OPTIDRIVE™ P2 SOLARPUMP

New Variable Frequency Drive for Solar Pumping

Invertek Drives.com

Solar Pumping

- All living beings have a dependency on water
- Throughout human history, the most significant applications of engineering have revolved around our need to access and transport water
- A great example of such an engineering application, is the harnessing of the natural energy from the sun using photovoltaic panels and using this energy to pump water where a conventional power supply is not available – this application has improved the quality of life in numerous places around the globe

Solar Pumping

Current technology makes it possible to power pumping systems with photovoltaic generators. There are applications for pumping water from wells with depths of between 10 m and 500 m, as well as from surface water sources.

Solar Pumping

Globally, we have many successful installations using the Optidrive E3 working on irrigation pumps where the power to the drive is supplied by PV Panels. The drive operates in PI mode with the DC Bus Voltage as the feedback source. This is a good general purpose solution and still viable for the lower cost end of the market of solar pumping.

The P2 Solar Pump Drive utilises a highly efficient Maximum Power Point Tracking (MPPT) algorithm that can provide significantly higher levels of pumping than using the E3 in PI mode.

E3 – General Purpose
Lower cost solution

P2 Solar Pump Drive High
Performance Solution

Components of a PV system

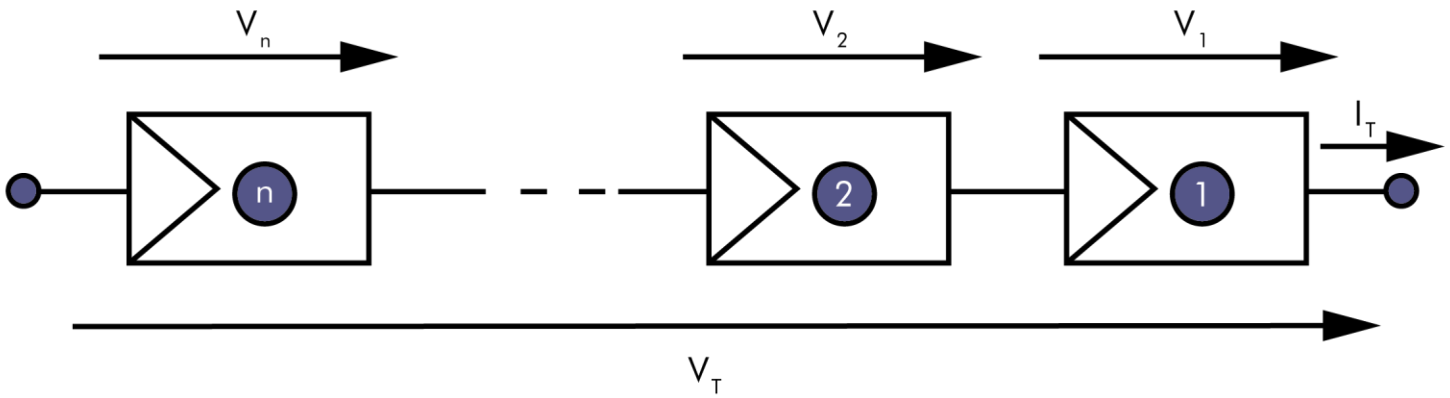
Some terms that are often used in the PV World

- **PV Panel** – this is a quantity of solar cells mounted on a back-plate electrically connected to simplify the handling and mounting of the devices. The panels will have a nominal voltage and nominal current
- **String** – this is a quantity of PV Panels connected in series
- **Array** – this is a quantity of ‘strings’ or ‘PV panels’ connected in parallel
- **Maximum Power Point Tracking (MPPT)** – As the actual conditions change (clouds pass by or the position of the sun moves in the sky), the array characteristics change. The MPPT tracks the point of maximum power available from the array and modulates the speed of the pump (load) accordingly

Components of a PV system

Modules with photovoltaic cells connected in series

Photovoltaic cells are not used individually because of the low voltage and low power produced. To achieve suitable voltage output, cells are normally connected in series.



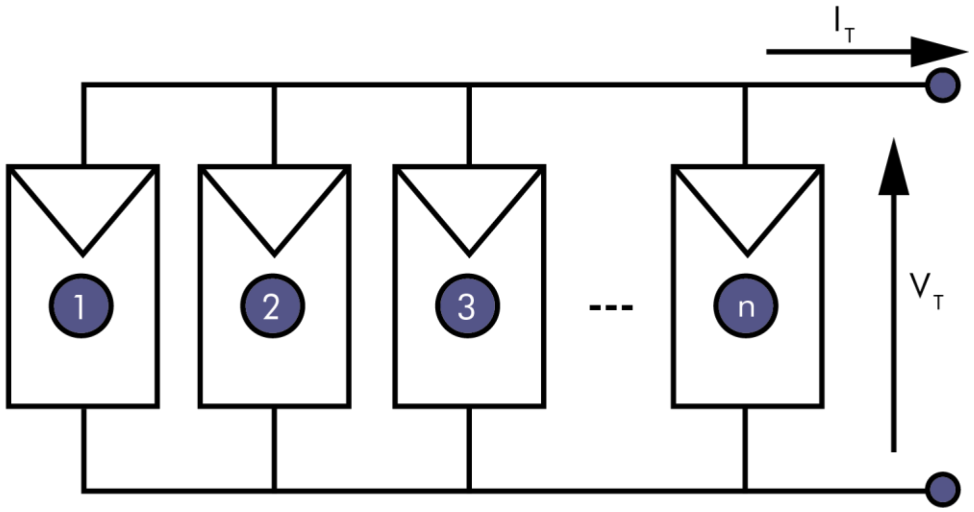
$$V_T = \sum_{i=1}^{n} V_i \qquad V_T = nV \qquad I_T = I_1 = I_2 = \cdots = I_n$$

A number of panels connected in series is known as a **STRING**

Components of a PV system

Modules with photovoltaic cells connected in parallel

An alternative way to connect photovoltaic cells so that they form a module is in parallel.



$$V_T V$$

$$I_{T=} \sum_{i=1}^{n} I_i$$

$$I_T = I_1 + I_2 + I_3 + \cdots + I_n$$

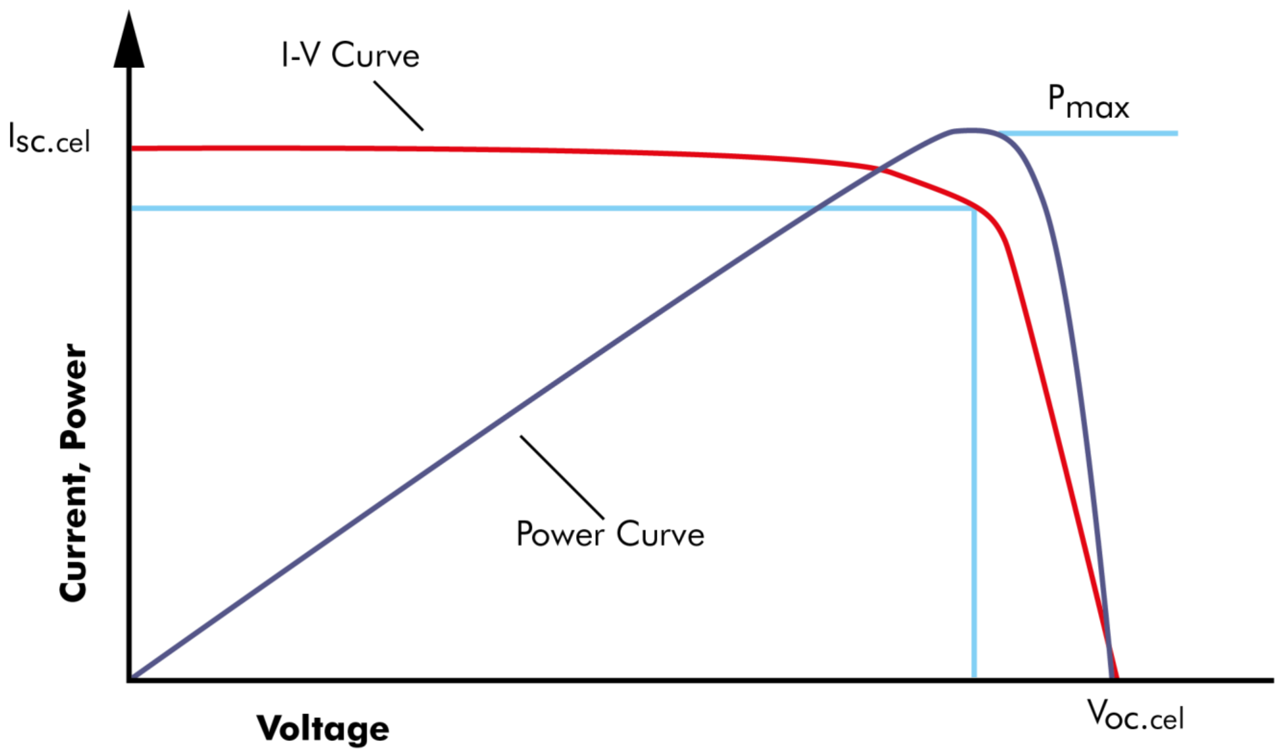
A number of Strings (or individual panels) connected in parallel is known as an **ARRAY**

Operating parameters of PV cells

The electrical parameters that define the operation of the solar cell

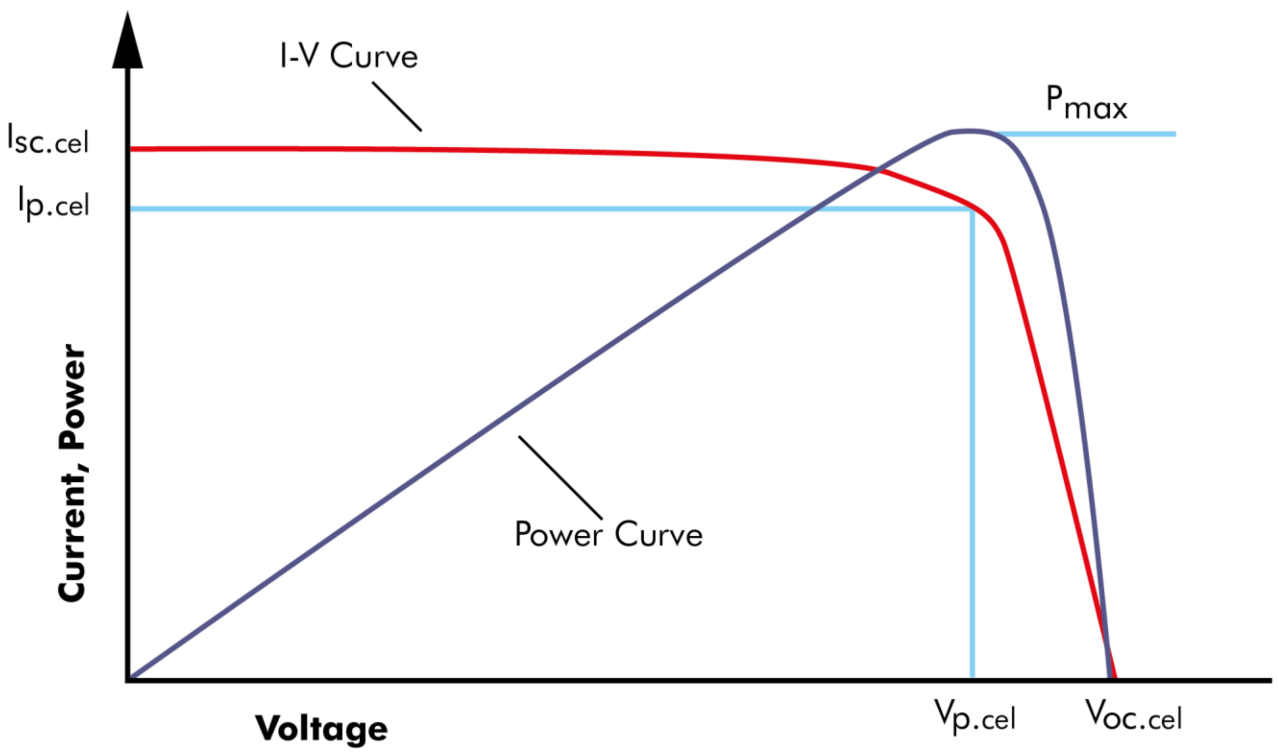
Short-circuit current, $I_{SC,cel}$. This is the electric current obtained from the cell which results in zero voltage across the terminals. It is the maximum current that can be obtained.

Open-circuit voltage, $V_{OC,cel}$. This is the voltage at which the current obtained from the cell is zero. It is the maximum voltage that can be obtained from the cell when there is no load connected and the current flowing is zero.



Operating parameters of PV cells

Maximum power or peak power, P_{cel}. The power obtained from the cell is the product of the current and the voltage, I·V. There is an operating point ($I_{P,cel}$, $V_{P,cel}$) at which the power available is at its maximum, known as the maximum power point. In summary, the maximum or peak power, P_{cel}, is the maximum power that a photovoltaic cell can generate under standard incident radiation conditions, and is obtained by multiplying the peak voltage by the peak current:



$$P_{cel} = I_{P,cel} \bullet V_{P,cel}$$

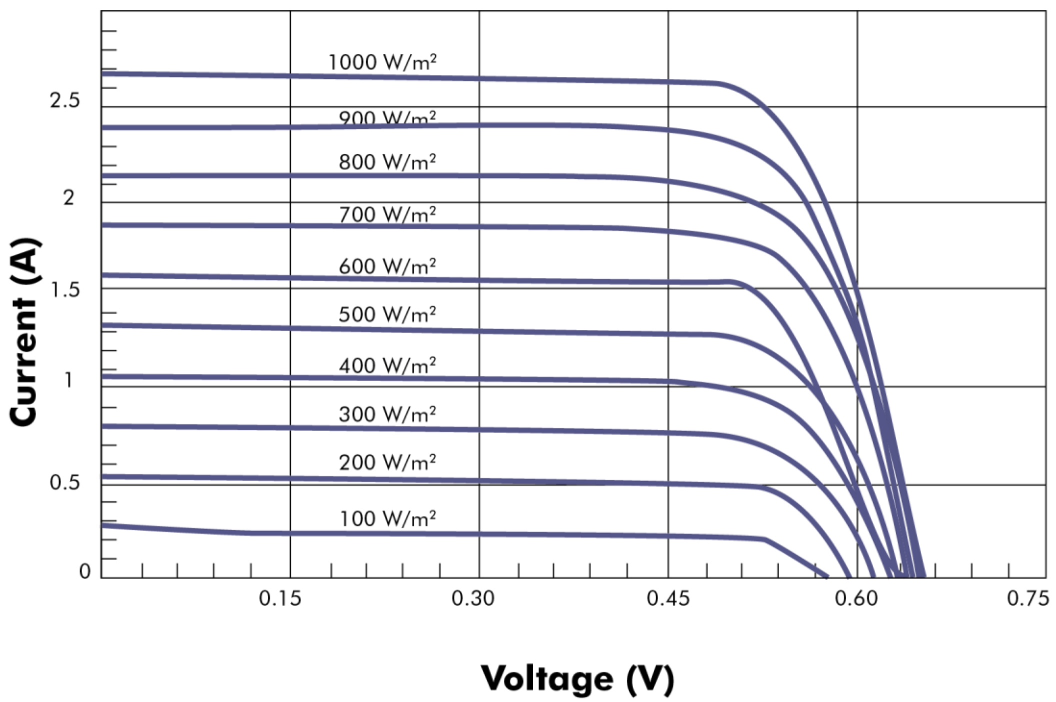
Effects of irradiance and temperature

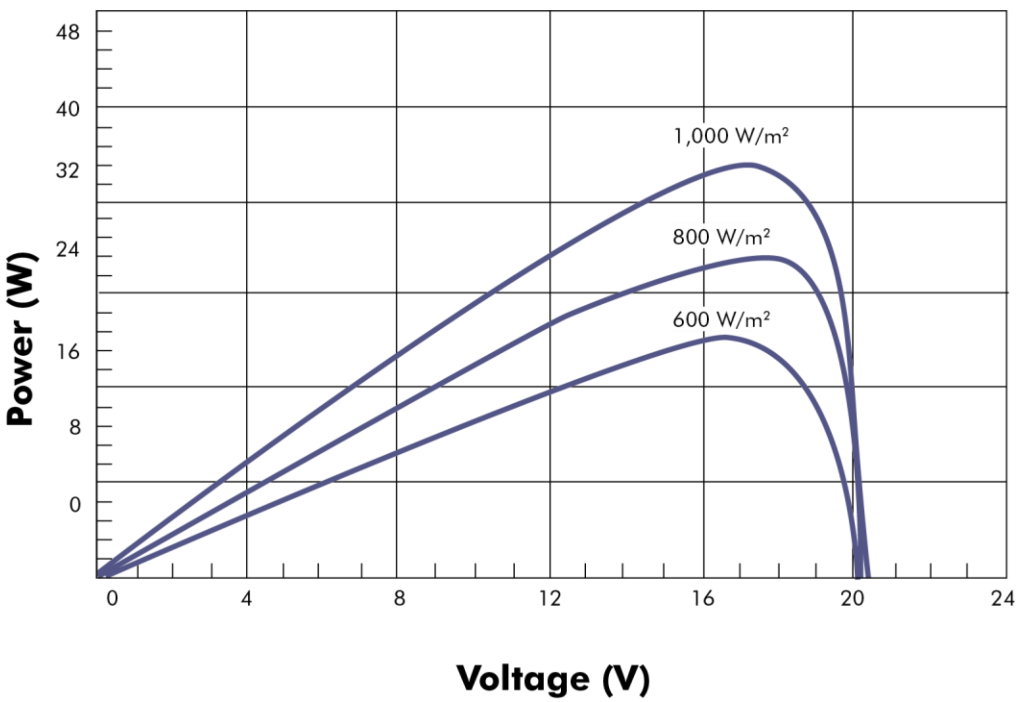
In reality, solar cells rarely operate under standard certification conditions. The two parameters with the greatest effect on the I-V curve of a photovoltaic cell are irradiance and temperature.

Irradiance	1000 W/m^2
Spectral distribution	AM 1.5
Incidence	Normal
Cell temperature	25 °C

Dependence of I-V curves on solar irradiance

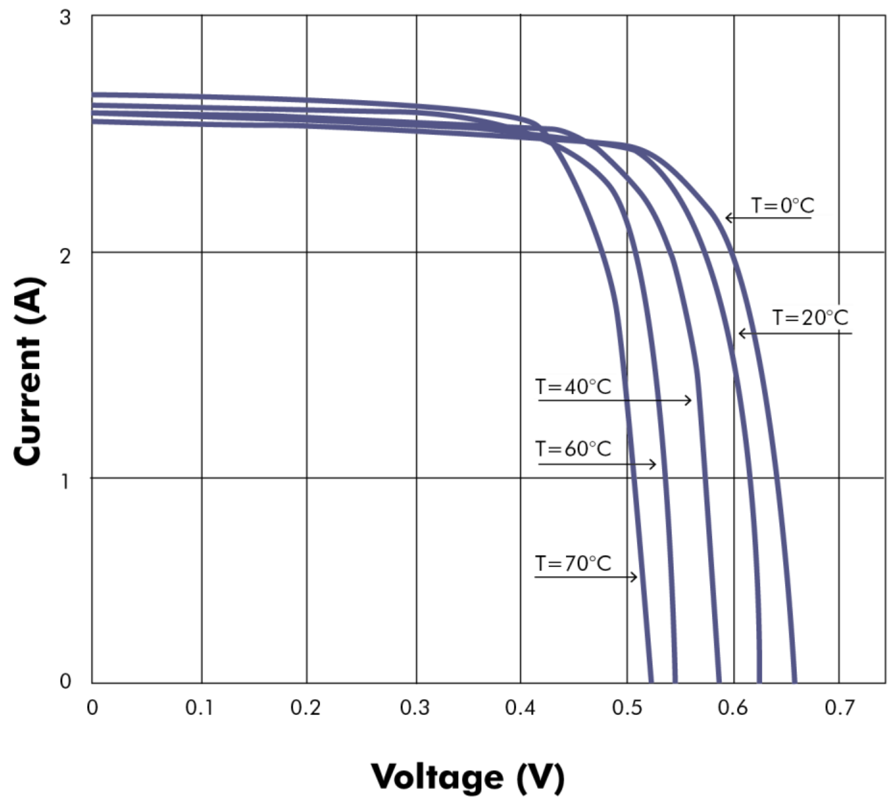
The power generated is essentially proportional to irradiance. This has interesting consequences. Firstly, the proportional relationship to irradiance allows daily production to be calculated easily.





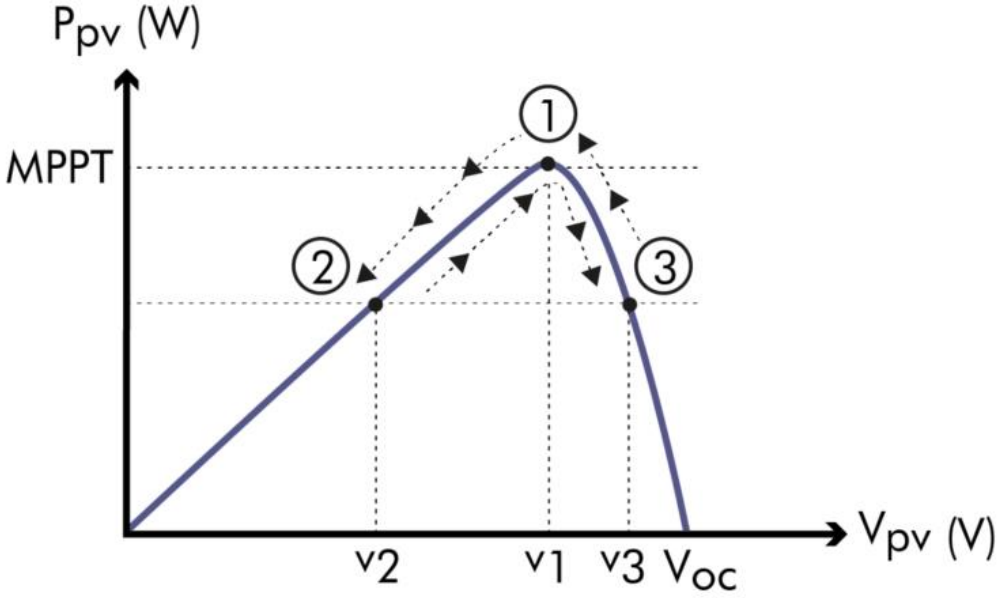
Dependence of I-V curves on temperature

The effect of temperature on the I-V curve is significantly different. With increasing temperature, the open-circuit voltage decreases (by the K factor). In addition, as a result of this variation in V_{OC}, the Fill Factor FF also decreases with higher temperatures, which in turn reduces the efficiency of the cell as the temperature increases. The short-circuit current, on the other hand, remains virtually constant.



Maximum Power Point Tracking MPPT

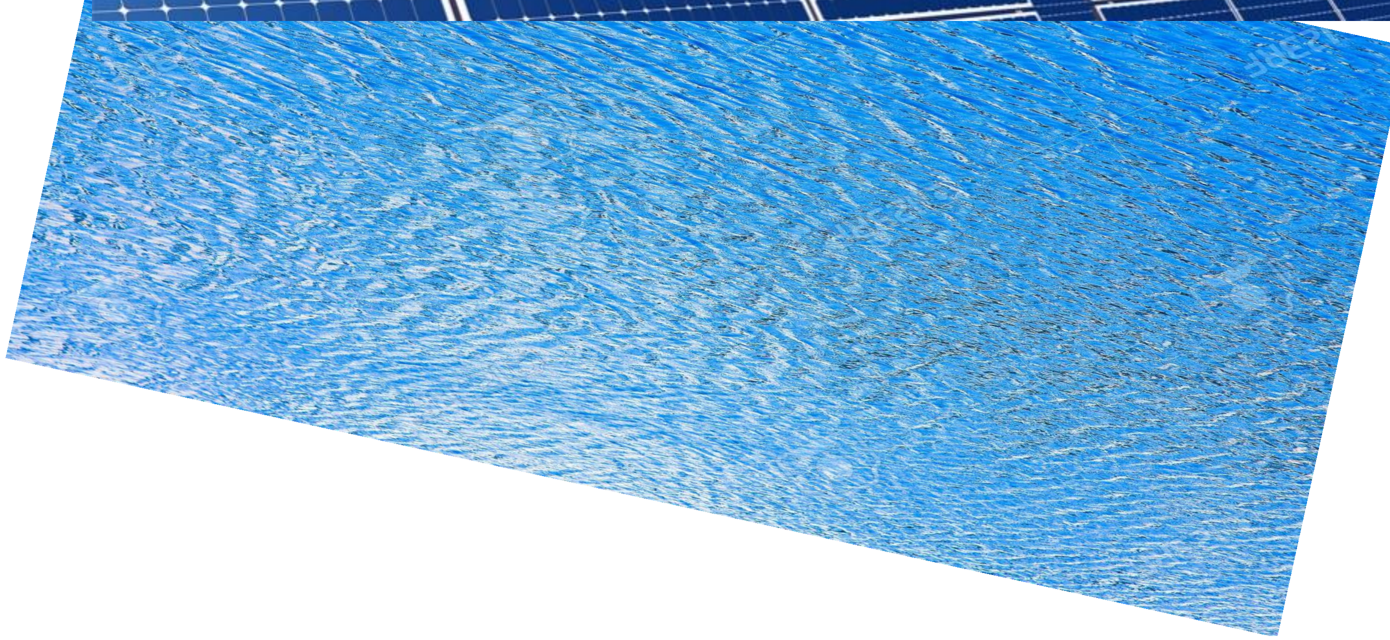
Maximum power point tracking (MPPT) continuously modifies the system load to achieve maximum output power at any time under varying conditions of irradiation and temperature. MPPT is the best choice to obtain the maximum pumping supply from photovoltaic cells under any conditions



Consider a solar pumping application running at the maximum power point shown as point '1' above. If the pump load is increased slightly (for the same environmental condition), the PV array voltage will decrease and so will the power available – we move to point 2. If the drive does not quickly react to this reduction in power by decreasing the output speed, the array voltage is likely to collapse to zero.

The MPPT algorithm is vitally important to not only optimise the pump output based on the environmental conditions but it should also provide stable operation whenever there is sufficient energy available

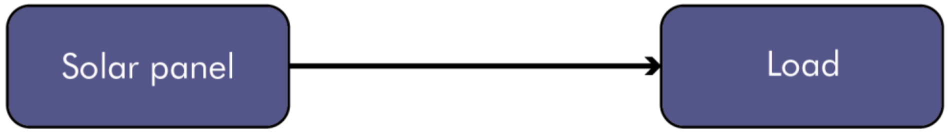
Classification of a PV system



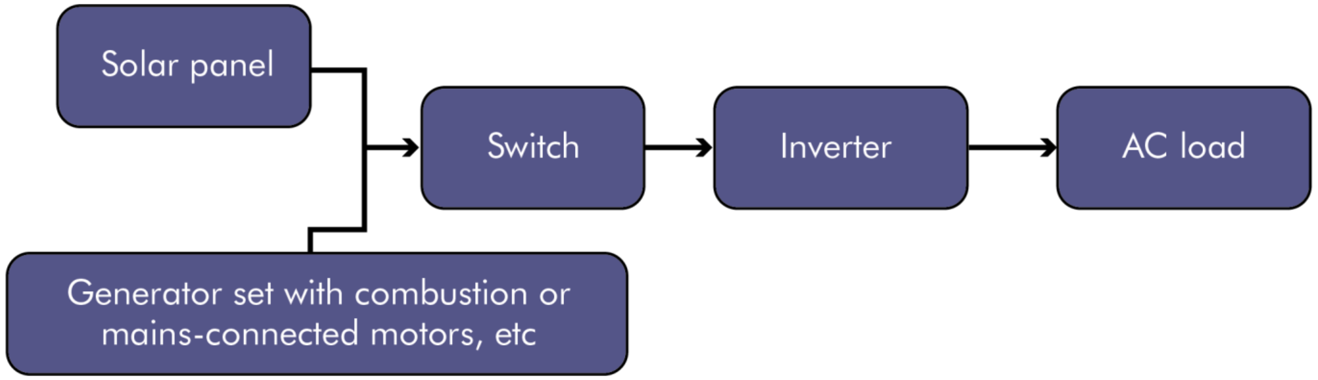
Classification of a PV system

The components of a photovoltaic system vary depending on the applications for which they are used. Those applications can be classified as:

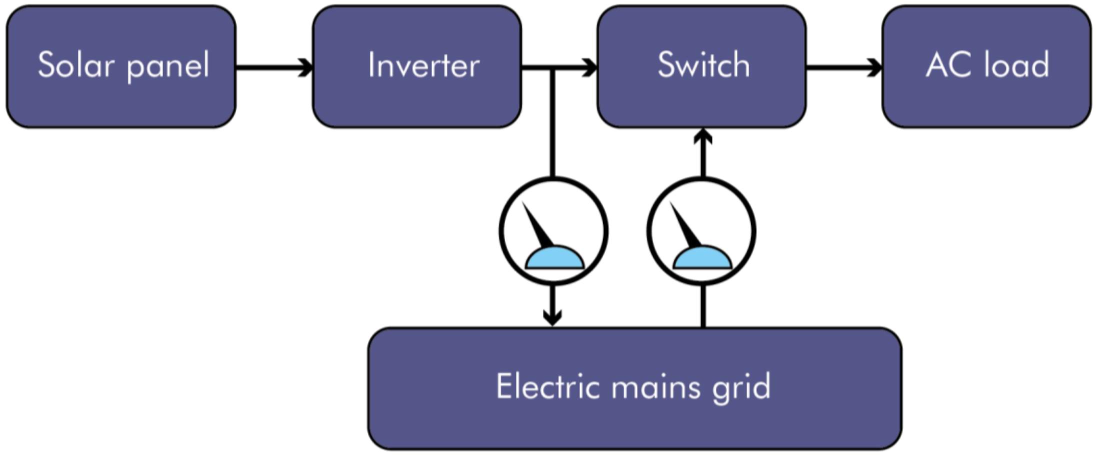
Isolated PV systems



Mixed PV systems

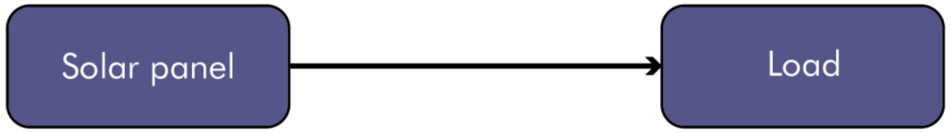


Grid-connected PV systems

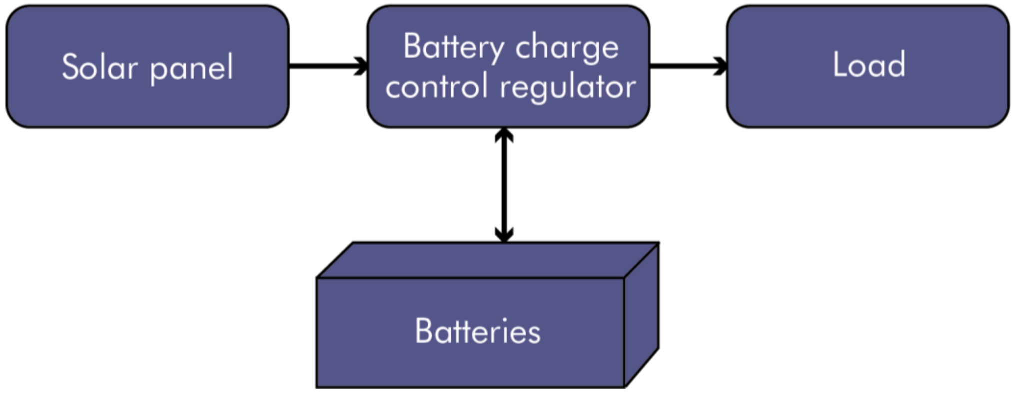


Isolated PV systems

Isolated photovoltaic systems are those in which the only source of energy is the solar generator – as such, energy is only produced when the sun is shining.



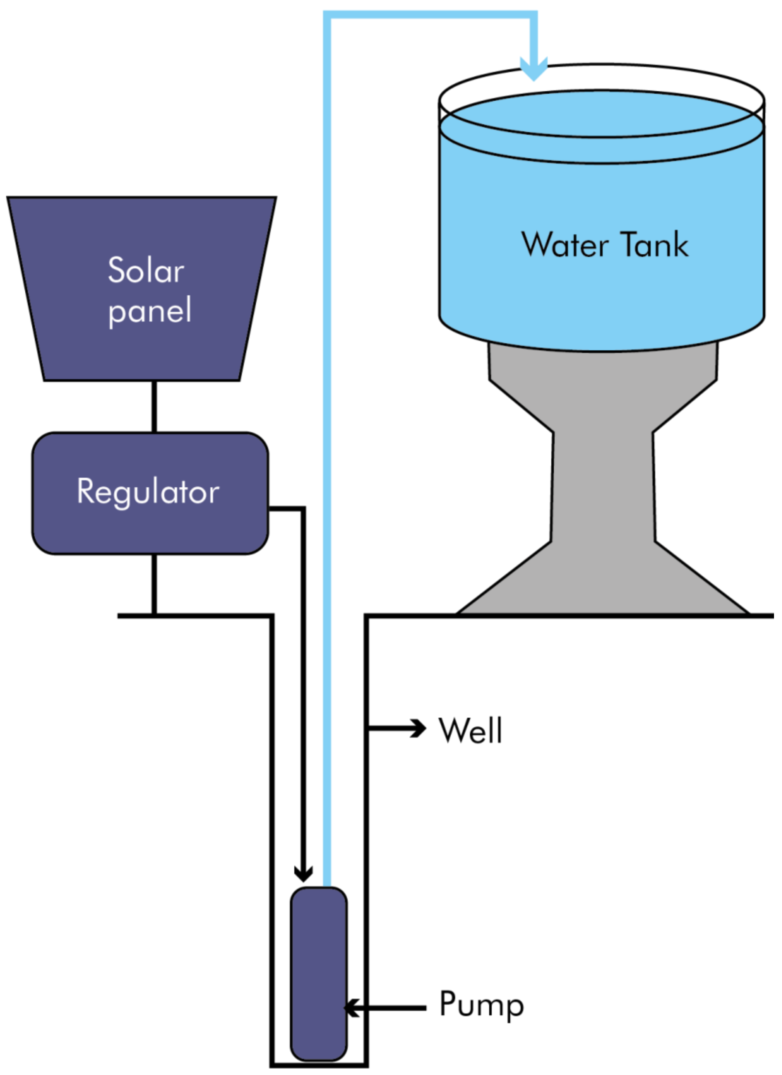
The most common photovoltaic systems are ones that use an energy storage system for those times when energy is not being produced by the solar panel. The most commonly used storage system is the chemical battery.



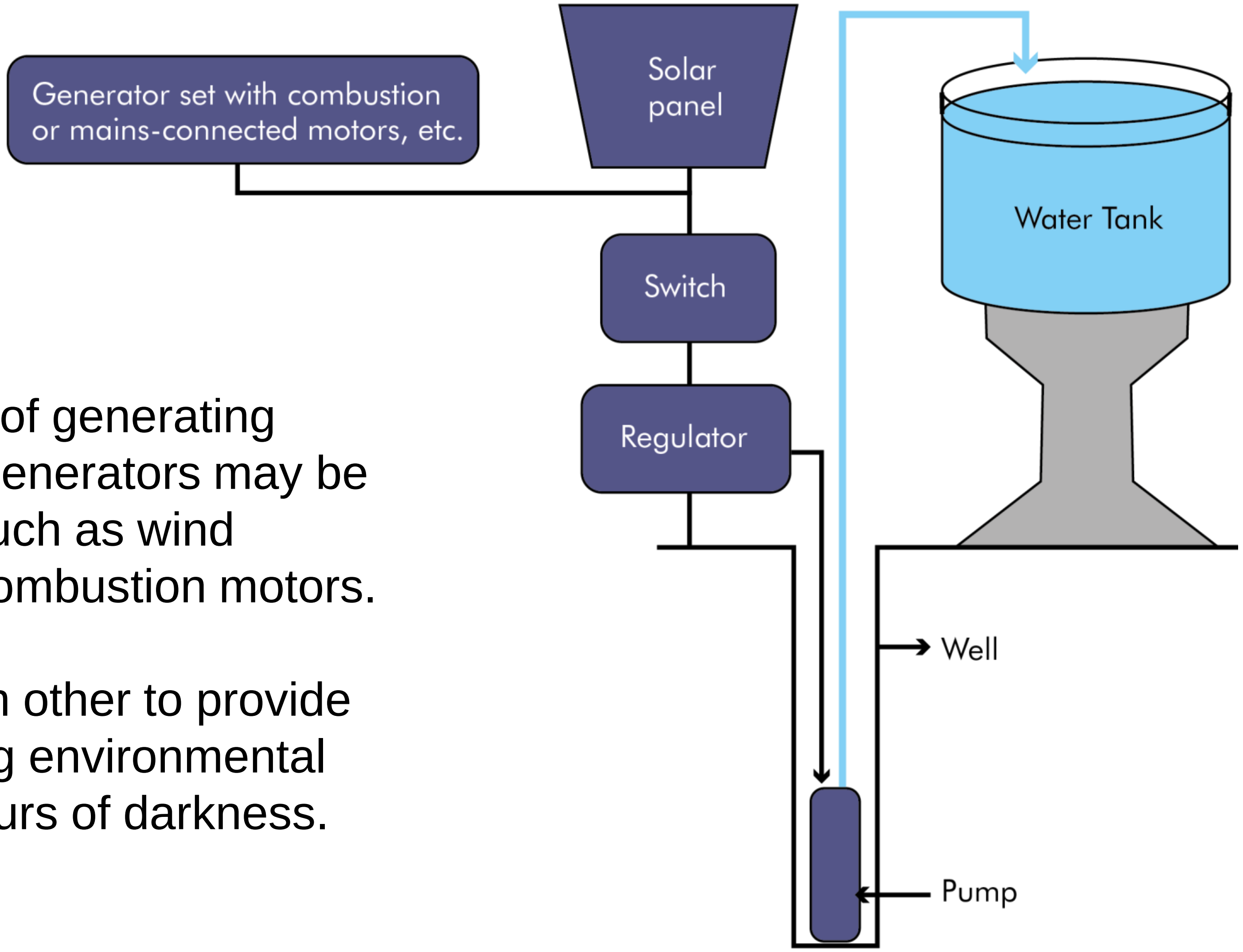
Isolated PV systems

Another form of energy storage is pumping water to a raised tank. The energy is then stored as potential energy which can be released when valves open and the water will flow due to gravity.

While the sun shines on the solar panels, the pump sends water to the tank. The water can be released from the raised tank when required with or without the presence of the sun.



Mixed PV systems



These are systems that include other means of generating electricity in addition to solar energy. These generators may be other systems for generating clean energy, such as wind energy, or electric generators connected to combustion motors.

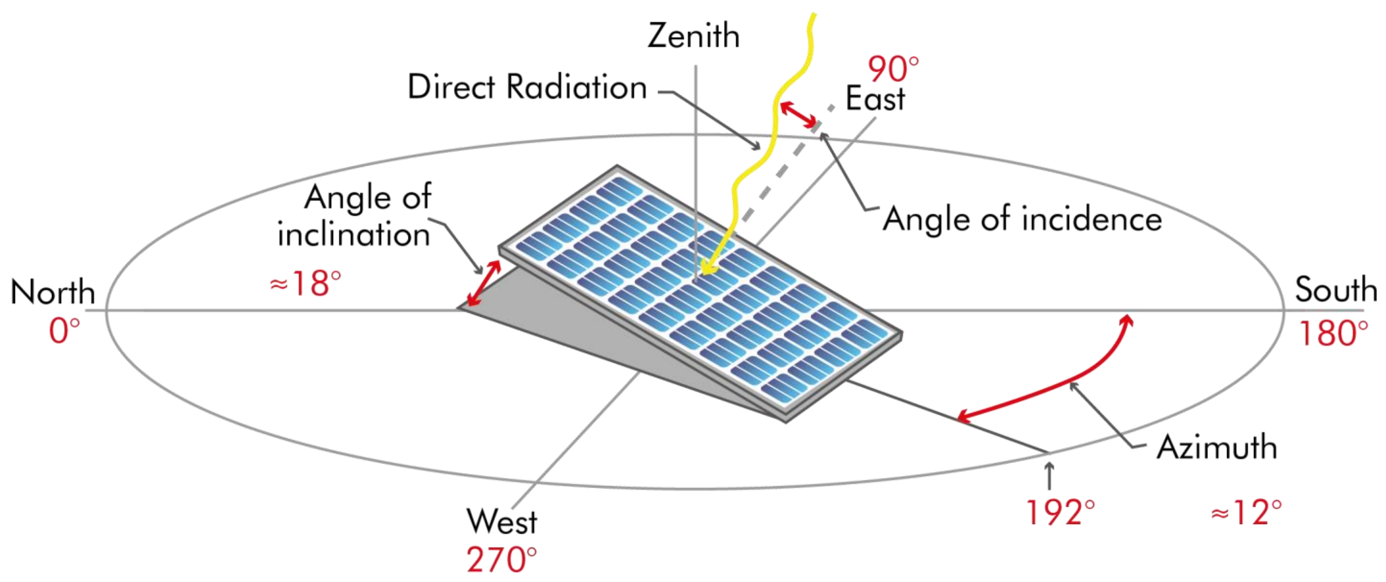
In such cases, the systems complement each other to provide the energy required for the load under varying environmental conditions or to provide energy during the hours of darkness.

Orientation and angle of the solar panel

In order to maximise the energy obtained from a solar panel, it is essential to position it correctly relative to the sun in such a way that irradiation is maximised. The closer the angle at which the light hits the panel is to the perpendicular, the more energy is produced. If the panel is fixed, the two most important parameters for maximising the energy produced throughout the day are: the angle of inclination relative to the horizontal, and the orientation of the panel relative to the cardinal directions.

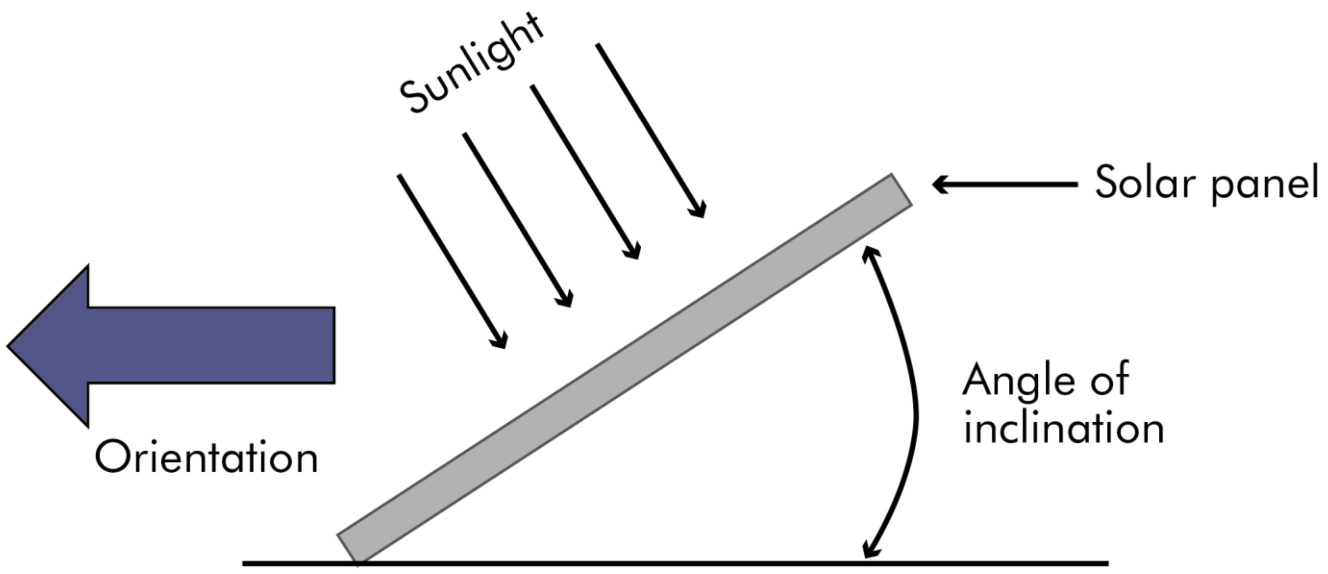
Orientation: in the Northern Hemisphere the panels should face south, while in the Southern Hemisphere they should face north.

Inclination: this depends on the latitude at which the panel is situated. The closer to the equator, the smaller the angle should be; the further from the equator, the larger the angle.



Orientation and angle of the solar panel

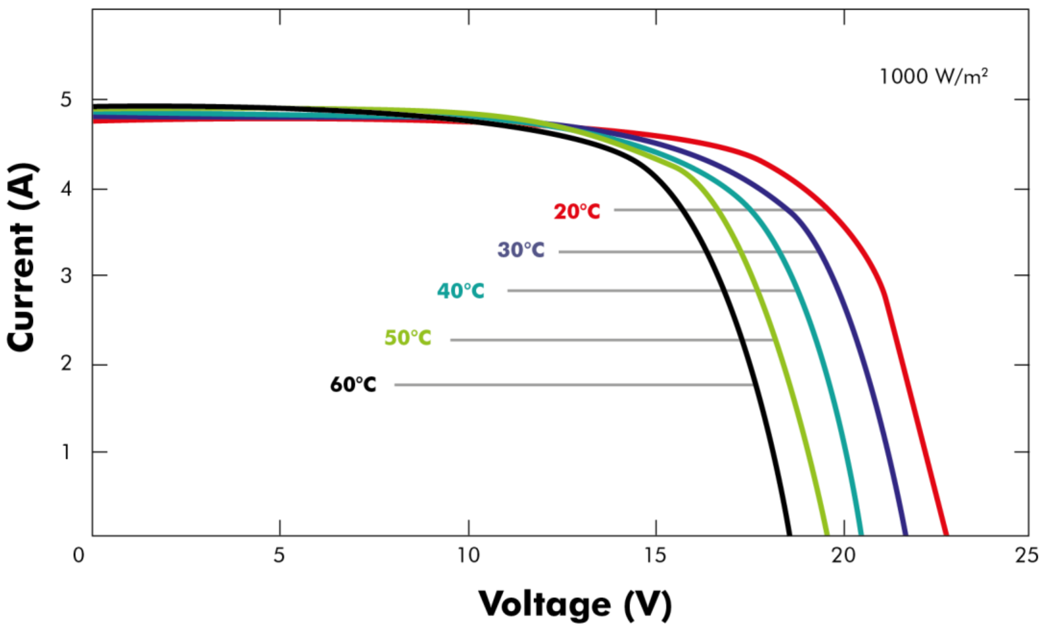
Another important aspect to bear in mind is the season: the angle of inclination should be larger in winter and smaller in summer. If the panel's angle of inclination cannot be modified, it should be positioned in a way that optimises the energy produced during the winter. Another alternative would be to have at least two angles of inclination in the support: one for the winter and another one for the summer.



Calculating the available solar energy

Effect of the panel's temperature and of irradiance on the power generated

The temperature has a direct effect on the panel's current (photocurrent) and on its voltage, causing the power to vary relative to its nominal or peak power. There is a formula to calculate the panel's power from its temperature.



$$P = P_N\,(1 - (\propto \times \Delta t)\,)$$

PN: nominal power of the panel [W]
α: percentage power loss coefficient per degree of temperature [1/° C]
ΔT: variation in temperature [° C]

This applies in the event that the solar panel's temperature is higher than 25 ° C (calibration temperature).
The value of α is around 0.5 %.

Example: if the nominal power of the panel is 50 W and the panel is operating at 55 ° C, then αΔT = 15 %, which makes the power of the panel 42.5 W, i.e. only 85 % of its nominal power.

Operating voltages of the installation

DC supply range

One of the most important variables is the working voltage with which isolated systems are designed.

Optidrive P2 Solar Pump models manufactured with an output voltage of 0 – 250 VAC require a DC supply of between 185 and 410 VDC, with a recommended V_{MP} value of 325 VDC.
Models with an output voltage of 0 – 480 VAC require a DC supply of between 345 and 800 VDC, with a recommended V_{MP} value of 565 VDC.

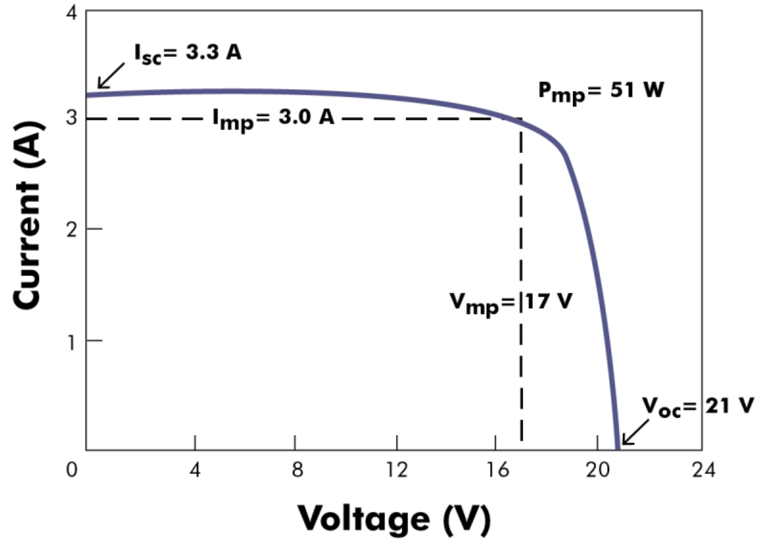
NOTE: The PV Array voltage (DC Bus voltage) will essentially limit the maximum output voltage from the drive – a PV Array Voltage of 425Vdc will only give an AC output of 300V

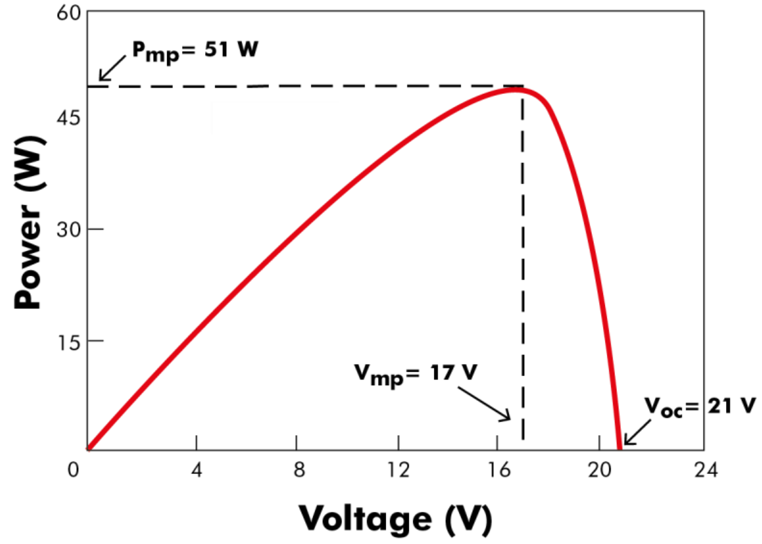
That is DC Bus Voltage divided by the square root of 2

Operating voltages of the installation

DC supply range

One of the most important variables in the system design is the working voltage and open circuit voltage.



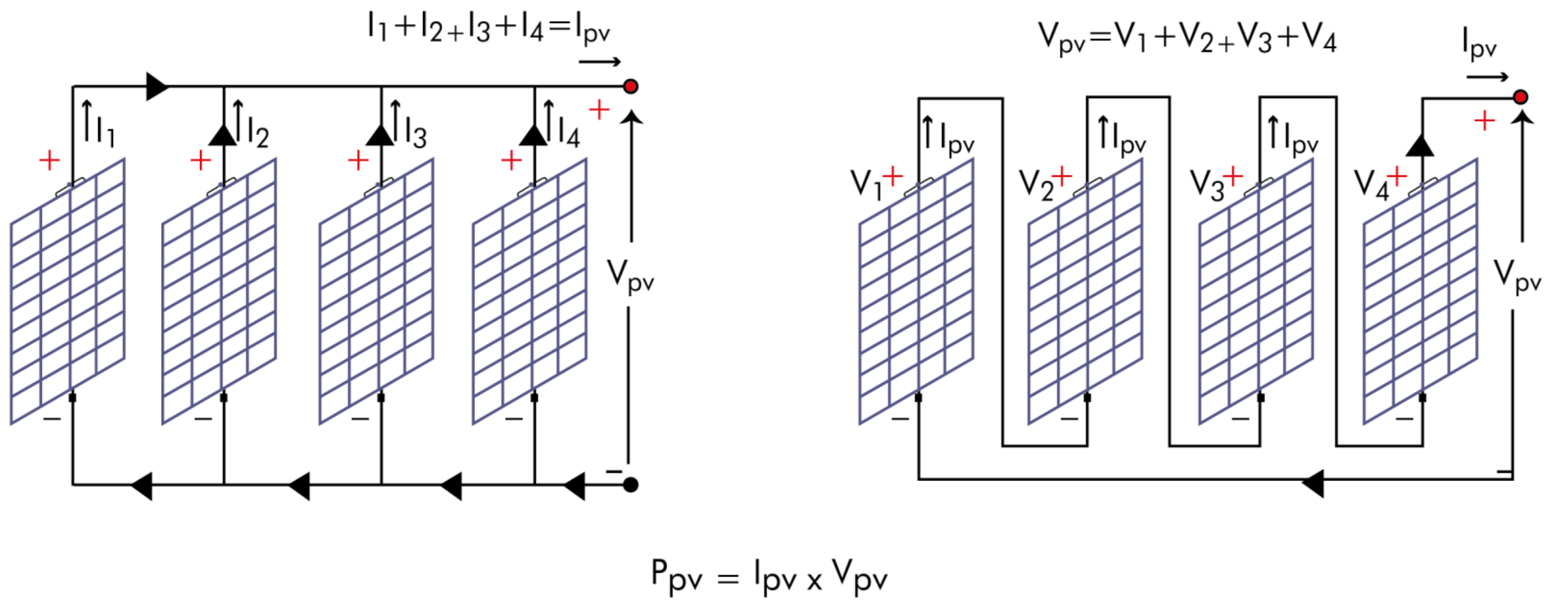


In the above example, the PV modules have an open-circuit voltage of 21 V.
When loaded, the panels will deliver a maximum power voltage of 17 V.
Care should be taken that the V_{OC} when the pump is stopped (highest voltage), and the V_{MP} when the load reaches its maximum value (lower operating voltage) remains within the rating of the drive.

Operating voltages of the installation

Output power

Connecting in parallel keeps all the panels at the same voltage (V_{PV}), but increases is the current (I_{PV}).
When connecting in series, the opposite happens: the voltage of the string (V_{PV}) is the sum of the voltages of each panel, while the current (I_{PV}) is the same for all the panels.
Of course, it is possible to combine the two in order to generate a greater power.



$$P_{PV} = I_{PV} \times V_{PV}$$

Yields

Wide operating DC range

Units with 0–250 VAC output, DC input: 185–410 VDC

Units with 0–480 VAC output, DC input: 345–800 VDC

Range of DC operating voltage, 345–800 VDC HV, 185–410 VDC LV, which increases the daily operating time of the system and reduces unnecessary stoppages caused by low voltages present at dawn and dusk.

Characteristics

IP range

Wide IP range for P2 solar (IP20, IP66, IP55)

Yields

PUMP PROTECTION

Pump protection (dry mode and others)

PIPE FILL

Burst pipe protection

Yields REMOTE MONITORING

Remote monitoring (Modbus TCP, Modbus RTU)

Yields

IRRADIATION SENSOR

Irradiance sensor can be connected and read W/m2 on display

LC FILTERS

LC filters available

Other…

- **Maximum Power Point Tracking (MPPT)** algorithm provides enhanced pumping capability – world class MPPT performance increases pumping output for given conditions.
- **Well and tank level detection**, forces the converter to stop when the tank is full or the well is empty.
- **Pressure monitoring**, useful for monitoring the pressure of the system locally or remotely or for stopping the pump if the pressure exceeds a configurable level.
- **Integrated PLC** to personalise more demanding applications where the user may need to control, for example, actuators or solenoid valves.

THANK YOU
FOR YOUR ATTENTION…