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Improving Solar Power System's Efficiency Using Artificial Neural Network

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ABSTRACT

Renewable energy sources are the best solution to reduce dependence on conventional and non-renewable sources that also cause environmental pollution. With the increase in the prices of conventional fuels globally, the increase of gas emissions resulting from its use, and the impact on the environment and the global climate; various renewable energy sources have emerged as an alternative to traditional sources of energy. Ssolar energy is one of the most important renewable energy sources used globally; The technology used is relatively simple and uncomplicated, compared to the technology used in other renewable energy sources. Solar energy is the ideal alternative to conventional energy in the Gaza Strip in Palestine, due to the relatively high solar radiation in the region, which makes its application more practical and economical compared to other parts of the world. Palestine has higher rates of total solar absorption, ranging from 4-8 kWh / m^2 *per day, which is high compared to other countries. This paper offers a solution to the Gaza Strip, which has suffered from a severe power shortage due to the Israeli blockade, by using solar PV as a backup system and a good alternative to diesel generators. Photovoltaic cells convert the sunlight into DC electric power. Where the major problem of the PV is that with the changing of atmospheric conditions, the voltage is changing, and so the maximum power is changing. We know that PV systems are still very expensive; therefore, the Artificial Neural Network controller is designed for the converter to secure the maximum power to the system to increase the efficiency of it.*

ANN controller is designed to bring out the maximum power from the solar panel. This paper uses a controller that utilizes MPPT technique to increase the efficiency of converting solar energy into electrical energy by modifying the duty cycle of Puls Width Modulation (PWM) for the boost converter to obtain the MPP energy from solar cells at all times.

A solar panel applied and their components are individually modeled in the MATLAB / SIMULINK program to simulate a real PV system behavior, then an MPPT technique, including DC/DC boost converter was designed. Then an ANN controller is designed and then trained to get the maximum power *point from the solar panel at different atmospheric conditions. Also, this controller is compared with the direct connected method without an MPPT controller. The system performance is measured by changing solar radiation and temperature of the PV module.*

The findings indicate that MPPT ANN has a fast response to the variability and is more efficient, which means more power transfer to the system. The outcome shows that the photovoltaic module directly associated without MPPT technique has less efficiency because of the mismatch between the photovoltaic module and the load.

Keywords: *ANN, MPPT, Gaza Strip Energy, PV, Solar Energy.*

1. Introduction

This paper aims to design an ANN controller and applied it to MPPT technique to control the duty cycle of the boost converter to get maximum power; thus, increasing the efficiency of PV cells.

This paper proposes using of solar power in Gaza in order to find alternative energy sources to cover the shortage of electricity and the continuously increasing demand of power supply at Gaza and to reduce the usage of normal grid electricity. Besieged Gaza Strip suffered for years from a chronic lack of energy due to the Israeli blockade. The situation worsened after the Israeli attack in 2014, which destroyed the only power station in Gaza, even before the war, the electricity supplied from Israel was less than half of the estimated needs of the sector. A power outage stream that lasts more than 16 hours a day, and when it is available electricity intermittently come for a period of between four and eight hours during the intervals. Fortunately, the Gaza Strip is one of the richest areas in the world in terms of sunshine. It delights in an average of 320 sunny days a year, thus making solar power an attractive alternative source of energy.

The increment of the volume of irradiance delivered from the sun is the best, most accessible way to improve the operation of solar energy. There are many techniques to increase and maximize production of power from solar systems. These methods depend on controlling certain aspects; thus, using control methodology such as intelligent methods is justified. Artificial Neural Network controller (ANN), as an intelligent control, will be used in this study.

2. Mathematical modeling of solar cell

Sunlight turns directly into electricity using modules consisting of many photovoltaics, solar cells manufactured from semiconductors such as silicon. The word photovoltaic comes from the Greek meaning “light” (photo) and “electrical” (voltaic), The popular abbreviation for photovoltaic is PV. The first solar cell was manufactured in 1954 around 5% efficient. The first solar cells were constructed specifically for space applications, so the cost scale was not important. The efficiency of solar cells has steadily increased while costs have declined significantly in recent decades. Silicon is the main component of solar cell construction, but other components and compounds have been developed to improve efficiency and reduce cost (Quaschning, 2016).

PV is mainly a PN junction manufactured from a thin wafer of semiconductor. The electromagnetic irradiation of solar power falling on the solar cells immediately turns into electrical energy through the PV technique. Photovoltaic model is based on the Shockley diode equation and modules naturally exhibit a nonlinear I-V and P-V characteristics which change according to the temperature and radiation.

Typically, solar cells produce less than 5 W at about 0.5 V DC. The circuit diagram of the PV solar cell module consists of a photocurrent, diode, parallel resistor -leakage current - and a series resistor as illustrated in figure 1 (Natsheh, 2013).

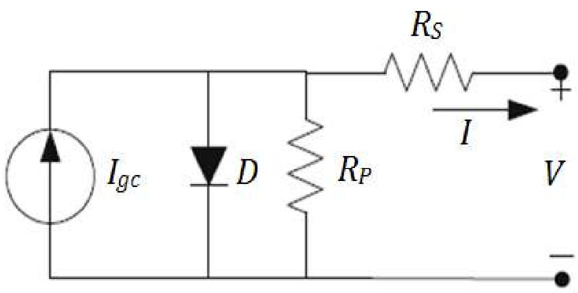

Figure 1. Equivalent circuit diagram of of PV solar cell.

The output power of a single diode is given by (Villalva, Gazoli, & Filho, 2009)

$$\mathbf{P = IV} \qquad \textbf{(1)}$$

From the photovoltaic cell circuit diagram shown in Figure 1 and Kirchhoff's laws, the PV current is calculated as the following: (Kim & Youn, 2005)

$$\boldsymbol{I = I_{gc} - I_{ds}[exp(\frac{q}{K_B F T_c}(V + IR_s)) - 1] - \frac{V+IR_s}{R_p}} \qquad \textbf{(2)}$$

Where I_{gc} is the light generated current, I_{ds} is the dark saturation current depends on the cell temperature, q is the electric charge 1.6 x 10^{-19} C, K_B is the Boltzmann's constant 1.38 x 10^{-23} J/K, F is the ideal factor of the cell, T_c is the absolute temperature of the cell, R_s is the series resistance, and R_p is the parallel resistance. The photocurrent I_{gc} which basicly rely on the solar irradiance and cell temperature, is presented as follows: (Villalva et al., 2009)

$$\boldsymbol{I_{gc} = [\mu_{sc}(T_c - T_r) + I_{sc}]G} \qquad \textbf{(3)}$$

Where μ_{sc} is the temperature coefficient of the short circuit current of the solar cell, T_r is the reference temperature of the solar cell, I_{sc} is the short circuit current of the solar cell at 25° C and 1000 W/m^2 and G is the solar irradiation in kW/m^2. Moreover, the saturation current I_{ds} of the solar cell changes according to the cell temperature and can be obtained as follows: (Villalva et al., 2009)

$$I_{ds} = I_{o\alpha}\left(\frac{T_c}{T_r}\right)^3 exp\left(\frac{qV_g}{K_B F}\left(\frac{1}{T_r}-\frac{1}{T_c}\right)\right) \quad (4)$$

$$I_{o\alpha} = \frac{I_{sc}}{exp\left(\frac{qV_{oc}}{K_B T_c F}\right)-1} \quad (5)$$

Where $I_{o\alpha}$ is the reverse saturation current of the cell at solar irradiation and reference temperature, Vg is the band gap energy of the semiconductor used in the solar PV cell, and Voc is the open circuit voltage of the cell. F is depending on the material from which the cell is manufactured as illustrated in Table 1 (Natsheh, 2013).

Table 1. Idealizing factor (F) depending on the cell's technology.

Cell Technology	F
Si-mono	1.2
Si-poly	1.3
a-Si: tandem	3.3
a-Si-tripple	5
a-Si: H	1.8
CdTe	1.5
CIS	1.5
GaAs	1.3

Mathematical modeling of PV module and array

Output power of solar PV cell is low. To raise the power, the cells are connected in series and parallel arrangement on a module. For PV systems, the PV array is the group of several PV modules which are connected in series and parallel circuits to produce the desired voltage and current. Figure 2 shows this configuration (Natsheh, 2013).

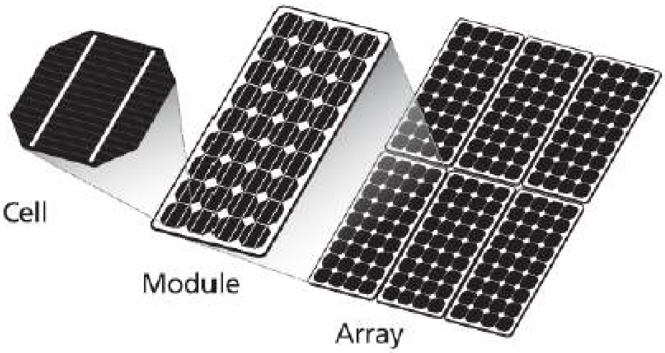

Figure 2. Configuration of photovoltaic cell, module, and array.

The equivalent circuit of the solar module is coordinated in NP and NS, it is illustrated in figure 3.

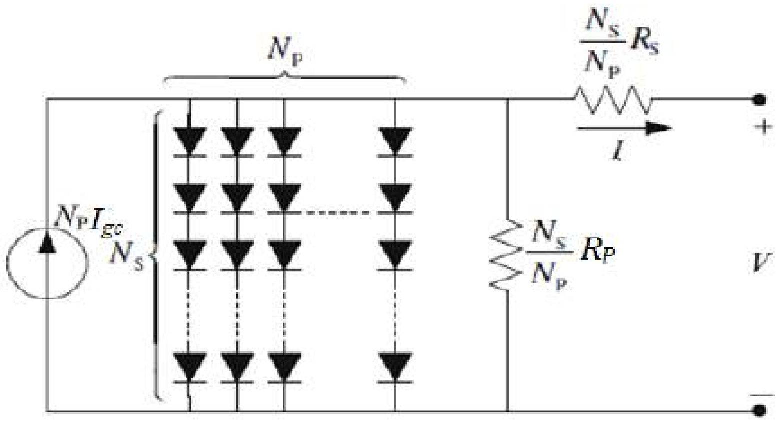

Figure 3. Equivalent circuit diagram of photovoltaic module.

The terminal equation for I_{PV}, to solar cell module goes out as follows (Kim & Youn, 2005)

$$\mathbf{I_{PV} = N_P I_{gc} - N_P I_{ds}\left[\exp\left(\frac{q}{K_B F T_c}\left(\frac{V}{N_s} + I\frac{R_s}{N_P}\right)\right) - 1\right] - \frac{{N_P}/{N_s}V + IR_s}{R_P}} \qquad (6)$$

Where NP: Number of parallel cells, NS: Number of series cells.

Photovoltaic characteristics

The PV modules are available in a range of sizes. Some are used in grid connected and others in standalone systems. Both types range from 80W to 300W. The performance of photovoltaic modules and arrays are generally assessed according to the maximum output of DC power according to Standard Test Conditions (STC). STC is achieved when the module operating at temperature (25º C) and the incident solar radiation level is 1 kW/m²; Since these conditions **do**

not always exist, PV modules and arrays operate with a performance of 85 to 90 % of STC (Kim & Youn, 2005). Table 2 presents the PV module (KYOCERA_ KC200GT) specifications which used in this thesis. All the data and numbers were taken from the data sheet (KYOCERA SOLAR).

Table 2. PV module specifications.

Solar Module Parameter	**KC200GT**
Maximum power (PMPP)	200.143 W
Open circuit voltage (Voc)	32.9 V
Voltage at MPP (Vmax power)	26.3 V
Short circuit current (Isc)	8.21 V
Current at MPP (Imax Power)	7.61 A
No. of cells (NS)	54
Diode ideality constant	1.3
Series resistance	0.221 Ω
I leakage	9.825x10-8 A

There are many factors that may affect the performance of photovoltaic panels, the changes in the shape of the power characteristic function depend on electrical connection, position of the nearby objects and of PV system, bypass diodes, time of the day, location, module mismatch, irradiance level, temperatures and technology.

3. Maximum Power Point Tracking

The major problem facing researchers and manufacturers in the using solar energy is to increase its efficiency, and meet the consumer's demand loads. The most efficient use of energy is one of the key options for obtaining sustainable global development in the 21st century. The output power of solar cell systems (PV) changes with the varying of solar irradiance and ambient temperature. Because of the nonlinear current–voltage (I–V) characteristics of the PV, there is a unique MPP on the power–voltage (P–V) curve. MPPT is an important technology to improve the overall efficiency of solar cell systems.

When generating power from solar cells, the output power must be produced with maximum efficiency by working always at the highest point of power (peak power point), regardless of changes in weather conditions and load. To apply this, MPPT technology is implemented to ensure maximum power transmission during the operation of the solar module that traces the maximum power output from differences in weather conditions. The MPPT is an electronic device that is mainly introduced between the PV module and the load. This technique consists of two important parts, as shown in figure 4, a DC to DC boost converter with MPPT control technique to operate the PV system, In a way that enables it to deliver maximum power to the load.

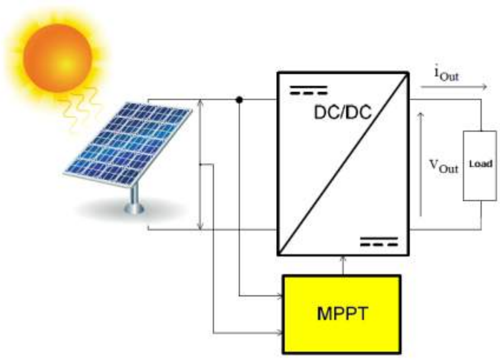

Figure 4. PV with MPPT technique.

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The maximum output power of the solar system is changed by varying in solar radiation and temperature of the cell, and the electrical characteristic of the load may also change. So, the photovoltaic module internal impedance rarely matches the load impedance. It is important to operate the photovoltaic generation system at the maximum power point or near to it to guarantee the optimal utilization of the available solar power. The primary aim of the MPPT is to match these two parameters by adjusting the duty cycle of the converter. Because the maximum power point changes in the I-V curve in an unexpected way, it cannot be defined in advance because of changes in the temperature of the solar cells and the radiation changes. Therefore, MPPT technique or calculation model should be used to determine this point (Cheikh, Larbes, Kebir, & Zerguerras, 2007; Enrique, 2009).

A characteristics curve of PV module I-V curves is illustrated in figure 5, and the P-V curve is presented in figure 6.There exists a single maximum power corresponding to a particular voltage and current (Cheikh et al., 2007).

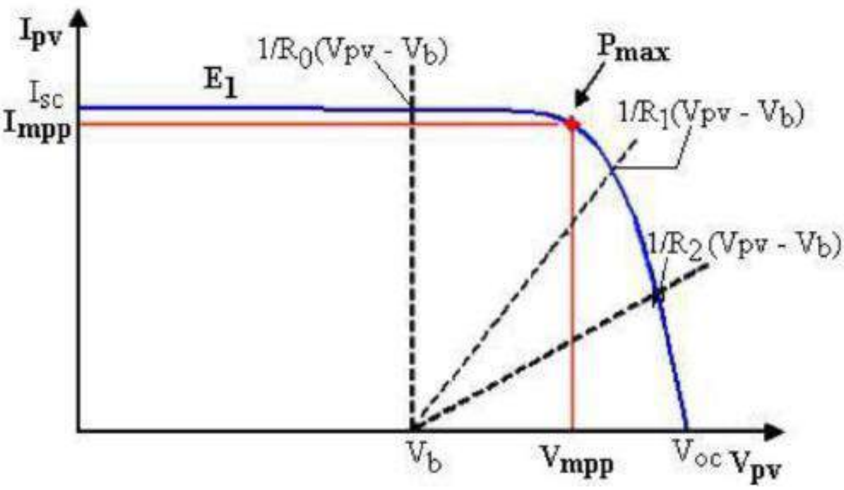

Figure 5. I-V characteristics curve of PV module.

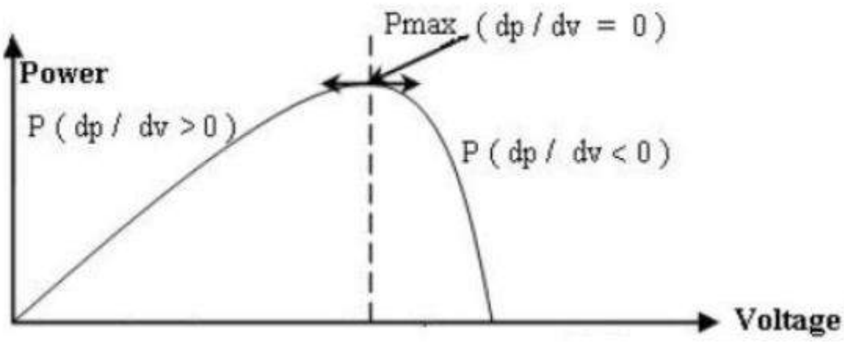

Figure 6. P-V characteristics curve of PV module.

The DC / DC boost converter is considered the most important component of an MPPT system. The same converter is applied for an MPPT to provide load matching for the maximum power transfer by regulating the input voltage at the PV module MPP by controlling the duty cycle. If the PV module is joined to a load directly, its operating point will be determined by the intersection of the load and PV generation curves as illustrated in figure 7. Thus, there is only one point where both curves intersect each other at MPP. The generation curve nonlinearly varies with the variation of the irradiation G and temperature T, while the load curve has a various characteristic according to the type of load is joined to the PV module. And therefore, DC / DC converters are used to join the PV module with the load, so as to guarantee the PV module is always working at the MPP. This is achieved by controlling the converter duty cycle with MPPT technique (Mohan & Undeland, 2007).

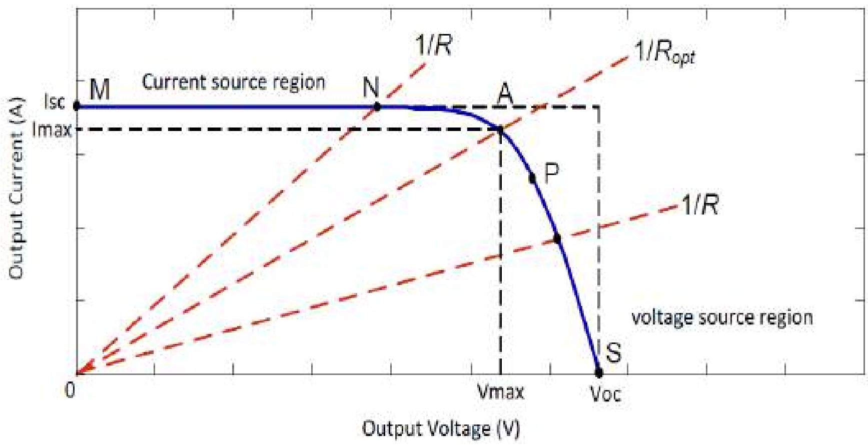

Figure 7. Intersection of the load characteristic with PV generation curve.

The output voltage of the boost converter is always larger than the input voltage, so the step up converter can be applied with MPPT systems, where the output voltage must be larger than the input voltage. Circuit diagram of the step up converter is shown in figure 8 (Messenger & Ventre, 2010).

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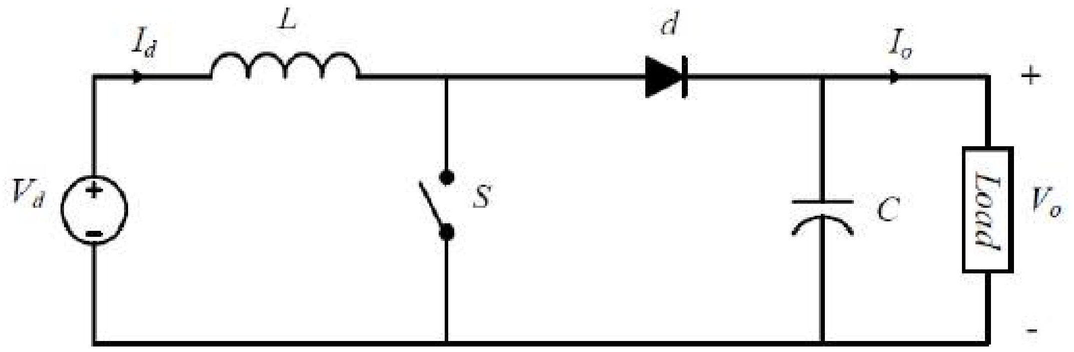

Figure 8. DC-DC step up boost converter.

Therefore, the current passing through the inductor rises linearly due to the source of the input voltage, in which case the output phase is isolated and the capacitor is partially discharged to provide the current load. When the switch is off during the second period the diode is conducting, and during this time the load receives energy from both the inductor and the input source. The signal form of the inductor current during continuous conduction mode is illustrated in figure 9. When the converter is running at steady state condition, the duty cycle, D, can be calculated as follows (Kasat, 2004; Mohan & Undeland, 2007).

$$\boldsymbol{D = 1 - \frac{V_d}{V_o}} \qquad (7)$$

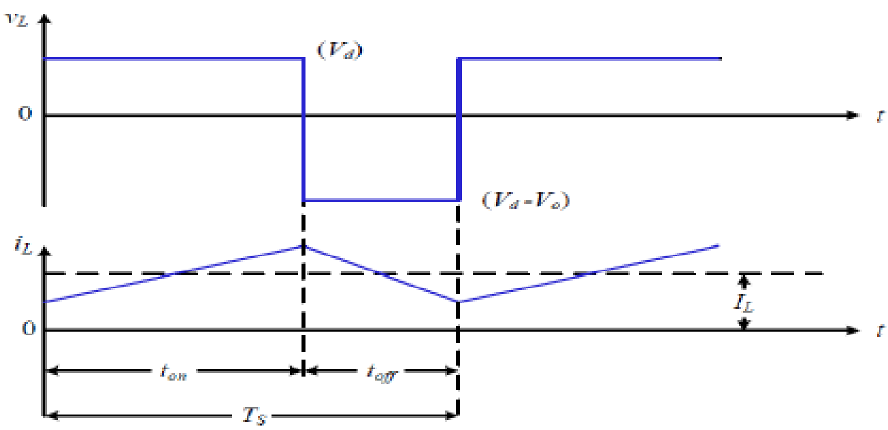

Figure 9. Step-up converter signal form of the VL and IL in continuous conduction mode.

Where Vd input voltage and Vo output voltage of the converter. In addition the modification of the duty ratio results in a change in the input and the output current of the boost converter.

The filter inductor and capacitor to operate the converter in the continuous conduction mode can be calculated as follows (Kasat, 2004);

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$$\mathbf{L} = \frac{\mathbf{V_d D}}{\mathbf{2\Delta I_L f_s}} \qquad (8)$$

$$\mathbf{C} = \frac{\mathbf{I_o D}}{\mathbf{\Delta V_o f_s}} \qquad (9)$$

4. Artificial neural networks

You receive a highly interconnected set of some 10^{11} neurons to facilitate your reading, writing, movement, breathing, thinking and so along. Each of your biological neurons, a rich assembly of tissue and chemistry, has the complexity, if not the speed, of a microprocessor. Some of your neural structure was with you at birth. Other parts have been shown by experience (Hagan, Demuth, & Beale, 1996).

It consists of a number of very simple and highly interconnected processors, called neurons, which are correspondent to the biological neurons in the brain. The basic model of a single neuron is illustrated in figure 10, which, p an input vector, w a connection weight vector, b a bias , f an activation function and a an output (Haykin, 1998).

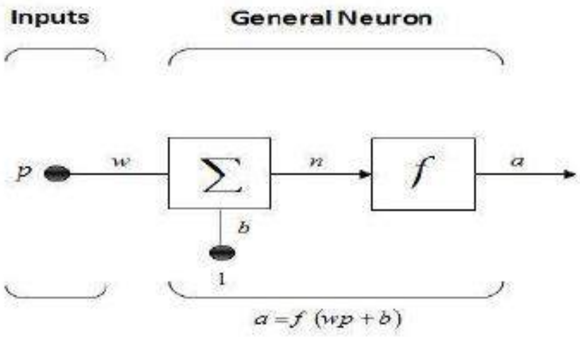

Figure 10. Basic model of single neuron.

The summation output, often mentioned to as the net input, goes into a transfer function f (also called activation function) $a = f(W_P + b)$:

$$\boldsymbol{a = f(W_P + b) = f(w_{1,1}p_1 + w_{1,2}p_2 + \ldots\ldots + w_{1,R}p_R + b)} \qquad (10)$$

There are three main activation functions used commonly in neural networks, the activation function f can be got from a set of activation functions as a hard limit function, piecewise-linear function, sigmoid function (Hagan et al., 1996).

ANN may be one or more hidden layers, the structure is determined by experience and trial and error. And there are two types of machine learning based on ANN, one is called supervised learning where the other is called unsupervised learning (Scott, 2008).

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There are many different algorithms are utilized to train the ANN, including Backpropagation, Quasi-Newton, Conjugate Gradient, Kohonen training, Delta-bar-Delta and Levenberg Marquardt. To train the multilayer feedforward network, the Levenberg Marquardt algorithm is generally recommended due to its robustness, providing fast convergence and the user does not necessarily to initialize parameters (Resende, 2012).

ANN technique is used with MPPT to optimize the response of the MPPT, in order to increase the efficiency of PV module.

5. Model and Calculation

In this paper, KYOCERA – KC200GT PV module is taken as an example. PV model was constructed and applied by using Matlab / Simulink to verify the nonlinear I-V and P-V output characteristics. The schematic of the PV module is implemented and illustrated in figure 11.

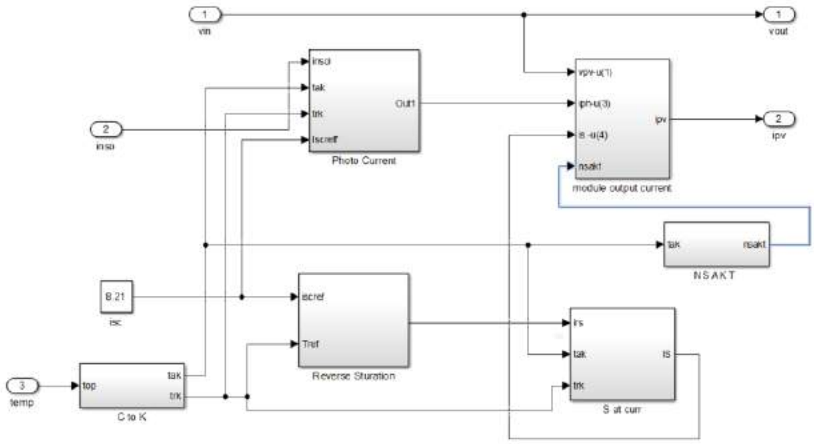

Figure 11. Detailed schematic diagram (sub systems) for the PV module.

The PV model was simulated and illustrated in figure 12.

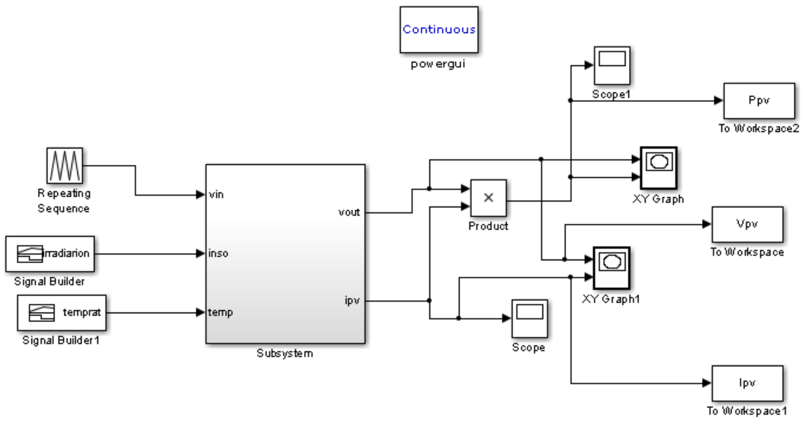

Figure 12. The schematic of PV module.

The P-V and I-V output characteristics of the produced PV module are illustrated in figure 13, also, from this figure we can see the nonlinearity of the output power and the output current which depend on the solar irradiance and the temperature of the cell, and the cell terminal operating voltage as well.

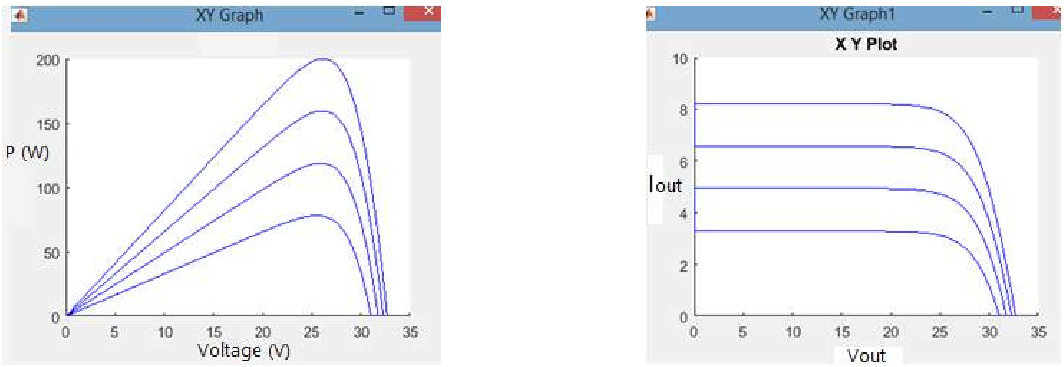

Figure 13. P-V and I-V output characteristics at 25°C.

It was found from figure 13 that, the voltage and current output both increases when the irradiations are increasing, so the maximum power output of PV module are increasing.

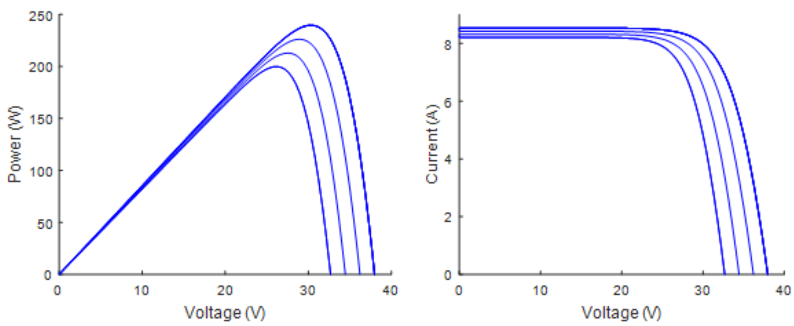

Figure 14. P-V and I-V output of varying temperature and fixed irradiation.

As we observe from figure 14, increasing in the input temperature will cause the output current increases while the voltage decline accordingly. This contributes to decrease the output power of the PV module.

The design specifications of boost converter are shown in Table 3. The specifications are for a variable value of the input voltage of the boost converter where the input voltage comes from the renewable source and the output voltage of boost converter is fixed to 45V DC.

Table (3): Specification of Boost Controller.

Parameter	Value
Input Voltage	26.3Vdc
Power Converter	200.143 w
Output Voltage	45Vdc
Output Current	4.5A
Switching frequency f_S	20kHz
Percent of output voltage	1
Efficiency n	0.9

$$D = 1 - \frac{V_{in} \times n}{V_{out}} = 1 - \frac{26.3 \times 0.9}{45} = 0.526 \rightarrow D = 52.6\%$$

$$I_{out} = \frac{P_o}{V_o} = \frac{200}{45} = 4.45\ A$$

$$di = I_{ripple} \times I_{out} \times \frac{V_{out}}{V_{in}}$$

I_{ripple} a good estimation of the inductor ripple current is 20% to 40% of I_{out}

$$di = 0.4 \times 4.45 \times \frac{45}{26.3} = 3.1$$

$$L = \frac{V_{in} \times (V_o - V_{in})}{d_i f_s V_o} = \frac{26.3 \times (45 - 26.3)}{3.1 \times 20000 \times 45} = 1.763 \times 10^{-4}\ H$$

$$d_{vo} = V_o \times \frac{1}{100} = 45 \times \frac{1}{100} = 0.45$$

$$C_{out} = \frac{I_{out} \times D}{d_v f_s V_o} = \frac{4.45 \times 0.526}{20000 \times 0.45} = 2.6008 \times 10^{-4}\ F$$

$$C_{in} = \frac{I_{in} \times (1 - D)}{d_{vin} f_s V_{in}} = \frac{7.61 \times (1 - 0.48)}{20000 \times 0.26} = 693.681 \times 10^{-6}\ F$$

$$R = \frac{45}{4.45} = 10.11\ \Omega$$

D = 48 % , L = 1.771e-4 H, let ΔV = 0.45; so capacitance C = 2.373e-4 F, R = 10.11 Ω.

The output characteristics of the PV module are nonlinear. Moreover, the solar irradiance is changed continuously and unpredictable, so the maximum power point varied continuously.

To design an ANN model, "nnstart" or "nntool" function is used to create the ANN model. The proposed ANN in this thesis is a multilayer feed forward back propagation NN, which consist of two layers which are hidden layer and output layer. Inputs on this design are irradiance and temperature also the output of the ANN model is a voltage at maximum power.

Neurons number in each layer and structure of multilayer feed forward propagation NN are mostly variable and thus determined by experience and trial and error. So many of the trials are implemented until reaching the best design. And the final design consists of hidden layer constructed of 5 neurons whose activation function is a tangent sigmoid and the output layer has 1 neuron which activation function is a pure linear transfer function. The building of the ANN is illustrated in figure. 15.

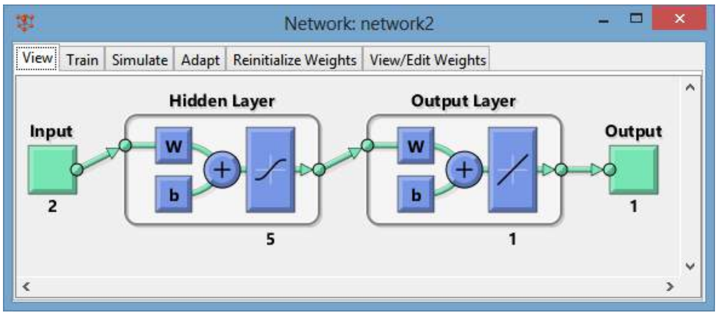

Figure 15. The training network model in MATLAB.

The "trainlm" tool at Matlab is used to train the ANN using Levenberg-Marquardt, so the ANN is trained to discover the relationship between inputs (irradiation and temperature) and the output (maximum voltage) as shown in figure 16.

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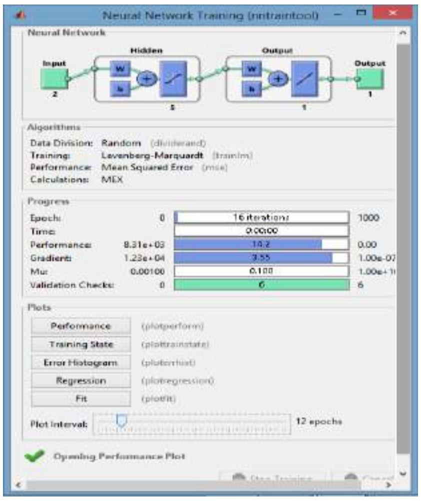

Figure 16. Training neural network.

MSE with different epochs, training state plot and the R plot are presented in figures. 17, 18, and 19 respectively.

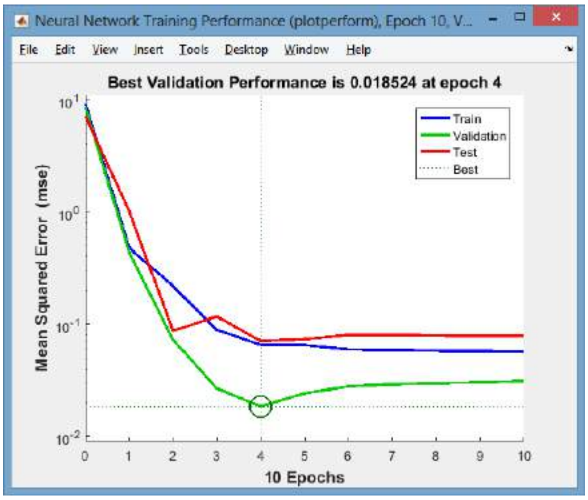

Figure 17. Training result of ANN block.

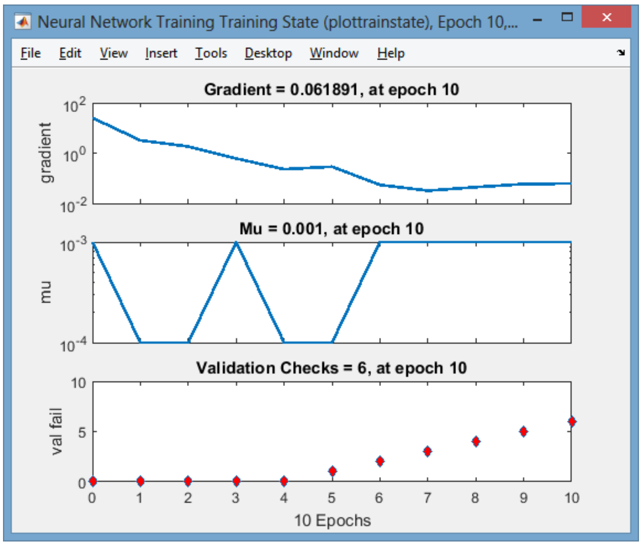

Figure 18. The plot training state for ANN.

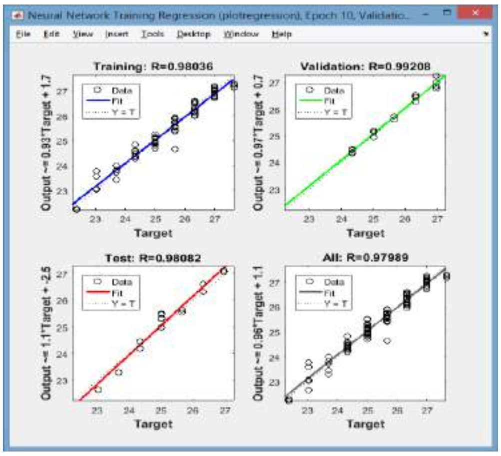

Figure 19. The regression plot performance analysis.

Then the trained NNs can get an optimum voltage for MPP under different atmospheric cases and the output of the ANN model is applied to determine the duty ratio, as shown in the next sections. The trained ANN model for MPPT is illustrated in figure 20.

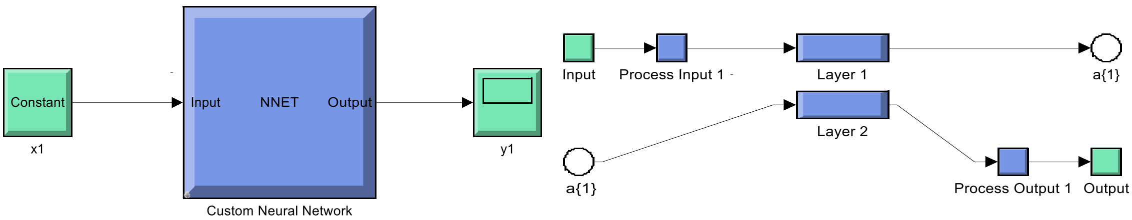

Figure 20. Block diagram of ANN with two layers.

The complete system with the ANN MPPT controller was designed as shown in figure 21, the system was tested with multi cases and the designed system is compared with the direct connected System (DCS) wich is directly connected with load without using MPPT technique. the outcomes are illustrated in figures. 22, 23, 24 and 25. The simulation results show that the output power of a PV module is greater when the ANN technique is connected to the MPPT controller at all variables radiation and temperature than the DCS as observed in figures 24 and 25. This yields an indication that, the DCS is working far from the maximum power point all the time. Thus, when the radiation varies the ANN model controller calibrates the duty cycle, to get the operating points where the power is at the maximum value (MPP), and that happened by decreasing the PV current operating point and increase the PV voltage operating.

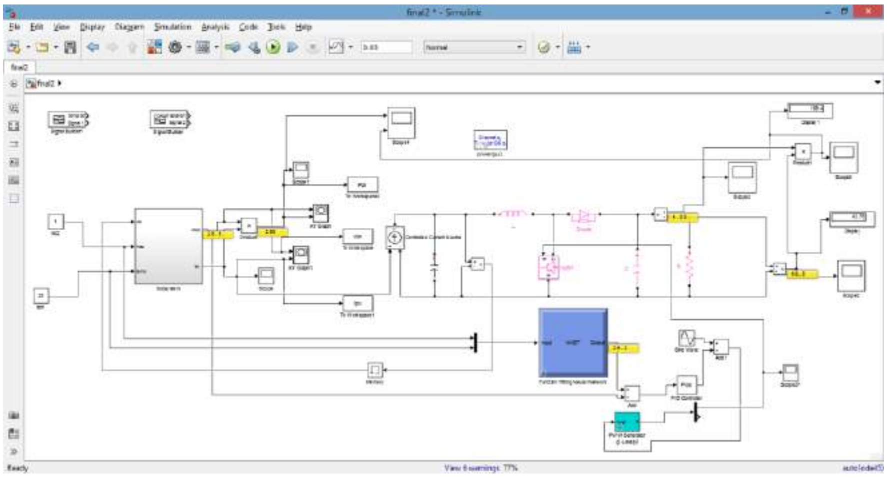

Figure 21. The complete MPPT system with ANN network.

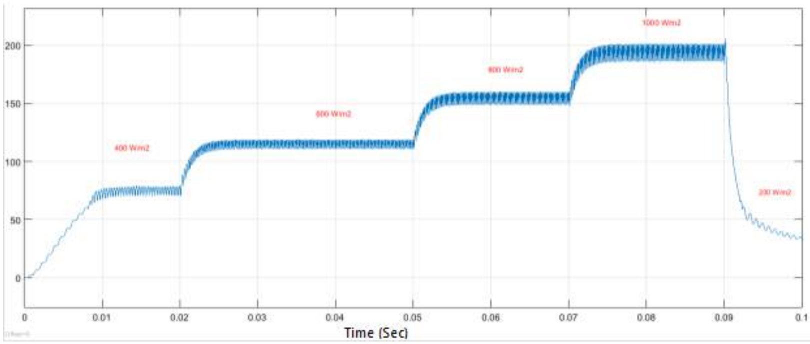

Figure 22. Output Power for MPPT system with ANN network with variable irradiation and constant temperature (25˚C).

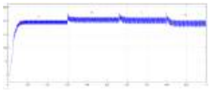

Figure 23. Output Power for MPPT system with ANN network with variable temperature and constant irradiation 1000 W/m2.

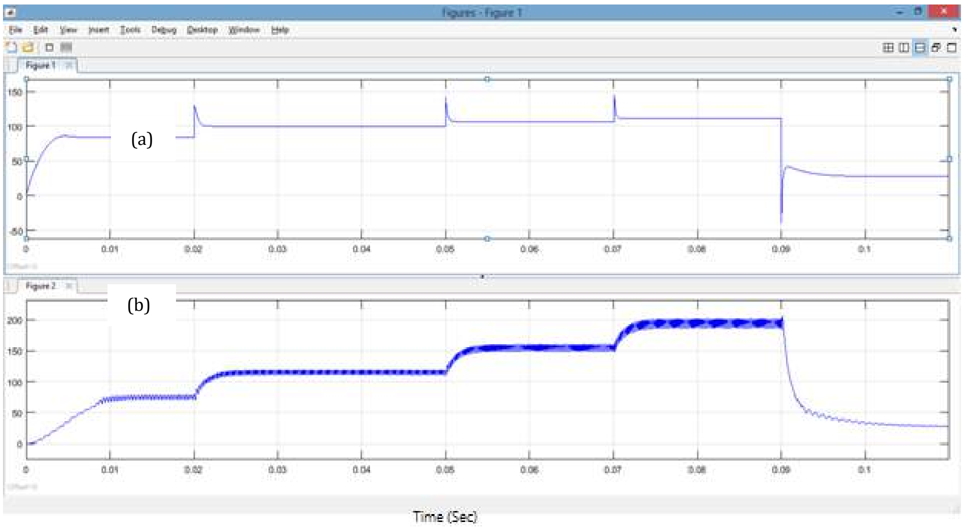

Figure 24. PV system with (a) the direct connected system compared with (b) ANN MPPT controller with variable irradiation and constant temperature.

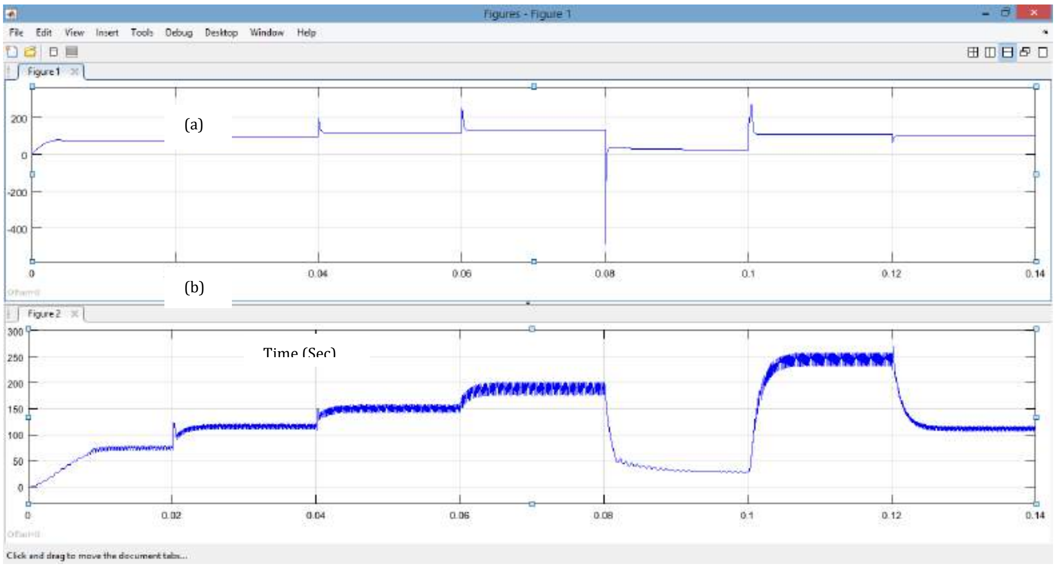

Figure 25. PV system with (a) the direct connected system compared with (b) ANN MPPT controller with variable irradiation and variable temperature.

From the diagrams and previous results the Artificial neural network technology shows a quick and accurate response, according to sudden solar radiation change. Figs 22, 23, 24 and 25 show that, the output power of the photovoltaic module changes as the solar irradiance varies at different time periods, And thus results in a change in the maximum power value, so changes must be detected and handled by the ANN MPPT controller technique by changing the value of the duty cycle. The designed system ANN MPPT controller can increase the total efficiency of the system by more than 14 % higher than the system without an MPPT controller.

At the direct connected system without ANN MPPT controller is working at a lower PowerPoint than the MPP and has a slower response to solar radiation changes. On the other hand, the directly associated without MPPT technique has less efficiency because of the mismatch between the photovoltaic module and the load. These cause loss of energy so that the ANN MPPT technique is better and saving energy.

In addition, the ANN MPPT technology shows the ability to adapt rapidly to the rapid change in radiation and to avert the accompanying deviation from the maximum power point.

Finally, we can say in general that the ANN controller, which is applied to MPPT technique is effective to track the maximum power point and this technique can increase the efficiency of the PV module when rapid change in radiation and temperature occur.

6. Summary

Recently, solar energy has become increasingly and effectively used worldwide because of the increasing demand for energy and fossil fuels begin to diminish, also the huge pollution resulting from its use.

In particular, Gaza Strip suffers from a severe shortage of electricity, reaching a maximum at 2017, where the power failure period from 12 hours to 14 hours continuous, while the link period is about 4 to 6 hours per day. Also lack of fuel, noise and pollution resulting from the use of electrical generators, led to reduce the use of electrical generators, so residents resorted to using solar energy as an alternative solution, effective and clean. Which it available all the time.

Because of the relatively high cost of the solar system, the overall efficiency of the solar cell system should be increased to reduce the use of a large amount of solar panels; so MPPT technology has been used to improve the efficiency of the solar cell system.

An artificial intelligent maximum power point tracking technique using neural networks is proposed, which predicts the appropriate duty cycle for which the DC-DC converter can operate with and thus the maximum power can be obtained from the PV system. The system comprises of PV modules, DC-DC boost converter and ANN controller to get MPPT. Each component is simulated and discussed in details using MATLAB/SIMULINK software. The PV model was verified The ANN MPPT method is designed and developed and it is compared with the direct method without MPPT system.

Also DC-DC boost converter model is simulated which is the key for changing the PV's terminal voltage to track the maximum power.

The system is tested by the artificial neural network MPPT method under the sudden irradiance and variable temperature, and the ANN method gave very fast and accurate response. Where an ANN MPPT controller has been designed and implemented; so the designed system increased the overall efficiency of the solar system by more than 14%.

7. Future Directions

Using hybrid control consists of P&O technique with an ANN control to eliminate the oscillation around the MPP in steady state. Also a good area of research to implement Fuzzy control and compare it with ANN control. Another area which it is Implementation of a physical model for MPPT controller with an artificial neural network technique using microcontrollers and applying it on a real PV panel.

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