element and necessary to obtain the desired conditions under any variation of irradiation and temperature.

The model scheme we have used is shown in Fig 1.

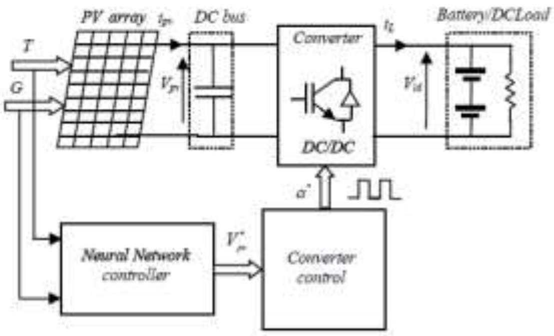

Fig. 1 Model scheme of the PV system

It comprises of a solar cell array or PV array, a DC bus capacitor to hold the voltage while switching, a DC/DC converter, which in our case is a boost converter, a load unit and a MPPT unit.

4. Perturb and Observe Method

One of the most common algorithms to track the Maximum Power Point (MPP) is the Perturb and Observe (P&O) algorithm. The underlying concept of this method is to give a perturbation to the PV array, which causes the power of the module to change continuously. This algorithm uses a single voltage sensor to reach the maximum power point of the said PV array. The MPP is reached when the following condition is fulfilled:

$$\frac{dP}{dV} = 0 \tag{1}$$

Fig. 2 shows the implementation of the Perturb and Observe algorithm using a buck convertor.

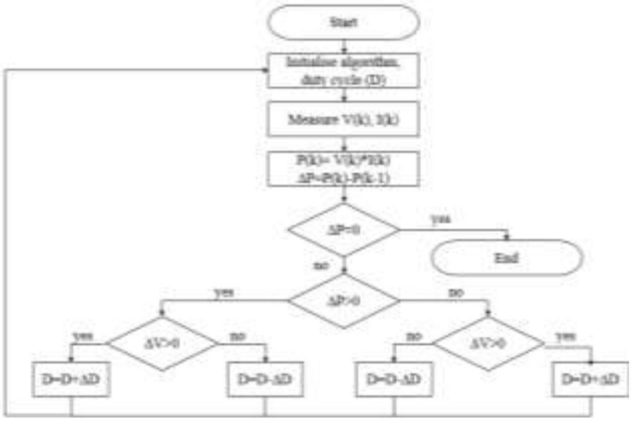

Fig. 2 Perturb and Observe Flowchart

The initial power of the PV module is calculated and is considered as the reference point. A perturbation is given near the operating point by increasing or decreasing the voltage by a small step size. If the power increases, i.e., $\frac{dP}{dV} > 0$ the algorithm continues to perturb the module in the same direction, i.e., it increases the voltage by the small step size. Thus, the perturbation moves the operating point of the module towards the MPP. If the new power after perturbation is lesser than the power calculated at the preceding step, i.e., $\frac{dP}{dV} < 0$ the voltage is inspected and increased and decreased.

The algorithm then reverses the direction of perturbation taking the module towards the MPP. The system oscillates around the operating point until the maximum power point is attained.

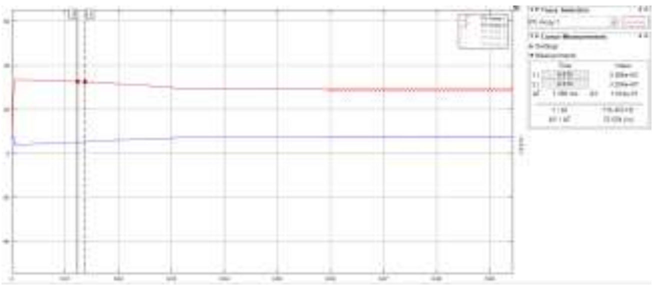

Fig. 3 PV Band Measurements

Initially, the reference power is calculated using the reference current and reference voltage.

$$P = V * I \qquad (2)$$

After giving the perturbation to the reference voltage, the new power is calculated and the difference between the powers (dP) is calculated. Thus, four possibilities arise:

$$dP > 0 \; and \; dV > 0 \qquad (3)$$

$$dP > 0 \; and \; dV < 0 \qquad (4)$$

$$dP < 0 \; and \; dV > 0 \qquad (5)$$

$$dP < 0 \; and \; dV < 0 \qquad (6)$$

In (3) and in (6), the duty cycle is decreased by small increments which translates to increase in voltage perturbation in the same direction for the next iteration.

In (4)and (5), the direction of voltage perturbations reverses. The voltage and power are updated and the algorithm continues to run until $dP = 0$. Thus, the MPP is reached. The algorithm can also be said to reach the MPP by increasing or decreasing the voltage sensor by a step size.

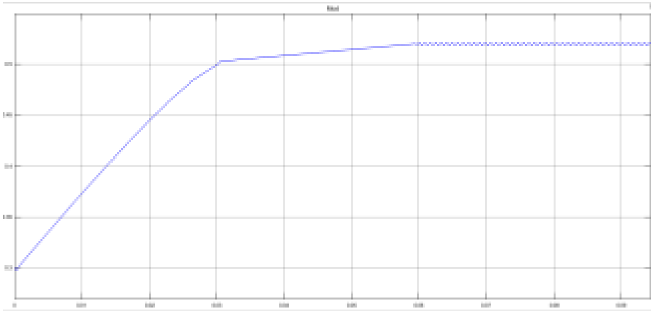

Fig. 4 Decision Variable Variation

The P&O method has been observed to exhibit power loss and is unable to consider any quickly changing atmospheric conditions such as irradiance. In addition to these shortcomings, the algorithm is a time-consuming process. The Incremental Conductance (IC) algorithm is used to overcome the disadvantages of the P&O algorithm.

5. Incremental Conductance Method

The algorithm was developed in 1993 to overcome the limitations of Perturb and Observe algorithm. It is able to keep a track of the maximum power point with higher accuracy under varying environmental conditions which is not possible in the case of Perturb and Observe Algorithm. It can also determine the peak power point more accurately instead of oscillating around it and stop perturbing at that point, or, it can calculate the direction where the maximum power point is to be perturbed by comparing the incremental conductance and instantaneous conductance.The flowchart for the whole method can be expressed as follows in Fig (5).

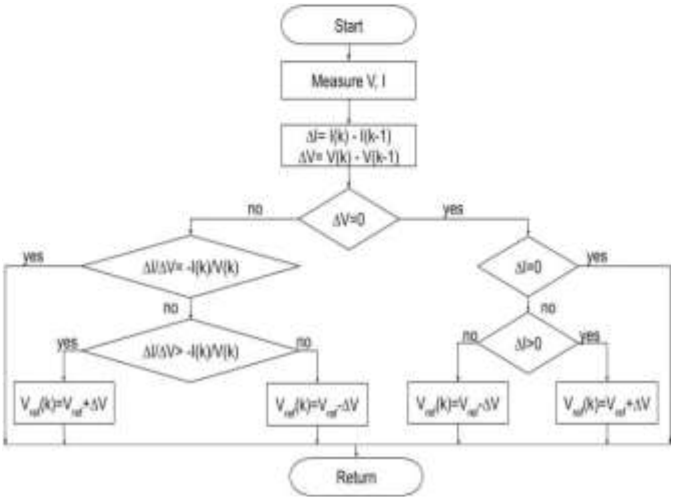

Fig. 5 Incremental Conductance Flowchart

In this method, the voltage of solar array is adjusted according to the MPP voltage, to draw maximum power from the solar panels. The incremental change in array voltage and current is used to calculate the effective change in voltage.

The MPP voltage is computed by comparing the incremental conductance to the instantaneous array conductance. When both of them are equal, the maximum power point (MPP) is reached and the output voltage becomes equal to the MPP voltage. At this point, the slope of PV curve of the solar array is equal to 0.

The basic equations of the algorithm can be written as follows:

$$dI/dV = -I/V \text{(At MPP)} \quad (7)$$

$$dI/dV > -I/V \quad \text{(Left of MPP)} \quad (8)$$

$$dI/dV < -I/V \quad \text{(Right of MPP)} \quad (9)$$

The left-hand side of equations refer to the incremental conductance of the P-V module and the right-hand side refers to the instantaneous conductance. When the ratio of change in output conductance is equal to the negative output conductance, the solar array will operate at the maximum power point.

Thus, the slope of PV curve is 0 at the Maximum Power Point (MPP). It becomes positive and increases on the left-hand side of the point, and becomes negative and decrease on the right-hand side.

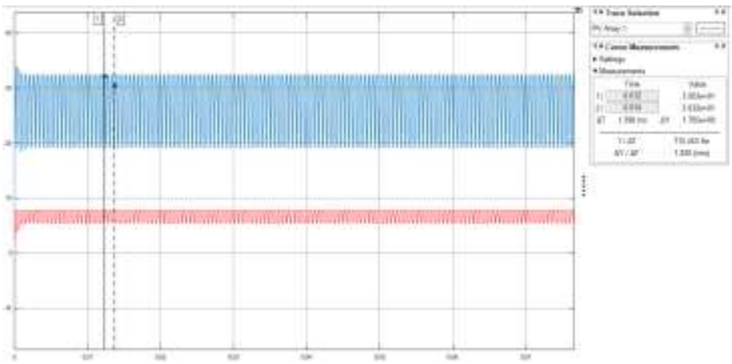

Fig. 6 PV Band Measurements

To derive the equations, an assumption has been made that the change in array conductance is equal to the negative of the array conductance.

On applying the rules of derivation to **(2)** and differentiating both side with respect to voltage V,

$$\frac{dP}{dV} = \frac{d(V*I)}{dV} \quad \textbf{(10)}$$

Substituting **(1)** we have:

$$0 = I + V * \frac{dI}{dV} \quad \textbf{(11)}$$

Thus:

$$\frac{dI}{dV} = -\frac{I}{V} \quad \textbf{(12)}$$

Therefore, in order to get the maximum power point, the above stated condition **(12)** must be satisfied.

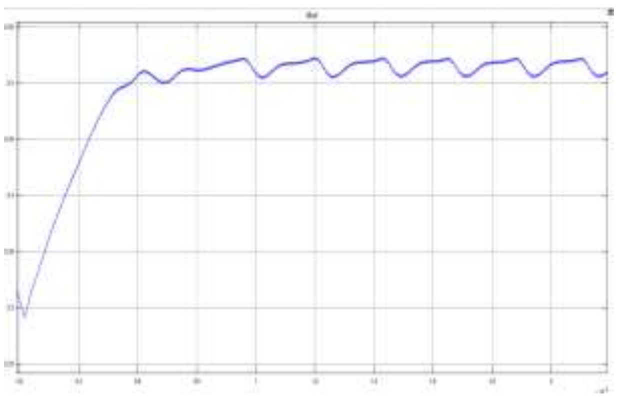

Fig. 7 Decision Variable Variation

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However, the incremental conductance algorithm cannot be used to measure the maximum power point if the irradiance conditions are altered rapidly and suddenly. Additionally, the time required to determine the MPP depends on the size of the reference voltage (V_{ref}) calculated, as larger the V_{ref}, faster is the MPP obtained. The oscillations around MPP also depend on the size of V_{ref} since a smaller size leads to lesser noise. Thus, a trade-off among the two parameters leads to errors in computations as well.

6. Artificial Neural Networks Based Approach

Counterfeit Neural Networks (ANN) are multi-layer completely associated neural nets that are spoken to beneath. They comprise of an info layer, different concealed layers, and a yield layer. Each hub in one layer is associated with each other hub in the following layer.

Fig. 8 The training of the ANN

When we zoom in, we get one of the hidden layers as seen in Fig. 9.

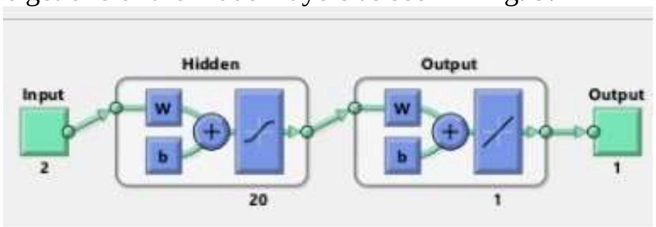

Fig. 9 Neural network used in the simulation

A given hub takes the weighted whole of its sources of info, and goes it through a non-straight enactment work. This is the yield of the hub, which at that point turns into the contribution of another hub in the following layer. This info information streams from left to right, and the last yield is determined by playing out this technique for all the edges.

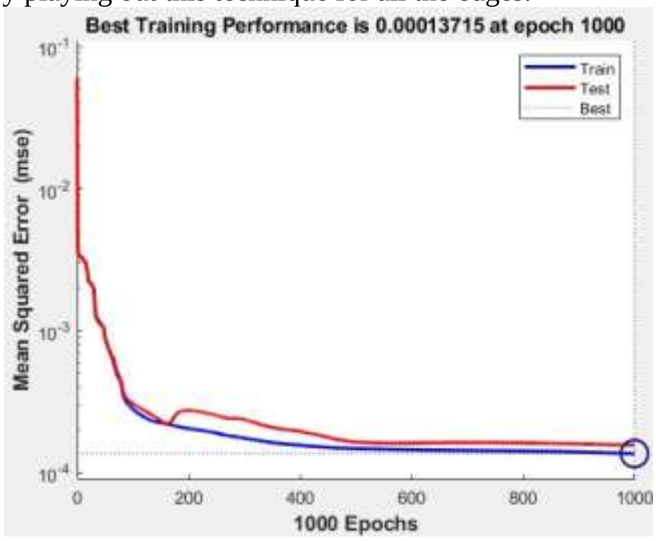

Fig 10 Mean squared error (MSE) for the training and test sets

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RESULTS

The plan of the neural system controller for an electronic burden, driven by the sunlight based vitality framework has been featured right now. The pinnacle power from the sunlight based board is extricated utilizing Incremental Conductance (IC) strategy. This strategy is favored over the Perturb and Observe (P&O) technique on account of the speed of arriving at the MPPT just as the productivity of the calculation. Sun powered board yield voltage and current are controlled by a solitary finished essential inductor (SEPIC) converter which takes care of the single-stage inverter and that thusly drives the heap. The beats from the individual controller and Incremental Conductance calculation based MPPT Controller are joined to be given to the SEPIC converter to build the voltage got from the sun oriented board. The heap yield is given as criticism to the controller. To beat the said weaknesses of the IC strategy, which are moderate following velocity and yield motions, a neural system based controller was attempted. The reproduction for the neural system controller has been done utilizing the Bayesian Regularization strategy and the mentor work for preparing. The mean square mistake and relapse plots are utilized to comprehend the proficiency and speed of the controller. Recreation results got shows that the neural system controller performs better for the electronic burden through MPPT improvement.

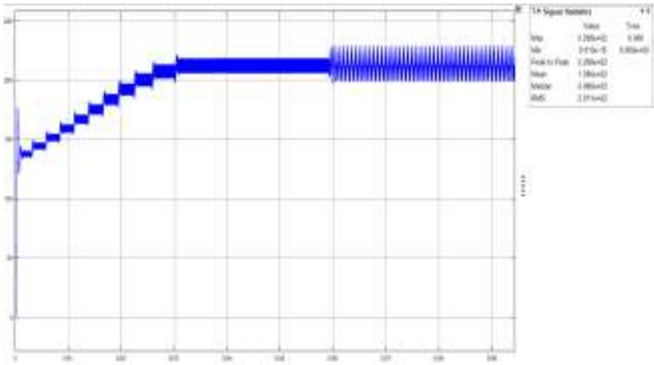

Fig.11 Perturb and Observe Output Power

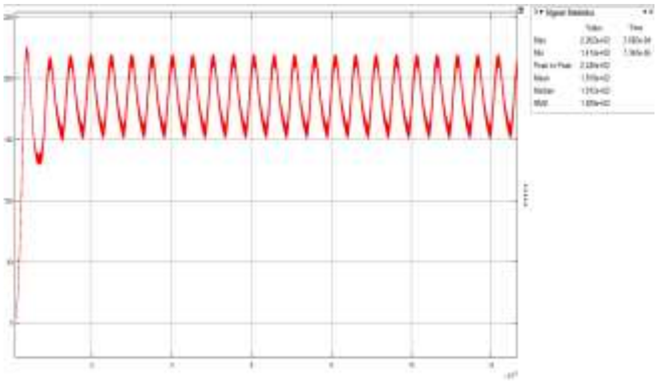

Fig. 12 Incremental Conductance Output Power

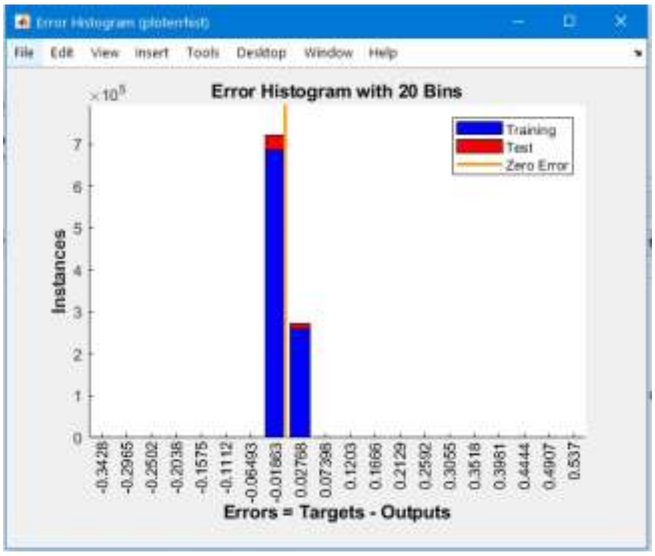

Fig.13 ANN Error Histogram

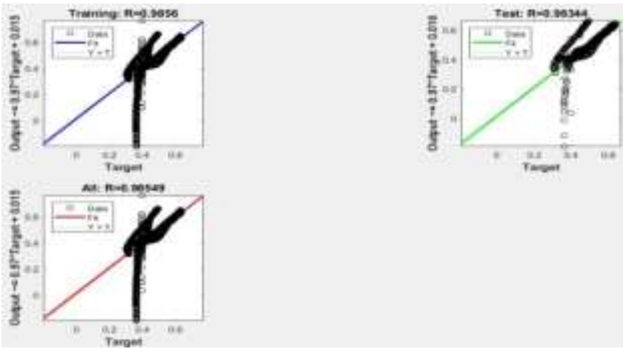

Fig. 14 Regression plots for the training set, test set and the entire set

References

[1] S. A. Mohamed, M.A. El Sattar, "A comparative study of P&O and INC maximum power point tracking techniques for grid-connected PV systems." SN Appl. Sci. 1, 174 (2019). *https://doi.org/10.1007/s42452-018-0134-4J*.

[2] C. Algarín, J. Giraldo, O. Álvarez, "Fuzzy Logic Based MPPT Controller for a PV System." *Energies* 2017, *10*, 2036.

[3] K. Jain, M. Gupta and A. Kumar Bohre, "Implementation and Comparative Analysis of P&O and INC MPPT Method for PV System," *2018 8th IEEE India International Conference on Power Electronics (IICPE)*, JAIPUR, India, 2018, pp. 1-6.

[4] M.Lokanadham , K.Vijaya Bhaskar, " Incremental Conductance Based Maximum Power Point Tracking (MPPT) for Photovoltaic System" International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622

[5] M. Dev Anand, N. Ramasamy, "PV System Simulation using Various Incremental Algorithms Applied in Maximum Power Point Tracking: A Comparative Study" International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878,Volume-8 Issue- 1C2, May 2019

[6] Motahhir, Saad & Abdelaziz, el ghzizal & Sebti, Souad & Derouich, Aziz. (2018). Modeling of Photovoltaic System with Modified Incremental Conductance Algorithm for Fast Changes of Irradiance. International Journal of Photoenergy (2018) 1-13. 10.1155/2018/3286479.

[7] G. Rao, S.K. Shrivastava & M.G. Baig, "Modeling and Simulation of Incremental Conductance Maximum Power Point Tracking (MPPT) Algorithm for Solar PV Array Using Boost Converter." (2016)

[8] S. Thangavel, "Neural Network Based MPPT Controller for Solar PV Connected Induction Motor." (2018) IAES International Journal of Robotics and Automation (IJRA). 7. 129. 10.11591/ijra.v7i2.pp129-139.

[9] N. Rao, &N. Eswar, "Performance Study of Incremental Conductance and Modified Incremental Conductance MPPT Algorithms for Photovoltaic Applications."(2016)

[10] D. Choudhary & A. Saxena, "Incremental Conductance MPPT Algorithm for PV System Implemented Using DC-DC Buck and Boost Converter", Int. Journal of Engineering Research and Applications ISSN : 2248-9622, Vol. 4, Issue 8(Version 6), August 2014, pp.123-132

[11] S.R. Chafle, U.B. Vaidya, "Incremental Couctance MPPT Technique FOR PV System", IJAREEIE, Vol.2, Issue6, June2013