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International Journal of Electrical and Electronics Research (IJEER)
Research Article | Volume 12, Issue 3 | Pages 991-1000 | e-ISSN: 2347-470X

A Comparative Investigation of Hybrid MPPT Methods for Enhancing Solar Power Generation in Renewable Energy Systems

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ABSTRACT- Photovoltaic (PV) systems are among the types of renewable energy that are frequently employed. Since the characteristics of the solar cell depend on the amount of insolation and temperature, it is necessary to use MPPT "Maximum Power Point Tracking" to move the operating voltage close to the maximum power point under changing weather conditions. This article aims to design a photovoltaic energy system based on boost converter control to obtain maximum power using a hybrid algorithm based on artificial neurons (ANN). Additionally included is a proportional-integral (PI) controller, which improves the performance of the ANN-MPPT controller; this method is quick and precise for tracking the maximum power point (MPP) in the face of variations in temperature and solar radiation. The efficiency of the tracking algorithm was calculated and compared to one of the traditional methods, the incremental conductance (INC) method, in addition to comparing it to other hybrid methods and by simulating the system using MATLAB/Simulation and analyzing the results. This study unequivocally proves the superiority of the hybrid ANN+PI strategy; the efficiency reached 99.91%. This approach excels at tracking maximum power accuracy by leveraging the adaptive learning capabilities of neural networks, ensuring maximum power even in the face of changing environmental conditions.

Keywords: Photovoltaic; MPPT; DC-DC Converter; ANN; INC.

ARTICLE INFORMATION

Author(s): Ashraf Abdualateef Mutlag, Mohammed kdair Abd and Salam waley Shneen;

Received: 13/06/2024; **Accepted**: 02/08/2024; **Published**: 30/08/2024;
e-ISSN: 2347-470X;
Paper Id: IJEER 1306-11;
Citation: 10.37391/ijeer.120333
Webpage-link:
https://ijeer.forexjournal.co.in/archive/volume-12/ijeer-120333.html

crossref member
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1. INTRODUCTION

Photovoltaic (PV) systems have become a favourable and sustainable renewable energy source. Using a photovoltaic cell is one method of producing electricity using solar radiation. The power production from photovoltaic arrays depends on the amount of solar radiation falling on the panels [1]. The increasing use of photovoltaic (PV) devices in power systems has given rise to new challenges, including those concerning control strategies intended to offer PV systems favourable, even optimal, operating conditions. Moreover, the control methods must take into account that the performance of PV systems is affected by the amount of solar radiation, temperatures, and loads [2]. In various electronic systems, including power production systems, renewable energy systems, communication systems, and many industrial procedures, the usage of DC-DC converters becomes critical to settling the active exploitation of the produced solar energy [3] [4]. Numerous designs exist for DC-DC converters, including the Boost, Buck, Buck-Boost, Zeta, Sepic, and Cuk; due to its capability to step up output voltage, the boost converter stands out among the types of DC-DC converters in this article [5] [6][7].

Solar panels cannot produce their full potential without special technology. For solar panels to produce the most electricity feasible, a technique known as MPPT, or maximum power point tracking, is used [8] [9]. To keep the solar panel operating at its peak power level, this point is tracked by the MPPT controller, which modulates the panel's voltage and current. Many conventional MPPT techniques can be applied, with incremental conductance and observation and perturbation (P&O) being the preferred MPPT [10] [11]. Due to their simplicity, convenience of use, and affordability, these approaches are extensively employed. However, these methods each have their drawbacks. When PV systems reach MPPT, P&O experiences operating point fluctuations that cause it to oscillate around MPP [12]. Additionally, due to slower convergence, P&O is similarly unable to implement MPP in environments with frequent environmental changes. Since the (INC) MPPT technique handles sudden changes in irradiation and helps account for variation in current about voltage, it has a more sophisticated algorithm than P&O. Still, uncertainty in determining step size and accompanying oscillations is a downside of this approach [13]. Recently, artificial intelligence (AI)-based solutions have been published using neural networks (ANN), machine learning, and fuzzy logic (FL) [14]. In addition, parser technology can be used to handle these problems, such as particle swarm optimisation (PSO), ant colony optimization, plant growth simulation algorithm (PGSA) and the cuckoo search technique for MPPT [15][16].

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The various types of traditional and intelligent algorithms were defined and classified, and multiple comparisons and analyses were also made in [17] [18].

In recent years, researchers have turned to studying hybrid algorithms to obtain the maximum power from solar panels and overcome the disadvantages of traditional methods. The INC algorithm is paired with a fuzzy logic-based hybrid MPPT method, as suggested in [18]. Tests were conducted on typical and variable settings, and the hybrid MPPT method was evaluated against the INC algorithm and the traditional fuzzy logic control. Findings established that under both stable and rapidly changing conditions, the suggested hybrid MPPT method achieves well. Also in [19], two MPPT hybrid algorithms are put forth: (a) an MPPT controller that integrates the fuzzy logic controller (FL) with the perturb and observe (P&O) approach; (b) an MPPT controller that integrates the fuzzy logic controller (FL) with incremental conductance (INC). The two-hybrid algorithms integrated FL, INC, and P&O strength into a single framework. Both algorithms' responses are examined using MATLAB/Simulink. Simulated meteorological circumstances include (i) consistent illumination, (ii) abrupt changes, and (iii) partial shading. Multi-peaks emerge in the power-voltage characteristics of a photovoltaic panel when it is partially shaded. The findings of the simulation demonstrated that FL's capacity to track MPP dramatically deteriorates when tested in weather conditions different from those utilized for training. Finally, with an efficiency of over 97%, the suggested hybrid algorithms successfully remove the prior drawbacks related to the FL, INC, and P&O algorithms, and in [20], propose an MPPT algorithm that uses the PID + INC algorithm. Here, a PV system is evaluated in a range of environmental settings. MATLAB SIMULINK is used to simulate the planned task. The suggested approach's outcomes demonstrate that, compared to P&O and incremental, the PID method takes a very short time to achieve the ideal position. The suggested MPPT approach also yields improved voltage, current, and power values. This management approach will also lessen oscillations. It has been discovered that the PV system's efficiency increases with the PID controller more than with the other two methods. The efficiency of this method was calculated using the MATLAB program and reached 99.52%.

In [22], an MPPT algorithm that combines PSO and hybrid neural networks is proposed. This was tested against the fundamental PSO method and in partial shading conditions. The ANN uses various sensors to measure irradiance; however, imperfect sensors might cause issues for actual systems. It suggests doing away with these sensors by focusing exclusively on the I-V curve, but this would have the drawback of requiring more data and a better-trained ANN. The hybrid approach That combines LF and ANN, known ANFIS, as in [23], an ANFIS-based MPPT controller connected with a Z-source DC-DC converter. Two 9-rule tables were suggested to help more precisely identify the controller's structure. Without using sensors, the network was trained using actual weather data. The technique works well in various circumstances, as demonstrated by the MATLAB simulation.

The authors in [24] provide an MPPT algorithm that combines ANFIS + P&O. that maximizes both the member function and the parameters. The MPPT function determines the fuzzy region, and the resulting parameters are subsequently supplied to a P&O technique. The algorithm's performance was evaluated in a variety of environmental scenarios. Ultimately, the approach goes beyond the drawbacks of applying each technique independently.

The authors in [25] propose an MPPT algorithm that uses ANFIS + PSO to optimize the membership functions and reduce the error of the least squares approach. The proposed ANFIS uses a five-level system in which four rules are chosen for the membership functions. The method uses PSO to locate the global optimum and prevent tripping, which leads to stability and ensures convergence. The results were tested at different I level and simulated using MATLAB/Simulink, which produced a faster response time than conventional P&O. Also, the algorithm used in [26] is an adaptive neuro-fuzzy technique with PSO. One benefit of this approach is that it can compute G and T without needing sensors. The advantages of this approach are better PV power monitoring capabilities, a lower RMSE runtime, and free derivation to determine the above parameters for appropriate training under non-uniform, uniform, and fluctuating shading situations.

This work is concerned with designing a photovoltaic system that generates 60 kW. This article studies and analyses an MPPT algorithm based on a PI controller and an artificial neural network (hybrid ANN + PI) [27]. The MPPT based on artificial neural networks (ANN) is widely used as a reliable, quick, and effective method [28] [29]. The key benefits of using the ANN approach with PV systems are the ability to detect nonlinear correlations between dependent and independent variables and the lack of a deep grasp of internal system characteristics [30]. This study primarily contributes to enhancing ANN-based MPPT performance through a supervised machine-learning technique with a PI controller. The PI is used to improve ANN performance and reduce its drawbacks. Simulating PV applications simultaneously in various weather scenarios is the second main goal. It is worth noting that PID was used due to its simple design, simplicity of use, low cost, and reliable performance in a variety of operating conditions. The study will be conducted using several scenarios, including temperature changes, solar radiation, and load changes. By comparing the results obtained, valuable insights will be gained regarding the suitability and effectiveness of these control strategies in improving the operation of PV systems using boost converters. The results of this study will help establish PV system control technologies and provide recommendations for developing more efficient and reliable renewable energy systems.

This article is organized as follows: *Section 2* is reserved for the study and modelling of the photovoltaic system; the first subsection is reserved for the presentation of the photovoltaic panel; the second sub-section is reserved for the study of the DC-DC Boost Converter, and the third sub-section is reserved for the study of the design of the MPPT controller. In section III, the system has been simulated, the simulation results are presented, and a discussion in *section 4*. A comparison between

International Journal of
Electrical and Electronics Research (IJEER)
Research Article | Volume 12, Issue 3 | Pages 991-1000 | e-ISSN: 2347-470X

the two methods used is made in *section 5*. Finally, concluding comments are provided in *section 6*.

2. PHOTOVOLTAIC SYSTEM

This study examines a microgrid system consisting of photovoltaics as a power source to supply power to DC loads, and it assumes there are no energy storage systems.

Figure 1 shows the block diagram for the PV system that is being researched. A photovoltaic module serves as the system's energy source. The boost converter links the load, and the solar panel, and the MPPT controller enables the pulling of the most power feasible from the system.

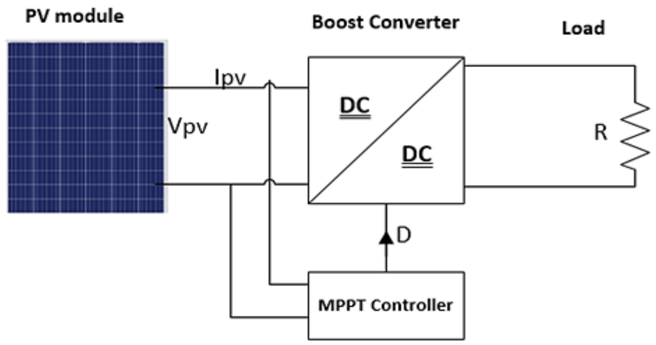

Figure 1. Block diagram of PV system

2.1 Model of a Photovoltaic Module

A photovoltaic system typically consists of modules of many solar cells connected in series or parallel [31]. *Figure 2* shows the equivalent circuit for solar cells. The cell or module's solar PV current can be expressed as follows [11],[32]:

$$I = I_{PH} - I_S\left(exp\left[\frac{(V + IR_S)}{V_{th}\delta}\right] - 1\right) - \frac{(V + IR_S)}{R_{SH}} \quad (1)$$

Where I denotes the module's current, V denotes the module's voltage, I_{PH} denotes the photo-current of the module, I_S denotes the diode current at saturation, R_S denotes the series resistor, R_{SH} denotes the shunt-resistor, δ denotes the diode constant, and V_{th} denotes the thermal voltage.

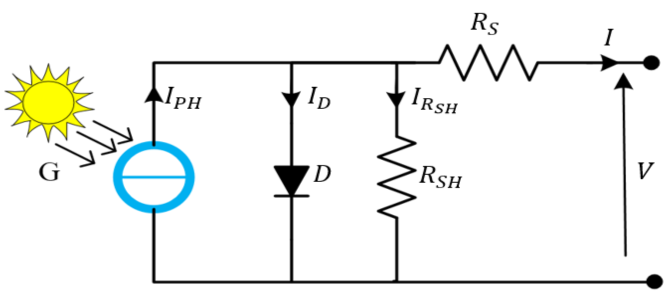

Figure 2. The equivalent circuit of the solar cell

Figure 3 shows the solar module's characteristics tested in this work under the influence of different solar radiation and temperature constants. This figure illustrates how the system's MPP depends on the irradiation value, which ranges from 0 KW/m2 to 1 KW/m2. The system's maximum power of 60KW is produced by a voltage of 394.5 V and a current of 152.2 A, according to the system's high power, or MPP.

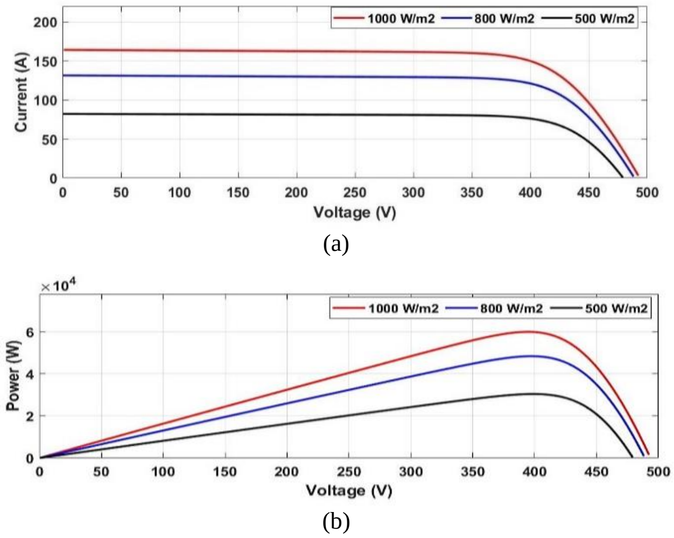

Figure 3. Photovoltaic panel curves at various levels of irradiation and the constant temperature 25 °C (a) I-V curves, (b) P-V curves

2.2. Model of DC-DC Boost Converter

Boost converters are DC-DC power converters that increase the voltage from their input source to their output. A solar panel's voltage is used as the input source. A boost power converter's circuit diagram is displayed in *figure 4*.

The boost converter can increase the unregulated DC voltage generated from clean energy to a higher voltage required by loads. This circuit is made up of (L) inductance, (C) capacitance, and (R) load resistance. *I* and *V* stand for the output at the capacitor terminals and the current flowing across the inductor, respectively. *Equations (2–5)* are used to compute the parameters of a DC-DC boost converter [33] [34]. The output voltage for a DC-DC boost converter is higher than the input voltage, which is written as:

$$\mathrm{Vdc} = \frac{V_i}{1 - D} \quad (2)$$

Where: D denotes the duty cycle, V_i denotes the input voltage, and Vdc denotes the output voltage. The output current can be calculated via:

$$Idc = I_i\,(1 - D) \quad (3)$$

Where: I_i denotes the input current. For the converter to operate on continuous current conduction mode, the amount of inductance is determined so that the current through the inductor I_L flows continuously and never goes to zero as provided by:

$$L_1 = \frac{D(1 - D)^2 R_L}{2 f_S} \quad (4)$$

Where f_S denotes the boost converter's switching frequency, R_L denotes the load resistance, and L_1 denotes the minimum inductance.

Calculations were made to determine the output capacitance and input capacitor to produce the desired output voltage.

$$C = \frac{D}{(\Delta Vo/Vo)\, f_S R_L} \tag{5}$$

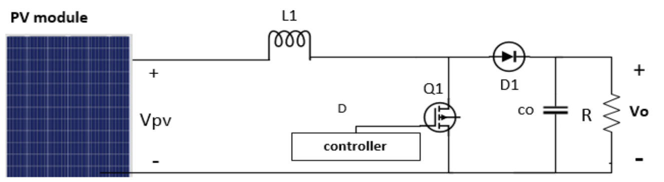

Figure 4. Block diagram of DC-DC Boost converter

2.3. The Proposed MPPT Algorithm (ANN)

The MPPT is a name given to the technology used to track the maximum power of PV panels and wind generators and increase their efficiency. It is an electronic system that relies on algorithms that change the PV panels' operating point to produce the maximum power [35]. The ANN has recently undergone significant development in theory and practice. A typical NN contains numerous levels, including input, hidden, and output layers. ANN has several advantages, including offline training, fast-tracking, and tolerance for nonlinearity. As a result, numerous ANN-based PV MPPT algorithms have recently been developed [36]. Environmental information, such as radiation and temperature, as well as PV array parameters, like PV voltages and currents, can all be used as ANN inputs for MPPT. The output is often one or more references that are used to force the electronic converters to operate at or close to the MPP, such as a signal that monitors the duty cycle.

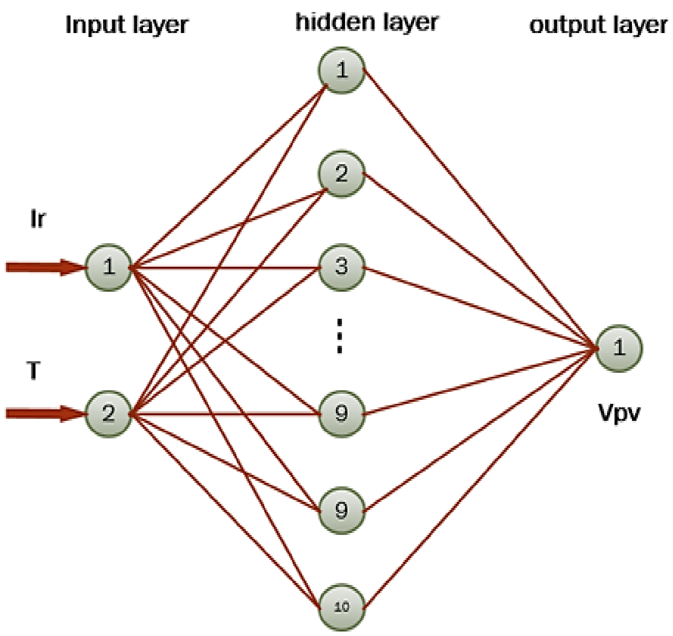

Figure 5. Block diagram of Neural Network

To create a high-performance controller, we used an optimized controller using a strategy for ANN in this investigation. *Figure 5* shows an example of a feed-forward ANN structure. It is made up of multiple neurons that resemble genuine brain cells. The neurons are arranged in layers, each with a substantial number of connections weighted to the other layers. Inputs are combined by the hidden layer neurons to form a single result, which is then transmitted to the output via an activation function. Each neuron of the input layer gets a collection of data from the input variables and sends it to the neurons of the hidden layer. Finally, to produce the final output, each neuron in the output layer adds the hidden layer output to the bias and relays the result through the activation function.

The PV system is shown in *figure 6*. The system's main elements are the solar panel, load, DC-DC boost converter, and ANN-MPPT controller.

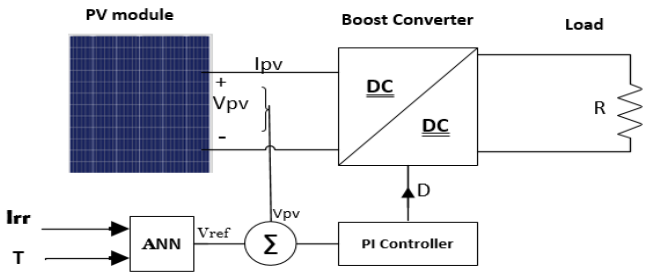

Figure 6. Block diagram of PV system with Hybrid ANN + PID MPPT algorithm

The ANN algorithm tracks the maximum power point (MPP) by forecasting the voltage at that point (V_{mpp}) using instantaneous information such as temperature and solar irradiation. After training, the maximum power point voltage of the PV array is calculated and compared to the measured voltage of the PV panels, and then this difference is sent to a PI controller to obtain the appropriate duty ratio for the pulse-width modulation (PWM) signal. PID gains are modified via various techniques, including the Ziegler-Nichols approach and genetic algorithms [37][38]. The output signal drove the switch to achieve maximum power tracking. *Figure 7* shows the flowchart of MPPT based on an ANN.

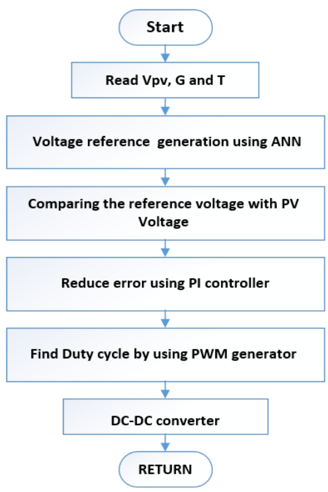

Figure 7. The flowchart of MPPT based on ANN

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3. SIMULATION MODELING

In this part, we will simulate the DC microgrid using MATLAB/Simulink to implement the photovoltaic system, consisting of a solar module, boost converter, resistance of external loads, and MPPT controller, as shown in *figure 8*.

Figure 9 shows the simulation model of hybrid ANN + PI, where temperature and solar radiation are considered inputs. They are entered into the ANN, and after training processes and obtaining the assumed maximum voltage, they are compared with the measured voltage value. The result of this comparison is then entered into the PI control, whose parameter values are (Ki= 1.5, Kp= 0.214), and then to the PWM generator to generate the duty cycle that controls the switch of the DC-DC converter.

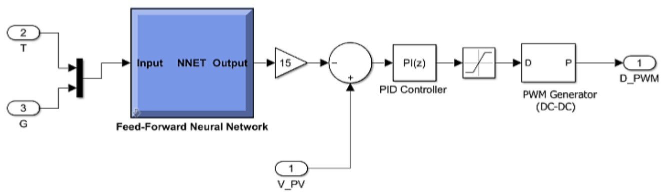


Figure 9. Simulation model of hybrid ANN + PI.

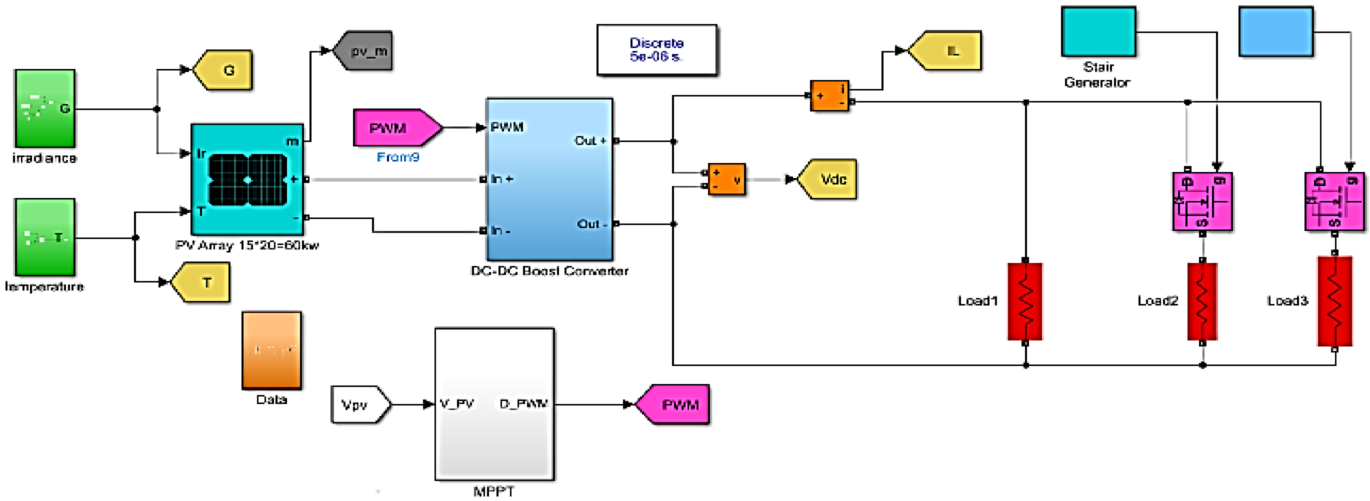


Figure 8. Simulation model of hybrid ANN + PI

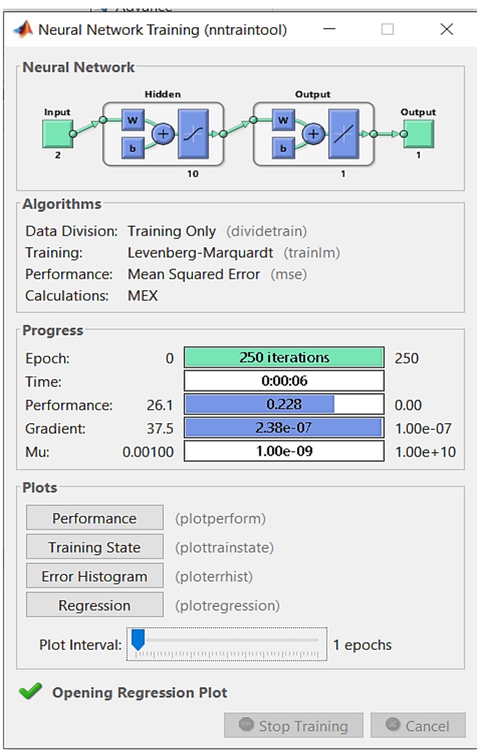


Figure 10. The neural network training

Figure 11 shows the ANN block and the layers inside the ANN block.

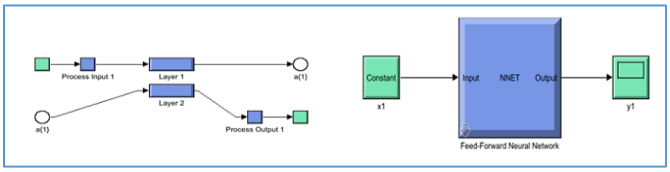


Figure 11. The ANN block and the layers inside the block

The values for the PV panel and the parameters of the boost circuit are listed in *tables 1* and *table 2*.

Table 1. Parameters for PV panel at STC (1000W/m2, 25°C)

Parameter	Value
Maximum power (PMPP)	200.143W
Maximum power point voltage (VMPP)	26.3 V
Open-circuit voltage (VOC)	32.9V
Maximum power point current (IMPP)	7.61A
Short circuit current (ISC)	8.21A
Cells per module (Ncell)	54
Number of series modules	15

Table 2. The boost converter's parameters

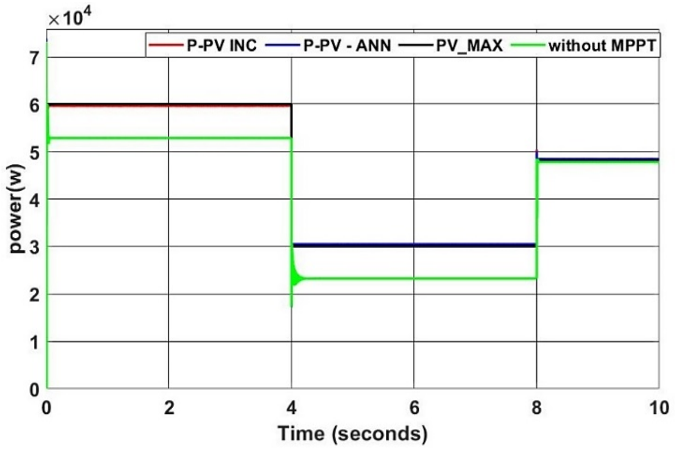
Parameter	Value
Output Voltage	750V
Input Voltage	400 V
Input capacitor (Ci)	325 µF
Boost Inductor (L)	7.696 mh
witching frequency (fs)	Hz

4. RESULTS OF THE SIMULATION AND DISCUSSION

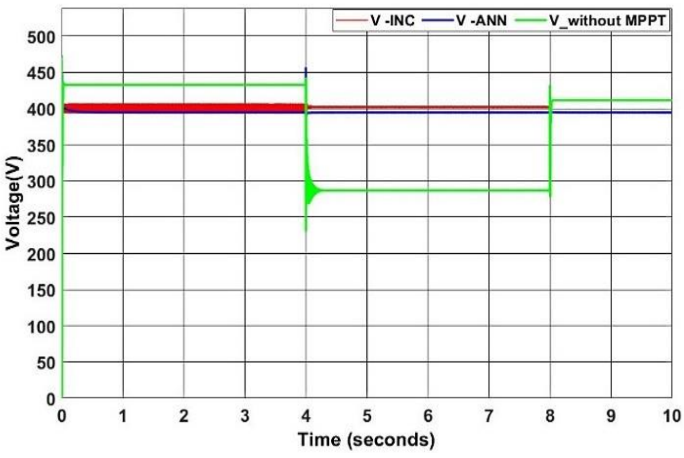
The simulation was carried out in three cases in terms of solar radiation and loads with constant temperatures.

Case 1: In this case, the load in the system is considered a constant of 40 kW, and the amount of solar irradiation decreases from 1000 W/m2 to 500 W/m2 at 4s, then at 8s, the radiation rises to 800 W/m2. Considered is a constant temperature of 25 °C.

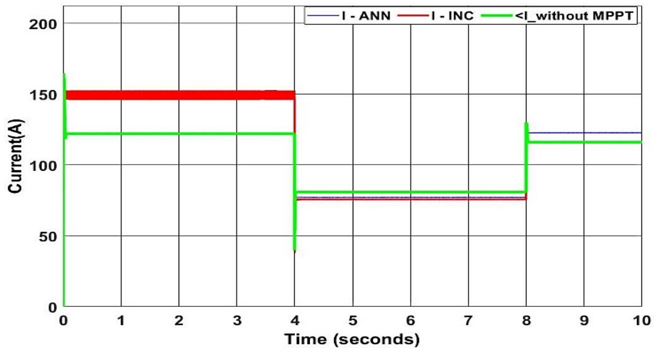
Figure 12 shows the results under case 1. *Figure 12a* shows the power produced by the solar panel, and *Figures 12b* and *figure 12c* show the current and voltage of the solar panel, respectively.



(a)



(b)



(c)

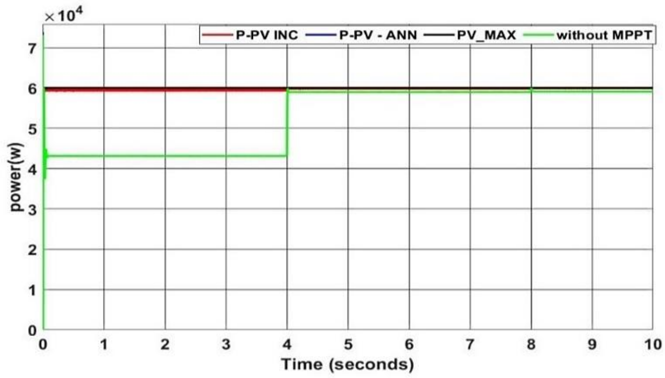
Figure 12. Results of the simulation Case 1. (a) The PV array power (PPV), (b) the PV array voltage (VPV), (c) the PV array current (IPV)

The black line represents the maximum design power level theoretically obtained from the power from the total number of panels; the blue line represents the maximum power tracked by the hybrid ANN + PI algorithm; and the red line represents the maximum power tracked by the INC algorithm. While the green line represents the amount of energy produced by the solar panels without using any MPPT technology, the DC-DC converter switch is controlled by a PWM generator with a duty cycle value of 0.466.

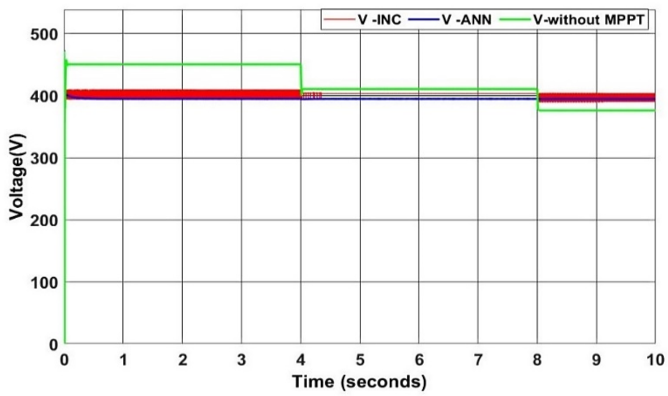
The maximum theoretical power figures are attained at a constant temperature of 25 °C: 60 kW for 1000 W/m2, 30 kW for 500 W/m2, and 48 kW for 800 W/m2. In both methods used to track the maximum power of PV panels, the effect of decreased solar radiation leads to a decrease in the value of the current, thus a decrease in the value of the power, and vice versa, while maintaining the voltage level as the voltage is not greatly affected by changes in solar radiation and the voltage is more affected by changes in temperature. As for the circuit curve that does not contain the MPPT algorithm, it fails to track the maximum power of the PV panels.

Case 2: The load suddenly increases from 30 kW to 50 kW at 4 seconds to 60 kW at 8 seconds while maintaining a constant sun irradiation of 1000 W/m2 and a temperature of 25°C.

Figure 13 shows the results under *case 2*. *Figure 13a* shows the power produced by the solar panel, and *figures 13b* and *figure 13c* show the current and voltage of the solar panel, respectively.



(a)



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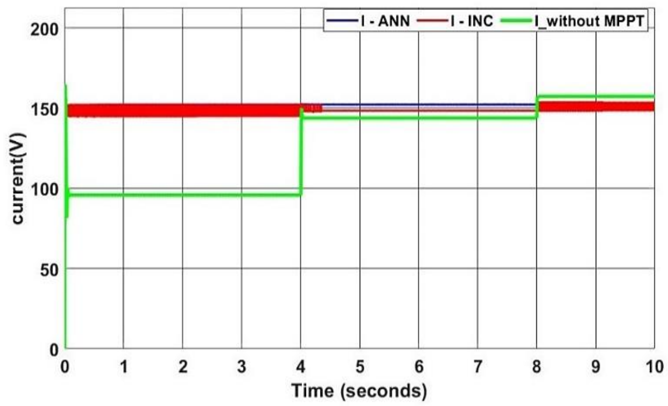


(c)

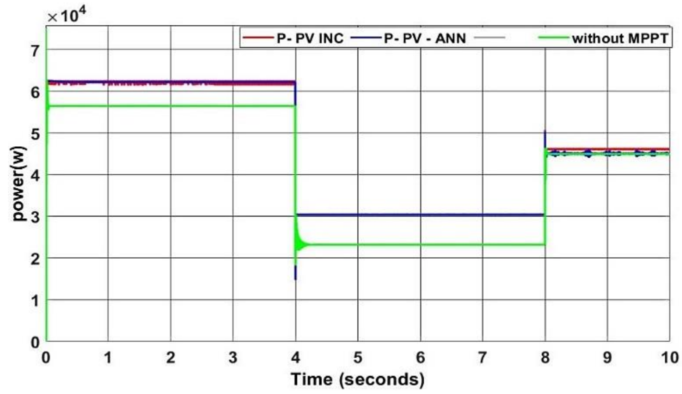
Figure 13. Results of the simulation Case 2. (a) The PV array power (PPV), (b) The PV array voltage (VPV), (c) The PV array current (IPV)

The results obtained from the simulation in case 2 show that changing loads do not affect the power, voltage, and current curves. The results also demonstrate the success of the two algorithms in tracking the maximum power with high efficiency. On the other hand, the circuit that does not contain the MPPT algorithm did not perform well.

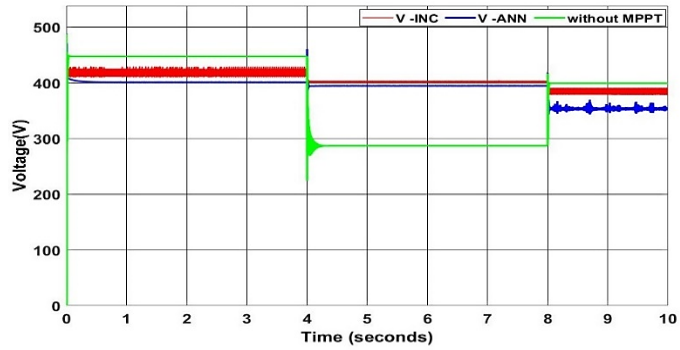
Figures 12a and *figure 13a* show the similarity of the results between the two algorithms in tracking the solar panels' maximum power. Still, we will compare more to determine which method is more efficient.

Case 3: The load is constant at 40 kW, and the solar radiation and temperature values are variable. The amount of solar irradiation decreases from 1000 W/m2 to 500 W/m2 at 4 s, then at 8 s, the radiation rises to 800 W/m2, and the temperature starts at 15°C, then rises to 25°C at 4 s, then rises again to 35°C at 8 s.

Figure 14 shows the results under Case 3. *Figure 14a* shows the power produced by the solar panel, and *figures 14b* and *figure 14c* show the current and voltage of the solar panel, respectively.



(a)



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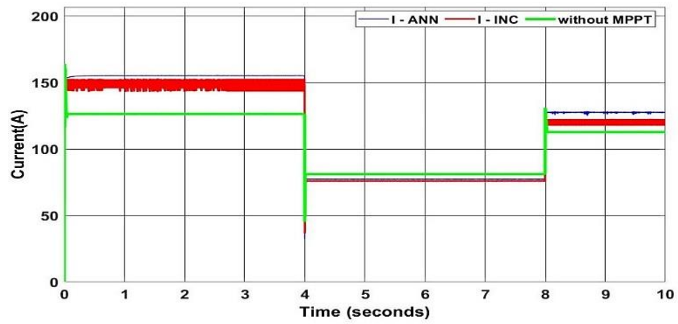

(c)

Figure 13. Results of the simulation Case 3. (a) The PV array power (PPV), (b) The PV array voltage (VPV), (c) The PV array current (IPV)

In the first period in *figure 14*, due to the decrease in temperature, the current increased and thus the generated power increased to more than 60 kW. In the second period, the temperature was at the ideal value of 25°C, and the radiation was half the perfect value of 500 W/m2, so the generated power was close to 30 kW. In the third period, at 8 s, where the temperature increased, and the solar radiation decreased compared to their ideal values, the generated power was less than the design value. The curves resulting from the third case show that the efficiency of the proposed method becomes low in some periods. There is an oscillation in the curves and a delay in tracking, especially when the temperature increases. This requires improving the proposed method and training it with more data to obtain more efficient and accurate results.

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Research Article | Volume 12, Issue 3 | Pages 991-1000 | e-ISSN: 2347-470X

To compare the two methods used, took a close-up of the simulation results in case 2. In this case, the load is not constant, and the environmental conditions are assumed to be constant (radiation = 1000 W/m2 and temperature = 25°C). The load is 30 kW first, and then it is changed to be equal to 50 kW at time t = 4 s, then it becomes 60 kW at t = 8 s.

In *figure 15*, the curve of the ANN algorithm is close to or identical to the MPPT value for solar panels under standard solar radiation and temperature conditions. While the INC algorithm curve oscillates around the maximum value, the circuit that does not contain an MPPT system has no control over the duty cycle value in the boost converter, so this circuit cannot track maximum power when operating conditions vary. In addition to the clear comparison from *figure 14* and the Ann algorithm preference, the rise time is 2.9µs for ANN, while in the INC algorithm, the rise time is 44.75 µs. Our data analysis indicates that, compared to the traditional INC, the suggested ANN-based controller performs better, particularly regarding minimal oscillation and quick response time. According to the simulation findings, the suggested MPPT algorithm generates more power output in the steady state with less oscillation.

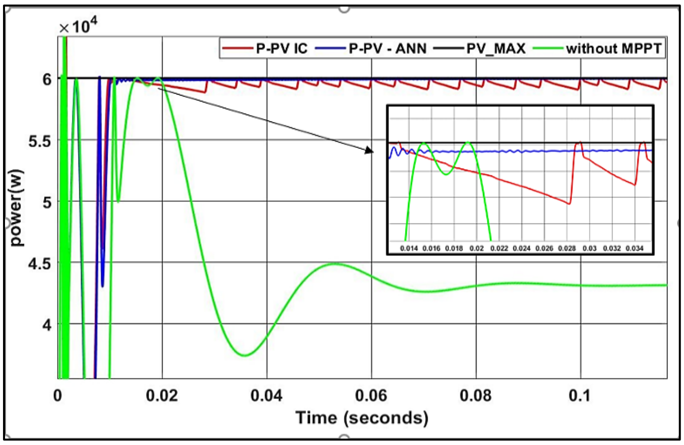

Figure 15. The maximum power curve for the PV system of Case 2. from 0 to 0.11 s

In addition to these simulation tests, other evaluations using other indices are taken into account to show how the proposed and compared algorithms perform under static and dynamic changes. The indices listed below [39]:

***Accuracy** MPP:* This indicator reflects the degree to which the tracking matches the maximum point. In our research, it was employed to show how close the PV current was to the current maximum power point during tracking, as below:

$$\text{Accuracy } MPP = \frac{I_{PV}}{I_{MPP}} * 100 \quad (6)$$

The static efficiency index ($S_{efficiency}$ MPP): shows how the maximum power and the actual PV power relate to one another. It is given by:

$$S_{efficiency}\ MPP = \frac{P_{PV}}{P_{MPP}} * 100 \quad (7)$$

Table 3 shows the study indicator values for the MPPT algorithms used in this paper. It has been proven that the hybrid ANN+PI algorithm guarantees better performance compared to the INC algorithm. The index values were calculated at 6 s because the power curves of the two methods are apparent over this period, as shown in *figure 15a*.

Table 3. Comparison between hybrid ANN+PI algorithm and INC algorithm

Index	ANN + PI	INC
I_{PV}	152.91A	148.48A
P_{PV}	*59988.6*W	59554.69W
Accuracy MPP	*99.81*%	*97.56*%
$S_{efficiency}$ MPP	99.9*1*%	99.18%

Table 4 shows some of the hybrid algorithms presented in the introduction part and the efficiency of each method in tracking peak power.

Table 4. The efficiency of the maximum power tracking algorithms

REFERENCE	Type	Efficiency of MPPT
[14]	INC + PI	99.52%
[18]	FL+ INC	95.3%
[19]	FL+P&O,FL+INC	97%
[21]	ANN+PSO	99.89%
[22]	ANFIS	80%
[23]	ANFIS+P&O	85%
[24]	ANFIS+PSO	97%
[25]	ANFIS+PSO	98.35%
The proposed	ANN + PI	99.91%

By comparing the efficiency of the proposed methods in this article with the efficiency of the other methods in *table 4*, the hybrid ANN+PI method is one of the best methods for tracking the maximum power of PV panels.

5. CONCLUSION

In this study, an algorithm based on artificial neurons was combined with a PI controller to obtain maximum power from solar panels by controlling the duty cycle of the boost converter. Using MATLAB/simulation software, operations were simulated under different conditions in terms of solar radiation and changes in loads with constant temperatures. After simulation and getting results, the efficiency and accuracy of the ANN+PI algorithm reached 99.91% and 99.81%, respectively. In comparison, the efficiency and accuracy of the INC method reached 97.56%, and its efficiency reached 99.18%, which saves maximum energy from PV panels. It is evident from the data that the suggested ANN-based controller outperforms the traditional INC, particularly when it comes to reduced oscillation and quick response times. The simulation results demonstrate that the suggested MPPT algorithm generates higher power output in a steady state with less oscillation. In future work, it is recommended that the ANN algorithm be improved by studying more extensive and realistic climate data and training it better to increase its efficiency in tracking the maximum power of PV panels. It is additionally recommended in future work that ANN be used with metaheuristic optimization algorithms to obtain the best performance of the photovoltaic system. This algorithm can also be used in microgrid systems to get the maximum power to supply loads with sufficient power and charge batteries.

Conflicts of Interest

"The authors declare no conflict of interest."

Author Contributions

"Conceptualization, M. K. Abd and S. W. Shneen; methodology, M. K. Abd and S. W. Shneen and A. A. Mutlag; software, A. A. Mutlag; validation, M. K. Abd and S. W. Shneen; formal analysis, M. K. Abd and S. W. Shneen and A. A. Mutlag; investigation, A. A. Mutlag; resources, A. A. Mutlag; data curation, A. A. Mutlag; writing—original draft preparation, A. A. Mutlag; writing—review and editing, M. K. Abd S. W. Shneen; visualization, A. A. Mutlag; supervision, M. K. Abd S. W. Shneen; project administration, M. K. Abd S. W. Shneen ."

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