# Analysis of Photovoltaic (PV) Power Technology

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***Abstract*— The light from the sun is a renewable enerygy source that is not tainted by nature and noise. It can easily compensate for the energy taken from non-renewable energy sources such as fossil fuels and inland gasoline. Performance of solar cells have undergone a large number of developmental steps from one generation to the next. Silicon-based solar cells were first generation solar cells grown in Si Wafers, especially single crystals. Continous development in thin films, dye is sensitiveto solar cells and living solar cells improve cell performance. Development is basically hampered by its cost and efficiency. A PV cell is a specialized semiconductor diode that converts visible light into direct current (DC). Some PV cells can also convert infrared or ultraviolet (UV) radiation into DC electricity. Photovoltaic cells are an integral part of solar-electric energy systems. In this paper a deep analysis of Photovoltaic cell is done, focusing on PV functionality, working, environmental impact and overall photovoltaic system configuration**

***Keywords-Photovoltaic system, Solar cell, PV Array, PV module***

## I. INTRODUCTION

When light shines on a photovoltaic (PV) cell – also called a solar cell – that light may be reflected, absorbed, or pass right through the cell. The PV cell is composed of semiconductor material; the “semi” means that it can conduct electricity better than an insulator but not as well as a good conductor like a metal. There are several different semiconductor materials used in PV cells. When the semiconductor is exposed to light, it absorbs the light’s energy and transfers it to negatively charged particles in the material called electrons. This extra energy allows the electrons to flow through the material as an electrical current. This current is extracted through conductive metal contacts – the grid-like lines on a solar cells – and can then be used to power your home and the rest of the electric grid. The efficiency of a PV cell is simply the amount of electrical power coming out of the cell compared to the energy from the light shining on it, which indicates how effective the cell is at converting energy from one form to the other. The amount of electricity produced from PV cells depends on the characteristics (such as intensity and wavelengths) of the light available and multiple performance attributes of the cell. An important property of PV semiconductors is the bandgap, which indicates what wavelengths of light the material can absorb and convert to electrical energy. If the semiconductor’s bandgap matches the wavelengths of light shining on the PV cell, then that cell can efficiently make use of all the available energy.

## II. FUNCTIONALITY

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## III. WORKING OF PV CELL

PV cell is a semiconductor diode whose p–n junction is exposed to light. Photovoltaic cells made of several types of semiconductors using different manufacturing processes. The mono crystalline and polycrystalline silicon cells are the only found at commercial scale at the present time. Silicon Photovoltaic cells are composed of a thin layer of bulk Si or a thin Si film connected to electric terminals. One of the sides of the Si layer is doped to form the p–n junction. A thin metallic grid is placed on the Sun-facing surface of the semiconductor. Fig. 1 roughly illustrates the physical structure of a Photovoltaic cell. The incidence of light on the cell generates charge carriers that originate an electric current if the cell is short circuited. Charges are generated when the energy of the incident photon is sufficient to detach the covalent electrons of the semiconductor—this phenomenon depends on the semiconductor material and on the wavelength of the incident light.

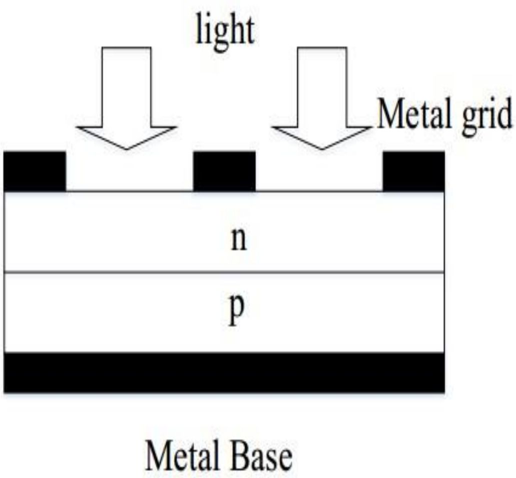


Fig. 1: Structure of a PV cell

Basically, the Photovoltaic phenomenon may be described as the absorption of solar radiation, the Generation and transport of free carriers at the p–n junction, and the collection of these electric charges at the terminals of the PV device. Generation rate of electric carriers depends on the incident light flux and the capacity of absorption of the semiconductor. The capacity of absorption depends mainly on the semiconductor band gap, on the reflectance of the cell surface (that depends on the shape and treatment of the surface), on the intrinsic concentration of carriers of the semiconductor, on the electronic mobility, on the recombination rate, on the temperature, and on several other factors. The solar radiation is composed of photons of different energies. Photons with energies lower than the band gap of the photovoltaic cell are useless and generate no voltage or electric current. Photons with energy superior to the band gap generate electricity, but only the energy corresponding to the band gap is used— the remainder of energy is dissipated as heat in the body of the PV cell. Semiconductors with lower band gaps may take advantage or a larger radiation spectrum, but the generated voltages are lower. Si is not the only, and probably not the best, semiconductor material for PV cells, but it is the only one whose fabrication process is economically feasible in large scale. Other materials can achieve better conversion efficiency, but at higher and commercially unfeasible costs. In a practical system, one PV cell will not be able to provid sufficient energy. Thus, several cells are grouped together to form a PV module, and several modules are grouped together to form a PV array. This combination of cells is what allows for a larger percentage of solar power to be absorbed due to a larger area of PV cells, and thus more current and voltage to be produced at the output. The solar PV array or module used has to be carefully designed to produce the right amount of power to charge the battery and also has to be designed to adhere to the charging characteristics of the battery as much as possible so as to minimize losses. Below epitomizes the formation of the PV module and array from the PV cell.

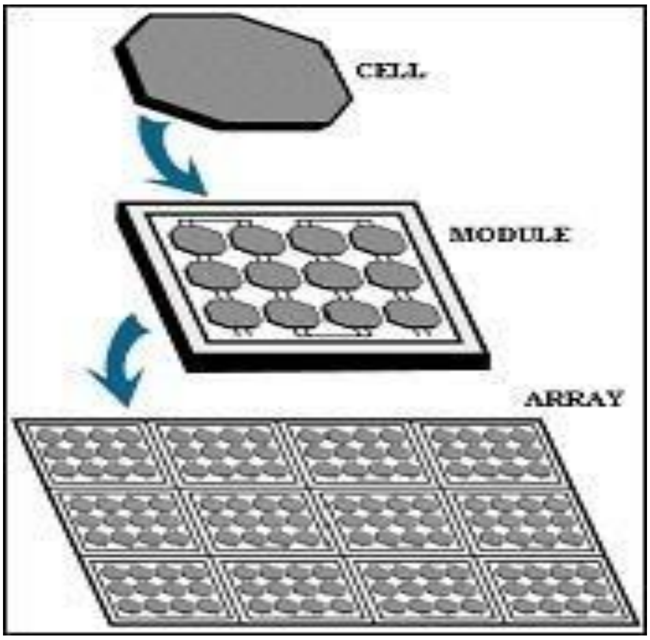


Fig 2: PV module and array formation from PV cells

### PV MODULE

The solar module is normally connected in series sufficient number of solar cells to provide required standard output voltage and power. One solar module can be rated from 3 watts to 300 watts. Actually a single solar PV cell generates a very tiny amount that is around 0.1 watt to 2 watts. But it is not practical to use such a low power unit as the building block of a system. So required numbers of such cells are combined together to form a practical commercially available solar unit which is known as solar module or PV module. When needs higher voltage, connect PV cell in series and if load demand high current then connect PV cell in parallel A PV array is simply an interconnection of several photovoltaic modules in serial and/ or parallel.

### PV ARRAY

The power generated by individual modules may not be sufficient to meet the requirement of trading applications, so


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the modules are secured in a grid form or as an array to gratify the load demand.

## IV. PV CELL AS CURRENT SOURCE

A solar cell can be modeled as a current source which is parallel to a diode and an equivalent resistance. The equivalent resistance is comprised of a shunt (Rsh) and Series resistance(Rser). The series resistance factors in all the losses due to the resistive semiconductor material that the cell is made of, the resistance of the contacts, and other series losses. The shunt resistance is due to localized shorts in the silicon wafer that is the primary material of the cell.

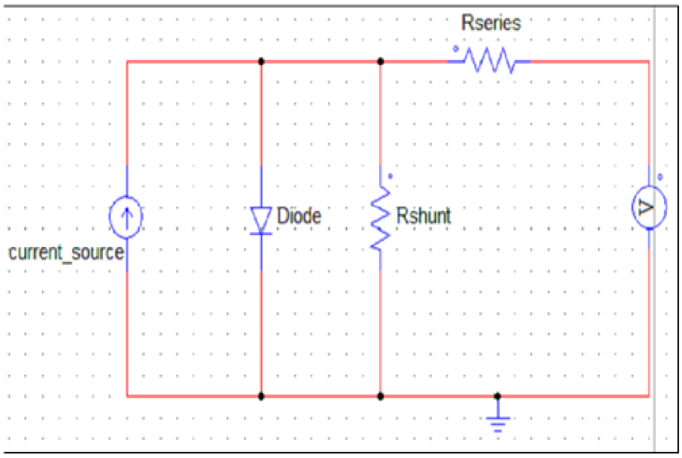


Figure 3: General circuit representation of a solar cell.

Generally, the series resistance is very small, and the shunt resistance is very large, making these losses almost negligible. Upon observation of the IV characteristics of a commercial solar panel such as the SQ150, it can be seen that changes in irradiance bring about significant changes in the panel short circuit current but barely affect the open circuit voltage. In effect, the short circuit current is approximately proportional to the irradiance. proposes that the current source used in the solar cell model be one that is dependent on a voltage; this voltage in turn is representative of the irradiance condition. Thus, the cell's characteristics can be made to vary with irradiance in a way that mimics the variations in the IV profile of a practical solar cell. A solar panel can be constructed out of series and parallel connections of the solar cell model given above. But, keeping in mind that the objective of the modeling process was to simply obtain a system whose IV characteristics are identical to that of a solar panel, another method was used: It was found that the open circuit voltage of the solar cell model is roughly proportional to the number of series-connected diodes that are in parallel to the short-circuit current source. Thus, by adding more diodes and increasing the shortcircuit current, the characteristics of the solar cell become more and more like that of a panel. A photovoltaic panel is constructed out of several cells in series and parallel combinations. This allows a panel to output an utilizable voltage and current. The figure below illustrates the typical Current-Voltage (I-V) characteristics of a PV panel.

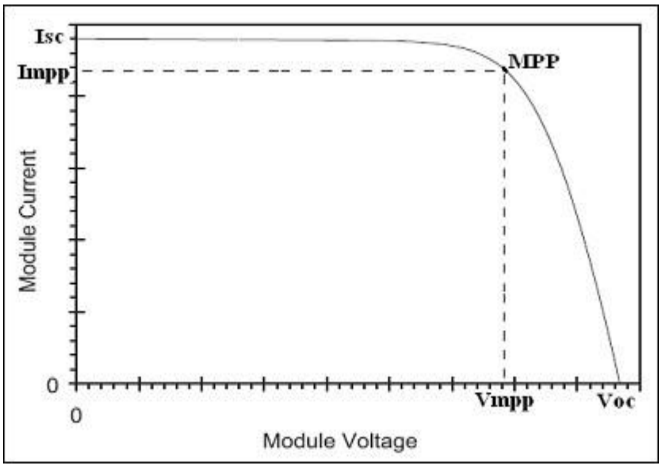


Figure 4: I-V characteristics of a PV panel

The curve shows how the current supplied by a PV panel varies with its voltage. The point of maximum power occurs at the knee of the curve and is called the maximum power point (MPP). The maximum power is given by Pmpp = Vmpp x Impp

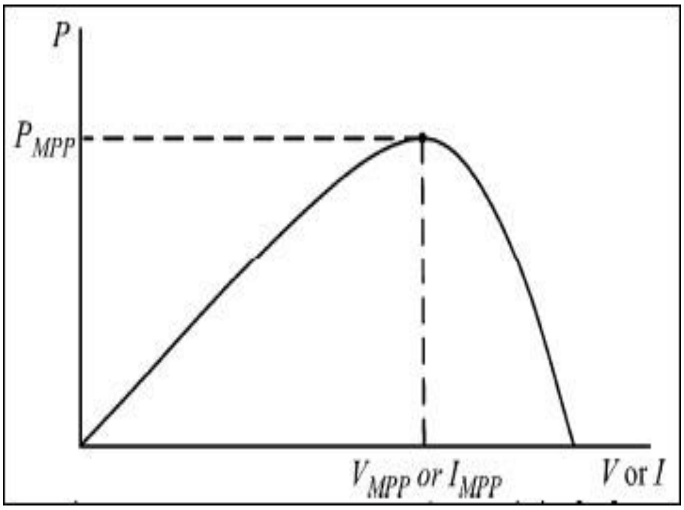


Figure 5: PV output power characteristics

In order for the PV panel to supply maximum power, it should supply a load of resistance (Rmpp): Rmpp = Vmpp / Impp If the load resistance as seen by the panel is below this value, the bias point would move to the left of the MPP, and to the right if the resistance is above this value.


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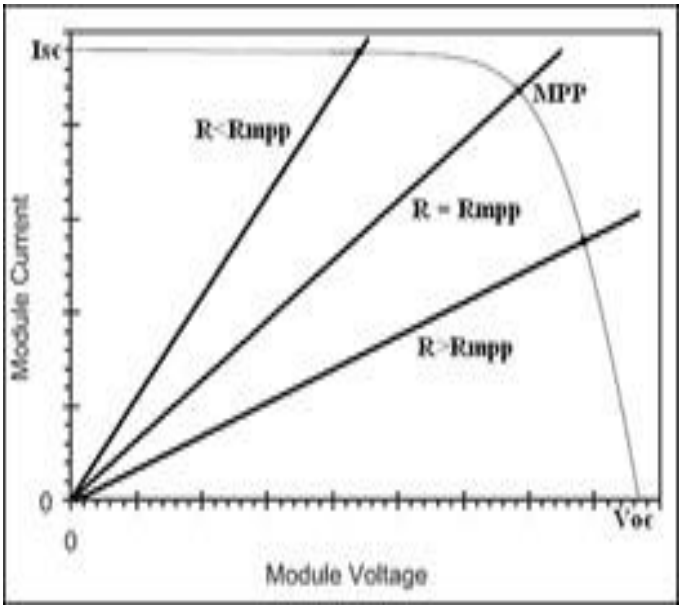


Figure 6: Bias points for various load resistances

## V. ENVIRONEMENTAL IMPACTS OF PHOTOVOLTAIC SYSTEM

### POSITIVE

1. **Using less water:** Water is one of our most precious natural resources. We live on the driest continent on the planet, and we run the risk of running out of fresh water in the future. Traditional electricity production can use thousands of litres of water each year. Water is used for cooling generators, processing and refining fuel and transporting fuel through pipes. Generating power through solar panels, however, uses no water whatsoever. The operation of solar photovoltaic cells doesn't require water at all to generate electricity, reducing the strain on this precious resource. The only water needed is rainwater to naturally clean the panels when they get a bit grubby. Using less water is a benefit to the environment of generating solar energy.

2. **Reducing air pollution:** the air we breathe can help or hinder our health and wellbeing. Electricity generation from fossil fuels can generate harmful carbon dioxide and methane gases that lower the quality of the air we breathe. Breathing poor quality air on a daily basis can have dire consequences for our health. Air pollution has been linked to asthma and allergies, bronchitis, pneumonia, headaches, anxiety, heart attacks and even some cancers. Using the sun to generate more and more of our power means less and less harmful emissions from burning fossil fuels. Generating electricity from solar panels produce no harmful emissions, and the more homes and businesses that rely on solar power means less toxic emissions from fossil fuels into our air.

3. **Help to slow climate change:** the release of toxic gases into the atmosphere, such as carbon dioxide, methane and nitrous oxide, doesn't just contribute to air pollution, but also contributes to the enhanced greenhouse effect. While the greenhouse effect is a natural process that warms the Earth's surface to a liveable temperature, human activities, such as the burning of fossil fuels, have increased the amount of greenhouse gases in our atmosphere. This has led to the enhanced greenhouse effect, which is warming our earth faster than ever before. In recent years, this has been linked to a number of catastrophic weather events, such as flooding, cyclones, storms, extreme heat and drought. Generating electricity from solar panels produce no greenhouse gases whatsoever, and so can help to reduce the effect of climate change if used widely. With solar energy powering a home or business, there is no burning of fuel and no emissions from energy production.

4. **Reducing your household's carbon footprint:** Solar energy is one of the cleanest sources of energy, and it's an extremely effective way of your household more efficient and sustainable. Solar panels don't use any water to generate electricity, they don't release harmful gases into the environment, and the source of their energy is abundant and, best of all, free. Using solar energy instead of the grid also means you reduce the need for carbon dioxide emitting energy to be produced for the grid on your behalf – for energy users on mainland Australia, you could offset anywhere between a half to one tonne of carbon dioxide for every megawatt-hour of solar energy you use. With even a small system installed on your home, you can help reduce your household's carbon footprint and contribute personally to the Australian Renewable Energy Target.

5. **Reducing our reliance on fossil fuels:** Solar energy supplies are massive; if we could harness all of the sunlight shining on the earth for just one hour, we could use that energy to power the entire world for a whole year. The sunshine used in solar energy production is free, and there's lots of it. On the other hand, fossil fuels are running out, and fast. Reducing our reliance on these finite resources and taking advantage of an abundant, free source of energy, such as sunlight, could mean lower energy prices, reduced greenhouse gas emissions and a stronger, more stable energy future.

### NEGATIVE

Solar energy systems offer significant environmental benefits in comparison to the conventional energy sources, thus they greatly contribute to the sustainable development of human activities. At times however, the wide scale deployment of such systems has to face potential negative environmental implications. These possible problems may be a strong barrier for further advancement of these systems in some consumers. The potential environmental impacts associated with solar power can be classified according to numerous categories,


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some of which are land use impacts, ecological impacts, impacts to water, air and soil, and other impacts such as socioeconomic ones, and can vary greatly depending on the technology.

1. **Land Use and Ecological Impacts:** In the point of generating electricity at a utility-scale, solar energy facilities necessitate large areas for collection of energy. Due to this, the facilities may interfere with existing land uses and can impact the use of areas such as wilderness or recreational management areas. As energy systems may impact land through materials exploration, extraction, manufacturing and disposal, energy footprints can become incrementally high. Thus, some of the lands may be utilised for energy in such a way that returning to a pre-disturbed state necessitates significant energy input or time, or both, whereas other uses are so dramatic that incurred changes are irreversible.

2. **Impacts to Soil, Water and Air Resources:** The construction of solar facilities on vast areas of land imposes clearing and grading, resulting in soil compaction, alteration of drainage channels and increased erosion. Central tower systems require consuming water for cooling, which is a concern in arid settings, as an increase in water demand may strain available water resources as well as chemical spills from the facilities which may result in the contamination of the groundwater or the surface. As with the development of any large-scale industrial facility, the construction of solar energy power plants can pose hazards to air quality. Such threats include the release of soil-carried pathogens and results in an increase in air particulate matter which has the effect of contaminating water reservoirs.

3. **Heavy Metals:** Some have argued that the latest technologies introduced on the market, namely thin-film panels, are manufactured using dangerous heavy metals, such as Cadium Telluride. While it is true that solar panel manufacturing uses these dangerous material, coal and oil also contain the same substsances, which are released with combustion. Moreover, coal power plants emit much more ofthese

   toxic substances, polluting up to 300 times more than solar panel manufacturers.

## VI. ECONOMICS OF A PV SYSTEM

Some important terms related to photovoltaic system economics are presented herein. The most important PV economic parameters are the total costs of installing a PV system, electricity price, Feed-In tariffs and the energy payback time - EPBT. Investments into renewable energies, particular into PV and wind technologies are another economics related area. The cost of a PV system is measured in price-per-peak-watt (€/Wp or US$/Wp for example). Peak watt is defined as the power at standard test conditions (solar irradiance 1000 W/m2, AM of 1.5 and temperature 25°C). Photovoltaic system costs encompass both module and BOS costs. Module costs typically represents only 40-60 % of total PV system costs. Typically the cost of installing a photovoltaic system having a power of 10 kW was about ₹ 70,000 /kWp and cost of 100 kW was about ₹ 60,000 /kWp in 2020. Approximately about half of this investment would be for the PV modules, and the inverter, PV array support structures, electrical cabling, equipment and installation would account for the rest. Please note that BOS and installation costs can vary significantly. For example: when costs for site preparation, laying a foundation, system design and engineering, permitting, as well as assembly and installation labour are higher, total installation costs are higher too. The life cycle cost (LCC) of a PV system may also include costs for site preparation, system design and engineering, installation labour, permits and operation and maintenance costs. Photovoltaic systems have an anticipated 25-year lifetime. For the most part, the commitment to renewable resources has come from individuals, big businesses and countries. Besides solar energy, companies such as Google (GOOG) and Amazon (AMZN) have committed to using wind to power company facilities. With big businesses, individuals and countries continuing to transition to renewable energy sources, adverse environmental effects from burning fossil fuels can hopefully be moderated.

## VII. CONCLUSION

The sun is the most plentiful energy source for the earth. All wind, fossil fuel, hydro and biomass energy have their origins in sunlight. Solar energy falls on the surface of the earth at a rate of 120 petawatts, (1 petawatt =1015watt). This means all the solar energy received from the sun in one days can satisfied the whole world's demand for more than 20 years. We are able to calculate the potential for each renewable energy source based on today's technology. Future advances in technology will lead to higher potential for each energy source. However, the worldwide demand for energy is expected to keep increasing at 5 percent each year .olar energy is the only choice that can satisfy such a huge and steadily increasing demand. PV cells are a proven environmentally benevolent power source whose attractive characteristics will continue further photovoltaic research. Because current Dye sensitized solar systems are still inefficient and uncommon, they are not yet cost competitive with Silicon-based generators, the efforts to increase their potential are growing day by day. These solar devices are low-cost, sustainable and easier to fabricate. As efficiency increases, PV technology will attract a greater number of people, due to low cost. Because the sun delivers ten thousand times more energy than people currently consume, photovoltaic improvements will one day replace environmentally unfriendly power plants with a proven and clean energy source.


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