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# Photovoltaic panels measures

5$^{th}$ report

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# Index

# 1.   Introduction

This report will illustrate the laboratory experience, carried out on 12 May 2023, focused on the study of photovoltaic panels.
The collection of data took place inside the courtyard of the ITT Buonarroti (TN), during the afternoon with suitable weather conditions,direct sun exposure, positioning the panels appropriately with an inclination of approximately 37° facing northwest.
We underline how the duration of the collection of the values could slightly compromise the reliability of the measurements, this is mainly due to the variable exposure conditions of the panels to solar radiation over time and the variation of temperature of the panels that reached 44°C starting from around 28°C.
The report also contains the analisys of the data collected, the power output and an approximative extimation of the radiation.
PV cells are electrically connected in a module. PV panels vary in size and in the amount of electricity they can produce. PV panel electricity generating capacity increases with the number of cells in the panel or in the surface area of the panel. PV panels can be connected in groups to form a PV array. Photovoltaic cells generate direct current (DC) electricity. Nearly all electricity is supplied as alternating current (AC) in transmission and distribution systems. Devices called inverters are used to convert the DC to AC.
PV cells and panels will produce the most electricity when they are directly facing the sun.
Most PV systems have panels in a fixed position that are usually facing directly south in the northern hemisphere—directly north in the southern hemisphere, and at an angle that optimizes the physical performance of the system.
The maximum current is obtained in the short circuit configuration and the maximum voltage is obtained with the open circuit configuration.
Connecting the rheostats in series leads to a higher tension and a lower current and viceversa for the parallel.

# 2.   Pv panels theory



**Cross section of a solar cell**
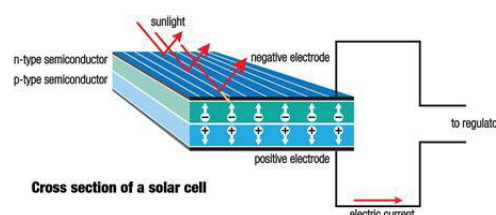
The main component of a PV Panel are the PV cells, a photovoltaic cell is a nonmechanical device that converts sunlight directly into electricity.
Sunlight is composed of photons, or particles of solar energy. These photons contain varying amounts of energy, called Quanta, that correspond to the different wavelengths of the solar spectrum.
A PV cell is made of semiconductor material.
When photons strike a PV cell, they may reflect off the cell, pass through the cell, or be absorbed by the semiconductor material. Only the absorbed photons provide energy to generate electricity. When the semiconductor material absorbs enough sunlight, electrons are dislodged

from the material's atoms. Special treatment of the material surface during manufacturing makes the upper surface of the cell more "receptive" to the free electrons so that the electrons naturally migrate to the surface of the cell.

The movement of electrons, each carrying a negative charge, toward the front surface of the solar photovoltaic cell creates an imbalance of electrical charge between the cell's front and back surfaces.

This imbalance, in turn, creates a voltage potential like the negative and positive terminals of a battery.

Electrical conductors on the cell absorb the electrons. When the conductors are connected in an electrical circuit to an external load, such as a battery, electricity flows through the circuit.

# 3.  Request

The objective of this activity was to survey the characteristics of three photovoltaic panels made with different technologies and from their comparison derive an estimate of the incident energy. In order to achieve this we collected the current and the tension generated by the three panels and write the values in Excell tables.

Using the voltamperometric measurements collected under the same condition and in different load configurations we were asked to trace the graph of the panels characteristics.

Using the graphs we traced and the ones in the datasheets we are requested to estimate the radiation on the panels.

# 4.  Wiring diagrams
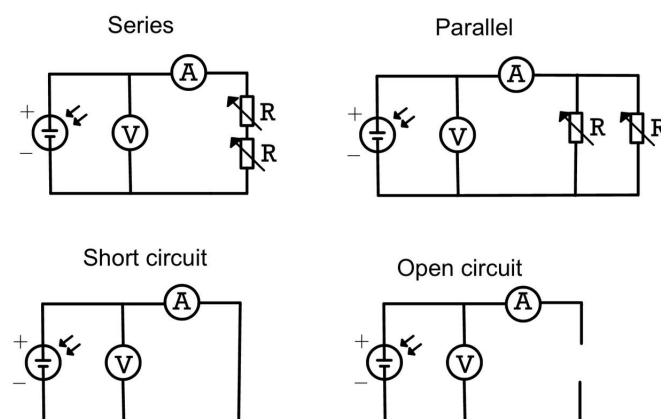
## 4.1 Equipment

- Connection Wires

- Benq PM245P00

- Panda 60 cells

- Sharp NA-E135L5 series

- 2x Rheostat 200Ω and 2,5A maximum

- 2x Multimeter

All the equipment is certificated and used in optimal condition.

# 5. Procedure

First of all even before starting the wiring process we calcuted the max current with the full resistance of the rheostat and the maximum current of the panels and we chose to put the ammeter in DC current with the maximum value mesurable at 20A.

For every panel we first connected the circuit in series and took the open circuit voltage, then we connected the rheostats in series and we took from 4 to 6 voltamperic measurements sliding the cursor further every time in order to change the resistance value.

Then we disassemble the circuit and we connect the rheostats in parallel, then we take more measurements than the series, about 14, sliding forward the cursor as before.

When sliding the cursor is important to check the current value because it doesn't have to increase over 4,5 amps, doing so avoids the generation of overcurrents therefore the risk of damage for the equipment.

To achieve the best graph we tried to move the cursor by the same distance every measure and to have a reguar number of points in all the lenght of the curve.

We tried also to avoid shades as much as possible and we avoided aking measurements if the sun was temporarily covered by passengers clouds.

The temperature reached by the panels after the measurements was of 44°C that is completely in their optimal condition according to the panel's datasheets.

# 6. Tables

## 6.1 Benq PM245P00

| Voltage [V] | Current [A] | Power [W] |
|---|---|---|
| 33,7 | 0 | 0 |

Table 1: Open circuit

| Voltage [V] | Current [A] | Power [W] |
|---|---|---|
| 33,6 | 0,007 | 0,2 |
| 33,4 | 0,009 | 0,3 |
| 33,2 | 0,11 | 3,7 |
| 33,2 | 0,15 | 5,0 |

Table 2: Series

| Voltage [V] | Current [A] | Power [W] |
|---|---|---|
| 33,2 | 0,3 | 10,0 |
| 33 | 0,36 | 11,9 |
| 33 | 0,41 | 13,5 |
| 33 | 0,46 | 15,18 |
| 33 | 0,53 | 17,5 |
| 32,9 | 0,6 | 19,7 |
| 32,8 | 0,7 | 23,0 |
| 32,6 | 0,86 | 28,0 |
| 32,5 | 1,18 | 38,4 |
| 32,1 | 1,77 | 56,8 |
| 30,1 | 4,08 | 122,8 |
| 29 | 4,26 | 123,5 |

Table 3: Parallel

| Voltage [V] | Current [A] | Power [W] |
|---|---|---|
| 0 | 5,45 | 0 |

Table 4: Short circuit

## 6.2 Panda 60 cells

| Voltage [V] | Current [A] | Power [W] |
|---|---|---|
| 35,5 | 0 | 0 |

Table 5: Open circuit

| Voltage [V] | Current [A] | Power [W] |
|---|---|---|
| 34,9 | 0,07 | 0,2 |
| 35 | 0,08 | 2,8 |
| 35,1 | 0,09 | 3,2 |
| 35,1 | 0,1 | 3,5 |
| 35,2 | 0,11 | 3,9 |

Table 6: Series

| Voltage [V] | Current [A] | Power [W] |
|---|---|---|
| 34,8 | 0,3 | 10,4 |
| 34,8 | 0,34 | 11,8 |
| 34,8 | 0,36 | 12,5 |
| 34,7 | 0,41 | 14,2 |
| 34,7 | 0,45 | 15,6 |
| 34,6 | 0,54 | 18,7 |
| 34,5 | 0,7 | 24,2 |
| 34,4 | 0,94 | 32,3 |
| 34,2 | 1,18 | 40,4 |
| 33,8 | 1,74 | 58,8 |
| 33 | 2,8 | 92,4 |
| 32,5 | 3,26 | 106,0 |
| 32 | 3,8 | 121,6 |
| 31,9 | 3,97 | 126,6 |

Table 7: Parallel

| Voltage [V] | Current [A] | Power [W] |
|---|---|---|
| 0 | 6,68 | 0 |

Table 8: Short circuit

## 6.3 Sharp NA-E135L5 series

| Voltage [V] | Current [A] | Power [W] |
|---|---|---|
| 56,9 | 0 | 0 |

Table 9: Open circuit

| Voltage [V] | Current [A] | Power [W] |
|---|---|---|
| 56,1 | 0,12 | 6,7 |
| 56 | 0,14 | 7,8 |
| 55,9 | 0,17 | 9,5 |
| 55,8 | 0,22 | 12,3 |
| 55,6 | 0,29 | 16,1 |
| 55,1 | 0,48 | 26,4 |

Table 10: Series

| Voltage [V] | Current [A] | Power [W] |
|---|---|---|
| 55,3 | 0,51 | 28,2 |
| 55,2 | 0,56 | 31,0 |
| 55,2 | 0,63 | 34,8 |
| 54,9 | 0,71 | 39,0 |
| 54,5 | 0,81 | 44,1 |
| 54,2 | 0,93 | 50,4 |
| 53,3 | 1,13 | 60,2 |
| 52,2 | 1,37 | 71,5 |
| 50,2 | 1,72 | 86,3 |
| 42,8 | 2,2 | 94,2 |
| 22,8 | 2,34 | 53,4 |

Table 11: Parallel

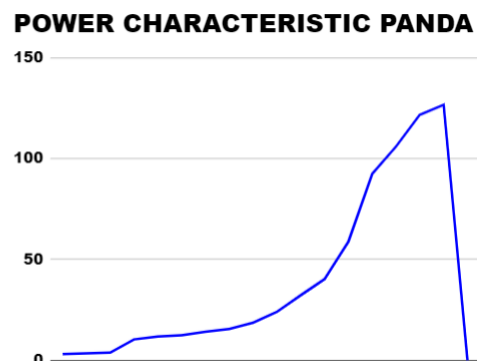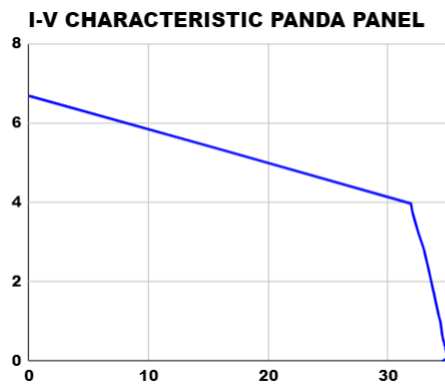| Voltage [V] | Current [A] | Power [W] |
|---|---|---|
| 0 | 2,45 | 0 |

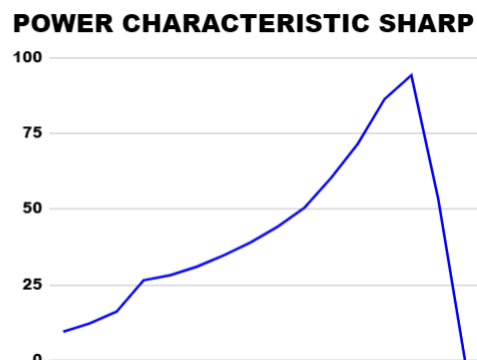Table 12: Short circuit
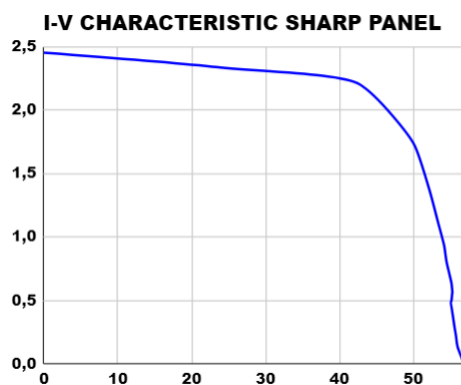
# 7. Graphs

## 7.1 Benq PM245P00
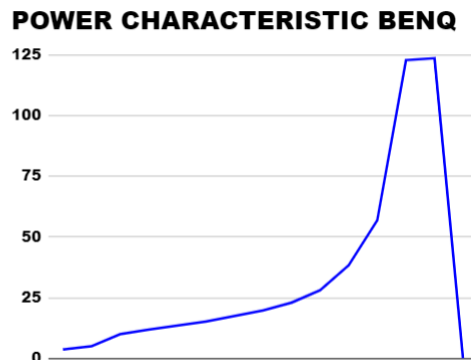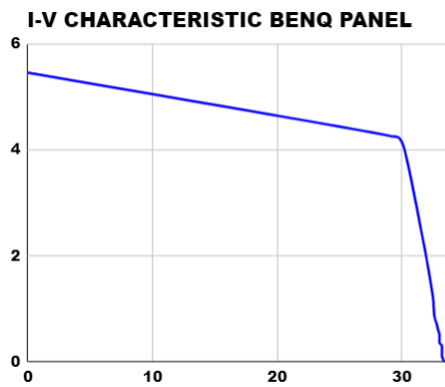




## 7.2 Panda 60 cells





## 7.3 Sharp NA-E135L5 series

# 8.   Data analisys

From the graphs we can see that the panel that produces the greatest current is the *Panda 60 cells* and the *Sharp* produces more tension of them all, however the greatest power output is generated by the *BenQ*.
Because the power is calculated with $P = V \cdot I$ and is greater in the *BenQ* because it has a more logaritmic shaped graph so the voltage and current are at their maximum value for more measurements that the other two panels.
Instead we can see how the *Sharp* and *Panda* graphs lines deacrease rapidly as the voltage increases.
After overlapping the two curves we notice that the maximum power is generated in the middle of the I/V curve's "knee", in other words when it start to decrease significantly. That proves what said before, because the power is at its highest when the product between the two values are at the maximum even if it is difficult to see in the graphs because they are inversely proportional.

## 8.1   Radiation

Traced the graph we were able to hypothesize the amount of light that was reaching the panelr in other words the radiation.
We did this comparing our graphs with the datasheet's one that have multiple curves for different radiation we used the maximum value of current for reference.
Only the graphs of the *BenQ* and the *Sharp* were provided, in both graphs our maximum current was between the $800 \ W/m^2$ and the $600 \ W/m^2$ or $500 \ W/m^2$ one, but it was surely closer to the $800 \ W/m^2$ curve so after doing an approximate average we came to the conclusion that the radiation was $730 \ W/m^2$.

# 9.   Conclusions

After the analysis wrote above the graphs are approximately similar to what we expected, that means that the measurements were taken correctly at the right conditions.
The request was fulfilled with success.