

IMPROVED ARTIFICIAL NEURAL NETWORK DESIGN FOR MPPT GRID-CONNECTED PHOTOVOLTAIC SYSTEMS

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Abstract. Photovoltaic (PVS) generators' nonlinear electrical characteristics allow for greater performance and efficiency when they are forced to operate at their peak power (MPP). This article suggests an adaptive method for maximizing power point tracking that makes use of artificial neural network (ANN) techniques (MPPT). A step-up converter powered by a separate solar generator is under the control of an ANN controller built on a neural network training database (PVS). The results show that ANN-MPPT has good control performance and is near to the maximum power point of PVS when compared to conventional MPPT methods like perturb and observe and incremental conductance.

Keywords: Photovoltaic system, Boost converter, P&O and INC control, ANN Controller.

1. INTRODUCTION

The positive benefits on the environment and financial returns of solar photovoltaic (PVS) systems make them more successful than other renewable energy sources [8].

Solar electricity production is the most abundant [8], least polluting, cleanest, and energy efficient renewable energy source [8].

The biggest benefit of using a solar power system is that it makes no noise and is not compatible with any moving walkway. A photovoltaic (PVS) solar cell array transforms sunlight into electrical energy [8]. However, it would be desirable if you could continuously check its maximum performance for any changes in ambient components like temperature and sun emission [2], [27]. Solar PVS systems are less efficient than other renewable energy sources [32]. For this reason, the idea of maximum power monitoring of solar PV arrangement was formed. Therefore, online MPP tracking is crucial [3]. Solar emission conditions and temperature greatly affect solar energy. The maximum power that a solar PV system may produce varies for small variations in solar emissivity and temperature values. Altitude climb system, INC system, and FOCV system are some of the most widely used MPPT algorithms. Fuzzy logic, ANN, etc. Grounded. This paper aims to set up a network-based MPPT algorithm and evaluate it against other conventional MPPT tracking techniques.

2. SYSTEM DESCRIPTION

A photovoltaic module [35], a DC-DC BOOST converter [28-35], an MPPT controller [35], and a load make up a PV system [35-37]. The PVS system is depicted in diagram form in Figure 1.

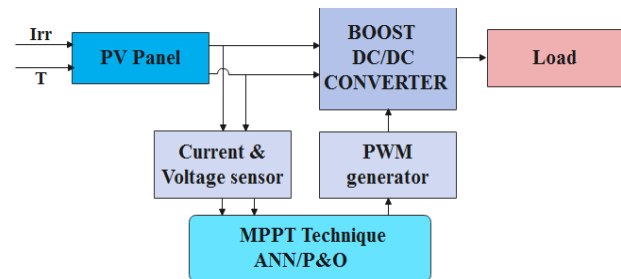


Figure 1. Photovoltaic system diagram

2.1 Photovoltaic cell

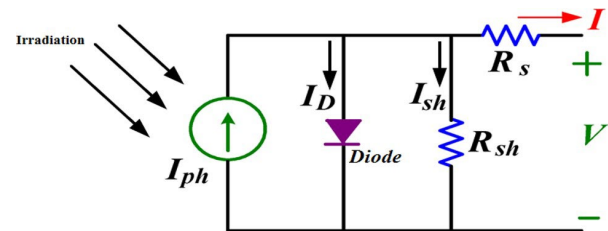


Figure 2. PV cell equivalent circuit

Kirchhoff's first law is applied to Figure 2 to produce the equation (1) [11-12-36]:

$$I_{ph} = I_d + I_{sh} + I_{pv} \quad (1)$$

The photovoltaic current I_{ph} function of the irradiance (G) and is formulated as [13-36]:

$$I_{ph} = I_{sc} * \frac{G}{1000} * \left[1 + a * (T - T_{ref}) \right] \quad (2)$$

The current through the resistor R_{sh} is given as:

$$I_{sh} = \frac{V + IR_s}{R_{sh}} \quad (3)$$

The current in the diode is given by [17-36-41]:

$$I_D = I_{pv} / \left[e^{\frac{V + IR_s}{nV_t}} - 1 \right] \quad (4)$$

With the diode saturation current:

$$I_0 = I_{sc} \left(\frac{T}{T_{ref}} \right)^3 \exp \left[\frac{qE_g}{nk} \left(\frac{1}{T_{ref}} - \frac{1}{T} \right) \right] \quad (5)$$

With:

$$I_0 = I_{sc} / \left[e^{\frac{V}{nV_t}} - 1 \right] \quad (6)$$

The output current equations become:

$$I_0 = I_{ph} - I_0 \left[e^{\frac{V + IR_s}{nV_t}} - 1 \right] \quad (7)$$

Where:

$$V_t = \frac{KT}{q} \quad (8)$$

2.2 DC/DC Converter [39]

Figure 3, displays the electrical circuit of a boost converter [20-39]:

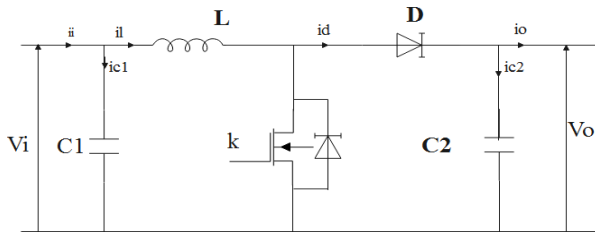


Figure 3. Diagram of Boost converter [39]

This type of converter can be used as an adapter Source-load when the load needs a higher voltage than that of the photovoltaic system generator [9-31-39]. Through changing the duty cycle D, it is possible to adapt the source to the load [16]. As a result, the relationships between the converter's input values (corresponding to the I_{pv} and V_{pv} generators) and converter output (corresponding to I_{out} and V_{out} , respectively) do not depend on the duty cycle D and may be represented as follows [10]:

$$\frac{V_{out}}{V_{in}} = \frac{1}{1 - D} \quad (9)$$

3. TECHNIQUES FOR TRACKING THE MPP

A non-linear electric generator can be used in such a way as to continually produce the maximum of its power by using the maximum power approach, a command linked to an adaptation step [14]. In most cases, MPPT systems are used with photovoltaic or even wind generators [5]. The static converter linking the load and the photovoltaic panel is then under the direction of an MPPT controller, ensuring that the load is continuously receiving the highest power possible [6].

Artificial Neural Network (ANN), Incremental Conductance Technique, and Perturbation and Observation are the MPPT approaches employed in this paper (ANN-MPPT) [15].

3.1 Perturbation and Observation

Anxiety and observation techniques are widely used [4]. It is very popular because of its simple feedback structure and small control range [16]. The fundamental concept is to alter the voltage; if doing so increases energy, future disturbances will also increase energy, and vice versa. This technique is simple to create and apply. However, there are delays associated with this approach of environmental monitoring, making it challenging to detect peak power points in real time. The graphic Figure 4 depicts the perturbation and control method's flowchart [17].

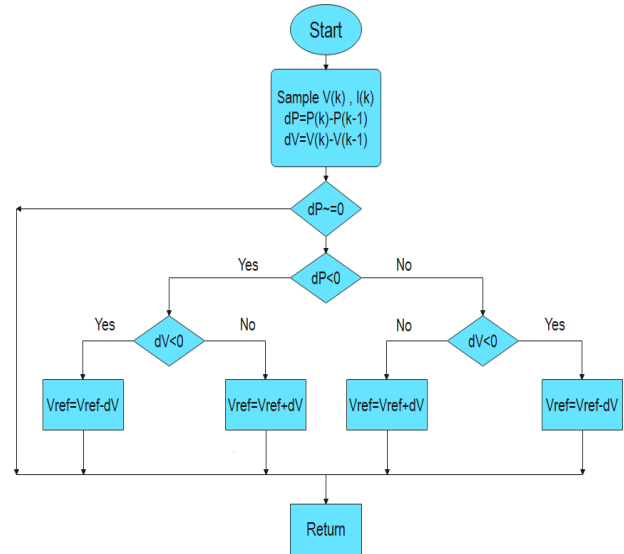


Figure 4. Flowchart for P&O

3.2 Incremental Conductance Method

The PV power Curve slopes positively to the left and negatively to the right of the MPP, with a zero slope at the MPP [19], [32- 33]:

$$\frac{dP}{dV} = \frac{d(V.I)}{dV} = I + V \frac{dI}{dV} \quad (10)$$

MPP is recharged when: $\frac{dP}{dV} = 0$ and

$$\frac{dP}{dV} = \frac{I}{V} \quad (11)$$

$$\frac{dP}{dV} > 0 \text{ then } V < V_{p \text{ mpp}} \quad (12)$$

$$\frac{dP}{dV} = 0 \text{ then } V = V_{p \text{ mpp}} \quad (13)$$

$$\frac{dP}{dV} < 0 \text{ then } V > V_{p \text{ mpp}} \quad (14)$$

To find the MPP, boost PV effectiveness, lower power loss, and lower system costs, INC techniques can be utilized [18]. If the MPP is on the right side [21], the PV voltage must be reduced before dI/dV , $-I/V$ [34], and finally the MPP [23]. The INC implementation on a microcontroller provided performance that was more dependable as compared to P&O [24]. Additionally, the oscillation in the MPP region can be suppressed using the implementation's complexity. Tracking durations are still lengthy because the voltage increase and decrement were manually selected after much trial and error. Figure 5, Shows Flowchart of INC [22].

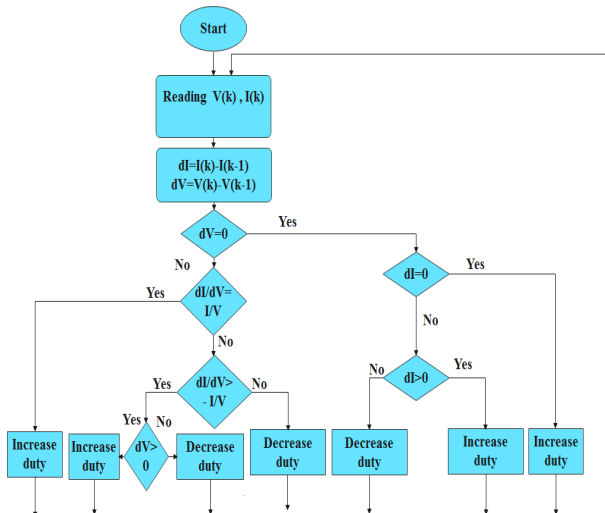


Figure 5. Flowchart of INC

3.3 MPPT Based on artificial neural networks.

A specific type of artificial intelligence method is called an ANN [25]. AI applications offer advantages over traditional approaches [7]. Drawbacks to conventional techniques include their long response times to sudden changes in the sun's temperature and radiation, as well as their intermittent failure to find points of maximum energy. In Figure 6.a, an overview of the ANN in MPPT is presented [8-34]. The inputs are the voltage V_{pv} and current I_{pv} brought on by variations in temperature and solar radiation [34]. The neural network's intended goal is to find the duty ratio of the DC-DC converter [28-34].

The highest power point is wanted., the neural network will supply an exact work ratio value for each fluctuation of the sun's temperature and radiation [26-30-34].

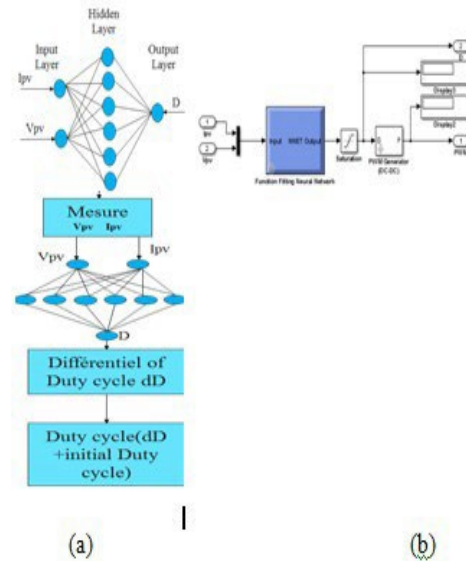


Figure 6. (a) ANN structure and flowchart for finding MPP, (b) ANN MPPT controller developed using Simulink.

Using Marquardt's algorithm, the network is constructed for Levenberg training. Duty ratios are computed and ANNs are trained for various combinations of temperature and solar irradiance variables [25]. The layer weights must be changed to get the necessary values during neural network training [29]. Over the course of training, weights are changed to best match the objective values. The mean squared error serves as the ANN's performance function (MSE). MSE will be if and is the current output and t is the target:

$$F = \frac{1}{N} \sum_{i=1}^N (t_i - a_i)^2 \quad (15)$$

ANN provides instructions for its design:

- Data collection.
- Choose the network topology.
- Network formation.
- Check the network for errors.

Table 1. PV module BP Solar "BP MSX 60" specifications [25° C; 1000W/m²]:

Open Circuit Voltage (Voc)	21.1 V
Short Circuit Current (Isc)	3.8 A
Voltage at MPP (Vmpp)	17.1 V
Current at MPP (Impp)	3.5 A
Maximum Power (Pmpp)	60W

4. RESULT OF SIMULATION

The simulation model for the photovoltaic module was made using the MATLAB *Simulink* program [40]. Table 1 and Figure 7, both display the data sheet for the solar

panels used in this simulation. Uses Matlab to illustrate a photovoltaic system.

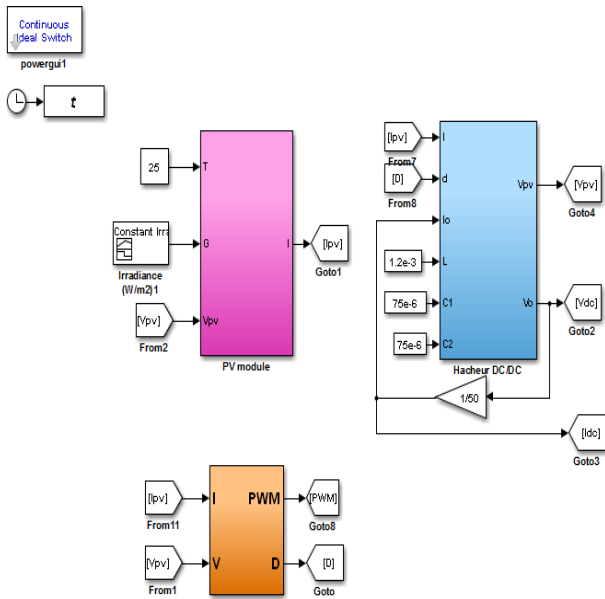


Figure 7. Photovoltaic System Using Matlab/Simulink

With a constant temperature of 25°C, we have already tested the radiation from 800W/m² to 500W/m² and 500W/m² to 1000W/m² in a short time 0.6s. These simulations allow us to test the performance of the controls for different levels of irradiance. From Figure 8, we see that the performance i.e., stability and speed obtained with ANN is better than the P&O and INC commands. They allow the system to function instantaneously at "PPM" despite the rapid change of irradiance.

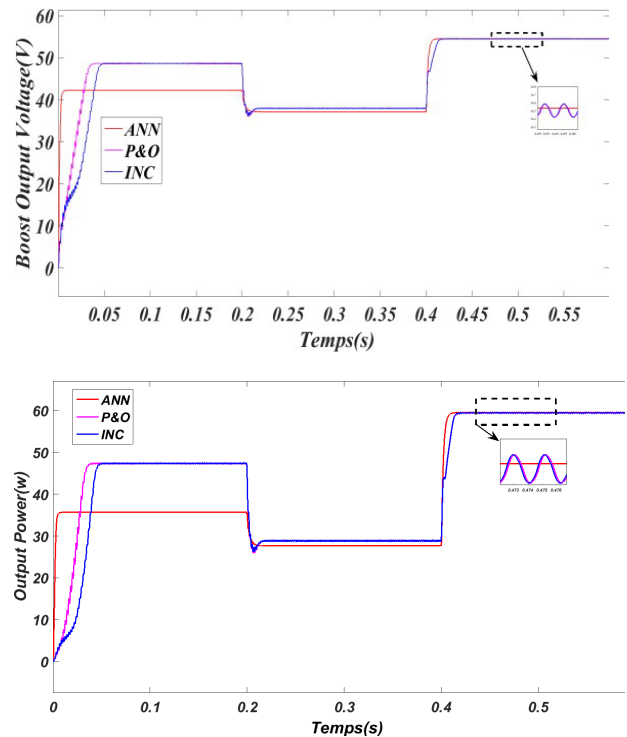
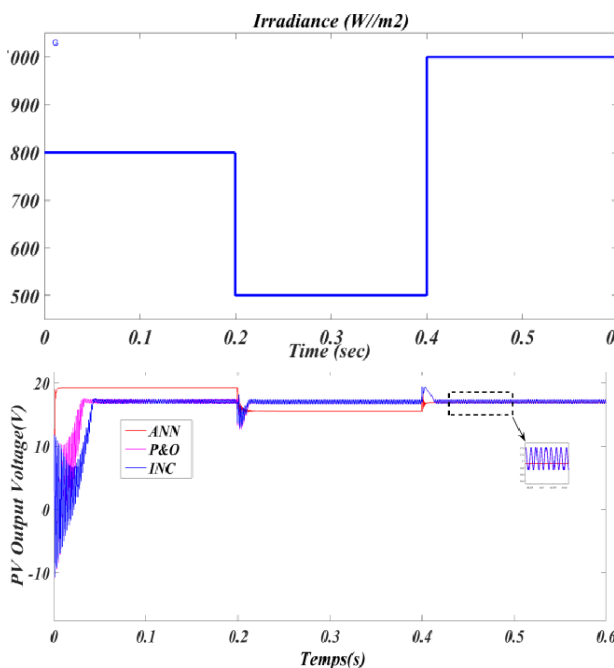


Figure 8. PV Output Voltage, Boost Output Voltage, and Output Power with ANN MPPT and P&O [35], INC algorithm when G is variable [35].

The P&O algorithm is a typical, simple algorithm. This approach typically oscillates around the best value and is very dependent on the first conditions. The main weakness of this method is the problematic behaviour during radiation change.

The INC algorithm appears to be a development over P&O. It does behave better when the metrological conditions change quickly. The algorithm is more complicated than the last one, though.

An efficient and reliable approach is the neural network-based algorithm (ANN). This method does indeed use at a stable, best position. Additionally, it shows good gest in the flash state. Nevertheless, the execution of this kind of algorithm is more difficult than the execution of ordinary algorithms. Additionally, the layers inside the ANN block have a significant impact on this algorithm's effectiveness.

Using ANN controllers has the following benefits:

- Fast reaction for maximum power point tracking.
- Less steady state inaccuracy.
- Because the learning mechanism is built-in, reprogramming is not needed.

ANN controller drawbacks include:

- Network requires extensive training.
- The neural network framework occasionally has a complex design.

5. CONCLUSION

In this article, artificial intelligence was used as a technique for finding the highest power point and as a tool for cell modelling. We compared the outcomes of networks of artificial neurons implemented to the results of a simulation of a photovoltaic panel model. Results from ANN (a novel method) outperform those from conventional algorithms (P&O, INC). As a first step toward balancing the exact mathematical endeavour with human judgment and ANN ability to follow up. These outcomes prove both the enhanced performance of the neural tracker and its proper functioning (P&O, INC). The latter has demonstrated that he performs better, has a lower error rate, and is a strong atmospheric regulator.

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