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"To Minimize Impact Of Partial Shading In PV System By Switched- Capacitor-Inductor Based Differential Power Processing Convertor"

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***Abstract* – As it affects the energy scavenged from the PV modules, partial shadowing of photovoltaic modules is one of the main sources of energy losses. The PV system's mismatch is what causes the energy loss. Differential Power Processing (DPP) converter, which surfaced as a novel switching strategy with positive outcomes, silently addresses these mismatch difficulties. The PV modules are normally connected in series, and by only processing the portion of the power that is mismatched, DPP converters are used to extract PV power. The goal of this study is to create a DPP converter based on a switched capacitor inductor (SCL) in order to reduce the unfavourable conditions in PV systems. A recommended SCL-based DPP design collects the most power even when the PV modules are partially shaded by just processing a portion of an output. The functioning concept of the recommended converter is also discussed here, along with a loss analysis. The suggested topology is explored and effectively contrasted with the standard topology with the aid of simulations and tests.**

Keyword –Differential Power Processing (DPP), Photovoltaic (PV), Switched Capacitor Inductor (SCL), Partial Shading, Bypass Diode.

I. INTRODUCTION

Generating energy from coal and other fossil fuels leads to environmental pollution. Therefore, it is important to develop various other eco-friendly types energy technology. In recent years, energy production from renewable sources has Solar energy has made great strides compared to other energy sources Photovoltaic (PV) energy is the fastest growing. Total by 2023 Installed PV capacity is expected to reach around 600 GWp. Unfavorable factors such manufacturing flaws, dirt, temperature changes, age, mounting orientation, shadows, and angle of incidence have an impact on a PV module's output. A PV system's total output might be decreased and its lifespan shortened as a result of all of these worries about power imbalance [4–7]. This imbalance has a terrible impact on power generation and overall power losses. The mismatch effect is widely divided into two categories based on severity: transient mismatch and permanent mismatch. . If the mismatch is transient, it is seen as a defect. shading of PV module happens due to temporary causes like,shadows from trees, dust over PV panels, bird drop, clouds, snow etc. The temporary mismatch causes around 19% of reduction in energy generation in a month [8-9].On the other hand, if the mismatch is due to soldering,removal of lamination, cracks in the PV panel/cell, degradation etc. then categorized under permanent mismatcheffect [10-12].

The fundamental element of photovoltaic system is the solar PV cell, the structure of which is illustrated in Figure 1 It is a semiconductor with added boron and phosphorus atoms to form a p-n junction with two layers

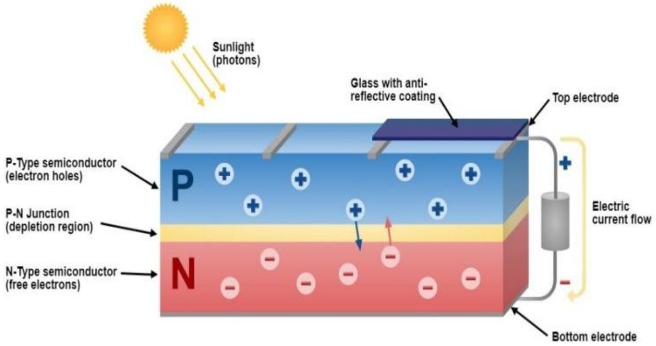

Figure 1: The structure of a PV cell

These two layers consist of positive and negative ions, which pertain to the P-holes and N-electrons, respectively. Then, a top electrode and bottom electrode are added for an electric current flow. Finally, it is covered in glass with an antireflective coating. The principle work of this cell is that it converts the lighting into electrical energy based on the photo-voltage effect phenomenon.

Typically, a photovoltaic module is made up of three to four smaller modules connected in series. Additionally, each of these submodules has 20 to 24 PV cells that are linked in series [13]. It is anticipated that the total power provided by all of the PV cells will be same, or there will be a mismatch. Because the series-connected PV cells produce a variable amount of current, this mismatch results the extra power produced by non-shaded panels evaporates across the shaded cell, putting strain on non-shaded cells and creating a hotspot [14]. This is because in series, the current must be the same. The long-term reliability of such cells may be impacted by the hotspot [15, 19].Figure 2 indicates the PV module with 4 series connected submodules namely, P1, P2, P3 and P4. For commercial use of PV system, a parallelly connected bypass diode (depicted in figure 2 (a)) is used which helps in minimizing the effect of mismatch occurred either due to partial shading of any other issue. The provided bypass diode continues in OFF position for "no mismatch" and current Ip continues to flow through all the submodules as shown in fig 2 (b). Figure 2 (c) shows the shaded PV module. For Occurrence of any mismatch ,a negative voltage appears across the PV module due to shading which in turn energises diode and hence diode turns ON which allows the current Id to flow though bypass diode as depicted in figure 2 (c). Since the bypassed submodule [P1 in figure 2 (c)] is responsible for mismatch, results in number of power hikes. The implementation of existing MPPT algorithms fail to find the maximum power (Pmax) for given duration in PV curve hence also influences the overall performance of PV module. To overcome the said lacuna, a unique Maximum Power Point Tracking algorithms are priority needed [20-24].

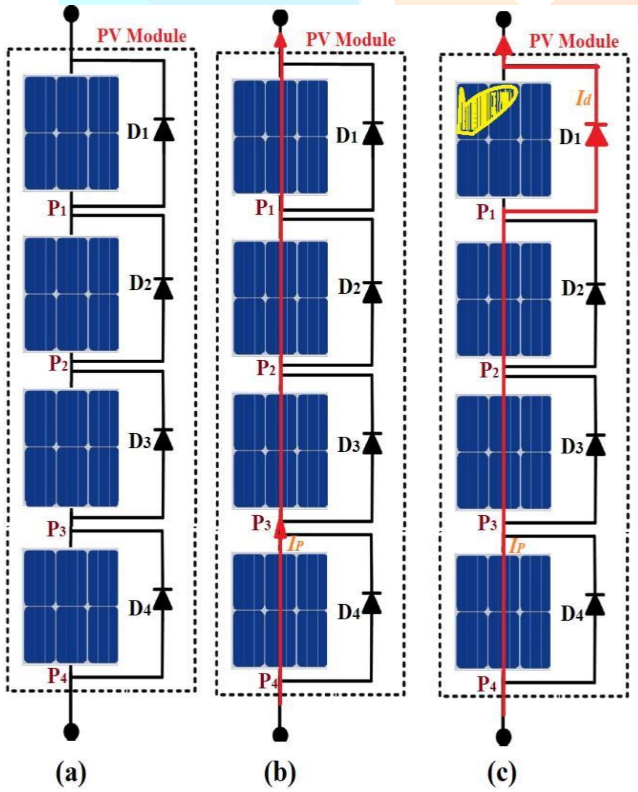

Fig. 2: (a) General diagram (b) without mismatch (c) Shaded PV panel P1

The development of power electronics-based mitigation methods for PV systems is receiving greater attention these days. Differential Power Processing (DPP) converters are the most promising among all these architectures for delivering a more efficient solution for mismatch effects. The DPP converters operate on a fractional power basis (also known as mismatch power). The DPP converters have a ladder-based design and are categorized as,

1. Non-isolated DPP converters
2. Isolated DPP converters and
3. PV-PV DPP converters.

This work presents a simple solution based on Switched-Capacitor-Inductor (SCL) to tackle mismatch concerns in PV systems. The operation of the SCL- DPP topology is described in this paper through an extensive analysis and experimental testing.

I. DPP TOPOLOGIES

If the PV modules are partially shaded, the DPP converter system can still provide the maximum amount of electricity. Since just a small portion of the power (produced) is delivered to the converter, the generation efficiency is excellent. As a result, DPP systems for PV applications are being advertised as next-generation PV.

DPP Architecture and Advantages

Figure 3 shows the several types of DPP converters utilised in PV applications. A PV-PV DPP system with a single DPP converter situated in-between the PV modules is what it refers to. The number of PV modules and DPP converters is never the same. Due to the architecture of the DPP system, non-isolated bidirectional converters, such as buck-boost converters, are used. DPP converters, which account for module variations, enable power conversion across PV modules.

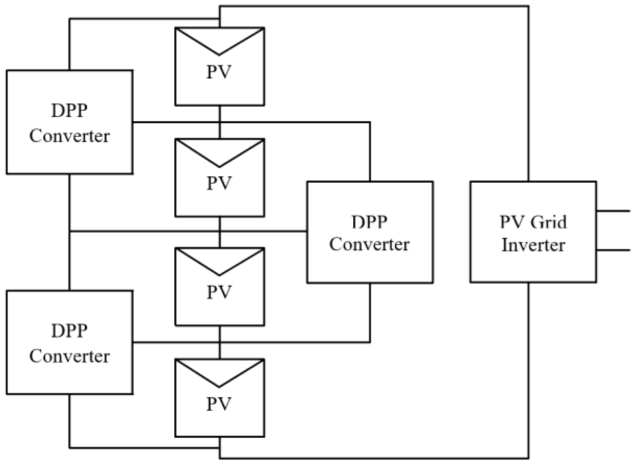

Figure 3: PV-PV DPP SYSTEM

A DPP converter and a PV module are part of the PV-to-Bus DPP architecture shown in Figure 4. In this case, the number of DPP converters utilised is always equal to the number of PV modules used. Due to the architecture of DPP, isolated bidirectional flyback converters are used. PV modules with parallel DPP converters may change power conversion across modules to account for module variations. As a result, this kind of DPP construction provides each panel with the highest power point, in contrast to the series connection approach, which limits the amount of power under partial shade..

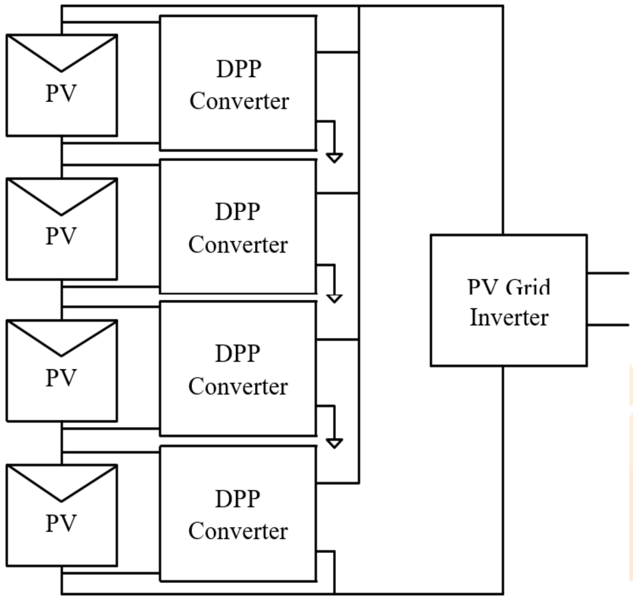

Fig. 4: PV-to-Bus DPP system

This can help to minimize the converters power capability and losses. With such benefits, the DPP system is considered as most sophisticated PV generating system.

A. *DPP Algorithm*

The MPP current varies depending on the amount of solar irradiation received. MPP, on the other hand, maintains a relatively constant voltage independent of irradiance. Since the voltages of MPP remains almost constant regardless of the number of solar irradiations, adjusting the voltage of each PV module to the same level results in each panel producing power that is close to MPP.

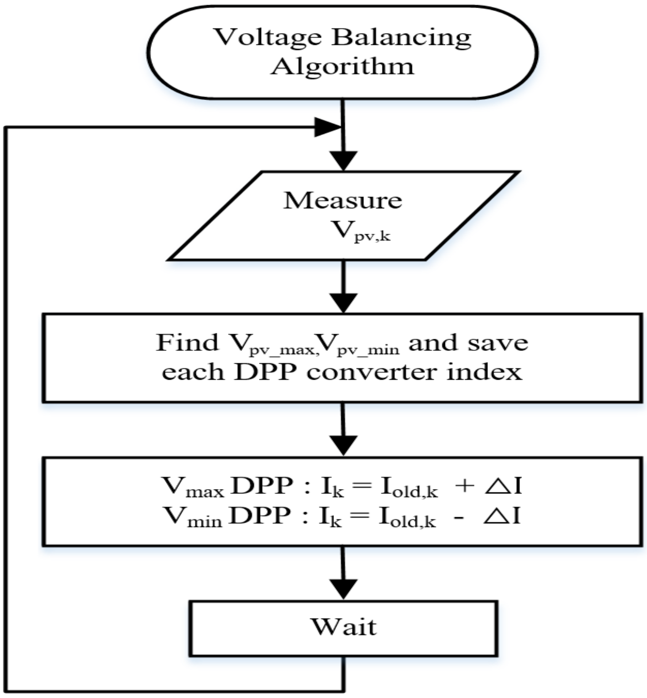

Fig. 5: Voltage balancing DPP algorithm.

II. PROPOSED SCL-DPP METHODOLOGY

There are a number of alluring DPP strategies that promise increased PV system performance in a variety of shadowed situations. But given the continuously shifting environmental circumstances, effective tracking might not be achievable. Some of the issues with the current DPP converters are addressed by the proposed Switched Capacitor Inductor (SCL)-based DPP architecture. The following benefits are taken into consideration while choosing the suggested method:

1] Improved performance though severe mismatch effects
2] Lower inductor ripple current
3] Simplified control actions and
4] PV submodule voltages in series equalisation

Figure 6 indicates the general circuit for proposed SCL-DPP approach. It consists of a PV-PV DPP architecture.

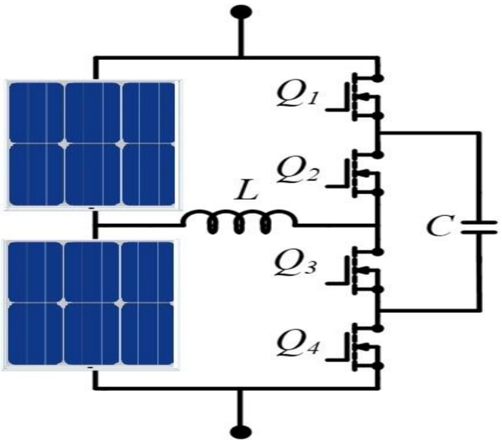

Fig. 6: Proposed SCL-DPP System

The role of switched-capacitor and inductor is to process the fractional amount of mismatch power in PV system. Basically, the proposed SCL-based DPP operates in twomodes. During the operation, four MOSFET devices, Q1, Q2, Q3 and Q4, are employed to spread the mismatch charges evenly throughout the submodule by running a high frequency. A duty cycle of 50% is used to switch these MOSFET devices. Q1 and Q3 are turned off during first cycle, but Q2 and Q4 remains ON. The transistors Q1 and Q3 are turned ON in the next cycle keeping Q2 and Q4 in OFF position. This ultimately results in flow of mismatch current IL across the inductor L.

III PERFORMANCE ANALAYSIS

To evaluate the effectiveness of the proposed SCL-based DPP architecture, simulations are done under various mismatch scenarios.

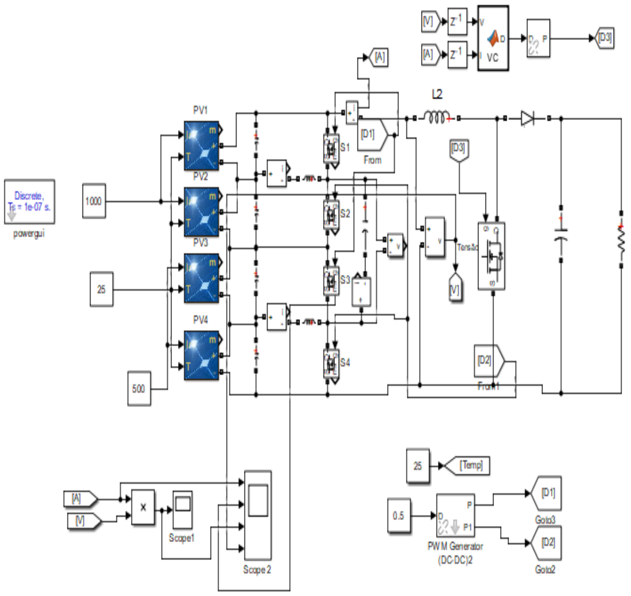

Fig. 7: Simulation Model developed

Figure 7 depicts the simulation model created for performance evaluation. To produce various mismatch scenarios, the irradiance over the PV modules is changed. In order to evaluate the performance of proposed system, 4 submodules (P1, P2, P3, & P4) of 30.4W each are arranged to form PV system. The analysis is done by allowing the system to operate in three different scenarios.

Case 1: No shading - in this case, the PV modules are working in normal condition. All the submodules i.e., P1, P2, P3 & P4 are generating equal amount of power and are maintained STC 1000W/m2 at 25^{0}C. Since, all the modules are generating same power thus no mismatch is observed in this case thus mismatch current can be neglected. The V-I & P-V characteristics of PV system at normal working condition is depicted in figure 8. Here, Imax and Pmax is found to be 1.8A and 15.04 W respectively.

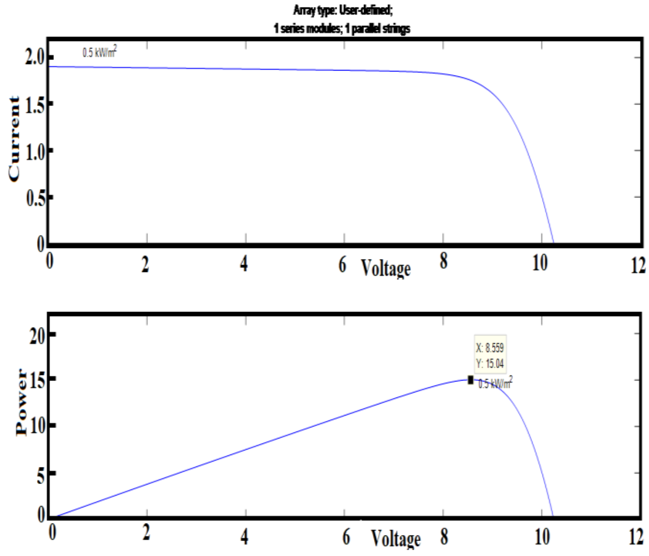

Fig. 8: V-I and P-V characteristics at "No shading"

Case 2: P4 is partially shaded – In this case, P4 submodule is partially shaded and receiving irradiance at 500W/m2 whereas the rest of modules i.e., P1, P2, & P3 are maintained at 1000W/m2. Figure 9 shows the V-I and P-V characteristics of PV system when P4 is at partially shaded condition.

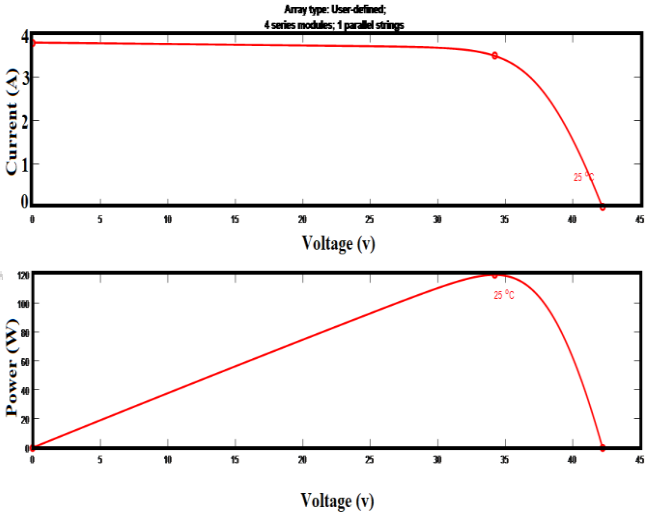

Fig. 9: V-I and P-V characteristics when P4 partial shaded

Here, when P4 is partial shaded, the theoretical Pmax (i.e., without using DPP) is calculated as,

$$P_{max} = P1 + P2 + P3 + P4$$

$$P_{max} = 30+30+30+15 = 105\ W$$

Whereas, when conventional Bypass diode is implemented then, P4 is completely ignored and the maximum power is 90W. Furthermore, with implementation of proposed DPP approach, the Pmax is found to be 120W indicating no any impact of shading on generation and showcases the proficiency of our proposed method over conventional approaches. The switching current, switching volage, string current, voltage and power for case 2 operation of system is graphically depicted in figure 10.

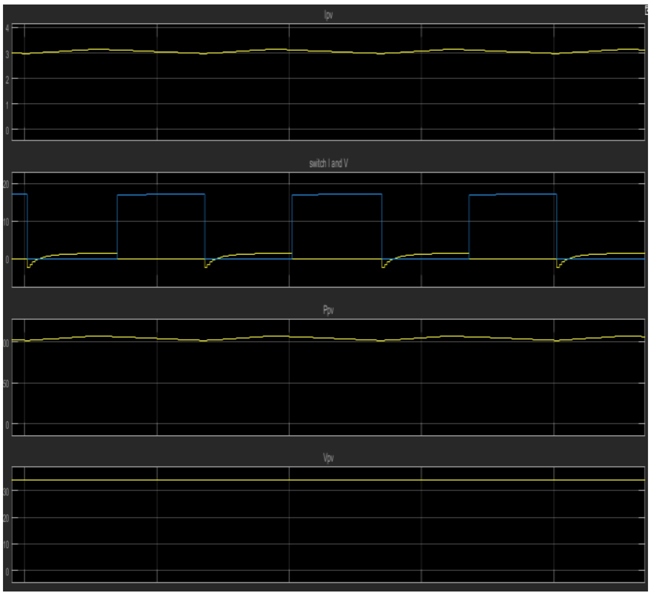

Fig. 10: Switching action when P4 is partially shaded.

Case 3: P3 & P4 are partially shaded – In this case, we have considered an intragroup operation of PV modules. P1 and P2 are getting 1000W/m2 of irradiance whereas, P3 & P4 are partially shaded and receiving 500W/m2. During such non-uniform irradiance, switched capacitor converter is now in operation.

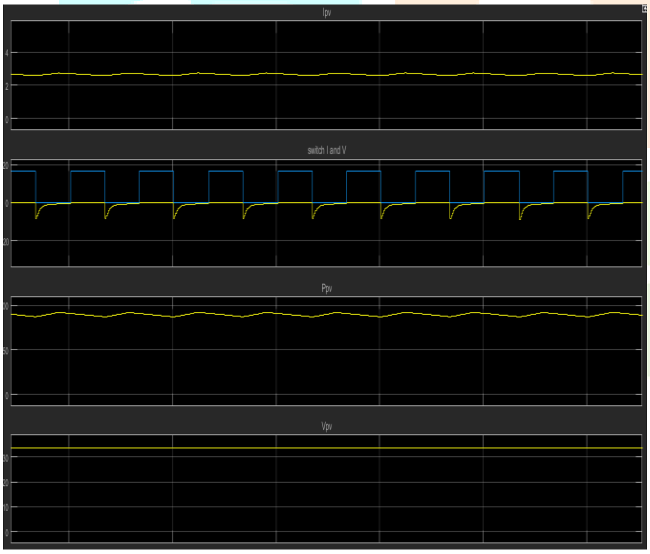

Fig. 11: Switching action when P3 & P4 are partially shaded

With the implementation of bypass diode, the maximumoutput of system will be 60W only since P3 and P4 will be totally ignored/bypassed. With implementation of our proposed approach the calculated Pmax is found to be 90W. Figure 11 indicates the parameters and switchingcurrent/voltage for the system for intragroup non-uniform irradiations

IV: CONCLUSION

The Switched-Capacitor-Inductor based DPP converter topology is used in this paper. The aim is focused to minimize the impact of partial shading on the performance of PV system. Here, four sub modules are used to develop proposed model using MATLAB/SIMULINK. The simulation results obtained shows that, the proposed topology is more effective in mitigating the impact of partial shading. It gives more efficiency with minimum power losses. The proposed converter is 100% effective when only one sub module is partially shaded. It has minimum impact of shading on generation and showcases the proficiency of our proposed method over conventional approaches

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