An Inspection on Solar Panel With Series And Parallel Connections Under Variable Influence of Radiation And Shading

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Abstract- *Solar energy is one of the abundant and pollution free renewable energy that can be harvested through solar panel. Solar radiation in the earth with maximum radiation level and minimum radiation level is 1,413 W/m^2 and 1,321 W/m^2. In general, Solar panel provides a high voltage on series connection and produces a high current on parallel connection. In this research paper, solar panel was connected in series and parallel for observing the performance of the solar panel in different radiation and shading conditions. The performance of individual solar panel is found to be increased in voltage when PV panel is connected in series and increased in current when PV panel is connected in parallel.*

Keywords- Renewable Energy, Radiation, Solar Energy, Solar Panel and Shading

I. INTRODUCTION

Solar panel is an important development in the energy harvesting of solar energy. The solar panel or PV panel is the arrangement of many solar cells [1, 6]. In common, solar cells are composed of semiconductor and depending upon the single or multiple semiconductor utilization in the manufacture of solar panel, the various generation of solar panel was produced [4]. Solar panels can be connected in three different ways namely parallel, series or a combination of the two.

Series circuits have only one path for current to travel along. Therefore, *all* the current in the circuit must flow through *all* the loads [2]. A series circuit is a continuous, closed loop - breaking the circuit at any point stops the entire series from operating. Parallel circuits have multiple paths for the current to move along. If an item in the circuit is broken, current will continue to move along the other paths, while ignoring the broken one [3]. This type of circuit is used for most household electrical wiring. The series-parallel circuits are not commonly used due to its usage of more panels that are expensive.

When the solar panel is connected in series, there will be increase in the voltage level and the current is the same. The main disadvantage in series systems is shading problems. When panels are wired in series, they all in a sense depend on each other. If one panel is shaded it will affect the whole string [5, 7]. This will not happen in a parallel connection.

When the solar panel is connected in parallel, there will be increase in the current and the voltage is the same. The disadvantage in parallel systems is the high current is difficult to travel long distances without using very thick wires. The paralleling systems also require extra equipment such as branch connectors or combiner box.

II .MATERIALS AND METHODOLOGY

A. Materials Required:

The required materials for the experimental investigation are solar module, Halogen lamp and Multi-meter. The specifications of the PV panel were clearly mentioned in the Table 1. A halogen lamp, also known as a tungsten halogen is an incandescent lamp consisting of a tungsten filament sealed into a compact transparent that is filled with a mixture of an inert gas and halogen. A halogen lamp produces a continuous spectrum of light, from near ultraviolet too deep into the infrared [8, 9].

Table 1. Specification of PV panel

Company	Ecosense INSIGHT SOLAR
Model No.	ELDORA 40P
Cell material	Polycrystalline silicon
Artificial Source of Radiation	Halogen - with regulator
V_{oc}	21.90V
I_{sc}	2.45A
Rated voltage	17.40V
Rated current	2.30 A
P_{max}	40W
Radiation used	1000 W/m^2
Cell temperature	25 °C

Fig. 1. Ecosence INSIGHT Solar systems.

Fig. 1. shows the Insight solar system which has two solar panels and the control module. The solar panels uses the halogen lamps for the radiation and the power generated from PV panels are connected to the controller, which controls and converts the power as needed.

B. Experimental Methodology

The experiment was conducted on the solar panel, in which the panel was made up of Polycrystalline silicon material. The dimensions of the solar panels were 660 × 460 mm of two insight solar panels, which uses halogen lamp as light source. The Multi-meter is connected to the solar module output for the result analysis.

Effect of radiation on solar panel connected in series and parallel

First the two PV panels are connected in series connection with 15% tilt angle, 100 ohms resistance. The voltage and current are measured while changing the radiation. Then the panels are connected in parallel and voltages, current are again measured by changing the radiation of the halogen lamps.

Effect of shading on left and right solar panel

The shading experiment was carried out on the left and right PV panel individually and the corresponding voltage and current were measured. The effect of the left panel was noted without and with load at varying shading conditions. The effect of shading in the right PV panel was examined in the similar way as left PV panel. The power values were calculated corresponding to the measured voltage and current.

Effect of shading on solar panel in series connection

The left and right solar panel was connected in series conditions. When connecting solar panels in a series, the voltage is additive, but the amperage remains the same. In some case both the connections are combined to get desirable voltage and current. The investigation on the effect of shading in series connection of solar panel was conducted with and without load. The resultant current and voltage of the experiment was noted and the power was also calculated.

Effect of shading on solar panel in parallel connection

The left and right solar panel was connected in parallel conditions. When connecting solar panels in parallel, the current is additive, but the voltage remains the same. The investigation on the effect of shading in parallel connection of solar panel was conducted with and without load. The outcome of the examination mainly the current and voltage was noted and the power was calculated.

III. RESULTS AND DISCUSSION

A. Effect of series and parallel connection on diverse radiations

First the two PV panels are connected in series connection with 15% tilt angle, 100 ohms resistance. The voltage and current are measured while changing the radiation. Then the panels are connected in parallel and voltage, current is again measured by changing the radiation of the halogen lamps.

Table 2. Effect of PV panel on series connection

Sl.	Radiation (W/m^2)	Voltage (V)	Current (mA)	Power (mW)
1.	110	37.5	179	6712.5
2.	120	38	188	7144
3.	130	38.3	190	7277
4.	145	38.6	195	7527
5.	160	39	199	7761
6.	185	39.7	205	8138.5
7.	195	40	210	8400

Table 2. shows that the solar panel on series connection is capable of producing voltage and current in different solar radiation. The output power of the solar panel in this specific connection was calculated through the obtained voltage and current.

Table 3. Effect of PV panel on parallel connection

Sl.	Radiation (W/m^2)	Voltage (V)	Current (mA)	Power (mW)
1.	110	18.3	302	5526.6
2.	120	19.4	390	7566
3.	130	19.7	436	8589.2
4.	140	19.8	453	8969.4
5.	150	20	479	9580
6.	160	20.1	487	9788.7
7.	183	20.3	495	10048.5
8.	190	20.6	500	10300

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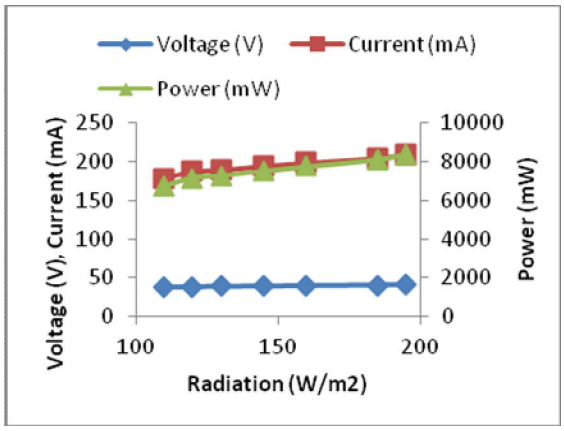

Fig. 2. Characteristics of PV panel on series connection

Fig. 2. shows the characteristics of solar panel connected in series with different radiation. The voltage increase more when the radiation increased but the current doesn't shows much difference.

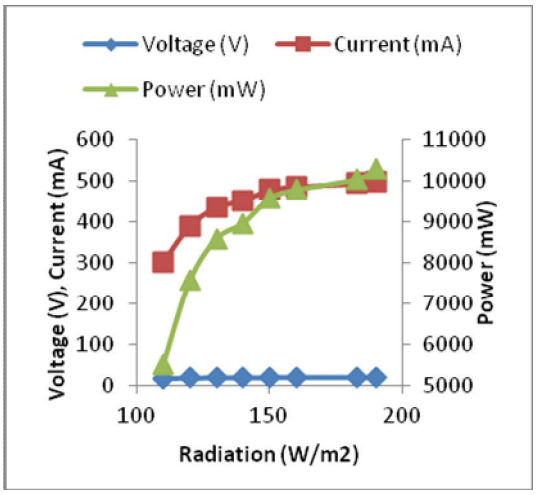

Fig. 3. Characteristics of PV panel on parallel connection

Fig. 3. shows the characteristics of solar panel connected in parallel with different radiation. The radiation with the parallel connection clearly shows the increase in current with the increase in radiation inturn increases the power output. From the Fig. 2 and 3 the observation is that in series voltage is more than in parallel and current is more in parallel than in series.

B. Effect of shading on left and right solar panel

The left and right solar panel was examined on different shading percentage besides varying load and the respective current and voltage were tabulated in table 4 to 7. The power was calculated by multiplying the current and voltage. The open circuit voltage (V_{OC}) and short circuit current (I_{OC}) were tabulated in the table 4 and 6 where the left and right solar panel were tested without load conditions.

Table 4. Effect of shading on left PV panel without load conditions

Percentage shading (%)	Voltage (V)	Current (mA)	Power (mW)
No shading	19.6	175	3430
25	18.8	20	376
50	18	16	288
75	17.4	12	208.8
100	16	11	176

Table 5. Effect of shading on left PV panel with load conditions

Percentage shading (%)	Voltage (V)	Current (mA)	Power (mW)
No shading	19.6	177	3469.2
25	18.6	22	409.2
50	18.1	16	289.6
75	16.8	13.6	228.48
100	15	12	180

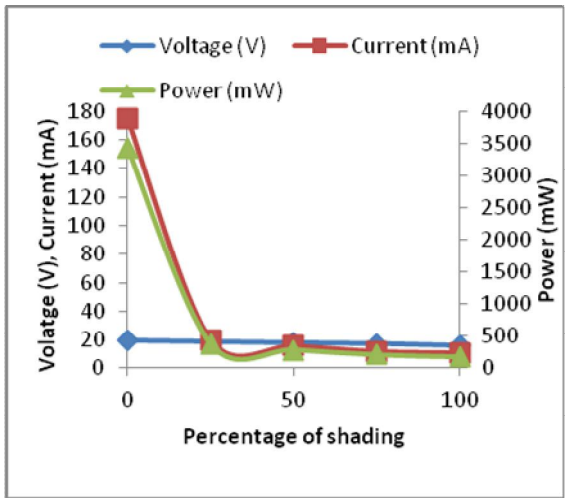

Fig.4. Effect of shading on left PV panel without load conditions

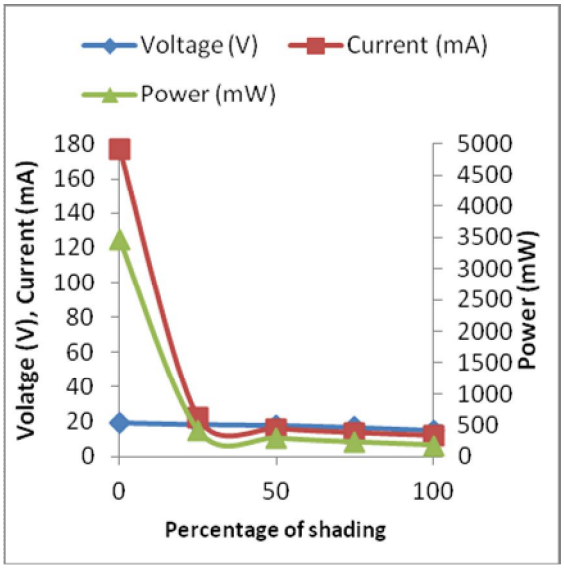

Fig.5. Effect of shading on left PV panel with load conditions

Fig. 4 and 5 gives the plot of percentage of shading on abscissa and other parameters are plotted in other axis. The graph of without and with load conditions of left PV panel is almost same due to the low load value condition applied in the closed circuit. If the high load is place in the closed circuit, there will be a noticeable variation in the voltage and current.

Table 6. Effect of shading on right PV panel without load conditions

Percentage shading (%)	Voltage (V)	Current (mA)	Power (mW)
No shading	19.15	160	3064
25	18	25	450
50	17.3	13	224.9
75	16	10	160
100	14	7	98

Table 7. Effect of shading on right PV panel with load conditions

Percentage shading (%)	Voltage (V)	Current (mA)	Power (mW)
No shading	19.1	159	3036.9
25	18	25	450
50	17	15.4	261.8
75	14.6	10.3	150.38
100	14.1	9	126.9

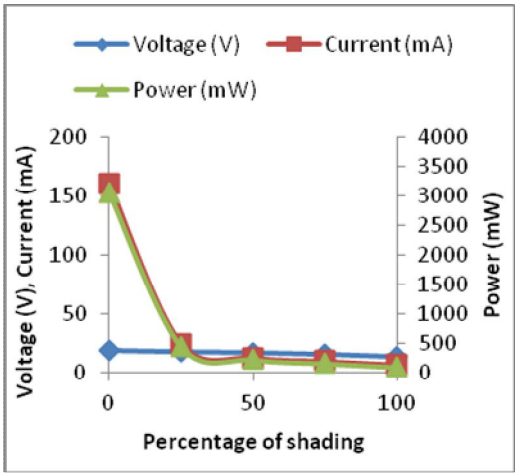

Fig. 6. Effect of shading on right PV panel without load conditions

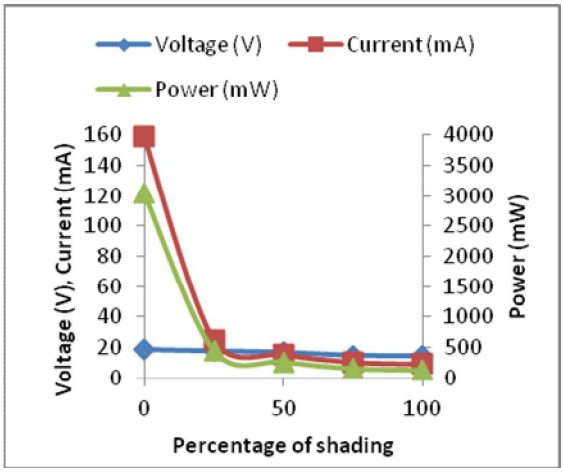

Fig. 7. Effect of shading on right PV panel with load conditions

Fig. 6 and 7 gives the plot of percentage of shading on abscissa and other parameters are plotted in other axis. The graph of without and with load conditions of right PV panel is almost same due to the low load value condition applied in the closed circuit. If the high load is place in the closed circuit, there will be a noticeable variation in the voltage and current.

C. Effect of shading on solar panel in series connection

When the left and right were connected in series and subjected to shading conditions of without and with load parameter. Table 8 and 9 gives the shading percentage on solar panel without and with load conditions. Table 8 is the series connection of solar panel, which provides the open circuit voltage (V_{OC}) and short circuit current (I_{SC}) under the variation of shading conditions.

Table 8. Effect of shading on PV panel connected in series without load conditions

Percentage shading (%)	Voltage (V)	Current (mA)	Power (mW)
No shading	39	188	7332
25	37	45	1665
50	36	42	1512
75	35.5	40	1420
100	35	37	1400

Table 9. Effect of shading on PV panel connected in series with load conditions

Percentage shading (%)	Voltage (V)	Current (mA)	Power (mW)
No shading	38.6	181	6986.6
25	37	43	1591
50	36	43	1548
75	32	38	1216
100	26	28	728

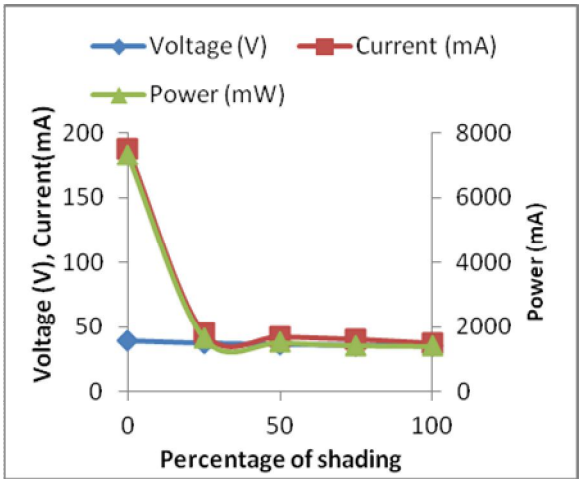

Fig. 8. Effect of shading on PV panel connected in series without load conditions

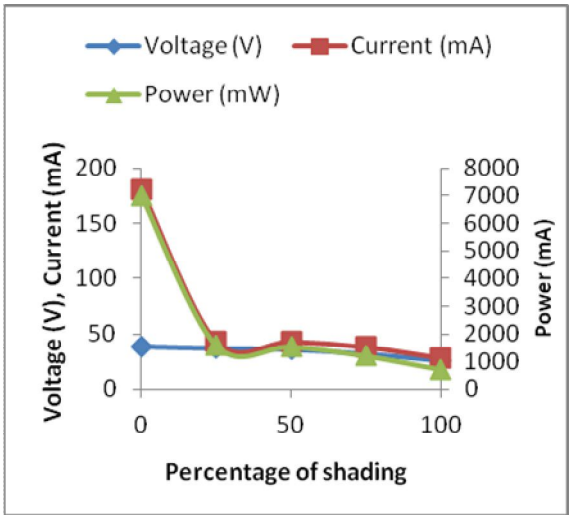

Fig. 9. Effect of shading on PV panel connected in series with load conditions

Fig. 8 and 9 shows the plot of shading effect on solar panel in series connection without and with load conditions. The graph of without and with load conditions were found to have a very slight variation due to low value of load. In series connection, there is a decrease in voltage and current when there is an increase in shading effect.

D. Effect of shading on solar panel in parallel connection

The left and right solar panel was connected in parallel to observe the effect of shading without and with load conditions. Table 10 and 11 gives the power values which was calculated from the current and voltage obtained under the shading conditions of parallel pattern. Table 10 is the parallel connection of solar panel, which provides the open circuit voltage (V_{OC}) and short circuit current (I_{SC}) under the variation of shading conditions.

Table 10. Effect of shading on PV panel connected in parallel without load conditions

Percentage shading (%)	Voltage (V)	Current (mA)	Power (mW)
No shading	19.4	390	7566
25	19.2	270	5184
50	18.9	240	4536
75	18.2	70	1274
100	17.8	90	1602

Table 11. Effect of shading on PV panel connected in parallel with load conditions

Percentage shading (%)	Voltage (V)	Current (mA)	Power (mW)
No shading	19.4	400	7760
25	19.3	240	4632
50	18.9	10	189
75	18.1	90	1629
100	17.8	65	1157

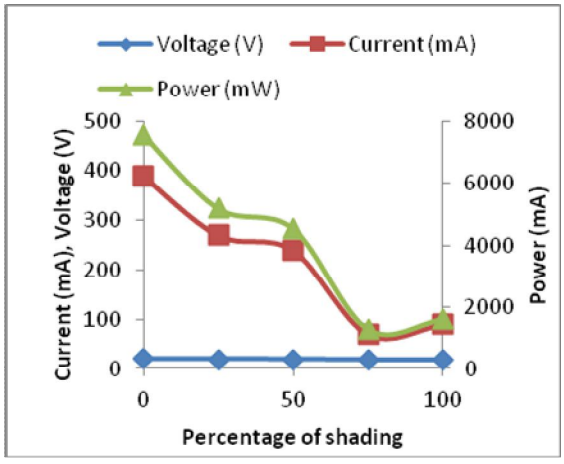

Fig. 10. Effect of shading on PV panel connected in parallel without load conditions

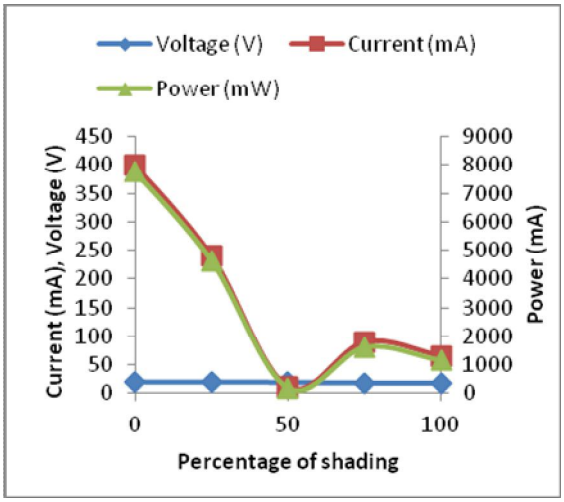

Fig. 11. Effect of shading on PV panel connected in parallel with load conditions

Fig. 10 and 11 shows the plot of shading effect on solar panel in parallel connection without and with load conditions. The graph of without and with load conditions were found to have a very slight variation due to low value of load. In parallel connection, there is a decrease in voltage and current when there is an increase in shading effect.

The effect of shading on solar panel in both series and parallel connection found to be decreasing the voltage and current as the shading percentage increases.

IV. CONCLUSION

The solar panel was individually tested for the effect of shading and found to have same performance in the shading. The without and with load condition in testing the solar panel individually was seemed to have slight differs due to the low value of load used.

The individual solar panel voltage and current were taken in the no shading region and compared with the voltage and current of series and parallel, the theory of solar panel connected in series produces a high voltage and parallel connection in solar panel yields a high current was proved.

The series and parallel connections of solar panel, decreases gradually as the effect of shading increases. The solar panel performance can be improved by either series or parallel connection depending upon the environment and necessity. The solar panel analysis can be carried out by the introduction of bypass diode in the series and parallel connection, which will be the further study of the research.

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