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Recent Advancement on Solar Photovoltaic Energy Generation System Special Reference to Shading Condition- A Review

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ABSTRACT

Design of a Solar PV Energy Generation to harness the optimum solar energy has been a big challenge among the researcher. It is quite essential to review the latest all the available technique, their advantages and disadvantages, prior to designing a new Solar PV Energy Generation system. In present paper a detail discussion is presented on various maximum power points tracking algorithms employed on Photovoltaic Energy generation system under shading condition. We have covered the various algorithms, PV modelling techniques, PV array configuration, monitoring system etc. up to till date. Impact of shading effect is reported massive on energy supply capacity. Hence, in this paper we have investigated and discussed the various type of PV module at different type of shading level. This paper provides a handy reference to undertake a mass research works on PV system in near future under shading condition.

Key words : PV Cell module, Shading condition, PV module algorithm, Maximum power point tracking (MPPT), PV Panel array

1. INTRODUCTION

Growing demand of energy and the life threatening health problem due to coal produced electricity make it essential to go for various green energy production techniques. Solar energy being abundantly available is the great hope for human beings to accomplish the rising need. Photovoltaic Energy generation under shading condition have a huge adverse efficiency effect [1]-[3]. It suddenly comes in our mind that how to avoid completely to the shading effect, but it is not possible. Natural phenomenon such as cloud, rain or the manmade obstruction such as high pollution or tall buildings is obviously comes in generation of energy by PV system. Even if a section of PV panel is in shade then there is a lot of differences in performance, this is due to the PV array configuration. As we know the usual configuration is the connection of number of photovoltaic cell together as a series or parallel connection [3]. Hence there is drastic reduction in final energy output of the panel even at partial shading condition. Another aspect is related to the presence of bypass diode in various ways in the configuration of PV panel. It is well known that curve of the PV cell varies on the radiation received and the temperature, here the diode allows the current flow through alternate path in the PV module. By pass diodes are used either as overlapped or non-overlapped depending on configuration, thus in the case of shaded PV panel the net output get reduced drastically as there is restriction in the direction of current flow. Many publication supported the theory of reduction of energy directly proportional to the area of shading of PV panel [8]. This finding seems reasonably accurate especially in the case of single PV cell but at the module or array level it is not exactly true as the module or array are often far from the linearity with the shaded portion [9].

Many research publications reported on various configurations to minimize the loss effect due to PV panel under shading condition [4]-[6]. Regular configuration such as series- parallel, total cross- tied, bridge –linked, etc. are been checked under shading condition with an aim to get an optimum energy output [32]. A modelling process having PV array connected in any configuration operating under uniform or partial shading is also been reported appreciating results [36].

Shading detection and tracking algorithm using the trend of slopes from each section of the curve is reported by a researcher having valuable findings for future application on artificial based technology (Global maximum GM). The hotspot detection algorithm is also proposed based on analysis of various PV array configuration, which is also been validated by simulation result by the researcher [45].

In present review work an attempt have been made by the authors to summarise with necessary details all the work done on various algorithms, PV modelling techniques, PV array configuration as well as monitoring system from earlier findings to the recent one, we have tried to present our view based on their discussions. We hope that this piece of work will be immense helpful for new research worker exploring to start a research work as well as working engineers who is in the process of fabrication of a new PV module. We have presented a chronology table of development on PV energy generation especially the papers focused on shorting out problem of shading.

2. PV CHARACTERISTICS

Diode model of Photoelectric cell is generally used to describe the I-V characteristics. In Figure 2.1, an equivalent circuit of a PV cell is displayed.

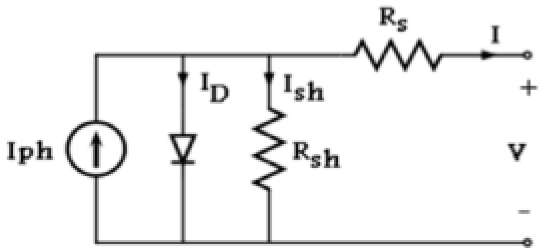


Figure 2.1: Equivalent circuit of a PV cell [7]

Here, in the Circuit
Ish – represent the shunt current in Ampere
Rsh – is the shunt resistance in Ohm
Iph – is the photo current in Ampere
I_D – is the diode current in Ampere
Rs – is the shunt resistance in Ohm
To determine the I-V characteristics, following relation is useful [7]-

$$Iph = I_D + Ish + I \qquad (1)$$

In literatures [7]-[9], the shading effect on output power is reported. However, in conventional models of PV modules, discussion on open circuit voltage, short circuit current, and various loss sources are quite often discussed [10]-[13]. We are presenting here two curves helpful in discussion of shading first one is current verses voltage and the second one is power verses voltage [7]. These curves are shown in Figure 2.2.

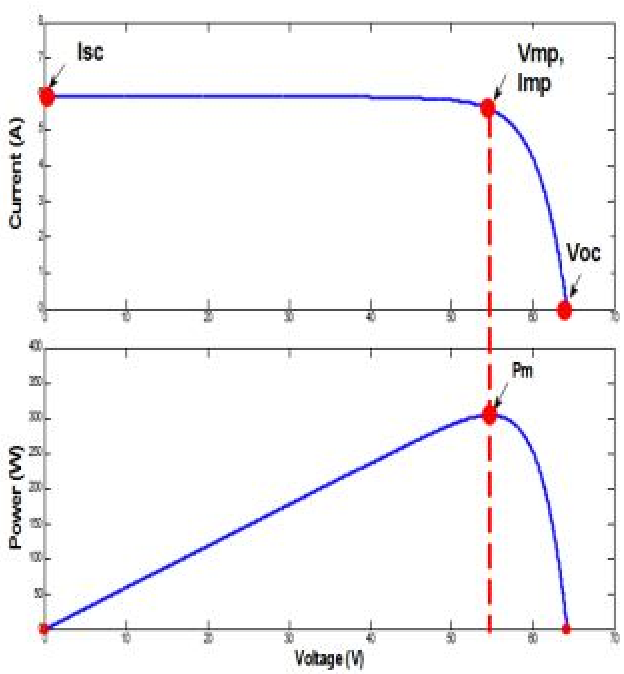
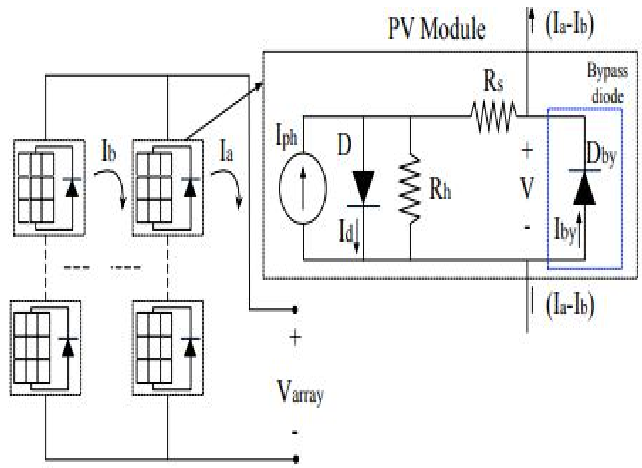


Figure 2.2: PV module I-V & W-V curves [7].

3. PHOTOVOLTAIC ARRAY–MODELLING

Various Modelling of PV cell has been attempted by authors [14]-[20], to overcome the shading problem. PV module having single diode model and a bypass diode is found to have many advantages to boost the efficiency [14]. The equivalent circuit diagram of the model is placed as Figure 3.1. Introduction of sub-array (SA) in the model make the concept more energy boosting which reflects in terms of the SA



current.

Figure 3.1: PV model having single diode and by-pass filter diode [15].

Author [15], has applied Kirchhoff's current and voltage law to establish a relation among the module voltage (V), and the mesh current at the right (Ia) and at the left (Ib) of the PV model. The equation representing the relation among the various parameters of PV model is given below as equation 1.

$$(I_a - I_b) = I_{ph} - I_{sat} \cdot \left(\exp\left(\frac{V + (I_a - I_b - I_{by}) \cdot R_s}{N_s \cdot \beta} \right) - 1 \right) + I_{sat,by} \cdot \left(\exp\left(\frac{-V}{\beta_{by}} \right) - 1 \right). \qquad (1)$$

Where,
Isat – be the saturation current of PV module diode
Ns – be the number of series connected cell in the module
β = n.k.Tpv/q , here n is the ideality factor, k is the Boltzman constant , q is the charge
by – represent for bypass diode.

In above equation only Iph and Isat depends on irradiance (S) and Temperature (T) while the other parameters are constant; hence this equation has found more relevancy in calculation of output power as far as the case of shading is concern.

4. MAXIMUM POWER POINT TRACKING (MPPT) ALGORITHM UNDER SHADING CONDITION

There are many report on various technique to tackle the shading in PV module is present [21]-[29]. These techniques are categorized under maximum power point tracking (MPPT) algorithm. A general representation of shading in a PV module is represented by a diagram shown in Figure 4.1 [21].

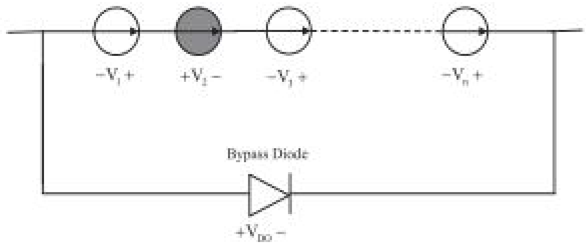


Figure 4.1: One shaded shell in bypass conduction diode diagram

In coming sub section various optimization techniques are discussed to understand the latest progress in the field of PV module in shading hindrance.

4.1 GRAY WOLF OPTIMIZATION

In the gray wolf optimization (GWO) simulation technique the leadership i.e. better efficiency of PV module is established by considering four types of gray wolves known by alpha(α), beta (β), delta (λ) and omega (ω). Simulation is based on attacking technique; the optimum fittest solution is found with the wolf alpha, then second with beta, after that the delta. Omega is denoted as rest of the candidate solution. Gray wolf optimization have three steps or better to say programming- hunting, chasing and tracking the prey by forming group and the encircling the prey and finally solved it by attacking. The Flow chart to represent the algorithm of GWO is displayed as Figure 4.2 [22].
Complete hunting mechanism of GWO is computed based on following two equations-

$$\vec{E} = |\vec{C}.\ \vec{X_P}(t) - \vec{X_P}(t)| \quad \vec{E} = |\vec{C}.\ \vec{X_P}(t) - \vec{X_P}(t)| \tag{2}$$

$$\vec{X}(t+1) = \vec{X_P}(t) - \vec{F}.\vec{E} \tag{3}$$

Here t represents for current iteration; E,F and C represents the coefficient vector. Xp is the hunting prey and X represent the position vector for the gray wolf.

4.2 Ant colony optimization

Ant colony optimization (ACO) is a probabilistic algorithm applied to tackle the shading problem by many authors [23]-[24]. Idea of food searching behaviour of ants is applied here to get the optimum power output. It provides the optimized duty cycle after sensing the output power in PV module. Optimized duty cycle is further applied to the convertor.

4.3 Artificial bee colony algorithm

Artificial bee Colony (ABC) algorithm is considered as a simple optimization technique in which a few controlled parameters are used ; here the important thing is that algorithm convergence criterion are independent of the initial condition of the system. It is a swarm based algorithm capable of solving multidimensional and multimodal optimization problem efficiently [25]-[26].

4.4. Swarm optimization

The deterministic particle swarm optimization (DPSO) is an improved PV module shading condition algorithm. It is a known to have better improved algorithm having capability to contribute in tracking and overcome the problem related to shading. If a change in the duty cycle for two successive counts is low, then DPSO is helpful in optimization in final output and making the PV module much efficient under shading condition [27]-[37].

5. MPPT AND HOT SPOT DETECTION

Many failures in MMPT are a result of the Hot-Spot phenomenon [38]-[47]. This is a occurrence in which defective cell turn out to be hot when shadow take place on the cell. This happening become basis for breaking of the cell or a fire. While there is a predictable method for measuring temperature, such as using an infrared camera, for the purpose of checking for a Hot-Spot, the method necessitate a lot of time and endeavour. A range of studies have been performed about Hot-Spot [42]-[44]. For example, there is a report about Hot-Spot detection method using AC parameter categorization of PV module [45]. However, occurring Hot-Spot cannot be monitored on these studies while PV system is operating. Authors developed Hot-Spot detection method to module before installation using projector [46]-[47]. However, Hot-Spot always occurs because of various factors even if the module is normal at checking for a Hot-Spot. Various models are available on study to manage the problem of hot spot.

5.1 Hot Spot shading detection

The reported Hot-Spot shading monitoring system make use of slope of I-V characteristic of PV module in region of high voltage part. It has been reported that current has a negative slope to the voltage in area of high voltage side in the case of Hot-Spot module [48]-[55]. It has been further reported that the current difference between the two points V1 and V2 volts and the short circuit current value determination helps in monitoring of hot spot shading detection and prevention of any damage.

6. CONCLUSIONS

Problem related to Solar PV Energy generation under shading condition is discussed elaborately in this paper. It is well known that shading condition has a huge adverse efficiency effect. Various PV array configuration to overcome the problem of shading is covered in this paper. It has been found through various reports that there is drastic reduction in final energy output of the panel even at partial shading condition. Another aspect found is related to the presence of bypass diode in various ways in the configuration of PV panel. It is well known that curve of the PV cell varies on the radiation received and the temperature, here the diode allows the current flow through alternate path in the PV module. Finding seems reasonably accurate especially in the case of single PV cell but at the module or array level it is not exactly true as the module or array are often far from the linearity with the shaded portion. It has been found that the regular configuration such as series- parallel, total cross- tied, bridge –linked, etc. under shading condition are results in an optimum energy output. A modelling process having PV array connected in any configuration operating under uniform or partial shading is also been discussed in this paper. Shading detection and tracking algorithm using the trend of slopes from each section of the curve is reported and discussed in the paper. Reports on various technique to tackle the shading in PV module is present in this paper. These techniques are categorized under maximum power point tracking (MPPT) algorithm. Many failures in MMPT are a result of the Hot-Spot phenomenon.

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