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Research paper

Performance Analysis of SPV Module Using Solar PVTR System

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Abstract

With a spurt in the use of non-conventional energy sources, photovoltaic installations are being deployed in several applications such as distributed power generation and standalone systems. Solar Photo Voltaic (SPV) module is the basic component of the solar PV system. The functioning of a photovoltaic array is influenced by solar insolation, shading and array arrangement. Often the PV arrays get shadowed, completely or partially by neighboring buildings, trees, towers and service poles. The efficacy of PV array unvaryingly depends upon temperature which in turn is reliant on radiation. In order to validate this hypothesis, there are certain instruments and experimentation methods available which are expensive. But carrying out hardware testing on the solar PV system with Photo Voltaic Training and Research (PVTR) system and simulating using software will lead to least economical method of achieving performance analysis which is the main objective of this paper. The efficiency of PV module is analyzed from I-V and P-V characteristics for this standalone solar PV system by changing radiation and temperature parameters. This paper mainly emphases on comparison of the testing results and simulation results for different radiation levels.

Keywords: *SPV, PVTR, Pyranometer, I-V and P-V characteristics*

1. Introduction

Any engineering process is incomplete without proper testing and analyzing. Performance analysis include (a)Hardware testing (b)Implementation in simulation environment and (c) Drawing inferences from either [1-2]. As solar generation system doesn't have any moving part, thus the required maintenance is comparatively less cumbersome. For getting the optimum output of SPV system, its regular maintenance and performance is required [3-4]. An accurate evaluation of photovoltaic (PV) system performance is important for optimizing its output [5-8]. This is an attempt to analyze the given SPV module by conducting series of hardware tests and certain simulations. The integration of hardware and simulation results will navigate the customer to select a proper SPV module which suits well to the requirement [9-15]. In this paper a standalone solar photovoltaic (SPV) module is experimented by using solar PVTR system in order to observe its behavior for various situations. All the hardware tests performed are recorded with ***Motivation*** as prefix and ***Termination*** as suffix as mentioned here after.

2. Hardware Testing

2.1 Single module with different radiation levels

***Motivation*:** To observe the effect of gradual increase in radiation level on the output power and current with I-V and P-V characteristics.

In order to obtain and plot the I-V and P-V curves of a SPV panel, the panel is inserted into the slot provided in the SPVTR system [6]. The circuit diagram to evaluate I-V and P-V characteristics of a system is shown in Fig.1.which includes PV module and a variable resistor (potentiometer) with ammeter and voltmeter for measurement. Potentiometer in this circuit works as a variable load for the module. When load on the module is varied by potentiometer, the corresponding current and voltage of the module gets changed which shifts the operating point on I-V and P-V characteristics.

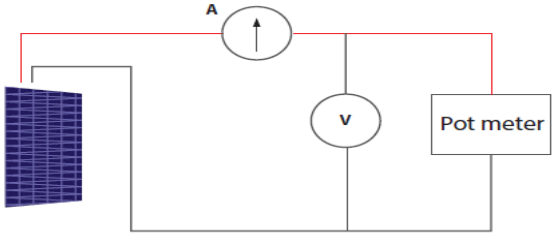


Fig.1 Circuit connections

Connections are made in the PVTR, the voltage and current readings are noted for different radiations and are tabulated as in Table 1, 2, 3 & 4. The power supplied by the panel is calculated from and figured in the last column of each table. The P-V and I-V curves for different radiations are shown in the Fig. 2 and 3 respectively.

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Table.1 voltage and current readings at radiation 150 w/m^2

S.No	Voltage(V)	Current(A)	Power(W)
1	0	0.38	0
2	1.5	0.38	0.57
3	2.4	0.38	0.912
4	4.5	0.38	1.71
5	6.8	0.38	2.584
6	10	0.37	3.7
7	12	0.35	4.2
8	13.1	0.33	4.323
9	14.2	0.3	4.26
10	15	0.28	4.2
11	17.2	0.23	3.956
12	18	0.2	3.6
13	19.2	0.1	1.92
14	19.5	0	0

Table.2 voltage and current readings at radiation 200 w/m^2

S.NO	Voltage(V)	Current(A)	Power(W)
1	0	0.92	0
2	12	0.92	11.04
3	13.5	0.91	12.28
4	14	0.9	12.6
5	15	0.88	13.2
6	17.5	0.75	13.12
7	19.1	0.6	11.46
8	20	0.5	10
9	20.5	0.3	6.15
10	20.8	0.1	2.08
11	20.9	0	0

Table.3 voltage and current readings at radiation 280 w/m^2

S.NO	Voltage(V)	Current(A)	Power(W)
1	0	0.48	0
2	12	0.48	5.76
3	13.5	0.47	6.34
4	15	0.44	6.6
5	17.5	0.3	5.25
6	18	0.27	4.86
7	19.1	0.18	3.43
8	19.8	0	0

Table.4 voltage and current readings at radiation 400 w/m^2

S.NO	Voltage(V)	Current(A)	Power(W)
1	0	0.67	0
2	1.2	0.67	0.80
3	5.2	0.67	3.48
4	6.4	0.66	4.22
5	10	0.65	6.5
6	12	0.63	7.56
7	13.8	0.6	8.28
8	15	0.56	8.4
9	17.2	0.53	9.11
10	19	0.42	7.98
11	19.5	0.38	7.41
12	19.8	0.3	5.94
13	20	0.18	3.6
14	20.1	0	0

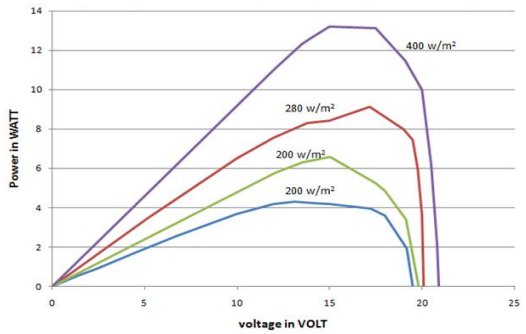


Fig.2 P-V curve for different radiations

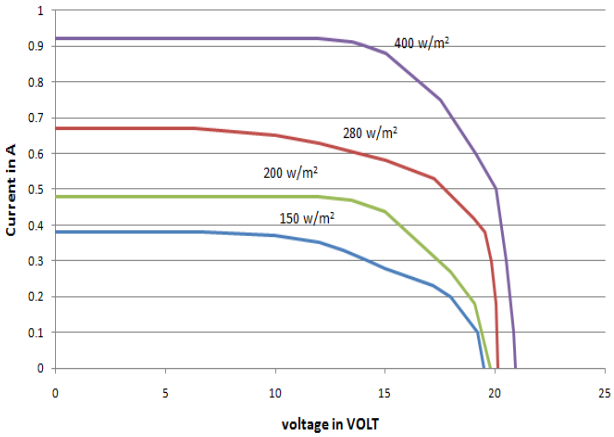


Fig.3 I-V curve for different radiations

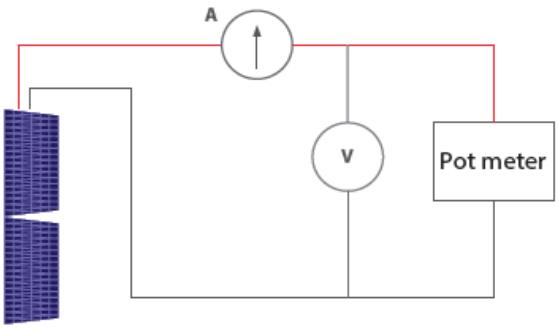
Termination:

It is observed from the figures 2 & 3 that, as the solar radiation increases the output values of voltage and power increases. Similarly, the current output is also increases to maximum value side at a maximum radiation level.

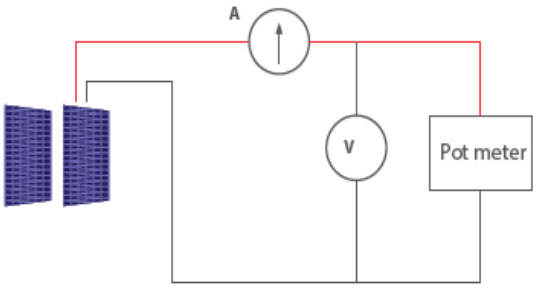
3. Series & Parallel Connected Modules

Motivation: To draw I-V and P-V characteristics by changing the radiation on a solar photovoltaic system.

In order to decide the I-V and P-V characteristics of the two modules when connected in parallel and series [9] with a capacity of each having 40wp. These two modules are inserted into a slot provided in the photovoltaic trainer kit. The circuit diagram to assess I-V and P-V features of modules connected in parallel and series are shown in figures 4(a) & (b) respectively. The voltage and current readings are recorded by varying the potentiometer at particular radiation, which acts as a load in the experiment, for the modules connected in series and parallel. The radiation can be measured with the help of a Pyranometer.



(a)



(b)

Figure.4 Circuit diagram for evaluation of I-V and P-V characteristics of

(a) series connected modules (b) parallel connected modules

Table5: voltage & current readings when modules are connected in parallel

S.NO	Voltage(V)	Current(A)	Power(W)
1	0	0.63	0
2	9.9	0.56	5.544
3	15.1	0.52	7.852
4	18.5	0.46	8.51
5	18.7	0.35	6.545
6	18.8	0.27	5.076
7	18.8	0.23	4.324
8	18.8	0.2	3.76
9	18.8	0.14	2.632
10	18.8	0.12	2.256
11	18.8	0.1	1.88
12	18.8	0.09	1.692
13	18.8	0.08	1.504
14	18.8	0.07	1.316
15	18.8	0	0

Table 6 voltage & current readings when modules are connected in series

S.NO	Voltage(V)	current(A)	Power(W)
1	0	0.3	0
2	2.6	0.3	0.78
3	6.3	0.29	1.827
4	8.5	0.29	2.465
5	13	0.29	3.77
6	17.5	0.28	4.9
7	20.4	0.28	5.712
8	25.3	0.26	6.578
9	28.3	0.24	6.792
10	30.4	0.23	6.992
11	33.2	0.22	7.304
12	35.8	0.18	6.444
13	35.9	0.16	5.744
14	39.1	0	0

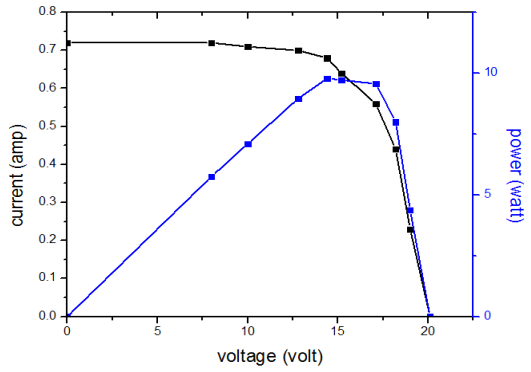


Fig.5 I-V & P-V curves when modules connected in parallel

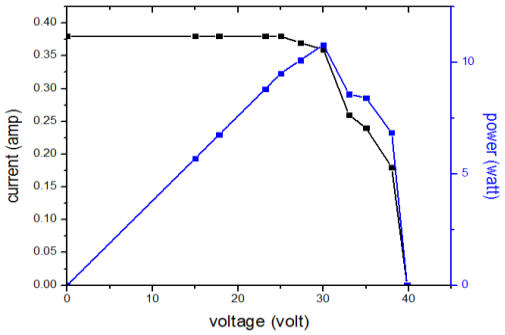


Fig.6 I-V-& P-V curves when modules connected in series

Termination: It is observed from the above figures 5 & 6 that the net current of the system increases when the modules are connected in parallel and the net voltage of the system is increases when the modules are connected in series.

4. Effect of Shading

Motivation: To record the variation of power output while gradual shading of the module occurs.

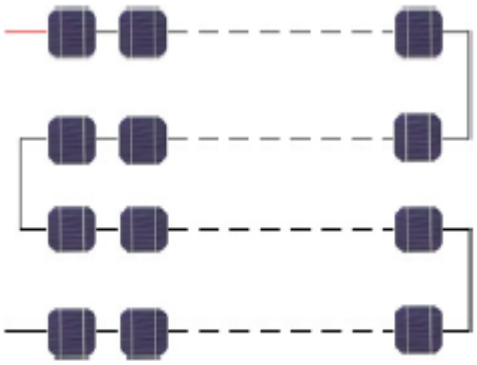


Fig.7 Internal structure of the module

There are 36 solar cells in a module. These 36 solar cells are in series as shown in Fig.7 which makes the module as series connected solar cells. These cells are in series without bypass diode so shading of one cell will be sufficient to reduce the power to zero. This arrangement gives zero power if the entire row of cells gets shaded. There are shading elements of different sizes (single cell, two cells, four cells and 9 cells of module) for covering the solar cell (or cells) of module completely. For executing this experiment [1],[5],[8],[9], one of these shading elements on the solar cells. After making the cells shaded by different sizes of shading elements, the readings of current and voltage are tabulated as shown in table 7.

Table 7 voltage & current readings with respect to shaded elements

Type of shading elements	Voltage(V)	Current(A)	Power(W)
0	17.2	0.27	4.644
1	7.6	0.11	0.836
2	2.9	0.04	0.116
4	1.7	0.02	0.034
9	1.1	0.01	0.011

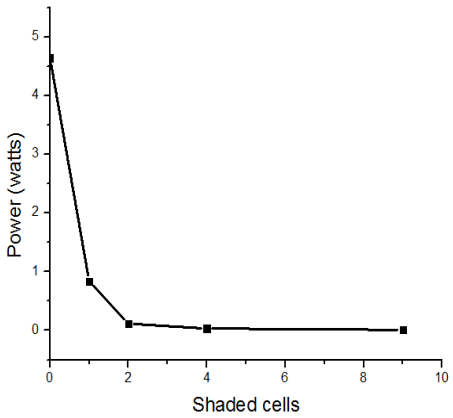


Fig.8. Variation of power with respect to shaded elements

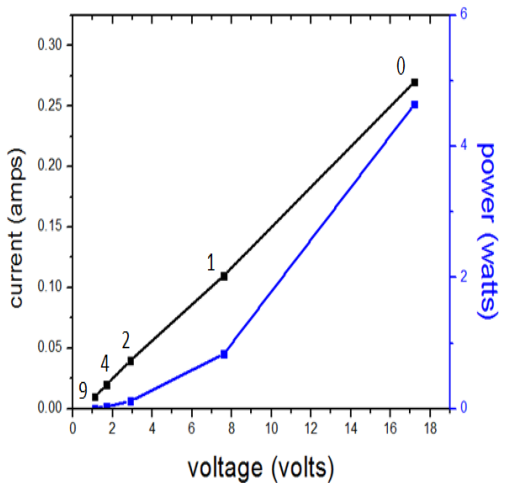


Fig. 9. I-V and P-V curves for shaded cells

Termination:

As the number of cells getting shaded increases the output power gets reduced as depicted in figure 8. The I-V and P-V curves for this situation is evident from figure 9 that both the current and voltage getting attenuated as the shading of cells increases. This is an alarming indication to shun away the solar photovoltaic system from any type of shading.

5. Simulation

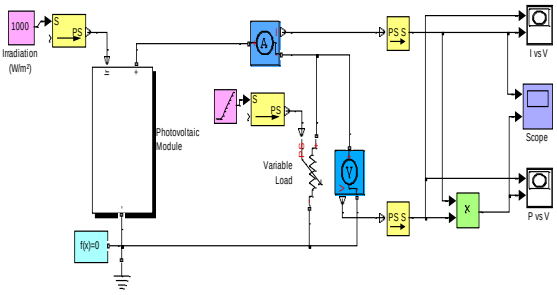


Fig..10 Complete simulink model of single PV module

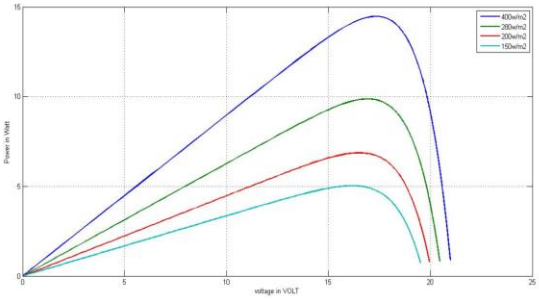


Fig..11 Simulation result of P-V curve for a single PV module

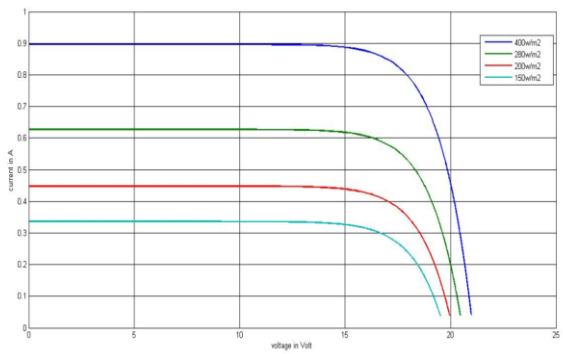


Fig..12 simulation result of I-V curve for a single PV module

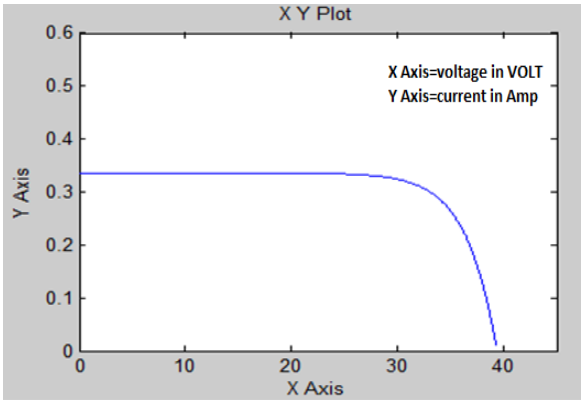


Fig..13 Simulation result of I-V curve for series connected modules

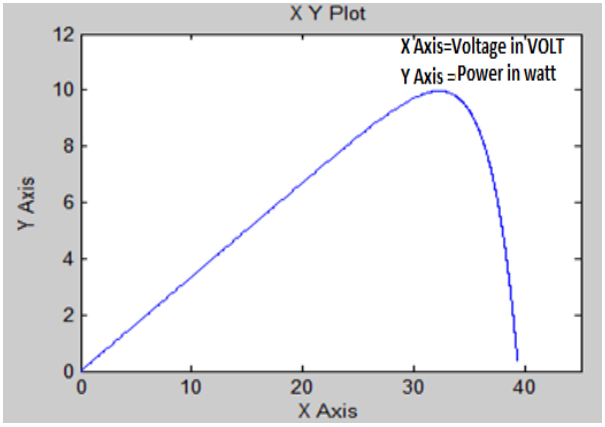


Fig.14 Simulation result of PV curve for series connected modules

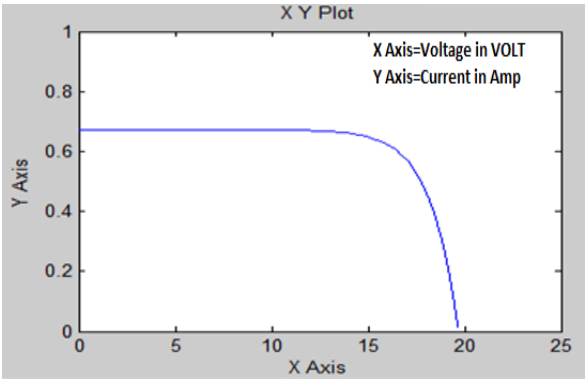


Fig.15 Simulation result of IV curve for parallel connected modules

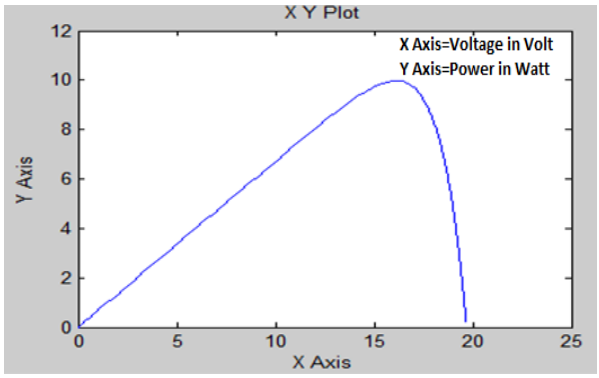


Fig..16 Simulation result of P-V curve for parallel connected modules

In order to validate hardware results a simulation is carried out for which a Simulink model has been developed as shown in figure

10. From the simulation I-V and P-V characteristics are obtained which are represented in figures 11 to 16 respectively.

6. Conclusion

It is observed from the hardware experimentation results that, the net current of the system is more when the modules are connected in parallel and the net voltage of the system increases when the modules are connected in series. These results are compared with simulation results and found coherent. It is also observed that, if data logger is added to the existing system will lead to system automation.

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