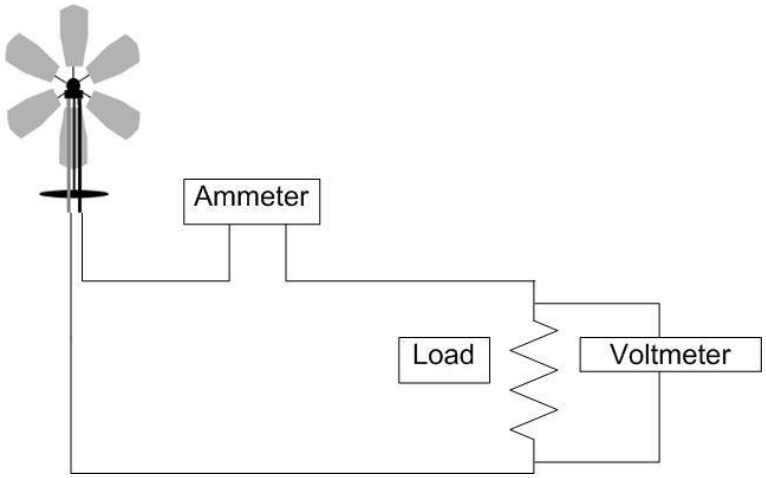
Experiment 1
Wind Energy

Objective:

The students become familiar with the typical features of a wind generator in this experiment. In the process, they investigate the influence of the rotor blade positioning, the direction of the wind and the number of rotor blades have on the electrical power of the wind generator.



Lab Equipment

-Wind generator
- Fan
-2 cables, 1 black, 1 red
-Voltmeter and ammeter
- Resistive load
-Anemometer

Procedures

1. Set up experiment as shown in Fig.1-1.
2. Affix all rotor blades on the wind generator. In doing so, affix the rotor blades so that they are unbent.
3. Find the rotor blade position with which the wind generator provides the highest no-load voltage.
4. The fan must be set up directly facing the wind generator with distance of approx. 50 cm.
5. Operate the fan at the first speed position.
6. Enter any observations in the following table at the constant load.

Variable	Value
V_L	
I_L	
Po	

7. Operate the fan at the second speed position.
8. Enter any observations in the following table at the constant load.

Variable	Value
V_L	
I_L	
Po	

9. Operate the fan at the third speed position.
10. Enter any observations in the following table at the constant load.

Variable	Value
V_L	
I_L	
Po	

11. Change the rotor blades position and repeat the experiment again.

Questions about the experiment

1. How do current and voltage behave with a varying rotor blade position?
   ……
   ……
2. How do current and voltage behave with varying wind speed?
   ……
   ……....
3. How do current and voltage behave with fewer rotor blades?
   ……
   ……

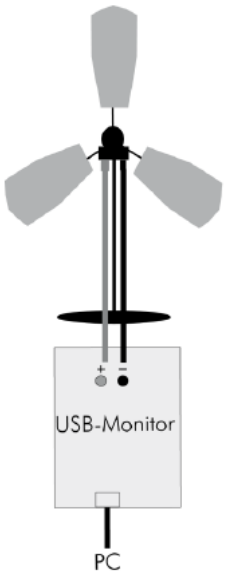
Conclusion:

The power that comes from the wind turbine vary with the varying of the wind speed and rotor blades positions.

Experiment 2
Wind Energy Maximum Power Point Tracking

Objective:

The students expand their knowledge by drawing the characteristic curve of a wind generator.
The students expand their knowledge when recognizing that there is a range of values in which the wind generator provides its maximum power.



Lab Equipment

-Wind generator
- Fan
-2 cables, 1 black, 1 red
-Data monitor card
  - USB cable
  - PC or laptop with installed software.

Procedures

1. Set up experiment as shown in Fig.3-2.
2. Align the wind generator and the angle of inclination of the rotor blades in such a way that the highest possible no-load voltage is achieved.

3. Start the software and select the *WIND GENERATOR* tab.

4. Switch on the fan (Level 2).

5. Switch the operation mode to *AUTOMATIC MODE* and start the measurement.

6. Record current and voltage values in a table and calculate the power.
   The power is calculated with the formula .
7. Draw the power characteristic curve.
   Click on POWER CHARACTERISTIC CURVE in the software and compare with the power characteristic curve which is shown.
8. Equip the wind turbine with six rotor blades.

9. Set the fan to Level 3.

10. Align the wind generator and the angle of inclination of the rotor blades in such a way that the highest possible no-load voltage is achieved.

11. Select the operation mode *AUTOMATIC MODE*.

12. Record current and voltage values in a table and calculate the power.

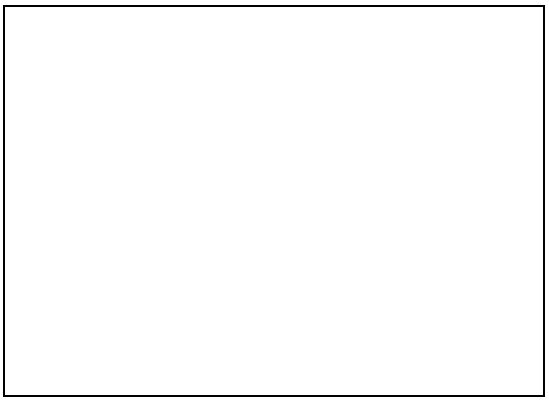
13. Draw the power characteristic curve.

14. Determine the maximum operating point from the power voltage characteristic curve.

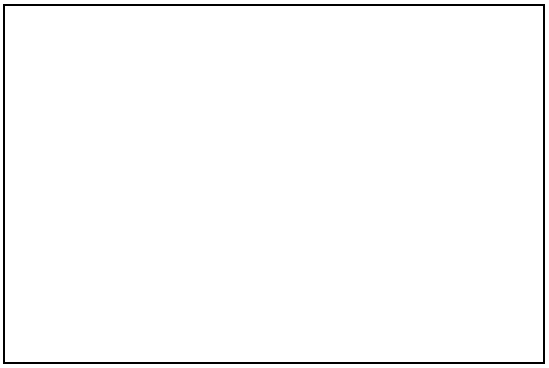
Questions about the experiment

1. How can the maximum power of the wind generator be achieved?
   ……
   ……

2. What does the power characteristic curve look like at Level 2?
   ……
   ……



3. What does the power characteristic curve look like at Level 3?
   ……
   ……



4. How can the maximum power of the wind generator be determined?
   ……
   ……

Conclusion:

The maximum power can be detected at a certain current and voltage in different speed of wind and different rotor position

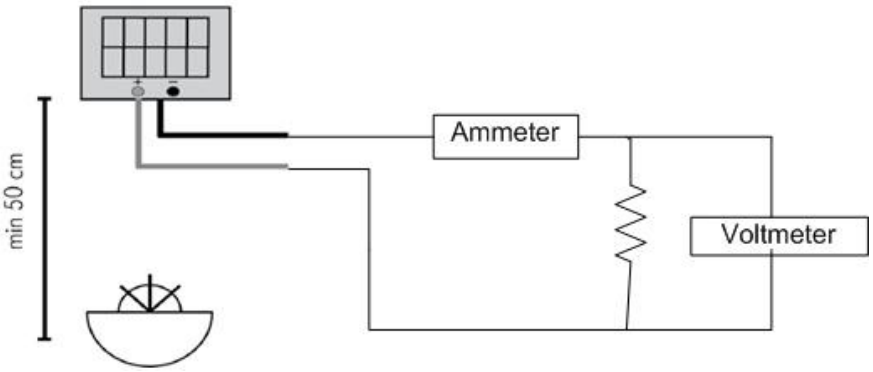
Experiment 3
PV Solar Power

Objective:

The students expand their knowledge in recognizing that the distance, the angle and the brightness of a source of light influence the power of a solar cell.

Lab Equipment

-2 PV modules
-2 Lamps
-2 cables, 1 black, 1 red
-Voltmeter and ammeter
- Resistive load
-LUX meter



Procedures

7. Set up experiment as shown in Fig.2-1.
8. . Adjust the distance of the lamp to the solar cell to 50 cm. The angle of irradiation should be approx. 90°.
9. Switch on the lamp.
10. Connect the two solar module series two each other.
11. Connect them to a resistive load
12. Enter any observations in the following table at the constant load.

Variable	Value
V_L	
I_L	
Po	

7. Change the angle of the solar module by hand. The distance to the solar module must always be the same. Make sure that the magnet base always remains in the same position.

8. Enter any observations in the following table at constant load.

Variable	Value
V_L	
I_L	
Po	

9. Repeat the experiment by keeping the solar module at constant position and changing the light intensity using dummy shadow.
10. Enter any observations in the following table at constant load.

Variable	Value
V_L	
I_L	
Po	

Questions about the experiment

1. How do the measurements behave depending on the tilt angle?
……
……....

2. How do the measurements behave depending on the intensity of illumination?
……
……
3. What general statements can be made about the measurements with a continuously increasing intensity of illumination?
……
……
4. What factors does the angle of irradiation depend on?
……
……...

Conclusion:

The power that comes from PV Module vary with the varying of intensity of light and position of PV module .

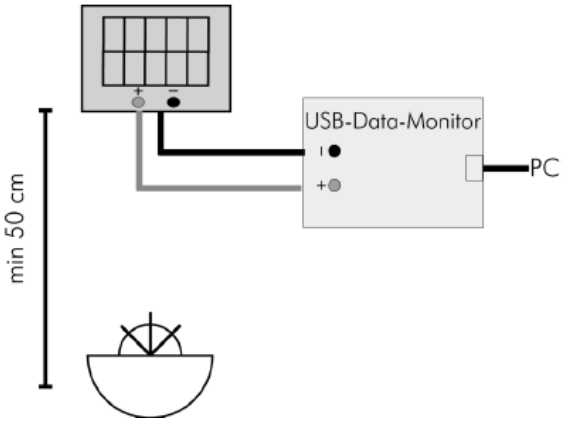
Experiment 4
Solar Energy Maximum Power Point tracking

Objective:

The students expand their knowledge when recognizing that there is a range of values in which the solar cell provides its maximum power.
The students expand their knowledge in determining the MPP (Maximum Power Point) of a solar cell.

Lab Equipment

-1 PV module.
- 1 lamp.
- 1 color transparent film.
-2 cables, 1 black, 1 red
-Data monitor card
  - USB cable
  - PC or laptop with installed software.



Procedures

1. Set up experiment as shown in Fig.2-2.
2. Adjust the distance from the lamp to the solar cell to 50 cm. The angle of irradiation should be approx. 90°.

3. Start the software and select the *SOLAR MODULE* tab.

4. Switch on the lamp.

5. Switch the operation mode to *AUTOMATIC MODE* and start the measurement.

6. Record current and voltage values in a table and calculate the power.
  - *The power* P *is calculated with the formula. P=V x I*
7. Draw the power characteristic curve.
  -*Click on POWER CHARACTERISTIC CURVE in the software and compare with the power characteristic curve which is shown*
8.Hold a film between the lamp and solar module and re-start the automatic measurement.
9. Record current and voltage values in a table and calculate the power.

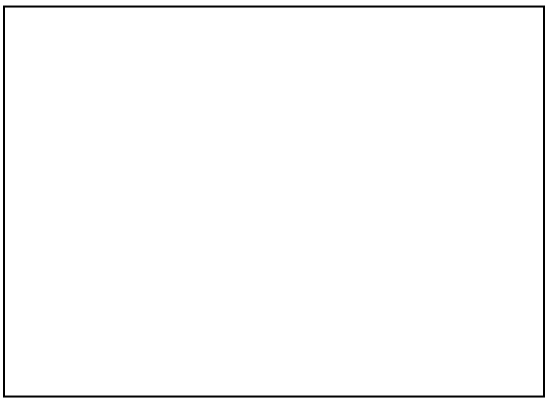
10. Plot the power voltage characteristic curve into the power voltage characteristic curve from the previous experiment (only if a previous experiment was conducted).

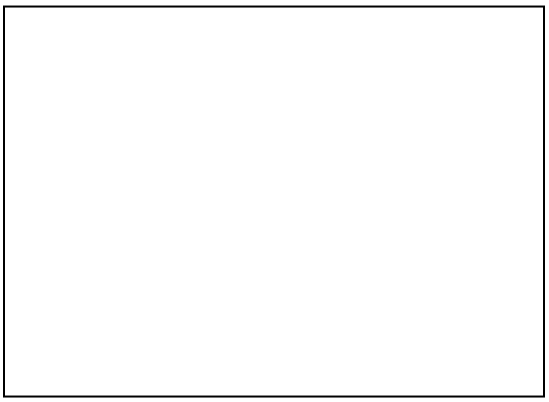
Questions about the experiment

1. When does the solar module provide maximum power?
   ……
   ……

2. When does the solar module provide maximum power with a low intensity of illumination?
   ……
   ……

3. What is a characteristic curve at the first case and the second case ?
   ……
   ……





4. Is the MPP constant? What does the MPP depend on?
   ……
   ……

Conclusion:

The maximum power can be detected at a certain current and voltage in different intensity of light and different position of PV module.

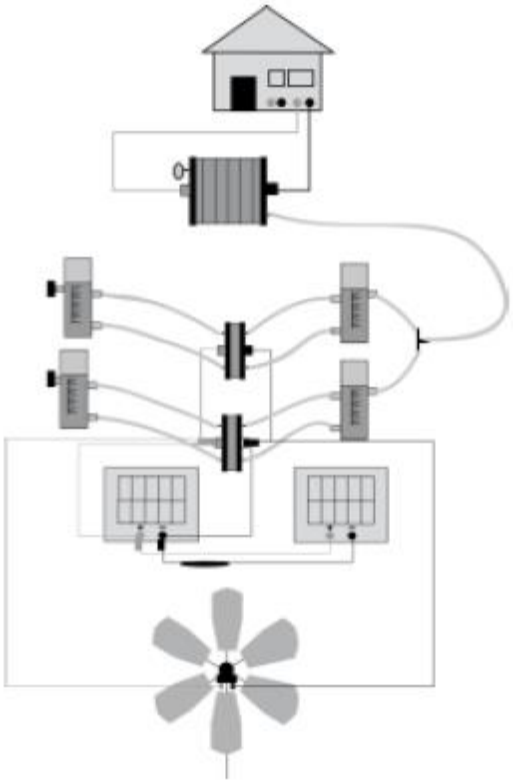
Experiment 5

Renewable energy resources

Objective

The students expand their knowledge by way of experiment in discovering that a combination of multiple different renewable energy sources can secure a constant supply of current.

Lab Equipment

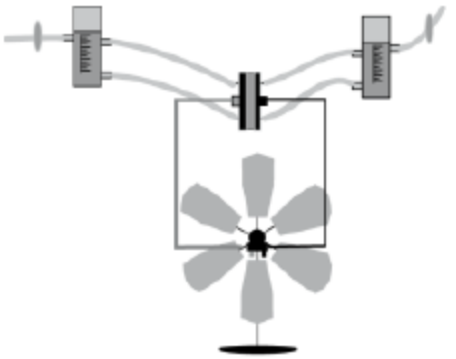


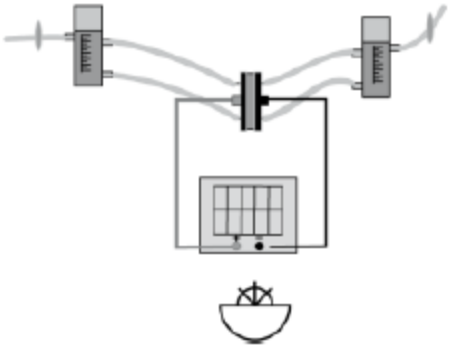
1 Solar module
2 One 75 W lamp (spotlight)
3 Wind generator
4 Fan (min. diameter 40 cm)
5 Electrolyzer
6 5-cell fuel cell stack
7 10 cables, 5x red and 5x black

Procedures

1. Set up experiment as shown in Fig.6-1.
2. Switch on the lamp and fan.
3. After three minutes, simulate various weather situations (day / night / no wind).
4. Observe the consumer.
5. Set up experiment as shown in Fig. 6-2.
6. Predict which energy source "wins".
7. Disconnect the solar module.
8. Align the fan towards the wind generator for three minutes and enter the generated amount of hydrogen in the following table.
9. Switch off the wind generator and empty the hydrogen tank.
10. Align the lamp (50 cm distance) towards the solar module for three minutes and enter the generated amount of hydrogen in the following table.

Time(min)	Wind generator hydrogen quantity [ml]	Solar module hydrogen quantity [ml]
1		
2		
3		





Questions about the experiment

1. Can a consumer be permanently operated with renewable energy sources?

   ……
   ……

2. Which energy source generates the most hydrogen?
   ……
   ……

3. Which factors must be taken into consideration so that a consumer can be permanently operated with renewable energy sources?
   ……
   ……

4. Can the assumptions be applied in practice?
   ……
   ……

Conclusion: