LA VERITAT

(www.amics21.com)

How to begin to dare to build a simple wind generator

by Manuel Franquesa Voneschen[1]

Contents

---

[1] Author of "Kleine Windräder : Berechnung u. Konstruktion" - Wiesbaden ; Berlin : Bauverlag, 1989; ISBN 3-7625-2700-8. **The author can be contacted via Facebook.**

1. 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 start trying 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 <u>VERY SOLID</u> components and <u>never</u> stay near the spinning rotor!

2. <u>Some words about the wind energy in general</u>

2.1 Mister Betz and the energy of a wind generator

The **maximum power** we can get from the wind with a ideal wind turbine (i.e. with no losses of any kind) can be calculated with the following formula:

$P = 0,29 \cdot D^2 \cdot v^3$

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

This simple formula – so called *Betz limit* - is a child of mister **Betz**, a German scientist who in 1926 published the first book about aerodynamics applied to wind turbines.
The first we can see is that the power increases with the cube of the wind speed, what means "the **more** wind**,** the **much more** power".

However, in real life it is not possible to reach this value, because all the components of a wind machine have aerodynamic and mechanical losses (the wind rotor, the bearings, the transmission system, the generator, the cables and battery to store de electricity etc.).

So, to estimate the maximum power of a real wind machine we shall use this one:

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

Example:
How much power can we "harvest" with a wind rotor of 6 meters diameter?
At a wind speed of 10 m/s (= 36 km/h), the maximum power we can get is:
P = 0,15 · 36 · 10³ = 5400 [W] = **5,40 [kW]**   (1 kW = 1000 W)
At a wind speed of 20 m/s (= 72 km/h), the power will be:
P = 0,15 · 36 · 20³ = 43200 [W] = **43,20 [kW]**
Conclusion: at **double** wind speed, we will get **8 times** more power (2^3=8)

2.2 Rotational speed of a wind rotor

The rotational speed of a wind rotor can be calculated with the following formula:

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

where

- **n** is the number of **revolutions per minute [rpm]**
- λ is a factor called **tip-speed ratio** of the rotor. It depends of the type of rotor (angle and width of the blades). In practice, its value ranges between 0,8 and 14. The Savonius rotor has a tip speed between approx. 0,9 and 1,1 (very slow).
- **v** is the wind speed in **meters per second [m/s]**.
- **D** is the diameter of the rotor in **meters [m]**

The tip-speed ratio is defined as follows

$$\lambda = u_o/v$$

where **u_o** is the speed of the blade tips and **v** the wind speed (Fig. 2.2.-1)
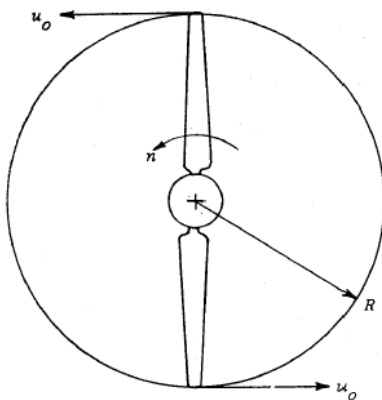
Fig. 2.2.-1 Definition of the velocity **u_o** of the blade tips

To get an idea:

A modern wind generator with a rotor diameter of 20 m has a nominal tip speed ratio of about λ_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 · 8 · 10) / (π · 20) = 76,4 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).
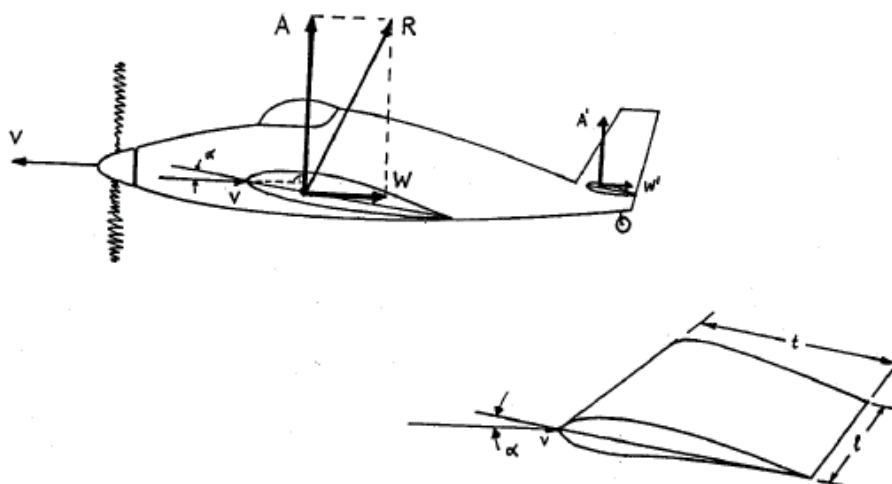
Fig. 3.1-1   **A** = lifting force (lift), **W** = resistance force (drag) of the wings (**R** = resulting force) α = angle of attack of the air

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 atmosphere[2] with an infinity number of smallest and most toxic particles of yet unknown composition. *But who cares*

The cross section of a modern wing has the shape (profile) of a protracted drop (Fig. 3.1-1). 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 rotor.


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 λ_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).

---

[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.
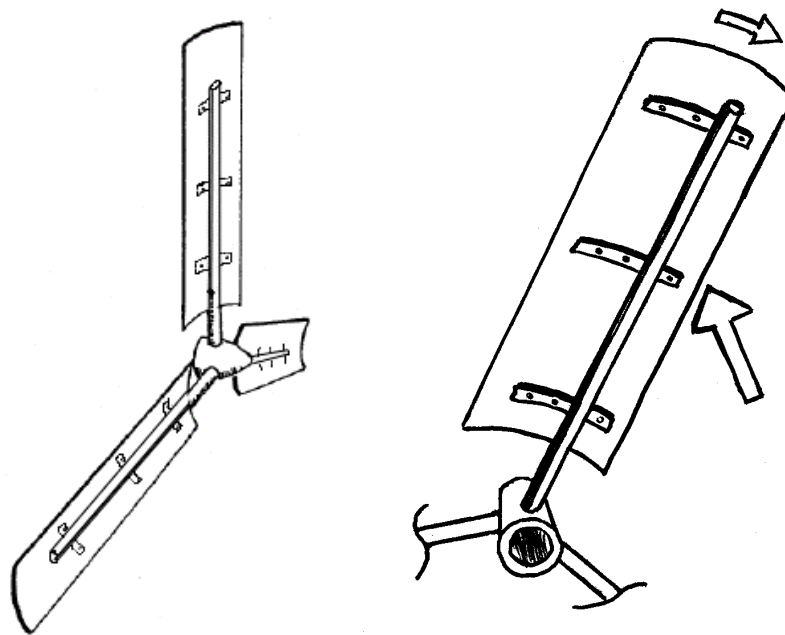
Fig. 4.1-1
Left: Wind turbine with blades made with (slightly) curved plates
**Right:** One possibility to attach the blades (for aerodynamic reasons, the mounting bar should be fixed on the concave side of the blades, i.e. on the wind-blown site, otherwise the aerodynamic efficiency of the rotor will 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 pully 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 (Fig. 4.1-2).

Matching of wind rotors to low power electrical generators

By H.J. Hengeveld,

E.H. Lysen and

L.M.M. Paulissen

CWD 78-3

December 1978
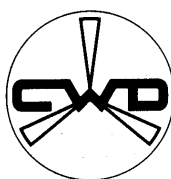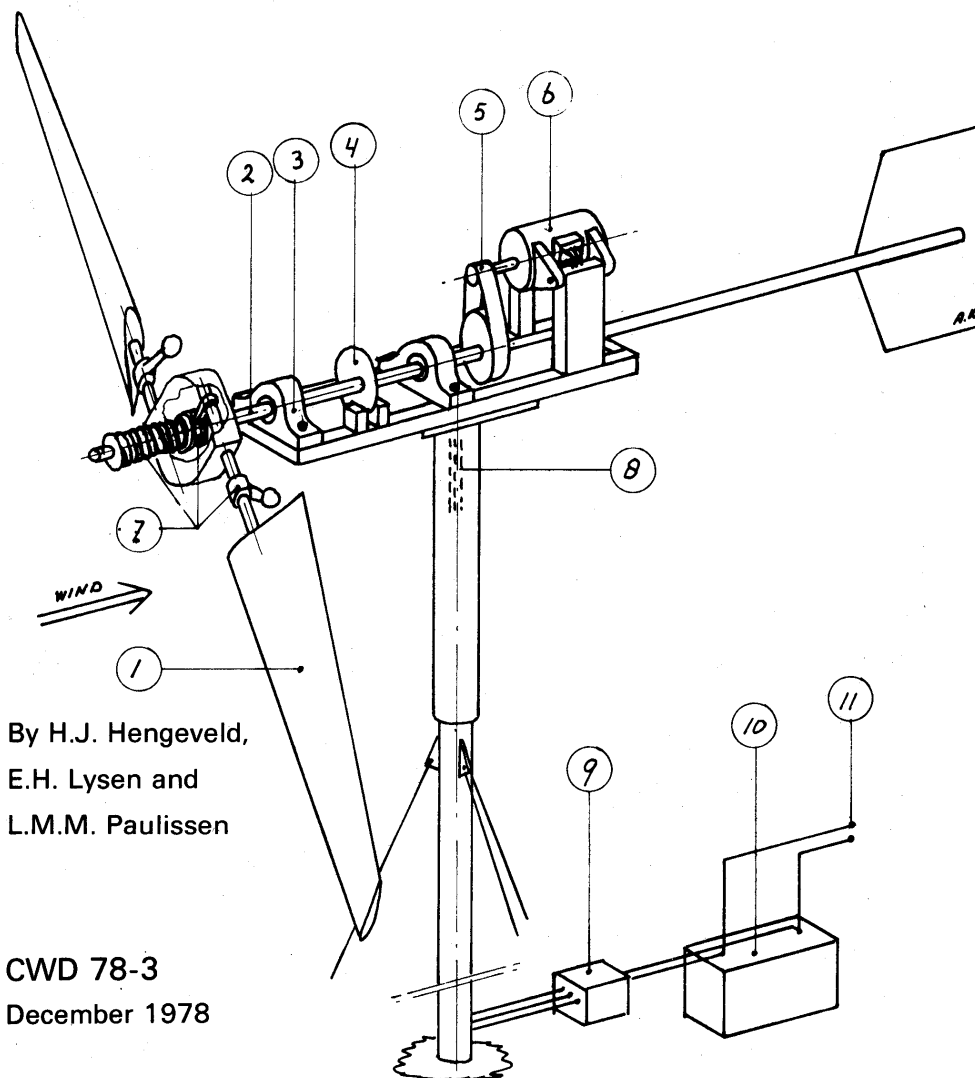
CONSULTANCY SERVICES | P.O. BOX 85
WIND ENERGY | 3800 AB AMERSFOORT
DEVELOPING COUNTRIES | THE NETHERLANDS

Fig. 4.1-2

1 Windotor, **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 de 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 <u>Main data of our wind generator</u>

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

curved blade $\quad \downarrow f = 0.05t$

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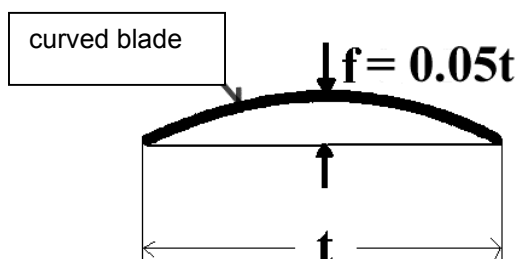
Diameter of the wind rotor D	2 m				
Number of blades* z	2	3	4	5	6
Width of the blades** t	31,4 cm	21 cm	15,7	12,6	10,5
Angle of attack of the blades δ ***	10º	10º	10º	10º	10º
Deflection of the blades	16 mm	11 mm	8mm	6 mm	5 mm
Minimum thickness of the sheet f	4 mm	3 mm	2 mm	2 mm	2 mm

* Note: The higher the number of blades, the higher the efficiency of the wind rotor
** For other diameters and number of blades **z**, the with of the blades in **[cm]** can be calculated with the following formula: **t[cm] ≈ 31.4 · (D[m]/z)**. Example.: D = 1 m, z = 4 --> t = 31.4· (1/4) = 7.85 cm
*** Angle which the blades build with the the surface perpendicular to de rotor shaft or to the wind direction. This angle does not depend on the diameter or the number of blades, but only on the rated tip-speed ratio λ_d of the wind rotor. Using the same type of blades, for 3 < λ_d < 5 the angle of attack can be calculated with the following formula: **δ ≈ 24º - 3.5· λ_d**

4.2.2 Approximate values of the maximum power, the optimal rotational speed, the starting torque and the optimal torque of the wind rotor as a function of wind speed

Wind speed v	8 m/s	10 m/s	12 m/s
Power P_{max}	300 W	600 W	1000 W
Optimal rotation speed of the wind turbine n_{opt}	305 rpm	380 rpm	460 rpm
Starting torque M_o	4 Nm	6 Nm	9 Nm
Optimal torque* M	9 Nm	15 Nm	20 Nm

*) The torque M is calculated with the following formula: M [Nm] = (60·P)/(2·π·n) (**Note**: To get the torque M in Newton metros [Nm], you have to introduce P in [W] and n in [rpm])

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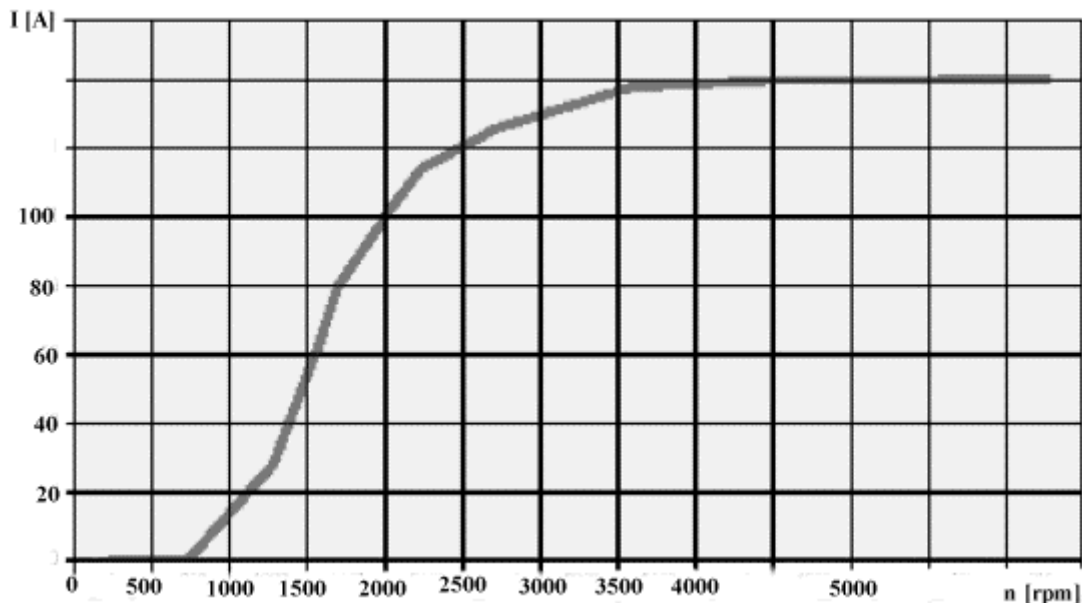
Fig.4.2.3 Current-speed curve of an arbitrary automobile alternator

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

At about 1250 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 V · 27 A = 378 W.

The following table shows the transmission ratio as a function of the rotation speed at which our alternator **starts to deliver current** (n_o):

Rotation speed n_o 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 n_o of the alternator (i.e. the speed when the alternator starts to deliver current):

> **diameter of the big pulley = k · diameter of the alternator pulley**

Alternator with n_o = 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**

Alternator with n_o = 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**

Alternator with n_o = 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**

Alternator with n_o = 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.

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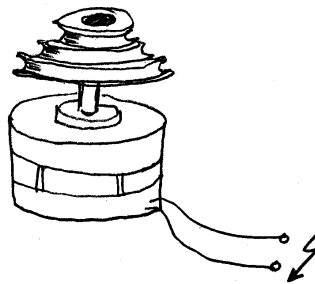
Alternator with a triple pulley (driving wheel of a scrapped table drilling machine)

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 to 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 vane of the wind generator
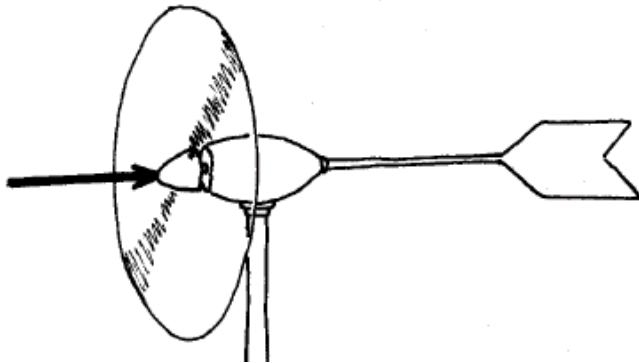
Fig. 4.2.4 Vane of a wind generator

The 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 vane *	1,2 m	2 m
Minimum surface of the 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 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 vane (i.e. a vane that stands perpendicular to the wind direction) is fixed rigidly to the body of the wind generator, while the main vane is fixed to de body of the wind generator means of a hinge (that you have to find out yourself) and a spring (which you have to calculate or find out empirically). The surface of the transversal vane is approx. 5% of the rotor surface. Fig 4.2.7 shows the principle.
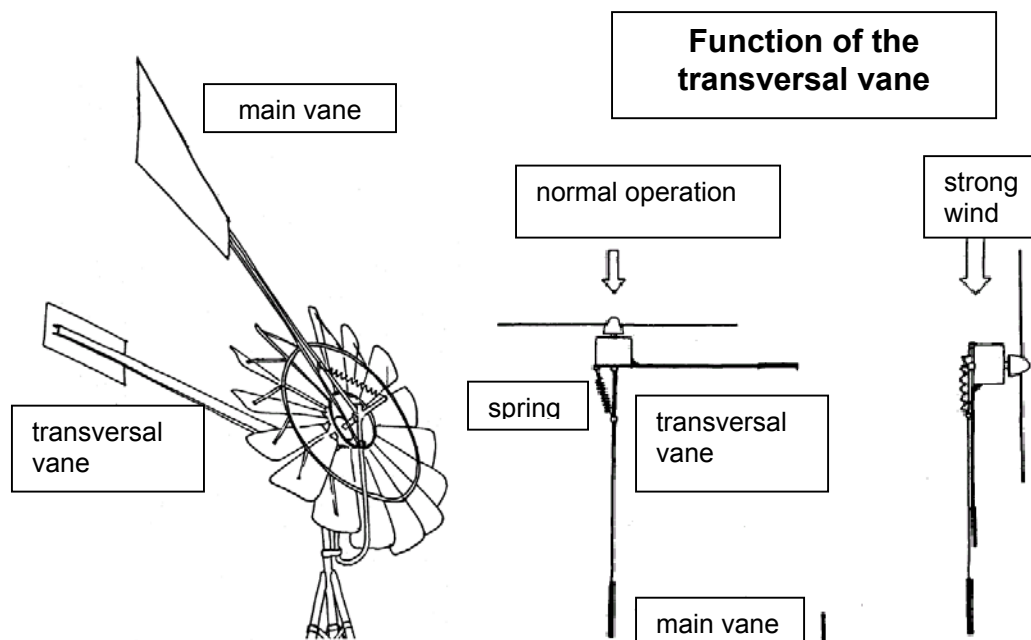
Fig. 4.2.7 Wind turbine with a transversal vane against strong winds

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 (Cretan windmill)

The "blades" of these old windmills consists of triangular fabric sails (Fig. 5.1). The "masts" of the sails (= radii of the rotor) can be made of wood or aluminum tubes. They should be as thin as possible.
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.
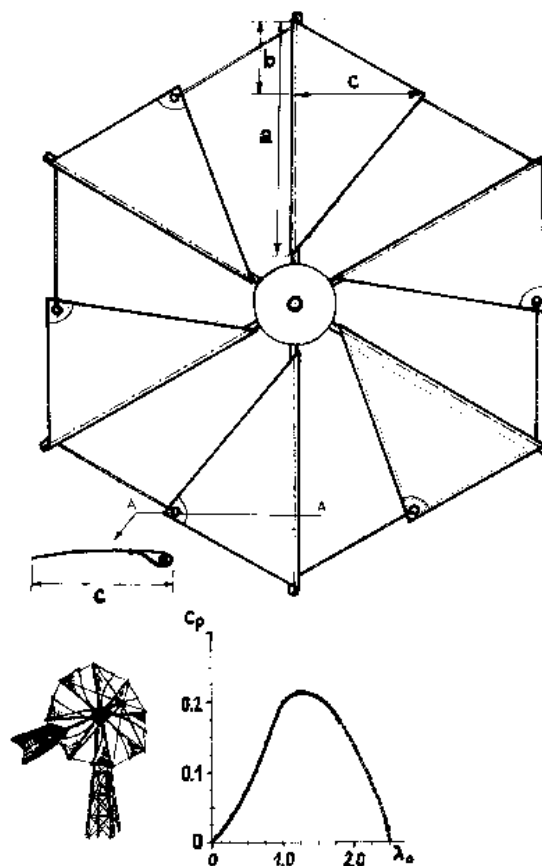
Fig. 5.1
Wind turbine with 6 sails, radius R (**a = 0,8·R; b = 0,25·R; c = 0,45·R**)

These rotors have a low rated tip speed ratio (λ_d **= 1,2 ... 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). They efficiency is modest, but they have the advantage of having a strong starting torque, so they start turning at relatively low wind speeds.

P [W]   *D = 2 m*

v = 12 m/s

500

10

8

6

5

100   **n [r.p.m]**
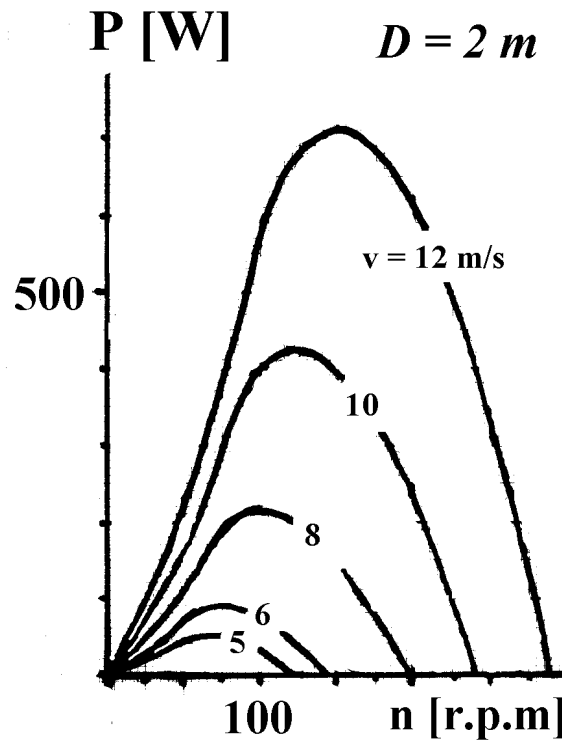
Fig. 5.2
P,n,v – characteristics of a wind rotor λ_d = 1,2 ... 1,4 with 6 sails and 2 meters diameter (Fig. 5.1), measured in a wind tunnel by [Smulders et al.].

Optimal rotation speed and 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:

Requiered rotation speed of the alternator n_o (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 shuld 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:

<div align="center">

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

</div>

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

Manuel Franquesa Voneschen, 2011, Castelldefels, Spain

<div align="center">

See also our short manual to build 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

For beginners we also recommend reading:
http://www.amics21.com/laveritat/notions_of_wind_energy_for_the_complete_idiot.pdf

</div>