Performance of Partially Shaded Solar Photovoltaic System

Tarana Afrin Chandel, Md Arifuddin Mallick, Mohd Yusuf Yasin

Abstract**: *Renewable energy is the energy which is directly collected from natural sources such as sunlight, wind, waves and geothermal. This form of energy is becoming important for us as the conventional sources are usually limited, and can be utilized, for example, in the field of electricity generation, where solar irradiance plays an important role. Shadowing anyhow may result in a non-uniform irradiance on the PV modules affecting their performance. This study aims at evaluating the performance of conventional SPV systems under shadowing effects. Simulations are done on Simscape of MATLAB for this study.***

Index Terms**: *About four key words or phrases in alphabetical order, separated by commas.***

I. INTRODUCTION

The sun is the heart of the solar system and the only source of energies available or perceived on our earth. Thermonuclear fusion of Hydrogen at the surface of the sun is responsible for its high surface temperature of about 6,000°C. Sun emits short waves of electromagnetic light all around which passes thru earth's atmosphere in the form of the known light spectrum, including infrared, visible and ultraviolet radiations. Sunlight passes through the atmosphere and reaches the earth as daylight. The earth surface receives approximately 1367 watts per square meter equivalent energy from the solar irradiance. This energy reception of the earth surface depends upon the tilt of the incident sun rays with respect to the normal on the incipient earth surface. The earth has a bright light and radiant heat when the solar radiation is not blocked by clouds or atmospheric dust, and has diffused light otherwise. The photon of the sun and its direction changing every time affects the radiation on the earth surface. A photovoltaic cell is a semiconductor device which converts light energy into electric current at a fixed voltage [1]. A silicon based solar photovoltaic cell produces an open circuit voltage of 0.5 to 0.6 volt. The basic operation of the SPV cell is based on three important factors i.e. generation of electron-hole pairs on absorbing the incident photons, separation of the charge carriers of opposite polarity and extraction of these carrier and their mobilization on to the external circuit [2,3]. Multiple solar cells integratingly form a photovoltaic module, a glass layer on the face side, allowing light to pass through while protecting the semiconductor cells from physical damage [4]. The solar cells are usually connected in series and parallel to control voltage and current conditions on the output nodes. Modules can be interconnected to form an array with desired loading capacity to produce maximum power point (MPP).

Normal operation assumes that the PV module is fully illuminated with sun rays as the solar systems are usually installed on terraces to let them fully open to sun. These systems also keep on working in cloudy weathers as the infrared radiations are always available. However, circumstances may cause a local problem due to which certain cells come under a quasi shade, or a shade continuing for a while. Examples for this type of shading may be feces of birds, stains due to water drops in a rain and sticky accumulation of dust, self shadowing due to the parts or instruments of the installation and dead leaves happen to fall on the panel and stuck there somehow. This partial shading causes the cells lying underneath to become standstill. This may affect the battery of cells depending upon their connections. The cells are acting as a supplier of electric current at a fixed voltage, therefore the cells happen to lie under shade may stop working and be considered as pure resister equivalent to the internal resistance of the cell. For the cells connected in series, a cell under shade will be ceasing offit's voltage and current contribution to the series branch. As a result, the branch will operate at a voltage reduced by a factor of "1", and hence the overall series circuit. Bypass diodes across branches are used for the purpose of security of the cell arrays or panels from any physical damage. This helps to put the affected cell strings shorted out, through the bypass diodes turned ON.

In order to enhance power out efficiency, the cell strings may be of shorter sizes and hence the number of bypass diodes increases. This will cost an increase in power loss due to the reverse biasing of the by-pass diodes. A reverse connected diode does ensue a constant current or reverse saturation current. The reverse saturation current of a diode is heavily temperature dependant and is reported to double for every 10OC temperature rise. In order to reduce power loss due to shadow on SPV panel a shunt diode is applied. Several studies had been done on shading which affects the characteristics of SPV system [4]. These effects can be seen by the analysis done by modeling of the Solar PV Panel under shading condition and its simulation done on Matlab Simulink. Since the cells connected in series and parallel circuits, the performance of solar panel is reduced even if small part of the panel somehow comes under a shade.

Revised Manuscript Received on 30 March 2019.
* Correspondence Author

Tarana Afrin Chandel, Electronics and Communication Engineering **Department**, Integral University, Lucknow, India.

Prof. Md Arifuddin Mallick, Electrical Engineering Department. Integral University, Lucknow, India.Country.

Dr. Mohd Yusuf Yasin, Electronics and Communication Engg Department, Integral University, Lucknow, India.

Another important parameter of partial shading is overheating. Partially shaded part of the solar panel generates less amount of energy as compared to the unshaded part of the panel. Hence power regenerated in shaded and unshaded parts of panel varies. The shaded and unshaded part of the panel is shown in fig 1(a, b) . Fig 1(a) shows the shaded area due to bird's feces and figure 1(b) shows the shaded part of panel due to building. Figure 1 and fig 2(a) and fig 2(b), these images are taken from the roof top of Integral University, having solar panel, manufactured from Vikram Solar, model ELDORE VSP.70.AAA.03.04. It is made of polycrystalline material having 72 cells and can generate 310-330 watt power (single panel). The I-V characteristic is affected by shading effects on SPV panel [5],[6],[7].

Figure1a: Shading due to Bird's Feces

Figure1b: Shading due to Building

Figure 2a: SPV Panels on Roof Top of Integral University

Figure 2b: SPV Panels on Roof Top of Integral University

There are techniques by which the shading effects of the solar panels can be reduced. One simple and quite elegant technique is to use bypass diodes. Here in this work, this aspect is studied in some detail.

Bypass Diode:

By pass diode are applied to prevent the damages occurring due to reverse bias on partial shading of SPV panels [8]. These diodes are connected in parallel to SPV panels in reverse direction to solar cell [9]. Under normal condition the solar cell operates in forward bias condition and these bypass diode will work as reverse bias hence act as open circuit. If this solar cell operates in reverse bias condition then the bypass diode will conduct in forward bias condition, allowing the current to flow through the load.

II. MODELING OF SOLAR PV PANEL UNDER SHADING CONDITION

Modeling of Solar PV Panel under Shading Condition is done using Matlab Simscape. Simsacpe helps to create model of physical system using simulink and test system-level performance. Figure 3 shows the model of SPV system under shading condition.

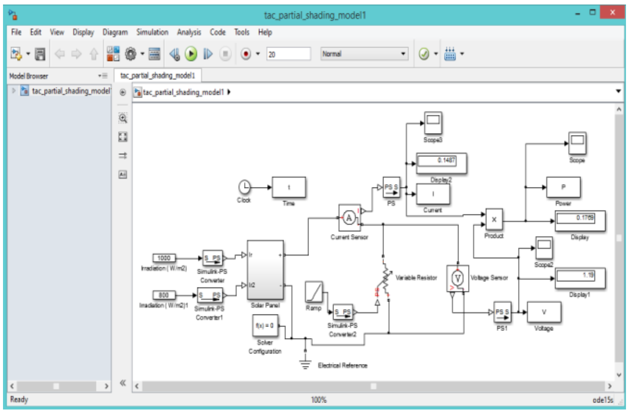

Fig3: SPV Model under Shading Condition

III. SIMULATION OF SPV MODULE WITH SHADED AND UN-SHADED PV CELLS

To understand the performance of SPV system under shading and un-shading of PV cel,l simulation is done in both the condition at the irradiance of 1000 w/m2 and 800 w/m2 and the variation in their characteristic clears the picture.

The subsystem model of shaded and un-shaded pv cell with bypass diode is shown in figure 4.

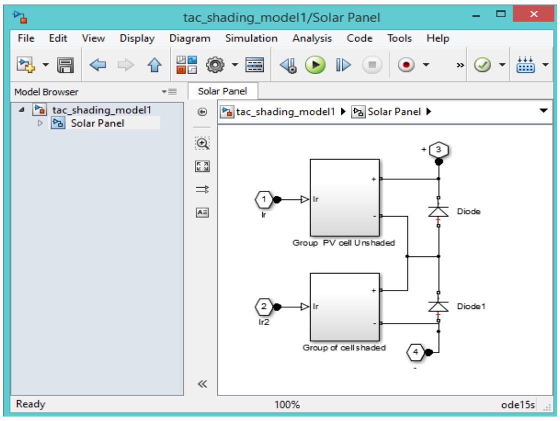

Fig 4: Subsystem of solar panel with groups of PV cell Shaded and Un-shaded

60 cells are connected in series (6 groups of 10 cells each). Bypass diode is connected across cells in a group. The characteristic curve of the SPV module under STC condition (1000 W/m ², spectrum AM1.5 and 25°C), the output current and power with respect to voltage is shown in figure 6 and 7 respectively. If 6th row of the cell is shaded or the circuit get disconnected as shown in 6th group of cell the current passed through the cell in serpentine arrangements through a bypass diode D3 as shown in figure5.

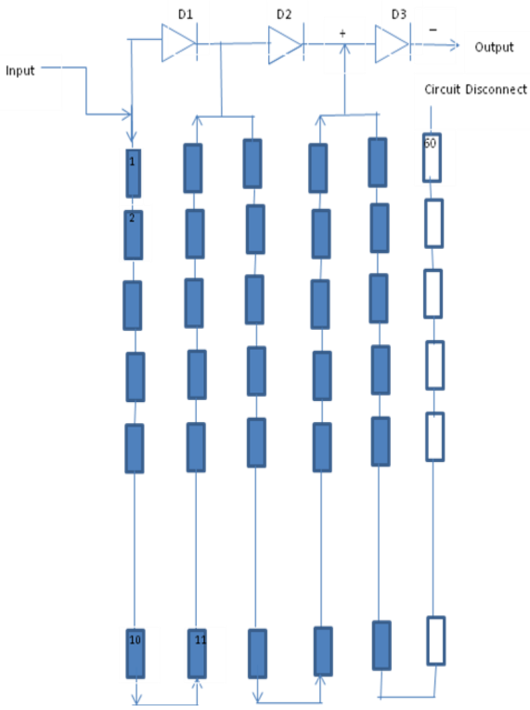

Fig 5: PV Module with Solar cells connected in series, serpentine arrangement.

IV. CHARACTERISTICS OF SPV MODULE WITH UN-SHADED PV CELLS

The un-shaded pv cell is shown in figure 6

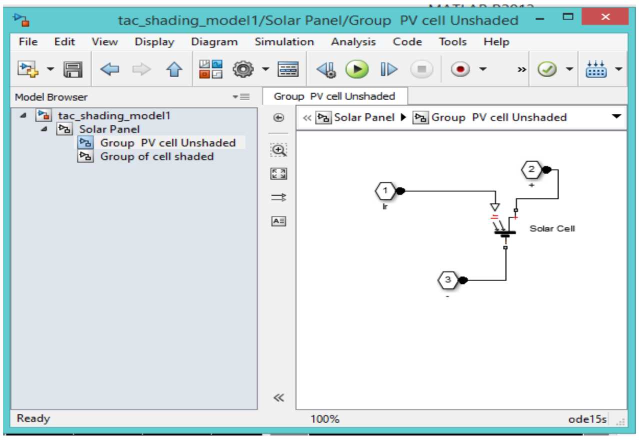

Fig 6: Un-shaded PV cell from subsystem solar panel

The output of current is given by the relationship

$$I = I_{ph} - I_o\left(e^{\left(\frac{V_d}{aV_t}\right)} - 1\right) \quad (1)$$

Where $V_t = \frac{kT}{q}$ = 20mV at room temperature

V_d = Forward bias voltage of diode

I_{ph} = Current generated due to irradiation,

I_o = The dark saturation current of diode

V_t = Thermal voltage of diode

Fig 7: I-V Characteristic of Un-shaded PV cell (Uniform irradiance)

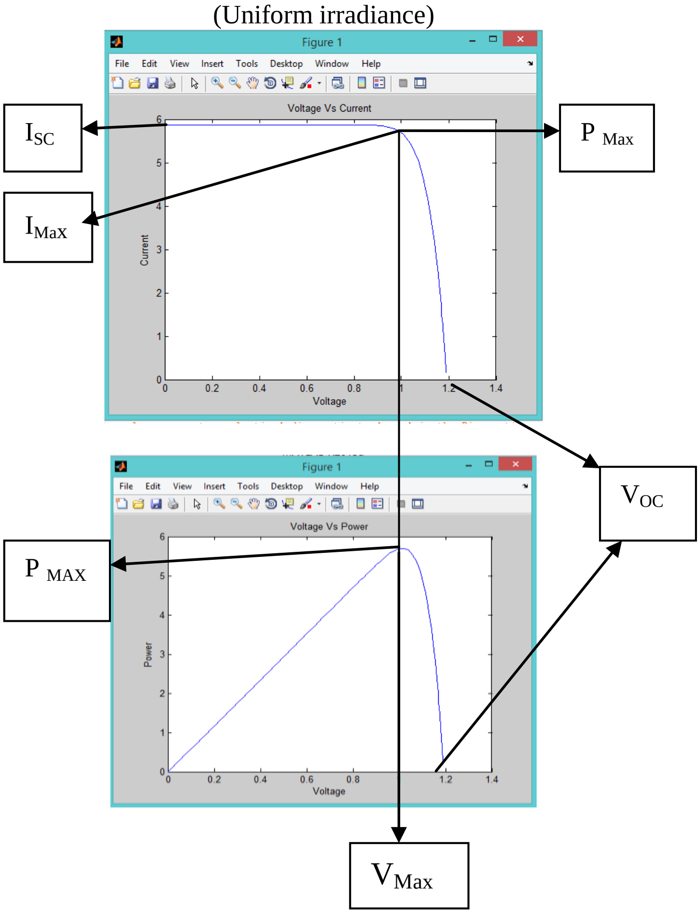

Fig 8: P-V Characteristic of Un-shaded PV cell (Uniform irradiance)

The DC power at the output is the product of current and voltage as shown in figure7. The current is maximum when there is no resistance. This maximum current is known as short circuit current (I_{SC}). The voltage is zero when there is shorting. The maximum voltage occurs when the circuit is open. This voltage is known as open circuit voltage (V_{OC}) [5]. Under this condition resistance is infinite and no current flows through the load [10].

The efficiency of solar cell is given by the ratio maximum power output to the input solar radiation thus

$$\eta = \frac{V_{mp} \times I_{mp}}{(I \times A)} \quad (2)$$

where, Vmp = maximum voltage at peak power
Imp = maximum current at peak power
I = solar radiation per square meter
A = area on which solar radiation falls

V. CHARACTERISTICS OF SPV MODULE WITH SHADED PV CELLS

The shaded pv cell of the subsystem solar panel is shown in figure 9. The partial shading was done by modeling two PV modules connected in series and a bypass diode in parallel to it [11], [12] as shown in figure 10.

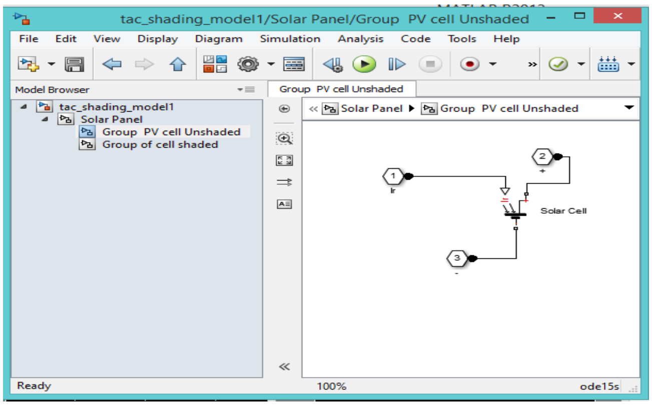

Fig 9: Shaded PV cell from subsystem solar panel

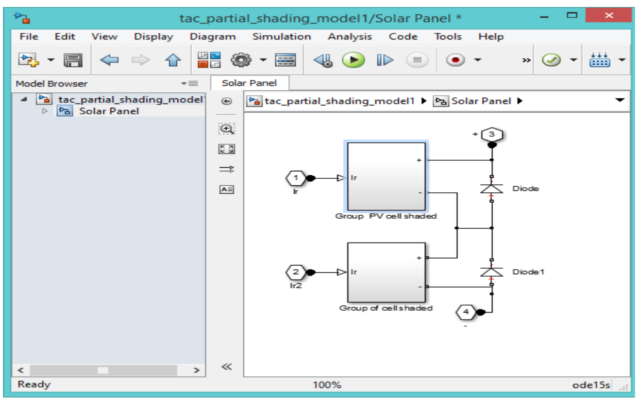

Fig 10: Two modules in series with bypass diode in parallel

The partial shading is given by irradiance 1000 W/m ² and 800 W/m² at 25° C temperature. During partial shading the solar cells produces low current as compared to unshaded solar cell. The low irradiance solar cell becomes reverse bias hence dissipating more power than the high irradiance solar cells. Thus low irradiance solar cell gets overheated causing damage or junction break in the cells. Thus, the characteristics of solar cell changes. This change can be seen in the graph given below. Due to these reasons the performance of current and power is poor in comparison with un-shaded panels as shown in figure 11 and figure12 respectively.

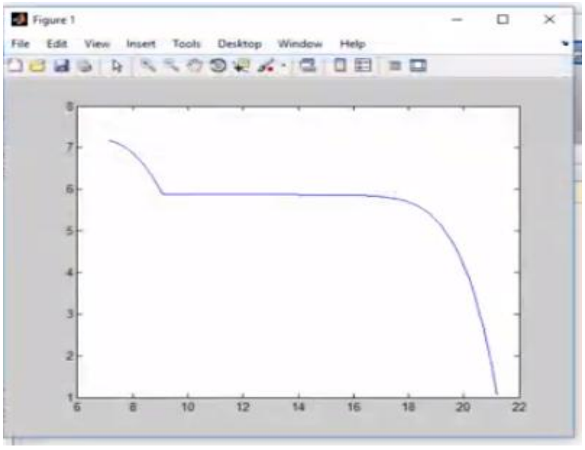

Fig 11: I-V Characteristic of Shaded PV cell

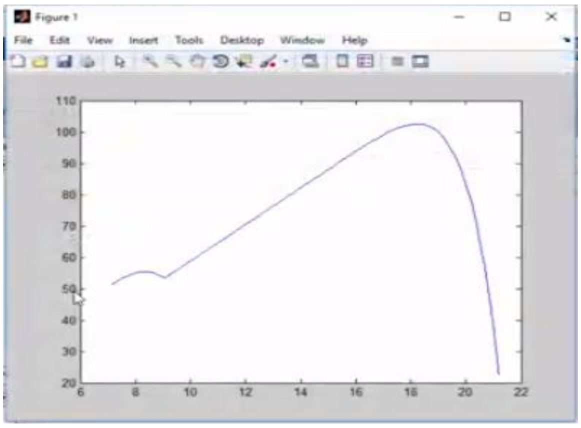

Fig 12: P-V Characteristic of Shaded PV cell

(Non uniform irradiance)

VI. COMPARATIVE ANALYSIS OF PERFORMANCE OF SOLAR PHOTOVOLTAIC MODULE

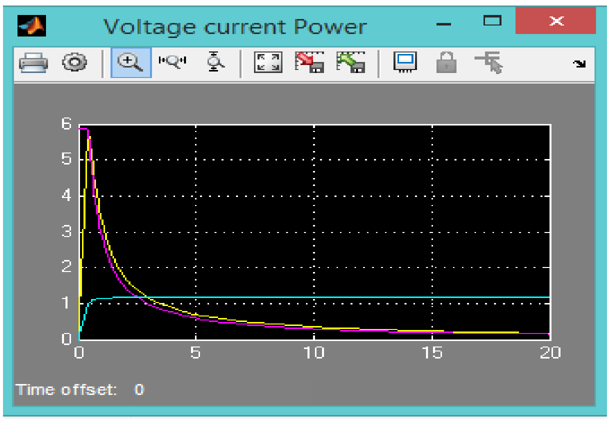

Fig 13: Current Voltage and Power w.r.t time for Un-shaded PV cells

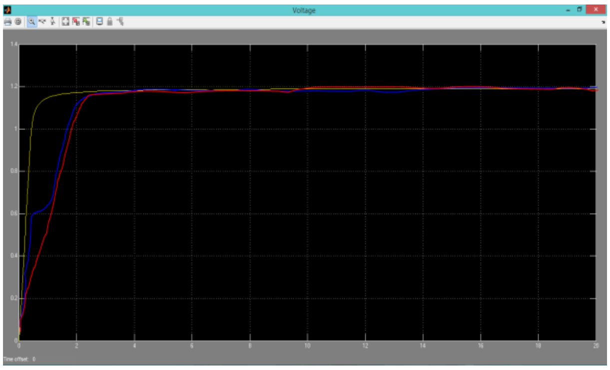

Fig 14: Compaison of voltage with normal irradiance (yellow), Blue partial shading (with bypass diode), Red partial shading (without bypass diode)

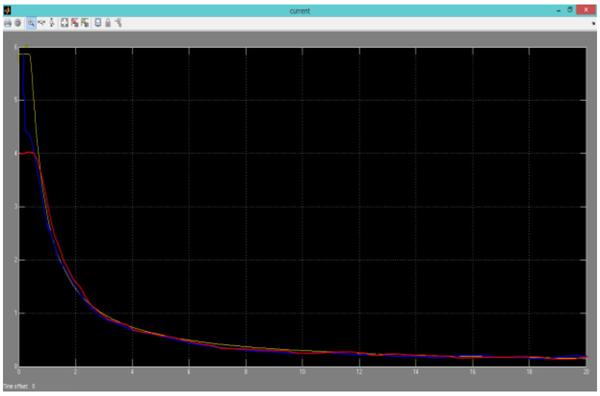

Fig 15: Comparison of Current in uniform irradiance (yellow), Blue partial Shading (with bypass diode) and Red partial shading (without bypass diode)

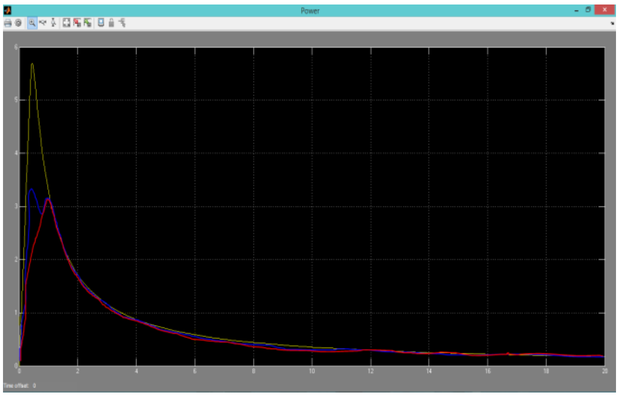

Fig 16: Comparison of power in uniform irradiance (yellow), Blue partial shading (with bypass diode) and Red partial shading (without bypass diode)

VII. CONCLUSION

The performance of SPV cell is affected by partial shading. The electrical characteristic of SPV module is analyzed and shown in graph. There is a difference in I-V and P-V characteristic in case of partial shading. The PV modules are connected in series and a bypass diodes in parallel (figure 10) reduces the power under shading condition as shown in figure 16. Thus, the degradation of maximum power is clearly visible from the graph

ACKNOWLEDGMENT

I am thankful to Dr. Mohd Yusuf Yasin and Prof. Mohd Arifuddin Mallick for inspiring me to design the model with partial shading on Simscape and analyze its performance by simulating it. We conclude that with partial shading, SPV module generate low power at the load and thus the power degrades. I am also thankful to Integral University for giving MCN No: MCN IU/R&D/2019- MNC 000546

REFERENCES

1. J. C. Teo et al, Impact of Partial Shading on the P-V Characteristics and the Maximum Power of a Photovoltaic String, Energies - Open Access Journal 17 July 2018
2. Idriss Hadj Mahammeda et al, Outdoor study of partial shading effects on different PV modules technologies, 4th International Conference on Power and Energy Systems Engineering, CPESE 2017, 25-29 September 2017, Berlin, Germany, Elsevier, Energy Procedia 141 (2017)
3. Smita Ganesh Pachpande et al, Studying the effect of shading on Solar Panel using MATLAB, International Journal of Science and Applied Information Technology, May – June 2012
4. Ekpenyong et al, Effect of Shading on Photovoltaic Cell, IOSR Journal of Electrical and Electronics Engineering, Nov. - Dec. 2013
5. Fawzan Salem et al, Detection and assessment of partial shading in photovoltaic arrays, Journal of Electrical Systems and Information Technology 3 (2016)
6. Pragyanshree Samantaray et al, Performance of solar photovoltaic module under partial shading conditions, 03 November 2016, 10th International Conference on Intelligent Systems and Control (ISCO)
7. Kota Kato et al, A study on effect of blocking and bypass diodes on partial shaded PV string with compensating circuit using voltage equalizer, 2015 IEEE International Symposium on Circuits and Systems (ISCAS), Added to IEEE Xplore: 30 July 2015
8. M.Saadsaoud et al., Study of Partial Shading Effects on Photovoltaic Arrays with Comprehensive Simulator for Global MPPT Control, INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH. 2016
9. Siyu Guo et al, Analysing partial shading of PV modules by circuit modeling. IEEE Xplore: 04 October 2012
10. Sathyanarayana P et al, Effect of Shading on the Performance of Solar PV Panel, 2015 Scientific & Academic Publishing
11. Kota Kato et al, A study on effect of blocking and bypass diodes on partial shaded PV string with compensating circuit using voltage equalizer, 2015 IEEE International Symposium on Circuits and Systems (ISCAS), Added to IEEE Xplore: 30 July 2015
12. L. Fialho et al, Effect of Shading on Series Solar Modules: Simulation and Experimental Results, Conference on Electronics, Telecommunications and Computers – CETC 2013, published in Elsevier. Procedia Technology 17 (2014)
13. Fei Lua et al, Improved PV Module Performance Under Partial Shading Conditions, PV Asia Pacific Conference 2012, Published by Elsevier Ltd 2013, Energy Procedia,

AUTHORS PROFILE

Tarana Afrin Chandel has received her M.Tech degree from UP Technical University, U.P and B.Tech degree from Magadha University, Bihar in the year 2002 and 2009 respectively and pursuing Ph.D from Integral University. Presently she working as Associate Professor (J) in Integral University, Lucknow, U.P.She is Principal Investigator of the project title “Performance Analysis of 1MW Grid Connected Solar Photovoltaic System using Image Analysis, sanctioned by Institute of Engineer, Kolkata-700020, West Bengal, India. She has been honored as **Pride of India** by International House on 12 September 2018. She is awarded **Excellent Teaching award in Higher Education** for AIRF-International Women Research and Connect Award 2018 on 8 March 2018,

Best Faculty award in Rural Institution, AIRFA- National Conference on Exploring Science and Technology for the Future Developments held on 25 November 2017, She is awarded **Best Paper Award:** Paper title "Efficient Address Generator for WiMAX Deinterleaver" in 4 National conference on Challenges & opportunities for Technical Innovation on 19th & 20th February 2016 held at Ambalika Institute of Management and Technology, Lucknow, U.P. She has achieved "**Rashtriya Gaurav Award" And Certificate of Excellence for Meritorious Services, Outstanding Performance and Remarkable Role** by Dr Bhishma Naraian Singh (Former Governor of Assam and Tamil Nadu) at the Seminar on Global Participation of India's Economic Development at New Delhi on 24 May 2010. She has published 18 research articles in International Journals and has published 22 papers in International and National conference and also had poster presentation in IEEE conference.

She is "Life member of Indian Society for Technical Education", Life member of The Institution of Engineers (India). She is President and Life member of Robotic Society, Integral University, Lucknow, U.P. **She also serves as reviewer in national and international journals.**

Prof. Md Arifuddin Mallick receives his BSc Engg and MSc Engg from AMU, Aligarh, from 1994 and 1998 respectively.He received his Ph.D degree in 2011 from Integral University, Lucknow.He is Presently working as Professor in Department of Electrical Engg, Integral University.His research interest include renewable energy, energy policy, instrumentation, power system modeling, electrical machine and drives. He is seving as fellow of Institution of Engineer, India.member if IEANG(Hong kong), Associate member of IETE, Member of IEEE respectively.He has also authored many books on electrical enginnering. He has also delivered lecture in national and internation conferences and seminar. He has many publication in national and international journal and conference proceedings. He also serves as reviewer in national and international journals. He is presently guiding government project on solar photovoltaic system. Moreover, he has two patents to his credit.

Dr. Yusuf Yasin is associated with ECE Department of Integral University, Lucknow, India.He did hid Ph.D in Low Power VLSI IN 2014. He obtained M.Sc. Engineering in Electronics Circuits and Simulationin 1996and B.Sc Engineering in Electrical Engineering in 1188, both from AMU, Aligarh, India. His research interest include Loe Power VLSI, Digital Signal Processing, Circuit and Systems, Non Conventional Energy sources e.t.c. He is working on government project