International Journal of LNCT
Volume-3 Issue-15 December -2019
ISSN: (Online):2456-9895

A COMPREHENSIVE REVIEW ON PARTIAL SHADING IN PHOTOVOLTAIC CELLS

Deepali Khabia[1]
[1]Research Scholar, Electrical and Electronics Engineering
LNCT Bhopal
Dr. K.N. Shukla[2]
Prof. Department of Electrical and Electronics Engineering
LNCT Bhopal
Prof .Amol Barve[3]
Head & Prof. Department of Electrical and Electronics Engineering
LNCT Bhopal
Corresponding author email Id-deepalikhabia@gmail.com

Abstract
In the recent past years there is a huge development in the field of Conservative source of energy due to reason that include the increase in fossil fuel prices and the decline in fossil fuel reservoirs. Among various renewable energy sources , due to abundance of source itself i.e. Sun, photovoltaic power generation is envisaged to an important source of energy of future .So the research work is directed to study, analyse and assess .Partial shading of PV reduce the power generated of PV system .The arrays have multiple peaks in the PV characteristic. The losses of shading are not proportional to shade area but it also depend on shading pattern, array configuration .This paper presents, a comprehensive study of research work done by different scholars on partial shading in Photovoltaic cells.

Keywords: *PV (Photovoltaic) cells, p-n junction diode, PV array ,Partial Shading*

1. INTRODUCTION

The factors encouraging the greater utilization of renewable energy include the increase in fossil fuel prices and the decline in fossil fuel reservoirs. Among various renewable energy sources, due to abundance of source itself i.e. Sun , photovoltaic power generation is envisaged to an important source of energy of future . Economic incentives and advancements in power electronic technology promote its application . Still there remain numerous drawbacks. Some of them are as follows:

i. High installation cost of photovoltaic panels

ii. Low efficiency of the system
iii. Inconsistency of solar irradiation
iv. Requirement of large land area for installation of panels
v. Storage of solar power is expensive.
vi. Dependency on weather conditions.

As per the graphical representation growth in Fig.1. in solar power generation is enormous. However it is in a state of recurrent energy lack with demand –

Supply gap of almost 12% of total energy demand .In a tropical Asian country like india ,with abundant solar insolation ,the most promising alternative of renewable green energy resource of the future is the Sun. The two main challenges are low conversion efficiency and its erratic nature of power output.

To achieve better conversion efficiency of the PV System, a process known as Maximum power point tracking technique is adopted . MPPT tends the P-V system to operate at the point of maxi. Power .The conventional methods of MPPT were apt for finding the maximum power in non -linear Power vs Voltage curve under uniform insolation , being there a single maxima.

But under partially shading conditions, there are multiple points of peak power power-voltage characteristic curve. So it is required to have detailed knowledge of I-V and P-V characteristic curve under varying environment conditions.

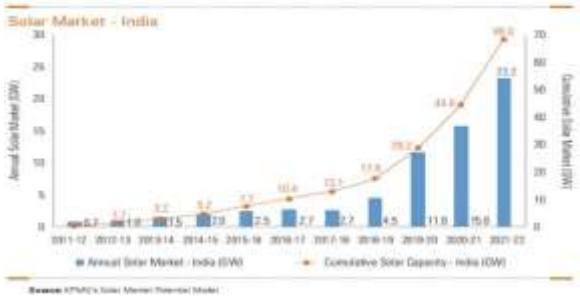

Fig 1. Annual Solar Energy Market

The rest of the paper is arranged as follows: Section 2 presents the background of the PV technologies. In section 3, related literature works on the partial shading in Photovoltaic array are discussed. Section 4 focus on the conclusion.

2. BACKGROUND

In 1883 Charles Frittes invented what was considered the first basis of the PV cell by compressing a thin film of selenium between two layers of different materials. The top layer is made of gold, which is able to collect the free electrons released because of the

impact of the light on the selenium. The gold is then able to produce electricity by transforming light into electricity at an efficiency of less than 2% .Pearson, Chapin and Fuller developed the first modern silicon cell in 1954 as a result of the significant development of the techniques used to manufacture crystal. The efficiency of this cell was about 6% . The first PV product was on the market the next year but was very expensive—around 1500 $/W (1000 £/W). The exorbitant cost prevented this PV technology from becoming an acceptable alternative power source . PV technology was then widely adopted and is now the main source of power for many satellites. The high level of demand for PV technologies on the part of the aerospace industry has encouraged work to develop these technologies and improve their efficiency. In addition many applications are currently operated by PV power, including offshore signal lights, railroad crossings and highway signals .

2.1 Basic Theory of diode

A p-type semiconductor and a n-type semiconductor together form a diode .The holes that diffuse from the *p*-type material into the *n*-type material recombine with the majority electrons on the *n*-type side. Thus, this portion of the *n*-type material becomes positively charged since the impurity atoms on the *n*-type side now have five protons that correspond to only four outer shell electrons. Additionally, these pentavalent impurity atoms are sometimes called donors since they can more easily donate their free electron. In other words, it takes less energy to separate these free electrons from its attraction to its atom.

An electric field is created at the *p*-*n* junction since the *n*-type material is positively charged with respect to the *p*-type material. When in equilibrium, this electric field restricts additional diffusion of holes and electrons due to its polarity. The electrons in the *n*-type material move towards the *p*-type region due to diffusion current. At some point, the electric field becomes strong enough that these electrons cannot diffuse anymore and are repelled back towards the *n*-type side. A similar explanation can be made for holes on the *p*-type side. Furthermore, the material in the vicinity of the junction is called the depletion region (or space-charge region) because it has been depleted of its entire charge carrier. In Fig.2 , a depiction of the depletion region is portrayed with its electric field.

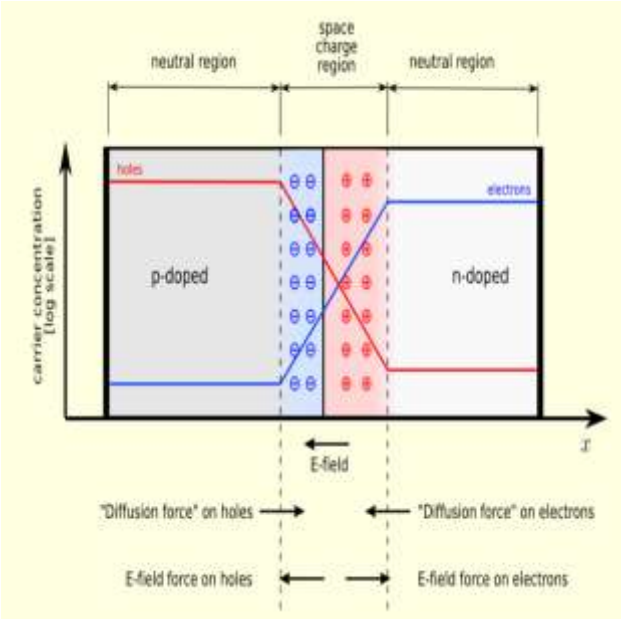

Fig.2 p-n Diode

2.2 Basic theory of photovoltaic cell

The term photovoltaic derived from photovoltaic effect ,which is the process of converting light (photons) into electricity (volt). PV cell are basically semiconductor diode. It's a p-n junction which is exposed to light to generate electric power. PV cell are made up of various semiconductor materials namely micro-crystalline, mono-crystalline silicon, poly-crystalline silicon, amorphous silicon, cadmium telluride .Asa matter of fact the mono-crystalline silicon and poly-crystalline silicon are mainly used for commercial use .In mono-crystalline type solar cells, individual crystal is aligned in a particular direction whereas in poly-crystalline type crystals are not all perfectly aligned together .The photovoltaic cell is shown in fig . 3

As a principle the absorbed energy from light is more than the band gap energy of the semiconductor, the electron from valence band jumps on to the conduction band. As the solar irradiance increases , more number of photons and electrons are released . The rise in flow of electrons ,obviously increases the current generated by photovoltaic cell . Therefore , the short circuit current (I_{sc}) is directly proportional to the solar irradiance .

The open circuit voltage (V_{oc}) is determined by the electric field created in the depletion region of the p-n junction which is independent of insolation .

The output characteristic of solar cell is obviously non-linear .To collect maximum power various tracking techniques have been developed . When insolation is uniform there is single maxima in the P-Vcurve .But when there is non-uniform insolation due to partial shading there are multiple peaks in P-V curve and this adversely effects the output.

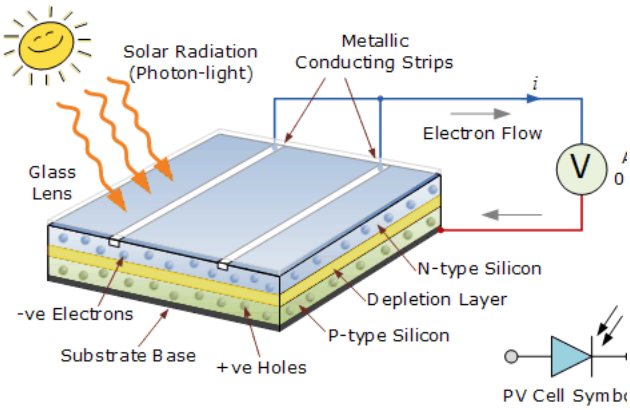

Fig.3 Photovoltaic cell

3. Literature Review

A number of research papers and articles have been published on the study and application of solar energy and solar cells .Some of them are as follows

M. Boxwell [1] presented solar cell that consists of P-N diode ,fabricated in the form of fine layer of semiconductor substance is a fundamental unit for solar photovoltaic energy-conversion system. The mono-crystal and the multi-crystal cells are the two most basic comparable silicon based types of P-V cell that are widely-used for traditional solar panels. Mono-crystalline cells offer better efficiency but the ordered crystalline-structure is rather expensive to manufacture. On the other hand, multi-crystalled cell is inferior qualitywise due to the presence of grain boundaries, reducing the cell performance by introducing more recombination losses at the boundaries.

A. K. Ghosh,et. al [2] presented that grain boundary play a dominant role in determining the electrical and photovoltaic properties of polycrystal Si . It performs as traps and recombination medium . The grain size of Si acts dominating role in giving the electrical and photovoltaic characteristic of silicon. Grain boundaries act as traps and recombination pockets .

H.L Tsai C.S Tu and Yi-Jie Su [3] presented the application of generalized photovoltaic model using software , which is illustrative of the cell, module and array of PV that is easy-to-use for simulation purpose. In the model there are icon & dialog box for benefit of users similar to that in Simulink block library .The authors have simulated and optimized the current–vollage and Power vs voltage curves of solar cell under the effect of various insolation and ambient temperature .In accordance with Shockley diode equation model of PV module is developed with consideration of temperature independent photocurrent source,a diode and a series resistance.

H.Patel and Sharma [6] and Krismadinata et al [6] presented the circuit based solar PV

model using Matlab and simulated it for different values of irradiation and ambient temperatures. These papers modeled and simulated PV array under non-uniform insolation for analyzing I-V and P-V characteristics .A numerical algorithm for mismatch in individual PV cells and its shading level is proposed .For a specific number of PV modules ,the array configuration that no. of modules in series and number of modules in parallel significantly affect the maximum power under PS condition . The bypass and blocking diode in PV array also effects the output characteristics.

Ramprabha and B .L Mathur [7] show that PV array operations suffer complexity in output PV characteristics under the influence of partial shading situation caused by movement of clouds , shadows of trees, buildings, dust particles ,snow, etc . To determine a characteristic by taking a variable resistance across the array and measuring V and I may not be always correct owing to moving cloud ,changing temperature. Quick method to find characteristics and recording it using an electronic load is presented . The characteristics of three solar panels with different insolations and with series connection is obtained for fast electronic load .

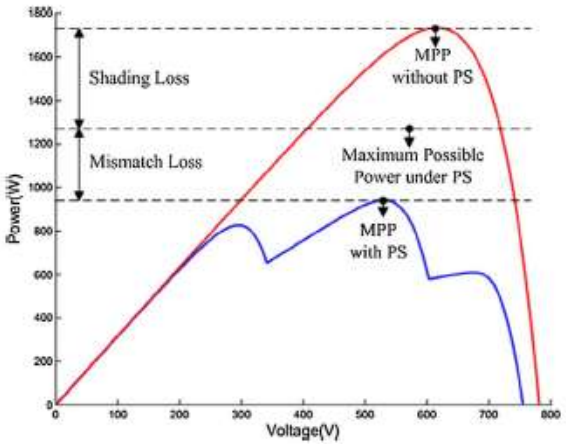

Fig.4 Various losses under partial shading of photovoltaic array [8]

Shams El-Dein et.al [8] presented that partial shading cause mismatch between the modules, leading to undesirable effects such as reduction in generated power and hot spot as can be seen in fig.4.Its adverse effect is reduced to a large extent by reconfiguration of array. The paper formulates the reconfiguration problem in a mixed–integer quadratic programming form and gives a optimal solution by branch & bound algorithm. This formulation is useful in equal or unequal no. of modules in each row. It can also be used for fully reconfigurable as well as partly reconfigurable arrays .

Dio *et.al* [9] discuss that the total power in such an array is lower than the sum of individual rated power of each module. When solar cells are connected in series, all the cells carry the same current .Now; although a few cells under shade produce less current, these cells are also forced to carry the same current equal to fully illuminated cells .The shaded cells may get reverse biased, start behaving as load, draining power from fully illuminated ones .

Y J Wang et. al [10] gave five different connection configurations of 36 PV cells to compare their performance under the condition of partial shading. They are simple series,series-parallel,total-cross-tied,bridge-linked and honey-comb configurations. The connection configuration is analyzed, taking care of the non –linearity cell characteristic, by using Kirchoff's voltage and current law . It follows solving simultaneous nonlinear equations , which gives the I-V (current-voltage) characteristic of the module with particular configuration with certain types and levels of partial shading is evaluated. The values of maximum power and fill factors of all five configurations is compared .This study is also carried out at the reverse bias voltage across each PV cell .

L Gao ,dougal et. al [11] described that in the scheme of series-connection , the residual energy produced in partly shaded cells is either cannot be harnessed due to bypass diode or in case of no bypass diode it impedes collection of energy from fully lit cells . Rapid change in shading pattern makes tracking of peak power difficult; there occur multiple local MPPs, with changing values as the irradiance changes . The proposed configuration has an array with parallel-connected solar cells, a low-input-voltage step up converter, and a wide bandwidth MPP tracker. . It showed that, even under rapid changing shading situations, the power generated in the new configuration is almost twice.

4. CONCLUSION

Partial shading of PV arrays reduce the energy yield of PV system and in the array characteristic there are multiple peaks . The losses due to shading are not in proportion to the shaded area but depend on shading pattern, array connection configuration. Under uniform illumination condition, all PV array configurations give identical maximum power output. However, under partial shading conditions, performances of PV

array configurations are different and depend on the shading case .So for a given surrounding , proper planning can help in installation of efficient and optimum photovoltaic arrays .

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