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DESIGN OF WIND TURBINE OF LOW POWER FOR COAST ZONES IN COLOMBIA

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Abstract. Now a day's humanity is affected for a many effect from the mismanagement of developments policies, whose consequences were not studied in many of these processes throughout history. So, it is up to the present generation to confront these problems and fence them with alternative solutions that affect in a positive way the medium. One of these problems is the excessive use with a closeness to dependence on sources from fossil fuels. It is therefore is decided to explore the field of green energy, of specific form of wind power. An abundant resource in Colombia that until recently began to explore. The use of wind turbines for rural electrification is an alternative clean to the exploitation of water sources and fossil fuels minimizing the environmental impact of our passage through the planet.

Keywords: *energy efficiency, mechanical design, renewable energy, wind turbine*

1. INTRODUCTION (TIMES NEW ROMAN, BOLD, SIZE 10)

Currently, planet earth is in environmental crisis due to the effects of pollution and the constant increase of temperature in the environment. Greenhouse gas production has increased alarmingly in recent decades. According to the IPCC (The Intergovernmental Panel on Climate Change) the planet's temperature increased by 0.74 ° C in the period of 1906-2005 (OTTMAR and SOKONA, 2012), causing accelerated melting of glaciers and frozen surfaces. Other data from the IPCC shows that between 1960/61 and 1989/90 the loss of frozen areas was 136 ± 57 Gt / year (0.37 ± 0.16 mm / year of sea-level rise equivalent) and between 1990 / 91 and 2003/04, of 280 ± 79 Gt / year (0.77 ± 0.22 mm / year of sea-level rise equivalent) (BRYSON and WU, 2008), which results in an increase of evaporated water due to the elevated temperatures that accumulates in lakes and water wells of the Alps and mountainous areas, causing floods and landslides. This is just one example of the environmental consequences.

Throughout the history of humanity there have been many social and economic phenomena that ended up being climate anomalies today, therefore, it is unlikely to find a source of this social and environmental emergency. However, among the causes of great magnitude, is the increase of global production caused by globalization. According to the increase of an industry without clear policies of environmental conscience (policies that until a little more than a couple of decades were begun to implement) generated a rupture in the ecosystemic balance. Greenhouse gas emissions, pollution of water resources and inadequate waste handling impact the global climate balance by making changes in the conditions for survival of life on the planet. By the end of this century it is estimated that the average temperature of the earth could increase between 3 and 4 degrees Celsius (ROSINA et al, 2010).

The evident climatic events and availability of resources oblige the man to be aware of its impact on the environment. Same impact as providing a short-term vision where the integrity of humanity will be drastically involved.

Today, social policies of change are encouraged to reduce and slow the rate of land degradation, by identifying and generating clean energy solutions that minimize the effects of global warming. Fossil and water sources have an abrupt impact on the environment, this has generated and encouraged the use of new unconventional renewable energies. A global initiative whose purpose is the use of resources that until a few years ago was an unknown concept of energy source. These renewable energy resources include wind, solar radiation, biomass, piezoelectric energy, wave energy, among other sources (OTTMAR and SOKONA, 2012). Considering the problems presented, adding the Colombian economic situation, where 7.9% of the population live in extreme poverty without access to basic housing services (PERFETTI et al., 2016). The development of a wind turbine for the use of existing air currents in an identified area in the country is considered. Starting off, the winds are analyzed throughout the Colombian territory, characterizing the areas of greatest influence through a statistical analysis of wind speeds and directions. Once the area of influence has been characterized, the type of wind turbine that allows the generation of clean and renewable energy is determined by taking advantage of the wind currents that exist on the entire surface of the earth. Its working principle is the transformation of energy, using kinetic energy prevalent to the air currents to transform it into mechanical energy causing a rotation in the rotor of the turbine and finally converting it into electrical energy with a generator or dynamo. The comparison of different turbine models and with the results of the zonal studies, its determine the Diarreux model can perform the best, even so, the rotor receives modifications to take advantage of as many currents as possible (high and low speed) inspired by the principle of the Savonius model, strong at low speeds, this gives a modern design and a greater bandwidth of effectiveness. With the numerical values of the wind potential in various places, the next step is to proceed with the design module of the aerodynamic profile of the blade. Using NACA (National Advisory Committee for Aeronautics) aerodynamic profiles as a reference, the power coefficient of different profiles is evaluated to determine which is suitable for the project. For this, the software Qblade is used, which is a tool for the analysis of aerodynamic profiles and allows to determine the type of aerodynamic profile suitable for the turbine. With a selected profile, the rotor and the structure comprising the mechanism are developed. Within the parameters of design, three fundamental elements are considered for the turbine: the generator that is in charge of converting mechanical energy into electrical energy, the transfer system (multiplier box) that converts the low speed of rotation and high potential of the shaft at an axis speed suitable for energy transformation.

With the parameters of the analysis of probabilities and types of winds in 16 places of the country its then proceeded to start a stage of parametric design for a specific place, adapting the characteristics of the rotor to ensure a high energy efficiency of the mechanism. Taking advantage of wind currents seeks a clean alternative for the energy production of a vulnerable population to provide social welfare in the form of rural electrification.

2. METODOLOGY

With the purpose of studying the currents present in the whole country, it is delimited to 16 places of interest (figure 1) in Colombia for wind studies given the geographic and meteorological conditions that these present. A Geographic constant of these points is their location at sea level, 6 of them are in coastal zones like the islands of San Andres and Providence (in their respective airports) and the Colombian Atlantic coasts. The others are in points of considerable altitude, located on the mountain range of the Andean mountain range.

With data obtained by IDEAM (HERITIER, 1995), its then proceeded to interpret and analyze the information contained. The study was divided into three main stages which were carried out in chronological and structured order.

2.1. Step 1: Data acquisition

Given the nature of the data presented in the Atlas of Wind and Wind Energy of Colombia (HERITIER, 1995) that are presented in contour diagrams and rosette diagrams (Figure 2), it is necessary to implement a study tool that allows to obtain numerical data of these elements to perform a mathematical analysis and thus determine constants that will be determinant in the design of the rotor of the turbine. Each one of the figures represents data referring to the wind behavior of the place in question, being the graph of contours, the representation of the speed of wind throughout a year, separated by months and time of day. The colors in the graph symbolize the average speed at a certain time in a month. Wind roses indicate the direction and percentage distribution of wind speed ranges as supporting information in the analysis relevant to the use of the wind resource.

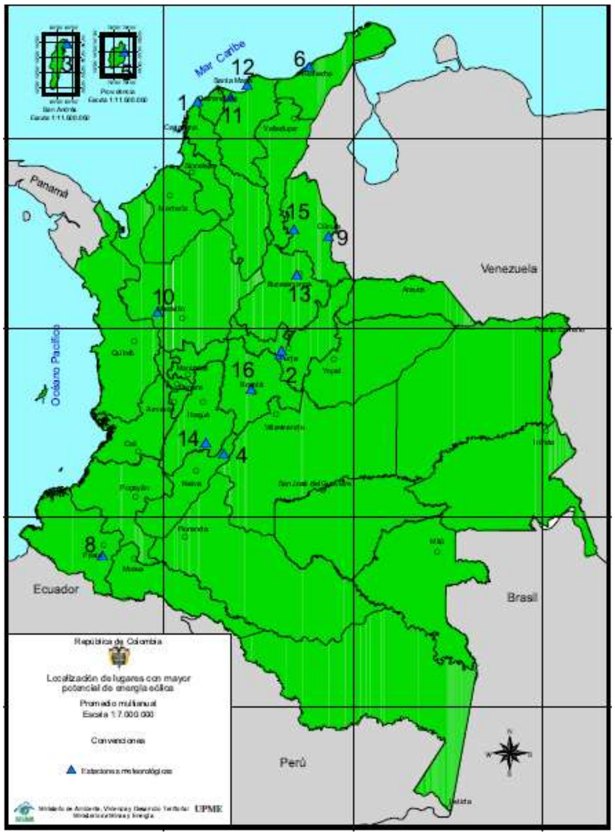


Figure 1. Geographical position of the 16 points of interest, IDEAM (HERITIER, 1995)

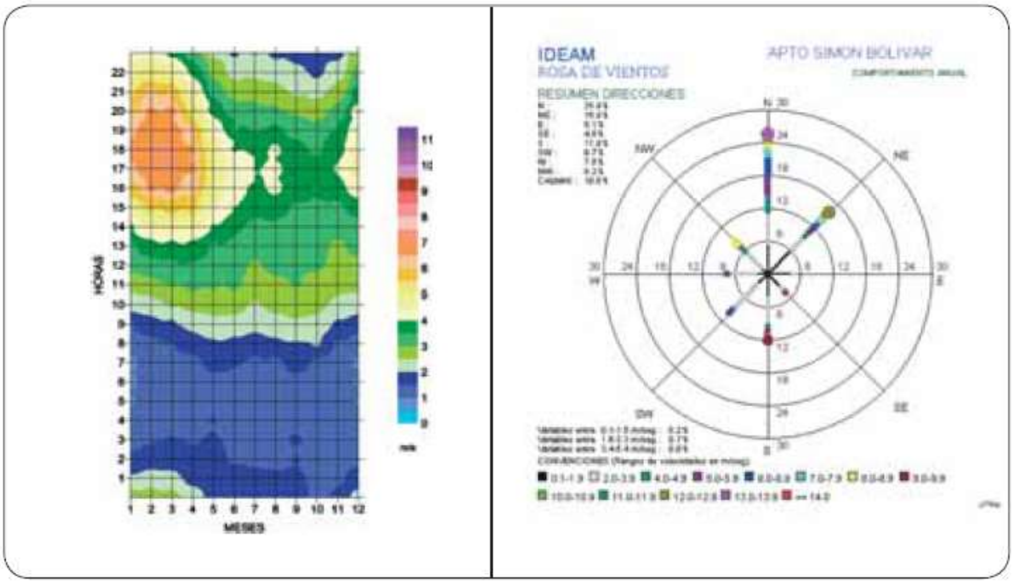


Figure 2. Isolation and wind rose diagram of the Simón Bolívar airport in the department of Magdalena, IDEAM (HERITIER, 1995)

Given the need to have magnitudes of these graphs, an application is developed in the software SCILAB © that allows to make the image processing to the contour map. For this analysis, clustering, a statistical method of separating variables, is used to group data with one or more identification parameters. In this case it is the speed scale that is separated by colors which allows to discriminate each pixel of the loaded image, this is traversed in matrix form obtaining as result a 12x24 matrix with the respective values of speed according to the season and time of day. To represent this data, a GUI (Figure 3) is developed to familiarize the user with the application, intuitively displaying important data for the analysis. The user can select a specific place, month and time of day to know the most probable wind speed. In addition, the histogram with Weibull distribution (Section 2.2) is shown and the graph analyzed with a simplified view of the obtained data. The idea is to have a simplified and superficial characterization of the points analyzed by showing the average speed offered by the dynamism of the wind resource in Colombian territory.

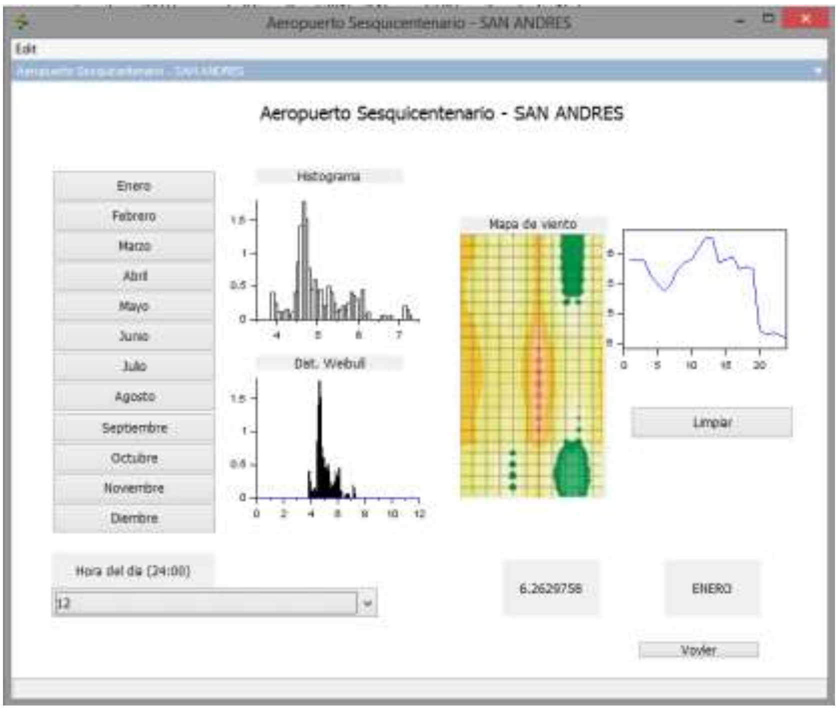


Figure 3. GUI application for visualization of wind speed data. By selecting the Sesquicentenario - SAN ANDRÉS airport in January at 12 noon, a probable velocity of 6.26 m/s

2.2. Step 2: Data Analysis

For the study of the wind, two essential parameters must be known: Speed and direction. For the second parameter, there are wind rose diagrams, where the wind directions are shown at different times and speeds (figure 2). However, the speed of the wind in a specific place is a very volatile magnitude, it changes due to meteorological reasons of irregular form. Therefore, it is necessary to determine it under statistical conditions, making use of different distributions it´s possible to approximate speeds and execute studies with this data. Once the database (GUI and data matrix) has been obtained, a detailed study of each of the values obtained is started to determine values that will be the design parameters. To simplify the processing of these values, Microsoft Office Excel is used to load the data matrix into a spreadsheet. Then a statistical wind analysis environment is developed. The most relevant data for the wind study are:

2.2.1. Distribution of Weibull

To characterize the wind, we use the Weibull probability density law (MARTIN, 2015) (SCHAFFARCZYK, 2014), this statistical tool implements a model of the wind speed distribution over a period, given that it has wind speed data from various places during a year, the wind behavior is estimated for 12 months. The function is defined as:

$$f(v) = 1 - e^{-\left(\frac{v}{c}\right)^{k}} \tag{1}$$

Where k and c are parameters of form and scale, respectively. These two parameters can be found using a least squares approximation, starting from the distribution function. The Weibull probability density function is defined as:

$$f(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} e^{-\left(\frac{v}{c}\right)^{k}} \tag{2}$$

This statistical element is executed in the spreadsheet using its canonical formula, even though the DIST.WEIBULL function executes the same procedure. This is done to observe the precise variation of each element of the equation as the study site is changed, which are in a sliding element. It allows a place to be selected randomly and the velocity histogram obtained is shown along with the option to adjust a second graph to show the Weibull distribution (Figure 4).

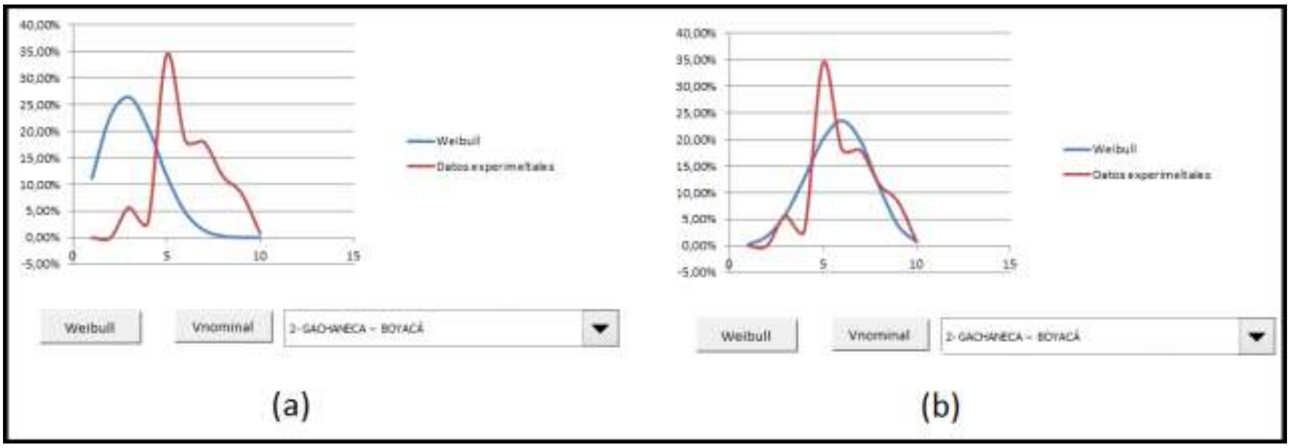


Figure 4. (a) The experimental data shows the histogram of the wind velocities (m/s) in Gachaneca - Boyacá. (b) In addition to the experimental data, the graph pf the adjusted Weibull distribution is shown, with a 23.53% the most likely velocity at this location is 6,26 m/s

2.2.2. Available Power

The available power is an estimate of how much energy can be obtained from the wind, it is considered an estimate because of the inconsistency that can be the magnitudes used in its measurement, which is given by:

$$N_{viento} = \frac{1}{2}\rho v^3 \tag{3}$$

Where ρ is the air density and v is the wind velocity, the air density for Colombia varies between 0.7kg / m3 on high mountain areas and 1.2kg / m3 in places located at sea level (IDEMA and UPME, 2006). Due to the volatility of these two parameters, which vary throughout the year according to meteorological conditions, it is considered that the available power is an approximate available energy per square meter.

Densidad aire	1,225
c	4,434472199
Pv	5,85%
Vm	4,19571804
Vmp	4,809010387
<v>	4,047776775
<v3>	78,68099158
pd	48,19210734

Figure 5. Fragment of the spreadsheet showing the calculation of the available power (W / m2) (Red), with an air density of 1.22 kg / m3 (Yellow) and cubed product of the speed of 78.68 m3 / s3 (Gray). For Obonuco - Nariño the available power is 48.19 W / m2

2.3. Step 3: Selection the profile

To find a suitable profile for the blade it is necessary to be clear about the conditions and reasons of operation for the mechanism. For the design of this turbine a profile with a high lift coefficient is required to support the drag force which will increase the mechanical energy in the shaft. The design of the model allows to modify the aerodynamic profile given the nature of these, the standardization lies in being able to have the measurements of the profile only with its reference regardless of its scale. The NACA 6412 profile was chosen and for this the polar analysis (figure 6) that indicates the slenderness of the profile, in (MATTIO AND TILCA, 2009) slenderness is defined as the relation between the coefficients k_x and k_y of the form:

$$f = \frac{k_y}{k_x} = \frac{c_y}{c_x} = \frac{1}{\tan \alpha} \quad (4)$$

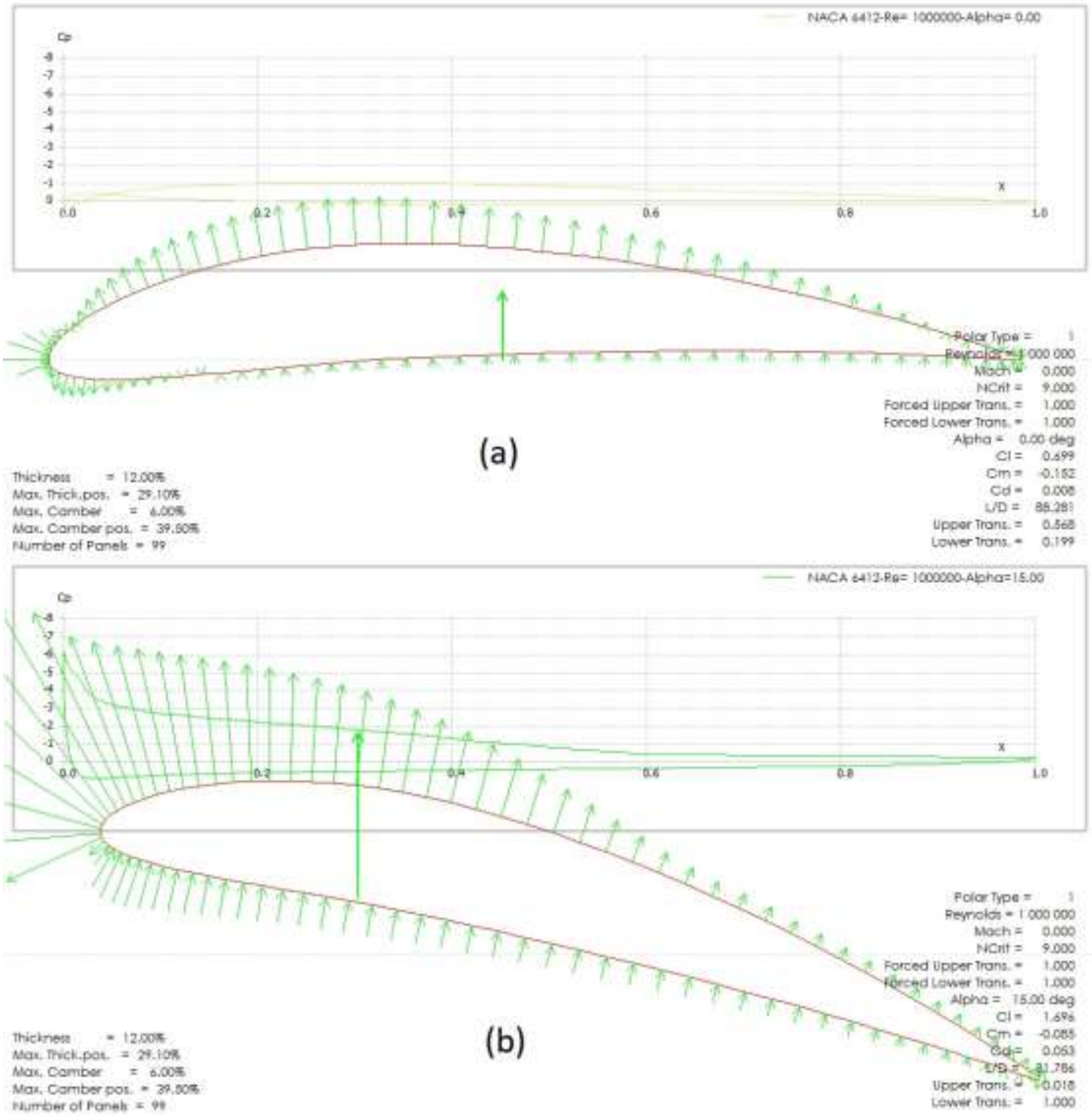


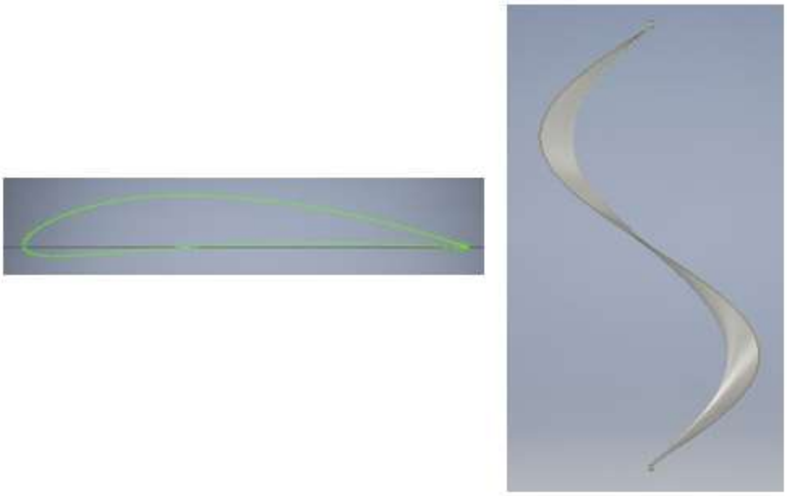
Figure 6. Polar and distribution in a Naca profile 6412 (a) α = 0° (b) α = 15°

3. RESULTS

The design parameters of the vertical axis wind turbine are based on the Darrieux model and vertical propellers. For which, this project focuses mainly on the design of the Darrieux rotor, since these rotors are of greater interest for research groups since their development focuses more on the generation of electricity, even competing mainly with the vertical axis of aerodynamic blades. The designs of the generator blades start from the NACA 6412 profile, which was previously mentioned. This profile is used to create the helix on the Z axis whose dimensions are 1 meter in height with a revolution of half a turn as presented in figure 7.

Since the proposal is a wind turbine with vertical axis, there are three blades with the same characteristics, where the structure is designed so that in its implementation the system has a zero-start torque and reaches high power per unit weight of the rotor, the proposed design is shown in figure 8.

As it is wanted that the aerogenerator is efficient according to the characterization of the winds of the zone, it´s proposed to be hybrid, placing vertical propellers as shown in Figure 9 to improve wind flow through the Darrieux wind turbine, this combination seeks to increase efficiency.



(a) (b)

Figure 7. Representation of the helical blade of the proposed vertical generator. (a) Profile NACA6412. (b) Half revolution helical NACA6412

Figure 8. Design Darrieux three-bladed wind turbine.

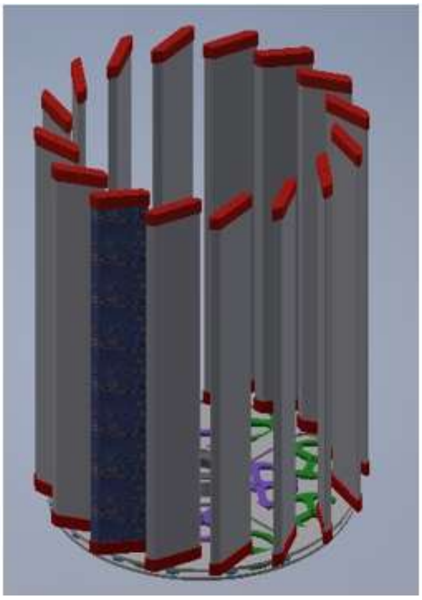
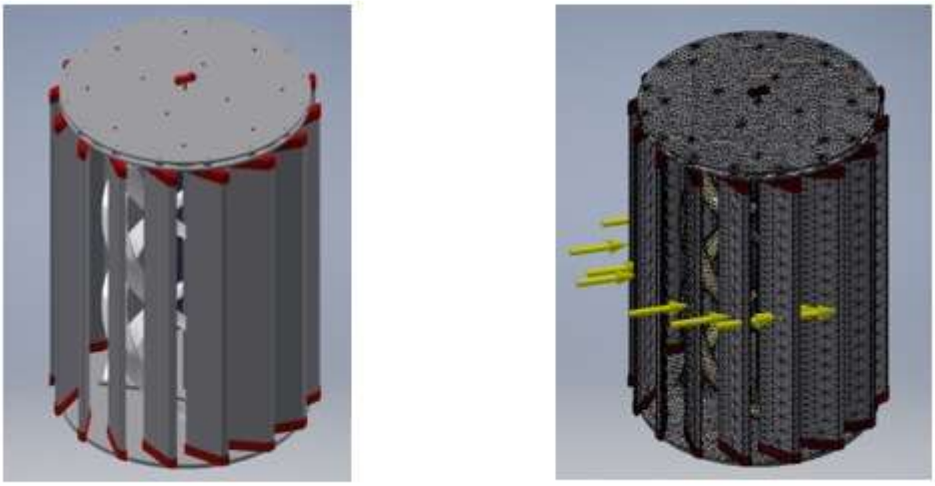


Figure 9. Vertical propeller Model

The final design is presented in figure 10 (a), additional in figure 10(b) shows an analysis of the force of the wind that is exerted on the vertical blades and how the wind is used for the turbine to be activated by the rotation of the Darrieux model making better use of the wind that can pass through the turbine.



(a) (b)

Figure 10. Wind turbine final design

4. CONCLUSIONS

The study concludes by highlighting Colombia's great wind energy potential and encourages its study to generate sustainable alternatives that contribute to the energy and social problems of today's world. With a proposed turbine design, it is evident that the hybridization of two wind models is possible, obtaining the best of each part. The interior design inspired by Darrieux rotors enhances wind performance in high speed winds thanks to the support provided by the helical internal model given the characteristics of its aerodynamic profile. The external system inspired by Savonius wind turbines boosts the low-speed wind screening force and is an important agent in breaking the inertia in order to achieve the necessary connection speed to reach a speed of operation, where power generation will be the end result.

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