

LA VERITAT

(www.amics21.com)

How to begin to dare to build a simple wind generator

by Manuel Franquesa¹

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Introduction

"Think globally, act locally"

Sooner or later, the global warming and the oil shortages will force us to look for more modest, and therefore more respectful energies.

This short guide will give you an idea of how you can try to start to build a small wind generator with simple materials.

But be warned: like any rotating machine, a wind generator can be very dangerous!

Make sure you use VERY SOLID components and never stay near the spinning rotor!

1. Mr. Betz, the energy of the wind and the power of a wind turbine

The **maximum power** that we can "harvest" from the wind with a machine is approximately (if we take into account all losses of the system):

$$P = 0,15 \cdot D^2 \cdot v^3$$

¹ Autor von "Kleine Windräder : Berechnung u. Konstruktion" - Wiesbaden ; Berlin : Bauverlag, 1989; ISBN 3-7625-2700-8

- P is the power in watts [W]
- D is the diameter of the wind turbine in meters [m]
- v is the wind speed in meters per second [m/s].

This simple formula is a child of Mr. **Betz**, a German scholar who in 1926 first published the theoretical base of wind turbines.

We see that the power increases with the cube of the wind speed, i.e. the more wind, the (much) more power.

Example:

¿What is the maximum power of a wind turbine with a diameter of 6 meters?

At a wind speed of 10 m / s (= 36 km / h), the power is:

$$P = 0.15 \cdot 36 \cdot 10^3 = 5400 \text{ [W]} = \mathbf{5.40 \text{ [kW]}}$$
 (1 kW = 1000 W)

If we double the wind speed to 20 m / s (= 72 km / h), we will get **eight times more power** ($2^3=8$):

$$P = 0.15 \cdot 36 \cdot 20^3 = 43200 \text{ [W]} = \mathbf{43,20 \text{ [kW]}}$$

2. The rotation speed of a wind turbine

The rotation speed of a wind turbine can be calculated with the following formula:

$$n = (60 \cdot \lambda \cdot v) / (\pi \cdot D)$$

- n is the rotation speed in revolutions per minute [rpm]
- λ is the so called **tip speed ratio** of the wind turbine. This factor depends on the width and the angle of the blades of the wind turbine. Its nominal value can be between approx. 0.8 and 14. Our wind turbine will have a design tip speed ratio of about $\lambda_d = 4$.
- v is the wind speed in **meters per second [m/s]**.
- D is the diameter of the wind turbine in **meters [m]**

To get an idea:

A modern wind generator with a rotor diameter of 20 m has a nominal tip speed ratio of about $\lambda_d = 8$.

If we calculate with the formula above its rotation speed at a wind speed of 10 m/s (= 36 km/h), we will get:

$$n = (60 \cdot 8 \cdot 10) / (\pi \cdot 20) = 76,4 \text{ U/min}$$

It does not seem much, but the tips of the blades have a velocity of 288 km / h! This creates a lot of noise and represents a significant threat to the birds.

General rules:

- The larger the diameter of the wind turbine, the lower its rotation speed (at the same wind speed)
- A higher number of blades does not increase the rotation speed, but it increases the aerodynamic efficiency of the wind turbine (at the same diameter and wind speed).

3. A little bit of aerodynamics

The wings of a wind turbine are nothing else than airplane wings, which rotate around a horizontal (sometimes vertical) axis.

When the airplane takes off, the engine(s) moves it forward, and the wings begin to "cut" the air. Since they have a specific profile (shape) and are somewhat inclined towards the wind direction (angle of attack), the air circulating around the wings creates an overpressure at their bottom. This pressure (lifting force) "pushes" the wing up and thus the entire aircraft: Hallelujha, it "flies" (full of tourists to Majorca).

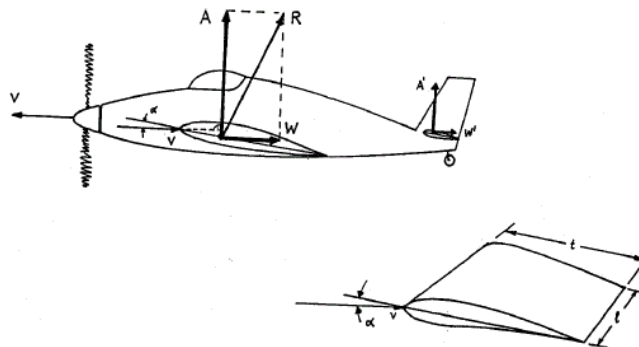


Fig. 3.1 A Lifting force , W Resistance force of the wings (R Resulting force)

As with any human invention, the wings are not ideal: they have a resistance that increases the fuel consumption of the plane.

The propeller of the airplane has also wings (like an "inverted" wind turbine!), which turn around the engines drive shaft. The propeller is "screwed" into the air like a corkscrew in the cone of a good old Spanish red wine.

In this context one must mention that the propeller planes have a higher efficiency than jets. But they are much slower, which today seems to be a disaster. Under ecological considerations, jets are actually prehistoric machines: What is creating its enormous power is nothing else but a stream of badly burned exhaust fumes, polluting our atmosphere² with an infinity number of smallest and most toxic particles of yet unknown composition. *But who cares*

...

² Our life-spending atmosphere has an altitude of 30 - 50 km. If we compare this distance with the 12,000 km diameter of the Earth, the atmosphere is like a latex skin of 1.5 mm thickness (condom) slipped over a football of 30 cm diameter.

The cross section of a modern wing has the shape (profile) of a protracted drop. This profile increases lift and reduces resistance. Long, narrow and thin sections have a much higher efficiency than short, wide and thick ones. A good example is the albatross, a bird that can fly for days without barely flapping its wings. Or gliders, circling for hours with their very long and narrow wings over the Alps without an engine!

One great advantage of a (home made) wind turbine is that as long the wind is (still) free of charge, it does not need high-tech-blades. The blades of the old Quixote mills consisted mainly of a grid of wooden laths, covered with a cloth sail! The lower efficiency of the simplified blades can be compensated increasing the diameter of the wind turbine.

4. Construction of the wind generator

4.1 Description of the machine

We will now try to construct a simple wind generator with a design tip speed ratio $\lambda_d = 4$ and a rotor with a diameter of $D = 2$ meters. As power generator we will use a car alternator with his (usually) built-in regulator.

The rectangular and slightly curved blades (deflection = 5% of the width of the blades), will be made with metal sheet, e.g. aluminum. The thickness of the sheets should be about 1,5% of the width of the blades (see below).

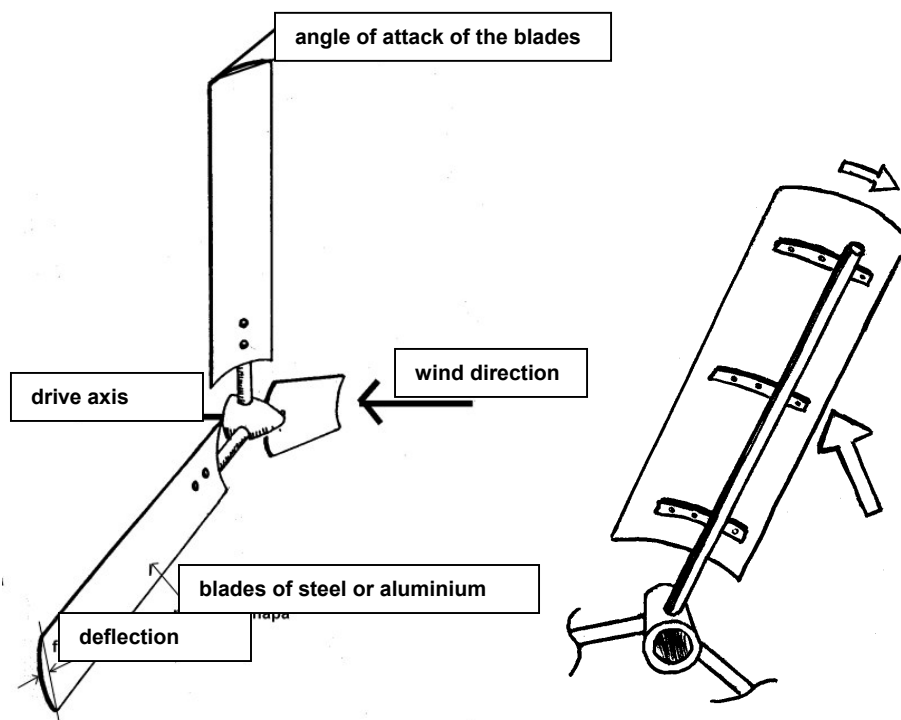


Fig. 4.1

Left: Wind turbine with blades made with (slightly) curved plates

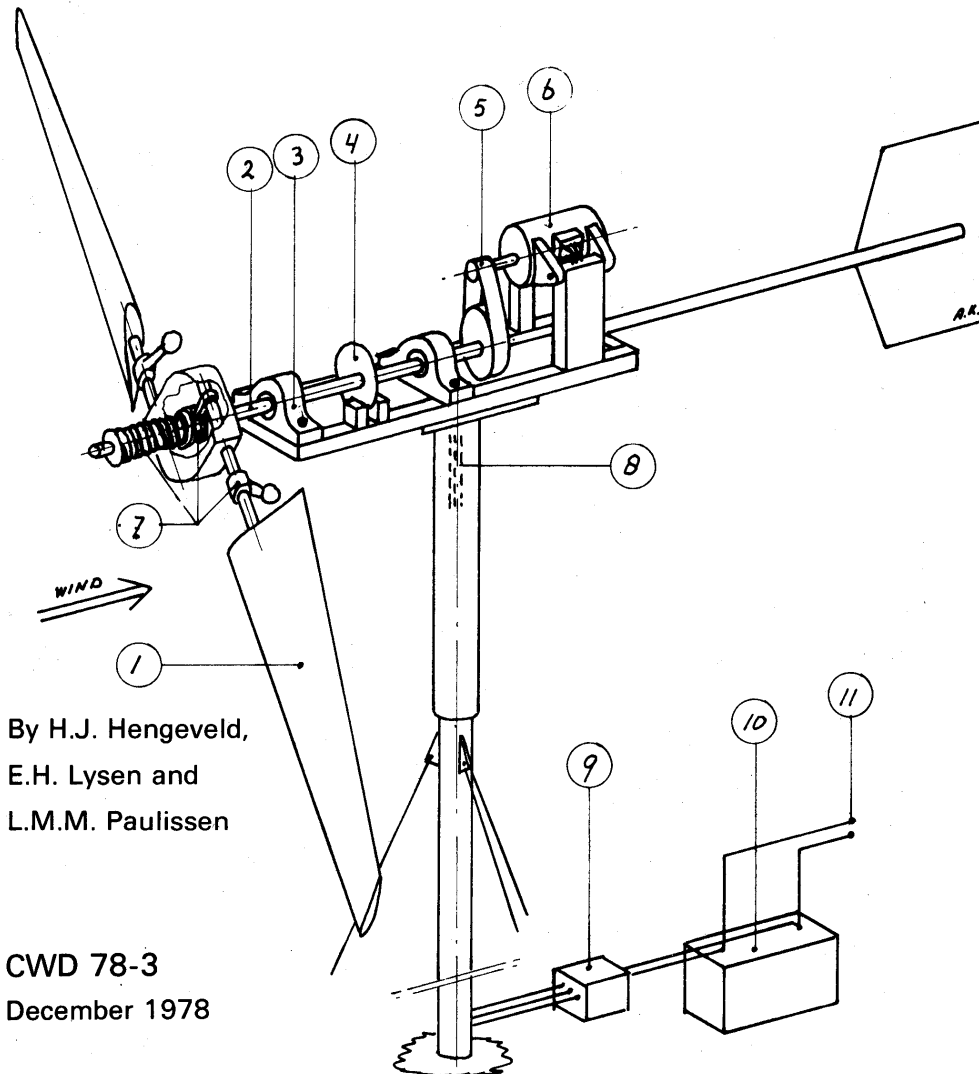
Right: One possibility to attach the blades (for aerodynamic reasons, the mounting bar should be fixed on the concave side of the blades, i.e. on the wind-blown side, otherwise the aerodynamic efficiency of the rotor will markedly decrease).

The hardest part is finding a suitable "body" for our wind turbine, i.e. the bearing which transmits the rotation of the blades to the generator (or alternator) (however: junkyards are gold mines!). But remember that this element should:

- be (very) robust
- have an axis with a pulley or similar device at one end, to which one can attach the blades of the rotor, and at the other end a pulley for the transmission belt of the alternator

The next page shows the cover of the excellent pamphlet about matching wind turbines to low power electrical generators written by Hengeveld, Lysis and Paulissen. The drawing is very inspirational.

Matching of wind rotors to low power electrical generators



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Fig. 4.2

1 Wind rotor, **2** Rotor shaft, **3** Shaft bearings, **4** Disc brake, **5** Transmission, **6** Electrical generator (for example car alternator), **7** Protective device against high wind speeds and overspeed of the rotor (it changes the angle of the blades), **8** Wiring (eventually sliprings) to conduct the generated electricity to the foot of the tower, **9** Generator control device (field current, voltage control), **10** Storage battery (in case of DC systems), **11** Load connection

4.2 Main data of our wind generator

4.2.1 Width, angle of attack and deflection of the rectangular, curved blades (deflection in the middle of the blades = 5%) / thickness of the sheet

Diameter of the wind rotor	2 m				
Number of blades*	2	3	4	5	6
Width of the blades	31,4 cm	21 cm	15,7	12,6	10,5
Angle of attack of the blades**	10°	10°	10°	10°	10°
Deflection of the blades	16 mm	11 mm	8mm	6 mm	5 mm
Minimum thickness of the sheet	4 mm	3 mm	2 mm	2 mm	2 mm

* Note: The higher the number of blades, the higher the efficiency of the wind rotor

** Angle which the blades build with the the surface perpendicular to de rotor shaft or to the wind direction.

4.2.2 Optimal rotation speed and power of the wind turbine as a function of the wind speed

Wind speed	8 m/s	10 m/s	12 m/s
Optimal rotation speed of the wind turbine	305 rpm ³	380 rpm	460 rpm
Power (approx.)	300 W	600 W	1000 W

4.2.3 Transmission ratio between the wind turbine and the alternator

It is important to emphasize **that a car alternator is not the best choice for a wind generator**. Its efficiency is very poor (probably a side effect of low gasoline prices from the old days): **it will hardly exceed 50%**! Nevertheless, there are some advantages: these machines are very robust, cheap, and available at any time (scrap dealers). If we do not necessarily aim a high efficiency for our wind generator, we can start with such an alternator.

A car alternator requires a certain rotation speed in order to deliver current (at least about 750 rpm). As the wind turbine rotates much more slowly, we must provide a translation. The simplest solution is a larger pulley fixed to the drive shaft of the wind rotor (for example a bicycle wheel or the driving pulley of the drum of an old washing machine), connected via transmission belt to the drive wheel of the alternator (see Fig 4.2).

Fig.4.2.3 shows the current-speed curve of an arbitrary automobile alternator:

³ Revolutions per minute

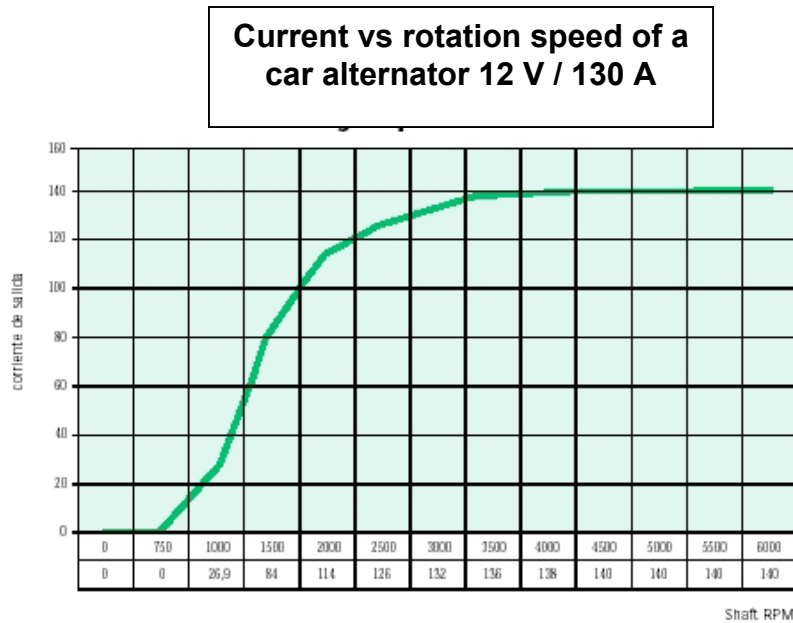


Fig.4.2.3 Current-speed curve of an arbitrary automobile alternator

In this curve we can see that this alternator begins to deliver current at a rotation speed of about 750 rpm.

At about 1000 rpm it delivers approximately 27 Amps.

Under a charging voltage of 14 V and a current of 27 A, the power delivered by the alternator will be about $14 \text{ V} \cdot 27 \text{ A} = 378 \text{ W}$.

The following table shows the transmission ratio as a function of the rotation speed at which our alternator will provide an acceptable amount of current (15 to 30 Amps):

Rotation speed of the alternator (rpm)	1000	1200	1400	1600
Transmission ratio	2,6	3,2	3.7	4,2

Once we have determined the transmission ratio, the diameter of the pulley connected to the drive shaft of the wind rotor will only depend on the diameter of the pulley of the alternator and the required rotation speed of the alternator:

If the required rotation speed of the alternator is 1000 rpm:

Diameter of the pulley of the alternator	4 cm	6 cm	8 cm
Approximate diameter of the drive pulley of the wind rotor	10 cm	15 cm	20 cm

If the required rotation speed of the alternator is 1200 rpm:

Diameter of the pulley of the alternator	4 cm	6 cm	8 cm
Approximate diameter of the drive pulley of the wind rotor	12 cm	20 cm	19 cm

If the required rotation speed of the alternator is 1400 rpm:

Diameter of the pulley of the alternator	4 cm	6 cm	8 cm
Approximate diameter of the drive pulley of the wind rotor	15 cm	22 cm	30 cm

If the required rotation speed of the alternator is 1600 rpm:

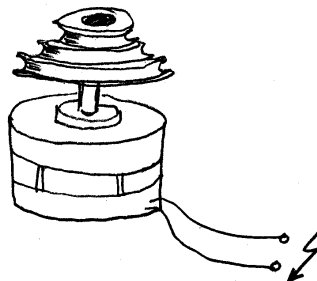
Diameter of the pulley of the alternator	4 cm	6 cm	8 cm
Approximate diameter of the drive pulley of the wind rotor	17 cm	25 cm	33 cm

In the scrap of our postmodern society you will find countless pulleys and wheels of machines or engines in all sizes and designs.

Who does not seek will find (old Zen Buddhist proverb)

Comments on the transmission system

- Anyway, the optimum transmission ratio of the drive must be found by trial and error. The engines of bench drills have a conical drive wheel with different diameters. This permits more quickly to find the optimum rotation speed of the alternator. You must provide a device to raise and lower the alternator and tighten the belt after you've chosen a different diameter.



Alternator with a triple pulley (driving wheel of a scrapped table drilling machine)

- As shown in the tables above, one should select an alternator with a smaller drive pulley, otherwise the diameter of the pulley of the wind rotor will be quite big, leading to space problems

Note on the electrical system

About the electrical system we will not say much. **Get advice from a good auto electrician.** It is important to know whether the (usually) built-in **regulator** of our alternator (an electronic device which prevents the voltage of getting too high, limiting the charging current and switching off the current when the battery is charged) is suitable for charging the battery of our self-made wind generator.

And one more important remark

The higher the transmission ratio, the lower will be the starting torque of the system wind rotor / alternator, which means that the wind rotor will have difficulty to put the alternator into motion, especially when the alternator is already excited. For this reason you should provide a regulatory system that switches on the excitation current of the alternator only when the wind rotor has reached a certain rotation speed (ask a car electrician).

4.2.4 The wind vane of the wind generator

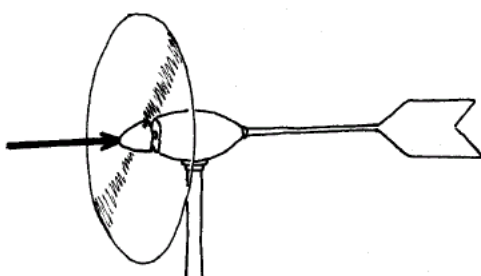


Fig. 4.2.4 Wind vane of a wind generator

The wind vane puts the wind rotor always perpendicular to the wind direction. It consists of a metal plate, whose shape plays no major role (but it should be beautiful), which is connected by means of a robust pole with the main body of the wind generator. The length of this rod should be between 60 and 100% of the diameter of the wind rotor.

The plate must have a minimum surface (see table below):

Length of the rod of the wind vane *	1,2 m	2 m
Minimum surface of the wind vane plate	0,40 m² (e.g. rectangular plate 80 x 50 cm)	0,25 m² (e.g. rectangular plate 63 x 40 cm)

* Distance between the axis of symmetry of the tower and the center of gravity of the wind vane plate

4.2.5 Tower of the wind generator

The tower of our self built wind generator has no special limits. An old telephone pole made of wood can also be used.

Important: It must be (very) robust and be firmly anchored in the earth. Of course, you must also connect the upper pivot bearing system of the system wind turbine / alternator VERY well to the tower. **DANGER DURING A STORM!** Keep in mind that the tower must not only bear the weight of the wind generator, but also resist the bending moment created by the wind pressure (= **force**) on the rotating wind turbine. It's like a toothpick set in a cone of a good old Spanish red wine: if you press strongly with your fingertip against its free end, it will break - and tilt.

4.2.6 A (relatively) simple safety device against strong winds

Let's not forget that the energy of the wind increases with the cube of its speed - and hence the forces. **We must cope with the wind.** ¡A storm can destroy your beloved wind generator in minutes - **and this represents a threat to humans, cattle, chickens and stuff!**

We can provide a disc brake (see Fig 4.2), which can be operated at the foot of the tower (you have to find out yourself...).

There is also a very "primitive", but cheap, solution to take the wind turbine “**out of the wind**” during a storm:

If you live next to the wind generator, for example if you are a farmer who can **never** leave his farm because of the animals or your husband, then you can attach two ropes to the wind vane and let them hang free during normal operation of the wind generator. When the wind gets dangerous, you can use these two ropes to get the wind generator out of the wind attaching the two ropes to two sturdy and separated anchorages.

Do not forget that in a storm the wind plays a starring role, and that you can never know what he will do in the next moment.

If you're not always there, then you can assemble a relatively (!) simple "storm protection device with a transversal wind vane" to your wind generator.

Principle: A transversal wind vane (i.e. a wind vane that stands perpendicular to the wind direction) is fixed rigidly to the body of the wind generator, while the main wind vane is fixed to the body of the wind generator means of a hinge (that you have to find out yourself) and a spring (which you need to find out empirically or calculated).

Fig 4.2.7 shows the principle.

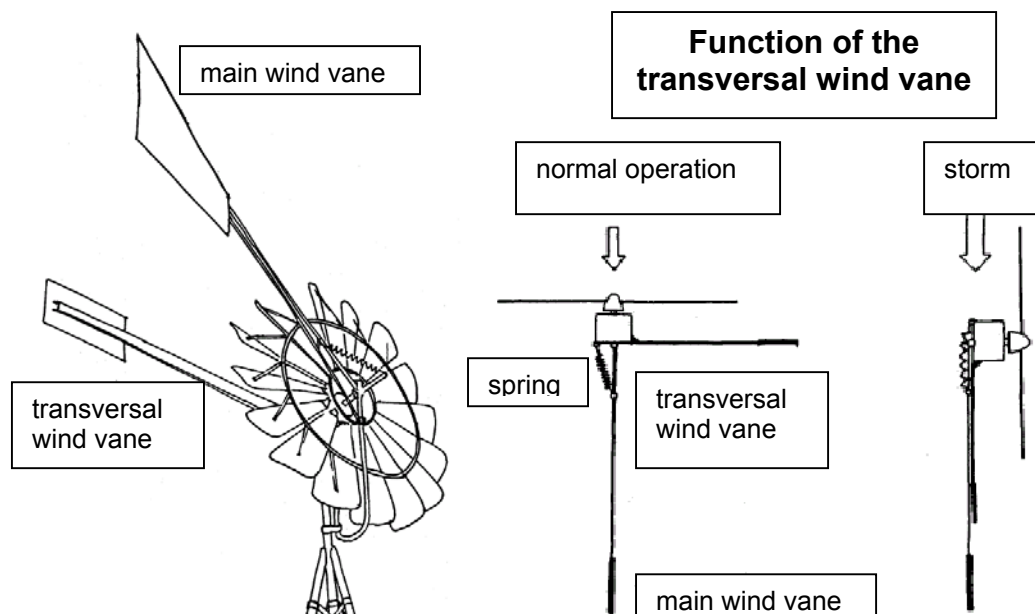


Fig. 4.2.7 Wind turbine with a transversal wind vane against strong winds

How it works: As soon as the wind exceeds a certain dangerous speed, it "pushes" the transversal wind vane and with it the body of the wind generator out of the wind (the wind rotor stops turning or does it slowly).

Important Notice

If the wind generator is far from the house, one must be aware that it takes very thick cables to transmit the power at 12VDC, otherwise you will have only a few volts available in the house. Today there are relatively low-cost DC / AC converters, which convert the 12 VDC voltage in a 220VAC /50Hz voltage.

5. Wind turbine with sails

The "blades" of these old windmills (Crete) consists of triangular fabric sails (Fig. 5.1).

The "poles" of the sails (= radius of the rotor) can be made of wood or aluminum tubes.

Each sail is connected to the next radius using a rope or cable. To keep the sail always tight, you can also use springs or rubber bands. This has the advantage of keeping the sails relatively tight even at strong winds.

As the sails offer a considerable resistance against the wind, these wind turbines often have the drive shaft prolonged to the front, to which the different radii are fixed by means of cables. This prevents that the wind pressure breaks the radii or bend them over backwards.

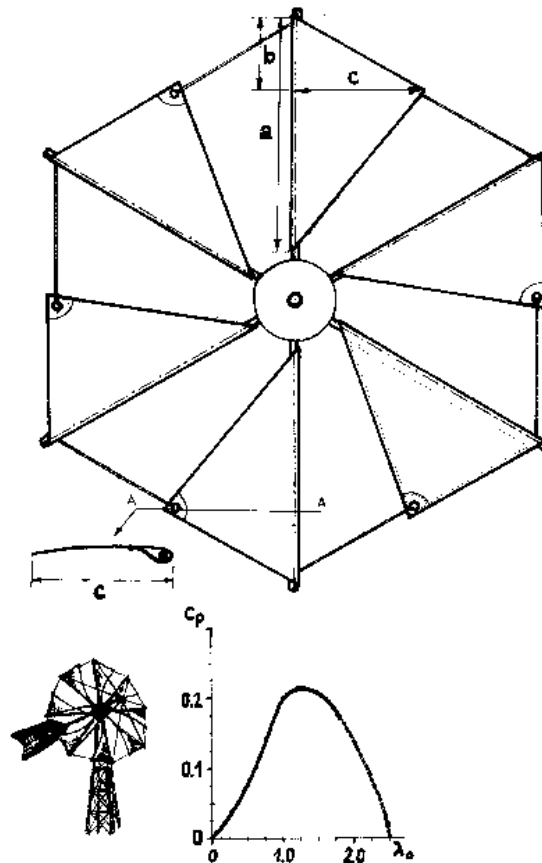


Fig. 5.1

Wind turbine with 6 sails ($a = 0,8 \cdot R$; $b = 0,25 \cdot R$; $c = 0,45 \cdot R$)

These rotors have a low nominal tip speed ratio ($\lambda_d = 1,2 \dots 1,4$) and thus a low rotation speed. Therefore, to drive a car alternator you need a large transmission ratio ($k > 8$ for a rotor with 6 sails and a diameter of 2 meters (Fig. 5.2)).

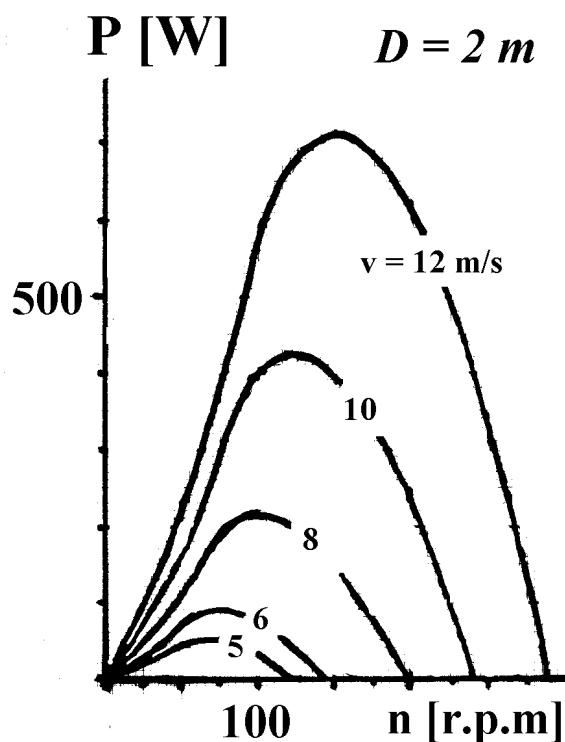


Fig. 5.2

P, n, v – characteristics of a wind rotor $\lambda_d = 1,2 \dots 1,4$ with 6 sails and 2 meters diameter (Fig. 5.1), measured in a wind tunnel by [Smulders et al.].

Maximum power of a wind generator build with the wind rotor with 6 sails shown in Fig. 5.1 (2 meters diameter) and a car alternator with approx. 50% efficiency:

Wind speed	8 m/s	10 m/s	12 m/s
Optimal rotation speed of the wind rotor (approx.)	100 rpm	125 rpm	144 rpm
Power (approx.)	100 W	200 W	350 W

Transmission ratio between a wind rotor with sails $D = 2$ m and a car alternator:

Required rotation speed of the alternator (rpm)	1000	1200	1400	1600
Transmission ratio (approx.)	8	10	12	14

Conclusion

I must admit that personally I have build only two of these homemade wind generators. What I have proposed to you here is a quintessence of my humble experiences.

Nevertheless I'm convinced that this little "manual" can bring you a big step further.

In the worst case, i.e. if your good do-it-yourself wind generator should not provide you enough energy, you can just think of a better solution.

This way you will reach faster the third line of this old Chinese proverb:

**"What I hear, I forget;
What I see, I remember;
What I do, I understand."**

I wish you good health, lots of humor and wind!



Manuel Franquesa Voneschen, Castelldefels, Spain

See also our "guide" to construct a wind generator with the two halves of an old 200 liter oil barrel (*Savonius* wind generator) at:

www.amics21.com/laveritat/savonius_generator_english.pdf