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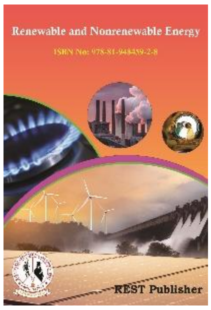

Reduction of Reverse Current Losses in Photovoltaic Cells by Using Isolators

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Abstract: *In recent days most of the people are convinced that Solar PV cell technology is the best solution for future energy supply. The crystalline silicon cells have been a workhorse of photovoltaic industry for a long time. Hotspot phenomenon emerges in solar power plant frequently, although the hotspot endurance tests for extreme outdoor condition are used for qualification tests procedures, and bypass diodes are also built in silicon PV modules. In earlier there are several approaches to detect the hotspot such as infrared camera and theoretical comparison of currents etc. The main objective of this work is to identify the hotspot and to limit the reverse current to reduce power loss by using electronic equipment. Isolators are used to trip the solar PV module which is under hotspot and that panel restart working after hotspot is removed. Due to this the permanent damage of the cell is avoided and the reliability of the PV system can be improved.*

Keywords: *photovoltaic (PV) systems, Comparators, current sensors, microcontroller, isolators, reliability.*

1. INTRODUCTION

Energy consumption had increased rapidly population growth in the world. Conventional energy sources have no longer enough, renewable energy sources such as wind power, solar power, geothermal and fuel cells are considered to reach the global demand for energy [1]. Solar energy is a renewable energy source which is very attractive with high reliability and a long service life. Energy contribution is less than other sources due its high cost and low efficiency. The main element in the solar power generation is the solar photovoltaic cell. There are two ways to improve the performance of the PV cell, one to maximize the efficiency by using Maximum Power Point Trackers (MPPT) and another way is to reduce the power losses in the PV cell. In this work an experimental setup is developed to reduce the power losses and to improve the reliability of the entire photovoltaic system.

Power Generation:

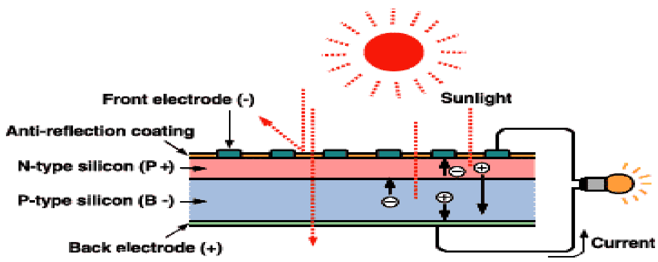

FIGURE 1. Power generation using PV cell

The sun radiates the solar energy uniformly in all directions in the form of electromagnetic waves is called solar energy. Sun radiates the energy per year is around 2.8*10^23 kw/year, but the earth receives the energy per year is around 1.5*10^18 kw/year. The rate at which solar energy arrives at the top of the atmosphere is called Sun or Solar constant Isc. This is the amount of energy received in unit time on a unit area perpendicular the sun's direction at the mean distance of the earth from the sun [2]. In recent years India has one of the highest potentials for the effective use of renewable energy technology. One of the important energy sources is the solar energy. Silicon semiconductor is used to make the solar cells. The combination of a p-type and n-type semiconductors constitutes a PV cell or solar cell. When a semiconductor absorbs photons from the sun, free electrons are created with high energies compared to the electrons by which bonding in the base crystal is provided. An electric field must be there, once free electrons are created to induce these high energy electrons to flow out of the semiconductor to do useful work. In most solar cells a junction of materials provides an electric field and they consist of different electrical properties [2]. When the shading occurs on the solar cell, there are consequent mismatches in the irradiation of the PV cells the in the module. Under this condition the diode part of the cell is reverse biased (voltage across cell is reversed) due to this the current flows in reverse direction in that particular cell and starts dissipate power, with a consequent temperature increase. This causes the overheating (hotspot) of the PV cells. This reverse current may be several times more than the normal maximum current (short circuit current) of the PV module [3], [4].

2. ELECTRICAL MODEL OF PV CELLS

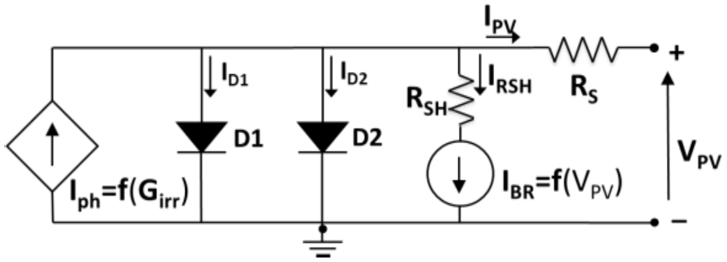

FIGURE 2. Electrical model for PV cells.

When the PV cell exposed to sunlight, it generates a photo current given by

- *Iph=(Jph.Acell.Girr)/Gmax*
- Girr (W/m^2) = solar irradiation
- Gmax=1000(W/m^2) = max solar irradiation
- Jph=3.43(µA/m^2) = max current density

The current delivered to the load is

- *Ipv = Iph-Id1-Id2-Irsh*
- Id1 = saturation current due to the diffusion mechanism
- Id2 = saturation current generated by the recombination in the space charge layer.
- Irsh = leakage current of the PV cell
- Reverse breakdown current is given by
- *Ibd=a.(Vpv/Rsh).(1-(Vpv/Vbd))^-m*
- a, m are the fitting parameters
- a=1.93, m=1.10

The current Ipv increases with the decrease of Vpv, and strongly depends on the shunt resistance Rsh [5]. If the Rsh is diminishing, the current increases faster, and large power is dissipated on Rsh, this causes the temperature increase on that particular panel [6]. It may cause the permanent damage of PV cell. To avoid this problem we proposed a hotspot detection scheme and isolation of PV panel which is under hotspot.

3. EXPERIMENTAL SETUP

The experimental setup consists of solar panels, current sensors, voltage sensors, comparator, Micro Controller, LCD display, alarm, Isolator circuit connecting wires, power supply components etc.

TABLE1. Specifications of the Equipment

Component	Quantity	Model name	Rated Voltage(v)
Solar panels	4	MS 1250	24
Current sensors	5	WCS 2210, 10A	60
Voltage sensors	4		24
Comparators	4	Ua741	15
Micro controllers	1	Arduino Nano Atmega 328p	20
Isolator	4	Hrs4h s dc 12 V	24 DC /230V AC
LCD	1	20×4 Alpha numeric	5.5
Alarm	1	piezo buzzer	15

Solar Panels: The solar panels used here are of model MS 1250, 50W, 24V.

FIGURE 3. Solar panels arrangement

Four panels are used here; four panels or connected in parallel for this experiment and a pair of panels are connected in series those two pairs are again connected in parallel to obtain desired voltage and current for inverter and battery setup the output power from these panels is used as supply for 200W of load.

Hall Effect Current sensors: The WCS2210 consists of a precise, low-temperature drift linear hall sensor IC with temperature compensation and AC to DC rectifier circuit and a current path with 0.4 mΩ typical internal conductor resistance. This extremely low resistance can effectively reduce power loss, operating temperature and increase the reliability greatly. Applied current flowing through this conduction path generates a magnetic field which is sensed by the integrated Hall IC and converted into a proportional rectified DC voltage [7].

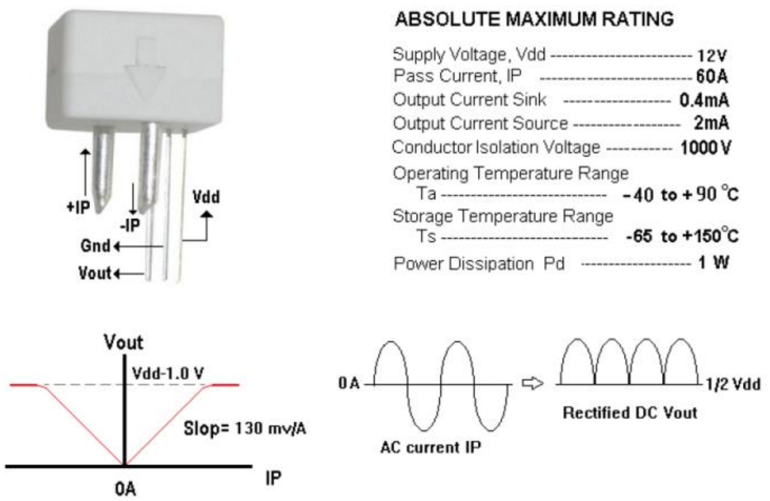

FIGURE 4. Current sensor

Micro controller

FIGURE 5. Arduino Nano Atmega 328p micro controller

Arduino NanoAtmega 328p micro controller is used in this work. The purpose of micro controller is to give the commands to the LCD and isolator circuits.

Isolator circuit: Hrs4h s dc 12 V relays (isolators) are used to trip the solar panel which is under hotspot and connect it to the system after removal of hotspot.

Comparator: Voltage comparator is a circuit which compares two voltages and switches the output to either high or low state depending upon which voltage is higher. A voltage comparator based on opamp is shown here. Figure 1offigure 6 shows a voltage comparator in non-inverting mode and Fig 2of fig 6 shows a voltage comparator in inverting mode in.

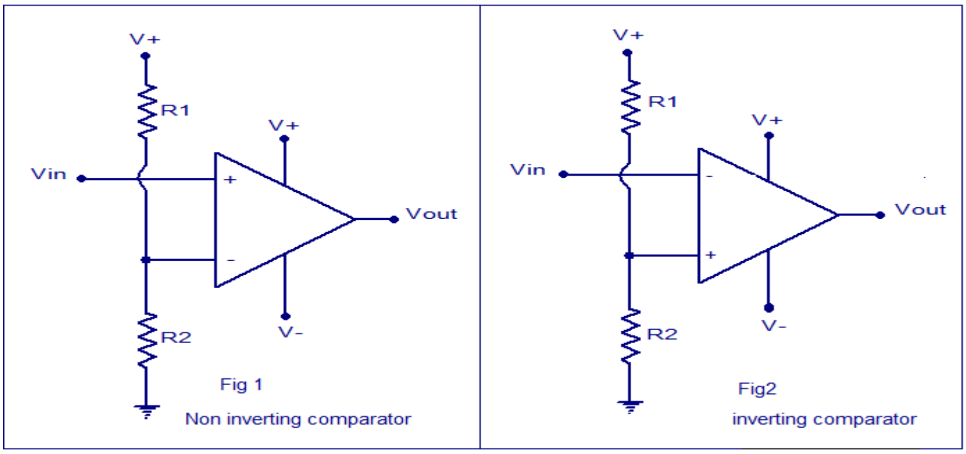

FIGURE 6. Voltage comparator circuit

In non-inverting comparator the reference voltage is applied to the inverting input and the voltage to be compared is applied to the non-inverting input. In the case of an inverting comparator, the reference voltage is applied to the non-inverting input and voltage to be compared is applied to the inverting input.

LCD display: In this work monochromatic 20x4 alphanumeric LCD is used. 20x4 means that 20 characters can be displayed in each of the 4 rows of the 20x4 LCD, thus a total of 80 characters can be displayed at any instance of time.

Alarm: Piezo buzzer is used for alarm with operating voltage of 3 – 15 V. Here 5V is applied.

4. OPERATION OF THE HOTSPOT DETECTION

The voltages and currents from the PV panels are given to the voltage sensors and current sensors respectively. The current sensors give the voltage signal equivalent to the measured currents are given to the micro controller and comparators. Micro controller gives the signals to LCD, Alarm circuit. The comparator compares each voltage signal those given from current sensors with reference signal and converts it from analog to digital output. Whenever the shading occurs on the panel, the voltage signal is higher than the reference signal (the current is reversed and increasing rapidly i.e. Hotspot) then the comparator gives 1 to the corresponding isolator (i.e. comp1 to R1, comp2 to R2 etc.), otherwise 0. If 1 is given to the isolator it will disconnects the corresponding panel and give the signal to the micro controller, then microcontroller then it will give signal to the alarm circuit [8]. Whenever the hotspot is removed the panel restarts working automatically then alarm is OFF.

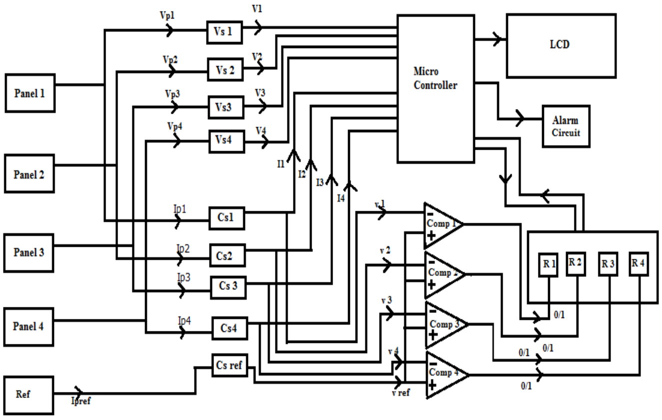

FIGURE 7. Block diagram

All this operation had done with the load of 5A and the solar PV panels are using for power generation. When doing project the panels are connected to the circuit board and after completion of the experiment the panels are connected to the inverter for power generation. It is done by using DPDT (Di Pole Double Through) switches.

5. RESULT

The proposed Hotspot detection and isolation scheme to reduce the reverse current losses is implemented and validated for 5A of load, the three observations are given below Table 1, Table 2, and Table 3. Table 1 is observed when there is no shading. At this time the four panels are shared the load equally (1.25A each), Table 2 is observed when there is partial shading on the 2nd panel without isolation, the reverse current is observed in the 2nd line of LCD, and Table 3 is observed at the same partial shading conditions with isolation on the same panel, the current from that panel is zero, so that panel is protected from the hotspot. The reverse current losses can be avoided by this scheme.

TABLE 2. Without Any Partial Shading Condition

LCD output	Voltage(V)	Current(A)
Panel 1	20.14	1.25
Panel 2	20.12	1.25
Panel 3	20.14	1.25
Panel 4	20.15	1.25

TABLE 3. With Partial Shading Condition without Isolation

LCD output	Voltage(V)	Current(A)
Panel 1	20.14	2.04
Panel 2	15.09	-1.15
Panel 3	20.12	2.04
Panel 4	20.15	2.04

TABLE 4. With partial shading condition with isolation

LCD output	Voltage(V)	Current(A)
Panel 1	20.14	1.66
Panel 2	20.63	0.00
Panel 3	20.12	1.66
Panel 4	20.15	1.66

The experiment is conducted at the load of 5A, the result with isolation (Table 3) shows that the load draws 1.66A from three panels without any excess current. The partially shaded panel (2nd) is completely isolated and then the current is zero in that panel. Whereas in Table 2 (without isolation), it is observed that the excess current of 0.38A from each panel which is responsible for 1.15A reverse current in 2nd panel. In this case, 2nd panel is not isolated which can cause the permanent damage of the solar panel. The hotspot detection and isolation is used to reduce the losses and to improve the solar panel performance and life.

6. CONCLUSION

The following conclusions were drawn from the experimental work. Under partial shading condition the reverse currents are observed. These reverse currents can cause the temperature increase; if the temperature reaches critical value (Hotspot) the cell is permanently damaged. An experimental model is developed to detect hotspot and isolate panel which is under hotspot by using isolator circuit. If the shaded panels is not disconnected the reverse current increases rapidly and power dissipation is also high. So it has to be isolated. That panel starts working automatically after shading is removed. The panel voltages and currents are observed for three conditions they are, without any partial shading, with partial shading without isolation and with partial shading with isolation. This helps to protect the solar panel from permanent damage and improve the reliability and performance of solar plant.

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