

PROFESSIONAL TRAINING REPORT

at

Sathyabama Institute of Science and Technology

(Deemed to be University)

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering Degree in

Electrical and Electronics Engineering

By

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS

SCHOOL OF ELECTRICAL AND ELECTRONICS

SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY

JEPPIAAR NAGAR, RAJIV GANDHI SALAI,

CHENNAI – 600119. TAMILNADU.

JULY 2021



Certificate

OF INDUSTRY INTERNSHIP

This is to certify that

RAVURIARAVIND

Studying 3rd Year, B.E., EEE in SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY

has successfully completed the Industry Internship Programme at VATIO Energy India Pvt Ltd, Chennai through Online from 2nd July to 05th August 2021 in the area of "Solar Photovoltaics system & its Design Practices"

Best wishes from VATIO Energy for future endeavors!



G. Rajaganesan, Director – Technical
VATIO Energy India Pvt Ltd.



05th August 2021

Date

VATIO ENERGY INDIA PRIVATE LIMITED

VATIO Energy is an efficiency-driven entrepreneurship inspired by a vision of creating a greener tomorrow by harnessing the power of solar energy. In doing so, we seek to improve our customers' daily lives by significantly reducing your electricity bills.

VATIO has provided solar panels and inverters to large corporations and government agencies, and has also helped thousands of individual homeowners with tailor-made solar and energy systems.

SOLAR PV SYSTEM

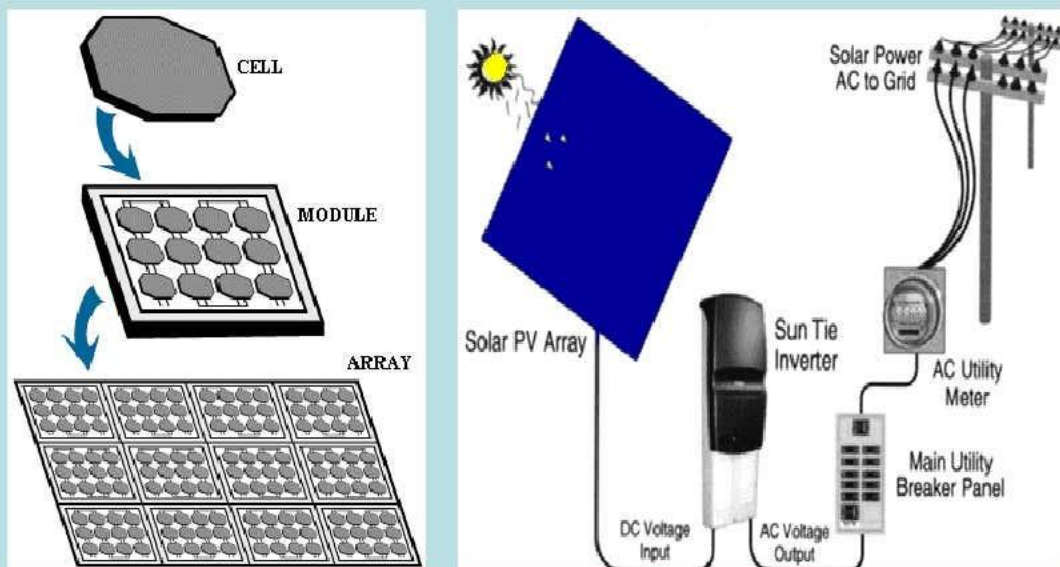


Photovoltaic systems are solar energy systems that produce electricity directly from sunlight. Photovoltaic (PV) systems produce clean, reliable energy without consuming fossil fuels and can be used in a wide variety of applications.

Photo means light. Voltaic means electricity. Photovoltaic means getting electricity from light.

Photovoltaic System

Typical output of a module (~30 cells) is ≈ 15 V, with 1.5 A current



SOLAR CELL:

A typical silicon PV cell is composed of a thin wafer consisting of an ultra-thin layer of phosphorus-doped (N-type) silicon on top of a thicker layer of boron-doped (P-type) silicon. An electrical field is created near the top surface of the cell where these two materials are in contact, called the P-N junction. When sunlight strikes the surface of a PV cell, this electrical field provides momentum and direction to light-stimulated electrons, resulting in a flow of current when the solar cell is connected to an electrical load

Regardless of size, a typical silicon PV cell produces about 0.5

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0.6 volt DC under open-circuit, no-load conditions. The current (and power) output of a PV cell depends on its efficiency and size (surface area), and is proportional to the intensity of sunlight striking the surface of the cell.

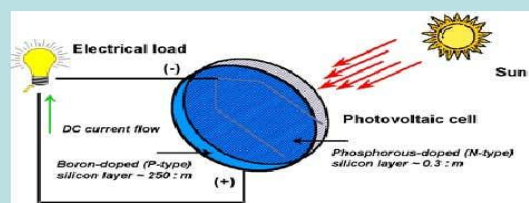
Solar Cell Types

A solar cell (also called photovoltaic cell or photoelectric cell) is a solid state electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage or resistance, vary when exposed to light.

The following are the different types of solar cells.

- Amorphous Silicon solar cell (a-Si)
- Bio-hybrid solar cell
- Cadmium telluride solar cell (Cd-Te)
- Concentrated PV cell (CVP and HCVP)
- Copper indium gallium selenide solar cells (CI(G)S)
- Crystalline silicon solar cell (c-Si)
- Float-zone silicon
- Dye-sensitized solar cell (DSSC)
- Gallium arsenide germanium solar cell (GaAs)
- Hybrid solar cell
- Luminescent solar concentrator cell (LSC)
- Micromorph (tandem-cell using a-Si/ μ c-Si)
- Monocrystalline solar cell (mono-Si)
- Multi-junction solar cell (MJ)
- Nanocrystal solar cell
- Organic solar cell (OPV)
- Perovskite solar cell
- Photo-electrochemical cell (PEC)

- Plasmonic solar cell
- Polycrystalline solar cell (multi-Si)
- Quantum dot solar cell
- Solid-state solar cell
- Thin-film solar cell (TFSC)
- Wafer solar cell, or wafer-based solar cell crystalline
Non concentrated heterogeneous PV cell



PV Module

Also called a solar panel or photovoltaic (PV) module

, an integrated

assembly of interconnected [solar cells](#) designed to deliver a selected level of working voltage and current at its output terminals, and suited for incorporation in a [solar power system](#). In addition to the cells, a typical solar module includes

the following components: A transparent top surface, usually glass An encapsulate

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usually thin sheets of ethyl vinyl acetate that hold together the top surface, solar cells, and rear surface A rear layer

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a thin polymer sheet, typically Tedlar, that prevents the ingress of water and gases A frame around the outer edge, typically aluminum Solar modules are normally mounted on top of a roof as part of a [roof-mounted solar power system](#), or a holding rack of some sort, within a frame structure. A solar module is the smallest building block of the power generating part of a [solar array](#).

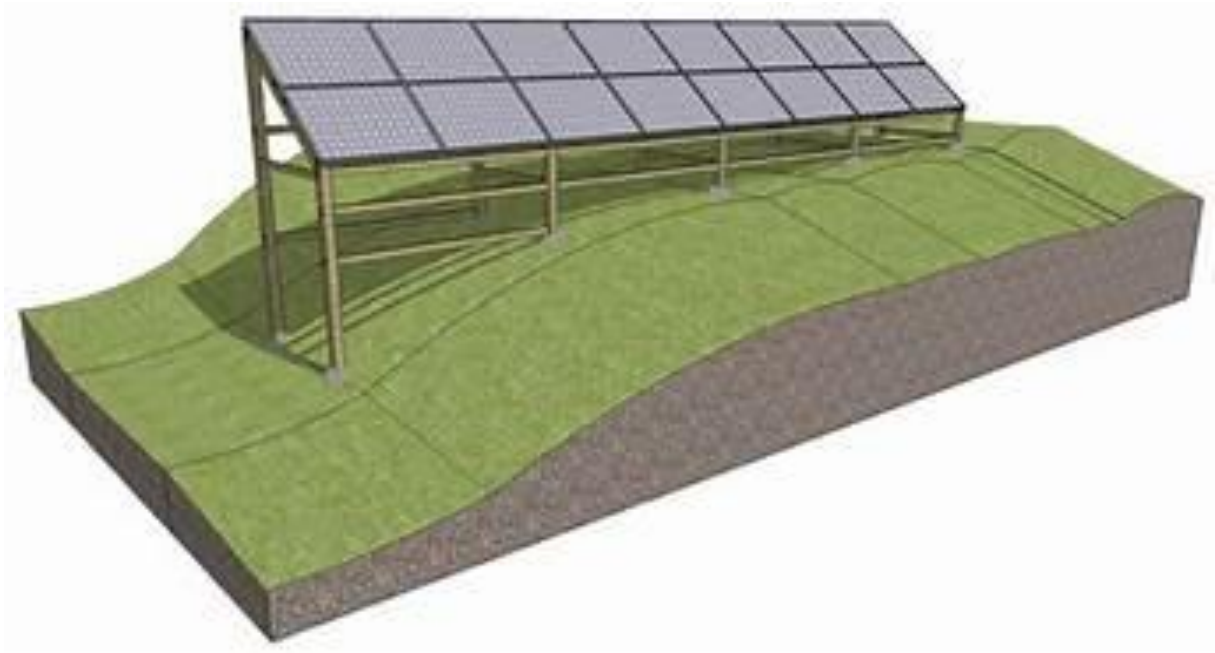


Solar PV Array

If *photovoltaic solar panels* are made up of individual photovoltaic cells connected together, then the Solar Photovoltaic Array, also known simply as a Solar Array is a system made up of a group of solar panels connected together. A *photovoltaic array* is therefore multiple solar panels electrically wired together to form a much larger PV installation (PV system) called

an array, and in general the larger the total surface area of the array, the more solar electricity it will produce.

A complete photovoltaic system uses a photovoltaic array as the main source for the generation of the electrical power supply. The amount of solar power produced by a single photovoltaic panel or module is not enough for general use. Most manufactures produce standard PV panels with an output voltage of 12V or 24V. By connecting many single PV panels in series (for a higher voltage requirement) and in parallel (for a higher current requirement) the PV array will produce the desired power output.



INVERTERS

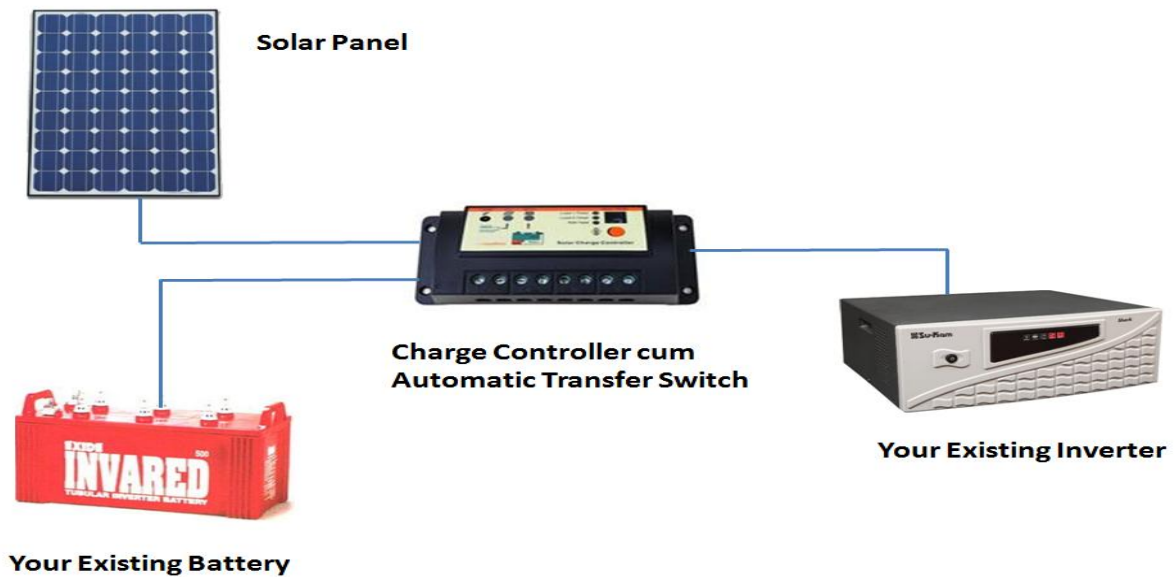
Working Principle

A solar inverter can be defined as an electrical converter that changes the uneven DC (direct current) output of a solar panel into an AC (alternating current).

This current can be used for different applications like in a viable electrical grid otherwise off-grid electrical network.

In a PV system, it is a dangerous BOS (balance of system) component that allows the utilization of normal AC powered apparatus.

These inverters have some functions with PV arrays like tracking of utmost PowerPoint & protection of anti-islanding. If we are using a solar system for a home, the selection & installation of the inverter is important. So, an inverter is an essential device in the solar power system.



Types of Inverters

Solar inverters may be classified into three broad types:

- Stand-alone inverters, used in isolated systems where the inverter draws its DC energy from batteries charged by photovoltaic arrays. Many stand-alone inverters also incorporate integral battery chargers to replenish the battery from an AC source, when available. Normally these do not interface in any way with the utility grid, and as such, are not required to have anti-islanding protection.
- Grid-tie inverters, which match phase with a utility-supplied sine wave. Grid-tie inverters are designed to shut down automatically upon loss of utility supply,

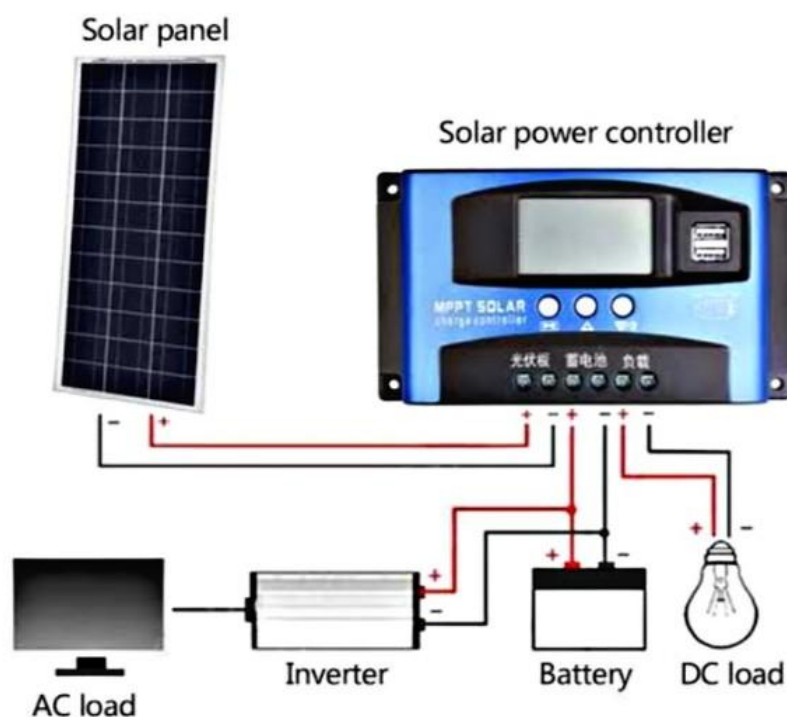
for safety reasons. They do not provide backup power during utility outages.

- Battery backup inverters, are special inverters which are designed to draw energy from a battery, manage the battery charge via an onboard charger, and export excess energy to the utility grid. These inverters are capable of supplying AC energy to selected loads during a utility outage, and are required to have anti-islanding protection.**
- Intelligent hybrid inverters, manage photovoltaic array, battery storage and utility grid, which are all coupled directly to the unit. These modern all-in-one systems are usually highly versatile and can be used for grid-tie, stand-alone or backup applications but their primary function is self-consumption with the use of storage.**

► CHARGE CONTROLLER

IF AN INVERTER IS TO BE USED AS PART OF SOLAR SYSTEM WITH BATTERIES, THEN THE ADDITIONAL COMPONENT CALLED CHARGE CONTROLLER WILL BE PART OF THE INVERTER

A CHARGE CONTROLLER IS A DEVICE THAT REGULATES VOLTAGE AND/OR CURRENT TO KEEP BATTERIS SAFE FROM OVERCHARGING



Types of Controller

There are three different types of solar charge controllers, they are:

1. Simple 1 or 2 stage controls
2. PWM (pulse width modulated)
3. Maximum power point tracking (MPPT)

Simple 1 or 2 Controls: It has shunt transistors to control the voltage in one or two steps.

This controller basically just shorts the solar panel when a certain voltage is arrived at.

Their main genuine fuel for keeping such a notorious reputation is their unwavering quality – they have so not many segments, there is very little to break.

PWM (Pulse Width Modulated): This is the traditional type charge controller, for instance, anthrax, Blue Sky, and so on. These are essentially the industry standard now.

Maximum power point tracking (MPPT): The MPPT solar charge controller is the sparkling star of today's solar systems.

These controllers truly identify the best working voltage and amperage of the solar panel exhibit and match that with the electric cell bank.

The outcome is extra 10-30% more power out of your sun oriented cluster versus a PWM controller.

It is usually worth the speculation for any solar electric systems over 200 watts.



BATTERY

Battery in PV System

Batteries store and produce energy as needed. In PV systems, they capture surplus energy generated by your PV system to allow you to store energy for use later in the day. Like technologies such as fuel cells, a battery converts chemical energy to electrical energy. Rechargeable batteries also convert electrical energy into chemical energy. Depending upon your particular PV system, batteries may help you to use more of the energy collected by your PV system. Batteries can provide power when electrical loads require more power than the PV panels are generating. This can be due to the generation of less electricity due to adverse weather conditions, greater than normal power usage, or other anomalies with the PV power collection. Batteries also help establish the DC operating voltage for the required auxiliary components in the PV system. However, they can be expensive, and each system needs to be designed extremely well so that they are worth the added expense.

During the day:

- The PV system generates solar energy
- The system will check to see if all of the energy

generation can be used to power your household

- Any surplus energy will be used to charge the battery
- If the battery is already charged, excess energy will be exported to the grid

At night or when there is low power generation:

- The PV system generates little to no solar energy
- Energy is obtained from the battery system
- After the battery is discharged, electricity can be obtained from the grid



Types of batteries

There are four main types of battery used in connection with storing electricity from solar power systems. Below is a summary of the various technologies currently commercially available and links to further information on each type.

1) Lead acid

Boring perhaps. Ugly and bulky definitely. But also dependable, tried and tested. Lead acid batteries have been taking Aussies off-grid for decades. But they are rapidly being eclipsed by other technologies with longer warranties and lower pricing as solar battery storage becomes more popular.

2) Lithium-ion

Lithium-ion (Li-ion) batteries are evolving in leaps and bounds as the electric car industry drives their development. Spearheaded by the brilliantly marketed Tesla Powerwall, lithium-ion batteries are looking to become the most popular choice for on-grid solar battery storage for the foreseeable future.

3) Flow

Flow batteries are a relatively new entrant to the battery storage marketplace (though their technology has been around for many years).

They are called flow batteries because they have a water based solution of zinc-bromide sloshing around inside them. At the moment only a few companies are producing flow batteries for the residential market, the most prominent of which is Redflow, an Australian-based flow battery company that outsources battery manufacturing to Thailand (previously North America). The ZCell is the smallest flow battery on the market

4) Sodium Nickel Chloride

Sodium nickel chloride technology is yet another competitor to the dominant lithium-ion storage technology. In Australia, GridEdge is producing their Quantum battery which, offers a range of environmental and safety benefits due to its unique battery chemistry.

Photovoltaic (PV) Cell: Characteristics and Parameters

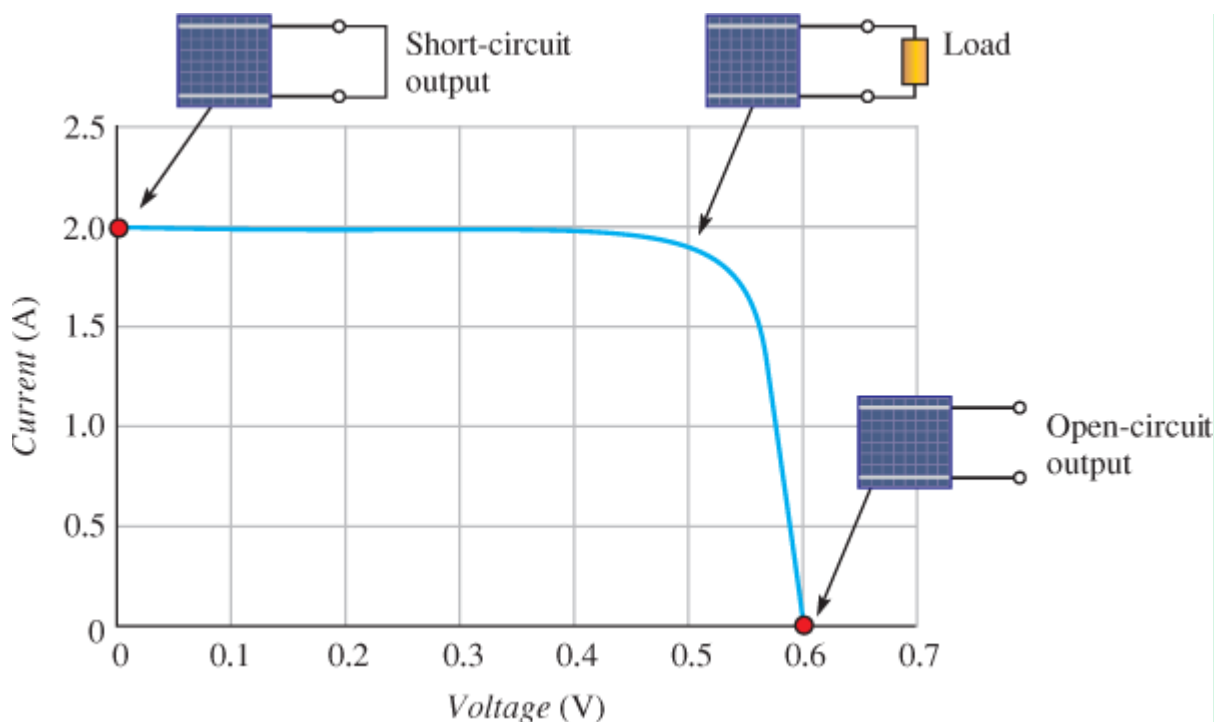
PV cell characterization involves measuring the cell's electrical performance characteristics to determine conversion efficiency and critical parameters. The conversion efficiency is a measure of how much incident light energy is converted into electrical energy.

The optimum operating point for maximum output power is also a critical parameter, as is a spectral response. That is, how the cell responds to various light frequencies.

Other important characteristics include how the current varies as a function of the output voltage and as a function of light intensity or irradiance.

PV Cell Current-Voltage (I-V) Curves

The current-voltage (I-V) curve for a PV cell shows that the current is essentially constant over a range of output voltages for a specified amount of incident light energy.



In this the short-circuit output current, I_{sc} is 2 A. Because the output terminals are shorted, the output voltage is 0 V. For an open output, the voltage, V_{oc} is maximum (0.6 V) in this case, but the current is 0 A, as indicated.

PV Cell Output Power

The output power of the PV cell is voltage times current, so there is no output power for a short-circuit condition because of V_{OUT} or for an open-circuit condition because of $I_{OUT} = 0$.

Above the short-circuit point, the PV ceoperates with a resistive load.

Between the short-circuit point and the knee of the curve, the output power depends on the voltage because the current is essentially constant.

The maximum output power occurs in the knee at the point, called the maximum power point (MPP), where the voltage is approximately 0.52 V.

After that point, the curve decreases drastically and the output power declines, as illustrated in Figure 2. In the figure, the blue curve is the power. In this particular case, the maximum output power is $P_{OUT (MAX)} = V_{MPPT}I_{MPP} = (0.52 \text{ V}) (1.85 \text{ A}) = 0.96 \text{ W}$.

For maximum power, the load on the cell would have to be:

$$R_L = V_{MPP} / I_{MPP} = 0.521 / 1.85 = 0.281 \Omega$$

The output voltage of a PV cell is affected only slightly by the amount of light intensity (irradiance), but the current, and thus the power, decreases as the irradiance decreases.

PV cell parameters are usually specified under standard test conditions (STC) at a total irradiance of 1 sun ($1,000 \text{ W/m}^2$), a temperature of 25°C and coefficient of air mass (AM) of 1.5. The AM is the path length of solar radiation relative to the path length at zenith at sea level.

The AM at zenith at sea level is 1. Figure 3 shows typical I-V curves for three values of irradiance. Cells vary in the amount of current at a given irradiance.

Energy Conversion Efficiency

The efficiency of a PV cell is the ratio of light energy falling on the cell to the light energy that is converted into electrical energy.

It is expressed as a percentage, as shown in the following formula:

$$\text{Efficiency} = \frac{P_{\text{out(max)}}}{E \times A} \times 100$$

Where

$P_{\text{out(max)}}$ is the maximum electrical power output of the cell, in watts (W)

E is the irradiance (light energy) at the surface of the cell, in watts/meter² (W/m^2)

A is the surface area of the cell, in meter² (m^2)

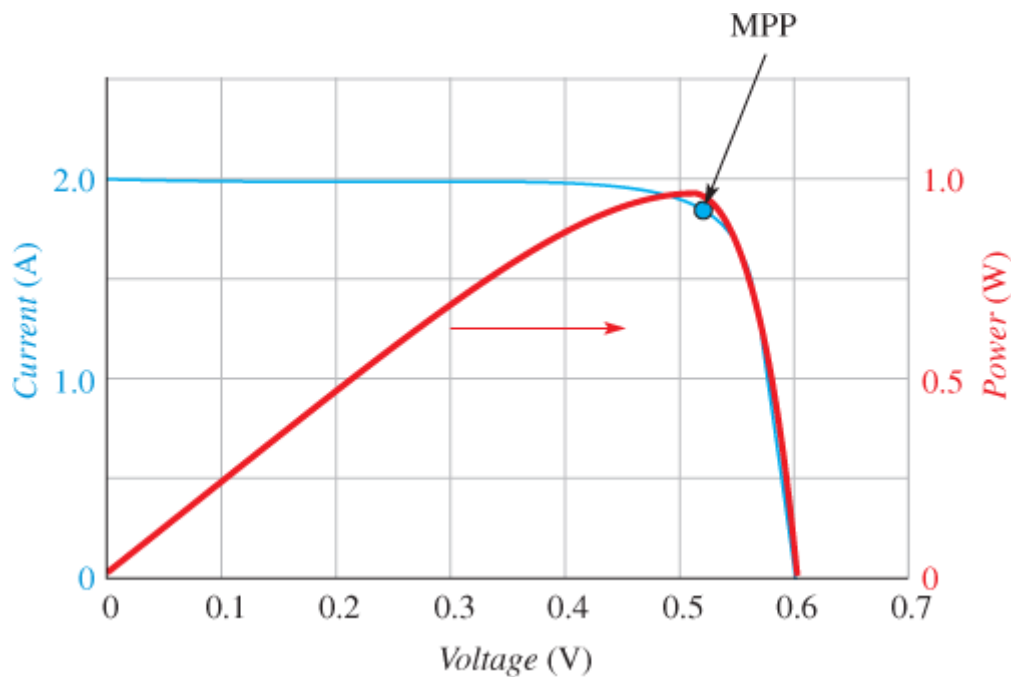


Figure 2: Power Curve for a Typical PV Cell

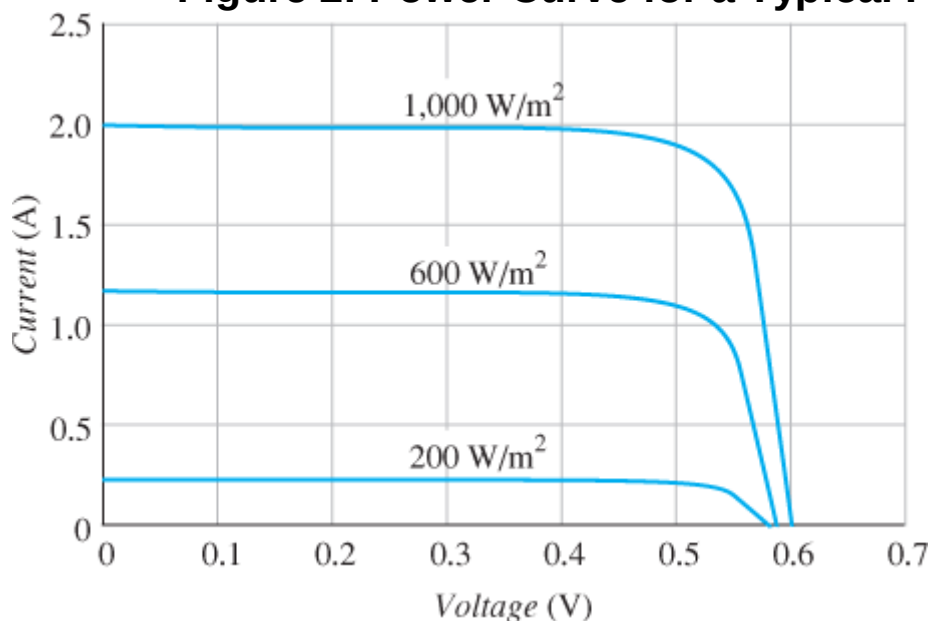


Figure 3: I-V Characteristics as a Function of Irradiance

PV cells are typically square, with sides ranging from about 10 mm (0.3937 inches) to 127 mm (5 inches) or more on a side. Typical efficiencies range from 14% to 18% for a monocrystalline silicon PV cell. Some manufacturers claim efficiencies greater than 18%.

Factors That Effect Conversion Efficiency

Several factors determine the efficiency of a PV cell: the type of cell, the reflectance efficiency of the cell's surface, the thermodynamic efficiency limit, the quantum efficiency,

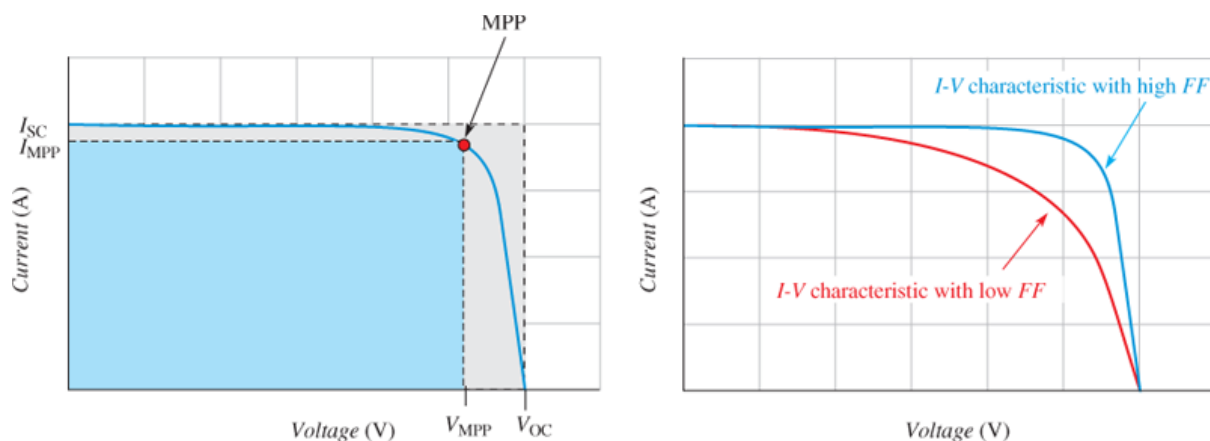
the maximum power point, and internal resistances.

PV Cell Fill Factor:

The fill factor of a PV cell is an important parameter in evaluating its performance because it provides a measure of how close a PV cell comes to providing its maximum theoretical output power.

The fill factor (FF) is the ratio of the cell's actual maximum power output ($V_{MPP} \times I_{MPP}$) to its theoretical power output ($V_{OC} \times I_{SC}$).

$$FF = (V_{MPP})(I_{MPP}) / (V_{OC})(I_{SC})$$



Fill Factor for a PV Cell

SOFTWARE-SOLAR PRO

The software calculates the I-V curve of solar modules accurately and quickly based on the electric characteristics of each manufacturer's product. The software calculates the amount of generated electricity based on the latitudes, longitudes, and the weather conditions of the installation site.



Report

Solar Pro is used to create 3D models of residential, commercial flat-roof, ground-mounted, and single & dual-axis tracker PV systems. The shading effects of each object created in Solar Pro, including trees, buildings, and adjacent PV arrays, can be easily visualized on a minute-by-minute basis, 365 days of the year.

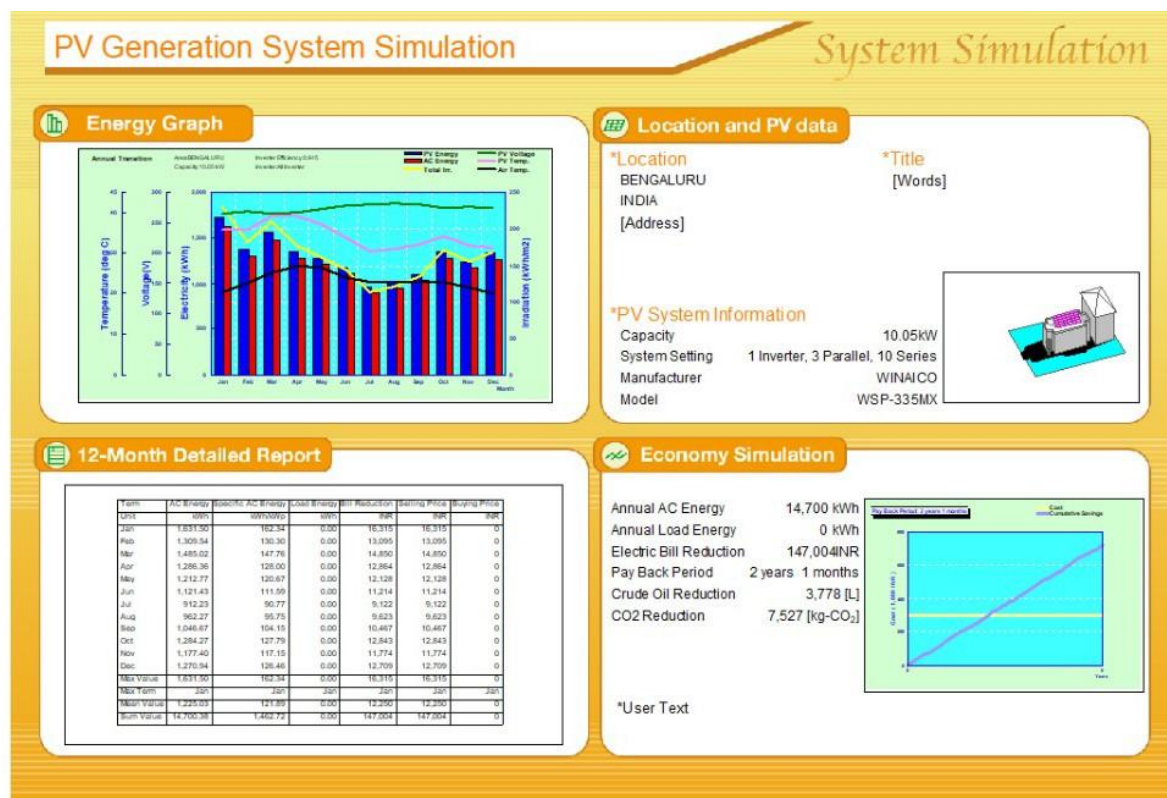
Solar Pro predicts hourly electricity generation using scientific, industry-standard mathematical models. IV Curve calculations are

performed at the module level and take into account irradiation & temperature data, shading, and other detailed loss factors.

PV Generation System Simulation

This is a example report for Bangalore.

This report has a energy graph, each month detailed report, economy simulation and PV data for complete 365 days.



REFERENCE

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