Wind Power is a Breeze

An experimental wind power station for young people.

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Summary

As a part of the international science festival in Göteborg, Sweden, the experimental workshops welcomed over 10 000 visitors for a period of two weeks. During the weeks, students aged 8-15 visited the workshops and during the weekends the public joined in. At the workshop “Wind Power is a Breeze” students were able to construct their own turbines for a miniature wind power station and thereby learn about wind power. There were two turbines, a smaller one intended for the younger children and a larger one intended for the older ones. The small one was connected to a little model house with a light bulb and the larger one to three lamps connected in parallel plus a volt meter, ammeter and oscilloscope. The station was appreciated by the visitors, pupils as well as researchers. The station can be further improved and may be useful in laboratory practicals intended for older students.

The work was carried out within the EU-project Power Cluster in The Interreg IVB North Sea Region Programme.

Contents

1. Background

The international science festival, Göteborg, takes place once every year and is the largest knowledge fair in Sweden[1]. It is tied to the international network European Association of Science Events (EUSCEA) and includes several corporations and companies as partners. Chalmers University is one of the main trustees. In 2009 there were over 100 000 visitors and over 100 activities. 10 different countries were represented in 3 main branches: the public program, the school program, and the specialist program. One of the main areas in the festival is the experimental workshops, available both for school classes and the public. There are about 20 hands-on experimental stations providing opportunities to investigate and experience natural science phenomena and exciting technology. One of the workshops is the station “Wind Power is a Breeze”. With simple materials and tools the basic principles of wind power are illustrated. Students get the chance to construct their own turbines and thereby investigate which properties that gives the highest power. Also, the principles of the generator are illustrated and the students are able to investigate relationship between, for example, voltage and connected load. Over the course of two weeks 10 000 people visited the experimental workshops. The station “Wind Power is a Breeze” is also part of the EU-project Power Cluster in The Interreg IVB North Sea Region Program. Similar activities are also carried out in the different countries of the partners of Power Cluster.

2. Introduction

At the station, children design their own turbines and try them on one of the two small scale wind power stations. The children can either build a complete rotor for the small wind turbine or build blades for the large wind turbine. As wind source a fan blower was used and in order to minimize turbulence a matrix was built out of paper rolls. An anemometer was set up to illustrate relationships related to wind speed. In order to build the turbines, simple materials like corrugated cardboard and wooden sticks were attached by the use of hot glue (see appendix 1).

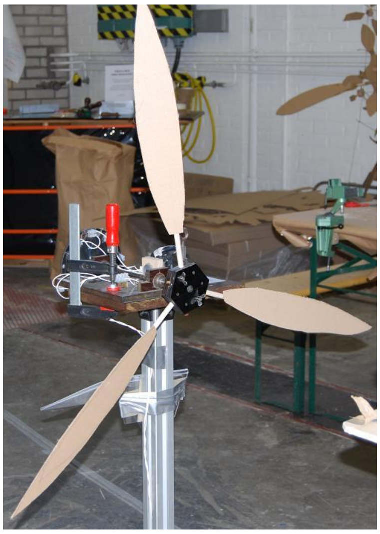
2.1 The small wind turbine

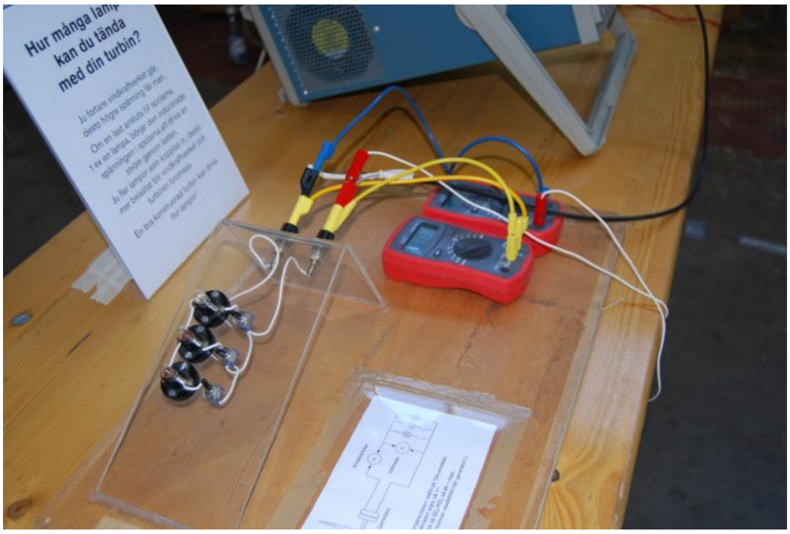
For the smaller turbines, small wooden wheels with a diameter of 47 mm were used which could be attached onto the rotor shaft connected to the generator. The turbines were built on these wheels with different kinds of wooden sticks (see appendix 1) and corrugated cardboard. The generator for the smaller turbine was placed into the wooden tower. A miniature house with a light bulb was connected to the station and the challenge was to construct a turbine that provided enough electricity to light the

lamps in the house. With this setup, students could learn how we can get electricity out of wind power and how it can be used in practice. Also, relationships between the constructions of the turbines and how strongly the lamp shines or the rotation speed could be studied. That is, this setup only provided qualitative information and the station was intended for the younger students.

2.2 The large wind turbine

For the larger turbines wooden sticks with a diameter of ca 10 mm were mounted onto the rotor hub and the turbines were built out of corrugated cardboard onto these sticks. This kind of construction provides an opportunity to change and adjust the number of blades in an easy manner. Also, the blade angle can be adjusted easily. The generator for the large turbine was constructed as described below and the station was connected to three lamps connected in parallel. A voltmeter, an ammeter and an oscilloscope were also included. With this setting-up rotation speed versus voltage could be illustrated. Also,





students could witness the decrease in voltage when turning on the lamps (different loads). The electric power could be calculated and related to wind velocity or the construction of the turbine. This station was intended for the older students.

2.3 Information at the station

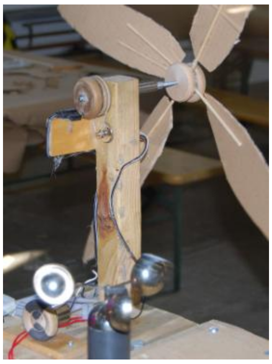
There were always at least two hosts at the station helping the students to build and mount the turbines and answering their questions. At the tables, information of what the students could try out when building turbines was available. There were also small signs with facts nearby the generator, the rotation speed display, the anemometer, the three lamps connected in parallel and the small model house. Three placards on the wall described the construction of a wind power station, the history of wind power and the highest wind turbine tower today. On these boards the answers to questions for a quiz could be found. Every day two students with the right answers won nice prizes.

3. Methodology

3.1 The fan

A 3900 W centrifugal fan with adjustable rotation speed was used as a wind source, which made it possible to study how the wind speed affects the outcome. The maximum speed of the produced wind is about 10 m/s. To make the wind less turbulent a 59×60 cm matrix made of paper rolls, with a diameter of 45 mm and a length of 100 mm, was mounted at the outlet of the fan.

3.2 The small wind turbine



The small wind turbine is depicted in Figure 1. It is made up of a small wooden tower that contains the generator. The generator is a permanent magnetized electric motor of 4,5 V. Through the top of the tower a small steel pipe is mounted. A threaded metal rod is mounted through the pipe and fastened with nuts. A wooden wheel attached to the rod is connected to the generator with a rubber-band. On the generator shaft a small two step pulley is attached. In the wooden wheel a groove for the rubber band is machined. The gear ratio is about 1:6. The turbines are built on another wooden wheel which can be attached to the other end of the rod. The electricity generated from the wind turbine runs a light bulb (3,8 volt, 0,3 ampere) in a model house.

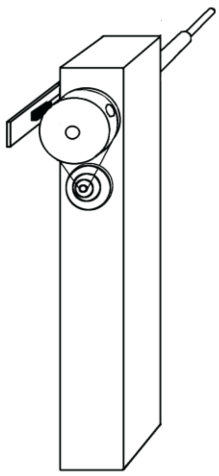


Figure 1. The small wind turbine.

3.3 The large wind turbine

The large wind turbine is built on a board with the turbine in one end and the generator in the other end. A metal rod serves as rotor shaft and connects the rotating turbine with the generator. The shaft is suspended by ball bearings. The blades are built on wooden sticks that can be attached via holes in the hub and fixed in position by tightening of a pair of wing nuts. The generator is made with inspiration from the Hamster Wheel Generator described on the website Other Power[2]. It is made of a circular disc, attached to the rotor shaft, with twenty strong neodymium permanent magnets mounted on it. The magnets are arranged with alternate polarity. Opposite the turning disc eight handmade coils, wound with 400 turns of enameled copper wire, are mounted. The coils are made using a coil winder, made especially for this purpose. For more details on making coils, readers are referred to the website Other Power[2]. A summary of this material is also available in appendix 3. The coils are connected in series of two, which are connected in parallel with two other series of coils. The outgoing electricity runs a series of light bulbs. The children can switch on one, two or three of the light bulbs and study how the load affects the voltage and the current. The light bulbs are 3,8 volt and 0,3 ampere each.

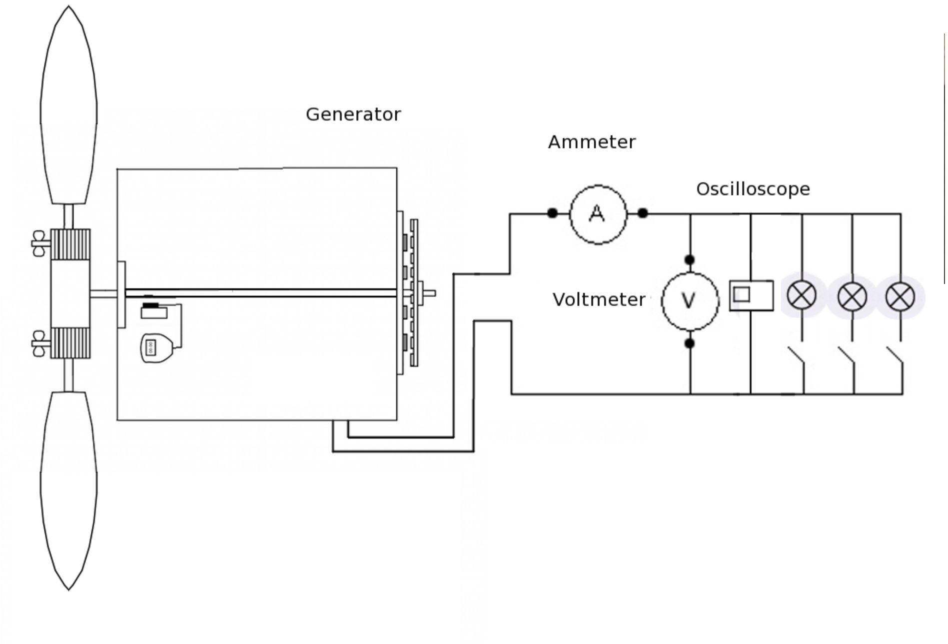


Figure 2. The large wind turbine connected to a series of light bulbs.

3.4 Rotation speed

The rotation speed of each wind turbine is measured with bike computers. The magnet from the bike computer is attached to the turning wheel of the small wind turbine and to the turning rod of the large wind turbine. The sensor is mounted straight opposite the magnet. The display of the bike computer shows the rotation speed. Charts of the best rotation speed are kept for each day and for the entire fair.

3.5 Wind speed

The wind speed is measured with a cup anemometer. The anemometer has a pulse output connected to signal conditioning to produce an analog reading of the wind speed.

4. Conclusion

The station seemed to be appreciated by the visitors. Many of them showed interest in making a turbine and those that did showed a greater understanding of its basic functionality. Also, many of the visitors attempted to improve the turbines in order to obtain a higher rotation speed. It proved more difficult to turn their attention to the other properties of turbines. For example, making them understand exactly how the electricity is generated and how it is used. This might also be a bit harder to digest, especially for the younger visitors. Much of the visitors' experience was dependent on the attitudes of their hosts, who varied widely in background and experience. Some of them had more knowledge on wind power and electricity while others had less knowledge on this subject. The number of visitors on the station was the same as average for all stations in the experimental workshops.

5. Future perspectives

The station can be improved in many ways. There are losses of mechanical and electrical energy in both wind turbines which can be reduced by different methods. For example, vibrations of the rotor shaft of the small wind turbine could be reduced to decrease losses of mechanical energy. The construction with a rubber-band on the small wind turbine is a bit fragile and could be improved. There is also space for more coils on the generator which would raise the output power. This could make it possible to connect more light bulbs to the wind turbine.

Measurements of different quantities, such as rotation speed, wind speed, voltage and current, is quite simple and could be more sophisticated. There have been suggestions to connect all measuring devices to a computerized measurement and control system which would make it possible to import and process data with computer software such as Labview. This approach would be appropriate for older students. There have been many suggestions of functions in the user interface. Two possibilities include displaying measured quantities and studying the relationships between different quantities such as power and wind speed. It could also be possible to control the rotation speed of the fan and adjust the connected load. The investments for this improvement are small, but it would require some time for assembly and programming.

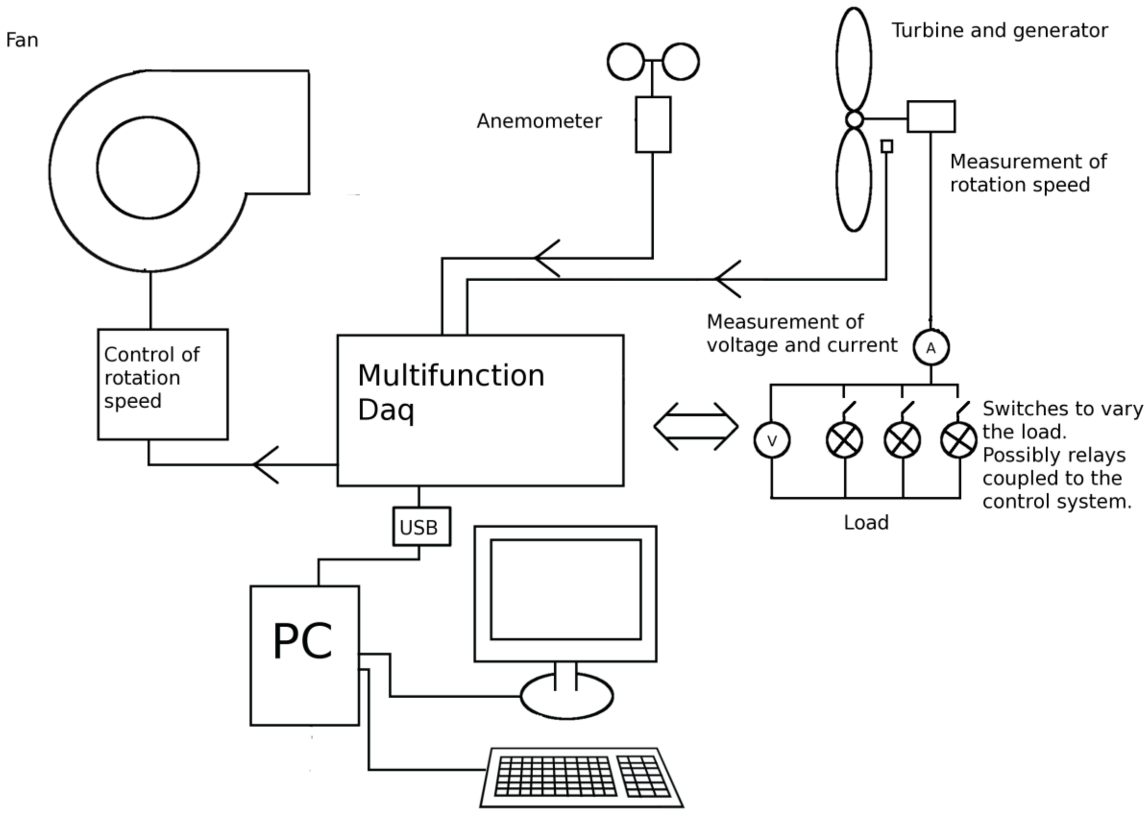


Figure 3. Proposal of further improvement of the station

Other things to evaluate continuously are the information presented at the station and the information sent out to the teachers.

6. References

1. www.vetenskapsfestivalen.com

2. Other Power, www.otherpower.org/hamster.html

7. Appendix

Appendix 1: Material consumption an approximate cost[1]

Naming	Approximate consumption	Unit cost	Total cost
General			
Hot glue 7,5*100 mm	2000 pcs	0,5 SEK	1000 SEK
Corrugated cardboard 4*750*1150 mm	200 pcs	9 SEK	1800 SEK
Flexible corrugated cardboard 500*7500 mm	1 roll	171 SEK	171 SEK
Pencils	50 pcs	3,25 SEK	162,5 SEK
Scissors	10 pcs	59 SEK	590 SEK
Duct tape	3 pcs	13,5 SEK	40,5 SEK
Glue gun	20 pcs	275 SEK	5500 SEK
Ruler 600mm Alu	5 pcs	76 SEK	380 SEK
Paper to cover the tables 100*300 cm	7 rolls	79 SEK	553 SEK
Multi-socket extension lead	8 pcs	39 SEK	312 SEK
Rubber-band	1 pkg	10 SEK	10 SEK
The large wind turbine			
Wooden stick 10*900 mm	400 pcs	3,13 SEK	1250 SEK
Saw	2 pcs	50 SEK	100 SEK
The small wind turbine			
Wooden wheel	3000 pcs	1 SEK	3000 SEK
Wooden stick 4*110 mm	3000 pcs	0,175 SEK	525 SEK
Wooden stick 4*250 mm	1000 pcs	0,375 SEK	375 SEK
Wooden stick, plane, 10*150 mm	1000 pcs	0,08 SEK	80 SEK
	Total approximate cost	**15 849 SEK** (≈ 1528 EUR)	

[1] These prices and materials are approximate suggestions and should be treated as a rough guide. The approximation is calculated for roughly 2500 visitors.

Appendix 2: Materials for construction of the station and approximate cost[1]

Naming	Number	Unit cost	Total cost
General			
Fan[2]	1	From 8400 SEK[2]	8400 SEK
Light bulbs	4	19 SEK	76 SEK
Anemometer	1	3000 SEK	3000 SEK
Terminal blocks, 9 terminals	2	20 SEK	40 SEK
Flexible conductor cable 100m	1	174 SEK	174 SEK
Flexible mains cable 20m	1	80 SEK	80 SEK
Bike computers	2	80 SEK	160 SEK
Small turbine			
Permanent magnetized electric motor of 4,5 V	1	20 SEK	20 SEK
Large turbine, generator			
Neodymium magnets	20	5 SEK	100 SEK
Copper wire 0,3*32000 mm	1	100 SEK	100 SEK
Rotor shaft	1	50 SEK	50 SEK
Ball bearings	2	40 SEK	80 SEK
Large turbine, measuring devices			
Multimeter	1	150 SEK	150 SEK
Oscilloscope	1	From 1700 SEK	1700 SEK
		Total approximate cost	**14 130 SEK** (≈ 1362 EUR)

[1] These prices and materials are approximate suggestions and should be treated as a rough guide. The approximation is calculated for roughly 2500 visitors

[2] Second-hand Ziehl Abegg RD50A-4DW.6T.1L, 3,9 KW, airflow ≈ 5 m^3/second, control system PKDM-10. Retail price: 30560 SEK. There are other possible, less expensive, alternatives. For example, a leaf blower (from 700 SEK, 12 m^3/minute) might be used if the station was scaled down some.

Appendix 3: Construction of the coils:

A summary of the material on Other Power (reference 2)

In order to wind the coils a simple homemade hand cranked coil winder is used. The center insert of the winder should have about the same size and shape as the magnets. Each coil is 400 turns and will then have an inner hole of the same size as the magnet. The wire should be packed as tightly as possible, 400 turns of a copper wire with a diameter of 0,3 mm gives a coil that is about 5 mm thick. Before starting, the coil winder was waxed with stearine in order to easily remove the finished coil. A big tail should be left at both ends of the wire which can, when the coil is finished, be twisted together. Before taking of the coil from the winder, superglue was used to fit the coil tightly. Additional superglue can be used if the coil falls apart when removing it from the winder. Be careful! The coils are then mounted on the generator and connected two in series, as described in section 3.3. Before connecting the coils, the ends have to be stripped with sandpaper, razor blades or a knife. The coil should be as close to the magnet as possible without, of course, grinding it. Now, when spinning the wheel, the AC voltage from the mounted coil can be determined. The same procedure is then repeated for the rest of the coils. Make sure to place the second one exactly the same way as the first, and so on. The best way to test this is to use a voltmeter: the voltage for coil one and two should be approximately twice the value of coil one alone. If no voltage is observed, the wires from one coil should be reversed. Also make sure that the second coil is in phase with the first, i.e. exactly centered on the magnet. The easiest way is to place the second coil opposite to the first one. Test the voltage again and make sure that it is about twice as high as for one coil alone. For further details readers are referred to the website of other power[2].

Appendix 4: Additional pictures