International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Using Odd Even Configuration Technique to Reduce Mismatch Power Losses of PV Array under Partial Shading Condition

[1]Siddhant Adhave, [2]Prof. S. V. Murkute

[1]M. Tech (EPS), P.E.S College of Engineering Nagsenvana, Aurangabad (MS), 431001

[2]Associate Professor, Department of Electrical Engineering, P.E.S College of Engineering, Aurangabad (MS), 431001

ABSTRACT

The given paper presents a review about the effect of Partial Shading Condition (PSC) on various solar photovoltaic (SPV) array topologies. Under the influence of Partial Shading Condition, the level of solar irradiance varies from one SPV module to another, and because of this total power generated of a SPV system reduces. In order to reduce these losses in SPV panels, we can modify the configuration of the panels in array/module. One of the way to improve the output energy and power efficiency is that panels may be configure in many different configurations such as Series(S), Parallel (P), Series Parallel (SP), Total Cross Tied (TCT), Bridge Linked (BL), and Honeycomb (HC). A novel PV array configuration, named as the Odd Even Configuration (OEC) has been proposed to reduce the effects of Partial Shading Condition.

Keywords: Keywords: Partial Shading Condition (PSC), solar photovoltaic (SPV), Series Parallel (SP), Total Cross Tied (TCT), Bridge Linked (BL), Honeycomb (HC), Odd Even Configuration (OEC), Maximum Power Point (MPP)

Introduction

The consumption of energy is increasing every day. As the consumption is increasing the, the demand for the power production from power plants is also increasing. The present world is spiraling down into an energy crisis. The energy crisis is the concern that the world's demands on the limited natural resources such as coal, oil, gas, fossil fuel, wood etc. that are used to power industrial society and household are reducing as the demand rises. These natural resources are in limited supply. While they do occur naturally, it can take hundreds of thousands of years to reproduce the stores. Conventional energy resources like fossil fuels are being exhausted at an alarming rate and may be completely vanished in the next few decades. Also use of the conventional energy sources cause different types of pollution.

This type of situation leads to look out for solution to find an alternate source to meet our energy demands. An effective alternative can be found in renewable energy resources such as wind, solar, geothermal, biogas and ocean energy etc., which offer easy availability and get reproduce over time naturally, so they would not be depleted. Among all the renewable energy sources, the solar energy can be considered as the most essential and prerequisite sustainable resource because of its easy availability and abundance in nature.

Even though the renewable energy sources are easily available, utilizing them to their full extent is still challenging. Out of all the renewable energy generation technologies, solar PV energy is the most prominent technology. The primary goal for using renewable energy in India is to advance economic development, improve access to energy, improve energy security, and mitigate climate change. India is thickly populated and has high solar insolation level, an ideal combination for using solar power. One of the advantage using solar power, is the direct conversion of sunlight to electricity.

Under partial shading conditions (PSC), photovoltaic (PV) arrays are subjected to different irradiance levels caused by no-uniform shading. Non uniform shading is caused due to nearby objects such as trees, tall buildings, clouds etc., some of the modules of the PV array end up getting shaded, while the other modules receive the full insolation. Because of the variable irradiance level there will be mismatch between the power generated by each module and this will result into significant reduction in the total power generated. It is quite difficult to track the Maximum Power Point of the solar PV system due to the occurrence of Partial Shading Condition [2]. This further leads to the problem of not only reducing the total maximum output power of the PV module but also shows extremely non-linear behavior in the I-V and P-V curves. Due to partial shading condition and non-linearity in the curves, multiple optima point (MPPs) are observed, the greatest of which is referred as Global Maximum Power Point (GMPP) and rest of the points are called as local maximum power points (LMPP) [3], [1].

The goal of this paper is to state a technique which will help to mitigate the effects of partial shading condition. It is achieved by reconfiguring the physical positions of the PV modules within a TCT connected PV array. This type of configuration consists of positioning all the odd numbered module together and all the even numbered modules are clumped together, Hence the name given as Odd Even technique.

The structure of this paper is organized as follows. The introductory part is covered in section I. section II states Partial shading and mismatch effects. Section III deals with different techniques to mitigate Partial Shading in Photovoltaic Panels describes and section IV describes the proposed reconfiguration method of OEC. Last section concludes and the scope for further work is presented.

Partial Shading & Mismatch Effects

Generally, PV array is works under two possible conditions, namely uniform irradiance condition (UIC) and partial shading condition. In case of uniform condition, all PV modules in PV array receives equal irradiance and hence produce the same amount of maximum power and improves overall array performance. In any case, PV array is shaded by a tall building, tree, or passing clouds, it will result into partial shading condition. In PSCs, the amount of irradiance received by the shaded module is less than the unshaded ones, this scenario creates a hot-spot problem in PV array. Further, it may lead to damage the PV cells or modules [14]. In order to meet the load power demand, the Photovoltaic (PV) panels are usually connected in series or parallel connection. However, if any of the panels are subjected to partial shading condition, the power generated by this PV panels will be reduced by a great amount. The partial shading is result of the buildings, and poles, shadows of trees, and even the movement of clouds in large-scale PV systems. Power generated by a Photovoltaic (PV) cell reduces significantly due to non-uniform irradiance. And hence in the case of PV module or array, the generated output power gets reduced and further reduced the overall system performance. The amount of the reduction in the maximum power generated is not directly proportional to the shading area. Other factors such as the shading pattern and type of array configuration chosen also shows significant effect on the reduction of the maximum power generated.

Multiple solutions have been discussed in the literature to mitigate the effects of partial shadings. But, out of all the possible solutions, it is quite difficult to achieve the enhance the maximum power to the possible extent. Therefore, to compensate these power losses a promising technique is required which relies on reconfiguration strategies. It consists of reconfiguring the PV modules within the given PV array so that to increase the maximum power at highest level. These strategies are classified into dynamic and static reconfiguration techniques.

One of the solution to this problem is to use a bypass diode connected across each PV module to provide an alternative current path during partial shadings condition. This will lead to showing each PV module a different I-V characteristics, which creates mismatch losses in the PV system. The mismatch losses are categorized into internal and external mismatch loss. Internal mismatch loss can be seen as a variation of the parameters of a PV module due to changes on its physical conditions; nonhomogeneous characteristics of solar cells, defective manufacturing, faults in solar cells, malfunction of PV modules and physical effect of doping [15], [16]. The internal losses will have effect on parameters such series resistance (Rs), parallel resistance (Rp), the thermal voltage (Vt) and the reverse saturation current (I0). The external factors include degradation of cell material, dirt accumulation on surface, different temperatures and irradiance conditions [17], [18].

All of the above factors lead to a significant reduction of the modules performance in PV array. Under partial shading, the obtained maximum power is less than the maximum power of uniform condition. As stated, these losses cannot be completely avoided, but it can be minimized to a satisfactory level by using some effective techniques. The effect of PSC can be remedied to some extent by using different interconnections within a solar PV array. This is made possible by connecting the PV modules within a PV array in ways other than the classic Series Parallel (SP) configuration. This new connection will provide alternate paths for the current to flow, when some modules in a row are shaded and the current generated by them is reduced. A few of the configurations that can be obtained in this manner are Total Cross Tied (TCT), Series Parallel-Total Cross Tied (SP-TCT), Bridge Link-Total Cross Tied (BL-TCT) and Bridge Link-Honey Comb. SP, TCT, BL and HC configurations for 6 × 4 and 5× 3 size PV arrays have been investigated in [4] for different partial shading scenarios.

Another solution of reducing the effect of partial shading is to evenly disperse the shadow over the entire array as much as possible. As we cannot control the pattern of the shadows falling on the PV module, instead it is achieved by interchanging the positions of the PV modules within the PV array configuration, while keeping their connections the same. Using this reconfiguration method, many such PV array configurations have been developed in the past. In [5],

Half Reconfiguration Photovoltaic Array (HRPVA) and Full Reconfiguration Photovoltaic Array (FRPVA) have been studied along with SP, TCT and BL configurations for 6 × 4 PV arrays under different partial shading condition. The best results are obtained with the use of HRPVA configuration. A reconfiguration pattern for 9 × 9 size PV array based on the Su-Do-Ku puzzle has been proposed in [6] and has shown better performance than conventional configurations under PSCs. An optimization based approach to change the connections between the PV modules while keeping their physical locations fixed has been analyzed in [7] and [8]. Further, a shadow dispersion technique utilizing GA based optimization technique for Su-Do-Ku PV array configuration has been proposed which offers minimum power loss and best FF. In [9] and [10], Reconfiguration TCT (RTCT) configuration has been compared and found to be better than TCT by analyzing power losses and FF.

Different Techniques to Mitigate Partial Shading in Photovoltaic Panels

Non-uniform irradiance will lead reduction in the Power delivered by a Photovoltaic (PV) cell. The effect of partial shading in photovoltaic (PV) panels is one of the biggest concern regarding power losses in PV systems. When the irradiance level throughout a PV panel is inequal, some cells with the possibility of higher power production will produce less and hence start to deteriorate. The reduction of output power is not directly proportional to the shading area but depends on the shading pattern and type of array configuration used. Many solutions have been reported in the literature to mitigate the effect of partial shading condition [25]. These techniques are mainly classified into two types; (a) passive techniques and (b) active techniques [25]

(a) Passive Techniques: In passive techniques, the bypass diode is most commonly used passive element for reducing Partial shading condition. The diode connection is as shown in fig. 1 and 2. In any case where PV module is shaded by building or a passing clouds or a tree, irradiance received by the shaded module is less than the unshaded ones, this will create a hot-spot problem in PV module. This may cause damage to the PV cells or modules.

However, to overcome this, a bypass diode is connected across each PV module to provide an alternative current path during partial shadings. Under this condition, each PV module would generate different I-V characteristics, which lead to mismatch losses in the PV system. Bypass diode protects the PV modules from the heating and increases overall power output under shading condition. [25]

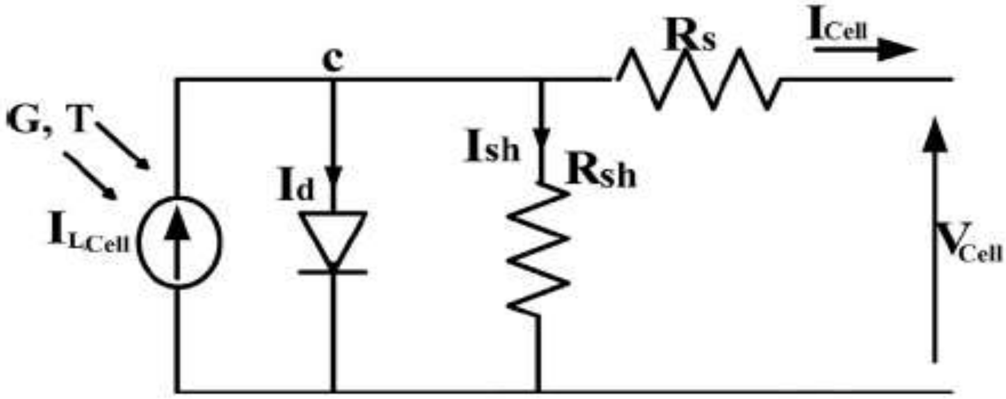

Fig. 1 Equivalent circuit of single diode PV cell model.

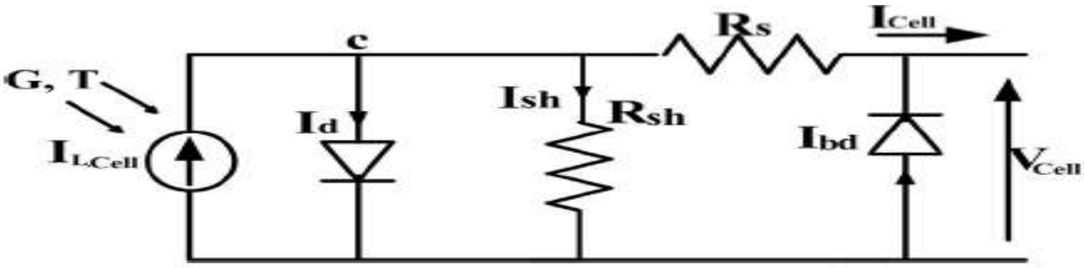

Fig. 2 Single diode PV cell with bypass diode.

(b) Active Techniques: The active techniques are found to be more superior than passive techniques for reducing PSC effects. These techniques are classified into three categories: (1) Distributed MPPT techniques, (2) Multi-level Inverters and (3) Reconfiguration Strategies.

(1) Distributed MPPT Techniques:

In this method each and every PV module is equipped with its own independent MPPT, which reduces the PSC losses. Also, this technique does not require the installation of bypass diodes. As a result, the corresponding losses are neglected [20], [21]. This technique involves additional components such as DC-DC converters or DC-AC inverters for each module. The additional components make this a very complicated structure, which is shown in Fig. 1.

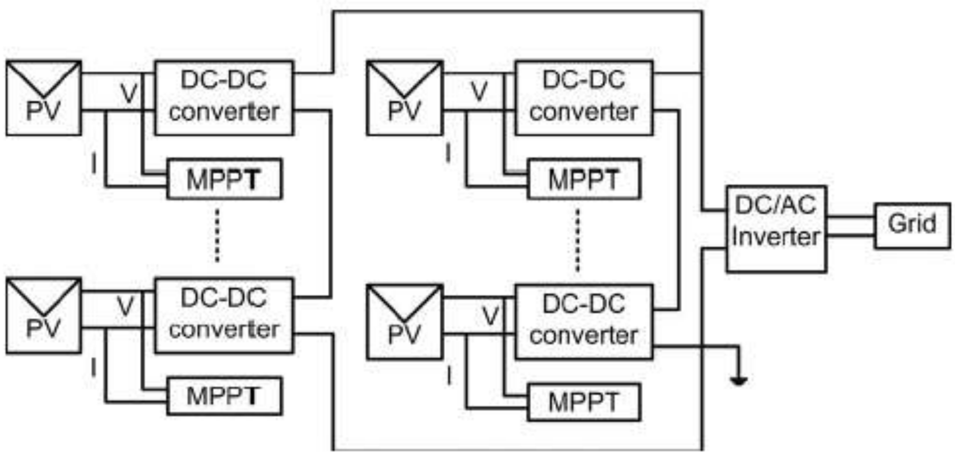

Fig. 3 PV module with Distributed MPPT

(2) Multi-level Inverters:

Multi-level inverters (MLIs) are the newest addition to the PV modules for reducing PSC losses. There are different types MLI topologies available such as diode-clamped, flyback capacitor and cascaded H-bridge. This different types of topologies helps to reduce shading effects on each module or group of modules by the controlling of individual output voltages. Moreover, these inverters reduce the voltage stress on the device and output AC voltage harmonics [22]. MLI requires an enhanced and effective control structure to achieve operation at the optimal power point [23]. In this approach, each module or group of modules has its own inverter, which add up to the total cost and hence its expensive. (refer Fig. 4)

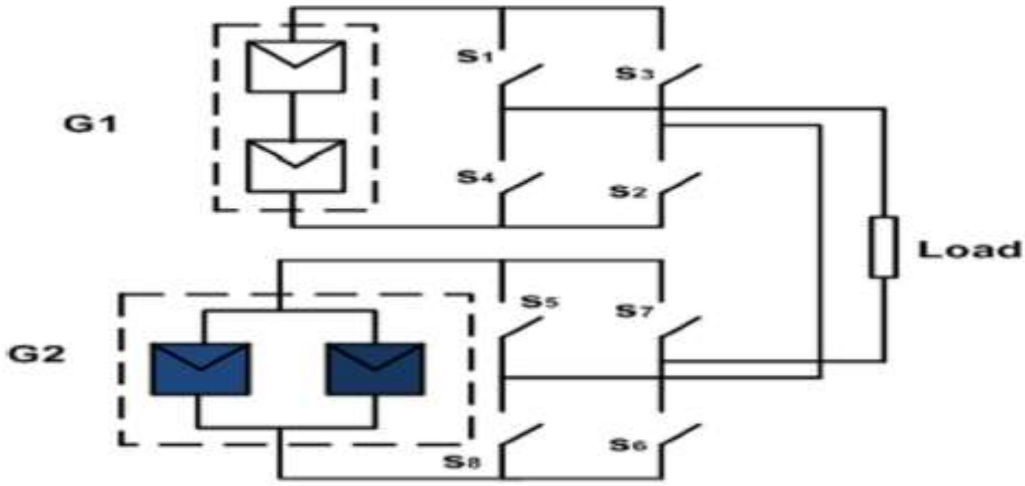

Fig. 4 Grouping of PV modules with multilevel inverters.

(3) Reconfiguration Strategies: In this technique, the PV modules are reconfigure based on irradiance levels, which is a function of their operating conditions and load request [24], hence it proves to be the most promising technique in order to increase the power output under PSC. Reconfiguration strategies are further classified into dynamic PV array reconfiguration Techniques and static PV array reconfiguration techniques.

4. Proposed Odd Even Configuration

A novel configuration technique named as the Odd Even Configuration (OEC) is presented in this paper and shown in Fig. 5. The PV modules are electrically connected in a manner which is similar as TCT configuration. The connection is designed in such a way that within a series column string, all the odd numbered row PV modules are clumped together physically within a PV array. After connecting all the odd numbered modules in this manner within a column, they are followed by modules belonging to even numbered rows according the electrical connections, which are again clumped together.

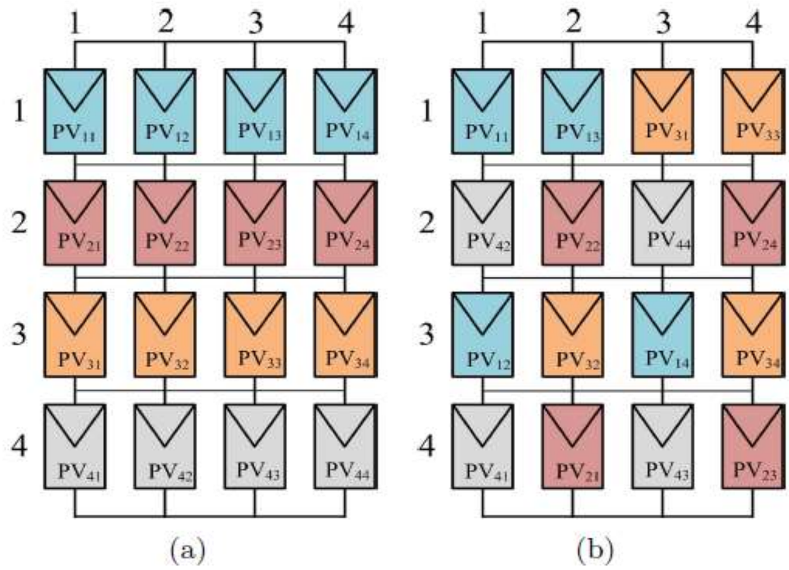

Fig. 5 The interconnections of PV modules within a 6 × 4 PV array with OEC

Furthermore, the physical position of the module connected in the 1st row of a given column is shifted by a certain number of rows after every column in arithmetic position. The odd-even reconfiguration of a PV array is a static technique. In [19], the odd-even reconfiguration technique was presented for a 4×4 TCT configuration. In this technique, the modules of the PV are numbered as P Vmn, where, m, n indicates row and column number. The reconfiguration is implemented by rearranging the PV modules in an odd numbered row as (P V11, P V13, P V31, P V33) and column as (P V42, P V22, P V44, P V24) as shown in Fig. 1. Further, the modules in odd numbered rows are arranged as (P V12, P V32, P V14, and P V34). Similarly, even number of columns are updated as (P V41, P V21, P V43andP V23). This technique results in higher performance and reduced mismatch losses compared to the conventional TCT configuration during partial shading conditions. The odd-even reconfiguration technique disperses the shade appearing over PV panels and thus helps to increase the power production.

The odd-even technique easy to implement and its very simpler. However, main drawback of this method is that it is limited to small rated PV arrays because of the physical relocation of PV modules.

Conclusion

This paper reviews the novel odd even configuration (OEC) technique to mitigate the effects of the partial shading condition. The partial shading condition is a major problem in efficient operation of the PV modules. The amount of maximum output power generated is greatly affected due the Partial shading phenomenon. There are number of techniques available in literature which helps to reduce the effect of PSC such as multilevel inverters, bypass diodes, distributed MPPT, PV modules interconnection, and reconfiguration strategies. The given paper emphasizes on reconfiguration strategies to enhance the maximum output power of PV module under Partial Shading condition. The paper also reviews different types of configuration such as TCT, SP-TCT, BL-TCT, ASY along with OEC. Proposed OEC configuration found to be simple and efficient. As the given configuration is suitable for only small rated PV module as it involves physical relocation of PV module, the future work can be carried out to improvise the technique so as to be suitable for higher rated PV modules.

References

1. Ashouri-Zadeha, Alireza, Toulabia, Mohammadreza, Dobakhsharib, Ahmad Salehi, Taghipour-Broujenia, Siavash, Ranjbara, Ali Mohammad, 2018. A novel technique to extract the maximum power of photovoltaic array in partial shading conditions. Int. J. Electr. Power Energy Syst. 101, 500–512.
2. Kovach, A., Schmid, J., 1996. Determination of energy output losses due to shading of building-integrated photovoltaic arrays using a raytracing technique. Sol. Energy 57 (2), 117–124.
3. Karatepe, Engin, Boztepe, Mutlu, Colak, Metin, 2007. Development of a suitable model for characterizing photovoltaic arrays with shaded solar cells. Sol. Energy 81 (8), 977–992.
4. Villa, Luiz Fernando Lavado, Picault, Damien, Raison, Bertrand, Bacha, Seddik, Labonne, Antoine, 2012. Maximizing the power output of partially shaded photovoltaic plants through optimization of the interconnections among its modules. IEEE J. Photovolt. 2 (2), 154–163.
5. Shams El-Dein, M.Z., Kazerani, M., Salama, M.M.A., 2011. Novel configurations for photovoltaic farms to reduce partial shading losses. In: Proceedings of IEEE International Conference on Power and Energy Society General Meeting. pp. 1–5.
6. Indu Rani, B., Saravana Ilango, G., Nagamani, Chilakapati, 2013. Enhanced power generation from PV array under partial shading conditions by shade dispersion using Su Do Ku configuration. IEEE Trans. Sustain. Energy 4 (3), 594–601.
7. Malathy, S., Ramaprabha, R., 2015. A static PV array architecture to enhance power generation under partial shaded conditions. Proceedings of IEEE Conference on Power Electronics and Drives System. pp.341–346.
8. Deshkar, Shubhankar Niranjan, Dhale, Sumedh Bhaskar, Mukherjee, Jishnu Shekar, Sudhakar Babu, T., Rajasekar, N., 2015. Solar PV array reconfiguration under partial shading conditions for maximum power extraction using genetic algorithm. Renew. Sustain. Energy Rev. 43, 102–110.
9. Potnuru, Srinivasa Rao, Pattabiraman, Dinesh, Ganesan, Saravana Ilango, Chilakapati, Nagamani, 2015. Positioning of PV panels for reduction in line losses and mismatch losses in PV array. Renew. Energy 78, 264–275.
10. Vijayalekshmy, V., Bindu, G.R., Iyer, S.R., 2015. Performance improvement of partially shaded photovoltaic arrays under moving shadow conditions through shade dispersion. J. Inst. Eng. (India) Ser. B 96, 1–7.
11. Yadav, Anurag Singh, Pachauri, Rupendra Kumar, Chauhan, Yogesh K., Choudhury, S., Singh, Rajesh, 2017. Performance enhancement of partially shaded PV array using novel shade dispersion effect on magic-square puzzle configuration. Sol. Energy 144, 780–797.
12. Vijayalekshmy, S., Bindu, G.R., Rama Iyer, S., 2016. A novel Zig-Zag scheme for power enhancement of partially shaded solar arrays. Sol. Energy 135, 92–102.
13. Mishra, Neha, Yadav, Anurag Singh, Pachauri, Rupendra, Chauhan, Yogesh K., Yadav, Vinod K., 2017. Performance enhancement of PV system using proposed array topologies under various shadow patterns. Sol. Energy 157, 641–656.

14. Kamarzaman, N.A., Tan, C.W., 2014. A comprehensive review of maximum power point tracking algorithms for photovoltaic systems. Renew. Sustain. Energy Rev. 37, 585–598.

15. Mäki, A., Valkealahti, S., 2012. Power losses in long string and parallel-connected short strings of series-connected silicon-based photovoltaic modules due to partial shading conditions. IEEE Trans. Energy Convers. 27 (1), 173–183.

16. Ramos-Paja, C.A., Bastidas, J.D., Saavedra-Montes, A.J., Guinjoan-Gispert, F., Goez, M., 2012. Mathematical model of total cross-tied photovoltaic arrays in mismatching conditions. In: Circuits and Systems (CWCAS), 2012 IEEE 4th Colombian Workshop on. IEEE, pp. 1–6.

17. Zhao, Y., Yang, L., Lehman, B., de Palma, J.-F., Mosesian, J., Lyons, R., 2012. Decision tree-based fault detection and classification in solar photovoltaic arrays. In: Applied Power Electronics Conference and Exposition (APEC), 2012 Twenty-Seventh Annual IEEE. IEEE, pp. 93–99.

18. Skoplaki, E., Palyvos, J., 2009. On the temperature dependence of photovoltaic module electrical performance: a review of efficiency/power correlations. Sol. Energy 83 (5), 614–624.

19. Nasiruddin, S. Khatoon, M. F. Jalil, R. Bansal, Shade diffusion of partial shaded pv array by using odd-even structure, Solar Energy 181 (2019) 519–529.

20. Femia, N., Lisi, G., Petrone, G., Spagnuolo, G., Vitelli, M., 2008. Distributed maximum power point tracking of photovoltaic arrays: novel approach and system analysis. IEEE Trans. Industr. Electron. 55 (7), 2610–2621.

21. Shmilovitz, D., Levron, Y., 2012. Distributed maximum power point tracking in photovoltaic systems emerging architectures and control methods. Automatika 53 (2), 142–155.

22. Malathy, S., Ramaprabha, R., 2015a. Performance enhancement of partially shaded solar photovoltaic array using grouping technique. J. Sol.Energy Eng. 137 (3), 034505.

23. Busquets-Monge, S., Rocabert, J., Rodríguez, P., Alepuz, S., Bordonau, J., 2008. Multilevel diode-clamped converter for photovoltaic generators with independent voltage control of each solar array. IEEE Trans. Industr. Electron. 55 (7), 2713–2723.

24. Salameh, Z.M., Dagher, F., 1990. The effect of electrical array reconfiguration on the performance of a pv-powered volumetric water pump. IEEE Trans. Energy Convers. 5 (4), 653–658.

25. Krishna, G. & Moger, Tukaram. (2019). Reconfiguration strategies for reducing partial shading effects in photovoltaic arrays: State of the art. Solar Energy. 182. 429-452. 10.1016/j.solener.2019.02.057.