

International Program

Josep Bosch Quiles

Index

Summary	1
Renewables energies	1
Geothermal Heat and Power	2
ATC (air traffic control).....	3
Annex	4

Summary

The international program is a program of the University of Applied Sciences of Karlsruhe, in which some courses are offered of different branches. I study the degree of mechanical engineering, the courses that I choose for this semester are about renewable energy because I think the degree of mechanical engineering lacks these skills. The courses I have studied are: "Renewable energy" and "Geothermal Heat and Power " these are courses that have made me acquire the knowledge necessary for a proper understanding of mostly all the different sources of energy. I have also completed two courses in German becoming an A2 level at the end of the semester, necessary for everyday life in a German city. Finally, thanks to the course of ATC (air traffic control) my understanding on air traffic has gone up a lot, qualities that I appreciate a lot for my future as I would like access to a master of aeronautics.

In short, the international program has allowed me to increase my skills in the branches that my grade have not available.

Renewables energies

Subject part of the international program certificate, this subject shows all the different forms of renewable energy and allows you the know the strongness and weakness of all the different kinds of energy. Power economics, conventional technologies for power generation, technologies for using renewable sources (sun, wind, water, biomass, geothermal heat), storage technologies, hydrogen economic.

Coming up next, the summary of the course contents is showed

1 Energy

2 Energy Demand

2.1 Worldwide

2.2 European Union

2.3 Germany

- 3 Solar Energy
 - 3.1 Photovoltaics
- 4 Hydro Energy
 - 4.1 Hydroelectric Plants
 - 4.2 Tidal Power
 - 4.3 Wave Power
- 5 Wind Energy
 - 5.1 Modern Wind Turbines
 - 5.2 Offshore Wind Energy
- 6 Bioenergy
- 7 Geothermal Energy
 - 7.1 Geothermal Heat Pumps
 - 7.2 Heat of Aquifers
 - 7.3 Drilling into magma Bodies
 - 7.4 Hot Dry Rock Technology
- 8 Energy Storage Systems
- 9 Hydrogen Economy
- 10 Conversion Factors for Energy

Geothermal Heat and Power

Subject part of the International program, this subject allows you to acquire deeper knowledge of this way of energy production. This energy is not common in Spain but it is very common in Germany. Within this subject I visited a Geothermal power plant in Insheim. This course allows you to get an overview about the geological, technical, infrastructural und commercial aspects of initiating, building and running geothermal heat and power plants. We consider examples in different countries and continents.

Coming up next, the summary of the course contents is showed

1. Energy, Geology, Tectonics
2. Geothermal reservoirs, ORC
3. Drilling technologies
4. Exploration methods
5. Hydrogeology and modelling

6. Heat pumps

ATC (air traffic control)

Aeronautical course for mechanical engineers, lot of content of how the navigation in the air space is working. This course allows me to visit an upper space controller office in Karlsruhe, talking and asking real airspace controllers, very useful for the understanding of the air traffic control.

Coming up next, the summary of the course contents is showed

1. Organizations and Authorities in Aviation
2. Legal Basis for Aviation and Air Traffic Services
 - 2.1. German Laws and Regulations for Aviation
 - 2.2. Legal Requirements for Air Navigation Services
 - 2.3. Air Navigation Services
 - 2.4. Air Traffic Services
 - 2.5. Air Traffic Control Service
 - 2.6. Flight Information Service
 - 2.7. Alerting Service
 - 2.8. Aeronautical Information Service
3. Aeronautical Publications
 - 3.1. ICAO Documents
 - 3.2. Aeronautical Information Publication AIP
 - 3.3. Nfl
 - 3.4. NOTAM
4. Units of Measurement
5. Altimetry
6. LuftVO/SERA
7. Airspace Structure
 - 7.1. Lower/Upper Airspace
 - 7.2. Flight Information Regions
 - 7.3. Airspace Classes
 - 7.4. Airspace E
 - 7.5. Uncontrolled Airspace

7.6. Special Use of Airspace

8. Flight Plan

8.1. Purpose of a Flight Plan

8.2. Obligation to File a Flight Plan

8.3. Contents of a Flight Plan

8.4. Flight Plan Associated Messages

8.5. Flight Plan Form

8.6. Flight Plan Filed

9. Abbreviations and Codes

Annex

1. Geothermal heat and power group homework.
2. Geothermal heat and power presentation "Geothermal exploration".
3. Renewable energy "report transmission lines"
4. Renewable energy "report solar module"

Homework Geothermal heat and power

Josep Bosch Quiles

Lesson 1

A well provides 70 liters of water every second, the electro-submersible pump ($\eta = 80\%$) has to lift it 450 meters high.

1) Which amount of mechanical Energy is necessary for the lifting procedure?

Mechanical energy is the sum of potential and kinetic energy. Considering only the potential energy is being used in this case,

$$E_p = m \cdot g \cdot h = 70 \cdot 1.013 \cdot 9.81 \cdot 450 = 309,015 \text{ KJ}$$

2) How much power is required for the ESP?

In 1 second the ESP have to consume this energy, but we have to consider the efficiency.

$$309,015 \text{ KJ} \times 1 \text{ sec} \cdot (1/0.8) = 386.268 \text{ KW}$$

3) How much fuel does a diesel engine ($\eta = 35\%$, power supply of 10,2 kWh/l) consume hourly?

Considering the energy necessary (309015 J) and converting it to kWh

($1 \text{ J} \rightarrow 2.78 \cdot 10^{-7}$). We can know the consumption with energy times power supply, considering the efficiency of the engine.

$$309015 \text{ J} \times 2,78 \cdot 10^{-7} \text{ kWh} \times (1/0.35) \times (1/10,2 \text{ kWh/l}) = 0.024 \text{ l}$$

4) How much thermal energy will be emitted by the diesel generator?

The amount of energy produced by the engine that is not converted to mechanical energy, is transformed to heat, so the amount of with would be

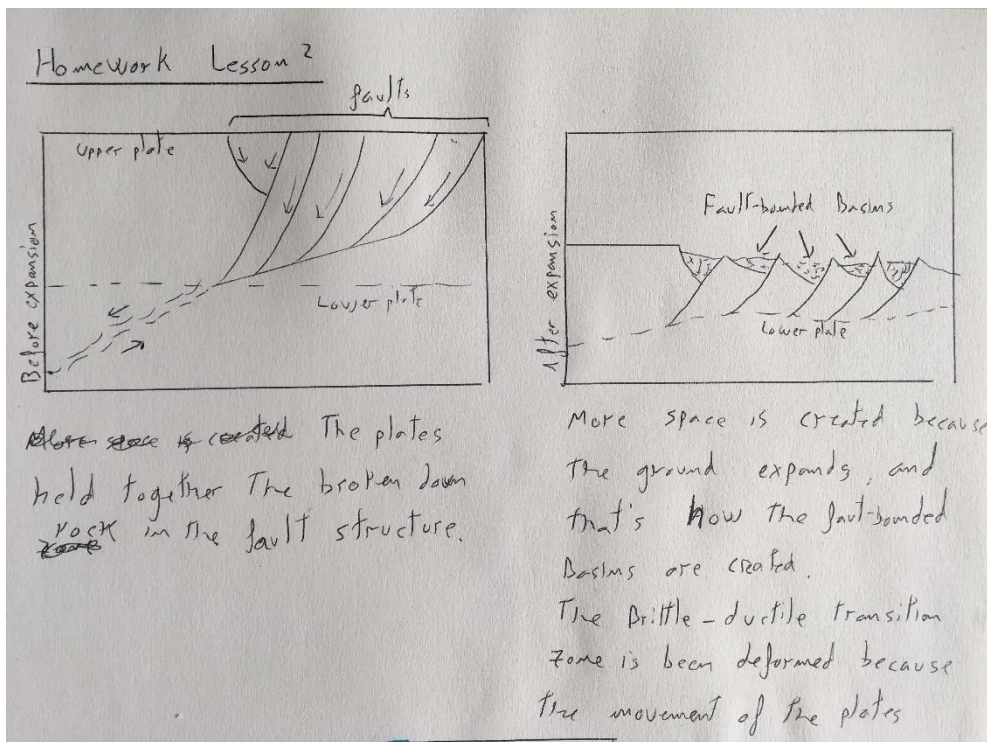
65%. With the consumption and the power supply we can know the amount of thermal energy.

$$10.2 \times 0.024 \times 0.65 = 0.159 \text{ kWh}$$

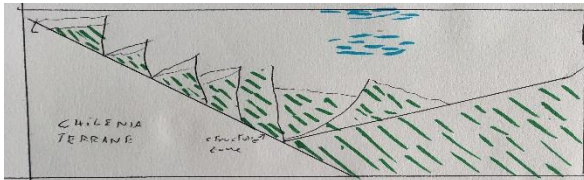
Lesson 2

Cuyo Basin, Argentina is located east of the Andes. Plate tectonics states this area to be a subduction zone of the Nazca Plate.

1) Study Fig. 1 concerning the direction of movement of the rocks.



2) Explain by means of Fig. 1 and the Expanding Earth Theory how the Cuyo Basin (Fig. 2) was formed. Depict the original state before the expansion and the process of movement in sketches.



Cuyo Basin was formed because the separation of the tectonic plates. The fractured rock of the crust are sink in the ground because of the separation.

Geothermal seismic exploration

Josep Bosch Quiles

Geothermal heat and power

Hochschule Karlsruhe - Technik und Wirtschaft

INDEX

▶ Geothermal exploration

▶ Exploration methods

- ▶ Drilling

- ▶ Geochemical

- ▶ Geophysical

 - ▶ SEISMIC EXPLORATION

 - ▶ PASIVE

 - ▶ ACTIVE

 - ▶ SEISMIC REFRACTION

 - ▶ SEISMIC + OTHER TECHNIQUES

GEOHERMAL EXPLORTION

- ▶ As much as 42% of all expenses associated with geothermal energy production can be attributed to exploration.
- ▶ Cost effective regions to drill and already constituted plumbing systems inherent within the subsurface.
- ▶ The process involves developing a conceptual model of the subsurface with the surface geology to identify specific drilling targets.
- ▶ Exploration methods include a big range of disciplines including drilling, geophysics, geochemistry and engineering.

EXPLORATION METHODS

▶ DRILLING

- ▶ Accurate { Temperature gradients, thermal pockets and other geothermal characteristics can be measured directly after drilling, providing valuable information.
- ▶ Expensive { The first wildcat well has a success rate of 25%. Following more analysis and investigation, success rates then increase to a range from 60% to 80%.
- ▶ Geothermal exploration wells rarely exceed 4 km in depth
- ▶ Most consultants and engineers consider exploration to continue until one production well is completed successfully

EXPLORATION METHODS

▶ Geochemistry

- ▶ Relate surface fluid properties and geologic data to geothermal bodies
- ▶ Geothermometers and other instrumentation are placed around field sites to increase the fidelity of subsurface temperature estimates
- ▶ Geochemical techniques can be used to determine subsurface temperatures when hot springs are present.
- ▶ Temperature-gradient holes can be used to project subsurface temperatures below the level of drilling

EXPLORATION METHODS

- ▶ Geophysical
 - ▶ Geophysical tools are also used to determine the approximate size of the reservoir.
 - ▶ Geophysical methods that can determine fracture intensity are of great importance to the explorationist.
 - ▶ Geophysical methods can help locate permeable structures with high-temperature water or steam and estimate the amount of heat that can be withdrawn from the ground in a given time period.
 - ▶ Gravity, magnetics or **seismology**.

Geophysical

- ▶ “Seismic, gravity and magnetotelluric methods combine to answer key economic questions for geothermal resource development”



GHEOPHYSICAL: Seismology

- ▶ Seismology has played a significant role in the oil and gas industry
- ▶ Seismic waves propagate and interact with subterranean components and respond accordingly
- ▶ The significance of these events, or of their absence, depends on the specific setting of the geothermal system being examined.
- ▶ Seismicity can provide information about the tectonic setting in which the geothermal system occurs

GHEOPHYSICAL: Seismology

- ▶ Where integral methods show average measurements of high accuracy but poor location precision, differential methods attain localized Advanced seismic imaging for geothermal development measurements with poor accuracy, but excellent location precision.
- ▶ Differential methods produce data related to changes in rock properties over short distances
- ▶ A modern seismic-reflection survey might not be able to distinguish whether a fault zone is 50 or 100 meters wide, but it will be able to locate the center of the fault zone with a precision of 100 meters or better, within a geothermal reservoir at 1-2 km depth.

GHEOPHYSICAL: Seismology

- ▶ Microearthquakes can also be useful to constrain the processes occurring during operations in a field.
- ▶ Exploration seismology has historically not been successful in delineating economic geothermal fields

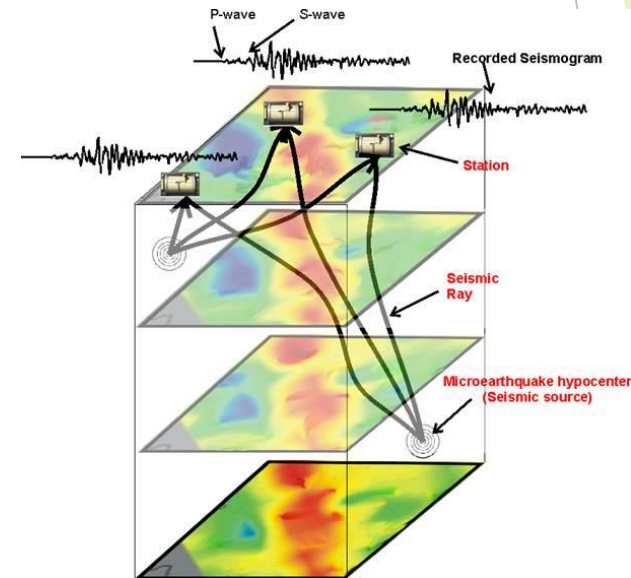
- ▶ Two different ways
 - ▶ Active seismology relies on using induced/man-made vibrations at or near the surface
 - ▶ Passive seismology uses earthquakes, volcanic eruptions or other tectonic activity as sources.

GEOPHYSICAL: Active Seismology

- ▶ Has history in the oil and gas industry
- ▶ Man made vibrational wave propagation.
- ▶ Seismic sensors are spread across the study site
- ▶ Basic principles can be used to identify subsurface anomalies, reflective layers and other objects with high impedance contrasts.

GEOPHYSICAL: Passive Seismology

- ▶ Use natural wave propagation through the earth
- ▶ Geothermal fields are often characterized by increased levels of seismicity
- ▶ Earthquakes of lesser magnitude are much more frequent than ones of larger magnitude
- ▶ For fluids to keep moving from hot regions toward cooler regions, microseismicity must occur to keep fractures open.



GEOPHYSICAL: Passive Seismology

- ▶ Passive seismic techniques for the detection of microseismicity have long been used to explore for geothermal fields.
- ▶ Several fields, have little or no detectable seismicity, and for others we do not know whether there was seismicity before production began.
- ▶ Passive seismic observations are also used to generate velocity images of the crust.
- ▶ By simultaneously solving for the earthquake locations, time, and the velocity and attenuation structures, three-dimensional (3D) images of geothermal fields can be developed

GEOPHYSICAL: Passive Seismology

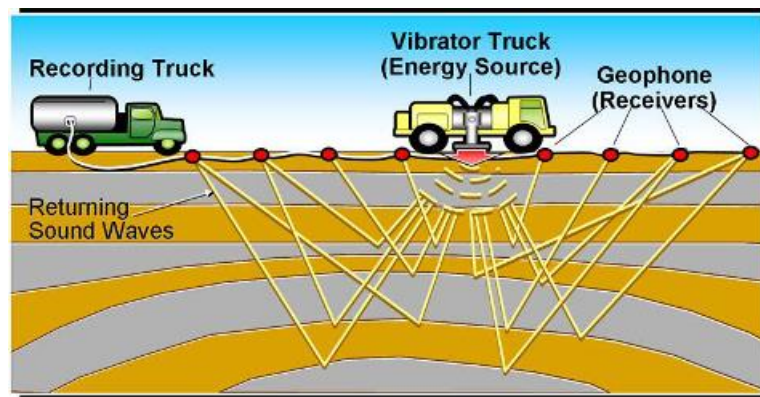
- ▶ Inferences about steam saturation and porosity can be drawn by comparisons of the P- and S-wave images or by comparing the velocity and attenuation images
- ▶ The velocity image provides valuable information about the structure as well as improving the imaging of discrete reflectors.
- ▶ Using state-of-the-art tools for 3D subsurface imaging, is it possible to map the underground geologic structures and fluid pathways. Each investigation adds information, refines the image, and reduces economic risk.

Seismic Refraction

- ▶ Common applications include:
 - ▶ Mapping depth to bedrock and bedrock topography
 - ▶ Providing elastic properties of the subsurface for engineering design
 - ▶ Calculating the subsurface velocity profile
 - ▶ Mapping subsurface water table in sediments
 - ▶ Identifying fault locations and weak rock zones
 - ▶ Determine permeability of hard rock prior to construction
 - ▶ Mapping slide planes of active landslide

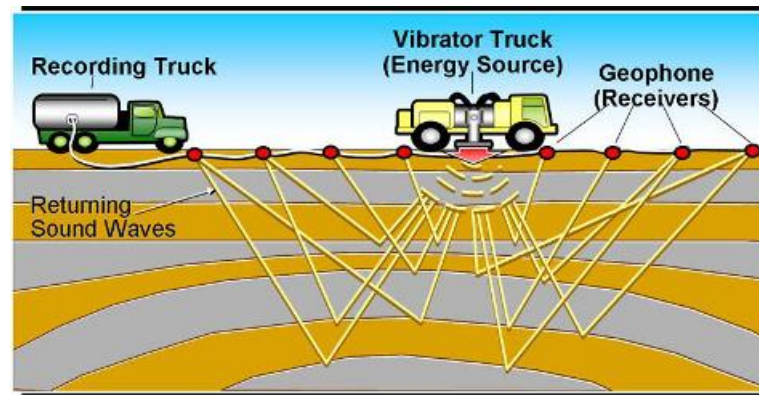
Seismic Refraction

- ▶ The seismic refraction method requires three components:
 - ▶ a controlled shot of seismic energy (source)
 - ▶ sensors to receive the energy (geophones)
 - ▶ A central data recorder (seismograph) connected via radio links or cabling.



Seismic Refraction

- ▶ The transmitted energy is recorded at each geophone along the seismic line.
- ▶ A hammer blow or explosive charge (the shot) generates a shock wave which travels through the earth by refraction along material boundaries.
- ▶ The energy received at the surface by an array of sensors or geophones is analyzed for structure and velocity.



Seismic Refraction

- ▶ The time at which the energy is received at the surface is analyzed for structure and velocity.
- ▶ Seismic data may be modeled using either layer-based or tomographic techniques
- ▶ Each method has its own strengths and weaknesses, and data collection parameters, thus should be determined prior to data collection to meet the objectives of the project.
- ▶ Data is typically presented in simple cross section highlighting the interface between soil and hard rock.

Seismic + other techniques

- ▶ Integrated modelling and interpretation of gravity, seismic, and MT data provides significantly more information than any method used independently and helps answer key economic questions related to flow rate, temperature, depth to resource, potential energy production, and project lifespan.
 - ▶ MT provides a combination of structural, permeability, and thermal information.
 - ▶ Seismic data adds important structural controls to the models, constraining the MT data.
 - ▶ Gravity data allows effective mapping of the basement surface and provides an additional control on the permeability structure.

Seismic + other techniques

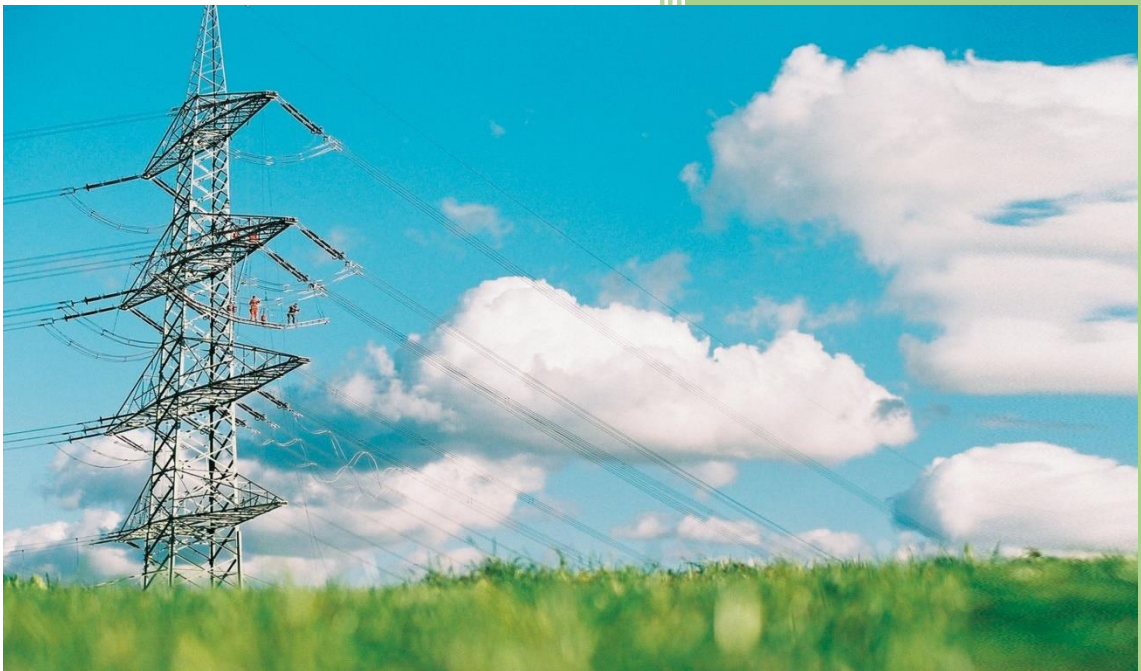
- ▶ Gravity and Magnetics geophysical methods, also known as the “Potential Fields” methods.
- ▶ **Gravity:** The gravity field on the earth’s surface varies with the distribution of mass subsurface materials. This lateral change can be measured and interpreted in terms of the likely geology causing it.
- ▶ **Magnetics:** The earth’s magnetic field induces a secondary magnetic field in ferrous materials. While all materials exhibit this susceptibility to a certain extent, iron and steel materials generally produce an effect that is easily measurable

Seismic + other techniques

Required Condition	Measurable Physical Property	Geophysical Tool
High Fluid Flow	Porosity and Fluid Saturation	Magnetotellurics
High Temperature	Temperature and temperature gradients	Magnetotellurics Gravity
Attainable Depth	Map of subsurface structure	Reflection Seismic

2016

Report Transmission Line



Team members:

- ✓ Omar Flores
- ✓ Jorge Acevedo
- ✓ Josep Bosch

University of Applied Sciences

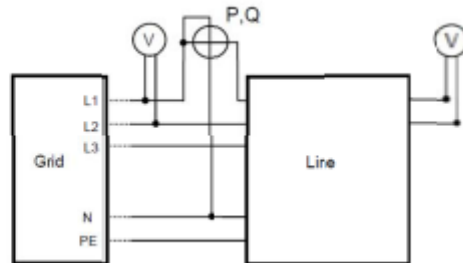
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Results from transmission line experiments

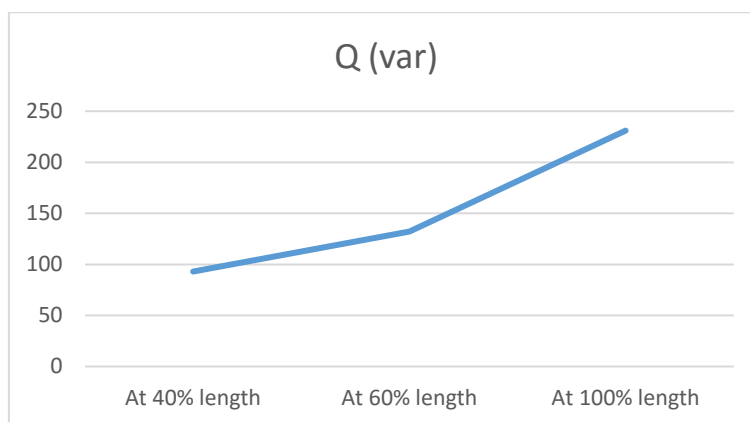
1. Performance at no load

Measurement of the voltage increase and (re active) charging power in lines of different lengths in no-load operation.



	U1 (V)	U2(V)	Q (var)	ratio U2/U1
At 40% length	380	390	93	1,03
At 60% length	380	400	132	1,05
At 100% length	380	420	231	1,11

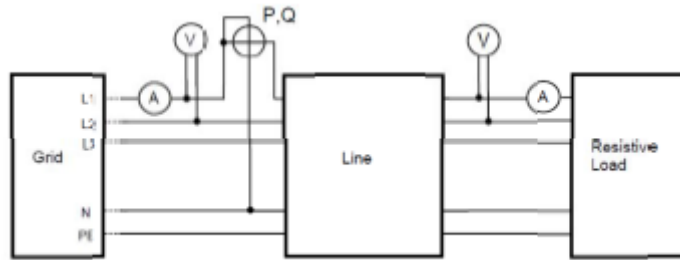
What is proportional to the line length, the ratio U_2 / U_1 or the reactive power Q ?



The reactive power is proportional to the line length, as we can see in the graphic, it shows nearly a straight line. But it can also be demonstrated mathematically, 40% of 231 (that is the Q at 100% length) is 93.

2. Resistive Load Characteristics

Measurement of the voltage and currents of a transmission line in the case of a resistive load. Interpretation of the expressions “leading”, “lagging”, and “wave resistance (surge impedance)”.



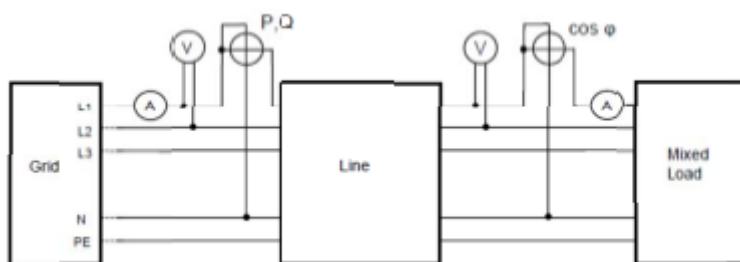
R(%)	U1 (V)	U2 (V)	I1 (A)	I2 (A)	P (W)	Q (var)
100	370	380	0,29	0,21	147	-114
90	370	380	0,32	0,26	183	-108
80	370	380	0,35	0,3	204	-105
70	375	380	0,39	0,34	234	-102
60	375	380	0,44	0,4	270	-75
50	380	380	0,51	0,48	330	-72
40	385	380	0,63	0,6	405	-63
30	390	380	0,84	0,83	555	-15
20	395	380	1	1	690	54

At which value the sign of the reactive power is changing from “capacitive” to “inductive”? What does that mean for the value of the load?

The reactive power is changing from capacitive to inductive in a value between 20% to 30% of the resistance. We start the experiment with a big capacitance but it finishes with an inductive. The apparent power increase because there is a huge increment in the current while you reduce the resistance.

3. Mixed loads (Resistive- inductive load)

Measuring and interpreting the voltages and currents with mixed resistive-inductive and resistive -capacitive loads. Start with the resistive- inductive load.



R(%)	U1 (V)	I1 (A)	P1 (W)	Q1 (var)	U2 (V)	I2 (A)	cos (φ2)
100	420	0,51	195	315	320	0,69	0,4
80	420	0,53	240	300	360	0,72	0,5
60	420	0,62	285	315	360	0,76	0,6
40	420	0,75	405	345	350	0,88	0,7
30	420	0,93	525	390	350	1	0,83

3. Mixed loads (Resistive- capacitive load)

Set the line length to 60 % and the voltage of the feeding transformer to 370 V and keep it constant. The resistive load is to be connected in parallel with a capacitance of 6 μ F. Starting at 100%, reduce the value of the resistor to 80 %, 60 %, 40 %, and 30 %, in that order.

R(%)	U1 (V)	I1 (A)	P1 (W)	Q1 (var)	U2 (V)	I2 (A)	cos (φ 2)
100	370	0,67	195	405	430	0,52	-0,5
80	370	0,71	270	390	430	0,55	-0,6
60	370	0,76	360	375	430	0,63	-0,7
40	370	0,9	495	315	420	0,78	-0,84
30	370	1,04	630	249	410	0,95	-0,9

4. Parallel compensation

Investigating the effect of parallel compensation on the transmission losses of the line.

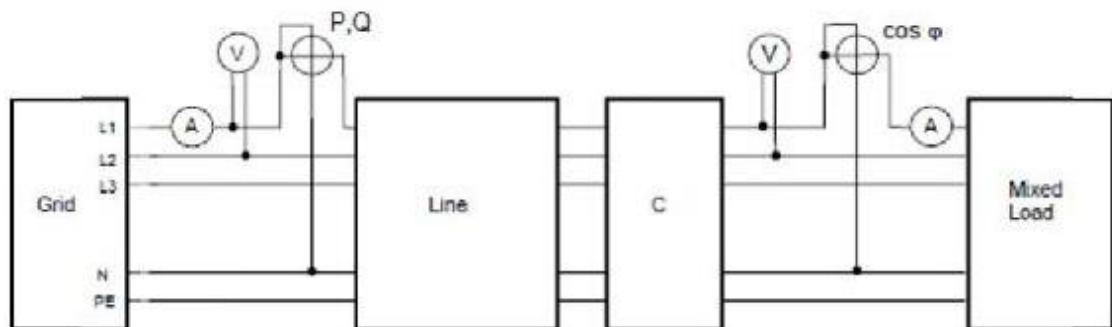
R(%)	U1 (V)	I1 (A)	P1 (W)	Q1 (var)	U2 (V)	I2 (A)	cos (φ 2)
100	310	0,32	150	75	320	0,23	0,99
80	350	0,41	240	105	360	0,39	0,99
60	355	0,49	300	90	360	0,46	0,99
40	350	0,66	405	45	350	0,66	0,99
30	350	0,84	525	7,5	350	0,84	0,99

What do you notice about the $\cos \varphi$ of the load and the real power at the line entrance?

Is constant and close to 1 because the active power is increasing at the same time the reactive power is decreasing.

4. Series compensation

Investigating the effect of series compensation on the voltage quality of the load.



	U1 (V)	I1 (A)	P1 (W)	Q1 (var)	U2 (V)	I2 (A)	cos (φ2)
with C	380	0,6	315	255	405	0,81	0,5
without C	380	0,36	180	156	305	0,62	0,5

Which value has the voltage at the load in the case of compensation and why does the power factor $\cos \varphi$ not change during the experiment?

The value of the voltage with compensation is 405 V and the power factor cannot compensate for the harmonic current by adding simple capacitors or inductors, as they could for the reactive power drawn by a linear load.

5. Experiments on three-phase short circuit

Measuring and interpreting the voltage and the current relations of a transmission line at three-phase short circuit current.

$$U_1 = 200 \text{ V} \qquad I_1 = 1.07 \text{ A} \qquad I_2 = 1.17 \text{ A}$$

Why the current at the line entrance is smaller compared to the current at the line end?

Because according to the short circuit the capacitor works as a power supply and gives an extra current which summated with the current of the main source gives a higher current.

2016

Report Solar module



Team members:

- ✓ Omar Flores
- ✓ Jussi Viitanen
- ✓ Jorge Acevedo
- ✓ Josep Bosch

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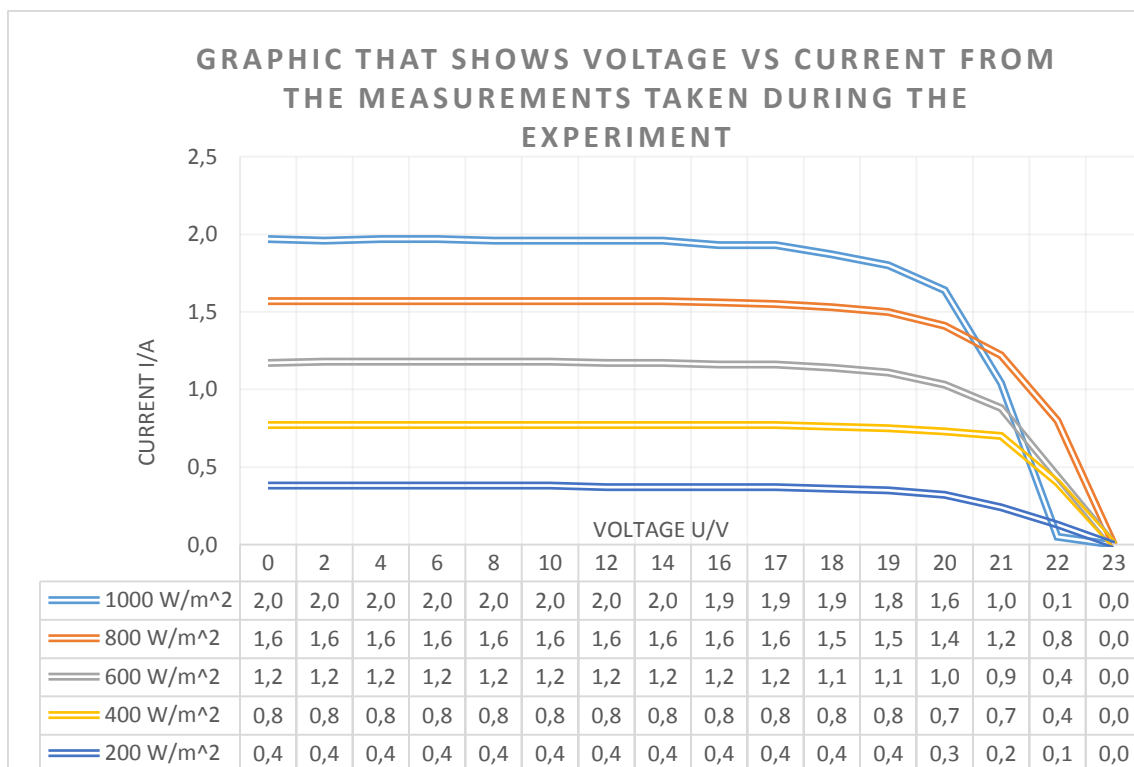
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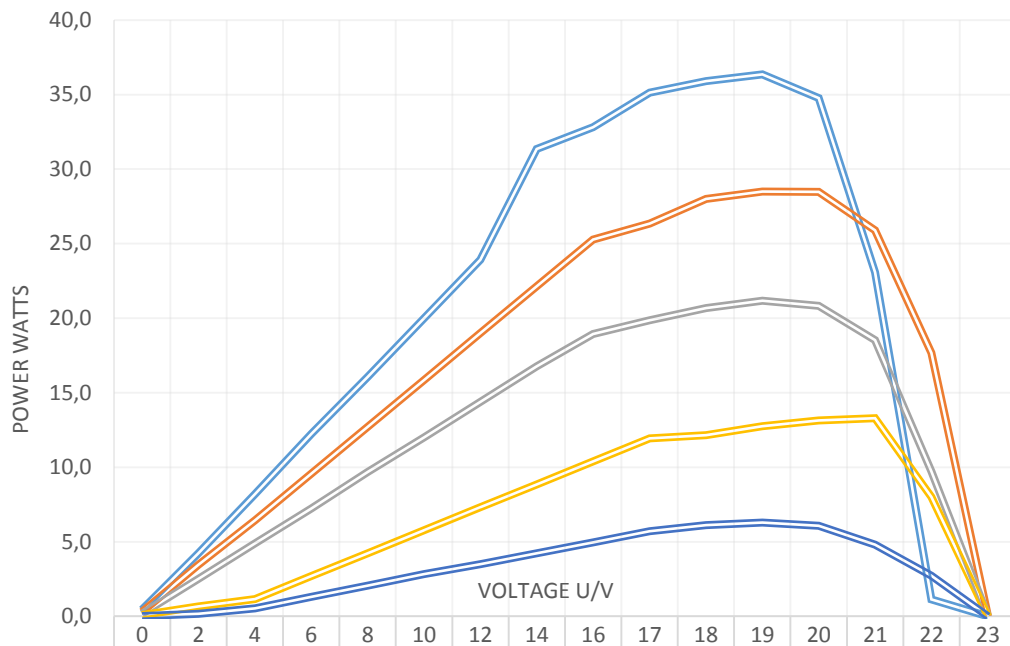
Results from solar module experiments

Experiment 1. Table that shows the measurements of current in change of voltage and power for each irradiance. One module tested.

1000 W/m ²			800 W/m ²			600 W/m ²			400 W/m ²			200 W/m ²		
U/V	I/A	P	U/V	I/A	P	U/V	I/A	P	U/V	I/A	P	U/V	I/A	P
0,2	2,0	0,5	0,2	1,6	0,3	0,1	1,2	0,2	0,1	0,8	0,1	0,1	0,4	0,0
2,2	2,0	4,2	2,2	1,6	3,5	2,1	1,2	2,5	0,9	0,8	0,7	0,4	0,4	0,2
4,2	2,0	8,2	4,1	1,6	6,4	4,1	1,2	4,9	1,5	0,8	1,2	1,4	0,4	0,5
6,2	2,0	12,2	6,1	1,6	9,6	6,1	1,2	7,2	3,5	0,8	2,7	3,4	0,4	1,3
8,2	2,0	16,1	8,1	1,6	12,7	8,2	1,2	9,7	5,5	0,8	4,2	5,4	0,4	2,1
10,2	2,0	20,0	10,1	1,6	15,9	10,2	1,2	12,0	7,5	0,8	5,8	7,4	0,4	2,8
12,2	2,0	23,9	12,1	1,6	19,0	12,3	1,2	14,4	9,5	0,8	7,3	9,4	0,4	3,5
16,0	2,0	31,4	14,1	1,6	22,1	14,3	1,2	16,8	11,5	0,8	8,9	11,4	0,4	4,2
17,0	1,9	32,8	16,2	1,6	25,3	16,3	1,2	18,9	13,5	0,8	10,4	13,4	0,4	5,0
18,2	1,9	35,1	17,0	1,6	26,4	17,1	1,2	19,9	15,5	0,8	11,9	15,4	0,4	5,7
19,2	1,9	35,9	18,3	1,5	28,0	18,1	1,1	20,7	16,0	0,8	12,2	17,0	0,4	6,1
20,2	1,8	36,4	19,0	1,5	28,5	19,1	1,1	21,2	17,0	0,8	12,8	18,0	0,4	6,3
21,2	1,6	34,8	20,2	1,4	28,5	20,2	1,0	20,8	18,0	0,7	13,1	19,0	0,3	6,1
22,2	1,0	23,1	21,2	1,2	25,9	21,1	0,9	18,5	19,0	0,7	13,3	20,0	0,2	4,8
22,7	0,1	1,1	22,1	0,8	17,7	22,1	0,4	9,7	20,0	0,6	12,6	21,0	0,1	2,7
23,0	0,0	0,0	23,0	0,1	1,6	23,0	0,0	0,0	23,0	0,4	9,2	22,0	0,0	0,0



GRAPHIC THAT SHOWS POWER IN FUNCTION OF VOLTAGE. POWER IS CALCULATED VOLTAGE TIMES CURRENT.



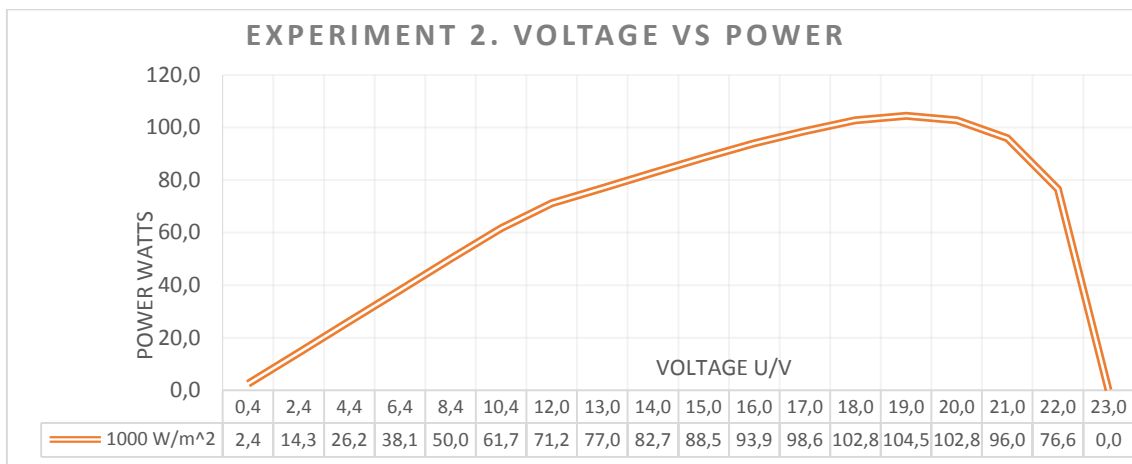
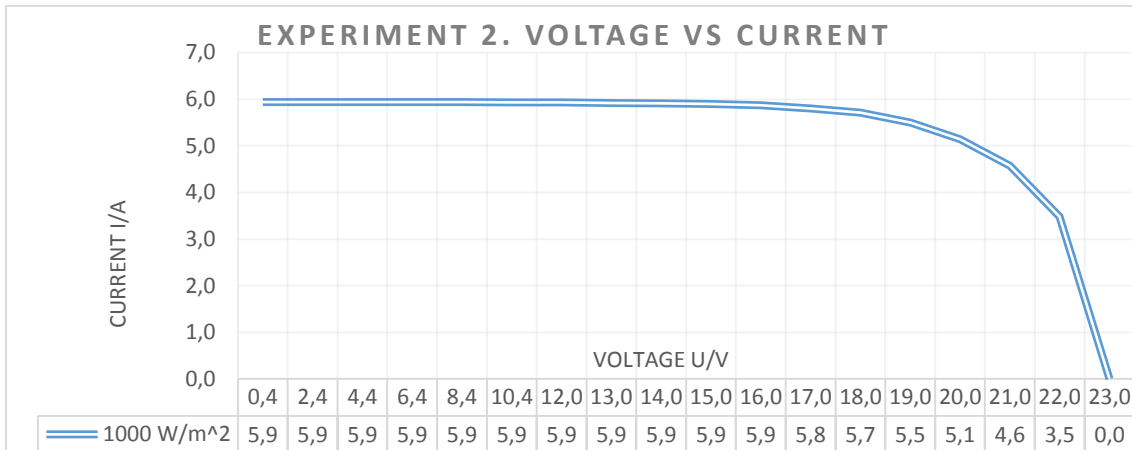
	0	2	4	6	8	10	12	14	16	17	18	19	20	21	22	23
1000 W/m ²	0,5	4,2	8,2	12,2	16,1	20,0	23,9	31,4	32,8	35,1	35,9	36,4	34,8	23,1	1,1	0,0
800 W/m ²	0,3	3,5	6,4	9,6	12,7	15,9	19,0	22,1	25,3	26,4	28,0	28,5	28,5	25,9	17,7	0,0
600 W/m ²	0,2	2,5	4,9	7,2	9,7	12,0	14,4	16,8	18,9	19,9	20,7	21,2	20,8	18,5	9,7	0,0
400 W/m ²	0,1	0,7	1,2	2,7	4,2	5,8	7,3	8,9	10,4	11,9	12,2	12,8	13,1	13,3	8,0	0,0
200 W/m ²	0,0	0,2	0,5	1,3	2,1	2,8	3,5	4,2	5,0	5,7	6,1	6,3	6,1	4,8	2,7	0,0

Experiment 2. Table that shows the measurements from the experiment with parallel circuit at irradiation of 1000 W/m². Three modules in a parallel circuit tested.

Which value has the maximum of the power output roughly?

As it can be seen from the table on the right side the maximum output value for the power is *104,5 Watts* and it happens when the voltage has a value of 19 V and the current of 5,5 A.

1000 W/m ²		
U/V	I/A	P
0,4	5,9	2,4
2,4	5,9	14,3
4,4	5,9	26,2
6,4	5,9	38,1
8,4	5,9	50,0
10,4	5,9	61,7
12,0	5,9	71,2
13,0	5,9	77,0
14,0	5,9	82,7
15,0	5,9	88,5
16,0	5,9	93,9
17,0	5,8	98,6
18,0	5,7	102,8
19,0	5,5	104,5
20,0	5,1	102,8
21,0	4,6	96,0
22,0	3,5	76,6
23,0	0,0	0,0



Experiment 3. Table that shows the measurements from the experiment with parallel circuit. Three modules in a parallel circuit tested, two at an irradiation of 1000 W/m² and one at 200 W/m². 1st case without the use of a bypass diode.

Which value has the maximum of the power output roughly?

As it can be seen from the table on the right side of the page, the maximum output value for the power is 75,62 Watts and it happens when the voltage has a value of 19 V and the current of 3,98 A. Having this result, we can compare it with the result of the previous experiment (experiment 2) and notice the difference of maximum power: Experiment two 104,5 Watts and experiment three 75,6 Watts. A decrease of 28,9 Watts.

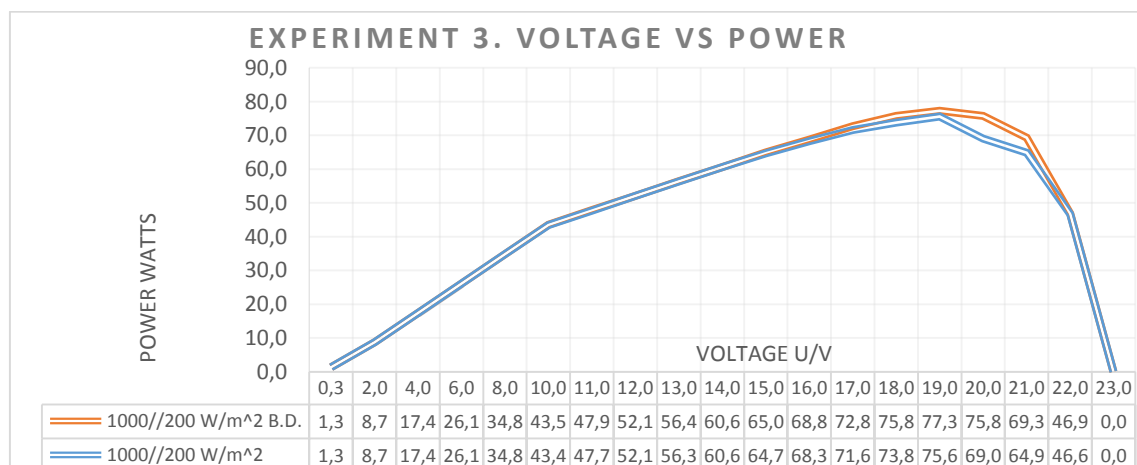
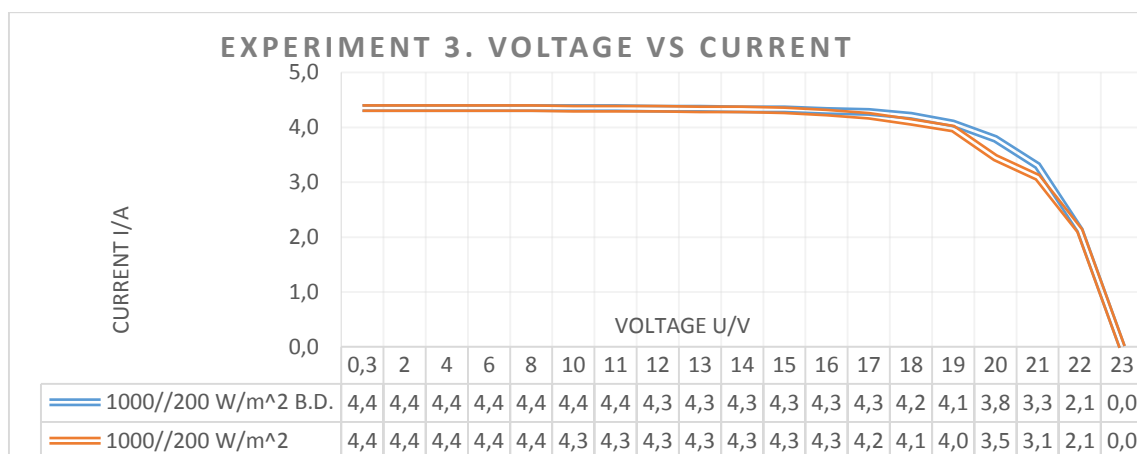
			Bypass diode (B.D.)	
1000//200 W/m ²			1000//200 W/m ² B.D.	
U/V	I/A	P	I/A	P
0,3	4,4	1,3	4,4	1,3
2,0	4,4	8,7	4,4	8,7
4,0	4,4	17,4	4,4	17,4
6,0	4,4	26,1	4,4	26,1
8,0	4,4	34,8	4,4	34,8
10,0	4,3	43,4	4,4	43,5
11,0	4,3	47,7	4,4	47,9
12,0	4,3	52,1	4,3	52,1
13,0	4,3	56,3	4,3	56,4
14,0	4,3	60,6	4,3	60,6
15,0	4,3	64,7	4,3	65,0
16,0	4,3	68,3	4,3	68,8
17,0	4,2	71,6	4,3	72,8
18,0	4,1	73,8	4,2	75,8
19,0	4,0	75,6	4,1	77,3
20,0	3,5	69,0	3,8	75,8
21,0	3,1	64,9	3,3	69,3
22,0	2,1	46,6	2,1	46,9
23,0	0,0	0,0	0,0	0,0

Influence of the bypass diode to the partially shaded module:

Bypass diodes are a standard addition to any crystalline PV module. The bypass diodes' function is to eliminate the hot-spot phenomena which can damage PV cells and even cause fire if the light hitting the surface of the PV cells in a module is not uniform. The bypass diodes are usually placed on sub-strings of the PV module, one diode per up to 20 PV cells. This configuration eliminates the creation of hot-spots and enables the PV modules to operate with high reliability throughout their lifetime. In addition to effectively fulfilling this function, many people believe the bypass diodes are also effective in reducing power loss due to shading in PV installations.

Is there an influence of the bypass diode (B.D.)?

As it can be seen from the next diagrams and comparing the numbers we can notice that the results are almost the same, there is a difference in the maximum power but not really considerable.

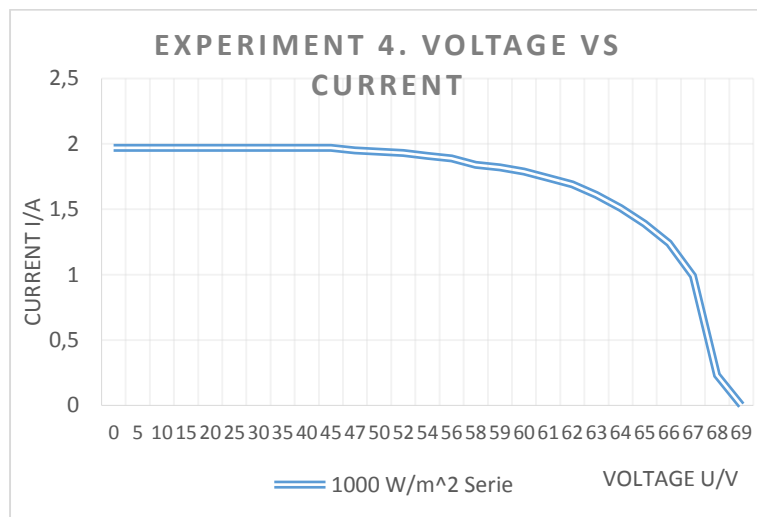
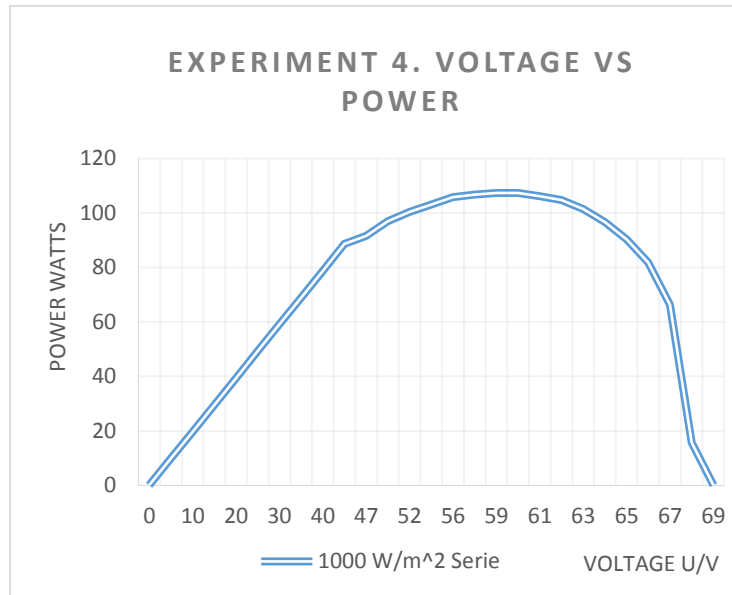


Experiment 4. Series connection of three modules with an irradiation of 1000 W/m².

Which value has the maximum of the power output roughly?

The maximum power value is presented when the voltage is 60 V and the current 1,79 A which generates a power of 107,4 Watts.

1000 W/m ² Serie		
U/V	I/A	Power
0	1,97	0
5	1,97	9,85
10	1,97	19,7
15	1,97	29,55
20	1,97	39,4
25	1,97	49,25
30	1,97	59,1
35	1,97	68,95
40	1,97	78,8
45	1,97	88,65
47	1,95	91,65
50	1,94	97
52	1,93	100,36
54	1,91	103,14
56	1,89	105,84
58	1,84	106,72
59	1,82	107,38
60	1,79	107,4
61	1,74	106,14
62	1,69	104,78
63	1,61	101,43
64	1,51	96,64
65	1,39	90,35
66	1,24	81,84
67	0,99	66,33
68	0,23	15,64
69	0	0



Experiment 5. Series connection of three modules at an irradiation of 1000 W/m² for two modules and 200 W/m² for one module.

Experiment a. Which value has the maximum of the power output roughly?

When the modules present a voltage of 60 V we can notice the maximum power of 22,2 *Watts*. Comparing this result with the previous one we can see how the power is affected by a lot, from 107, 4 *Watts* to 22, 2 *Watts*. We are talking about almost 80% of power lost.

Experiment b. Influence of the bypass diode to the partially shaded module:

Bypass Diodes which in electronics we know as free-wheeling diodes, are wired in parallel with individual solar cells or panels, to provide a current path around them in the event that a cell or panel becomes faulty or open-circuited. This allows a series (called a string) of connected cells or panels to continue supplying power at a reduced voltage rather than no power at all.

Experiment b. Which value has the maximum of the power output roughly?

Experiment a: Experiment without bypass diode.

Experiment b: Use of bypass diode.

As it can be seen from the next tables, we have a maximum power when the voltage is 38 V and the current is 1,8 A with a value of 69,2 Watts. As you can see the maximum power point is increased by three times so the bypass diode in this case causes a huge advantage.

1000/200 W/m ²			1000/200 W/m ² w. B.D.		
U/V	I/A	W	U/V	I/A	W
0	0,38	0,0	0,0	2,0	0,0
28	0,38	10,6	28,0	2,0	54,6
30	0,38	11,4	30,0	1,9	58,2
33	0,38	12,5	33,0	1,9	63,7
34	0,38	12,9	34,0	1,9	65,3
35	0,38	13,3	35,0	1,9	66,5
36	0,38	13,7	36,0	1,9	67,3
37	0,38	14,1	37,0	1,8	68,1
38	0,38	14,4	38,0	1,8	69,2
39	0,38	14,8	39,0	1,8	69,0
40	0,38	15,2	40,0	1,7	68,0
41	0,38	15,6	41,0	1,6	65,2
42	0,37	15,5	42,0	1,4	59,6
43	0,37	15,9	43,0	1,1	46,4
44	0,37	16,3	44,0	0,4	16,7
46	0,37	17,0	46,0	0,4	17,5
50	0,37	18,5	50,0	0,4	19,0
52	0,37	19,2	52,0	0,4	19,2
60	0,37	22,2	60,0	0,4	21,6
61	0,34	20,7	61,0	0,3	20,7
62	0,31	19,2	62,0	0,3	20,5
63	0,27	17,0	63,0	0,3	17,6
64	0,17	10,9	64,0	0,2	13,4
65	0,04	2,6	65,0	0,1	5,2
66	0,00	0,0	66,0	0,0	0,0

