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Analyzing The Effects Of Partial Shading On Photovoltaic Array Performance

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Abstract: This paper analyses the effects of partial shading on energy output of different solar photovoltaic array configurations and to mitigate the mismatch loss faced in solar photovoltaic system. The photovoltaic array configurations are modelled in MATLAB/SIMULINK with four different configurations. These configurations are Series Parallel (SP), Total Cross Tied (TCT), Bridge Linked (BL) and Honey Comb (HC). After modelling, the different configurations are simulated and compared under various partial shaded conditions such as 200W/m2, 500W/m2, 800W/m2. Finally, it is observed that the best configuration is TCT that can reduce the mismatch losses under partial shading conditions. The need for renewable energy sources is growing day by day because of the severe energy crisis in the world today. Renewable energy sources play a significant role in electricity generation. Solar energy is the most viable option for electricity generation because it is available everywhere and is free to utilize. Solar Photovoltaic (PV) arrays convert the solar energy into electrical energy. With the current concentration on greener and cleaner sources of power, PV arrays are being used as an important source of power in many applications. One of the main causes for the reduced energy yield of many PV systems is a partial shading of PV arrays. The phenomenon of partially shaded conditions is widespread in all kinds of photovoltaic systems.

Index Terms – Array Configurations , simulation.

I. Introduction

The energy through the photovoltaic (PV) effect can be considered the most essential and prerequisite sustainable resources because of the ubiquity, abundance, and sustainability of solar radiant energy. The use of photovoltaic systems for electricity generation started growing rapidly. However, their performance depends on insolation, temperature, partial shading condition, place where solar photovoltaic system is installed. Among these factors partial shading is considered to be the most.

Partial shading is the condition when some of the cells, modules, arrays receives less insolation due to falling leaves of trees, dirt, bird litters, rain, cloud, pole etc. At this condition, output of shaded cells fall down and mismatch losses occur. Under partial shaded conditions, photo current continues to operate unshaded cells to equal for all series connected solar photovoltaic cell. Therefore, the shaded cells conduct through large current [1]. The voltage at which the shaded cells operate in this condition is reverse voltage. So, it consume power during this period and thus extracted maximum power from whole solar photovoltaic array decreases. Hence high bias voltage causes hot spot problem and mismatch losses in solar photovoltaic system. Partial shading presents challenges for solar photovoltaic (PV) arrays, leading to power losses and reduced efficiency. To mitigate these effects, bypass diodes are integrated into PV modules to bypass shaded cells, while optimized array design considers orientation, tilt angle, and spacing. Module-level power electronics like microinverters or DC optimizers optimize output at the module level. Regular monitoring and maintenance are crucial to identify shading issues promptly, aided by software tools for simulation and optimization. These strategies collectively enhance PV system performance under partial shading conditions [2].Partial shading, caused by shadows on some panels, significantly reduces a solar PV array's power output. This happens because shaded panels act like weak links, limiting current flow and causing mismatch losses. The uneven current also creates multiple power peaks, making it difficult for MPPT systems to optimize power generation. To mitigate these effects, strategic array layout, advanced electronics, improved MPPT techniques, and even dynamic reconfiguration of connections can be employed..

II. Array Configurations

There are four different configurations. These configurations are Series Parallel Configuration (SP) fig.1(a), Total Cross Tied Configuration (TCT) fig.1(b), Bridge Linked Configuration (BL) fig.1(c), Honey Comb Configuration (HC) fig.1(d).

In SP configuration, modules are first connected in series to generate required current and then in parallel fashion to meet required voltage. TCT configuration is derived form of SP configuration in which modules are first connected in parallel and then these parallel connections are connected in series fashion to generate required power. BL is modified configuration of TCT and thus some of the ties from TCT is removed. The modification in BL configuration is made to form a new configuration called HC configuration. It is designed by the inspiration of honeycomb hexagon shape, in this case obliquely hatched blocks has a parallel combination of two cells while unhatched blocks show a single cell. In HC configuration selection of ties is an important factor hence ties can be connected in variant of two, four and six modules. However, TCT has so many ties. BL has fewer ties and SP has least number of ties. In literature TCT is reported to perform under partial shading condition [3].

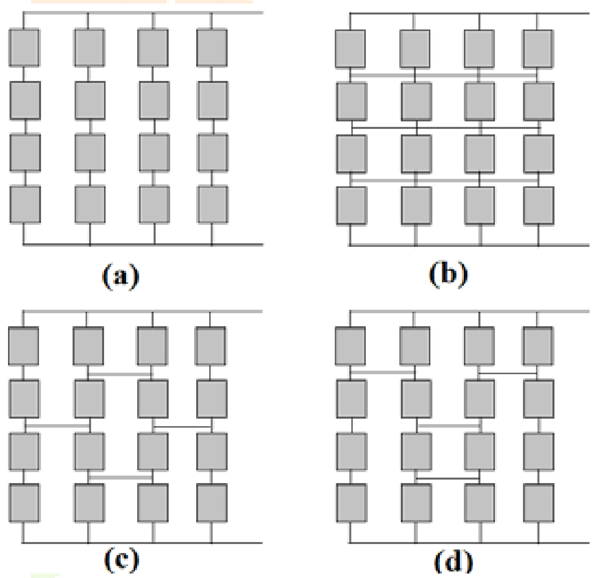
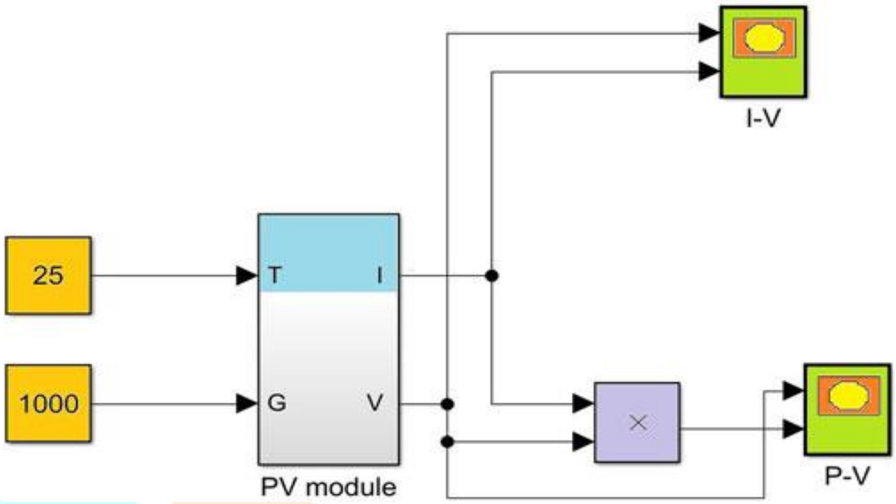


Fig 1 :- Types of connection configurations: (a) Series Parallel, (b) Total Cross Tied, (c) Bridge linked, and (d) Honeycomb

III. Modeling And Simulation Of Array

As the output of PV module varies with the variation in solar insolation and operating temperature. We have considered these parameters in the development of PV simulated model. The model is developed in masked subsystem stages in MATLAB/Simulink software [4]. The simulation model for the proposed module at standard isolation and temperature is shown in Fig 2. This module of 3*3, from this Simulink module we get Current-Voltage characteristic curve fig.3(a) and Power-Voltage characteristic curve fig.3(b) and also get



Current, Voltage and power graph with respect to Time.

Fig 2 **:-** Simulink Model for single PV Module

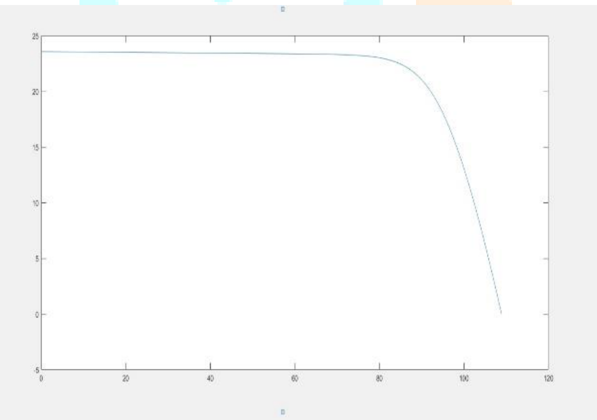


Fig 3 :- a) I-V Charcteristics

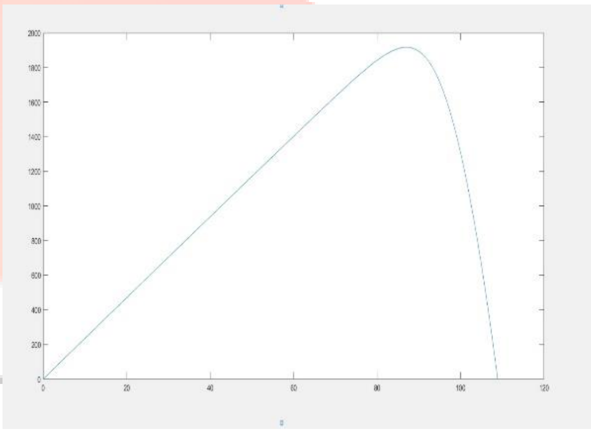


Fig 3 :- b) P-V Charecteristics

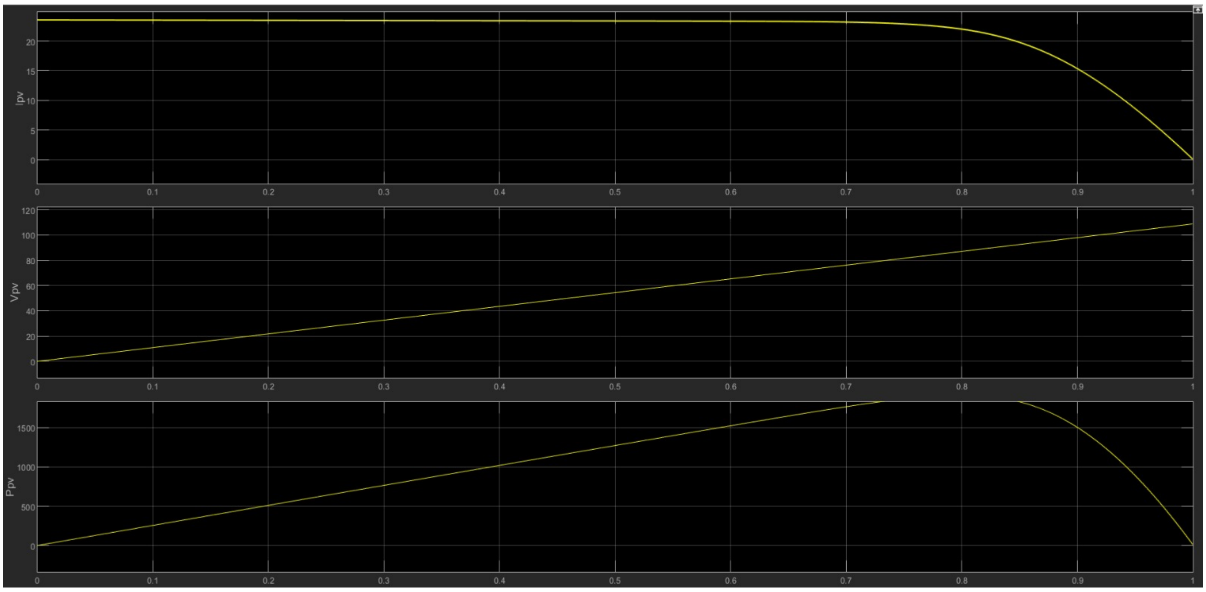


Fig 3: - c) Current, Voltage and Power graph with respect to Time

IV. Simulink Model of Photovoltaic With Different Raditions

To observe the performance of PV arrays with different radiation schemes, the simulation model is implemented with MATLAB/Simulink. In the model there are three series connected modules and the total number of parallel strings is also three. The implemented Simulink models are shown in Fig 4. After the MATLAB/Simulink run we get IV and PV Characteristics at different radiation. The Characteristics shown in Fig 5

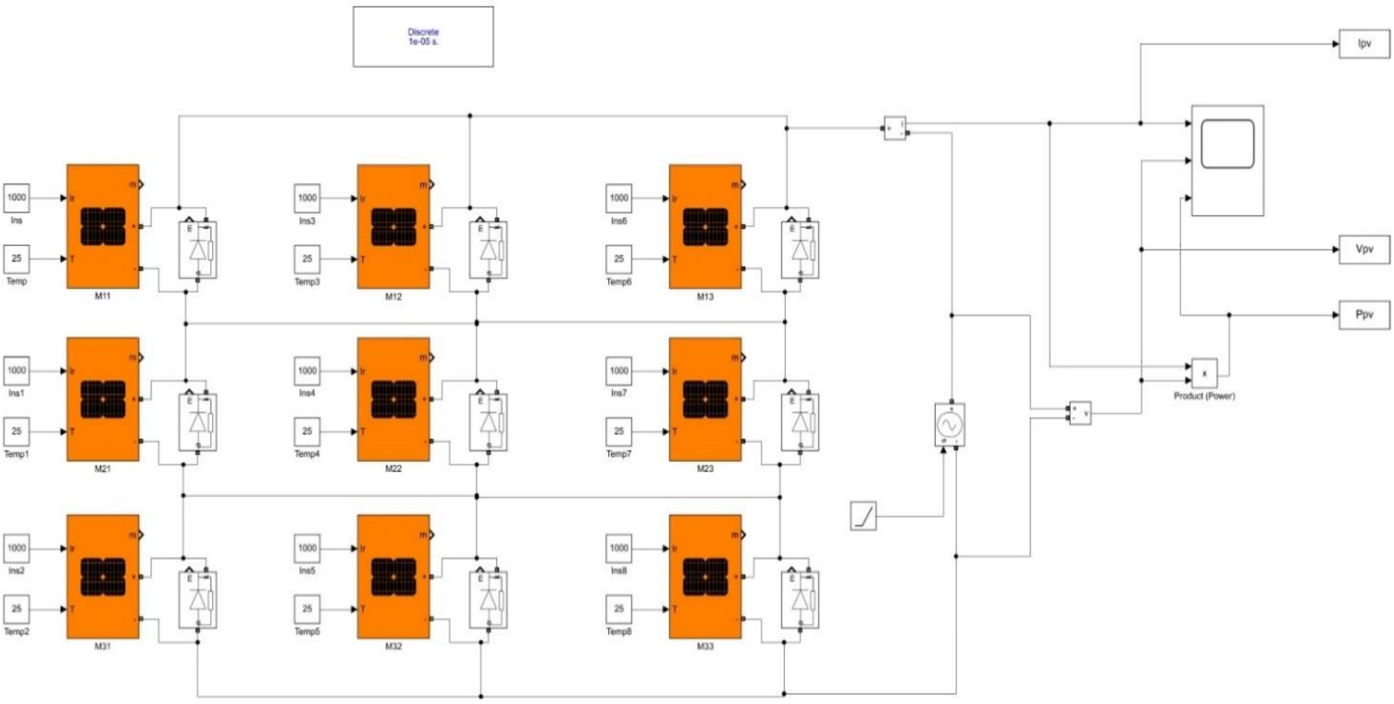


Fig 4:- Simulink Model Of PV Array

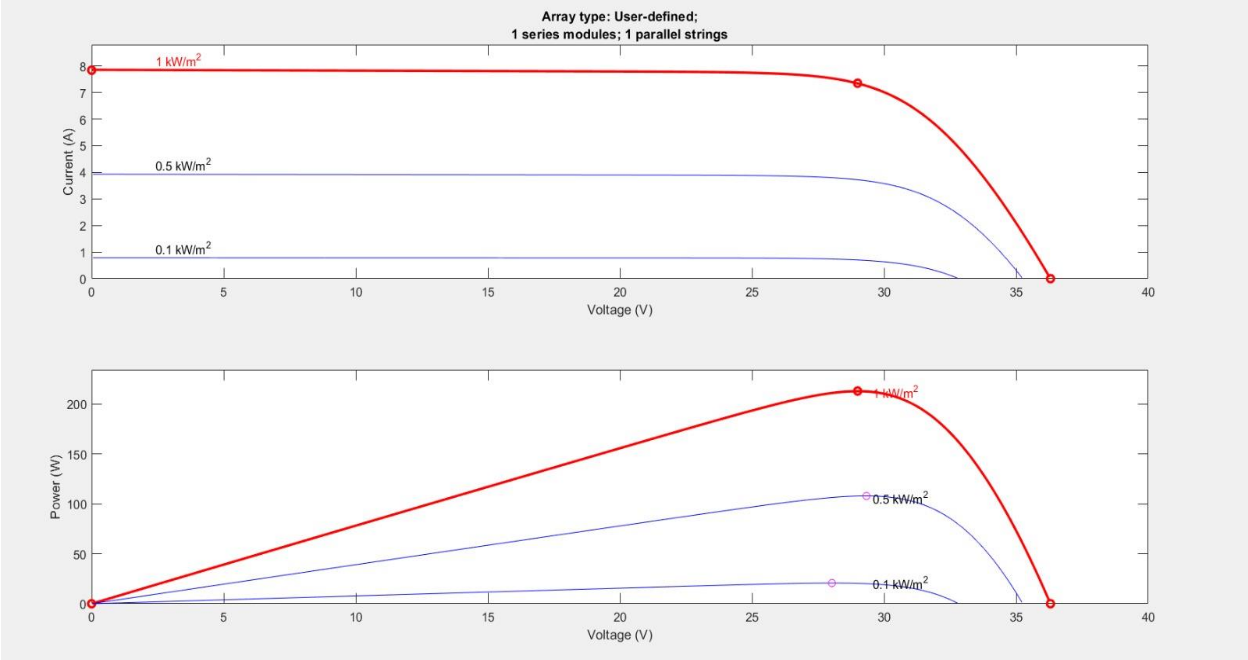


Fig 5 – I-V and P-V Charecteristics at Different Raditions

V. Conclusion

In this paper different configuration like SP, TCT, BL and HC configuration is simulated with the help of MATLAB/SIMULINK and their performance is compared under various partial shading conditions. It is reported in literature that TCT performs better under partial shading condition. TCT interconnection has a substantial reduction in mismatch losses that occur due to partial shading beside to it has greater reliability comparable with SP and BL.

Our study comprehensively analyzed the performance of solar PV arrays under partial shading conditions and investigated various array configurations to mitigate the negative impacts of shading. Through simulation and experimentation, we observed that partial shading can significantly reduce the overall energy output of PV arrays, leading to efficiency losses and potential system degradation. However, by configuring the arrays with techniques such as bypass diodes, distributed MPPT, or module-level power electronics, we demonstrated significant improvements in energy yield and system reliability.

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