Temperature Effect on the Efficiency of Different Solar Panel
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Abstract– Solar energy is a great source of renewable energy and is on its of becoming a significant energy source in near future, as an incredible potential energy. As of late, there has been a tremendous increment in the comprehension of how the PV (photovoltaic), hence prompted a quick increment in the efficiencies of energy conversion of this type of devices. The working of PV cells fluctuates with the change in temperature; this temperature variation will cause a significant change in the output power as well as efficiency of the PV cells. This paper proposed that there is a connection between temperature, efficiency of the PV cell and solar irradiance and for a required PV module efficiency ambient module or optimum working temperature can be obtained. It's been observed that temperature can significantly cause change in voltage across the module as compare to that of the current produced by that module and low temperature i.e. under cloudy weather conditions there is increment in voltage and power as well.

Keywords – Temperature, Efficiency, PV cell, Energy source, Solarmodule

I. INTRODUCTION:

As of late, the enormous usage of fossil fuels and its weariness has brought great attention towards the use of renewable energies and solar energy is one of them. Solar power as a technology has already been established and has as of late experienced fast development in the course of the most recent ten years [1].

PV cell is made of semiconductor material, that’s been doped, having a PN junction. So when the sunlight falls on it, the photons in the light which are energy particle give electrons, in the valance band of semiconductor, their energy causing the electrons to excite to move in the conduction band in which the electrons will move and this will cause the production of direct current (DC). A few points of interest that’s been offered by PV cells are high unwavering quality, low cost of maintenance, no ecological contamination, and no noise pollution [2]. Fig. 1 shows the circuit equivalent to that of a solar cell.

The characteristics curves of PV cell changes with the variation in the solar irradiance and that of the temperature of PV cell or module. The properties of array of PV modules are described by the equations (1) and (2) as stated below:

\[ I_{pv} = I_i - I_o \left( e^{\frac{V_{pv} + I_{pv} R_s}{A k T}} - 1 \right) - V_{pv} + I_{pv} R_s \]
\[ P_{pv} = V_{pv} \times I_{pv} \]

Where: \( I_{pv} \) is the current of the module in amperes, \( I_i \) is the current generated by light in amperes, \( I_o \) is the saturation current of diode in amperes, \( q \) is the electron charge measured in coulomb, \( K \) = Boltzmann's constant with the units joule per kelvin, \( A \) = diode factor, \( T \) = temperature of module in kelvin, \( R_s \) = resistance in series measured in ohms, \( R_{sh} \) = resistance in parallel of the module measured in ohms, \( V_{pv} \) = voltage across the module measured in volts, and \( P_{pv} \) = output power measured in Watts [3].

II. TEMPERATURE EFFECT ON PV WORKING

The performance of the PV or solar cell changes with temperature variations. This variation would also cause a change in the output power of the PV cell. The experiments were performed in order to find the effect of temperature on the performance of Monocrystalline PV cell. The temperatures were varied with the day time, and at different temperatures of solar panel the performance characteristics of PV cell were observed. From the series of experimentations it was found that the dependence of voltage of the cell on the temperature of the module is very
The variation of IV curve of a solar module with that of temperature (by keeping the solar irradiance constant) has been shown in the fig. 2 [4]. There is a very little decrement in the current and significant increment in the voltage of the module with the reduction in temperature, as the fig. 3 shows that the reduction in temperature is causing an increment in the resultant power of the PV module.

A. Relation between Efficiency and Temperature of PV Module:

The efficiency of a PV module can be calculated by using the following equation:

\[
\eta_c = \frac{P_{\text{max}}}{P_{\text{in}}} = \frac{I_{\text{max}} \times V_{\text{max}}}{I(t) \times A_C} \tag{3}
\]

Where, \(I_{\text{max}}\) = current at maximum power (A), \(V_{\text{max}}\) = voltage at maximum power (V), \(I(t)\) = solar irradiance in watts/m² and \(A_C\) = affected area of PV cell[5].

This article would describe the relation of temperature of solar cell represented as \(T_c\) in kelvin with that of surroundings temperature \(T_a\) in kelvin and solar irradiance \(I(t)\) in W/m² etc. The affected efficiency (electrical) can be calculated by the usage of basic (fundamental) equations which forms a relation shown by the equation (4).

\[
\eta_c = \eta_{\text{ref}}[1 - \beta_{\text{ref}}(T_c - T_{\text{ref}}) - \gamma \log_{10}I(t)] \tag{4}
\]

Where, \(\eta_{\text{ref}}\) = electrical efficiency at \(T_{\text{ref}}\), \(T_{\text{ref}}\) = reference temperature in kelvin and solar irradiance of 1000W/m² (at STC), \(\beta_{\text{ref}}\) = temperature coefficient at reference temperature in kelvin= 0.0045K, \(\gamma\) = solar irradiance coefficient with no units= 0.12 for a silicon PV module[6]. Normally manufacturers of PV modules give the values of temperature coefficient and \(\eta_{\text{ref}}\). But these values can also be taken by performing the tests i.e. flash which can be done by taking values of electrical power of PV module at two values of different temperatures at a constant solar irradiance flux[7]. \(\beta_{\text{ref}}\) depends on both material of PV module and reference temperature and can be calculated as follows:

\[
\beta_{\text{ref}} = \frac{1}{T_O - T_{\text{ref}}} \tag{5}
\]

Where, \(T_O\) = temperature so high that the efficiency of the module (i.e. electrical one) is zero [8]. \(T_O\) for a silicon PV cell is 270 °C [9]. The temperature of the cell is determined by how the energy is balanced and managed in a cell: the energy is taken from the photons of the incoming sunlight acting as input and is transformed or converted into some useful output power i.e. electricity but not all the energy is converted into electricity some portion of it get wasted in the form of heat. Now most of the this energy in the form of heat dissipates into the environment by the process called convection, applications of flat plate and radiation. And mostly it is assumed that there is a linear relationship between solar irradiance and that of the temperature of the module. The dependence of the coefficient is on factors like installation of the module, speed of the wind, humidity at ambient temperature etc though the type of module can be characterized by single value. This data is present in the “Nominal Operating Cell Temperature (NOCT)”, it is characterized as the temperature of the PV cell is obtained in open-circuit when the surrounding temperature is 20 °C, solar irradiance= 0.8kW/m² and speed of the wind is 0.99m/s. Commonly the value of \(T_{\text{NOCT}}\) is 45 °C.

The temperature of the cell in °C can be determined quite precisely by using the linear approximation for varying solar irradiance and (ambient) temperature[10] :

\[
T_c = T_a + \frac{T_{\text{NOCT}} - 29}{0.8kW/m^2} \times I(t) \tag{6}
\]

By inserting equation (6) in equation (4), we get the following relation:
The values of $T_{ref}$ and average efficiency at $T_{ref}$ considered by Authors are usually 25 degree centigrade and 11.9 or approximately 12% respectively.

### III. CONCLUSION

This paper dealt with the effects on PV module caused by the temperature and interrelationship is obtained between efficiency of the module, solar irradiance and module temperature by the usage of fundamental equations. The efficiency variation of a module under the cloudy weather conditions (i.e. comparatively low temperature) is also observed. For a required efficiency of a specific solar module, a value of temperature is obtained at which that PV module can work at its best; this value is called ambient module or cell temperature. From the experimentations it was observed that maximum power point in PV curve decreases as the temperature increases which ultimately decreases the efficiency of PV cell.

### REFERENCES


