Partial Shading Effect on Various Interconnection Schemes of SPVA

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Abstract: Partial shading affects the performance of solar photovoltaic system terribly badly. As a result of during this state solar insolation received by every cell don't seem to be uniform. Because in this situation some cells get very good insolation but shaded cells get very little insolation. And this non uniform insolation causes flow of no uniform current through the whole system, which causes multiple MPP for the same system. In this report, the effect of partial shading has been seen on various solar topologies such as**-:**Series-parallel (SP), Bridge-linked (BL), Total-cross-tied (TCT), and Honey-comb (HC) configuration**.** At the same time, this result was invested which one of these topologies is performing well in the partial condition. The results obtained can be easily understood so it has been shown in the form of I-V and P-V Characteristics.

***Index Terms* - Multiple MPP, Partial shading, and Solar cells.**

I. INTRODUCTION

Today's solar photovoltaic systems are often installed on rooftops and facades in urban area .where partial shading is a common problem; consequently each photovoltaic system has to endure this problem every day [1]. The performance of PV system is especially based on operating conditions such as solar radiation, and temperature. The amount of electricity made by a separate solar cell in its output terminals is predicted on the amount of radiation received at PN junction. It's really the proportion of radiation that truly gets converted into electricity in different words it demonstrates its conversion potency.

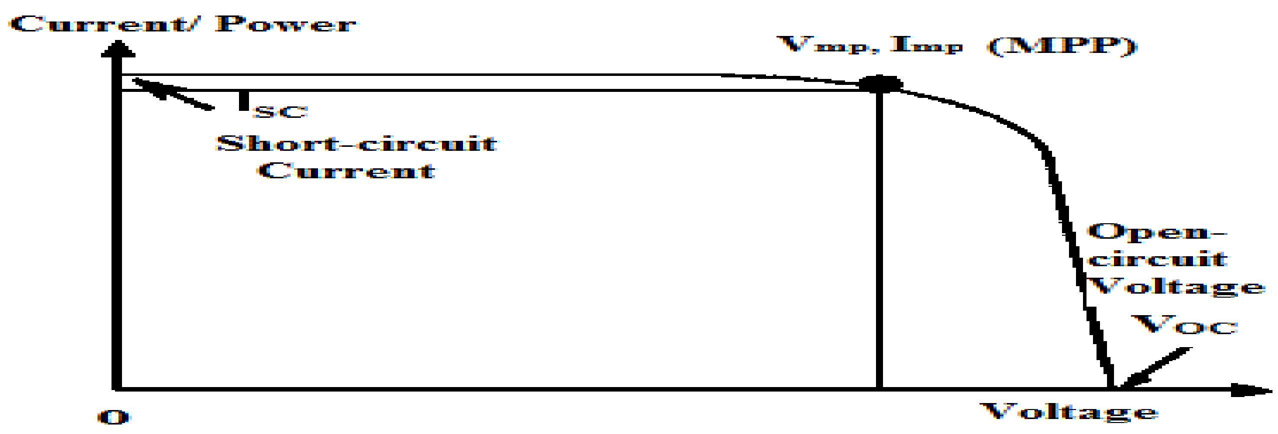


Fig.1: I-V and P-V Characteristics of Solar Cell

One solar cell can produces "open circuit voltage '(V_{oc}) of 0.5 to 0.6 volt (usually around 0.58v) at 25 ^{0}C. Regardless of how large a solar cell is the cells voltage is sufficiently stable enough, until the ample irradiance light become less irradiance light. Circuit voltage present here means that PV cells are not connected to any external load and hence it is often known as open circuit voltage therefore it will not be the reason of the assembly of any current flow. When the outer load is connected such as small bulb, the output of the individual cells goes up to 0.46 volts or 460 mV since the current start flows and the voltage will be around the practical voltage level. One of the most rigid behaviors of solar cells is that the slight variation in the solar radiation intensity does not make any distinction in its voltage level [2].

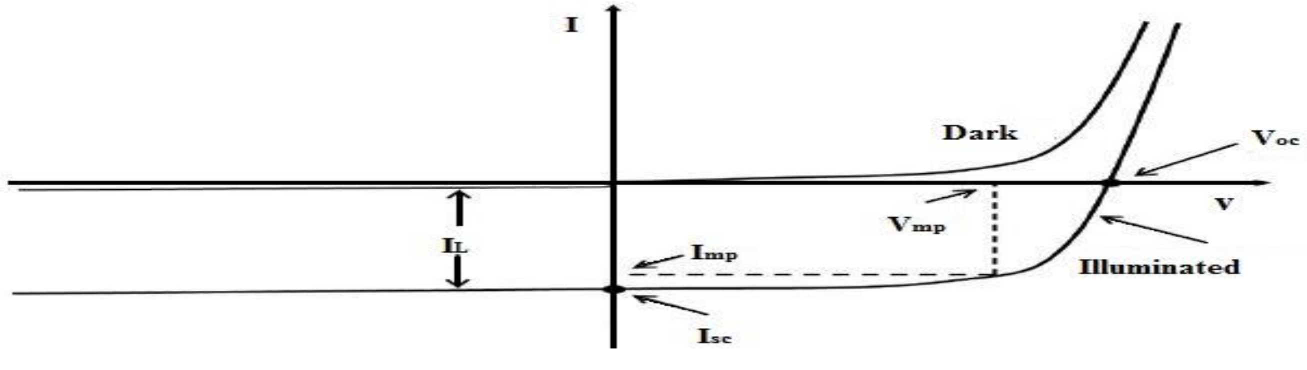


Fig.2: Practical I-V Characteristics of Solar cell

Temperature additionally affects the output of solar cells; the output of solar cell starts to decrease in very hot temperature. Theoretically it is believed that the output of the cell with the rise in temperature of 25^{0}C within the case of full bright sun might fall up to 5 %. Therefore, this feature of the cell dismisses the false discussion during which it had been aforementioned that it needs more temperature to create electricity [2].

Since partial shading is a vital issue that affects the output power of the PV module. It's necessary to judge the module performance in these things. It has been found that compared to different solar modules the impact of partial shading has been found more on the series connected solar panels. Therefore, to reduce the effect of partial shading on series connected solar panels some important changes are made which will be briefly mentioned later in this dissertation. But generally, to take care of this drawback a bypass diode is applied to every cell or a common bypass diode is employed for all the solar cells connected to a straight line [3]. Major reasons for the partial shading such as the passing clouds, the shadow of the neighboring buildings, the leaves of trees, bird's litters and the non-regular cleaning of solar cells, which often make the solid soil pearls on some solar cells. And this in a way, it seems like some of the normal reason for partial shading that can be overcome by keeping some caution. . The partial shading effect not only affects the conversion efficiencies of solar cells but also is responsible for non-linearity in its I-V characteristics which should be considered more complicated than the changes that come in the conversion efficiency [4]. At this condition, the output of shaded cells drop and this insufficient output performance of the entire photovoltaic system causes I_{sc} go down due to less insolation. And if the current-voltage curves decrease due to short circuit current (I_{sc}) reduction during this condition the possibility of power dissipation and decline in conversion efficiency increases [5], [6].Whenever a uniform radiation falls on the top of the solar cells an equal current passes through all the cells connected within the series[7]. However, even throughout non-uniform insolation the current continues to flow through unshaded cells as a result of the current should be an equivalent for all the solar cells connected in series. Therefore, it causes massive current flows through the shaded cells that are over its holding capacity [8], [9], [10], [11]. During this condition the shaded cells operates in reverse bias voltage. So it consumes power throughout this period then extracted most power from solar photovoltaic array decreases. Hence high reverse bias voltage causes avalanche breakdown that would be the main reason behind thermal breakdown of the cell. If it persists for an extended time it creates hot spot downside within the solar photovoltaic system. The bypass diodes are used to avoid hot spot problem. These are connected in anti-parallel to series connected solar photovoltaic arrays to limit the reverse voltage and then control the power loss in shaded cells. This bypass diode limits the reverse voltage to lower than the breakdown voltage of photovoltaic cells once the reverse voltage across the shaded cells will increase [12]. Therefore, power is going to be consumed by these cells instead to generate and this dissipation of power creates hotspot drawback under partial shading condition. However it's tough to differentiate between local and global (at that maximum power is recorded) maximum power point [13], [14].

It isn't straightforward to track maximum power point (MPP) throughout regular changes in shading pattern during partial shading condition. As a result of, with non-uniform insolation typically can be multiple local MPPs and they will amendment as quick as will the insolation changes [15]. For better resolution of partial shading issues along with models that improve MPP tracking some other necessary changes need to be made at the cell level so that the possibility of multiple local MPP can be avoided.

II. Partial Shading Effect

2.1 Case Study

The heuristic methodology modeling for the photovoltaic cell equivalent circuit with single-diode, shunt and series resistances was implemented in MATLAB/Simulink. In this dissertation already existing model of a single photovoltaic cell is employed for the characteristics curve. Bypass diode is also utilized in all simulation to eliminate a hot-spot downside. The simulated model of a single cell is shown along with the I-V characteristics curve and power-voltage characteristics curve. The information for the single cell is taken from MATLAB/SIMULINK and is shown in Table.1.

TABLE .1 Single Solar Cell Parameters and their Value

Parameter	Value
Fixed Circuit Temperature	**25◦C**
Energy gap, E_g	**1.11 eV**
Quality factor, N	**1.5**
Irradiance, I_r	**1000 W/m^2**
Open-circuit voltage , V_{oc}	**0.6 V**
Short-circuit current, I_{sc}	**7.34 A**

The output power of the one photovoltaic cell isn't enough to drive the load. Therefore, it's needed to attach several solar cells in series and parallel to make modules then a group of one or a lot of such modules is used to form an array. The simulation model of the equivalent circuit of the solar cell has been displayed below additionally its output characteristics that embrace I-V (in Fig.4) and P-V (in Fig.5) characteristics are also displayed.

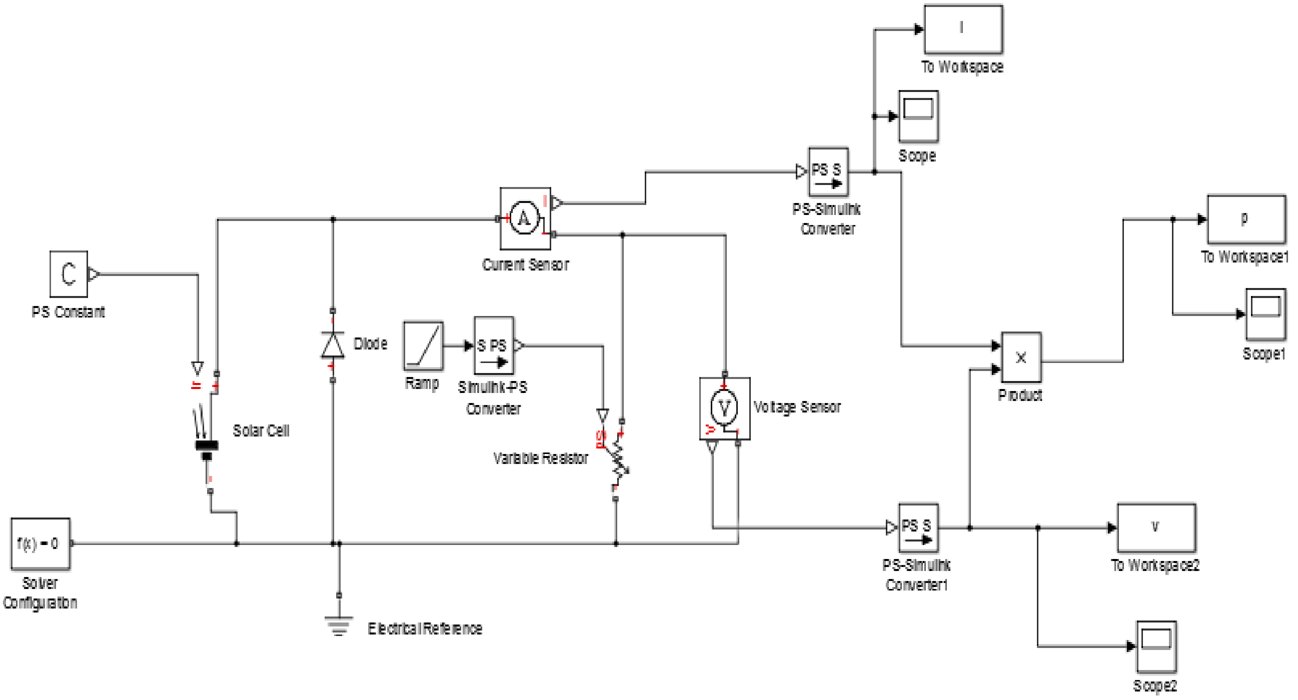


Fig.3: Single Solar Cell Model (MATLAB/SIMULINK)

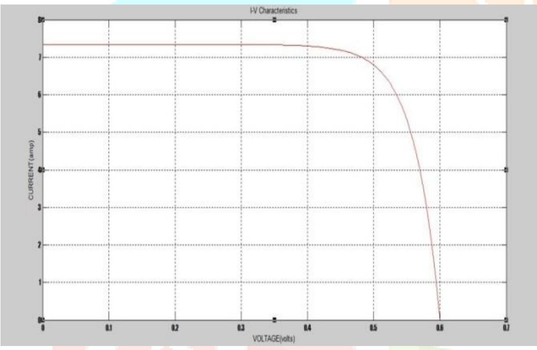


Fig.4: I-V Characteristics

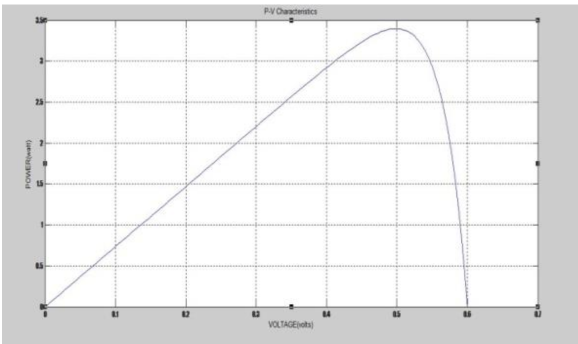


Fig.5: P-V Characteristics

The next solar model, shown below under the upper shaded partial condition contains a total of 28 solar cells in 7 * 4 arrangements. And P-V and I-V Characteristics have been plotted for 1000 W/m^2.Normally solar cell performance is seen at 1000 W/m^2 because this value is used as a reference to solar irradiance falling across the Earth. But the value of Solar Irradiance 1000 W/m^2 is not available everywhere on Earth and its value varies according to the position and time.

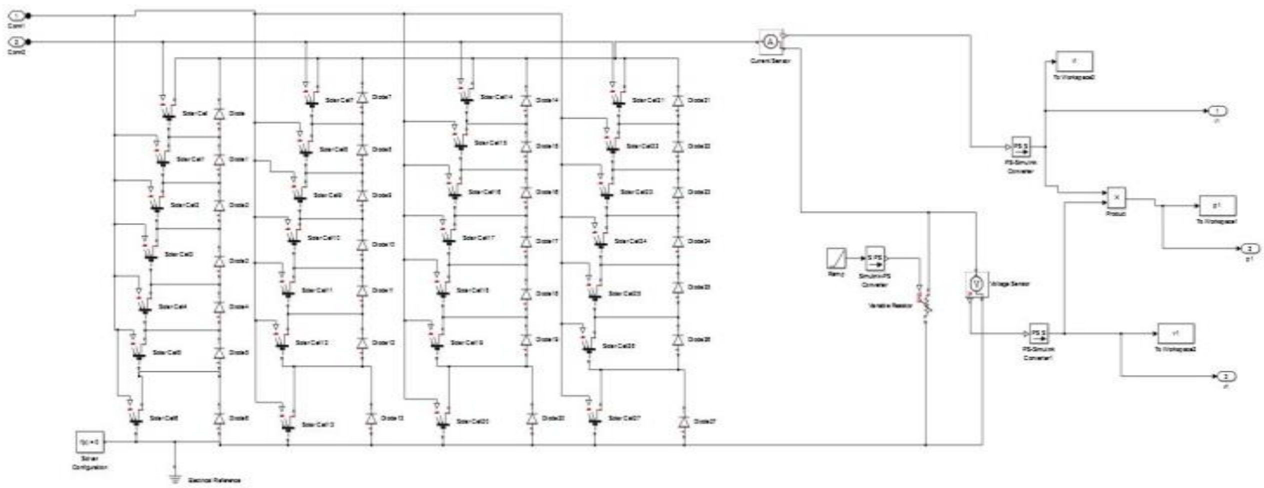


Fig.6: Model of 7*4 Arrays under partial shaded condition (MATLAB/SIMULINK)

PV simulation containing 7*4 solar cells which are shown above are subjected to partial shading condition. And this simulation has been run on MATLAB software R2014a (32-bit). The results are shown below in the graph of the I-V and P-V characteristics respectively.

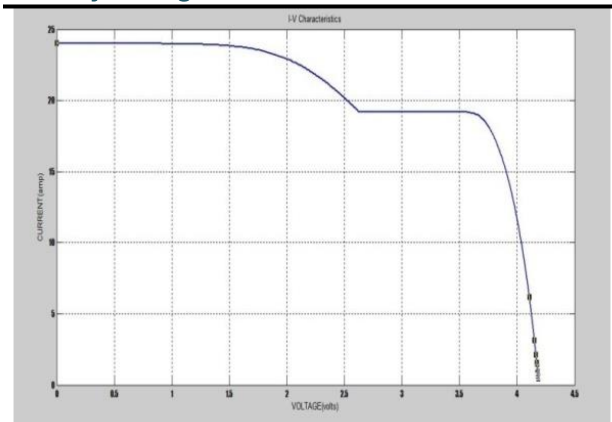


Fig.7: I-V Characteristics

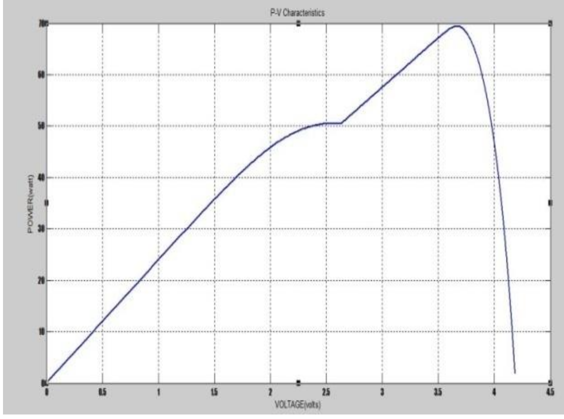
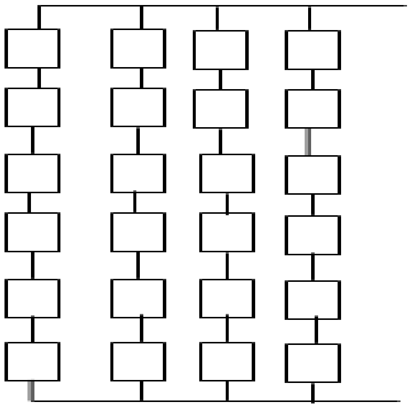


Fig.8: P-V Characteristics

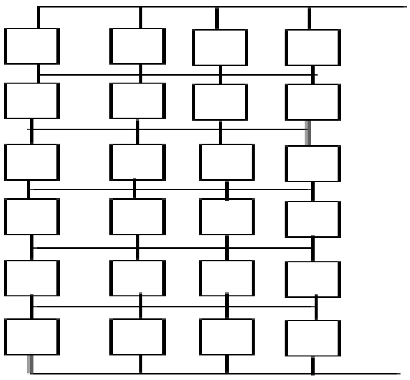
2.2 Partial shading effect on different interconnection scheme

The idea behind this project is to examine the effect of various types of partial shading on various topologies of the solar photovoltaic system. Here four solar topologies are being used for the examination and their names are given below respectively:-

It is vital to check the behavior of those configurations for various shading patterns. In SP configuration modules are first connected in series to get required voltage and then in parallel fashion to fulfill needed current [16], [17], [18]. TCT configuration is derived kind of SP configuration within which modules are initially connected in parallel and then these parallel connections are connected nonparallel (i.e. series) fashion to get needed power [19]. BL is changed configuration of TCT and therefore a number of the ties from TCT are removed [20]. The modification in BL configuration is formed to create a replacement configuration known as HC configuration. It's designed by the inspiration of honeycomb shape; during this case obliquely hatched blocks have a parallel combination of two cells whereas unhatched blocks show a single cell [21]. In HC configuration choice of ties is a crucial issue thus ties will be connected in variant of two, four and six modules [22]. However TCT has such a large amount of ties; BL has fewer ties and SP has the smallest amount variety of ties the diagram of various solar configurations has been given below.

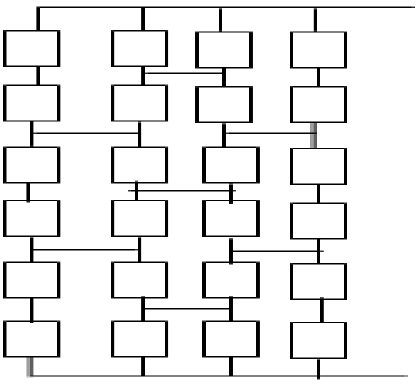


(a) SP

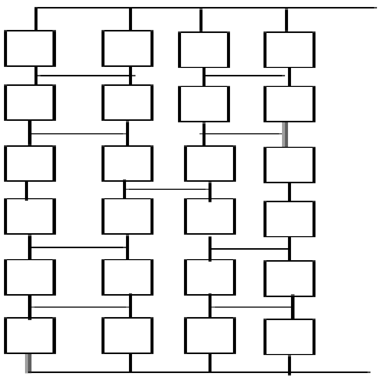


(b) TCT

Fig.9: SP & TCT configuration



(c) BL



(d) HC

Fig.10: BL & HC Configuration

2.3 Shading Patterns

Various shading impacts during this project are done to examine the effect of partial shading on different solar topologies. Thus the combination of 28 solar cells is simulated for SP, TCT, BL and HC configurations. During this configuration 7 cells are connected in series to create a string and so these strings are connected in parallel as shown in Fig.6. The simulated modules of those configurations are compared for varied shading pattern so as to search out the best topology for these shaded patterns. Different shading patterns are considered for this study i.e.(a) Randomly assumed shaded pattern-I(b) randomly assumed shaded pattern-II (c) randomly assumed shaded pattern-III (d) randomly assumed shaded pattern-IV (e) randomly assumed shaded pattern-V(f) quarter array shaded. For these six shading patterns mentioned on top of, the MPP power, MPP voltage, MPP current are calculated from characteristics and best topology is recommended based on the results and observations for these shade scenario.

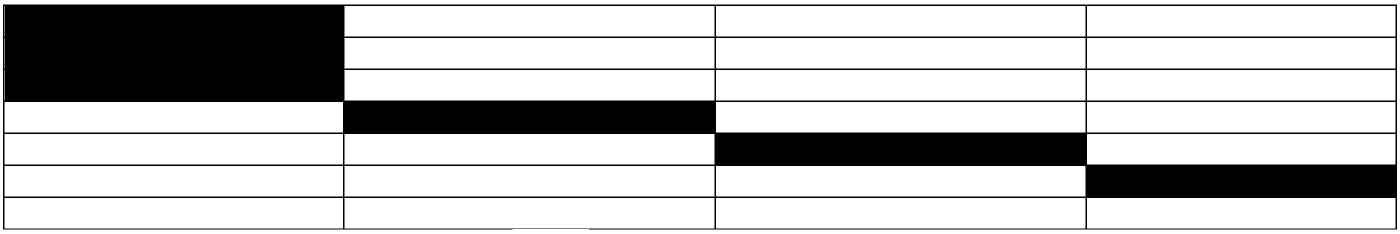


Fig.11: randomly assumed shaded pattern-I

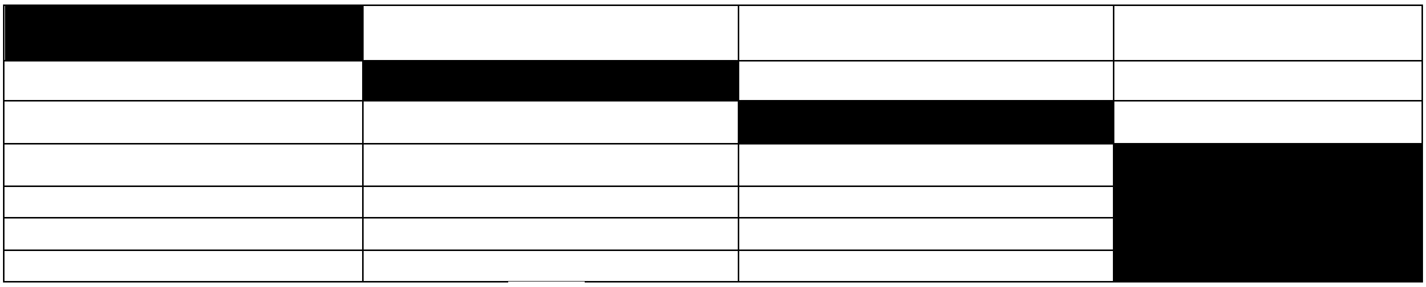


Fig.12: randomly assumed shaded pattern-II

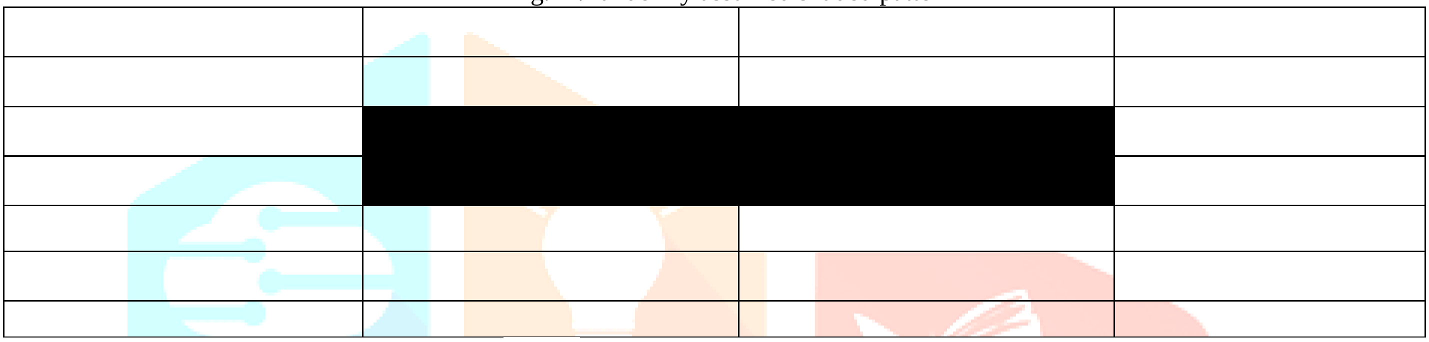


Fig.13: randomly assumed shaded pattern-III

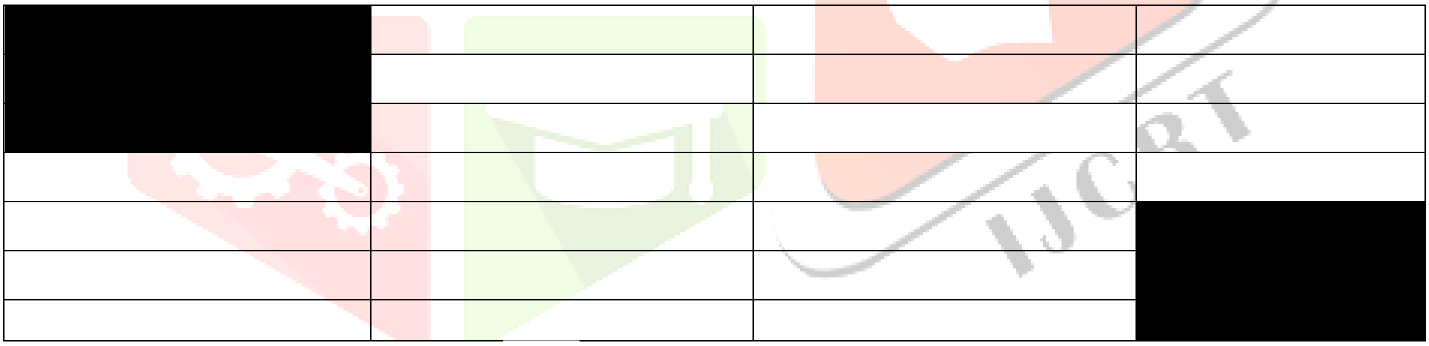


Fig.14: randomly assumed shaded pattern-IV

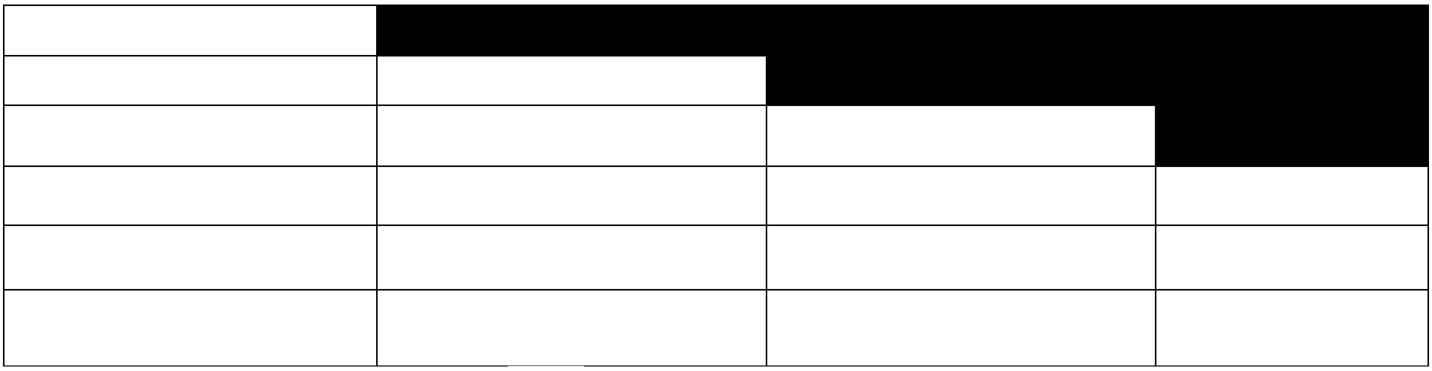


Fig.15: randomly assumed shaded pattern-V

Fig.16: Quarter array shaded

III. RESULTS AND CONCLUSIONS

3.1 Results

The Results for various topologies that is shown in Fig.9(a),(b) & 10(c),(d) under various partial shading patterns in terms of I-V and P-V characteristics of every configuration shown through Fig.17 to Fig.18 . Irradiation is taken as 500 W/m^2 for these shaded cells. While calculating the results of various topologies it has been carefully given that all topologies should have same parameters and only partial shading patterns can be different. Because by doing so, there is a possibility of a similarity coming in the results as well as different references are not required in comparison to the results.

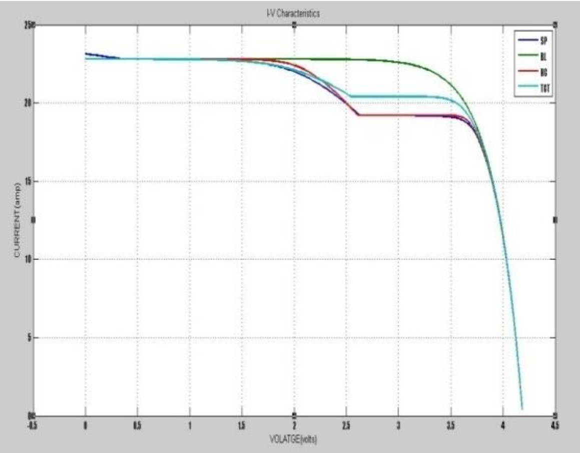


Fig.17: I-V Char. for randomly shaded pattern-I

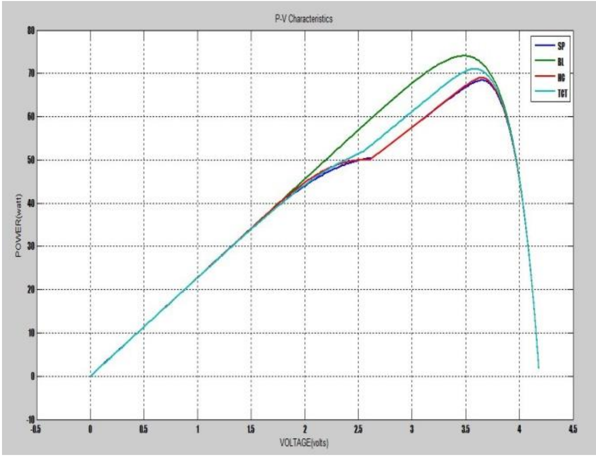


Fig.18: P-V Char. for randomly shaded pattern-I

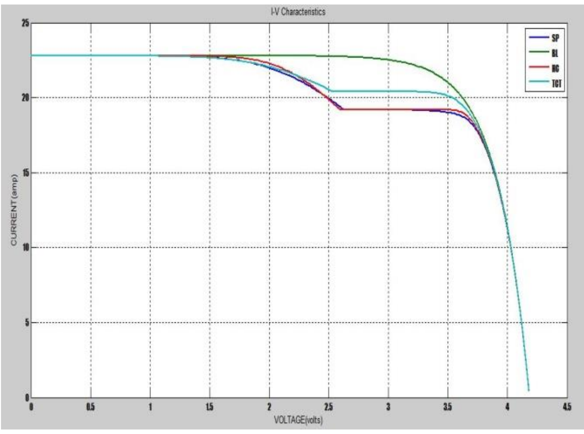


Fig. 19: I-V Char. for randomly shaded pattern-II

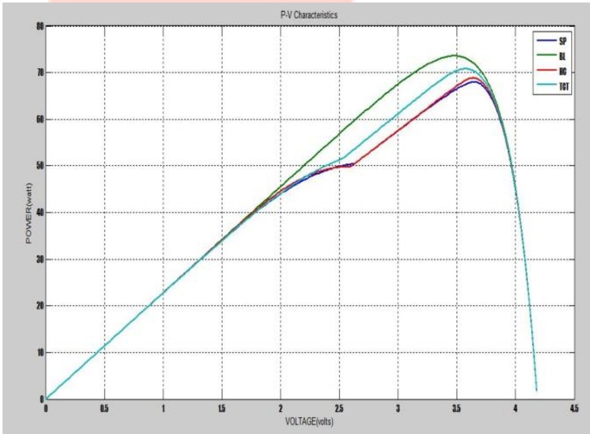


Fig. 20: P-V Char. for randomly shaded pattern-II

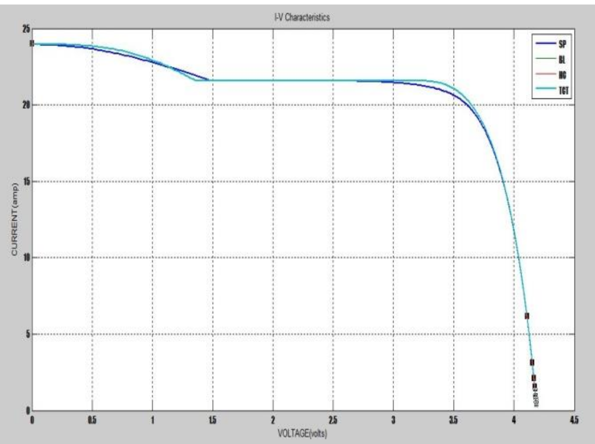


Fig. 21: I-V Char. for randomly shaded pattern-III

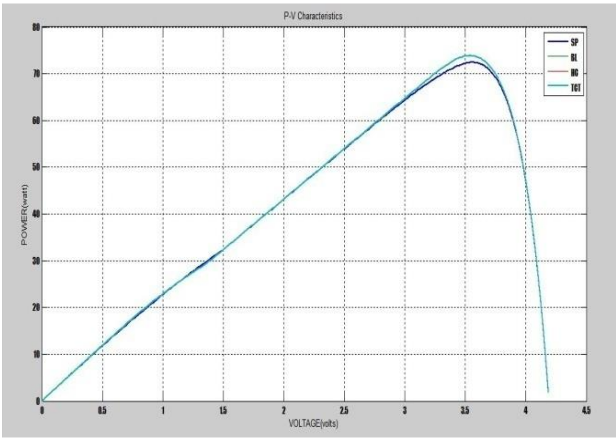


Fig. 22: P-V Char. for randomly shaded pattern-III

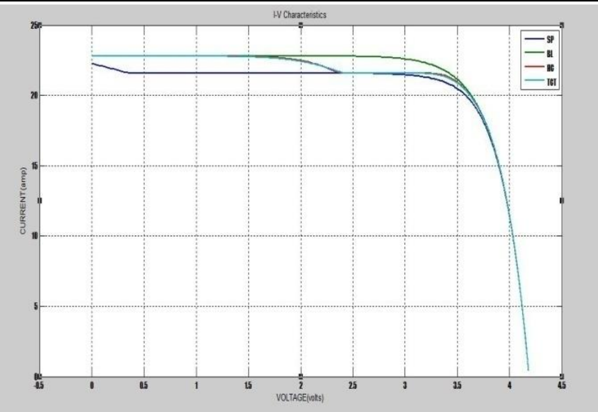


Fig.23: I-V Char. for randomly shaded pattern-IV

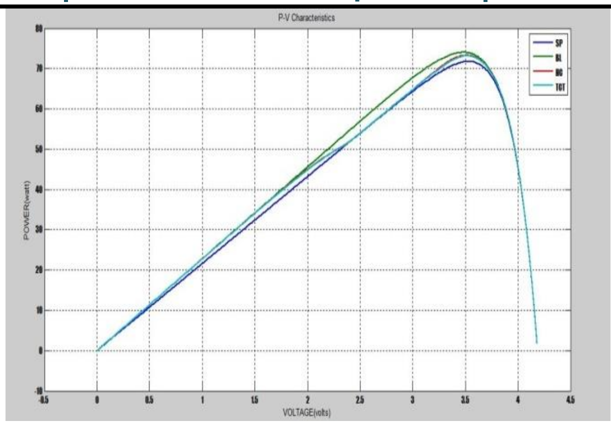


Fig. 24: P-V Char. for randomly shaded pattern-IV

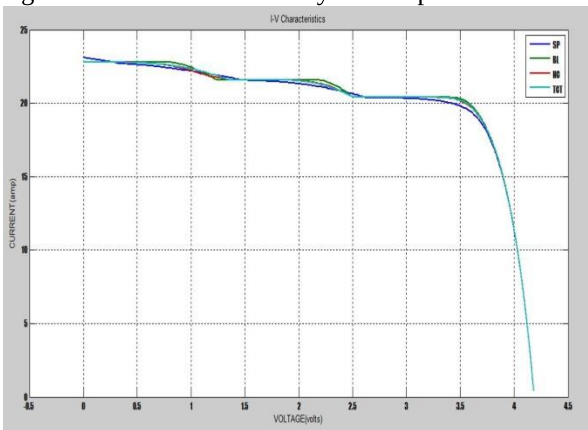


Fig. 25: I-V Char. for randomly shaded pattern-V

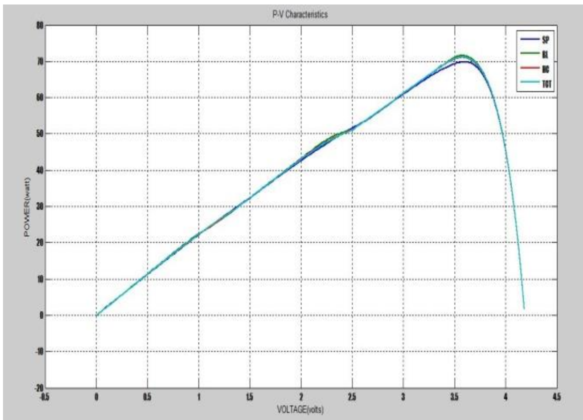


Fig.26: P-V Char. for randomly shaded pattern-V

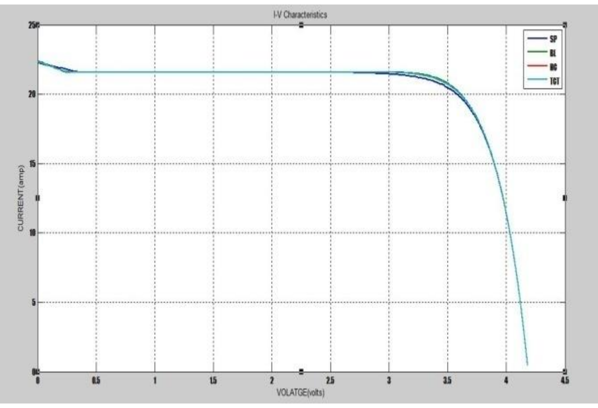


Fig.27: I-V Char. for quarter array shaded

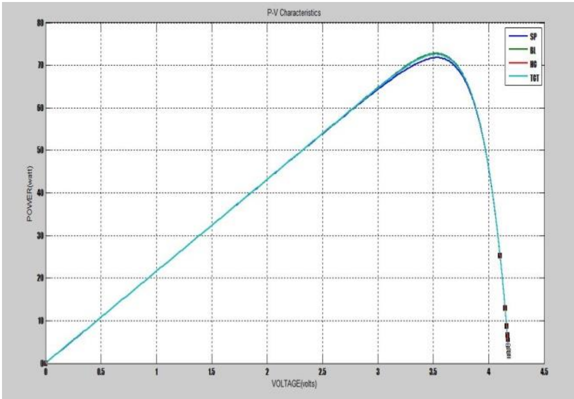


Fig.28: P-V Char. for quarter array shaded

After staring at every result carefully it's been concluded that for every partial shading pattern, which is shown in Fig. 11 to Fig.16. The value of the MPP for all topologies is nearly equal. As per as MPP concern in these partial shading conditions any topology can be recommended. But if there is a concern about simplicity then the SP shows simple configuration because there are fewer connections in it. And if the power-voltage graph of the entire shaded pattern is seen repeatedly then it seems that the BL configuration is performing well and all the results are shown in Fig. 18, 20, 24, 26 and 28 respectively. Apart from this, if the power-voltage curve of TCT, BL, and HC, is seen for shading pattern-3 then it seems that in this condition the characteristics for each topology are almost identical and which are shown in the Fig.22. But keeping all these things in mind it should be decided to select BL configuration because it has less connections than TCT.

3.2 Conclusion

The idea behind this dissertation is that in MATLAB different topologies like SP, TCT, BL, and HC are simulated and their performance is compared in various partial shading conditions. And try to find out the best configuration under various partial shading conditions.

If the results given in this dissertation are taken into consideration then it can be mentioned with the great confidence that the BL configuration performed well in almost all partial shading conditions. But still with the aim of making its performance better; there is a need to reduce the interconnections in it. Since it is commonly found that the interconnection is removed so that the number of tie can be reduced. And with the presence of low tie the losses in the cable can be reduced as well as the time taken to make the connection can be saved. It would be absolutely wrong to conclude that BL will perform well in all partial shading conditions because in some partial shading conditions the performance of SP & TCT is even more appreciable compared to BL.

It is advisable to see the results displayed in this dissertation as ideal results because here the intensity of the solar radiation has been taken as the constant value. This is quite different from the actual conditions since the intensity of the solar radiation changes every minute. Apart from this more improvements are needed to improve further such as automatic Sun-Tracking system, automatic MPP controllers, so that the results can be made more practical.

IV. References

[1]. P.S. Purnomo, S. Didik, P. Wahyudi, S. Harry and H. Djoko. (2013). Electrical energy management and engineering in solar cell system. *In Solar Cells Research and Application Perspectives, Intech*, 327-352, 2018.

[2]. Hsu, R. C., Liu, C. T., Chen, W. Y., Hsieh, H. I., & Wang, H. L. (2015).A reinforcement learning-based maximum power point tracking method for photovoltaic array. *International Journal of Photoenergy*, 2015.

[3]. Guo S, Walsh, T. M. Aberle, A. G., & Peters, M. (2012, June). Analysing partial shading of PV modules by circuit modelling. In *Photovoltaic Specialists Conference (PVSC), 2012 38th IEEE* (pp. 002957-002960). IEEE.

[4]. Fialho, L., Melicio, R., Mendes, V. M. F., Figueiredo, J., & Collares-Pereira, M. (2014). Effect of shading on series solar modules: simulation and experimental results. *Procedia Technology*, *17*, 295-302.

[5]. Moballegh, S., & Jiang, J. (2011, July). Partial shading modeling of photovoltaic system with experimental validations. In *Power and Energy Society General Meeting, 2011 IEEE* (pp. 1-9). IEEE.

[6]. Purohit, J., & Naveen, S. P. (2016). Comparison of Various Techniques to Mitigate the Effect of Partial Shading on Solar PV Systems. *IJIREEICE*, *4*(8), 88-91.

[7]. Pareek, S., & Dahiya, R. (2016). Enhanced power generation of partial shaded photovoltaic fields by forecasting the interconnection of modules. *Energy*, *95*, 561-572.

[8]. Spertino, F., & Akilimali, J. S. (2009). Are Manufacturing $ I $–$ V $ Mismatch and Reverse Currents Key Factors in Large Photovoltaic Arrays? *IEEE Transactions on Industrial Electronics*, *56*(11), 4520-4531.

[9]. Patel, H., & Agarwal, V. (2008). MATLAB-based modeling to study the effects of partial shading on PV array characteristics. *IEEE transactions on energy conversion*, *23*(1), 302-310.

[10]. Ghitas, A. E., & Sabry, M. (2006). A study of the effect of shadowing location and area on the Si solar cell electrical parameters. *Vacuum*, *81*(4), 475-478.

[11]. Drif, M., Perez, P. J., Aguilera, J., & Aguilar, J. D. (2008). A new estimation method of irradiance on a partially shaded PV generator in grid-connected photovoltaic systems. *Renewable energy*, *33*(9), 2048-2056.

[12]. Bidram, A., Davoudi, A., & Balog, R. S. (2012). Control and circuit techniques to mitigate partial shading effects in photovoltaic arrays. *IEEE Journal of Photovoltaics*, *2*(4), 532-546.

[13]. 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 Transactions on Energy Conversion*, *27*(1), 173-183.

[14]. Lappalainen, K., & Valkealahti, S. (2015). Recognition and modelling of irradiance transitions caused by moving clouds. *Solar Energy*, *112*, 55-67.

[15]. Pareek, S., & Dahiya, R. (2014). 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). Trans Tech Publications.

[16]. Moballegh, S., & Jiang, J. (2011, July). Partial shading modeling of photovoltaic system with experimental validations. In *Power and Energy Society General Meeting, 2011 IEEE* (pp. 1-9). IEEE.

[17]. Villalva, M. G., Gazoli, J. R., & Ruppert Filho, E. (2009). Comprehensive approach to modeling and simulation of photovoltaic arrays. *IEEE Transactions on power electronics*, *24*(5), 1198-1208.

[18]. Pareek, S., & Dahiya, R. (2016, March). Series-connected shaded modules to address partial shading conditions in SPV systems. In *AIP Conference Proceedings* (Vol. 1715, No. 1, p. 020020). AIP Publishing.

[19]. Pareek, S., & Dahiya, R. (2015, December). Power optimization of TCT configured PS-PV fields by forecasting the connection of modules. In *India Conference (INDICON), 2015 Annual IEEE* (pp. 1-6). IEEE.

[20]. Pareek, S., & Dahiya, R. (2014). Output Power Maximization of Partially Shaded 4* 4 PV field by Altering its Topology. *Energy Procedia*, *54*, 116-126.

[21]. Wang, Y. J., & Hsu, P. C. (2011). An investigation on partial shading of PV modules with different connection configurations of PV cells. *Energy*, *36*(5), 3069-3078.

[22]. Ramaprabha, R., & Mathur, B. L. (2012). A comprehensive review and analysis of solar photovoltaic array configurations under partial shaded conditions. *International Journal of Photoenergy*, *2012*.