Simulation of Solar PV Array Using Hybrid Maximum Power Point Tracking Technique- A Critical Review

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Abstract: Photovoltaic panels are the most important green energy source because of their in-exhaustible moreover its clean. It is important to connect the PV panels to the maximum power point tracking (MPPT) controller to optimize its output power. The PV panels output power efficiency is related to the rapidly variation of the incident irradiance moreover the partial shading pattern. The variation of the incident irradiance and the partial shading pattern makes the tracking of the global maximum peak (GMP) through the local ones too difficult, which extremely decrease the efficiency of the PV panels. The problem is the GMP value varies as the sun irradiance varies so; the detection of the GMP needs an efficient and fast algorithm which cannot be done by the traditional MPPT. In order to solve the problem, proposed system a hybrid new algorithm can combine a traditional MPPT algorithm, such as perturb and observe, or incremental conductance, with the ANN (artificial neural network) This new algorithm can combine a traditional MPPT algorithm. The proposed hybrid MPPT algorithm is based on the ANN and used to predict the global MPP region by estimating its voltage boundaries. Consequently, the conventional MPPT algorithm searches for the MPP in the predicted region. The proposed technique is modeled and simulated using MATLAB/Simulink. After a thorough study of vast literature available on MPPT, future scope have been presented to make the review study focused and useful for the researchers in this area.

Keywords: MPPT, Artificial neural network(ANN), Partial shading conditions(PSC), Perturbutation & observasion(P&O), Photovoltaic(PV).

1.Introduction

In the last decade, the use of renewable energy sources has expanded rapidly for many reasons, including the dwindling conventional energy sources, environmental issues, and fossil fuel price dispersion. Solar-based photovoltaic (PV) arrays represent one of the most promising renewable energy resources. However, PV systems still face an important challenges compared with traditional energy resources because of their low efficiency and high cost. Moreover, PV arrays are nonlinear. Figure 1 shows the characteristics of a PV array under uniform irradiance levels. The output power of the PV array depends on the ambient PV cell temperature, solar irradiance, and load experienced by the PV array. Under uniform irradiance and for the same weather conditions, the output power of a PV array is a function of its terminal voltage. Hence, there is only one operating voltage that results in maximum power. The process of searching for this optimum voltage is called maximum power point tracking (MPPT).

This paper presents a new algorithm that combines a conventional MPPT technique with an AI one. The paper is organized as follows: The mathematical model of the PV array is presented in section II. Section III illustrates the behavior of the PV array under PSC. The new hybrid technique combines the perturb and observe (P&O) approach and ANN is discussed in section IV. The results for different simulation scenarios for the proposed technique are presented and discussed in section V. A comparative study between the proposed topology and the ANN technique is presented in section VI. Finally, section VII concludes the paper. To emulate the effect of partial shading, the irradiances of the four PV arrays are set to different values. The mathematical model described in section II is modeled using MATLAB/Simulink, and it is utilized to obtain the characteristics of the four series PV arrays under PSC.

The main idea of the proposed MPPT technique is to identify the global MPP region and recognize its minimum and maximum voltages using an AI technique. Consequently, one of the conventional MPPT methods, such as P&O or IC is utilized in this region to obtain the reference voltage. In order to accomplish the above proposed technique, the ANN technique is employed to recognize the region owing the global peak. In addition, the P&O technique is utilized to allocate the optimal operating voltage inside the recognized region by controlling the duty cycle of the boast converter. This paper presents review on different effective methodologies used to solve GMP problems. It will provide a good starting reference.

2.Problem Formulation

The PV array current for a number of panels connected in series and/or parallel combinations with each other is given by:

$I = I_{pv}N_p - I_0N_p[\exp((V+R_s(N_s/N_p)I)/V_taN_s)-1] - (V+R_s(N_s/N_p)I)/R_p(N_s/N_p)$

Where:

Ipv: currents of the PV array.

I0: saturation current of the diode.

a: ideal factor (depends on PV technology).

Rp: shunt resistance.

Rs: series resistance.

Np: number of parallel cells.

Ns: number of series cells.

Vt: thermal voltage.

The thermal voltage of the array is given by

$Vt = N_skT/q$

Where:

q: electron charge

k: Boltzmann's constant

T: temperature of the pn junction in Kelvin.

The photovoltaic current Ipv is given by

$I_{pv}=(I_{pv,n} + K_I\Delta T)*G/G_n$

Where:

Ipv;n: nominal condition PV current (1,000 W/m2 and

25_C),

G: irradiance at the panel surface,

Gn: irradiance under nominal conditions,

KI: cells' short circuit current temperature coefficient,

ΔT =T -Tn

Where:

T: actual temperature [K],

Tn: nominal temperature [K].

The diode saturation current is given by:

$I_o=I_{o,n}(T_n/T)^3\exp[(qE_g/Ak)*\{(1/T_n)-(1/T)\}]$

Where:

Io;n: nominal reverse saturation current,

Eg: band gap energy of the semiconductor,

The nominal reverse saturation current can be given by:

$I_{o,n}= I_{sc,n}/[\exp(V_{oc,n}/aV_{t,n})]-1$

Where:

Isc;n: short circuit current under nominal conditions,

Voc;n: open circuit voltage under nominal conditions.

Vt;n: array thermal voltage at the nominal

temperature Tn.

The above equations are modeled and simulated using MATLAB/Simulink.

3.Electrical Characteristics of Photovoltaic Array

The electrical attributes of a photovoltaic exhibit are outlined in the connection between the yield current and voltage. The sum and power of sun-based insolation (sunlight-based irradiance) controls the measure of yield current (I), and the working temperature of the sun-based cells influences the yield voltage (V) of the PV exhibit. Photovoltaic board (I-V) bends that abridge the connection between the current and voltage are given by the producers and are given below in fig.5.

3.1 Modelling of PVA

The solar panel equivalent diagram implemented in MATLAB can be seen below.

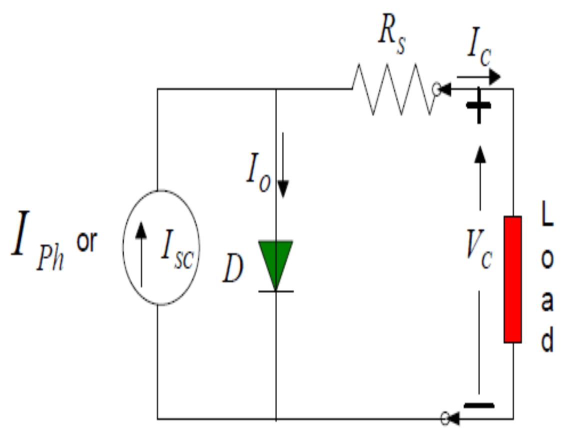

Fig. 3: Equivalent diagram of PVA

Where,

I_{ph}: photocurrent, function of irradiation level and junction temperature (5 A).

I_o: reverse saturation current of diode (0.0002 A).

R_s: series resistance of cell (0.001 Ω).

V_c: cell output voltage, V.

3.2 Solar Powered Array Parameters

1.V_{OC} =Open-circuit voltage: – This is the most extreme voltage that the cluster gives when the terminals are not associated with any load (an open circuit condition). This esteem is significantly higher than Vmax which identifies with the task of the PV exhibit which is settled by the load. This esteem relies on the quantity of PV boards associated together in arrangement.

2. I_{SC} =Short circuit current: – The greatest current gave by the PV exhibit when the yield connectors are shorted together (a short out condition). This esteem is significantly higher than Imax which identifies with the typical working circuit current.

3.P_{max}= Most extreme power :– This identifies with the point where the power provided by the exhibit that is associated with the load (batteries, inverters) is at its greatest esteem, where $P_{max} = I_{max}*V_{max}$. The most extreme power purpose of a photovoltaic cluster is estimated in Watts (W) or pinnacle Watts (Wp).

4. FF = Fill Factor:– The fill factor is the connection between the greatest power that the cluster can really give under typical working conditions and the result of the open-circuit voltage times the short out current,($V_{oc}*I_{sc}$) .This fill factor esteem gives a thought of the nature of the exhibit and the closer the fill factor is to 1 (solidarity), the more power the cluster can give. Run of the mill esteems are in the vicinity of 0.7 and 0.8.

5. % η =Percentage efficiency– The productivity of a photovoltaic cluster is the proportion between the most extreme electrical power that the exhibit can deliver contrasted with the measure of sun-based irradiance hitting the cluster. The productivity of a regular sun-based exhibit is ordinarily low at around 10-12%, contingent upon the kind of cells (monocrystalline, polycrystalline, indistinct or thin film) being utilized.

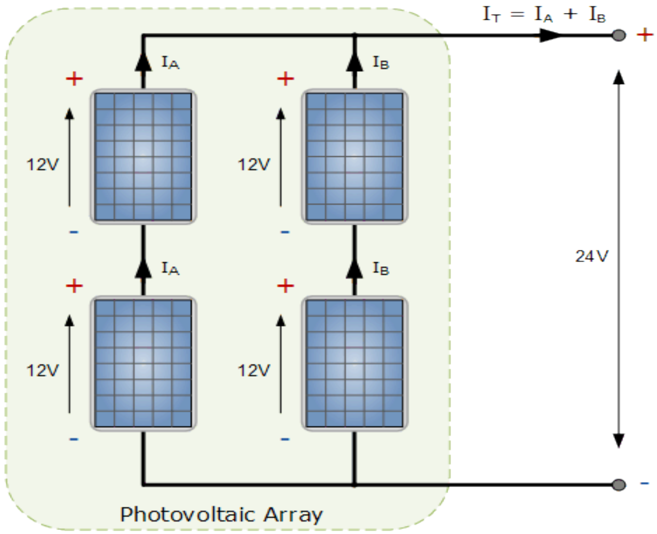

Fig.4: Photovoltaic Array Connections

This basic photovoltaic cluster above comprises of four photovoltaic modules as appeared, creating two parallel branches in which there are two PV boards that are electrically associated together to deliver an arrangement circuit. The yield voltage from the exhibit will in this way be equivalent to the arrangement association of the PV boards, and in our case over, this is ascertained as: V_{out} = 12V + 12V = 24 Volts.

The yield current will be equivalent to the whole of the parallel branch currents. In the event that we accept that each PV board produces 3.75 amperes at full sun, the aggregate current (I_T) will be equivalent to: I_T = 3.75A + 3.75A = 7.5 Amperes. At that point the greatest power of the photovoltaic exhibit at full sun can be figured as: Pout = V x I = 24 x 7.5 = 180W. The PV exhibit achieves its most extreme of 180 watts in full sun in light of the fact that the greatest power yield of each PV board or module is equivalent to 45 watts (12V x 3.75A).

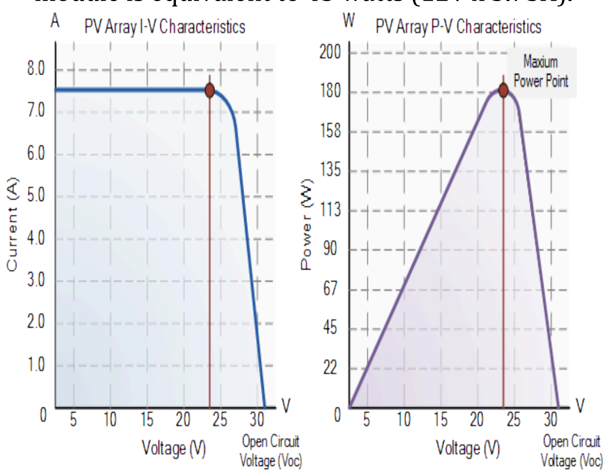

Fig.5.Photovoltaic Array Characteristics

3.3 ANN (Artificial Neural Network)

Artificial neural networks are built like the human brain, with neuron nodes interconnected like a web. The human brain has hundreds of billions of cells called neurons. Each neuron is made up of a cell body that is responsible for processing information by carrying information towards (inputs) and away (outputs) from the brain.

- An artificial neural network (ANN) is the component of artificial intelligence that is meant to simulate the functioning of a human brain.
- Processing units make up ANNs, which in turn consist of inputs and outputs. The inputs are what the ANN learns from to produce the desired output.
- Backpropagation is the set of learning rules used to guide artificial neural networks.
- The practical applications for ANNs are far and wide, encompassing finance, personal communication, industry, education, and so on.

ANNs are composed of multiple **nodes**, which imitate biological **neurons** of human brain. The neurons are connected by links and they interact with each other. The nodes can take input data and perform simple operations on the data. The result of these operations is passed to other neurons. The output at each node is called its **activation** or **node value.**

4.Methods used to achieve global MPP of the PV array

Many researchers are working on global maximum power point problem and using different methods which given as follows:

4.1Conventional MPPT methods

There are various types of conventional algorithms that can be used to track the MPP, such as P&O and IC. However, these algorithms may fail to track the MPP under PSCs, and they may become trapped at a local peak.

Novel MPPT method is presented by Y. Ji et.al in [1] shows that is capable of tracking the real MPP under partially shaded conditions is proposed. The performance of proposed MPPT is analysed according to the position of real MPP and is verified by simulation and experimental results

V.M.Unlu et al [2] proposed a new method which can track the maximum power under partially shaded conditions (PSC). Global maximum power (GPmax) searching method is used in this study, that is obtained by combining incremental conductance (IncCond) and scanning approach method which utilizes duty cycle sweep to track the global maximum when the PV array operates under PSC. This method is used in photovoltaic (PV) array simulation model that established in MATLAB/Simulink simulation platform. This study shows that the proposed method can track the real maximum power point accurately.

A novel hybrid maximum power point tracking (MPPT) method under partially shaded conditions (PSC) is proposed by Cheng-Yu Tang et al [3]. The duty cycle of the dc-dc converter is controlled from small to large with fixed intervals in order to scan the P-V characteristics curve under partially shaded conditions, and then find out the maximum power value, which is called duty sweep (DS) algorithm. With the proposed control algorithm, as soon as the DS process is finished, the perturbation and observation (P&O) method immediately starts so as to track the real MPP under PSC.Finally, experimental results confirm the proposed maximum power point tracking method that can accurately and promptly track the real MPP of PV arrays even under PSC, overcoming unpredictable weather conditions and rising up the utilization of PV arrays..

Aiming at the multi peak phenomenon in the output power characteristic curve of photovoltaic (PV) array under partially-shaded conditions. X. Zhu et al [4] addresses a new global maximum power point tracking (GMPPT) method based on sliding mode control (SMC). First, the output power characteristic curve of the PV array is scanned and the global maximum power point (GMPP) is stored at the same times. The SMC is introduced in this process, which greatly reduces the scanning time. Then the SMC based MPPT (SMC-MPPT) method is adopted to quickly stabilize the operating point of the PV array at the GMPP, reducing the power fluctuations during steady-state operation

The power-voltage characteristic of the photovoltaic (PV) array shows multiple maximum power points (MPP) under partially shaded conditions. A new MPPT method based on tabu search (TSMPPT) for PV systems under partially shaded conditions is proposed by Y. Zheng et al [5]. It combines three different search strategies, i.e.diversification search, local search and intensification search, to avoid the risk of trapping into the local MPP. Simulation results show that the proposed method could accurately track the global MPP with low complexity.

4.2 Advanced MPPT Methods

A power electronics converter is essential to connect PV arrays to the grid or load, as well as to execute the MPPT algorithm. There are different types of the DC/DC converters that can be utilized to carry out MPPT. In this paper, a boost converter is used. To explain the proposed technique, consider a string comprises four series PV arrays, each array is connected in parallel with a bypass diode. The schematic diagram for the proposed system is shown above in Fig. 4. In order to accomplish the above proposed technique, the ANN technique is employed to recognize the region owing the global peak. In addition, the P&O technique is utilized to allocate the optimal operating voltage inside the recognized region by controlling the duty cycle of the boost converter, as shown in Fig. 4. Large datasets are needed to train the neural network. To generate these datasets, the PV array is modelled and simulated in the MATLAB/Simulink environment under various shading conditions. The proposed ANN consists of three layers, as follows: an input layer with four different irradiance values for the four PV arrays as an input, a hidden layer containing 180 neurons, and an output layer with two outputs. The outputs of the ANN are the minimum and maximum voltages for the region with the global peak. The output signal from the ANN is used as an input for the next step. The next step is based on utilizing the P&O MPPT technique in the region bounded by the minimum and maximum voltages recognized by the ANN. This process surely reaching the global MPP and avoiding operation at local MPPs.

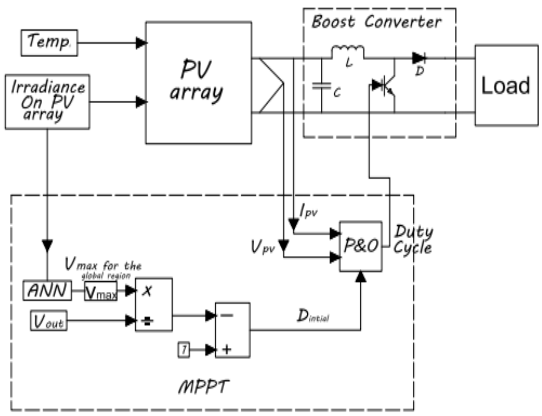

Fig. 4. Schematic diagram of the photovoltaic system using the proposed hybrid maximum power point tracking method.

5.Future Scope

After understand the literature in detail, it can be said that maximum power point tracking technique (MPPT) is still in a developing stage. In future, studies in MPPT should try to improve the power quality and efficiency. It is well known that various types of methods are used for generating the electricity like Thermal Power plants (Nuclear, Coal, petroleum etc.), Hydro (water) power plants, but it is non-renewable resources and also harmful for humans as well as environment. As many types of other charge controllers like PWM etc. also available, but due to low efficiency it cannot be used completely by the consumers. Hence there is need to develop more other cheap and effective MPPT algorithms, so that almost 100% efficiency can be achieved

1)MPPT operating APP: An application of operating MPPT with the help of mobilephones can so be made operate from whenever via the Internet.

2)DC-DC running loads: DC from MPPT can be taken directly and DC load can be run. DC loads helps to consume low electricity.

3) Management of energy: There is need to manage energy when these algorithms are developed.

4) To solve GMP problem, new approaches should be proposed, which include hybrid MPPT algorithms that merge the best qualities of conventional method and advanced method.

6.Conclusion

There are various types of conventional algorithms that can be used to track the MPP, such as P&O and IC. However, these algorithms may fail to track the MPP under PSCs, and they may become trapped at a local peak. This paper presents an efficient hybrid algorithm for PV systems working under PSCs. A simplified ANN was proposed to obtain the region for the global MPP of the PV characteristics by estimating its boundary voltages, which varied with changes in the shading pattern on the PV array. After finding this region, a conventional method—namely P&O—was used to locate the MPP in the estimated region by adjusting the duty cycle of the boost converter. The results demonstrated the adequacy of the suggested hybrid MPPT technique in tracking the global MPP of the PV array with different partial SPs and under both steady-state and dynamic conditions.

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