Journal of Advances and Scholarly Researches in Allied Education
Vol. 20, Issue No. 1, January-2023, ISSN 2230-7540

Characteristics of The Photovoltaic Cell

Reetu[1]*, Dr. Pradeep Kumar[2]

[1] Research Scholar, Sunrise University

[2] Assistant Professor, Sunrise University

Abstract - In order to make good use of the various PV technologies at our disposal, it is essential to have a thorough understanding of how such systems function in practice. This work combines a photovoltaic cell equivalent circuit mode with the goal of studying the photovoltaic cell and electrical characteristics of photovoltaic cells during the flight of solar-powered unmanned aerial vehicles.

Keywords - Photovoltaic Cell, Electricity, Solar Cell, Generations and Open Circuit Voltage

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INTRODUCTION

The photovoltaic effect is a phenomenon explored in physics, photochemistry, and electrochemistry; photovoltaics (PV) is the conversion of light into energy using semiconducting materials that show this effect. Electricity production and photosensors are two commercial applications of the photovoltaic effect. sun modules, each of which contains several sun cells, are used to produce electricity in a photovoltaic system. Solar photovoltaic systems may be installed on the ground, on a roof, on a wall, or even on water. A solar tracker may be used to move the mount in the sky to follow the sun.

Because it produces far less carbon dioxide than fossil fuels, photovoltaic technology contributes to climate change mitigation efforts. Although silicon is abundant in the Earth's crust and other materials needed in PV system manufacture, like silver, may limit the technology's growth, solar photovoltaics (PV) have distinct benefits as an energy source. Once installed, PV systems produce no pollution or greenhouse gas emissions from their operation. Competition for land usage has also been noted as a key limitation. The use of PV as a primary source has a number of special drawbacks, such as fluctuating power production, which must be balanced, and needs energy storage devices or worldwide distribution through high-voltage direct current power lines, both of which increase expenses. There is some pollution and greenhouse gas emissions during production and installation, although it is little compared to those of fossil fuels.

Since the 1990s, grid-connected PV systems have been employed in addition to their lengthy history of usage in specialized applications as stand-alone installations.[2] In 2000, the German government supported a 100,000-roof scheme, marking the beginning of widespread production of photovoltaic modules. PV's popularity as solar energy source has increased as its price has dropped. Large-scale government investment in China's solar industry from the year 2000 has helped spur this growth and achieve economies of scale. Manufacturing prices have gone down as a result of technological advancements and increased productivity. Many governments have encouraged the use of solar photovoltaics by providing net metering and monetary incentives such favorable feed-in tariffs for solar-generated power. The price of solar panels fell by a factor of four between 2004 and 2011. In the 2010s, module costs went down by almost 90%.

Over 2 percent of the world's power consumption is met by the over 635 GW of PV capacity that was built throughout the globe in 2019. PV ranks third among renewable energy sources in terms of worldwide capacity, after hydropower and wind power. From 2019 to 2024, the International Energy Agency predicted an increase of 700-880 GW. With bids as low as 0.01567 US$/kWh in Qatar in 2020, PV has shown to be the cheapest source of electrical power in areas with a strong solar potential.[9] For projects with low-cost financing that access high-quality resources, solar PV is currently the cheapest source of power in history, according to the International Energy Agency's World Energy Outlook for 2020.

LITERATURE REVIEW

Zhe Li, Jian Yang, et.al (2021) To combat the problem that the complexity of photovoltaic cell parameters may easily affect the impact of light intensity on solar cells, this presentation is grounded on the effect of light intensity on the power production performance of solar cells. By analyzing the electrical performance parameters of solar-powered photovoltaic cells to identify the influencing factors, discarding other weakly related parameters, and developing focused research programs, we were able to gain a better understanding of the performance of photovoltaic power generation. The current and voltage at the moment of maximum power generation were analyzed. By looking at how photovoltaic cells work with other factors, we were able to determine how their power generation performance may be improved. The results of these experiments show that the open circuit voltage, the short-circuit current, and the maximum output power of solar cells all increase as the light intensity grows. Since light intensity increases the efficiency of the solar cell in producing electricity does as well.

Sahoo, Dipankar et.al. (2022). Perovskite is the most attractive material for thin-film solar cells because of its optoelectronic properties and photovoltaic efficiency. Tin-based perovskite solar cells, on the other hand, have less issues with thermal instability and poor performance. Research on thermal instability is required to decipher the gadget's inner workings. Determine the source of the heat by calculating the temperature coefficient of different electrical and photovoltaic properties. This work used a SCAPS-1D simulator to examine the effects of temperature on the electrical and photovoltaic properties of lead-free tin-based perovskite solar cells with an ITO/ETL/CH3NH3SnI3/HTL design. These variables' temperature coefficients have been calculated. In order to transport electrons and holes, scientists used titanium dioxide and Spiro OMeTAD. Dark current-voltage analysis reveals that although the temperature coefficient of the barrier height is positive, the temperature coefficient of the ideality factor is negative. It is calculated that the ideality factor is 0.0017 per K, whereas the absolute temperature coefficient of barrier height is 170 eV per K. Light current-voltage (J-V) study demonstrates that all photovoltaic parameters have negative temperature coefficients. This study reveals the temperature dependence of lead-free tin-based perovskite solar cells: open circuit voltage decreases by 1.6 mV per K, short circuit current decreases by 9 A/cm2 per K, fill factor decreases by 0.031 per K, and power conversion efficiency decreases by 0.074 per K. The decline in value of many device parameters is very encouraging for future research into obtaining temperature-invariant performances in lead-free perovskite solar cells.

Chen, Guifeng et.al (2016). In this research, Mo-doped ZnO (MZO) sheets on a glass substrate were fabricated through magnetron co-sputtering of ZnO and Mo targets. All films, as determined by x-ray diffraction (XRD), have a wurtzite ZnO structure with the c-axis perpendicular to the substrates. The optical energy gap decreases from 3.35 eV to 3.25 eV when the growth rate is increased. Hall effect measurements allowed for the determination of a minimum resistivity of 2.8 x 103 cm. UV-vis testing also reveals that MZO film has 80% transmittance in the visible light region, indicating it might be used in transparent optoelectronics.

Li, Hui. (2020). While chalcogenides like CdTe, Cu (In,Ga)(S,Se)2, and Cu2ZnSn(S,Se)4 have made considerable leaps in their thin-film photovoltaic performance, concerns including the toxicity (CdTe) and scarcity (Cu(In,Ga)(S,Se)2) of the component elements have prevented further improvement in efficiency. This study focuses on the development and characterization of the new thin-film absorber Cu2MnSn(S,Se)4. Sol-gel is used to create the precursor film, which is then selenized at high temperatures. The absorbance of the precursor film is more than 98% at wavelengths between 200 and 1300 nm. The film's crystallinity and phase shift may be customized by modifying the selenization process. Cu2MnSn(S,Se)4 films with a highly crystalline stannite structure may be made by heating the material to 570 °C for 30 minutes. When used as the absorber layer in a solar cell, a Cu2MnSn(S,Se)4 film achieves a record-high efficiency of 1.79%. This study demonstrates the potential of Cu2MnSn(S,Se)4 as a photovoltaic material, suggesting it might be utilized to create low-cost solar cells.

Jung, Mi-Hee. (2017). Controlled injection of vaporized CH3NH3I molecules is claimed to transform the two-dimensional perovskite C6H5CH2NH3PbI4 into the three-dimensional perovskite (C6H5CH2NH2) (CH3NH3) nPbI3n+1. After then, solar systems may make use of this substance. The dimension of the resultant (C6H5CH2NH2) (CH3NH3) n-1PbnI3n+1 perovskite film is controlled by the length of time the film is exposed to the CH3NH3I vapor. As the lead iodide lattice is stacked higher, the crystallographic planes of the inorganic perovskite compound rise vertically, facilitating more efficient charge transfer. The higher absorption and smaller band gap of these devices may also increase the photocurrent density of solar cells. Under AM 1.5G solar irradiation (100 mW cm2), a photovoltaic device based on the (C6H5CH2NH2) (CH3NH3) n-1PbnI3n+1 perovskite has a power conversion efficiency of 5.43 percent, which is a substantial increase over the 0.3 percent recorded by a solar cell based on pure two-dimensional BAPbI4.

CHARACTERISTICS OF THE PHOTOVOLTAIC CELL

Open circuit voltage and short circuit current that of an unclosed circuit When the terminals are physically separated (infinite load resistance), a photovoltage is created as a consequence of charge separation due to incoming light, and V_{OC} is the resulting physical quantity. The photocurrent, denoted by the short circuit current Isc, flows when the terminals are connected in a closed circuit. The cell delivers a current I such that V = IRL, where I(V) is the current-voltage characteristic of the cell at that illumination level, and V is the voltage established between 0 and Voc. When a load is connected to the external circuit, the cell produces current and voltage and may do electrical work.

Quantum efficiency and photocurrent the amount of current generated by a shorted cell is dependent on the intensity and energy spectrum of the incoming light. Quantum efficiency QE of the cell is related to the light spectrum through photocurrent, which is the probability of creating an electron per incoming photon as a function of photon energy. The short circuit current density, Jsc, is then:

$$J_{sc} = q \int b_s(E) QE(E) dE$$

where q is the electronic charge and bs(E) is the number of photons per unit area per second in the energy range E to E + dE. Instead of being dependent on the incoming spectrum, QE is determined by the absorption coefficient of the solar cell material and the efficiency with which it separates and collects charges. QE is hence an important measure of solar cell efficiency in a wide range of applications.

Dark current

When a load is applied to the cell, a potential difference is produced between the terminals, resulting in a current that is opposite to the photocurrent. Whenever a bias V is given to a device, a current Idark(V) runs across it, causing this reverse flow of electrons to be known as the dark current. A p-n junction solar cell behaves in the dark just like a diode, and the same rule that describes the dark current density Jdark in an ideal diode with an applied bias V also applies to a solar cell with a p-n junction.

$$J_{\mathrm{dark}}(V) = J_0(e^{\mathrm{qV/k_BT}} - 1)$$

the Boltzmann constant kB, the constant J0, and the temperature T [13]. The overall current of the cell is roughly equal to the sum of the photocurrent and dark current during a short circuit. This approximation is valid for many photovoltaic materials despite the fact that the reverse current flowing in response to voltage in an illuminated cell is not technically equal to the current which flows in the dark. The net current density in a cell, denoted as J(V), is equal to

$$J(V) = J_{sc}(V) - J_{\mathrm{dark}}(V)$$

When the contacts are separated and the bias is at its greatest value, the open circuit voltage, the potential difference also increases, but the net current decreases. V_{oc}

Efficiency and fill factor

The solar cell is operational and produces power when the bias is between 0 and Voc. (The illuminated part acts as a photodetector at V V_{oc} throughout the detecting process,

using a flow of electrons to generate a voltage. $V > V_{oc},$ Since the device is also an LED (light-emitting diode), electricity is being utilized once again. The cellular power density, P, is equal to

$$P = J(V)\ V$$

At the cell's operating point, when the most power is generated, P reaches its maximum value when J(V) is given by Eq. 1.4. As can be shown in Fig.1, this occurs at a voltage Vm, close to V_{oc}, and a current density Jm. Maximum load resistance occurs at this point.

F F, often known as the fill factor, is the percentage:

$$FF = \frac{J_m V_m}{J_{sc} V_{oc}}$$

the "squareness" of the J V curve, which it defines

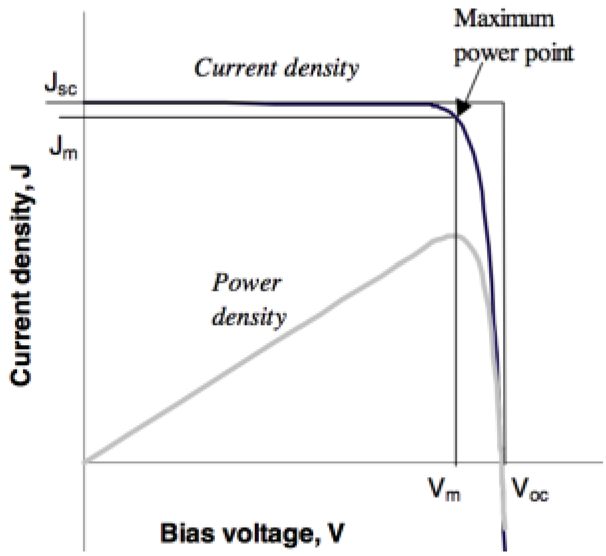

FIG: 1 BAIS VOLTAGE, V

In Figure 1, we see the power-voltage (grey) and current-voltage (black) properties of a perfect cell. The inner rectangle's area corresponds to the highest power density in JmVm. The total area of the outer rectangle is Jsc Voc. The outer rectangle would be followed by the current-voltage curve if the fill factor were.

The efficiency of the cell is defined as the ratio of the power density at the cell's operating point to the power density of incident light, Ps.

$$\eta = \frac{J_m V_m}{P_s}.$$

The four factors Jsc, Voc, F F, and are the most crucial in determining the efficiency of a solar cell. Key performance characteristics of the most popular solar cell materials are summarized in Table 1. Solar cell materials with a higher Jsc often have a lower Voc.

Table 1: Performance of Some PV Cells

Cell Type	Area (cm^2)	V_{oc} (V)	J_{sc} (mA/cm^2)	FF	Efficiency (%)
crystalline Si	4.0	0.706	42.2	82.8	24.7
crystalline GaAs	3.9	1.022	28.2	87.1	25.1
poly-Si	1.1	0.654	38.1	79.5	19.8
a-Si	1.0	0.887	19.4	74.1	12.7
$CuInGaSe_2$	1.0	0.669	35.7	77.0	18.4
CdTe	1.1	0.848	25.9	74.5	16.4

Equivalent Circuit Model of Photovoltaic Cell

Maximum power point characteristics, measured under standard circumstances (atmospheric quality of 1.5, solar radiation of 1000 W/m2, and temperature of 298.15 K), are often provided by PV cell manufacturers to their customers. When the PV cell's output power is at its highest value, the cell's short-circuit current Iscref, open-circuit voltage Vocref, maximum power-point current Imref, and maximum power-point voltage Vmref are all known under standard circumstances. In order to simplify engineering calculations, we used the aforementioned four factors to build a simplified equivalent circuit model of a PV cell (Eq. 9). By incorporating relevant compensation factors, the output of features under arbitrary environmental circumstances may be approximated (Liu et al., 2016; Gao et al., 2021).

$$\begin{cases} I_{pv} = I_{sc} \cdot C_1 \left\{ e^{V_{pv} / (C_2 V_{ocpv})} - 1 \right\} \\ C_1 = \left(1 - \frac{I_{mpv}}{I_{scpv}}\right) \cdot e^{-\frac{V_{mpv}}{C_2 V_{ocpv}}} \\ C_2 = \left(\frac{V_{mpv}}{V_{ocpv}} - 1\right) \cdot \left[\ln\left(1 - \frac{I_{mpv}}{I_{scpv}}\right)\right]^{-1} \end{cases}$$

where Vpv and Ipv are the PV cell's voltage and current outputs It may be written as (Liu et al., 2016; Gao et al., 2021) where Iscpv and Vocpv represent the short-circuit current and open-circuit voltage, respectively, and Impv and Vmpv represent the current and voltage when the battery output power reaches its maximum under any situation.

$$\begin{cases} I_{scpv} = I_{scref} \cdot \frac{S_{pv}}{S_{ref}} \cdot (1 + a_1 \Delta T) \\ V_{ocpv} = V_{ocref} \cdot \ln(e + a_2 \Delta S) \cdot (1 - a_3 \Delta T) \\ I_{mpv} = I_{mref} \cdot \frac{S_{pv}}{S_{ref}} \cdot (1 + a_1 \Delta T) \\ V_{mpv} = V_{mref} \cdot \ln(e + a_2 \Delta S) \cdot (1 - a_3 \Delta T) \end{cases}$$

where Spv is the photovoltaic cell's solar radiation per unit area, which varies with latitude, longitude, time of day, height, and other factors; Standard condition solar radiation (Sref) is 1000 W/m2, and the temperature differential (ΔT) between the PV cell and its reference temperature (Tref = 298.15 K) is written as ΔT=T - Tref. The compensation coefficients a1, a2, and a3 are obtained by fitting a large amount of experimental data, and their typical values are shown by: S = S - Sref;e = 2.71838; a1, a2, and a3 are the compensation coefficients; their values are typically shown by:

$$\begin{cases} a_1 = 0.0025/K \\ a_2 = 0.0005 W/m^2 \\ a_3 = 0.00288/K \end{cases}$$

The power conversion efficiency is defined as the ratio of electrical energy produced to solar radiation incident on the PV cell and is one of the most important metrics of the PV cell. For the sake of argument, let's say that the following figure represents the electrical properties of the PV cell per unit area. The power conversion efficiency of a ηPV cell may be determined using the short-circuit parameters, open-circuit parameters, and the following formula (Singh et al., 2021):

$$\eta_{pv} = \frac{I_{scpv} \cdot V_{ocpv} \cdot FF}{S_{pv}} \times 100\%$$

where FF is the fill factor, determined by:

$$FF = \frac{I_{mpv} V_{mpv}}{I_{scpv} V_{ocpv}}$$

Maximum power is calculated by plugging in the specifications for the maximum power point under ideal circumstances, which are stated as

$$P_m = I_{mpv} V_{mpv}$$

$$= I_{mref} \cdot V_{mref} \cdot \frac{S_{pv}}{S_{ref}} \cdot (1 + a_1 \Delta T) \cdot \ln(e + a_2 \Delta S) \cdot (1 - a_3 \Delta T)$$

The PV cell equivalent circuit is modeled.

CONCLUSION

We use the equivalent circuit of a photovoltaic cell in a solar radiation model and a thermodynamic model of airfoil surface for this investigation. In this article, we examine the impact of time of day and altitude on the output parameters of the photovoltaic cell. The maximum power point shifts forward and the peak power drops by 6.6 W when typical thermal effects are taken into account. As one climbs higher into the atmosphere, they get more exposed to more sunlight.

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Corresponding Author

Reetu*

Research Scholar, Sunrise University