How to build an energy generator with an old oil barrel without oil (Savonius wind generator)

Index

1. Introduction

"Think globally, act locally"

Sooner or later, the global warming and the shortness and/or the high prices of oil will force us to search for energies that are more respectful with nature.

This modest manual will give you a rough idea about how to build a small wind generator with a 200 liter oil barrel.
This rather simple machine is called Savonius generator, in honor of its inventor[2].
Its power is quite low, but it is beautiful, cheap and relatively simple to build. An other advantage is its vertical axis, so the direction of the wind doesn't matter.

But careful: Like any turning machine, a wind generator can be quite dangerous (especially under strong winds!

You have to use very strong parts and be careful with the turning rotor!

2. *Some words about the wind energy in general*

2.1 *Mister Betz and the energy of a wind generator*

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

P = 0,29 · D^2 · v³

- *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 · D^2 · v³

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 ratio between 0,9 and 1,1.
- 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)
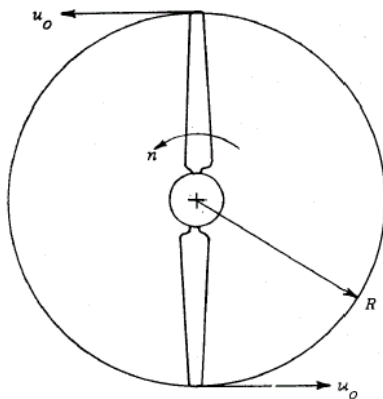
Fig. 2.2.-1 Definition of the velocity u_o of the blade tips

To get an idea:
A modern high-tech wind generator of 20 meters diameter has a tip speed of about $\lambda = 8$.
Let's calculate its rotation speed under a wind speed of 10 m/s (= 36 km/h):

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

It doesn't seem much, but the tips of the blades will turn at a speed of
288 km/h! This makes a lot of noise and is a great danger for the birds!

General rules:

- the bigger the diameter, the lower the rotational speed of the rotor
- a higher amount of blades does not necessarily increase the rotational speed, but increases the efficiency of the wind rotor.

3. Construction of the Savonius generator

3.1 General

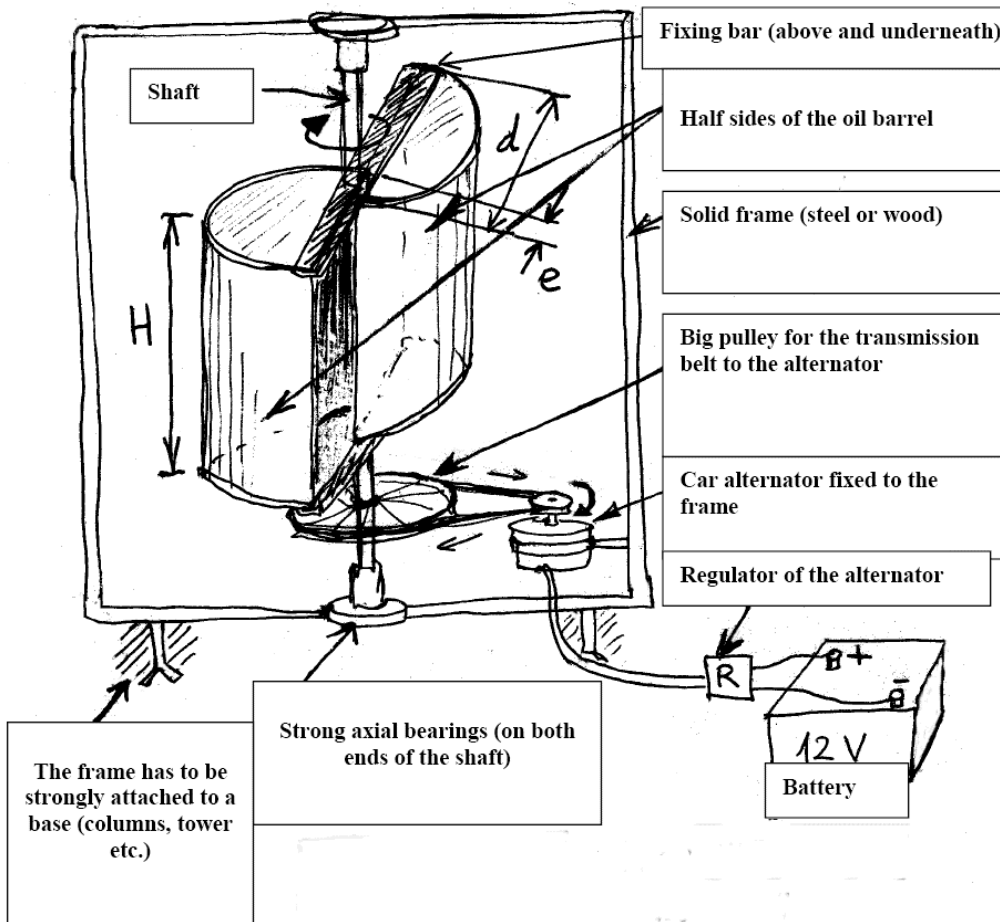The following drawing will give you an idea about the construction of a Savonius wind generator:

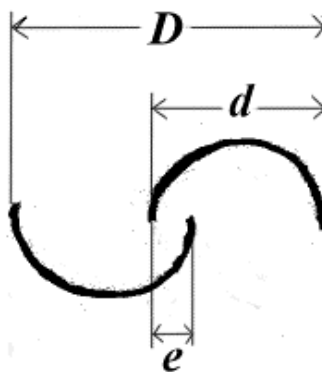**Fig. 3.1-1** Principle of a Savonius Wind generator


Fig. 3.1-2 Definition of the values *D, d* and *e*

3.2 _Description_

The rotor consists of the two halves of a 200 liter oil barrel, fixed to two bars or profiles soldered to the shaft. Both ends of the shaft should have strong axial bearings fixed to a solid frame. The frame should have enough width to take the rotor, the transmission system and the alternator. It is convenient to mount the frame at a certain high above the ground (more and better wind), at some distance from houses, walls, trees etc. It is not recommended to mount the frame directly on top of a wall, because it will disturb the flowing of the air trough the rotor.

Both half sides of the barrel have to be mounted leaving a gap between them (overlapping, distance **e** in the drawing). For a standard barrel (high **H = 90 cm**, diameter **d = 57 cm**, approximately), this gap should be about **e = 10 cm**.
(For other Savonius rotors → $e_{opt} = d/6$).

(This gap is quite important, because it allows the wind to flow trough the rotor, increasing its aerodynamic efficiency).

Note: Search also for pictures and videos of Savonius generators in the Internet. Many of them will inspire you to build your own. Example:
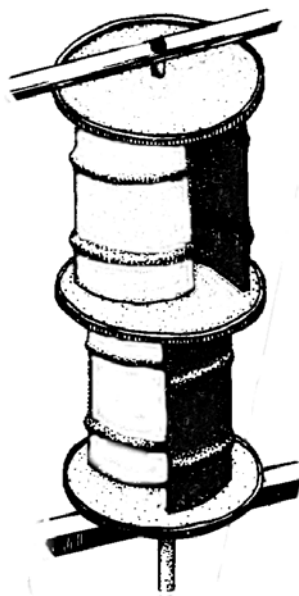
Fig. 3.2-1 Two-barrel-Savonius-generator = double power, double torque, same rotation speed

3.3 _Power of a Savonius generator_

According to measurements done in a wind channel[3], the maximum power of a 1-barrel Savonius rotor can be calculated with the following formula:

$P_{max} = 0{,}18 \cdot H \cdot D \cdot v^3$ [W]

If we take into consideration all the efficiencies of the system (rotor approx. 50%, transmission device approx. 90%, car alternator approx. 50%), the maximum power of a **1-barrel** Savonius wind generator will be ($H \cdot D$ = 0,94 m²):

$P_{max} = 0{,}08 \cdot v^3$ [W]

Note: to get the power in watts [**W**], the wind speed v has to be introduced in meters per second [**m/s**] and the height H and the diameter D in meters [m]. The following table shows the maximum power and the optimal rotation speed of a Savonius wind generator for different wind speeds:

Wind speed [m/s]	Maximum power [W]		Optimum rotational speed [rpm]
	1 barrel	**2 barrels**	
5 (= 18 km/h)	10	20	75
7 (= 25,2 km/h)	27	54	105
10 (= 36 km/h)	80	160	150
12 (= 43,2 km/h)	138	276	180
14 (= 50,4 km/h)	220	440	210
16 (= 57,6 km/h)	327	654	240
20 (= 72 km/h)	640	1280	300

Maximum power of a Savonius wind generator
build with one and two 200- liter oil barrels for different wind speeds

The following figure shows the power and torque characteristics of a **1-barrel**-Savonius rotor for different wind speeds (8, 10, 12 and 14 m/s):
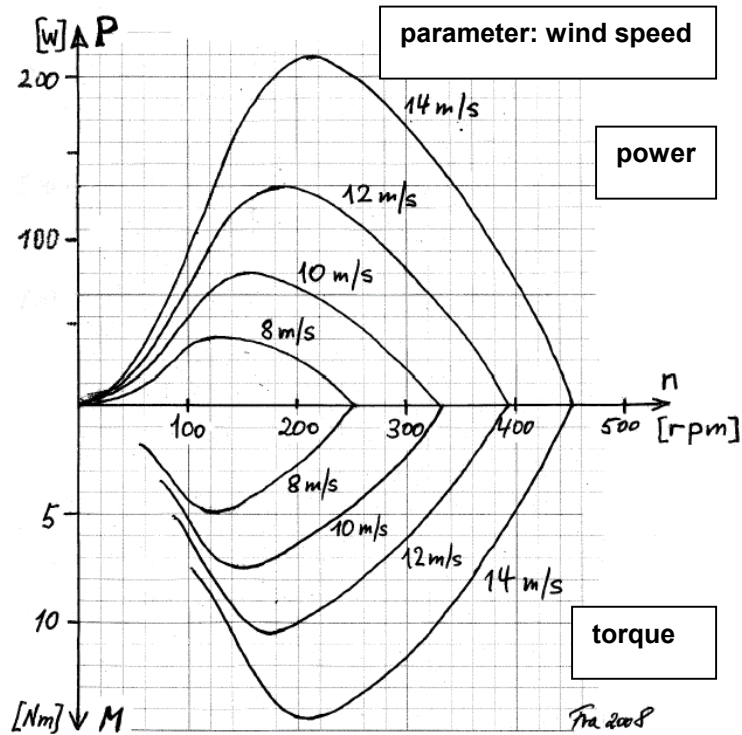
Fig. 3.3-1 Power and torque characteristics of a Savonius wind rotor

### 3.4 *Multiplication factor (transmission ratio)*

First of all, we have to say that **a car alternator is not a good choice for a wind generator**[4]. The efficiency of a car alternator is never more than about **50 percent**. The only advantage is that they are strong, cheap and easy to get (scrap yard). If you don't need a high efficiency of your Savonius machine, you can start with a car alternator.

A car alternator needs a certain rotation speed to start delivering current (minimum approx. 750 rpm). Because the Savonius rotor turns slower, we will have to multiply the alternators rotational speed. The simplest and cheapest way is using two pulleys and a transmission belt (see Fig. 3.1-1). The diameter of the car alternator pulley may vary between 4 and 8 cm.
The following illustration shows the current-speed curve of a car alternator:
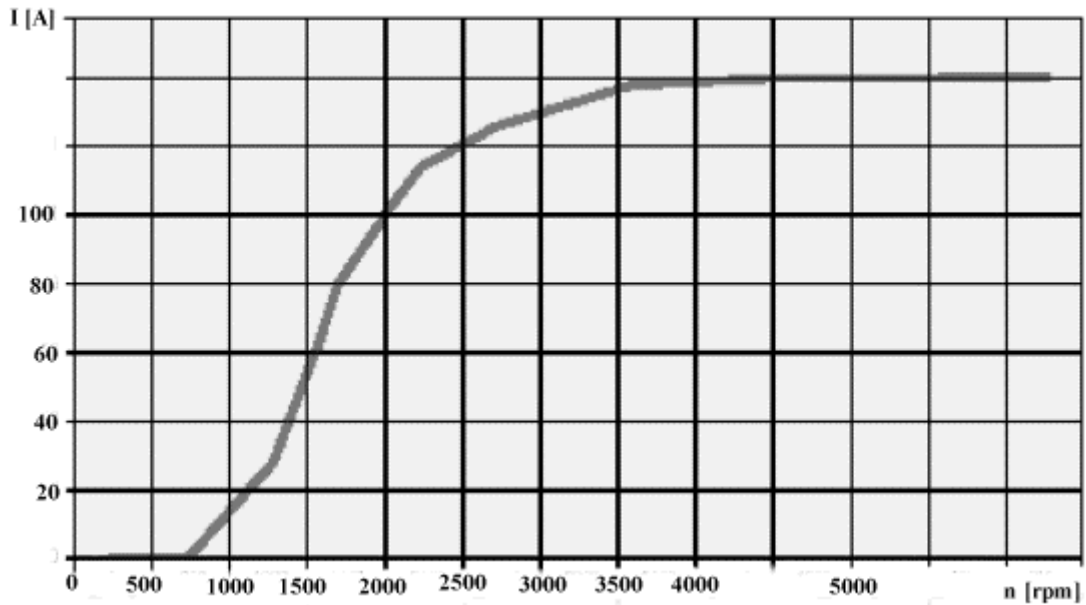
Fig. 3.4-1 Current curve of a car alternator

We can see that this alternator starts to deliver current at a rotation speed of approx. 750 rpm. At 1250 rpm, the current will be approx. 27 amperes.
If the charging tension of the battery is about 14 volts, the power delivered by the alternator at 1250 rpm will be approximately 14 V · 27 A = 378 W.
Between 750 and 1250 rpm, the current increases practically linearly. The following figure shows the power versus rotation speed of this alternator:
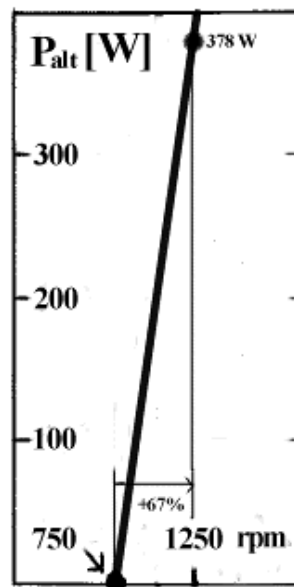
Fig. 3.4-2 Power versus rotational speed of the alternator

Now we can draw this curve in the field of characteristics of the Savonius rotor (Fig. 3.3-1):

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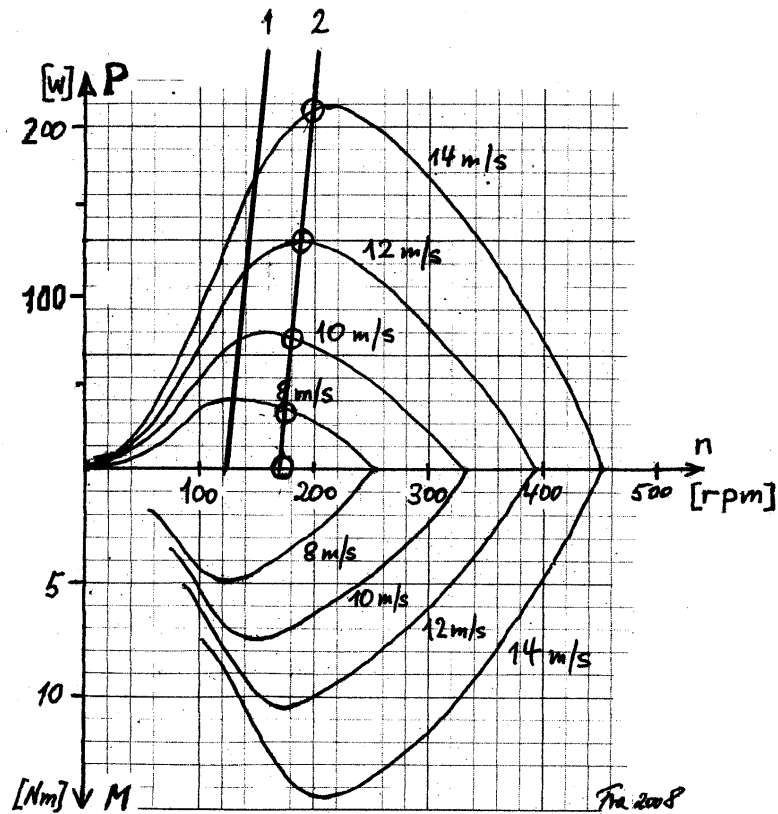
Fig. 3.4-3 The power versus rotation speed curve of the alternator drawn in the set of characteristics of the **one-barrel-**Savonius-rotor

We should place the alternator curve so it cuts the different curves of the Savonius rotor near their respective maxima:

The possibility **"1"** in Fig. 3.4-3 cuts the 8 m/s - curve near its maximum, but for the other wind speeds it cuts the curves too far from their respective maxima.

The possibility **"2"** is better, because it cuts all curves near their respective maxima.

To calculate the multiplication factor we will do the following: the curve **"2"** cuts the rotation speed axis at about 170 rpm. This rotation speed of the rotor corresponds to the 750 rpm of the alternator, so the transmission ratio will be:

k = 750 : 170 = **4,4**

In Fig. 3.4-3 we see that for a wind speed of 14 m/s, the Savonius rotor delivers a power of approx. 210 W, witch corresponds to a current of the alternator of about 210 W : 14 V = 15 amperes.

To calculate de multiplication factor for any alternator, we should know at least two working points of its current versus rotation speed curve:

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- n_0 = rotational speed at witch the alternator starts to deliver current and, for example
- n_{20} = rotational speed at witch the alternator delivers 20 amperes.

With these two working points we can draw de current curve of the alternator as a line and –if we multiply the current by the charging tension (14 volts)- its power curve, in the same way we have done in Fig. 3.4-2.

If we only know the value n_0, we can make a first try with the following transmission ratio: **$k = n_0$: 170**

If n_0 = 1000 rpm, the transmission ratio will be approximately
k = 1000 : 170 = **5,9**

To calculate the diameter of the rotor pulley (the bigger one in Fig. 3.1-1), we have to multiply the diameter of the alternator pulley by the estimated transmission ratio k:

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

Note: Anyway, the ideal diameter has to be found by trying (trial-and-error-method). The motors of table drilling machines have a pulley with different diameters (Fig. 3.4-4). This allows to find quicker the optimal transmission ratio (it is convenient to mount a device to lift and lower the alternator and tighten the transmission belt every time you try an other diameter).
As we can see in this table, it is convenient to choose an alternator with a smaller pulley, otherwise the diameter of the rotor pulley will get quite big.
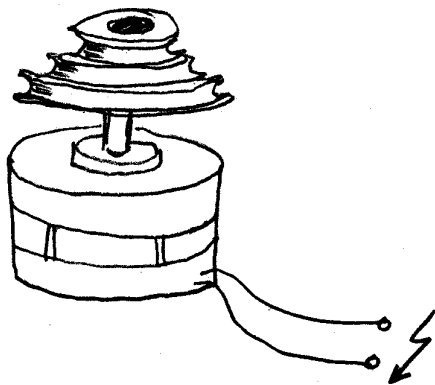
Fig. 3.4-4 Alternator with a triple pulley

With the intersection points of the alternator curve "2" with the rotor curves (Fig. 3.4-3) we can calculate the current versus wind speed characteristic of our Savonius wind generator:

Wind speed	Power of the Savonius rotor (approx.)	Current delivered by the alternator at 14 volts (approx.)
8 m/s	40 W	**2,5 A**
10 m/s	75 W	**5 A**
12 m/s	125 W	**9 A**
14 m/s	200 W	**14 A**

Delivered current of a **1-barrel**-Savonius wind generator (see Fig. 3.1-1) and the alternator with the current curve shown in Fig. 3.4-1 for different wind speeds

If we build our Savonius wind generator with **two barrels** (Fig. 3.2-1), the power and the torque will double, i.e.:

Wind speed	Power of the Savonius rotor (approx.)	Current delivered by the alternator at 14 volts (approx.)
8 m/s	80 W	**5 A**
10 m/s	150 W	**10 A**
12 m/s	250 W	**18 A**
14 m/s	400 W	**28 A**

Delivered current of a **2-barrels**-Savonius wind generator build with **two 200-liter barrels** (see Fig. 3.2-1) and the alternator with the characteristic shown in Fig. 3.4-1 for different wind speeds
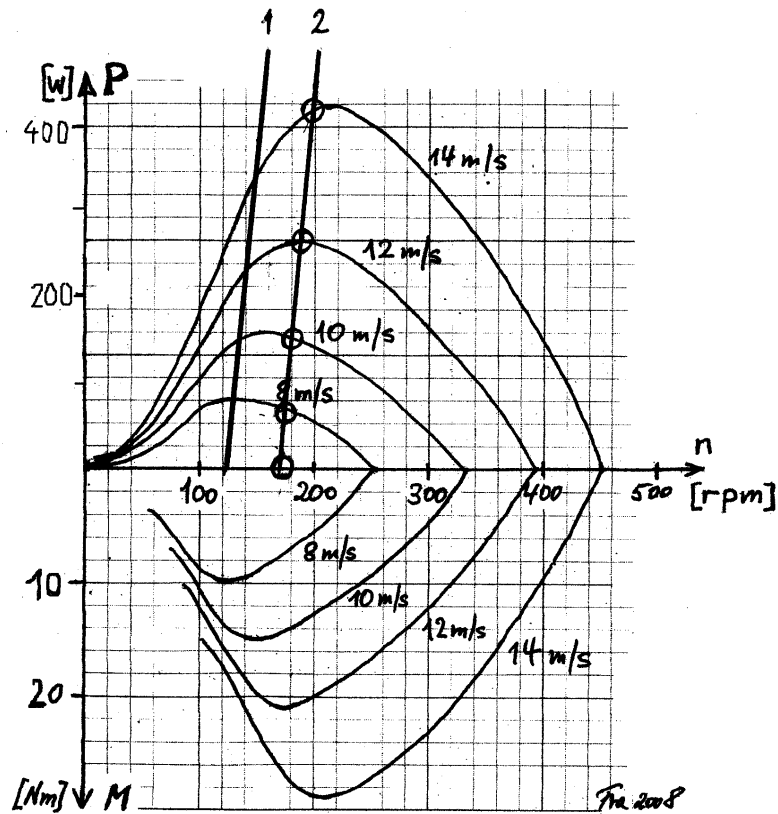
Fig. 3.4-5 Power characteristics of a **2-barrels** Savonius (see Fig. 3.2)

3.5 *Electrical system*

We will not say much about the electrical system. **Ask a good car mechanic.**
It is important to know if you can use the original **regulator** of the alternator to
charge the battery of your Savonius wind generator (the regulator is an
electronic device that avoids that the tension gets too high, limitates the
charging current and disconnects the battery when it is fully charged).
We recommend to use an alternator of a small car (from a motorcycle?),
because with a 1-barrel-Savonius you will hardly get more then 10 amperes (20
amperes with a 2-barrels-Savonius).

Important note
You have to take into consideration that if your Savonius wind generator is
mounted far from the house, you will need quite thick cables to transport the
current at 12 volts!

3.6 Conclusion

To be honest, I have never build a Savonius wind generator myself. What I have told you here is 100% theoretical.
But I'm sure I was not too far from the target. In the worst case, i.e., if your **one-barrel-**Savonius doesn't deliver enough power to read this manual at night, just add an other barrel! This way, you will reach pretty soon the third line of this old saying made in China:

<div align="center">

"What I hear, I forget,
what I see (read), I remember,
what I do, I understand"

</div>

I wish you health, humor and enough wind!

Appendix: Generadors with low rotational speed

Today on the market there are several generators which are capable of providing a decent power at rotational speeds well below those required for a car alternator.

For example, in Internet [www.ginlong.com] we found one with the following interesting voltage and power versus rotational speed curves:
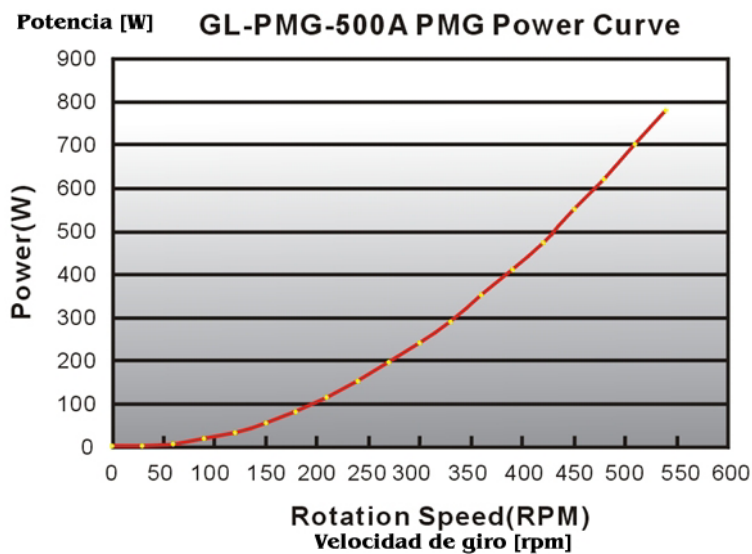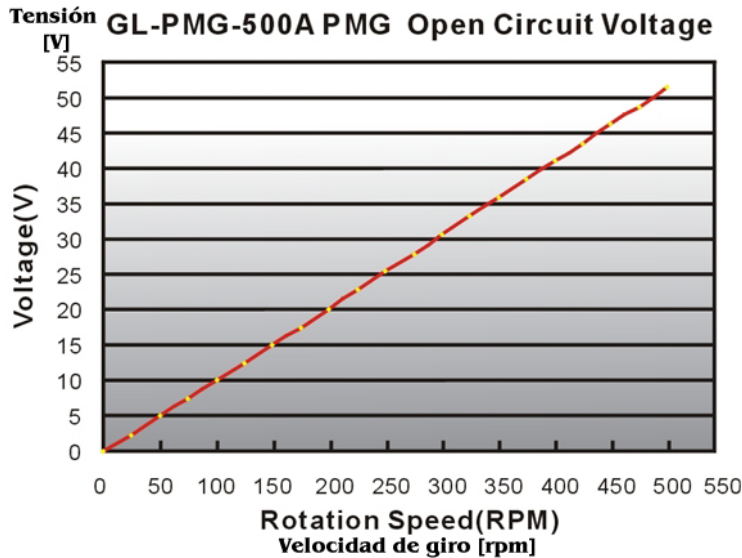
To introduce the power curve of this generator in Fig. 3.4-3 or Fig. 3.4-5 is a great pleasure. Try and see!

Perhaps it is worth to invest some money to produce more decent power!