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Improving the performance of photovoltaic module during partial shading using ANN

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ABSTRACT

Photovoltaic (PV) panels have drawback of having their peak power reduced when clouds or shade are present. Furthermore, it is only available while the sun shine. Nearby structures, plants, bird droppings, and other obstacles shade operating photovoltaic (PV) devices, effectively reducing the incident solar radiation produced by the modules. When these PV panels are exposed to partial shading, their power efficiency is reduced. A neural network with a kind of artificial neural network is used in the suggested hybrid method (ANN). The key focus of this article is to use environmental effects dependent on partial shading to get the maximum performance from a solar system. The suggested hybrid solution is tested in the MATLAB/Simulink working platform using partial shading test cases, and the efficiency is compared to other approaches. Additionally, the best options for the suggested procedure, current, voltage, and power are examined.

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1. INTRODUCTION

Over the last ten years, the global solar PV market is expanding significantly, and it now plays an essential part in renewable energy implementations, particularly in residential, agricultural, and industrial settings [1]. Because of environmental issues, green energy resources have recently received a lot of focus. Because of the advancement of photovoltaic (PV) fabrication technologies, photovoltaics (PVs) has gained a lot of attention among renewable energy sources [2]. PV modules are made up of PV cells that are electrically linked.

The main issue with PV is that it loses energy production due to variations in solar light, partial shading, orientation, pollen, and bird droplets [3]. As a result, it is critical to employ strategies that increase the PV system's energy consumption. To meet the load demand, the PV modules have a connection in series and/or parallel [4]. PV modules have the advantage of being extremely scalable, and with proper sizing, they can be assumed to have sufficient power for a large range of loads [5].

PV modules have evolved into stable and dependable power sources with a 20-to 30-year lifespan. Normal test conditions (NTC) are used to rate their efficiency (i.e., Temp. = 300 K, the solar irradiance = 1 kW/m^2, in addition to Air Mass 1.5). The difference between real-world operational conditions besides STC ratings causes a difference in predicted PV output. The combined identification and diagnosis of open circuit, decay, as well as partial shading has been suggested by some researchers [6], [7], wherever the PV curve of module's current-voltage considers a significant index to classify the output of PV modules.

Many developments have occurred as a result of the growing popularity of PV-based energy, allowing it to improve its efficiency while also lowering its cost. Single-crystalline silicon-based PV cells also have a 28 percent higher performance thanks to recent advances in silicon manufacturing [8]. Furthermore, several sophisticated maximum power point monitoring algorithms are now available, allowing for greater energy harvesting from a PV panel. Despite these advancements in solar energy processing, PV modules also use a fixed topology based on series-parallel (SP) [9], [10]. Photovoltaic (PV) devices are in charge of making conversion of solar energy into electrical energy. Such devices are made up of multiple integrated PV cells forming a package that provides sufficient security for the cells while also providing values of voltage and electric current which may be utilized in operation [11].

As an alternative to the SP-based PV module with bypass diode, a PV module with complementary metal oxide semiconductor (CMOS) switches has recently been proposed [12]. PV modules with switches have been seen in experiments to be more prepared to deal with partial shading, distortion problems, and unstable situations. Furthermore, similar PV modules can be restructured in real time (i.e., the number of PV cells attached in series versus parallel changes), allowing for the creation of a power island.

For improving the efficiency of the quest for maximum power point, some brilliant training-based algorithms like artificial neural networks (ANNs) or fuzzy logic were created. Smart controllers, including the fuzzy logic system, outperformed perturb & observe (P&O) controllers in some cases [13]. Furthermore, compared to the P&O approach, the neuro-fuzzy hybrid intelligent control scheme shows certain advantages [14]. Furthermore, certain artificial neural network training methods have been established so that to speed up the quest for the point of maximum strength. P&O, or maximum power point searching, may be utilized to practice a neural network, resulting in an optimum increasing or reducing duty ratio in the maximum power point orientation [15]. Many PV installations were using MPPT controlling, which means that the output energy varies with variations in irradiance strength as well as other environmental conditions. Furthermore, variations in output energy can be caused by electrical restrictions and PV system power.

2. PV SYSTEM MODELLING

The PV equivalent circuit when light is irradiated can be represented in Figure 1. The shunt resistance Rsh denotes for the leakage resistance characterized by a constant resistance, that is far off the ideal diode characteristics [16]. Meanwhile the PV voltage and current relationship considers strictly nonlinear, so that PV modeling could be presented for performing a complete scheme simulation so as to accurate system achievement characteristics.

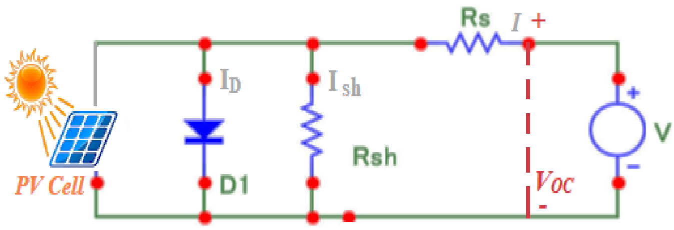

Figure 1. The equivalent circuit of the PV module

In an array of PV, the series and parallel cells number gives a characteristics of an open circuit voltage in addition to short circuit current as shown in:

$$V_{OC} = N_s V_{oc}$$
$$I_{SC} = N_p I_{sc} \quad (1)$$

Partial shading, in which the photo-generated current of shaded cells decreases as opposed to unshaded series-connected cells, is one of the main challenges for PV modules. The shaded PV cells would be reverse-biased without the bypass diode, resulting in actually destructive reverse breakdown voltage and hotspots loss. If the ambient temperature rises, the PV modules' open-circuit voltage Voc decreases linearly (and depending on the temperature coefficient of Voc), while the short-circuit current Isc rises linearly as the incident solar irradiance rises [17].

The characteristics I-V and P-V of the PV can be achieved is being as [18]:

$$I_{ph} = I_{sc}\, S_N + I_t\,(T_c - T_r) \tag{2}$$

$$I_d = I_O \left[\exp\left(\frac{q\,(V_L + I_L R_s)}{AkT}\right) - 1\right] \tag{3}$$

$$I_o = I_{or} \left[\frac{T_c}{T_r}\right] . \exp\left(\frac{q\,E_g}{BK}\left(\frac{1}{T_r} - \frac{1}{T_c}\right)\right)$$

$$I_L = I_{ph} - I_d - \frac{V_L + I_L R_s}{R_{sh}} \tag{4}$$

In (3) is effective with constant irradiation level besides with specific operating cell temperature Tc. The characteristics of I-V and P-V with numerous levels of irradiation by the side of constant temperatures may achieved by determining the PV, current & voltage, in addition to power can be seen in Figure 2. The PV cell characteristic current can be reformulated as:

$$I_L = I_{ph} - I_{sh}\left(e^{\frac{V + I_L R_{sh}}{nV_L}} - 1\right) \tag{5}$$

where, I_{sh} represents the diode saturation current, V_L indicates to the thermal voltage, I_{ph} designated for light generated current. If open circuit condition is applied, I_L equal to zero and (5) is rearranged as:

$$0 = I_{ph} - I_{sh}\, e^{\left(\frac{qV}{nV_L}\right)} - \frac{V_{oc}}{R_{sh}} \tag{6}$$

and ID can be considered as reverse saturation diode current that can express as:

$$I_D = \left(I_{ph} - \frac{V_{oc}}{R_{sh}}\right) e^{\left(\frac{qV}{nV_L}\right)} = \left(\frac{I_{sc}(R_{se} + R_{sh}) - V_{oc}}{R_{sh}}\right) e^{\left(\frac{qV}{nV_L}\right)} \tag{7}$$

Owing to the existence of obstacles in the surrounding of PV systems built in an urban environment, it is typical for the installation to experience shading. The effect of shading can be determined by a number of variables, including the form of PV module, bypass diode configuration, string configuration, and the quality of the shadow. In the occasion of partial shading moduling, the losses power will be correspondingly greater than the shaded field, and there may be loss owing to an inconsistency of the electrical current between the modules in the same line, besides an inconsistency of the electrical voltage in parallel strings within the same array [19].

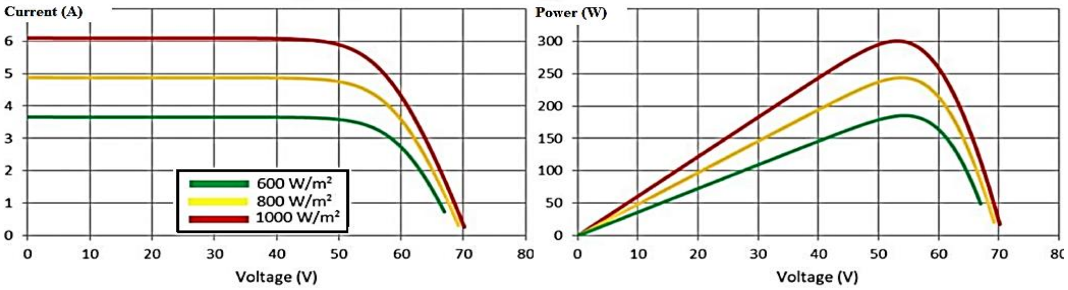

Figure 2. The characteristics of voltage-current and power-current with many irradiation levels at constant temperature

As seen from Figure 1, the irradiance as well as temperature has a change during the day, so that current, voltage, and power also change for consequences. Figure 2 demonstrate the I-V and P-V with irradiance differences, respectively. For acquiring the preferred values of current and voltage within PV module, series or parallel PV cells can be configured. Solar cell considers for PN junction formation that employs the sun light to create photo current then run as a diode within the shadows or darkness [20].

The bypass diode approach has been selected primarily employed in commercial devices. While it accomplishes for sufficiently handle the hot spots phenomenon besides reservation the modules life, here there is still a substantial matter concerning the P-V curve deformation. This aspect can be seen with Figure 3, that explain how the energy recovery is providing by the manner can be perceived, along with P-V curve distortion. Furthermore, an observance as a result of the power curve distortion, conventional MPPT techniques like perturb and observe (P&O) and incremental conductance (Inc Con) consider inactive and passive [21], they can also definitely get missing in any of different local maximum power points (LMPPs), therefore necessity for more applicable approaches is direct this problem.

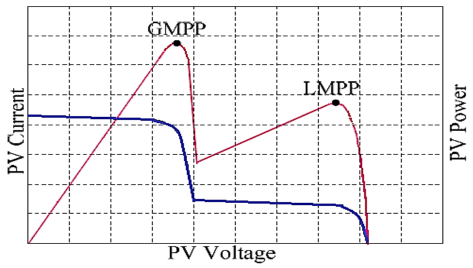

Figure 3. PV, V-I, and V-P characteristics under partial shading

Shading has a detrimental affect on solar PV system performance via lowering power output and producing irreparable damage to PV modules through the hotspots creation. It's easy to assume that the reduction in power output is equivalent to the area of shaded module, and that could be accurate for a single shaded cell. Shading can be applied to a single module cell, a whole module, or an array. Shadings are divided into two categories: 1) objective shading, which is produced by situations further than human control that diminish the sun's total intensity, such as cloud cover, haze, fog, or heavy pollution; and 2) subjective shading, which is caused by items blocking incoming solar energy and resulting in shadows. Dynamic shading is generated by things that cast shadows dependent on the angle of the light, whereas static shade is generated by blocking things such as bird droppings, accumulated dirt, leaf droppings, and so on.

3. PARTIAL SHADING CONDITION ON THE PERFORMANCE OF PHOTOVOLTAIC SYSTEMS

Environmental conditions, along with installation angles, have an impact on the solar system's performances and efficiencies. The suggested technique evaluates the system's performance using partial shading. Due to the existence of impediments in the proximity of PV systems deployed in an urban context, it is normal for the installation to experience some shading [22], [23]. The influence of shading will also be determined by a number of parameters, including the kind of PV module, bypass diode setup, string configuration, and the form of the shadow. The power loss could be correspondingly great when compared to the shading area in the partial shading situation of the module, and there will be loss owing to the inconsistent of electrical current among the same string modules, as well as a loss for the electrical voltage mismatching in parallel strings founded in the identical arrays, in addition to the energy losses owing to shading [24].

With the purpose of minimizing the effect on shading’s power generation in PV system, a proposed module has bypass diodes that, once polarized, redirect the current away from that substring. When the cell's electrical current is lowered by shading, so that it is convenient with the substring current, then the cell needs to be reversely polarized to act like a charge. Such bypass diode when polarized at a condition of substring total voltage stands less than zero, forcing the cell to run near to the voltage [25], [26]. At that point, individual curves of each substring besides the string's series-parallel arrangement will result in the current versus voltage curve of a PV array.

The performance of photovoltaic systems is also influenced by shadowing from numerous sources such as clouds, trees, surrounding structures, and so on. As a result of this phenomenon, the sun's radiation does not reach the panel adequately, resulting in a variety of distinct radiations in the panel. When all of the photovoltaic cells are shaded, the PV output power is extremely low. Solar PV produces a single peak output when exposed to homogenous radiation. Because the PV panel is partially covered, it is difficult to track the maximum power point (MPP). As a result, a new technique is required to track the MPP of the PV system in partial shadowing [27], [28]. When PV system is partial shading, then a converter’s global maximum power point tracking action (GMPPT), aims to locate the greatest global energy generation value from the multiple I-V curves of the module arising from the various partial shading situations [29]. The optimization procedure will next attempt for adjusting the DC-DC converter's operational such that it produces the highest output power, independent of partial shading.

4. PARTIAL SHADING SIMULATION RESULTS AND DISCUSSION

The ANN consider the earliest artificial intelligence paradigms, that simulate data processing deals with person brain over biological neural networks. Figure 4 demonstrates the arrangement of the multi-layer feedforward perceptron ANN in layer architecture that consist of processing units named neurons. The input signals are received by input layer and the outputs yield from the output layer, with single or multi hidden layers internally treating the signals. The artificial neurons function can be motivated with their expected counterparts and every neuron have numerous weighting input signals in addition to one output, while a fixed activation function is governing the connection between the collecting inputs and output [30]. The back-propagation algorithm can be utilized on the ANN to conform the weights related with their links for error minimizing between output and a based training dataset. Though, the hidden layers’ number with their neurons can be preferred by users by a designing process.

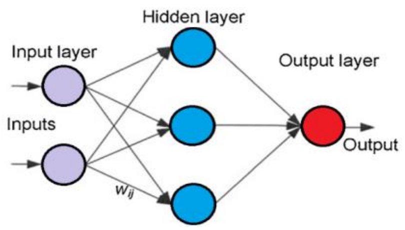

Figure 4. Multi-layer perceptron feedforward ANN

In this section, the description and analyses result of proposed ANN are given based on many factors like environmental and installation that have affect the PV system performances. The execution of this approach is made with MATLAB platform to find the extraction of the PV maximum power besides improvement of their efficiency the power quality under partial shading situation. The PV performances are focused on the main parameters like current, voltage and power system which analyzes based on various components.

As it reported, the shading effect is reducing the PV system performances. Hence, PV performance represented by the generated daily output power with partial shading condition can be shown with two modules at different characteristics. The irradiance variances along with constant temperature of these two PV modules under partial shading for every day can be seen in Figure 5. The irradiances of these modules are converting from 0 to 1000 Wm^{-2} with increasing and decreasing for 15 hours period, simultaneously the PV temperature seem to be constant all the day to about 25 ºC. Figures 5 (a) and 5 (b) show the irradiance variances for these two modules.

The generated output power from PV system in addition to the voltage and current, as a result of daily output power under partial shading can be seen in Figure 6. Here the output voltage is progressively increasing from 0 to reach 200 V as obviously displaying in Figure 6 (a) in between the time period of 0 to 16 hours which represent the total constant irradiance during the day then its decreasing gradually to attain 100 V within 24 hours, while the PV current can be seen in Figure 6 (b) under partial shading. The same procedure can also be applied to PV output current that has progressively increasing from 0 to reach 180 A within the same period of 16 hours. After that the output current will be in ranged way for reaching more 100 A. While, the PV generating output power by applying ANN method under a condition of partial shading can be seen in Figure 7 with a highest output power is more than 7000 W; the increasing value being gradually started from 0 to 16 hours, formerly it step by step will be reduced to 4000 W approximately within nest two hours. The rest of six hours have a rotation of increasing and decreasing values to reach 4000 W at 24-hour period. The output power generated with previous method like SSA and GBDT is less than the power generated to ANN which is higher to 8000 W.

Finally, the inverter power of the PV system can be seen in Figure 6. Here, an increasing power of the Inverter is gradually started at the first 2 to 5 hour from 0 to 3500 W. At that moment it slightly changed for the next 6 hours, while the next 5 hours, the power reach the maximum value of 6000 W which means that for 15 hours. After that it step by step the power will be decreased for reach the value of 2000 W. Afterward it increased and decreased to reach the range of 2000 W constant value within 20 to 24-hour period.

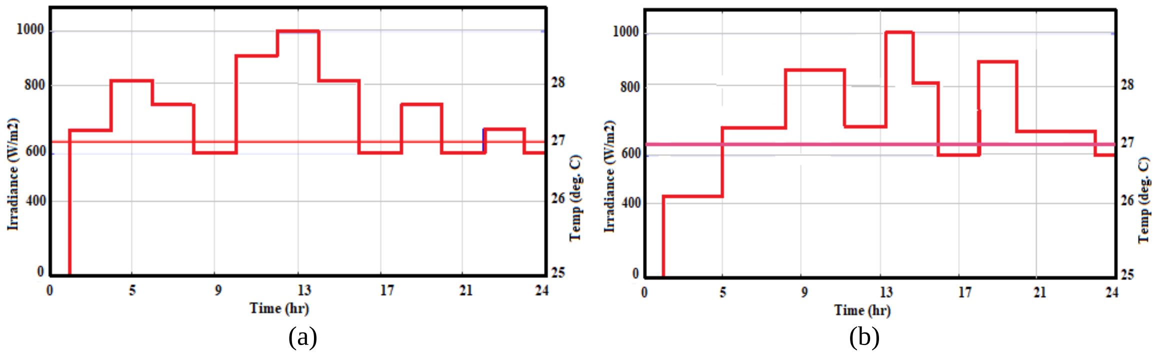

Figure 5. Irradiance variations of PV with partial shading at constant temperature, (a) PV1, (b) PV2

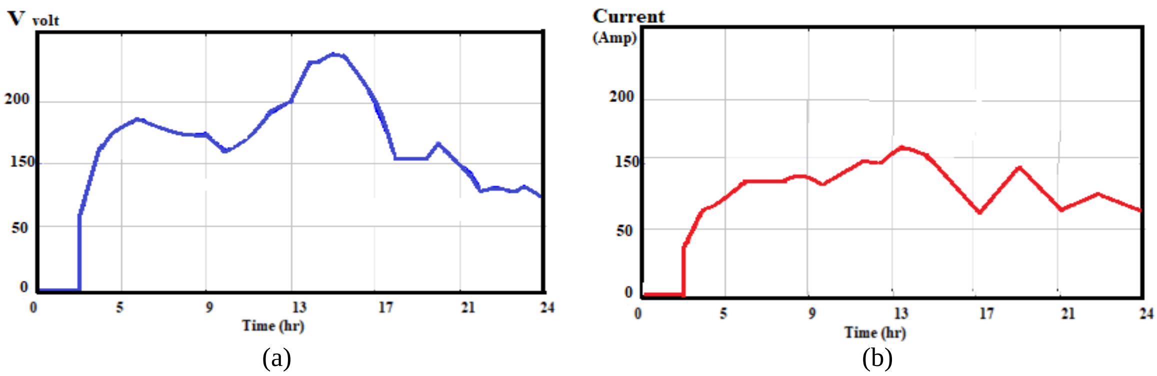

Figure 6. Performance and comparison of PV voltage and current under partial shading, (a) V volt, (b) PV current

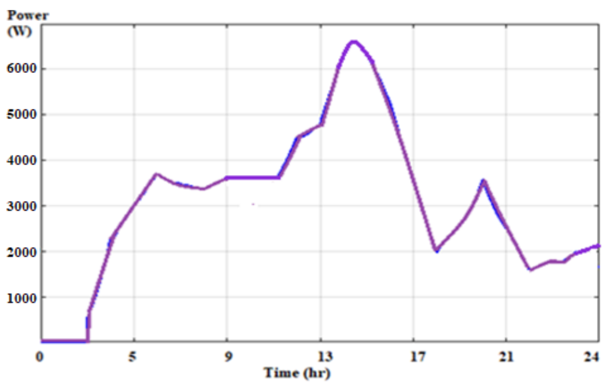

Figure 7. Performance of PV under partial shading for generated power of PV

5. CONCLUSION

Shading creates crucial problems for PV power systems, and can be always considers hot subjects in the PV research field. The proposed paper with ANN approach for obtaining the outcome of PV under partial shading environmental condition as well as maximum PV output system and moreover, analyzing the PV system performance when bases on various irradiance levels. A simulation with MATLAB gives a PV output of maximum power generating using ANN technique is evaluated with partial shading which is higher than 7000 W and can be consider an efficient method.

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