High Efficient Solar Energy Conversion Using Sepic Converter With String Current Diverter

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Abstract: ***Solar energy is the readily available and the cheapest form of energy. It is non-polluting and cheap of cost. Most of the proposed approaches thus far have relied on the use of series string of the DC-DC converter to create a high voltage string connected to the DC-AC inverter. However, under inhomogeneous irradiation, the power generated by each PV module and the output DC voltage of each boost become unbalanced so that the output currents of each DC-DC are balanced and equal to the string current. In this case, the boost converter cannot always deliver all the power from a mixture of shaded panels and those delivering full power. In this paper, a string current diverter is proposed to overcome this problem. One important feature of the proposed circuit is to decouple each converter from the rest of the string, making it insensitive to change in the string current .On the other hand, the string current diverter circuit is very easy to control and does not operate without inhomogeneous irradiation. Hence it is possible to obtain the maximum power from the PV module with the maximum power point tracking algorithm implemented on each DC-DC converter. The simulation and experimental results of the proposed topology are verified using MATLAB.***

Keywords: DC-DC Converter, SEPIC Converter, String Current Diverter

1. Introduction

The Photo Voltaic (PV) power generation system is gaining more and more visibility, while the world's power demand is increasing and awareness of the importance of protecting the global environment has been growing. The PV systems are modular, hence the major advantage of these systems is that they can be simply adopted in existing buildings and can be installed anywhere. In addition, manufacturers have designed various models, which can be placed in different types of houses or buildings to achieve better performance. In PV system topology, a series connected to PV module is used to create a high voltage string connected to the DC–DC converter. However, under real conditions the performance of this scheme is negatively affected fall its modules are in homogeneously illuminated. All the modules in a series array are forced to carry the same current even though a few modules, under shade, produce less photo current. The shaded modules may get reverse biased, acting as loads, and dissipating power from fully illuminated modules in the form of heat. On the other hand, the inhomogeneous illuminated part makes PV array have multiple power peaks. To avoid thermal overload, sub strings of cells inside the interconnection circuit of modules are bridged by bypass diodes. Although it is possible for string circuits to reduce the influence of partial shadow to some extent, they could not solve the maximum power point tracking (MPPT) problem in the shaded string circuit because the presence of the PV array has multiple power peaks due to the existing MPPT schemes which are unable to discriminate between the local and global power peaks. To overcome this problem a series string of the DC–DC converter with corresponding string current diverter circuits based on buck–boost converter is used. The string current diverter circuit is independently utilized to balance the output voltage of the DC–DC converter under shadow conditions. The proposed circuit enables the individual PV modules to operate effectively at the MPPT by imposing an optimum ratio under any conditions

2. Proposed System

2.1string Current Diverter

During the partially shaded condition of the PV panel, the output voltage of the panel is reduced. In the proposed method String Current Diverter is used which maintains the output voltage of the PV panel during the partially shaded conditions.

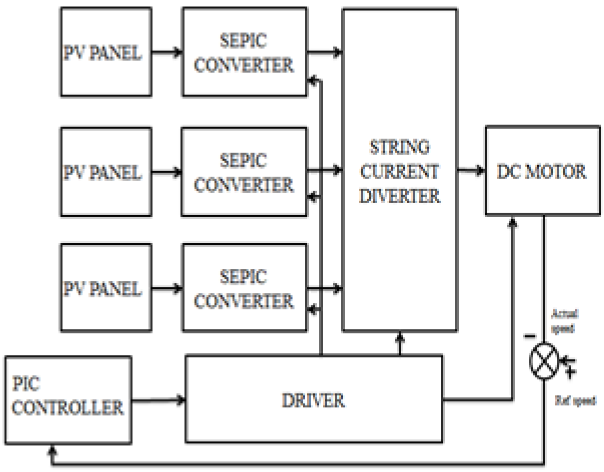


Figure 2.1: Overall Block Diagram of Proposed System

The proposed block diagram in the figure 2.1 consists of three PV panels. The output voltage of the PV is given to the SEPIC converter. The SEPIC converter steps up the voltage. The outputs of the three SEPIC converters are given to the String current diverter. The string current diverter diverts the output current when any one of the panel gets shaded else the string current diverter will be disabled. The output of the string current diverter is given to the DC motor in which the speed is controlled using Armature control method.

2.2 String Current Diverter

String current diverters provide a means to diverting the output currents of boost converters away from the unshaded PV module to the next module in the string. This allows the rest of the shaded modules to operate at the maximum power point voltage. The current diverter shown in the figure 2.2 is made of diverter modules connected across each pair of PV modules. Each diverter module consists of a switch pair (MOSFETs) in addition to an energy storage element L. The maximum value of the inductance current corresponds to the short circuit current (Isc) of a PV module. This most unfavourable case occurs when two consecutive PV modules receive extreme levels of irradiation, namely G = 1000 W/m2 for one and 0W/m2for the other. The diverter module along with the corresponding two PV modules forms a half bridge converter feeding an inductive load. During normal climatic conditions, the diverter modules are disabled and the string current flows serially through all output capacitors of the boost converters. When one or more PV modules are shaded, the corresponding current diverter is able to divert the string current. The string current diverter is switched ON or OFF according to balance or imbalance of output currents of PV modules. With the existing measures of output currents of PV modules, an error calculation is carried out and compared with a threshold value ε with the following method $\Delta IPV = |IPVN-1- IPV| \geq \varepsilon$ and then the SCD is switched ON or OFF. The value of ε is chosen different from zero to take into account the characteristic dispersions of PV modules and to leave light imbalances that are not harmful. For NPV modules, the number of active switches S (MOSFET T and diode D) is 2N−2 while the number of inductor is N−1. During operation, the diverter circuit provides equalization by directing energy from the un shaded PV converter to the shaded PV converter. It aims at keeping the output voltage constant under normal or shaded conditions .To simplify the analysis, we consider the case of only three PV modules. For example, if PV2 module is shaded, the MOSFET T4 is turned ON. As a result, the filter inductor current increases linearly and the energy is stored in the inductor L2 .When the switch is turned OFF, the energy stored in the inductor is delivered (D3 turned ON) to the output capacitor of the boost converter connected to the PV2. As a result, the inductor current decreases in a linear fashion. If the energy stored in the inductor L2 is completely transferred to capacitorC2 and the MOSFET T3 is still turned ON, the current changes directions.

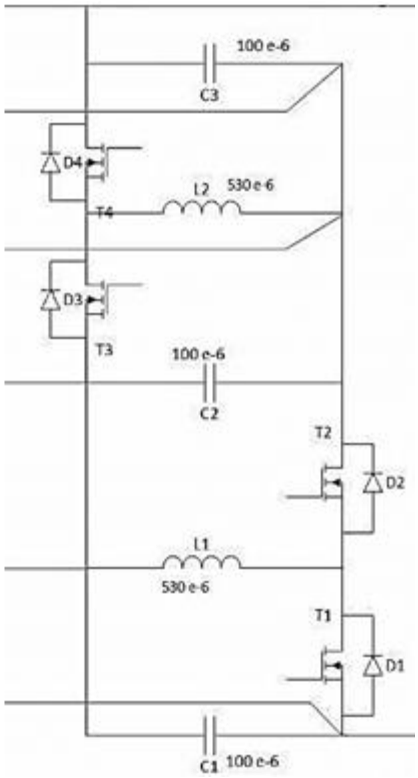


Figure 2.2: String Current Diverter

Then, when MOSFET T4 is turned ON, the diode D4 transfers the energy stored in the inductor L2 to the capacitor C3. First, the MOSFET T4 is turned ON. As a result, the filter inductor current increases linearly and the energy is stored in the inductor L2. When the switch is turned OFF, the energy stored in the inductor is delivered (D3 turned ON) to the output capacitor of the boost converter connected to the PV2. As a result, the inductor current decreases in a linear fashion. If the energy stored in the inductor L2 is completely transferred to capacitor C2 and the MOSFET T3 is still turned ON, the current changes directions. Then, when MOSFET T4 is turned ON, the diode D4 transfers the energy stored in the inductor L2 to the capacitor C3.

2.3 SEPIC Conveter

The buckboost feature of the SEPIC widens the applicable PV voltage and thus increases the adopted PV module flexibility. Among all the available converters, SEPIC has the merits of non-inverting polarity, easy to drive switch, and low input current pulsating for high precise MPPT that makes its integral characteristics suitable for the low power PV charger system. SEPIC converter can raise the output voltage to a suitable range, and can supply an isolation route to isolate the input and output terminal after terminate charging. But this circuit has two disadvantages; one is low efficiency and the other needs two inductors. The efficiency is not the major factor when charger is designed and use of coupling inductor solves the other disadvantage. Therefore the SEPIC is a good choice for constant current converter design.

The SEPIC converter is shown in the figure 2.3

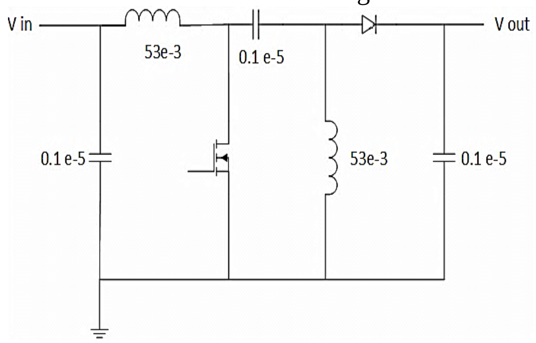


Figure 2.3: SEPIC converter

The operation principle of SEPIC is: when S turns ON, the input source stores energy in the inductor L1. The inductor current increases linearly. The energy stores in capacitor C1 will transfer into inductor L2. The energy for the load is supplied by capacitor C2.When S turns OFF, the energy stored in inductor L1 transfer to C1. The energy stored in L2 will transfer to C2 through Diode and supplying the energy to loading.

2.4 Pv Panel

The MonocrystallinePV panels are used. 40 cells are connected in series to form a single module. Voltage of single cell is 0.6V so the voltage of a single module is 24V. In this proposed method 3 modules are used.

2.4 MPPT (incremental conductance)

The incremental conductance algorithm is based on the fact that the slope of the curve power vs. voltage (current) of the PV module is zero at the MPP, positive (negative) on the left of it and negative (positive) on the right, as can be seen in the figure 2.4

- $\Delta V/\Delta P= 0$ $(\Delta I/\Delta P)$ at the MPP
- $\Delta V/\Delta P< 0(\Delta I/\Delta P)$ on the left
- $\Delta V/\Delta P> 0(\Delta I/\Delta P)$ on the right

By comparing the increment of the power vs. the increment of the voltage (current) between two consecutives samples, the change in the MPP voltage can be determined. A scheme of the algorithm is shown in the figure 2.4

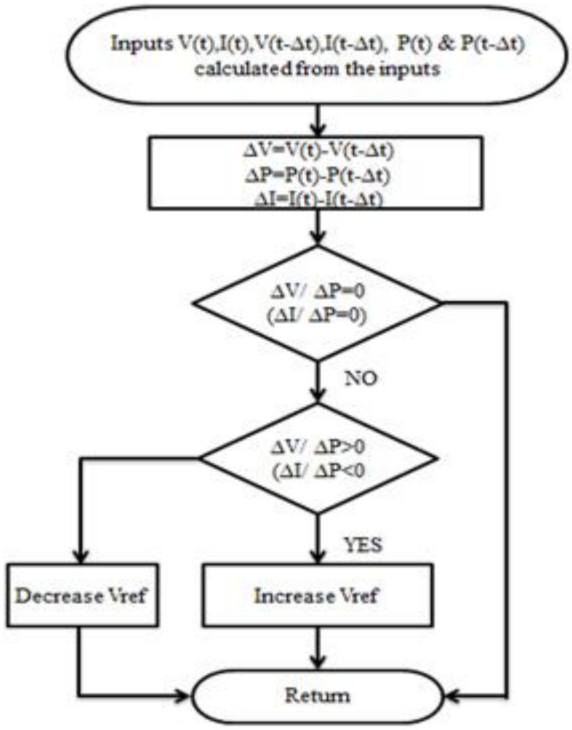


Figure 2.4: Incremental conductance algorithm

2.5 Speed Control In Dc Motor

Separately excited dc motor is used in this proposed method. In separately excited dc motor the speed is controlled using armature control. In armature control the output speed of dc motor is compared with the reference speed and by varying the input voltage to the motor the speed is controlled.

3. Simulation Circuit

3.1 Simulation Diagram Of Proposed System

The simulation block diagram of proposed system is shown in the figure 3.1. It consists of three solar panels. The output of each solar panel is given to individual SEPIC converter in which the MPPT is tracked using Incremental Conductance Algorithm. The outputs of the SEPIC converter are given to the string current diverter which diverters the current when the panel gets partially shaded and provides a constant output voltage. This is given to the dc motor in which the speed is controlled using armature control method using PI controller.

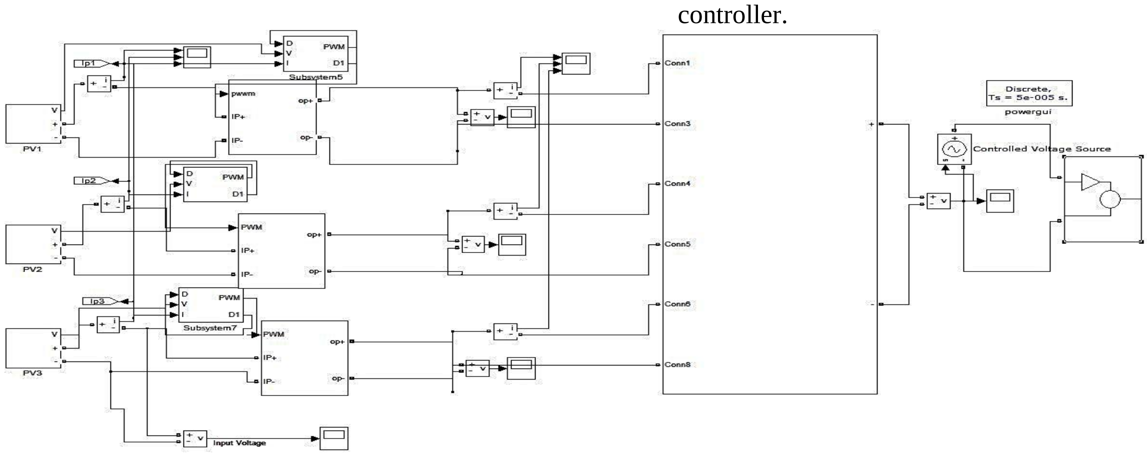


Figure 3.1: Simulation diagram of proposed method

3.2 Simulation Diagram of PV Panel

The subsystem of PV panel is shown in the figure 3.2 the solar cell is a physical system it cannot be directly connected to the Simulink model so a converter is used in between them to connect the two systems.

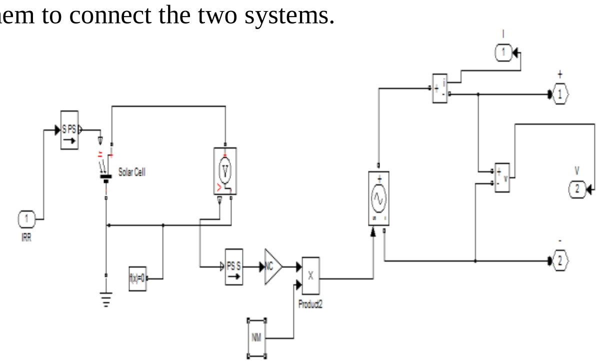


Figure 3.2: Subsystem of PV panel

3.3 Simulation Diagram Of MPPT Techniques

The simulation diagram of MPPT technique is show in the figure 3.3 In the proposed method Incremental Conductance Algorithm is used to track the MPPT. In this MPPT the maximum power is tracked by comparing the previous value of voltage, current and power with the recent values and the duty cycle is given accordingly.

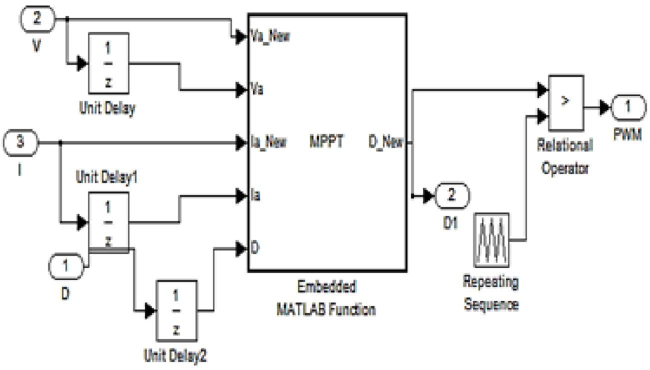


Figure 3.3: Simulation diagram of MPPT technique

3.4 Simulation Diagram of SEPIC Converter

The simulation diagram of SEPIC converter is shown in the figure 3.4. The SEPIC converter is Single Ended Primary Inductance Converter. It either steps up or steps down the voltage based on the turn on and off of IGBT.

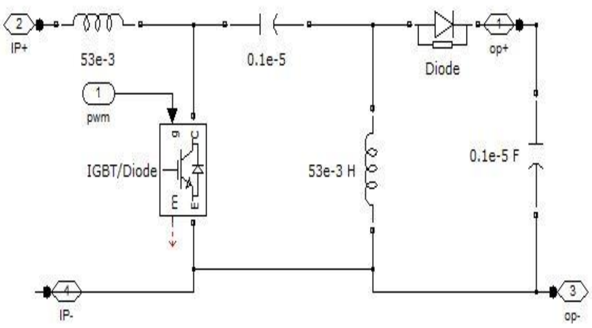


Figure 3.4: Simulation diagram of SEPIC converter

3.5 Simulation Diagram of String Current Diverter

The simulation diagram of String Current Diverter is shown in the figure 3.5 The String Current Diverter diverters back the output current of the DC-DC converter in order to maintain the output voltage of the DC-DC converters constant. String current diverter is switched ON or OFF according to balance or imbalance of output currents of PV modules. With the existing measures of output currents of PV modules, an error calculation is carried out and compared with a threshold value ε and the SCD is switched ON or OFF accordingly.

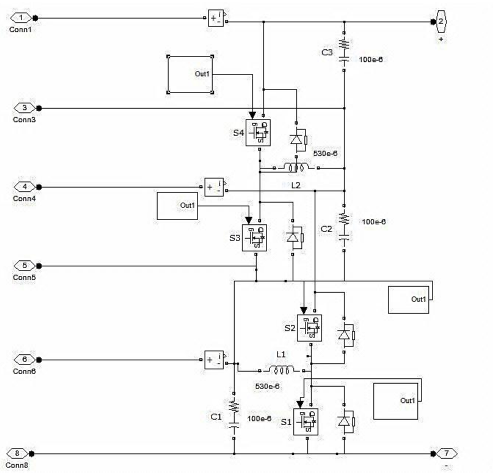


Figure 3.5: Simulation diagram of String Current Diverter

3.6 Simulation Diagram of Speed Control of Dc Motor

Speed control simulation diagram is shown in the figure. Here the actual speed is compared with the set reference and the error response is given to the PI controller. The PI controller produces the required response which is compared with the carrier waveform and the gating pulses are produced accordingly. The gating pulses turn on and off the IGBT which controls the Armature Voltage of the DC motor.

Thus here the speed is controlled by varying the armature voltage.

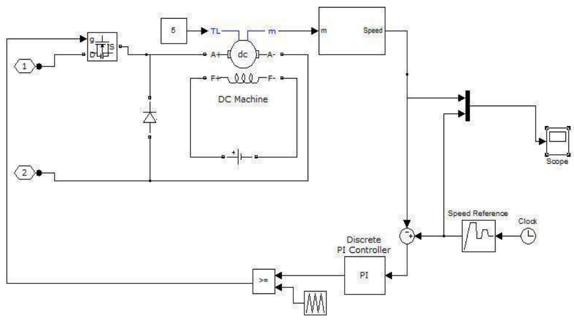


Figure 3.6: Simulation diagram of speed control of dc motor

4. Simulation Result

The output current of PV panel is shown in the figure 4.1

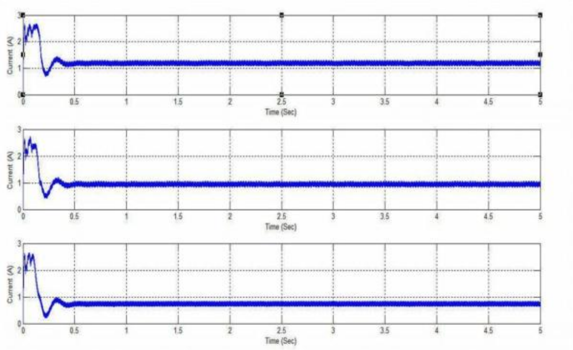


Figure 4.1: PV panel current
(X-axis 1 div=0.5s Y-axis 1 div=1 A)

The output voltage of SEPIC converter is shown in the figure 4.2

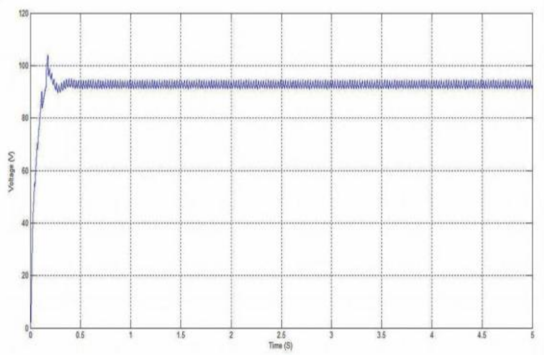


Figure 4.2: SEPIC converter voltage
(X-axis 1 div= 0.5s, Y-axis 1 div=20 V)

The output current of SEPIC converter is shown in Figure 4.3

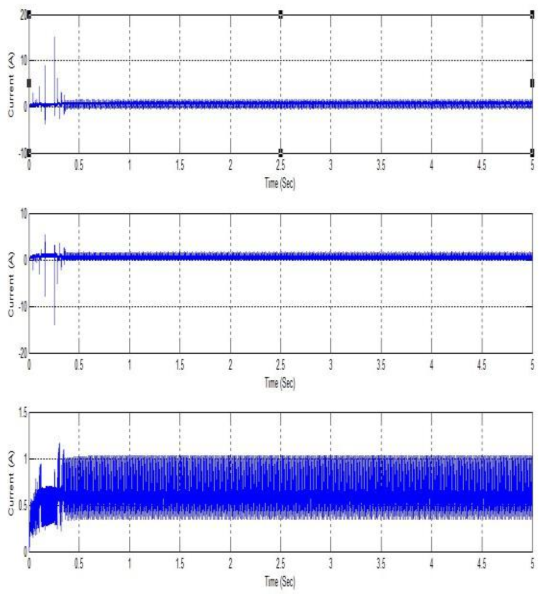


Figure 4.3: SEPIC converter current
(X-axis 1 div=0.5s, Y-axis 1 div=10A)

The output voltage of SEPIC converter is shown in Figure 4.4

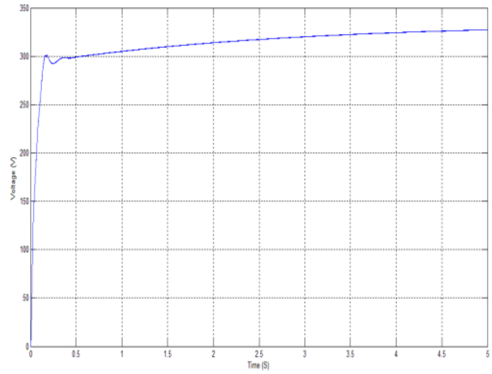
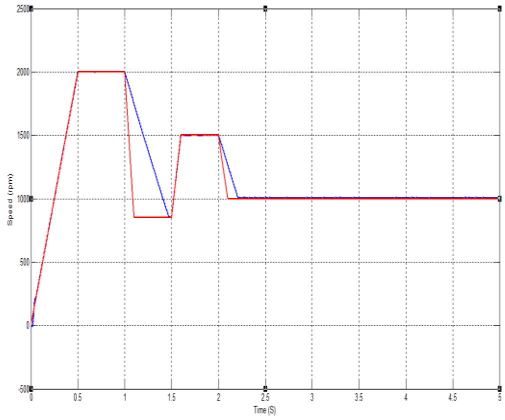


Figure 4: 4String Current Diverter Voltage
(X-axis 1 div=0.5s, Y-axis 1 div=50V)

The speed control of the dc motor is shown in the figure 4.5



Speed response of dc motor
(X-axis 1 div=0.5 s, Y-axis 1 div=500rpm)

5. Conclusion

Thus the performance of cascaded DC–DC converter topology under shaded conditions, this paper proposes a string current diverter connected to each SEPIC converter. During normal climatic conditions, the diverter modules are disabled and the string current flows serially through all output capacitors of SEPIC converters. When one or more PV modules are shaded, the corresponding current diverter is able to divert the string current. The detection of shaded PV modules is carried out simply by the comparison of the output currents of PV modules without any addition of sensors. This circuit is able to successfully decouple each converter from the rest of the string, making it insensitive to shading conditions. Moreover, the presented topology enables effective application of the algorithms of MPPT under shaded conditions. The MATLAB simulation and experimental results verify that the proposed topology exhibits good performance under inhomogeneous and homogeneous irradiations.

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