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# Comparison of Various Techniques to Mitigate the Effect of Partial Shading on Solar PV Systems

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**Abstract:** From past so many years, power production from solar photovoltaic has received expansion. It has lots of gratifications compared to other non-renewable energy sources. Also solar photovoltaic converts sunlight directly into electricity. However, the major snag in using solar photovoltaic is the effect of partial shading on it. The effect of partial shading on solar photovoltaic systems is such severe that it need not to cast on whole photovoltaic array to ruin its performance but if shading appears on even a small portion of array it will diminish the output of whole photovoltaic system to almost zero. In this paper, all the techniques that have been reported in literature to mitigate the effect of partial shading on solar photovoltaic systems are mentioned and compared. It is envisaged that this work will be a source of valuable information for photovoltaic researchers and professionals working in this area.

**Keywords:** Solar PV Systems, Mitigate, Partial Shading, solar photovoltaic.

## I. INTRODUCTION

Continuously growing of world's population due to lavish lifestyle increases demand of electricity, that increases the demand of resources. Thus, it increases use of non-renewable sources i.e. fossil fuels, coal. Extreme use of these resources has a drawback to use it in future. Also, these resources are fast degrading from many places from the world. By-products left after mining the non-renewable energy sources destructing the environment. Green house gases, acid rain, carbon compound and pollution are created by burning of fossil fuels. These also cause global warming that has adverse effect on environment. These carbon compounds are not produce by renewable energy resources.

Thus it is free from pollution. So use of these resources is increasing day by day to fulfill the needs of world's requirement of energy without any harm to the environment. These resources include hydro, solar, wind, tidal and biomass. Energy that produced from water, rainfall flowing into rivers is referred to hydroelectric power, and hence no adverse effect on environment. Another consideration of renewable energy is solar; the energy that is extracted from sunlight or heat of the sun is solar energy. In ocean, fall of tides, flood and ebb currents create potential and kinetic energy. The extraction of this energy can be taken as tidal energy. Wind energy is also the part of renewable energy and is extraction of power from wind powered ships, grain mills. It is production of electricity from wind by using high speed turbine. It is the alternative to burning fossil fuels and does not produces any green house gas. Wind energy uses air flow through wind turbines, connected to mechanical power generators and produce electricity. A wind turbine has many ranges so that many ranges of people can use them. As the wind energy has many advantages but it suffer from some disadvantages i.e. strength of wind varies from zero to storm force and do not produce constant electricity all the time. Construction of wind turbine is expensive and costly. Expensive storage is required during peak production. Problem of noise pollution is also associated with it. It has adverse effect on wild life, as birds can be affected or injured while flying into turbines. 'Solar' is the Latin word, which defines the energy from sun as a powerful source of energy. Solar power is cleanest and found most reliable form of renewable energy which is used in many forms to enhance the availability of power for industry and home. It is a part of renewable energy source because it converts sun's power into electricity without producing any kind of pollution. Solar energy has two approach solar photovoltaic (sunlight) approach and solar thermal (heat) approach.

In Solar thermal approach sunlight is concentrated with the help of many panels to heat up water to convert it into steam which moves turbine to produce electricity. As solar thermal energy have many disadvantages therefore from last couple of years, it is replaced by solar photovoltaic system with huge demand.
In photovoltaic approach, photovoltaic panel convert sun rays directly into electricity with the help of exciting

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electron. In this technique, number of cells is used to form solar panels or photovoltaic system in which each solar cell has electron that move or jump back and forth for generating direct power. As solar cell convert sunlight directly into electrical energy which is a semi-conducting material. Solar cell which are arranged in a form of large array used for power called photovoltaic or PV devices. In Photovoltaic process, few toxic chemicals are used such as cadmium and arsenic, which can be controlled by proper recycling method and disposed. In comparison with conventional energy sources of production of solar energy by using PV devices is slightly expensive which also suffers from low conversion efficiency. Generation of solar energy is totally depending on collection of sun rays that sometimes face shortage of energy. For optimum power generation, it requires to replace inverter which increases the cost. However, the possibility that there may be shade due to tree, shading due to near about panel, poles, moving clouds and bird litters over the PV.

## II. PARTIAL SHADING

Generation of power through solar photovoltaic system depends upon various condition as insolation, temperature and shading condition. Due to increasing electricity price it is being often solar photovolatic is placed on the rooftop of buildings[5]. For high voltage and current requirement photovoltaic cells are connected in series and parallel configuration. Output power from these configuration reduces due to shades on these photovoltaic cells. Shading can be categoried as easy-to-predict or difficult-to-predict. Easy-to-predict shades can be due to tree shown in fig. 1(a), due to near by panel shown in fig. 1(b), chimney, near by building, pole shown in fig. 1(c). Difficult-to-predict shades can be due to moving clouds[5], snow and dust in the vicnity of the photovoltaic array. Hence, effect of fluctuations in photovoltaic power have studied by some researchers[3]. It has studied that shading on photovoltaic due to passing clouds fluctuates power generation and affects the performance to which it is connected. Shading due to difficult - to - predict i.e. moving clouds has financial impact on utility[5]. The effect of size i.e. number of modules not only affects the performance but also the configuration of solar photovoltaic array significantly affects power output under partially shaded conditions.

Fig. 1 a) Shading due to nearby tree [www.homepower. comarticlessolar-electricitydesign-installationenergy-basics-shading-and-solar-electric-systems]

Fig. 1(b) Shading due to nearby PV panels [www.solaredge.comarticlespv-system-shading]

Fig. 1(c) Shading due to pole [www. builditsolar.comProjectsPVEnphasePVShading.htm]

Many techniques are explained to mitigate the effect of partial shading and explained as under:

Bypass Diode:
Under uniform shading condition the power-voltage characteristics of solar photovoltatic cedes single power maximum. However, at the time of non-uniform insolation that randers due to dust, aging effect and partial shading condition[3]. Superior photocurrent continues to operate unshaded cells. As the current must be equal for all series connected solar photovoltaic cell.

Hence, the shaded photovolatic cells conduct through large current [7]-[13]. The voltage at which the shaded cells operate in this condition is reverse voltage. So, it consume power during this period. Due to this, extrated maximum power from shaded solar photo voltaic arrray decreases. Hence high bias voltage causes avlanche breakdown that turn thermal breakdown of the cell. This creates hot spot problem in solar photovoltaic system. Due to excessive heating cell can burn out & thus it creates an open circuit in the shaded string. To step aside hot spot problem, bypass diodes are used.

These are connected in parallel to solar photovoltaic arrays to restrict the reverse voltage and then limit the power loss in shaded cells. This bypass diode limits the reverse voltage to less than the breakdown volt of photo voltaic cells. When reverse voltage across the shaded cells increases[3]. At partial shading condition , When bypass diodes add an alternate current path cells of a module does not follow the same current. Hence, multiple maximum develops on power-voltage current shown in fig. 2(b) . So, that it is difficult to find variance between local & global maximum.

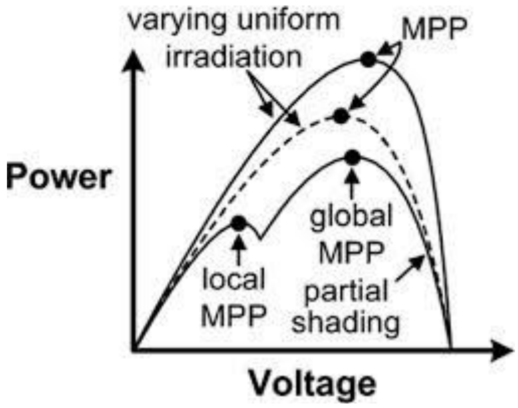


Fig. 2(b) Power-voltage curve under partial shading[www.tuc.gr/fileadmin/users_data/elci/Koutroulis/J.21.pdf]

Thus, it is hard to distinguish between local & global maximum from conventional MPPT algorithm[3]. There are some different MPPT techniques that address the partial shading condition:

Load line MPPT techinque includes two approach called Type I &Type II. In Type I, the ratio of Vmpp to Impp is taken for load line. By measuring the open-ckt voltage $V_{cc}$ & short ckt current $I_{sc}$ the load line for solar photovoltaic array can be constructed under uniform insolation [3]. For partial shading condition, the operating point moves toward glbal maximum to the result of intersection of load-line to current-voltage. This technique is helpful to track the global MPP for particular shading condition [14], [15]. For Type II load line MPPT, operating point comes in region of global maximum due to linear function[15]. This technique is helpful in improvement of output power of photovolatic system. Although, the accuracy decreases when electrical parameters of photovolatic array changes[16].

In power increment technique, a constant power is drawn from power converter in a successive manner. P & O or hill climbing algorithm are helpful to attain global maxima[3]. Previous knowledge of photovolatic is not required in power increment technique. This technique is helpful to track global MPP in both stand alone & grid connected photovolatic system[3],[16]. Power curve slope technique track global maximum at both sides of the last stored maximum[17]. In fibonacci search technique, sorted array using divide & conquer algorithm is searched . The optimal point that lies within that range by continuously narrow down the range. It finds useful to track maximum power point under uniform and non uniform insolation[18],[19]. Artificial neural network is another technique that is helpful to judge maximum power point under uniform and non uniform insolation conditions. It has layered feed forward configuration that has an input layer, hidden layer and output layer[20].

PV Array Configuration:

The effect of partial shading on solar photovoltaic array is discussed from recent years [21]-[24]. Therefore it is important to discuss the effect of partial shading on array configuration. There are many configuration to be discussed. Series, parallel, series parallel(SP), total cross tied(TCT), bridge linked(BL), and honey comb(HC) configurations are used for photovoltaic array. Among these configurations, series and parallel configurations are basic configuration used in photovoltaic array[3]. The disadvantage in using these configuration are that current and voltage are less in series and parallel configuration respectively[4]. In series-parallel configuration shown in fig. 3(a) to maintain the voltage at appropriate level, module is first connected in series and then series connected modules are further parallely connected. The modifications in TCT configuration shown in fig. 3(d) has been made by enhancement in SP configuration. In this configuration, ties are connected across rows of the junctions. Hence voltage across ties are equal and also the total current across many ties are equal. The output power in TCT configuration is as similar to SP configuration[4]. BL configuration shown in fig. 3(b) is made by connecting the modules in bride rectifier manner. The diagram shown here has four modules that forms a bridge. Therefore in this bridge two modules are first connected in series and then in parallel. Different current flows through photovoltaic string in case of TCT and BL configuration due to interconnection between photovoltaic strings. Thus. TCT and BL configurations can improve the maximum power under partial shading condition[3]. A study shows that TCT configuration has highest maximum power point[3]. To make a new configuration BL configuration is modified and named as honey comb configuration shown in fig. 3(c). HC configuration has advantages of both TCT and BL configurations.

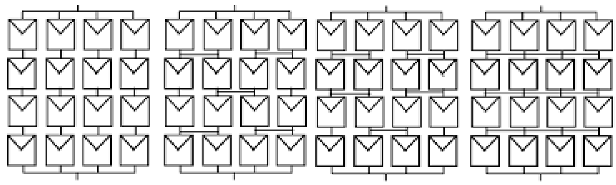

Fig. 3 (a) SP (b)BL (c) HC (d) TCT
[www.iaeng.orgpublicationWCE2014WCE2014_pp270-275.pdf]

Also an adaptive reconfiguration scheme is used so that it reduces shadow effect. A solar adaptive bank is connected through a switching matrix to fixed part of solar photovoltaic array[26].

PV array architecture:

For grid connected PV systems basic architectures are defined as centralized architecture, parallel connected microconverter, series connected microconverter and microinverters. Among all these architecture centralized is conventional inverter architecture . But it cannot track global maximum power point of individual photovoltaic modules. Hence this architecture is not suitable under shading and mismatching losses[3]. For parallel architecture, modules are connected through dc-dc converter from central inverter. Series connected microconverter architecture tracks maximum power point of individual modules through dc-dc converter then connected to central inverter[3]. Central inverter is not used in microinverter architecture and permits maximum power point techniques for individual modules.

Multilevel Inverter:
Multilevel inverter defines level and thus various voltage values are referred in a cycle[6]. The risen in voltage level indicates less harmonic content in the output voltage. Therefore, it produces sine wave output waveform easily. Multi string five-level inverter has advantage as it has reduced number of switches and thus reduces switching losses[6]. Transistor- clamped h- bridge based cascaded multi level inverter with capacitor voltage balancing is used. It has higher output quality.

## III. CONCLUSION

In this paper study of different configuration, architecture has been studied under partial shading condition. Bypasss diode provides an alternate path in partial shading condition but creates multiple maximum power point. Different MPPT techniques is provided by Type I and Type II to address partial shading condition. Power increment technique is helpful in fast and accurate tracking under critical application. Fibonacci search works for specific pattern whereas ANN has complicated system. At high efficiency conventional converter do not maintain broad range. Multilevel inverter approximately sinusoidal output voltage waveform thus many losses are low.

## REFERENCES


[1] Saranrom Wuttichai and Sompob Polmai, "The efficiency improvement of series connected PV panels operating under partial shading condition by using per-panel DC/DC converter." In Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), vol. 8, 2011, pp. 760-763.

[2] Patel Hiren and Vivek Agarwal, "MATLAB-based modeling to study the effects of partial shading on PV array characteristics," Energy Conversion, IEEE Transactions, vol. 23, no. 1, pp. 302-310, 2008.

[3] Bidram, Ali, Ali Davoudi and Robert S. Balog, "Control and circuit techniques to mitigate partial shading effects in photovoltaic arrays," Photovoltaics, IEEE Journal, vol.2, no. 4, pp. 532-546, 2012.

[4] Ramaprabha R. and B. L. Mathur, "A comprehensive review and analysis of solar photovoltaic array configurations under partial shaded conditions," International Journal of Photoenergy , 2012.

[5] Pareek Smita and Ratna Dahiya, "Output Power Comparison of TCT & SP Topologies for Easy-to-Predict Partial Shadow on a 4× 4 PV Field," In Applied Mechanics and Materials, vol. 612, pp. 71-76, 2014.

[6] Remya k Anto and Suma Muraleedhar, "Multilevel Inverter with Minium Switches in A PV System Under Partial Shadin Conditions," International Jouranal of Emerging Technology and Advanced Engineering, vol. 5.3, 2015.

[7] Spertino Filippo and J. Sumaili Akilimali, "Are Manufacturing–Mismatch and Reverse Currents Key Factors in Large Photovoltaic Arrays," Industrial Electronics, IEEE Transactions , vol. 56, no. 11, pp. 4520-4531, 2009.

[8] Patel Hiren and Vivek Agarwal, "MATLAB-based modeling to study the effects of partial shading on PV array characteristics," Energy Conversion, IEEE Transactions vol. 23, no. 1, pp. 302-310, 2008.

[9] Ghitas Ahmed E. and M. Sabry, "A study of the effect of shadowing location and area on the Si solar cell electrical parameters," vol. 81, no. 4, pp.475-478, 2006.

[10] Drif M., P. J. Pérez, J. Aguilera and J. D. Aguilar, "A new estimation method of irradiance on a partially shaded PV generator in grid-connected photovoltaic systems," Renewable energy, vol. 33, no. 9, pp. 2048-2056, 2008.

[11] A. Maki and S. Valkealahti, "Power loss in long string and parallel connected short strings of series-connected silicon-based photovoltaic modules due to partial shading conditions," IEEE Trans. Energy Convers., vol. 27, no. 1, pp. 173–183, 2012.

[12] E.V. Paraskevadaki and S. A. Papathanassiou, "Evaluation ofMPP voltage and power of mc-Si PV modules in partial shading conditions," IEEE Trans. Energy Convers., vol. 26, no. 3, pp. 923–932, 2011.

[13] R. A. Mastromauro, M. Liserre and A. Dell'Aquila, "Control issues in single-stage photovoltaic systems: MPPT, current and voltage control," IEEE Trans. Ind. Informat., vol. 8, no. 2, pp. 241–254, May. 2012.

[14] Kobayashi Kenji, Ichiro Takano and Yoshio Sawada, "A study of a two stage maximum power point tracking control of a photovoltaic system under partially shaded insolation conditions," Solar energy materials and solar cells, vol. 90, no. 18 pp. 2975-2988, 2006.

[15] Ji Young-Hyok, Doo-Yong Jung, Jun-Gu Kim, Jae-Hyung Kim, Tae-Won Lee and Chung-Yuen Won, "A real maximum power point tracking method for mismatching compensation in PV array under partially shaded conditions,"Power Electronics, IEEE Transactions, vol. 26, no. 4, pp. 1001-1009, 2011.

[16] Koutroulis Eftichios and Frede Blaabjerg, "A new technique for tracking the global maximum power point of PV arrays operating under partial-shading conditions," Photovoltaics, IEEE Journal, vol. 2, no. 2, pp. 184-190, 2012.

[17] Patel Hiren and Vivek Agarwal, "Maximum power point tracking scheme for PV systems operating under partially shaded conditions," Industrial Electronics, IEEE Transactions, vol. 55, no. 4, pp. 1689-1698,2008.

[18] Ahmed Nabil A. and Masafumi Miyatake, "A novel maximum power point tracking for photovoltaic applications under partially shaded insolation conditions," Electric Power Systems Research, vol. 78, no. 5, pp. 777-784, 2008.

[19] Miyatake, Masafumi, Takeshi Inada, Isao Hiratsuka, Hongyan Zhao, Hisayo Otsuka and Motomu Nakano, "Control characteristics of a fibonacci-search-based maximum power point tracker when a photovoltaic array is partially shaded, " In Power Electronics and Motion Control Conference, vol. 2, pp. 816-821, 2004.

[20] Nguyen Dzung D., Brad Lehman and Sagar Kamarthi, "Solar photovoltaic array's shadow evaluation using neural network with on-site measurement," In Electrical Power Conference, pp. 44-49, 2007.

[21] Herrmann W., W. Wiesner and W. Vaassen "Hot spot investigations on PV modules-new concepts for a test standard and consequences for module design with respect to bypass diodes," In Photovoltaic Specialists IEEE, vol. 26, pp. 1129-1132, 1997.

[22] Kaushika Narendra D. and Nalin K. Gautam, "Energy yield simulations of interconnected solar PV arrays," Energy conversion, IEEE transactions, vol. 18, no. 1, pp. 127-134, 2003.

[23] M. Klenk, S. Keller, L. Weber et al., "Investigation of the hotspot behaviour and formation in crystalline silicon Power cells, PV in Europe, From PV technology to energy solutions," in Proceedings of the International Conference, pp. 272–275, 2002.

[24] Woyte Achim, Johan Nijs and Ronnie Belmans, "Partial shadowing of photovoltaic arrays with different system configurations: literature review and field test results," Solar energy, vol. 74, no. 3, pp. 217-233, 2003.

[25] Ramabadran Ramaprabha and Badrilal Mathur, "Effect of shading on series and parallel connected solar PV modules," Modern Applied Science, vol. 3, no. 10, pp. 32, 2009.

[26] Nguyen Dzung and Brad Lehman, "An adaptive solar photovoltaic array using model-based reconfiguration algorithm," Industrial Electronics, IEEE Transactions, vol. 55, no. 7, pp. 2644-2654, 2008.