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An Experimental Analysis of Shading on Solar Photovoltaic System

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ABSTRACT: Photovoltaic arrays get shaded, completely or partially, by the passing clouds, neighboring buildings and power poles. Under partially shaded conditions PV characteristics get more complex with multiple peaks. Hence, it is necessary to understand them in order to extract maximum power. In this paper, the effect of shading on photovoltaic modules is evaluated. It also presents the change in open circuit voltage V_{OC}, short-circuits current I_{SC}, maximum current I_{max} and the maximum voltage V_{max} obtained at the customer's end. The effect of the partially shaded conditions on photovoltaic modules' maximum power point and the percentage of cells shaded are also being discussed

Keywords: Photovoltaic (PV), Maximum Power Point (MPP), Open circuit voltage and Short circuit current.

I. INTRODUCTION

With increasing industrialization and population the entire world's suffering from two problems firstly crisis of fossil fuel and environmental degradation. Rapid extraction and fast consumption of fossil fuels have led to reduction in under-ground resources of fossil fuels. Due to global warming and climatic changes, the countries are now concerned of the planet's carbon emissions and consumption of fossils fuels The increasing energy demand of natural energy sources like coal, hydro, crude oil, and natural gas has led to their depletion.. Hence, there is a need of alternative energy sources, which are sustainable and free of pollution. The renewable energy sources like wind, biogas, solar, or Photovoltaic (PV) has come up with promising features and are now well developed, cost effective and are used in many applications. India has a huge potential for solar energy. The location of India is between the Tropic of Cancer and the Equator; on an average India receives 6-7 kW/m^2 of solar radiant energy for about 300 days in a year [1]. The conversion of solar energy into electrical energy via solar cell panels is described as photovoltaic (PV) effect [2]. Solar energy or PV systems have widely being accepted because it is main prerequisite of the life on the earth. This conversion of solar energy into electrical energy is environmental friendly, sustainable and available free of cost. In general, PV array is formed by a couple of PV modules to obtain larger output power. The commercial available PV modules can be configured from series, parallel or combination of series and parallel connection of PV cells. The efficiency of solar photovoltaic cells with single crystal silicon is about 13 % - 17%. High efficiency cells with concentrators are being manufactured which can operate with low sunlight intensities. The output power and current characteristics of the PV module are affected by cell temperature, solar irradiance, tilt angle shaded condition and the operating condition. The incident light to the PV module will determine the total generation charge carrier hence the generated current and voltage in the PV module [3, 4].

II. IMPACT OF SHADING ON MPP

Shade is a significant design factor, which affects the performance of photovoltaic systems. Even a small area of shade can have a significant impact on the total output of the PV system [5]. The Sun keeps on changing its position throughout the day and year so the shade on a solar panel also changes and it becomes difficult to measure the amount of shade on a solar array. It is practically not feasible to avoid shading in PV systems, which may be caused by buildings, trees swaying in the wind, satellite dishes or more. Thus, the output of any PV system will be reduced in correlation with the reduction in amount of light falling on it. There is an individual operating point in each PV array where it generates maximum electrical power at optimum voltage and current, and this is called Maximum Power Point (MPP). If within the PV array, some individual PV modules of a string are shaded, then there will be drastic change in its electrical properties; the PV array has many operating points like dependence of MPP on the ambient temperature and solar insolation which keeps on changing throughout the day based on the latitude location of the plant installation. The ongoing research is focusing on increasing the efficiency of PV modules by improving the tacking of the maximum power point (MPP) and reducing the cost of power generated by PV array. Thus, there is a need of standardized methods to evaluate the effect of shading and for calculating the MPP.

III. EXPERIMENTAL SET UP

The current work is carried out on 36 solar cells connected in series and parallel PV module to demonstrate the effect of shading on PV module output power. These cells in series are 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. After making the cells shaded by different sizes of shading elements, voltage and current readings were noted down.

The circuit diagram to evaluate I-V and P-V characteristics of a module is shown in Fig.1, form a PV system which includes PV module and a variable resistor (pot meter) with ammeter and voltmeter for measurement. Pot meter in this circuit works as a variable load for the module. When load on the module is varied by pot meter the current and voltage of the module gets changed which shift the operating point on I-V and P-V characteristic.

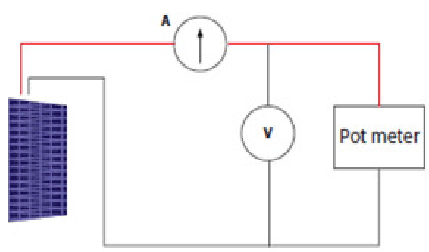

Fig. 1. Circuit diagram for evaluating I-V and P-V characteristics.

Any PV module is characterized by its I-V and P-V characteristics. In I-V characteristic the short circuit current (I_{sc}) is the maximum current at zero voltage, which can be measured by shorting the PV module and open circuit voltage (V_{oc}) is the maximum voltage at zero current .In P-V curve the maximum power is achieved only at a single point which is called MPP (maximum power point) and the voltage and current corresponding to this point are referred as V_{max} and I_{max}.

With the shading of module cells the module temperature also changes, the V_{oc} of PV module decreases while Isc remains the same thus decreasing the power as shown in table1.The cell shading has been done in percentage i.e 25%, 50%, 75% and the system performance has been analyzed and compared when the modules are not shaded. Current-Voltage (I-V) characteristics curve of photovoltaic (PV) modules under different temperature conditions are characterized by multiple steps is in figure 2. The typical Power-Voltage (PV) characteristics of a polycrystalline solar PV module are represented in figure 3.

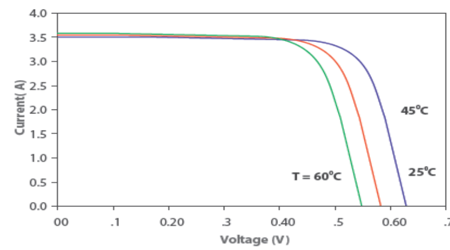

Fig. 2. Effect of change in temperature on MPP.

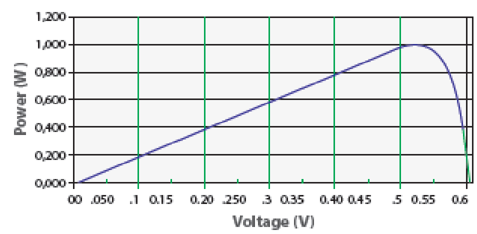

Fig. 3. Typical P-V curve of a solar module.

The term fill factor in the shown figure gives an insight into the performance of cells in the module. The Fill Factor (FF) is essentially a measure of quality of the solar cell.

Type of Connection	Percentage of Shaded Cells	Module Temperature (in ^{0}C)	Short Circuit Current I_{SC} (in Amp.)	Open Circuit Voltage V_{OC} (in Volt)	Maximum Current I_{max} (in Amp.)	Maximum Voltage V_{max} (in Volt)	Maximum Power Point (in Watt)
Single Panel	No Shading	38.8	2.40	19.59	2.01	15.28	30.71
	25%	37.0	1.96	16.78	1.31	12.47	16.33
	50%	36.8	1.05	10.34	0.68	07.40	05.03
	75%	35.9	0.04	04.12	0.01	03.28	0.032
Two Panels in Series	No Shading	37.6	2.40	40.14	2.16	29.76	64.28
	25%	36.9	2.16	34.55	1.37	17.94	24.57
	50%	36.4	1.20	21.63	0.94	11.80	11.09
	75%	35.7	0.07	09.42	0.05	07.56	0.378
Two Panels in Parallel	No Shading	37.9	4.90	19.57	4.14	14.32	59.28
	25%	36.2	3.89	16.53	3.27	11.75	38.42
	50%	35.7	2.76	08.45	2.54	07.14	18.13
	75%	35.2	0.15	05.13	0.10	02.86	0.286

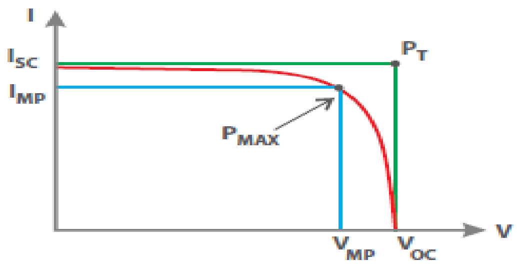

Fig. 4. Graphical interpretation of fill factor.

It is the ratio of the actual achievable maximum power to the theoretical maximum power *(PT)* that would be achieved with open circuit voltage and short circuit current together as shown in equation below. FF can also be interpreted graphically as the ratio of the rectangular areas depicted in Fig. 4. A larger fill factor is desirable, and corresponds to an I-V sweep that is more square-like. Typical fill factors range from 0.5 to 0.82. Fill factor is also often represented as a percentage.

$$FF = \frac{I_{max} * V_{max}}{I_{OC} * V_{SC}}$$

The fill factor from the table 1 can be obtained of a single module and the modules in series and parallel combination. The fill factor at the latitude location of this setup is 0.77.

CONCLUSIONS

This paper is explaining the effect of shading on the system performance and the maximum power point obtained in the I-V and P-V characteristics of solar modules. The cells of the module have been shaded and it has been observed that the output voltage and power is highest when the modules are connected in series. Whereas, in case of parallel connected modules the output current is maximum. It has also been analyzed that while setting up a PV plant, the number of modules connected in series is kept always higher than the number of modules connected in parallel so as to obtain the high voltage than the current. The effect of shading cannot be eliminated but can be reduced by placing the bypass diodes in between the cells and modules. On the other hand, if the PV array operates at the absolute MPP, the array can generate maximum output power.

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