Design of a 50KW Wind Turbine for Generating Electrical Power for the College of Mechanical Engineering.

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Course: Engineering Projects
Professional School of Mechanical Engineering
Faculty of Mechanical Engineering
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Summary

The objective of the present work is the aerodynamic and mechanical design of a wind turbine of 50 kW, that allows to generate electricity for the use of the faculty in a profitable way taking into account the potential of the wind in the hills of the UNI where it is intended to locate the device. In order to do this, we studied the variables involved in the aerodynamic behavior of a wind turbine and determined how a design can be made that allows a high aerodynamic efficiency and in this way generate economic savings to the Faculty and contribute to the use of the energies Renewable.

INTRODUCTION

In our current society there is a need to look for alternatives in terms of energy generation. This is due to the awareness that has emerged because of the volumetric limit of fossil fuel reserves on the planet and the adverse effects caused by the burning of these fuels.

In Peru, the largest amount of electricity production comes mainly from hydroelectric and thermal plants. The country has several energy resources still unexploited, such as solar and wind energy, however, the interest of local researchers is increasing by the implementation of innovative projects that take into account the use of this type of renewable energy.

That is why, in the Faculty, noting the growth that has had the use of solar energy and wind energy in recent times, with a view to being competent at the national and international level in the field of clean energy, interest has grown For the development of technological projects using the natural resources available to them.

This paper first shows how the problem arises for the idea of the project, then shows the objectives of the project and finally the solution taken for that problem where step by step the entire design of the wind turbine is explained.

PRESENTATION OF THE PROBLEM

Due to the high demand of Electric Power in the Faculty and the damage that the environment receives to use non-renewable energies has been raised the power generation of the Faculty from a renewable source such as the wind so in this way Reduce electricity consumption costs and encourage the use of clean energy by reducing environmental damage.

OBJECTIVES

General objective:

Design of a system of generation of electricity from wind energy, with a power of 50 kW, that adapts to the prevailing wind and generate an economic saving to our Faculty.

Specific objectives

- ✓ To study the methodology used for the design of a wind turbine.

- ✓ Carry out the aerodynamic and mechanical design of a horizontal axis wind turbine capable of generating 50kw of electrical power.
- ✓ Elaborate calculation algorithms that allow to obtain the optimal geometry for the wind turbine blades, by means of the theoretical modeling of the same ones.

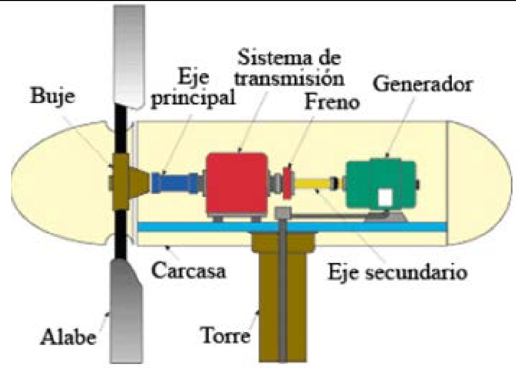
DESCRIPTION OF THE SOLUTION

The solution offered was to use renewable energy for the generation of electric power of the Faculty, it was decided to use the wind energy by taking advantage of the height of the hills of the UNI where the wind turbine was installed, the following shows the type of wind turbine Chosen and the design of this.

Horizontal axis wind turbine:

This type of wind turbine was chosen because they are the ones with the greatest current application and because they have been imposed due to their efficiency, reliability and the ability to adapt to different powers.

The key components of the low-scale horizontal axis wind turbines are the rotor, the internal structure (axes and transmission system), the generator, the housing, the guidance system, the tower and the electrical systems. The following figure shows the location of each of these components within the wind turbine.



Aerodynamic design

Rotor design:

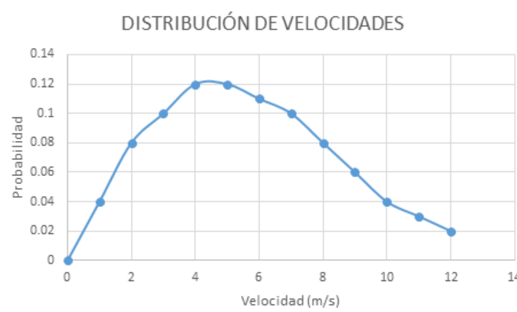
The following data will be used as starting data:

_ Specific speed at blade tip (λ_0)
_ Coefficient of power at rated speed (Cp)
_ Average Density (ρ)
_ Rated power of the wind turbine (P_n)
_ Nominal speed of operation of the wind turbine (v_n)

The power we want to get at the output of the wind turbine is 50 kW. Since a series of losses occur in the wind turbine, we must take them into account when designing.

$$P_n = \frac{P_e}{n_0}$$

The nominal speed of operation of the wind turbine could be chosen directly, however, there is a design procedure with which we can determine the optimal nominal speed that allows us to maximize the energy captured by the wind machine for a particular location characterized by a regime Of own winds.



According to this design procedure, we need the values of the Weibull parameters (c and k) of the studied area at the hub height.

We have: K = 2 and c = 4.5

Taking into account that: Vn = 1.8 * c

To obtain the diameter we use the expression that relates the nominal power (Pn) to the power coefficient (Cp), air density (ρ), rotor diameter (D) and nominal wind turbine operating speed (v_n):

$$P_n = C_p \cdot \frac{1}{2} \cdot \rho \cdot \pi \cdot \frac{D^2}{4} \cdot v_n^{\ 3} \quad \rightarrow \quad D = \sqrt{\frac{8 \cdot P_n}{\rho \cdot C_p \cdot \pi \cdot v_n^{\ 3}}}$$

And to calculate the rotational speed of the rotor we use the expression of the specific velocity (λ) as a function of the radius of the rotor (R), the rotational speed of the rotor (N) and the nominal velocity (v_n):

$$\lambda = \frac{\omega \cdot R}{v_0} = \frac{N \cdot \pi \cdot D}{60 \cdot v_n} \quad \rightarrow \quad N = \frac{60 \cdot v_n \cdot \lambda}{\pi \cdot D}$$

Design of the blades:

For the geometric design of the blades the starting data will be as follows:

_ Rated speed (Vn)

_ Rotation speed of the rotor (N)

_ Rated power (Pn)

_ Number of blades (p)

_ Rotor diameter (D)

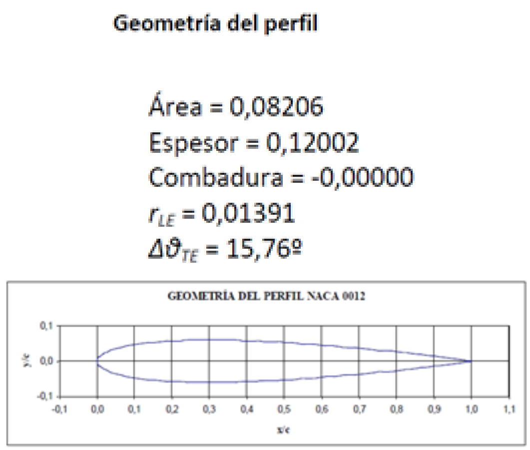
To calculate the length of the blade only we have to obtain the radius of the rotor:

$$L = R = \frac{D}{2}$$

Calculations of the parameters shall be made by analyzing the rotor in a given number of sections between the blade engagement radius with the hub and the outer rotor radius, defining lengths of equal length. For a generic section i of the sections under study, the following process is followed:

1. Starting from the radius ri of the generic section determines the specific speed in each of the sections of the blade (λi).
2. With λi we can determine the axial induction factor along the blade (ai).
3. With λi and ai we determine the induced rotation coefficient (hi), which will serve to calculate the rotation induced along the blade.
4. Evaluate the angle of inclination for each section of the blade (Ii).
5. The product is determined $C_L * c_i = Q_i$
6. Known Ii and the quantity Qi, we can determine θi and ci.

Selection of the blade profile:



We chose this profile because it is very simple constructively speaking, since it is symmetrical.

Mechanical design

Based on the defined geometry of the blade, the mechanical design begins with the creation of all parts of the wind turbine, from the rotor to the support tower.

An important aspect is the selection of materials used in the components of the wind turbine. The materials determine the strength of the components present in the machine. They must be commercial and minimize alternative efforts.

The components of the wind turbine designed as mechanical parts are as follows:

a) **Horizontal axis design (SOLID SHAFT)**

The starting data will be as follows:

Rated power: 50 KW

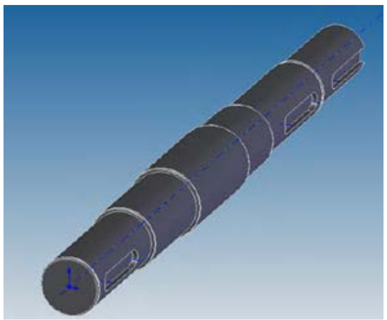
Nominal speed of rotation

Material selected: Steel A-36 (Permissible shear stress 40 MPa)

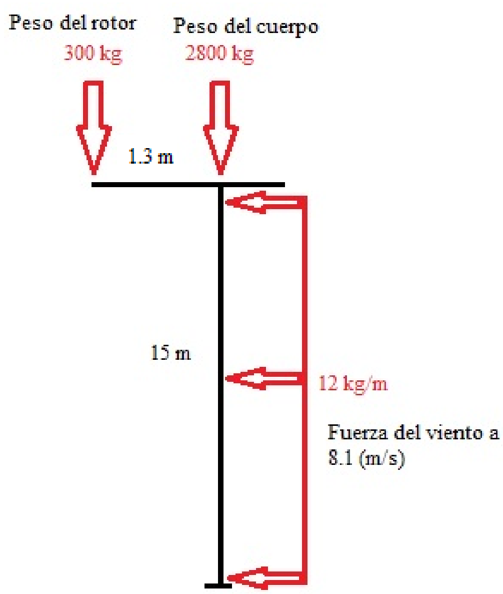
The torque is calculated:T=P/W

o determine the diameter of the horizontal axis, the following criterion is used:
Angular deformation formula:

$$S = \frac{16\ x\ T}{\pi\ x\ d^3}$$



b) Design of the vertical axis (SOLID SHAFT)



The force of the wind is calculated with an experimental formula of:

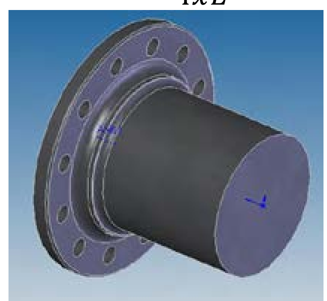
$$p = 0.1828xV^2\ [\frac{kg}{m}]$$

The moment is calculated and the Material is chosen: Steel A-36 (Permissible bending stress 75 MPa).
Total weight: Turbine-Generator (3100 kg) and assuming 100% of the vertical axis.
To calculate the diameter of the vertical axis the following criterion is used:

$$\sigma = \frac{32\ x\ M}{\pi\ x\ d^3} + \frac{P}{A}$$

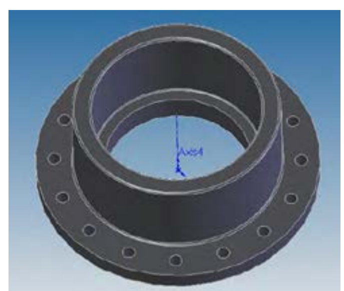
The check of the diameter is done by column effect:
Taking the following input data:
Modulus of elasticity (E): 21000 kg/mm^2
Shaft diameter
Shaft Length

$$P_{cr} = \frac{\pi^2 xExI}{4xL^2}$$



c) Design of the vertical axis support

It is attached to the tower by a configuration of 16 bolts and is designed to withstand loads generated by a wind of 20 m / s with a safety factor of 15. The material used is an AISI 1020 with a galvanized treatment to give resistance to corrosion.



d) Bushing design

RESULTS

✓ **Aerodynamic design:**

_ Rated speed (Vn = 8.1 m/s)

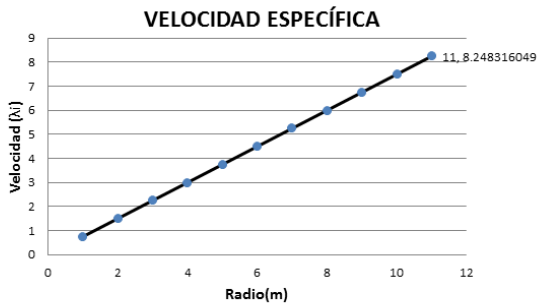
_ Rotation speed of the rotor (N = 58 r.p.m.)

_ Rated power (Pn = 50 KW)

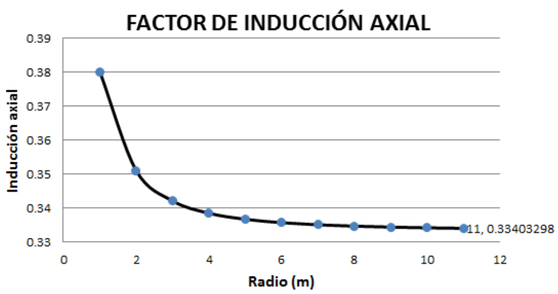
_ Number of blades (p = 3 palas)

_ Rotor diameter (D = 22 m)

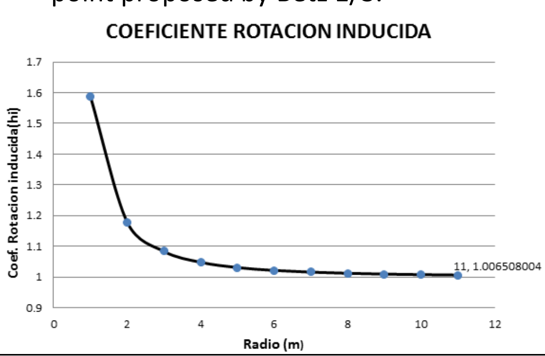
_ Shovel length (L=11m)

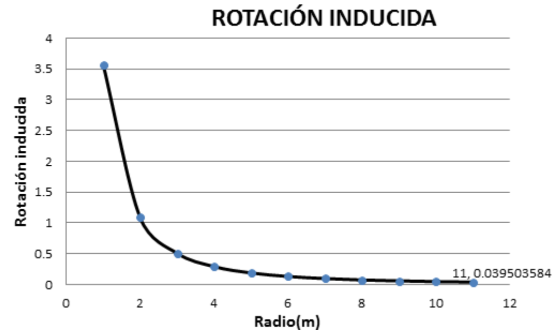


We can observe that the specific velocity follows a linear relation with the radius, as we can deduce from its expression.

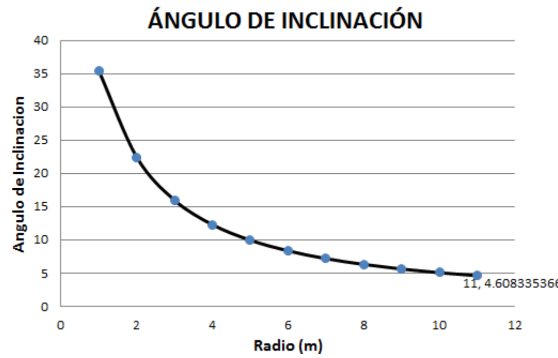


In this graph we can see that as we move in the blade to sections closer to the tip, the ratio of velocities between input and output that optimizes the energy produced comes close to the optimal point proposed by Betz 1/3.





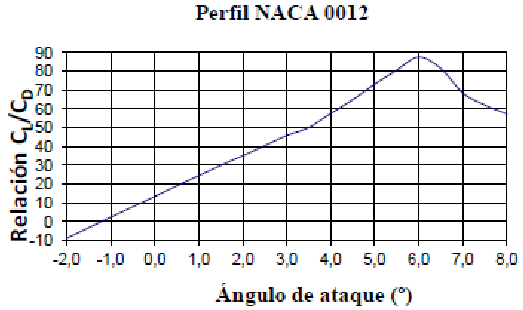
We now observe the indication made in the graph of the axial induction factor, where we pointed out that the induced rotation is large in the sections of the blade closest to the hub.



We note that the angle of inclination of the blade is reduced as we move towards the tip of the blade.

Profile of the blade: NACA 0012 with an angle of attack of 6 °.

α	Cl	Cd	Cl/Cd
-2,0	-0,0941	0,01060	-8,877358
-1,5	-0,0348	0,01061	-3,279925
-1,0	0,0246	0,01071	2,296919
-0,5	0,0835	0,01075	7,767442
0,0	0,1424	0,01062	13,408663
0,5	0,2015	0,01063	18,955786
1,0	0,2607	0,01068	24,410112
1,5	0,3197	0,01074	29,767225
2,0	0,3788	0,01081	35,041628
2,5	0,4377	0,01084	40,378229
3,0	0,4968	0,01086	45,745856
3,5	0,5556	0,01112	49,964029
4,0	0,6127	0,01067	57,422680
4,5	0,6703	0,01033	64,888674
5,0	0,7264	0,00995	73,005025
5,5	0,7831	0,00973	80,483042
6,0	**0,8400**	**0,00959**	**87,591241**
6,5	0,8748	0,01076	81,301115
7,0	0,8928	0,01305	68,413793
7,5	0,9141	0,01474	62,014925
8,0	0,9270	0,01620	57,222222

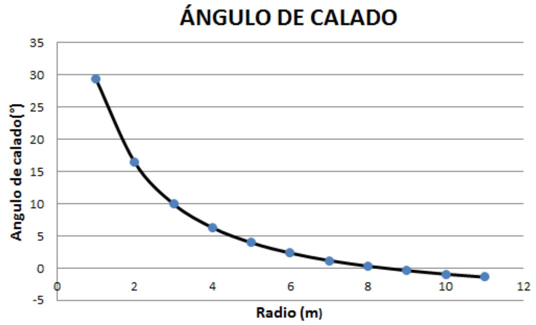


As can be seen in the graph, the maximum value of the relationship between the lift and resistance coefficients corresponds to an angle of attack of 6 °.

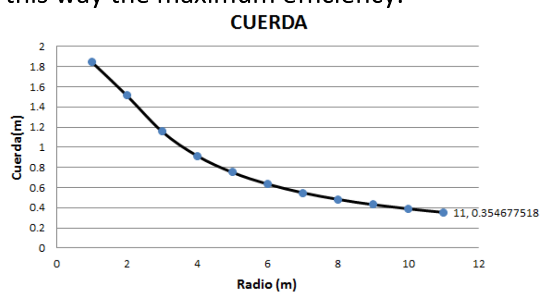
So:

αopt = 6º

CLopt = 0,84



This graph shows the optimum torsion that the blade must have in each section in order to always maintain the optimum angle of attack, at the point of design, obtaining in this way the maximum efficiency.



- ✓ **Mechanical design:**

  _ Drive shaft:

  Material: Steel A-36
  Length: 1.6
  Diameter: 100 mm solid

  _ Vertical support beam

  Length = 15 m
  Diameter: 170 mm solid

CONCLUSIONS

- ✓ We chose a NACA 0012 profile with an angle of attack of 6 °; Since of its graph we observe that the maximum value of the relation between the coefficients of sustentation and of resistance correspond for this angle, in addition that is a symmetrical profile easy to construct.
- ✓ The transmission shaft shall be Steel A-36 1.6 meters in length and 100 mm solid diameter.
- ✓ The vertical support beam will be 15 meters in length and a solid circular cross-section of 170 mm diameter, as these values are met when they are checked by the column effect.
- ✓ Sensitivity, high speeds (> 10 m / s) can damage shaft transmission; so mechanical brakes will be installed that block its operation to this regime.
- ✓ Energy demand is increasing, so the project can be extended to the implementation of a wind farm. This work will serve as the basis for the design of the wind turbine unit.

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