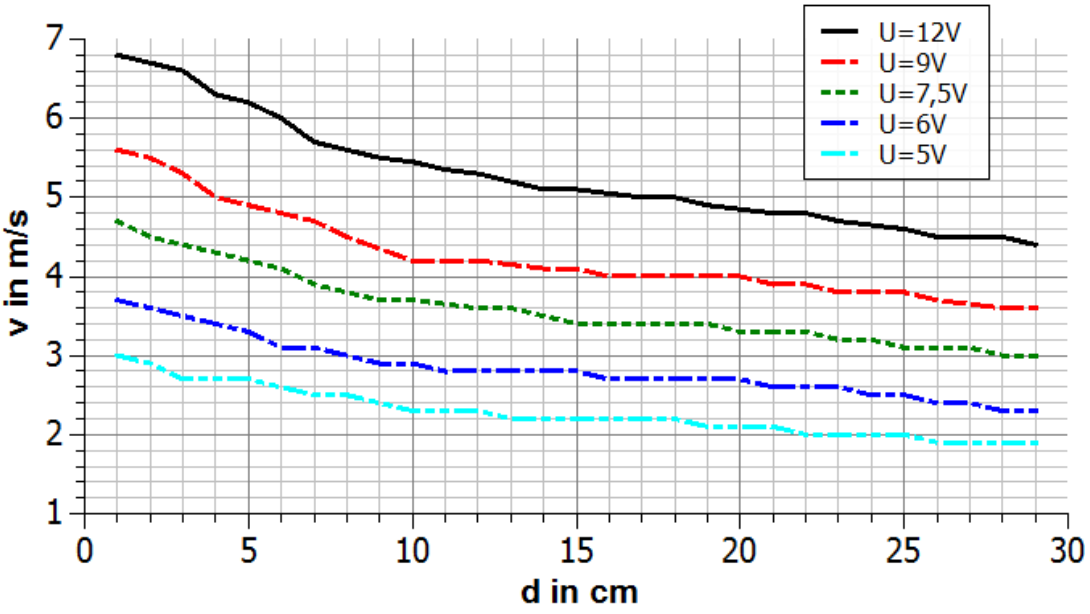
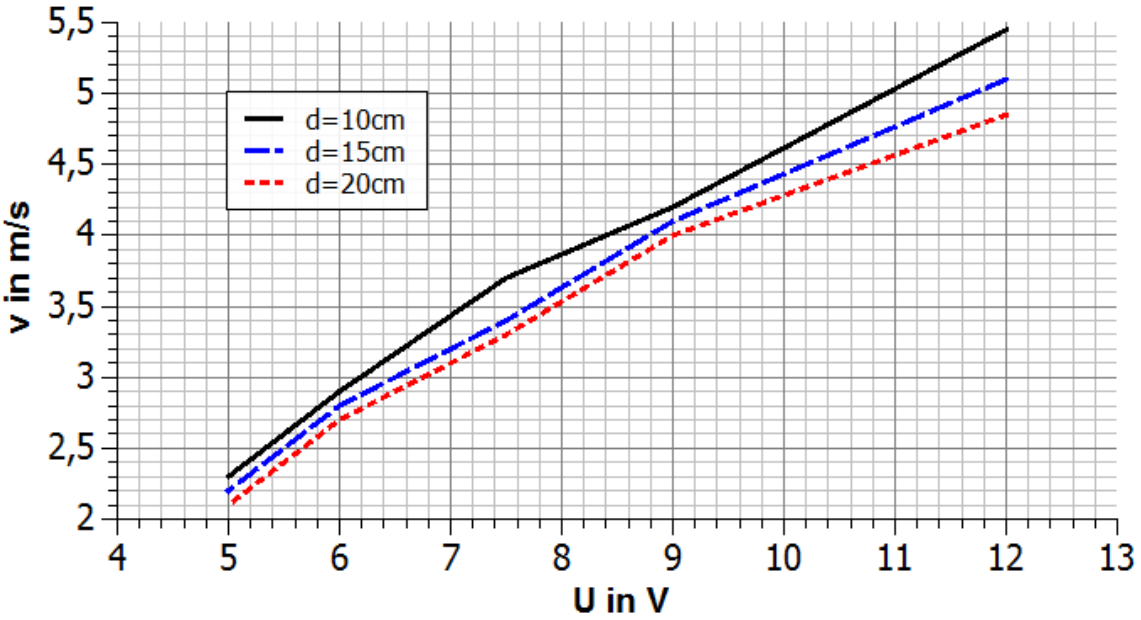
Charts for the experiments

The following are the charts needed to determine the wind speed of individual experiments if the anemometer extension does not exist (or is not in use).

Wind speed at constant voltage at the wind machine



Wind speed at constant distance from wind machine

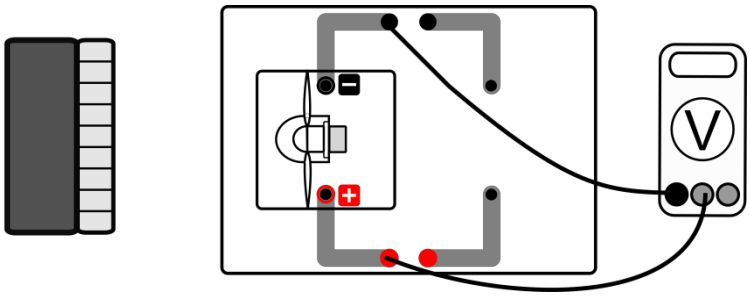


2. Changing wind speed by changing the distance (voltage measurement)

Excercise

Examine the voltage at the turbine when the wind speed at the wind turbine is changed by moving the wind machine.

Experimental setup



Equipment needed

- leXsolar main board
- Wind machine module with power supply (12V)
- Wind turbine module (with three rotor blades, 25°, optimized profile)
- Cable
- Voltage meter

Execution

1. Set the experiment up according to the experiment set-up.
2. Remove the wind machine from the wind turbine and move the components closer again. What do you observe at the voltage meter? Write down your observations.
3. Now measure the voltage V at the turbine at different distances (in increments of 5 cm) and enter your values in the table.

Observation

- The further the wind turbine is the from the wind machine, the smaller the voltage.

- The shorter the distance between the wind machine and the wind turbine, the higher the voltage.

Measurements

d in cm	5	10	15	20	25
v in m/s	6.2	5.45	5.1	4.85	4.6
V in V	3.83	3.63	3.35	3.11	2.88

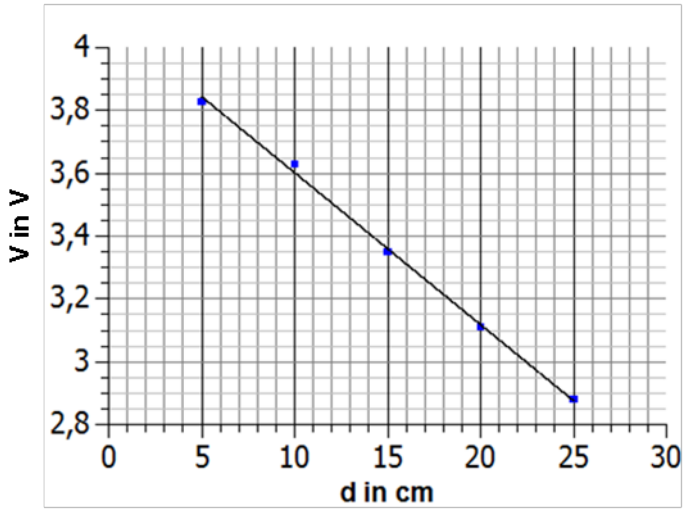
You can determine the values for the speed with the wind force transducer or read it off the respective chart (see page 7).

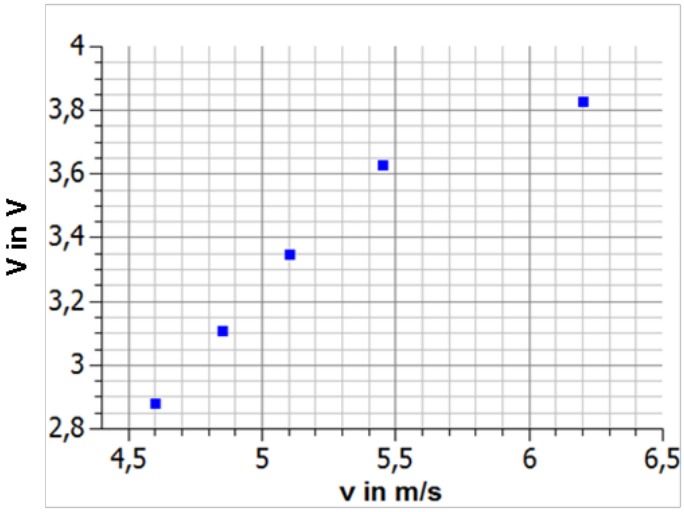
2. Changing wind speed by changing the distance (voltage measurement)

Evaluation

1. Enter your measurements in the specified charts.
2. Describe how the voltage changes when the distance between the wind machine and the wind turbine is changed. What is the correlation between the wind speed and the voltage at the wind turbine?

1.





2.

The greater the distance, the lower the voltage generated at the turbine.

With increasing distance from the wind machine, the voltage decreases (approximately) linearly.

At greater wind speed (smaller distance), higher voltage is also generated at the turbine.

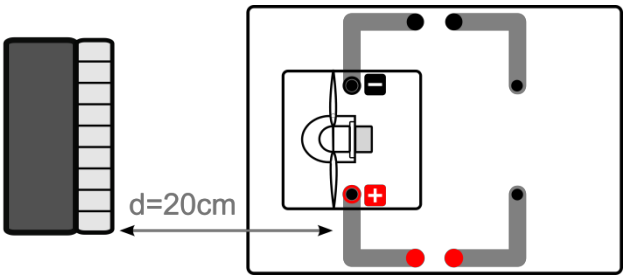
(A linear correlation between voltage and wind speed can be assumed.)

3. Start-up wind speed at a wind turbine

Exercise

Examine how high the wind speed must be for the wind turbine to be able to start.

Experimental setup



Equipment needed

- leXsolar main board
- Wind machine module with power supply (12V)
- Wind turbine module (with three rotor blades, 25°, optimized profile)

Preliminary remark

A wind turbine only starts to turn when there is sufficiently high wind speed. This is called start-up wind speed. With this experiment you can examine how high the start-up speed is in this model of a wind turbine.

Execution

1. Set the experiment up according to the experiment set-up.
2. Set different voltages V on the power supply unit and observe the wind turbine. Enter your observations in the specified table.
3. Determine the wind speed at the moment the wind turbine starts and write down your value. (Take the value of the relevant chart (see page 7) or follow step 4 if you have a wind force transducer.)
4. Switch off the wind machine, remove the wind turbine and restart the wind machine. Now measure the wind speed with the wind force transducer at the respective distance.

Observation

→ Start-up wind speed:

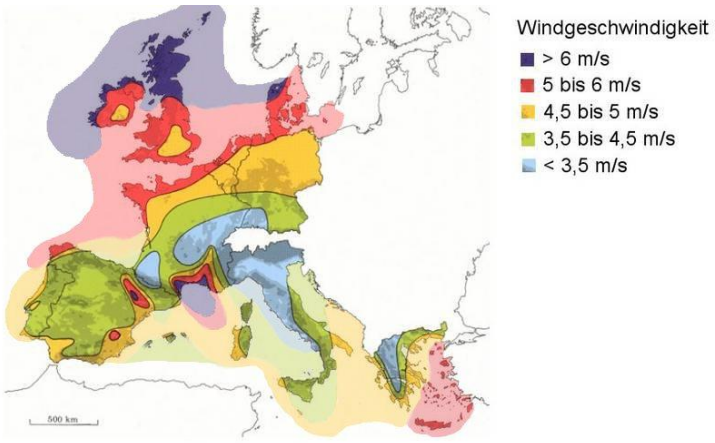
v_A = 4.0 m/s

	The wind turbine	
V in V	...starts	…does not start
3		x
4.5		x
6		x
7.5		x
9	x	
12	x	

3. Start-up wind speed at a wind turbine

Evaluation

1. What conclusions can you draw from these insights for the operation of wind turbines?
2. Find out more about the start-up speeds of real wind turbines and compare it with your measured values. Can you explain the differences?
3. Average wind speeds in Europe are depicted on the map.



Quelle: http://www.wind-energie.de/de/technik/entstehung/windpotential (16.11.2010)

Based on this illustration, explain with reasons in which areas wind turbines can be used efficiently. Where is the use of wind energy less profitable?

Solutions to the exercises

1. A wind turbine only starts to turn on when there is sufficiently high wind speed. Operating wind turbines Are only efficient at a location where there are sufficient wind speeds over an extended period of time.

2. Real wind turbines only start at wind speeds of approx. 2-3 m/s (depending on the model). The wind turbine model starts at approx. 4-5 m/s. The start-up speed is therefore slightly higher than in a real plant.

Possible reasons for this could be:

- The shape of the rotor blades is not optimal.
- Too high friction on the inside of the motor.
- Too much turbulence in the flow of the wind machine.

3. **useful applications**: Coastal areas of the North and Baltic Sea, British Isles, the French, Mediterranean coast, Denmark: (dark blue to red)→ efficient use of wind energy (average wind speed of about 5 to 6 m/s) and: northern regions of Germany and France, regions on the Mediterranean Sea (yellow to green) → use of wind energy possible but less efficient.

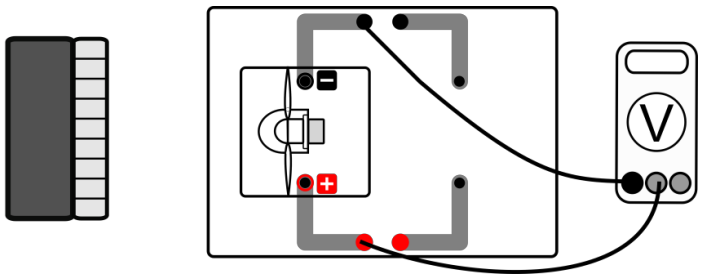
not useful: Italy, Spain, Greece, southeast France → average wind speeds only slightly above or below 3 m/s (systems do not start for long periods)

6. Comparison of two, three and four-blade rotors (voltage measurement)

Exercise

Examine the voltage at the wind turbine at different numbers of rotor blades.

Experimental setup



Equipment needed

- leXsolar main board
- Wind machine module with power supply (7.5 V)
- Wind turbine module (with two, three and four rotor blades, 25°, optimized profile)
- Cable
- Voltage meter

Preliminary remark

The individual rotors need different amounts of time until they produce a consistent peripheral speed and so a consistent voltage. The voltage should only be recorded when the reading no longer changes.

Execution

1. Set the experiment up according to the experiment set-up.
2. Place the two-blade rotor on the wind turbine, set a distance of 25 cm between the rotor and the wind machine and turn on the wind machine. Measure the voltage generated at different distances (5, 10, 15, 10, 25 cm) and enter the values in the table. Then switch the wind machine off again.
3. Repeat your measurement with the three and four-blade rotor. Enter all values in the provided fields.

Measurements

d in cm	v in m/s	V_2 in V	V_3 in V	V_4 in V
5	4.2	2.12	2.41	2.45
10	3.7	2.13	2.18	2.18
15	3.4	1.98	2.02	1.97
20	3.3	1.74	1.83	1.77
25	3.1	1.55	1.63	1.61

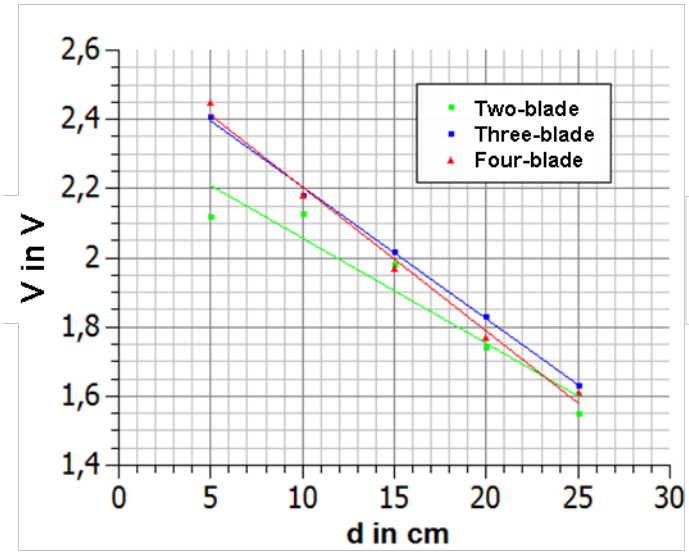
You can determine the values for the speed with the wind force transducer or read it off the respective chart (see page 7).

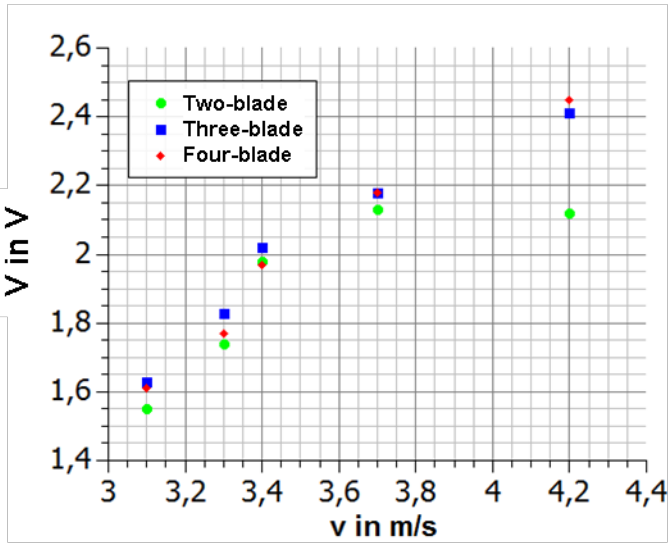
6. Comparison of two, three and four-blade rotors (voltage measurement)

Evaluation

1. Enter your measurements in the respective charts.
2. With which number of rotor blades the biggest voltage can be generated, which generates the lowest? What do you assume is the correlation between the number of rotor blades and the generated voltage?
3. The voltage generated at the wind turbine also changes at different wind speeds. Based on your results, explain why the use of three-blade and not four-blade rotors for power generation is preferred.

1.





2.

The biggest voltage was generated with the three-blade rotor. It is however almost exactly as large as the four-blade rotor. (It could be possible in the experiment that the four-blade rotor generates the maximum output, but here it is not the case)

It can be assumed that the output increases as the number of blades increases or that the (optimal) maximum output lies with 3 blades.

3.

There is little difference in the utilisation of wind energy between three and four-blade rotors.

A two-blade rotor can only generate low voltage and only starts at high wind speeds.

Moreover, less material is needed for a three-blade rotor than for a four-blade rotor.

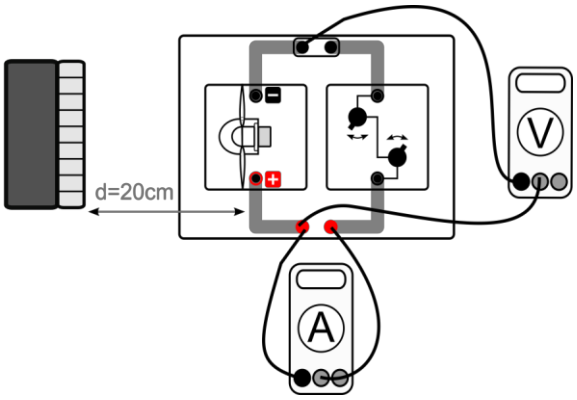
This is why mainly three-blade rotors are used for the utilisation of wind power.

7. Characteristic curves of a wind turbine

Exercise

Record the current-voltage characteristics of the wind rotor. Also determine the load resistance at which the maximum output is achieved.

Experimental setup



Equipment needed

- leXsolar main board
- Wind machine module with power supply (12 V)
- Wind turbine module (with three rotor blades, 25°, optimized profile)
- Potentiometer module
- Cable
- Voltage meter
- Ammeter

Preliminary remark

Before beginning the measurement, the potentiometer module must be adjusted to its highest possible resistance value.

Execution

1. Set the experiment up according to the experiment set-up.
2. Set different resistance values with the potentiometer module and measure the respective amperage. Reduce the voltage in steps of 0.2 V and enter your measurements in the table.

Measurements

V in V	3.0	2.90	2.8	2.7	2.6	2.5	2.4	2.3	2.2	2.1	2.0
I in mA	4.5	7.6	11.7	14.0	17.0	20.5	24.6	28.2	31.2	34.7	36.8
R in Ω	666.6	381.58	239.32	192.86	152.94	121.95	97.56	81.56	70.51	60.52	54.35
P in mW	13.5	22.04	32.76	37.8	44.2	51.25	59.04	64.86	68.64	72.87	73.6

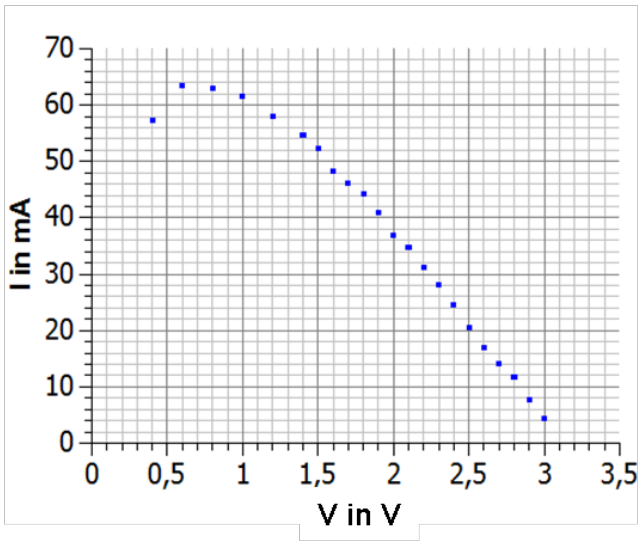
V in V	1.9	1.8	1.7	1.6	1.5	1.4	1.2	1.0	0.8	0.6	0.4
I in mA	40.9	44.2	46.1	49.2	52.2	54.7	58.1	61.5	63.1	63.5	57.4
R in Ω	46.45	40.72	36.88	32.52	28.74	25.59	20.65	16.26	12.68	9.45	6.97
P in mW	77.71	79.56	78.37	78.72	78.3	76.58	69.72	61.5	50.48	38.1	22.96

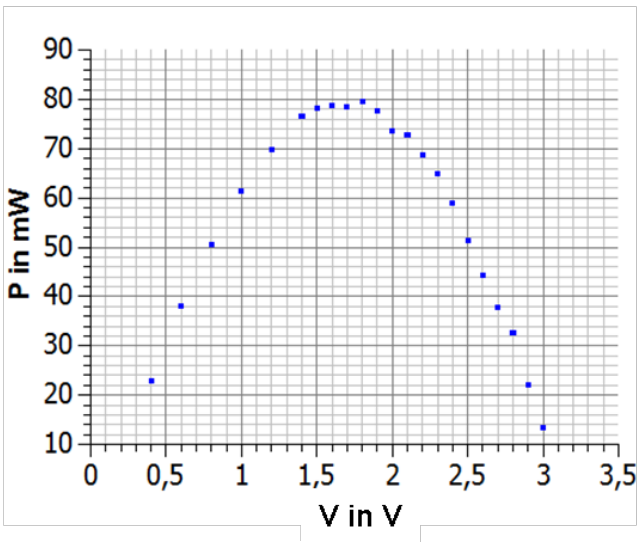
7. Characteristic curves of a wind turbine

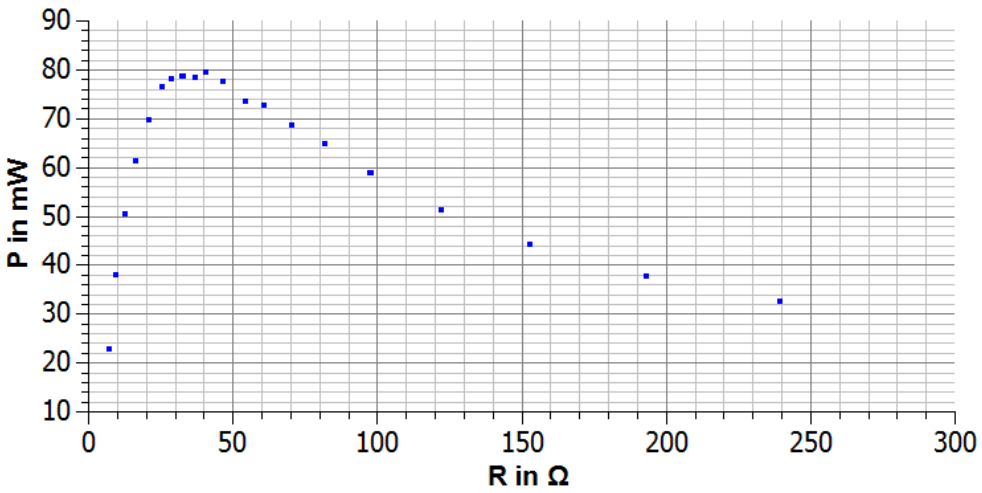
Evaluation

1. Enter your measurement pairs in the respective charts.
2. From the chart, determine the voltage value at which the output of the wind turbine is the greatest. How big is the load resistance at which the maximum output at the turbine is achieved?
3. What consequence follows from these results for the operation of real wind turbines?
4. The maximum output of a wind turbine depends therefore on the load resistance at the turbine. Name possible effects or physical variables that could also have an effect on the output of a wind turbine.

1.







2. V_{max} = 1.8V R_{max} = 40.72Ω

3. A wind turbine reaches its maximum output when the rotor generates a specific voltage.

A wind turbine reaches its maximum output when it is loaded by a specific resistance.

4. Rotor blade shape, Wind speed, Rotor size, …