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Bibliographical report

Research: Solar Photovoltaic Panel

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Table of Materials

Introduction:

Given environmental issues, the energy transition debate is much more than just a topical topic, it is at the centre of political agendas and companions and occupies a large part of the media scene. The most plausible alternative today is therenewed energy energies. We will discuss photovoltaics in this bibliographical report, and as part of the Work of Study and Research (TER).

Before we start here are some figures on the subject:

In 2017, it is estimated that renewable energy contributes 18.1%, of which almost 2% is due to photovoltaics. (see reference 8).

In France and according to the official website of Edf (the leading electricity supplierin France), photovoltaic electricity production of 9.2 TWh in 2017 is up 9.2% compared to 2016.

We see that the market is very promising and promising, but what about the principle of how this technology works, its composition, and the possibility of optimizing it?

Discussions of materials:

In the first we will distinguish the differentmaterials known to date and heavily used in the context and field of electrical engineering:

Insulating *materials:* Or so-called dielectric, is a material with very little load and therefore no electricity.

Thes conductive materials: these are elements that possess several load carriers and therefore capable of transmitting electricity.

Semiconductors: A material that can possess free carriers; it has the distinction of having 4 peripheral electrons, and thus half of an orbital filled, its electrical properties depend mainly on:

- The energy needed to 'snatch' an electron at the covalent bond.
- Temperature (Conductivity).

Since a material is composed of atoms, and therefore electrons that are considered to be load-carrying elements, the positioning of these electrons in the different layers of atom creates 3 energy levels in each material:

- Valence band (close to the nucleus of the atom).

- Conduction band (electron in the last atomic orbital).
- Forbidden strip gaps.

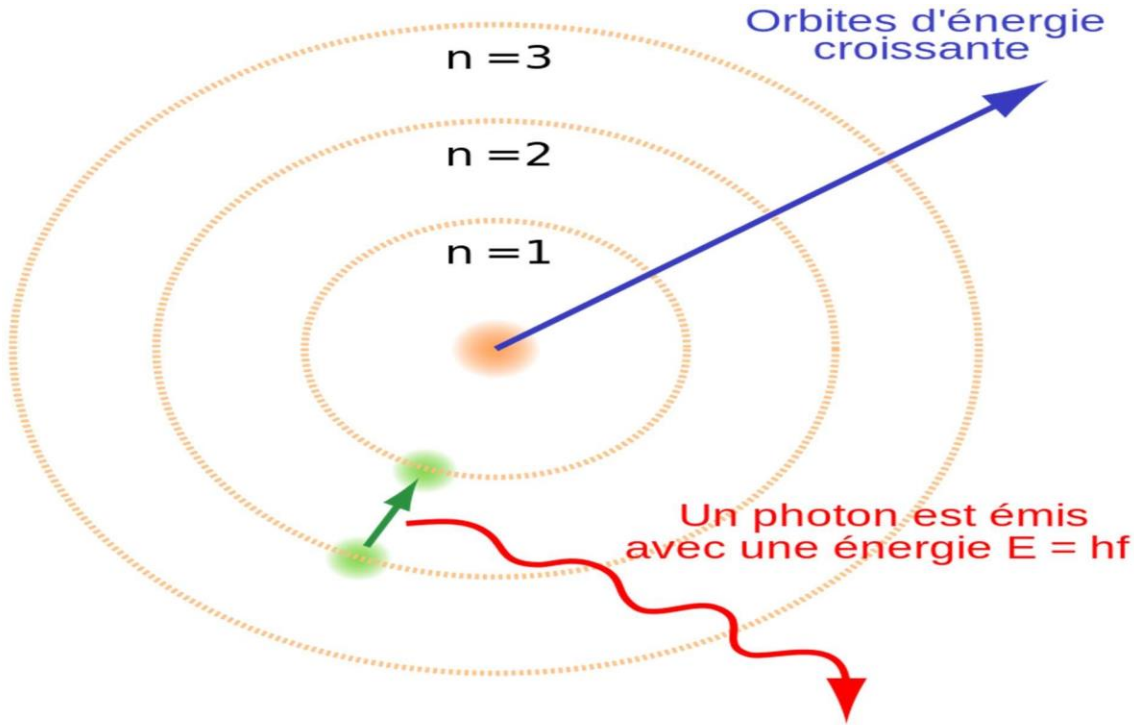


Figure 1Se atomic mode of Bohr, source: https://fr.wikipedia.org/wiki/Couche_%C3%A9lectronique

These energy levels are described and defined and are Schrodinger's equation solution stationary block theorem.

Stationary Schrodinger:

$$_{E\text{-}E}(x) - V(x)\ \psi_E(x) - \ \psi\ (x) \frac{2}{2N}$$

According to Block's theorem, the solutions are of form:

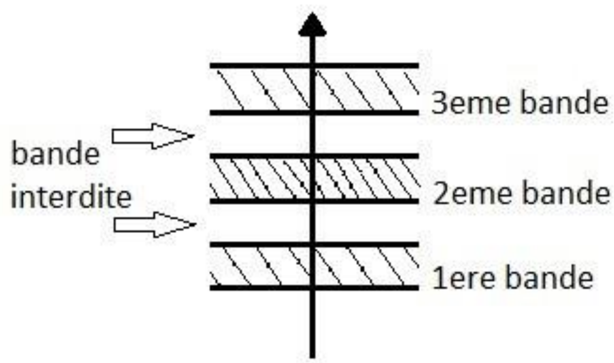
$$\Psi_k(x) = U_k(x)\ e^{iks}$$

$$U_k(x+a) = U_k(x)$$

With K: free electron wave vector.

We note E, the energy band that responds to the following expression:

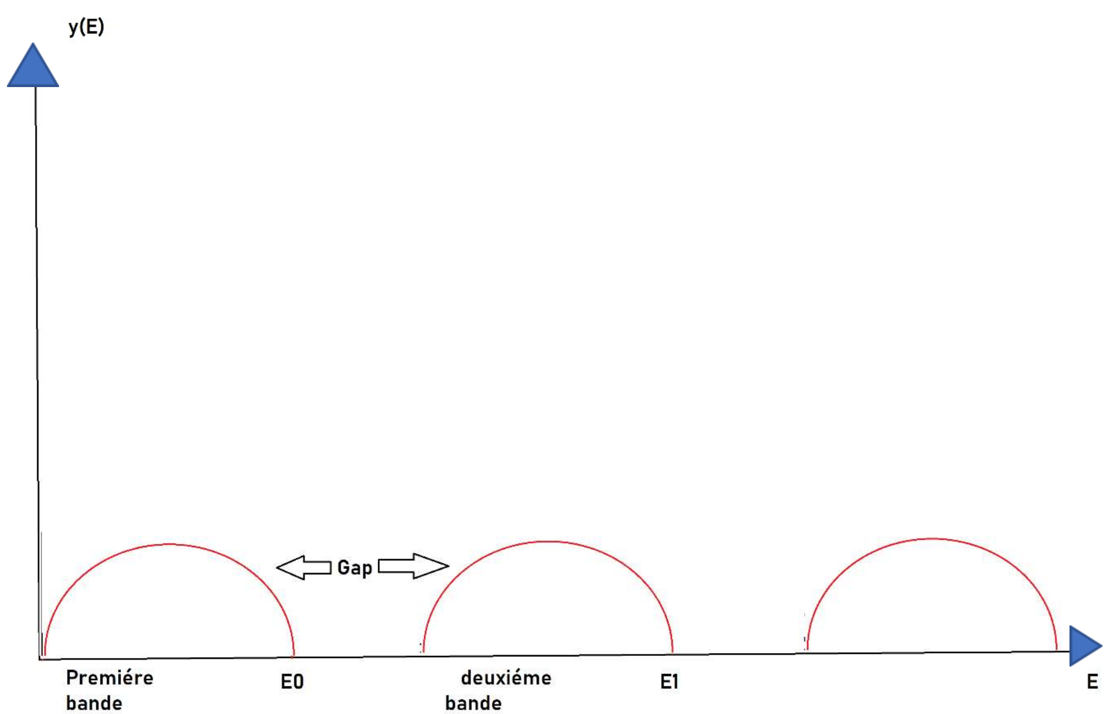
$$E\ (E) \frac{2k2}{2N}$$



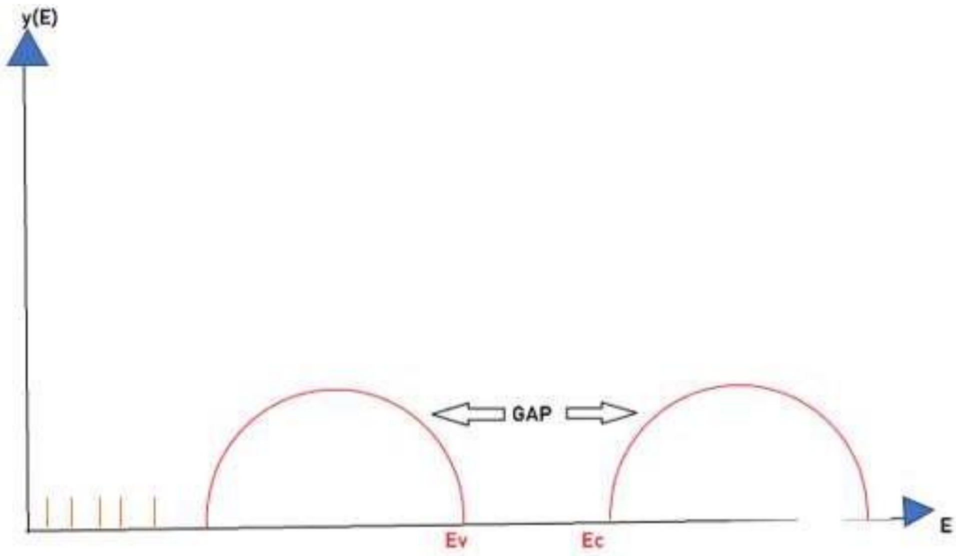
Energy state density is defined by:

$$y(A)\ \frac{Dn}{dE}$$

With N the number of energy state, and the look of y(E), according to the model ofKronig-Penney is:



In the case of a semiconductor, one has:



With:

Ev - the energy from the top of the valence band.
Ec - the energy at the bottom of the conductivity

band. Eg - Ec-Ev - the energy of the gap.

The gap defines the nature of the material, insulation, conductor, or semiconductor.

Electrical part:

The objective being to create a photovoltaic effect, it is necessary that the photon can transmit its energy to a valence electron, the latter will be torn from its initial atomic orbital, and therefore will no longer suffer the attraction of the atom (or very little), it results in an electron and a so-called free hole, if the electron and the hole do not "recombine" themselves, they will take opposite directions, their circulation then creates a current.

The phenomenon explained above cannot be achieved withs insulating materials, because in addition to the definition of these materials that do not contain or few load carriers, the gap between the valence layers is very large. Similarly with the so-called conductive materials but the reason is quite different, thesed erniers having a fairly high number of free electrons, this phenomenon would be unachievable.

The only material or gap has the right size to be penetrated by the energy of light that is given by the following formula:

$$E - E\frac{C}{ß}$$

Is the semiconductor.

Having created an electron and a hole is a necessary but sufficient condition to satisfy the realization of the desired phenomenon, there is no guarantee that these two elements will not "recombine", if any, thermal energy would have been obtained due to the movements of the charges.

In order to make these elements mobile, one can generate an internal electric magnetic field that we note E, by making a junction (a contact between two materials of different electrical properties). We will therefore create a semiconductor bar, one side will be doped N (electrons constitute the majority charge), and on the other side a doped P (holes constitute the majority charge).

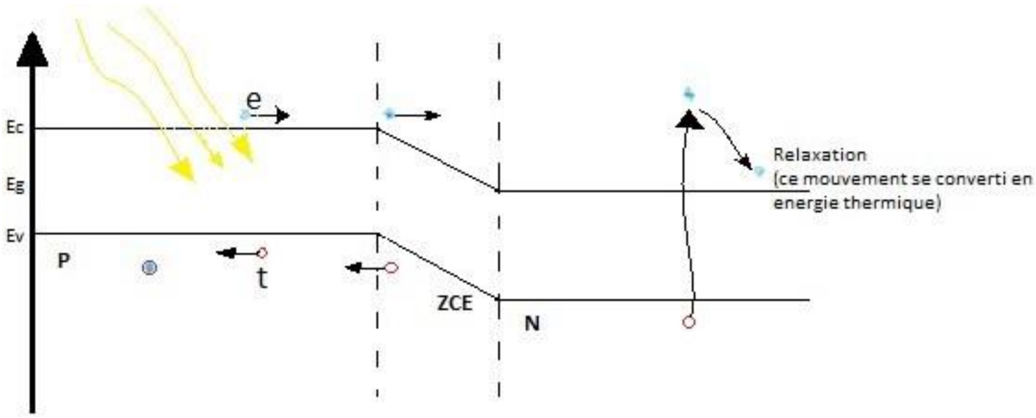
By doing this process, an internal electric field is created in the area where the Doped N side is in contact with its Doped P (difference in fixed load concentration), the area where this field is created is titled the charging area, or there are no free carriers.

Note: This field will prohibit the majority loads from crossing the junction, it will become a potential barrier.

When the junction is exposed to a light source, a current appears that is the result of the contribution:

Current broadcast:
Current due to distributions of minority loads that affect the space load area to the area where they majority by the E field.

Generation current:
The electron-hole pairs created by the photones in the space charge zone are separated by the E field, and the electrons go to the N zone, the holes towards the P zone.



In order to extract the loads from the semiconductor, two conductors are connected to the two ends of the material to create two poles and (-).

Note:

A simple achievement with this structure is not enough. We will therefore add to this structure a non-doped semiconductor because the P doped side is not a good driver photo.

It is therefore preferable that the photovoltaic effect occur in the pure and undoped intrinsic material. An exemachievement ple is shown in the figure below:

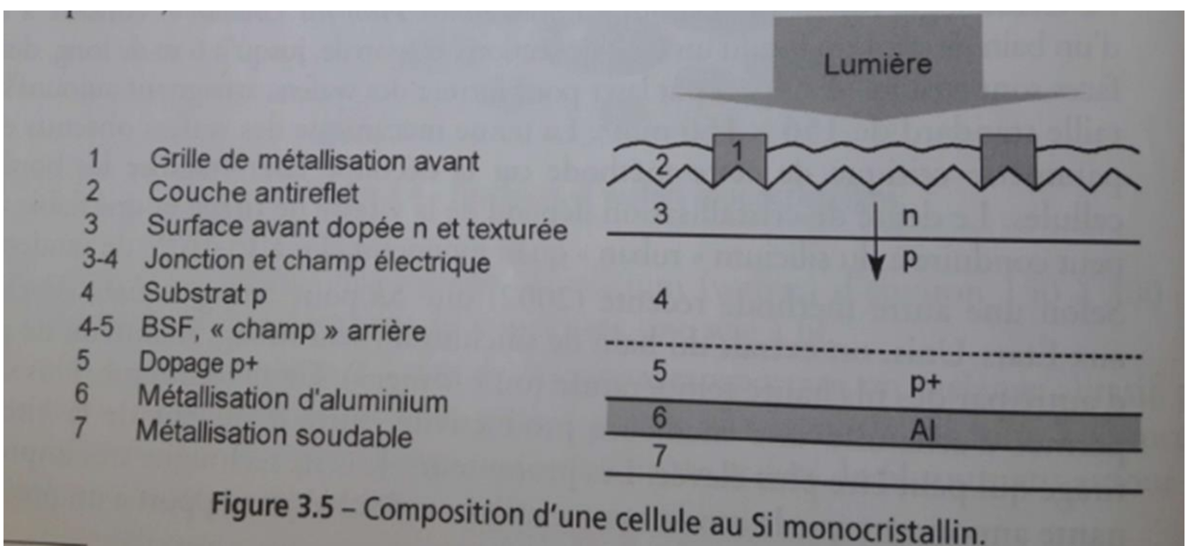
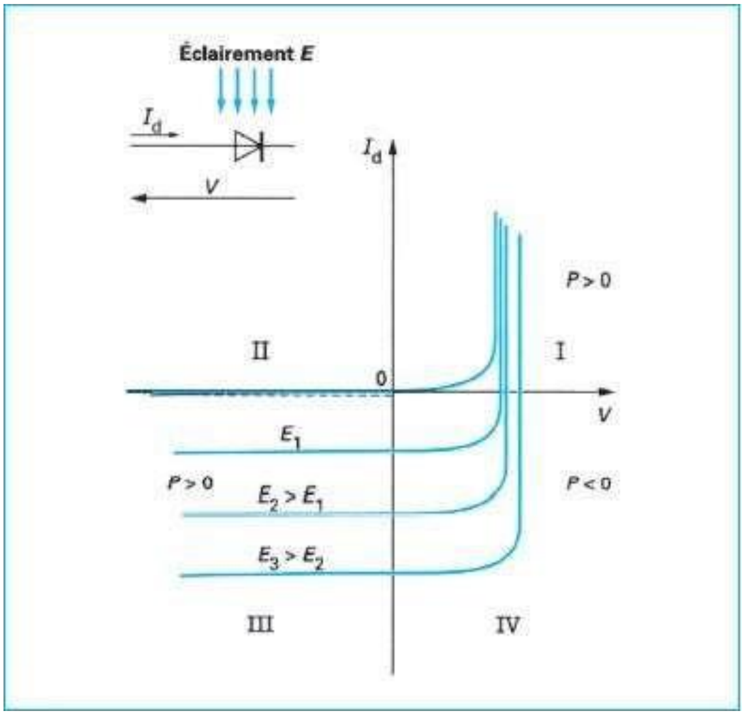


Figure 3.5 – Composition d'une cellule au Si monocristallin.

Figure 2 See reference

Analogy with the diode:

When a P-N junction is exposed to a light source, it has the behavior of a photodiode, so we will exploit the results of theerevastic curve in convention receiving a P-N junction, in darkness and light.



Quadrant I: Passing diode.

Quadrant II: Blocking diode, open circuit.

Quadrant III: The quadrant III zone is a receiver mode of operation, its resistance being variable depending on the illumination to a given voltage, this behavior is called resistive photo.

Quadrant IV: The area of the IV quadrant in agenerating mode, the light power has a direct proportionality relationship with the short-circuit current, it is a behavior in converter.

The short-circuit current is defined by the following formula:

$$I_{cc}'I_{ph}'\ q_e\ \eta\ \frac{\square_e}{C}$$

With: q_e: charge (C).

η: time constant (s^{-1}).

$\square_e$: Light flow (J)

Taking these physical considerations into account, we can deduce an equivalent model of an ideal photovoltaic cell.

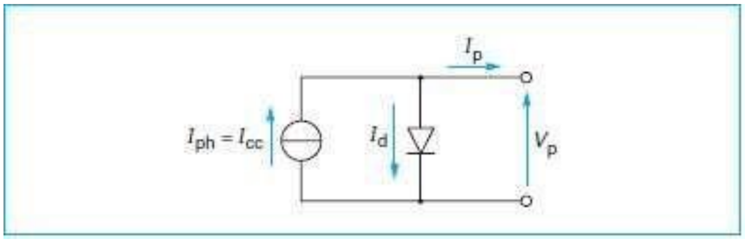


Figure 3 Reference 1

The current coming out of the photovoltaic cell rated I_p is the contribution of the short-circuit current Icc and the current passing through the diode $I_{d.}$

I d'i $_s(e^{\frac{7d}{7t}}$ - 1) avec $\frac{QDn\ NpO}{Ln}$ $\frac{qD\cancel{p\ \ pnO}}{Lp}$ and $V_T \frac{-}{Q}{}^{KT}$ where

i's

I'_s - Saturation Current.

K: Boltzmann's constant. T:

Temperature (Kelvin).

$V_{p:}$ Tension from the cell.

Q: Charge.
Dn: Broadcast constant. $Np_{0:}$
P.Ln load density: N.hj
zone length
Respectively for zone P.

Thanks to the formulas and demonstrations explained in this part of analogy, we can deduce the characteristic curve of a photovoltaic cell.

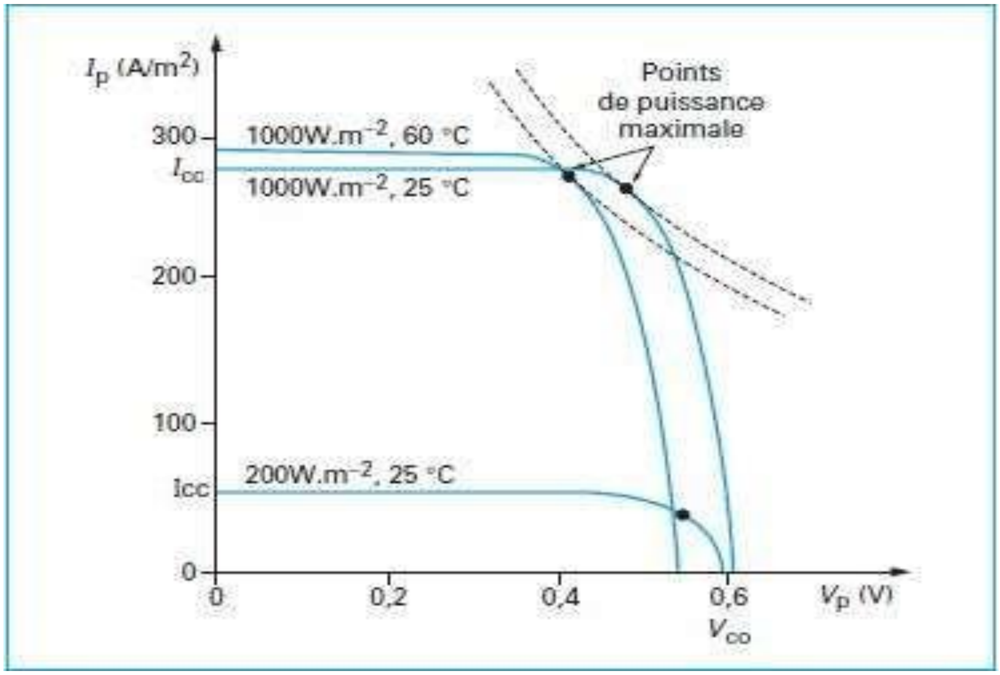


Figure 4 Reference 1

The power delivered by this cell is equal to the current voltage product, the latter is maximum when the product is maximum, as shown in the fig below:

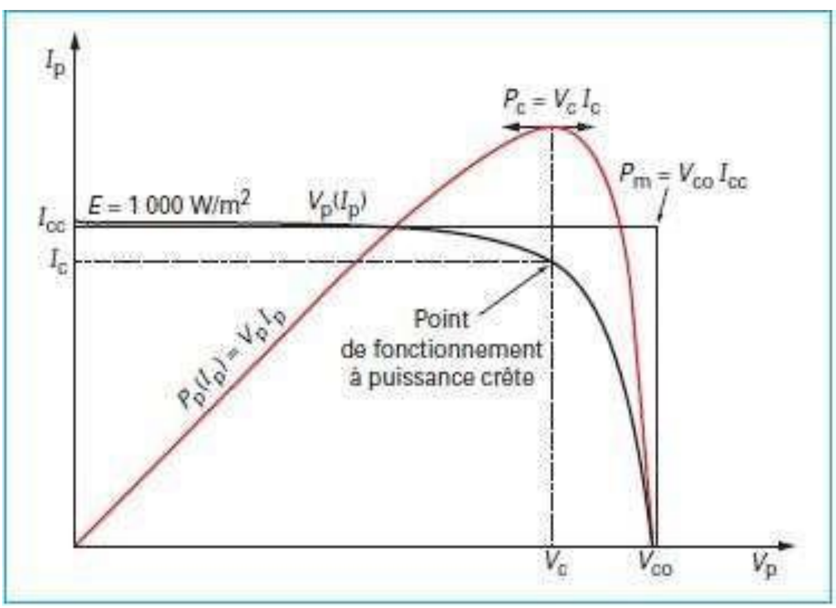


Figure 5 Reference 1

Photovoltaic system:

A cell of size: width 10cm, length 10 cm, and thickness 150- 300 m (values are order of magnitude), produces about 0.6V, 5A and 3W [see reference 7].

Note: These numbers vary depending on technology and manufacturing.

In general a cell is not sufficient, so depending on our needs we will associate the cells in series or in parallel in order to have the desired sizes.

Serial association:

By serial connection, the cells are traversed by the same current, and the final voltage is the sum of the voltages produced by each cell. The characteristic curve in this case becomes as below:

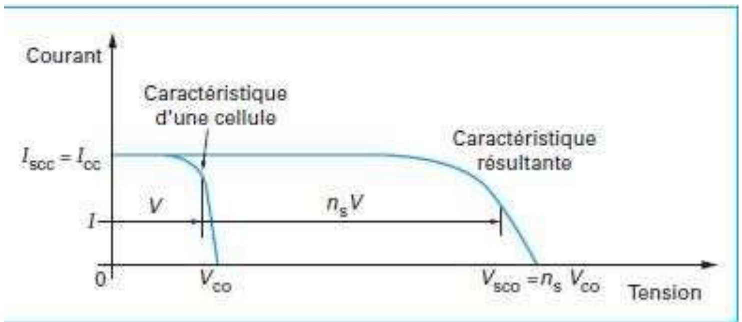
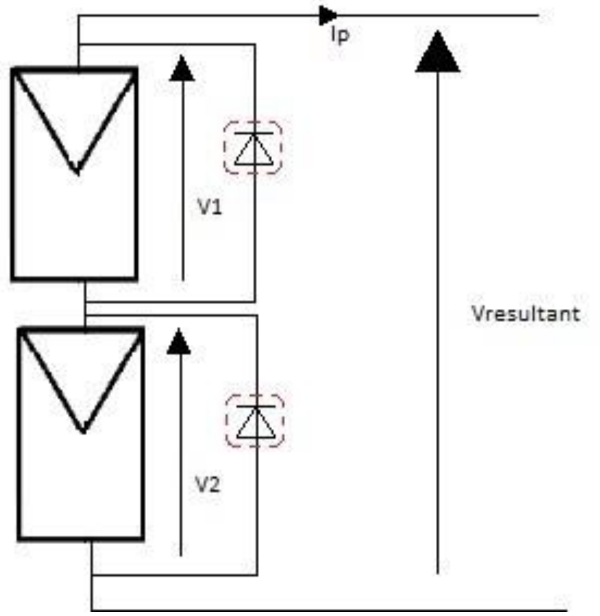


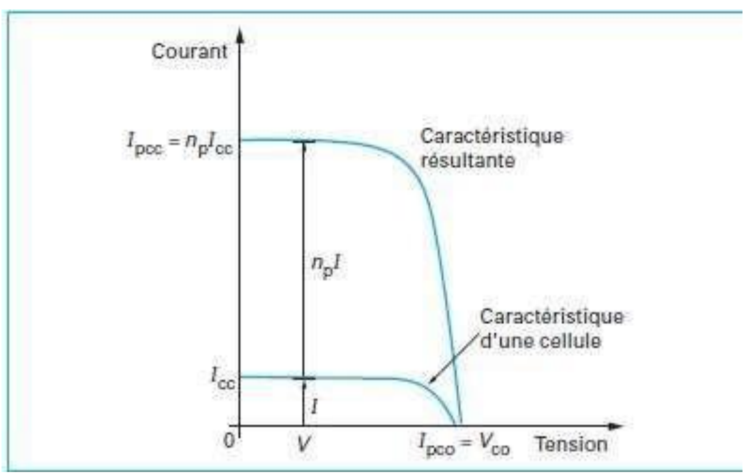
Figure 6 Reference 1

In this configuration, where the lighting cannot be uniform, the cells do not work in the same way. For example, during shading, the weaker cell becomes a receptor cell (traveled by reverse voltage) consuming the power produced by other cells. This can destroy the cell if the power and temperature become important. To avoid this problem we will put a diode in parallel with the cell, in other words a dioof by-pass. This diode prevents reverse tension in the cell.

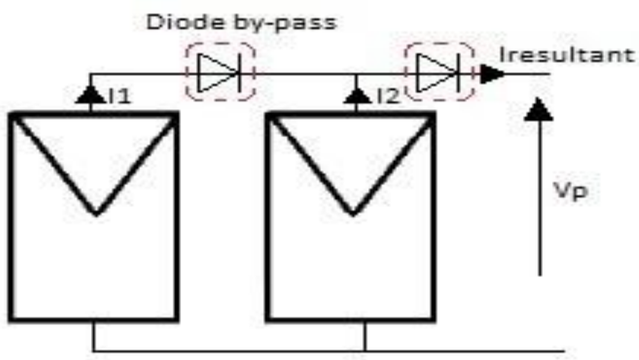


Parallel association:

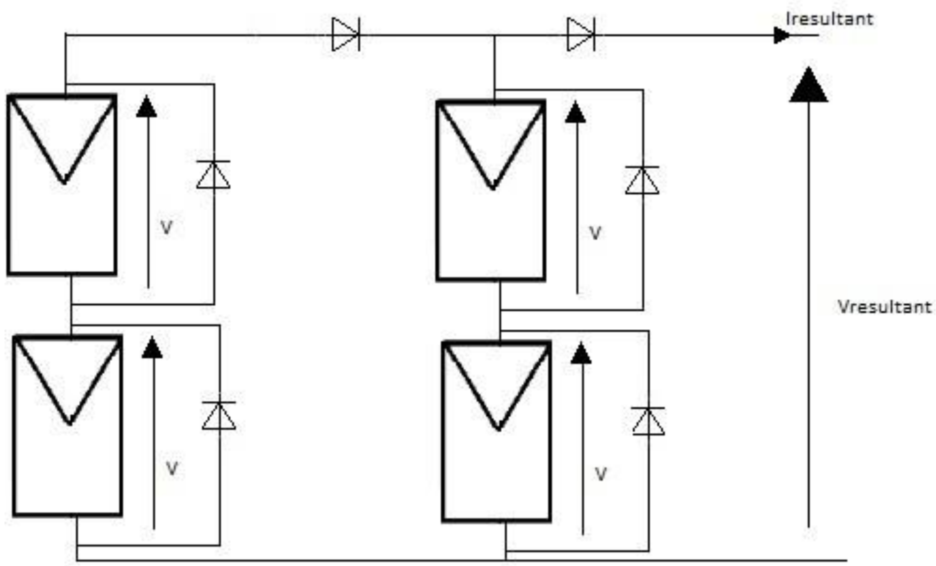
In order to increase the current, we will bind the cells in parallel. The cells have the same voltage and the final current is the sum of the courants produced by each cell. The characteristic curve becomes as below:



As in the serial association, the inconsistent lighting here is a problem. The weaker cell becomes receptor (using a reverse current)consumes the power produced by the other cells. To avoid this problem we will put a diode in series with the cell. This diode will prevent the reverse current from going through the cell in dark.



A panel is constructed of several associated cells in parallel or/and in series to be able to produce the necessary power.

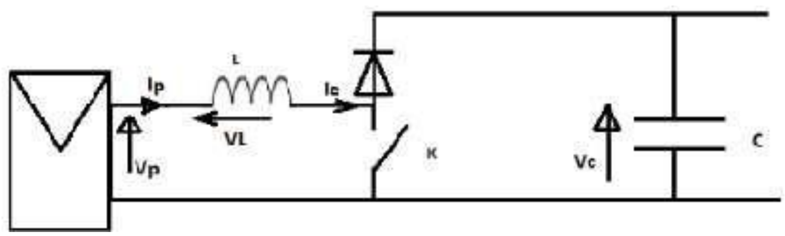


In the market the most used panels are the panels size 124cm-56cm, built of 36 cells. Like thepanels we're going to use for this project.

Converter:

In order to generate the transfer of energy between the photovoltaic panel and the battery (electric storage), we will use a DC/DC converter, called

Buck-boost or inducive storage chopper. The diagram of this device is as follows:



With the K switch, you can control the output voltage level. It shows that:

$$V_p \ - (1-\alpha) \ Vc$$

Or α represents the cyclical relationship.

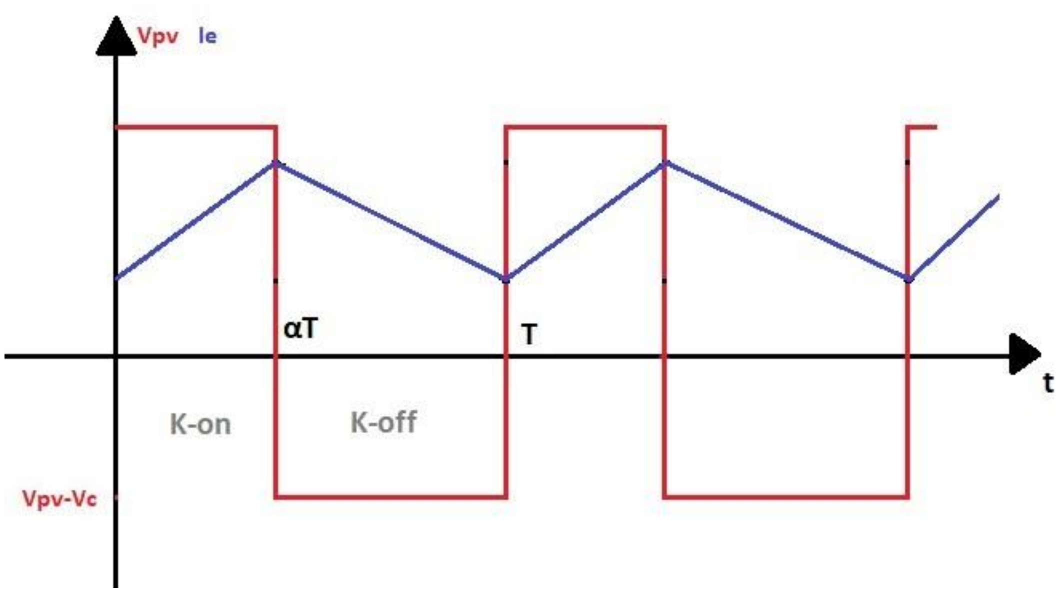
When K is closed:

$$L\frac{die}{Dt} V_{Pv}$$

When K is open:

$$L\frac{die}{Dt} - V_{PV} - V_C$$

We show the evolution of the voltage V_{PV}, and the current I_e, according to the time and states of the K switch, in the graph below.



The average voltage becomes:

$$V_{PV}\ \text{-T}\ \text{-}\ (V_{PV}\text{-}V_C)\ (\text{T-T})\ \ \text{-}$$

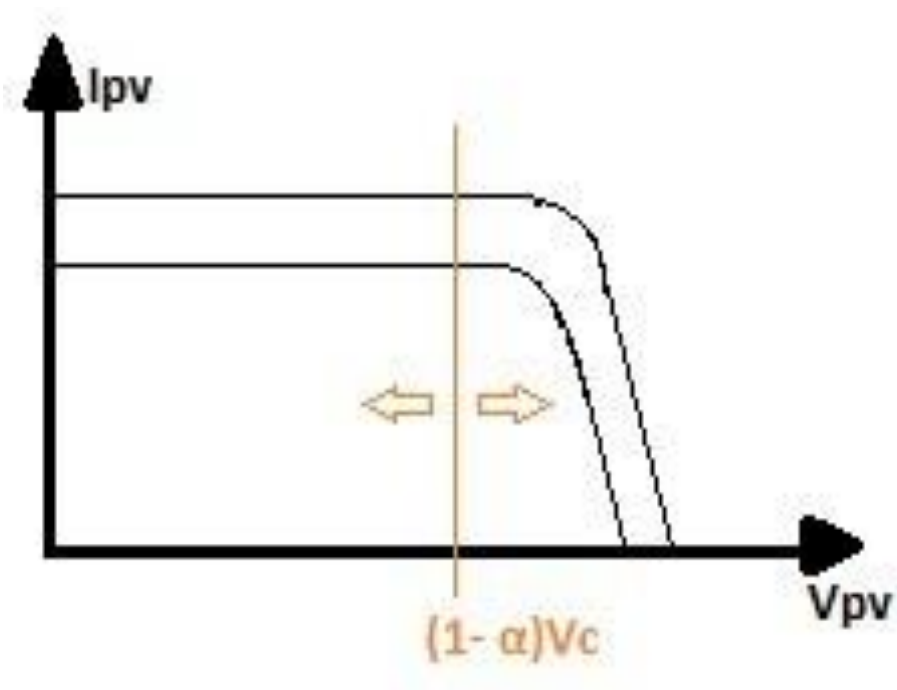
$$0\ V_{PV}\ \text{-T-T}\ (V_{PV}\text{-}V_C)\ (\text{T- T-}$$

$$\text{T)}$$

$$V_{PV}\ \text{-}\ (1\text{-}\alpha)\ VC$$

$$V_C\text{-}\frac{Vpv}{(A)}$$

As V_C (battery voltage) is fixed, then we will modify the cyclical ratio α ($0\leq\alpha\leq1$), to go through the characteristic curve and find the point where the power delivered by the PV is at its maximum.



Sizing the elements that make up the convertedeur **L** and **C:**

$$V_{PV}\ L\frac{Die}{Dt}$$

$$i_e\ \text{-}\ \frac{Vpv}{L}\ t\text{-}\ i_e(0)\ \text{with}\ i_e(0)\ i_{\ min}$$

$$V_{PV}\text{-}V_C\ L\frac{Die}{Dt}$$

$$i_e\frac{Vpv-Vc}{L}\ (\mathbf{t}\ \text{-}\ \alpha T)\ \text{-}I_{Max}$$

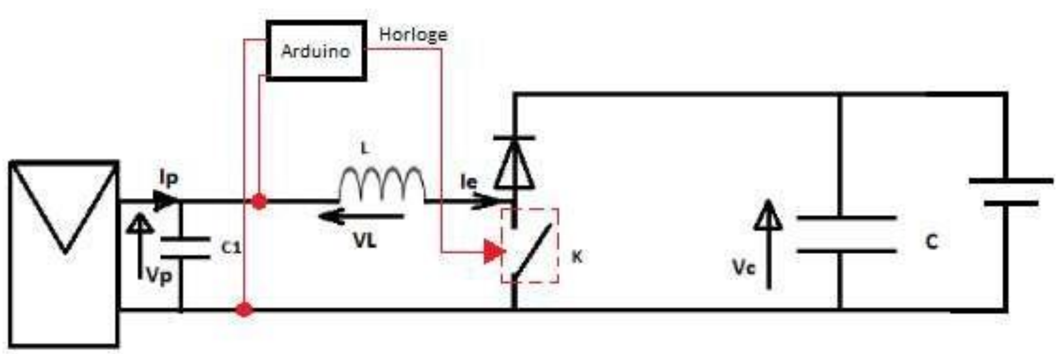
$$i_e(T)\ \text{-}\ \frac{VpvaT}{L}\ I_{min}$$

$I_{max}\ I_{min}\quad \frac{VpvaT}{L}$

$$\boxed{Th\frac{Vpv\text{-}T}{\text{It's a}}}$$

$\Delta QIt\Delta s\ A.D.c\ \boxed{C\text{-}\frac{\Delta Q}{\Delta V\,v}\quad \frac{Tt}{\Delta V_c}}$

The complete diagram of the editing we're going to use is:



Conclusion:

This bibliographical report was intended to provide us with the opportunity to address the subject that we will be studying in a few months within theframework of the TER, the understanding of the theoretical concepts was essential to the smooth running of the experimental part, or we will perform several tests on a photovoltaic panel and be able to study the yields according to the time of exhibitionition, light intensity and hours.

However, we have encountered some difficulties with regard to the algorithm specific to the realization of the converter, hoping to see more clearly during the weeks of realization and the advice of ourdials, Mr. Adrien MERCIER and Guillaume KREBS.

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