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Maximum Power Point Tracking Algorithms for Photovoltaic System

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Abstract: *This paper helps us analyse three different MPPT techniques like Perturb and Observe, Incremental Conductance and Artificial Neural Network. As the output characteristic depends on temperature and irradiance, therefore the maximum power point tracking (MPPT) is not always constant. Hence it is necessary to ensure that the PV panel is operating at its maximum power point. There are many different MPPT techniques but, the confusion lies in selecting which MPPT technique is best as every algorithm has its own merit and demerit. In order to extract maximum power from PV arrangement, Artificial Neural Network algorithm is proposed. Algorithms are implemented using the Boost converter. Results of simulations are presented in order to demonstrate the effectiveness of Artificial Neural Network algorithm, when compared to Perturb and Observe (P&O) and Incremental Conductance (INC). To simulate the proposed system MATLAB/ SIMULINK power system tool box is used.*

Keywords: Maximum power point tracking (MPPT), Artificial Neural Network algorithm, Photovoltaic System, Perturb and Observe, Incremental Conductance

I. Introduction

The rapid increase in the demand for electricity and the recent change in the environment condition such as global warming led to a need for a new source of energy that is cheaper and sustainable with less carbon emission. Solar energy has offered promising in the quest of finding the solution to the problem. Nevertheless, PV systems have problems, such as the conversion with low radiation (in general less than 17%) as well as the nonlinear characteristics that depends on irradiation and temperature in its operation which change the amount of electric generated.

The maximum power is generated by the solar module at a point of the I -V characteristics where the product of voltage and current is maximum. This point is known as the MPPT. The role of the MPPT is to ensure the operation PV module as its MPP, extracting the maximum available power. If there a good irradiation condition, the photovoltaic system can generate maximum power efficiently while an effective MPPT algorithm is used with the system. A lot of MPPT algorithm have be developed by Researchers all over the world such as Differential method, Perturb and Observe ,Incremental conductance, Curve fitting, Open-Circuit Voltage PV generator, Short Circuit PV generator method is shown in Fig:1

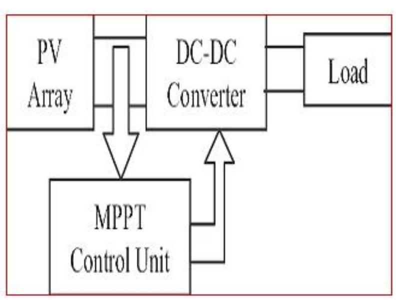

Figure 1: Block diagram of Typical MPPT system.

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In the section, the most commonly used MPPT method, i.e. P&O, INC, NEURAL NETWORK are implemented on a simulated solar panel with specific parameters, and the results are obtained using Boost as DC -DC converters. Then, the simulation results are presented graphically for each MPPT algorithms and the analytical comparisons will be done.

II. PV ARRAY

A solar panel cell basically is a p-n semiconductor junction when it exposes to the light, a DC current is generated. The generated current varies linearly with the solar irradiance. The equivalent electrical circuit of an ideal solar cell can be treated as a current source parallel with a diode shown in Fig: 2.

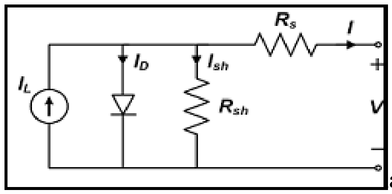

Figure ar cell

The I-V characteristics of the equivalent solar cell circuit can be determined by following equations.

The current through diode is given by:

$$ID = I\,[\exp(q(V + I\,RS)/KT)) - 1]$$

While, the solar cell output current:

$$I = IL - ID - Ish \quad (2)$$

$$I = IL - I\,[\exp(q(V + I\,RS)/KT)) - 1] - (V + IRS)/Rsh$$

Where I : Solar cell current (A)

I: Light generated current (A) [Short circuit value assuming no series/ shunt resistance]

ID: Diode saturation current (A)

q : Electron charge (1.6×10-19 C)

K : Boltzman constant (1.38×10-23 J/K)

T : Cell temperature in Kelvin (K)

V : solar cell output voltage (V)

Rs: Solar cell series resistance (Ω)

Rsh: Solar cell shunt resistance (Ω).

III. MPPT CONTROL ALGORITHM

3.1 Perturb and Observe (P&O)

In this algorithm a slight perturbation is introduce system. This perturbation causes the power of the solar module changes. If the power increases due to the perturbation then the perturbation is continued in that direction. After the peak power is reached the power at the next instant decreases and hence after that the perturbation reverses. When the steady state is reached the algorithm oscillates around the peak point. In order to keep the power variation small the perturbation size is kept very small. A PI controller then acts moving the operating point of the module to that particular voltage level. It is observed that there some power loss due to this perturbation also the fails to track the power under fast varying atmospheric conditions. But still this algorithm is very popular and simple is shown in Fig: 3(a) & 3(b)

3.2. Incremental Conductance (IC)

The disadvantage of the perturb and observe method to track the peak power under fast varying atmospheric condition is overcome by IC method. The IC can determine that the MPPT has reached the MPP and stop perturbing the operating point. If this condition is not met, the direction in wh ich the MPPT operating point must be perturbed can be calculated using the relationship between dl/dV and –I/V This relationship is derived from the fact that dP/dV is

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negative when the MPPT is to the right of the MPP and positive when it is to the left of the MPP. This algorithm has advantages over P&O in that it can determine when the MPPT has reached the MPP, where P&O oscillates around the MPP. Also, incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than perturb and observe. One disadvantage of this algorithm is the increased complexity when compared to P&O.

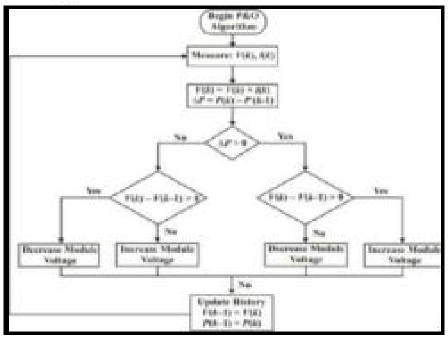

Figure 3(a) Perturb and Observe algorithm

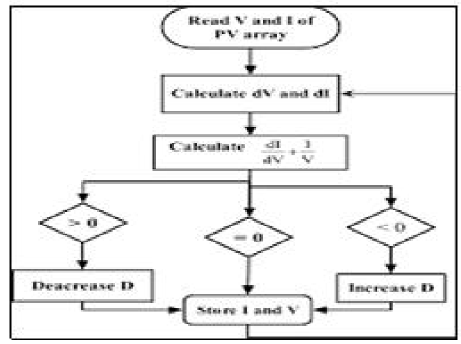

Figure 3(b) Incremental Conductance(INC) algorithm

3.3 Neural Network

In this paper for tracking maximum power point, an artificial neural network is used. A three -layer neural network is used to reach MPP, which is shown in Figure 4.

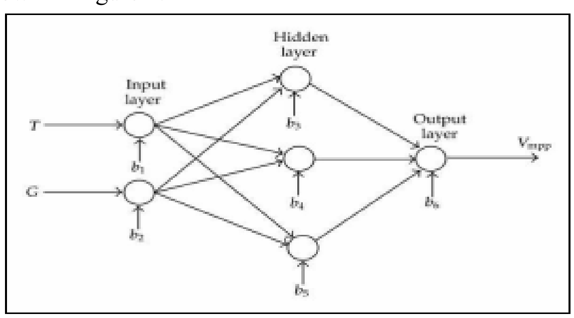

Figure 4: Artificial Neural Network layer for MPPT

Temperature (T) and irradiance (G) are two input variables and voltage of MPP (Vmpp) is the output variable of ANN. It is necessary to obtain some data as input and output variable to train the neural network. Consequently, weights of neurons in different layers are acquired. PV model programming in MATLAB is used in order to obtain data. There are several methods to train ANN. In this paper error back propagation method is used to train the ANN. After training the ANN and specification of neuron weights, for any T and G as inputs of ANN, output of ANN is the Vmpp. Now, current of maximum power point (Impp) can be obtained by using V-I characteristic of the model PV. Consequently, maximum power (Pmax) is reached by multiplying Vmpp and Impp.

3.4 ANFIS Algorithm

An adaptive Neuro-Fuzzy inference integrates fuzzy logic and neural networks principles. Its inference system relates to a set of fuzzy IF_THEN rules to approximate non-linear functions. Hence, ANFIS is considered to be a universal estimator. Associate adaptation Neuro-fuzzy logical thinking system or ANFIS may be a quiet ANN that's supported Takagi-Sugeno fuzzy logical thinking system. Hence it integrates each neural networks and logic principles, it's possible to detention the advantages of each in an exceedingly single framework.

However, accurate training data are a big challenge for designing an efficient ANFIS-MPPT. In this work, an ANFIS- MPPT method based on large simulation training data is designed to avoid the system from experiencing a high training error. To evaluate the performance, the proposed ANFIS -MPPT method is simulated using a MATLAB model for a photovoltaic system. The results reveal that the proposed method accurately tracks the optimized maximum power point.

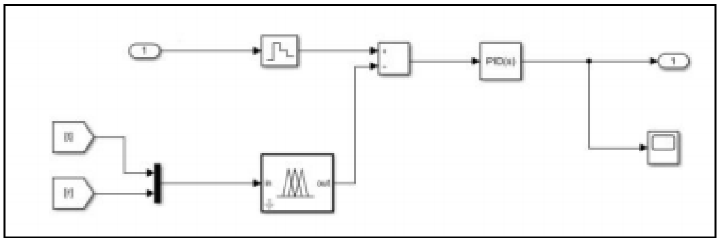

Figure 5: Subsystem Implementation of MPPT control for Fuzzy logic

In the last stage, ANN algorithm is tested in constant atmospheric condition (T =25 deg C, G = 1000W/m2), as other methods.

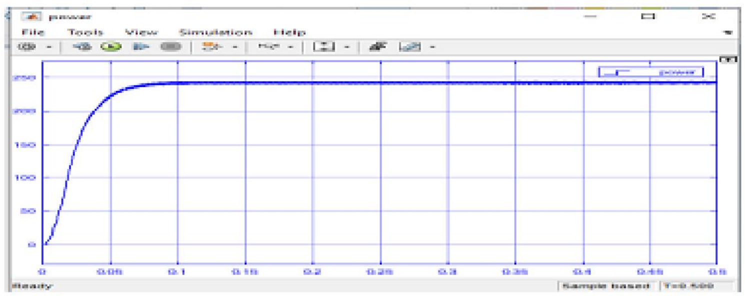

Figure 6: Power of PV panel using ANFIS MPPT controller applied to the boost converter under fixed weather conditions (R=1000W/m2, T=25deg C)

Output power with and without MPPT is compared to show the difference as shown in table 4. The ratio of voltage and current at maximum power point is 7.25 ohm. A greater output power is achieved when MPPT system is connected to the load compared to the load without MPPT system.

Load Resistance (R) ohm	Output power Without MPPT (W)	Output power with MPPT ANFIS (W)
4.1	110.7	243.9
6.3	167	245
7.3	193	245.2
11.6	239	244.8

IV. Simulation Results

In order to obtain a good characterization of the proposed topology, simulations were performed using MATLAB software. The system was simulated under different operating conditions, in steady state and during transient state caused by solar radiation variations. The P&O and Inc on techniques are the most widely used because of Inc and P&O simplicity to implement.

Load Resistance (R) ohm	Output power Without MPPT (W)	Output power with MPPTP&O(W)	Output power With MPPT Inc (W)	Output power with MPPT ANN(W)
4.1	110.7	243	242	243.6
6.3	167	244	244.4	244.5
7.3	193	244.6	244.6	244.8

Table 1: Comparison of output power with and without MPPT

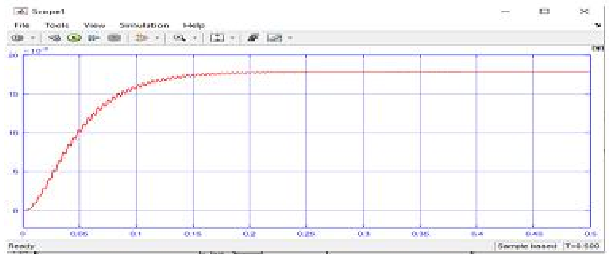

Figure 7 (a): Power of PV panel using P&O MPPT controller applied to the boost converter under fixed weather conditions (R=1000W/m2,T=25deg C).

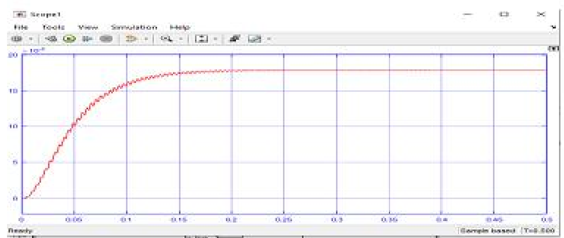

Figure 7 (b): Power of PV panel using Inc MPPT controller applied to the boost converter under fixed weather conditions (R=1000W/m2,T=25deg C).

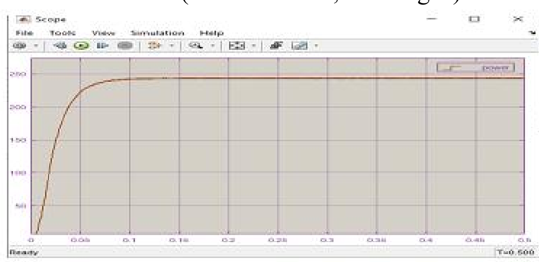

Figure 7 (c): Power of PV panel using ANN MPPT controller applied to the boost converter under fixed weather conditions (R=1000W/m2,T=25deg C)

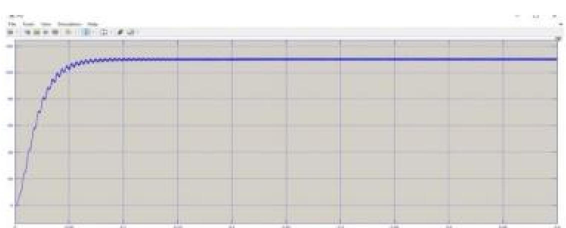

Figure 7 (d): Power of PV panel without MPPT controller applied to the boost converter under fixed weather conditions (R=1000W/m2,T=25deg C).

Output power with and without MPPT is compared to show the difference as shown in table 1. Different power to load is due to different illumination. The output power from the PV module is strongly dependant on irradiation. The ratio of voltage and current at maximum power point is 7.25 ohm. A greater output power is achieved when MPPT system is connected to the load compared to the load without MPPT system. So for higher loads low cost MPPT system could be a better choice to get maximum available power from the solar module.

V. Conclusion

The purpose of MPPT is to extract the high level power from PV systems. This paper presents a comparison of MPPT methods, which is the most effective. From this, it is clear that each MPPT method has its own advantages and disadvantages. In addition, the MPPT should be capable of minimizing the ripple around the MPP. Different MPPT methods are compared based on simulations in the MATLAB environment in terms of the dynamic response of the PV system. Therefore, the two techniques incremental conductance (Inc) and P&O algorithms are simple to implement but they have some inconvenience in the DC-link and the output inverter current. Finally, this work has focused on explaining some of the MPPT algorithms most widely used because it is one of the most interesting ways to increase the efficiency of PV systems.

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