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Wind turbine electric generation simulation and optimizations

by

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AIM: The main aim of this first report is to explain how a wind turbine works collecting information from different ways as internet, books and my own investigation with some technicians of my town.

OBJECTIVES:

- Make a simulation with ANSYS of a flow through a wind turbine
- The simulation have to be with ice on the blades and without ice.
- To do a analize of the results of the simulation

Presentation Date: 4/5/2012

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Introduction

Types of renewable energy

There are many types of renewable energy, some in full operation, other developing and even some that are still theoretical phase.

The classification here is not exhaustive but representative of all energies that have been used in our society, especially in the field of architecture.

This is a classification with respect to energy sources:

- Originating in the Sun, Moon and Earth.
  - Solar
  - Wind
  - Hydraulics
  - Tidal
  - Geothermal

- Organic

  - Biomass
  - biological

<u>Originating in the Sun, Moon and Earth</u>

Solar Energy

Figure 1: solar panels

Solar panels

Solar energy is used by the Sun as Energy Source Direct.
This energy is being used since the early days of humanity from its use as direct heating of the home (through proper orientation), natural lighting (direct or redirected by mirrors) and even for the generation of heat by lenses.
Currently the use of this energy has focused on the following systems for use:

- **Thermal (solar),** is one of the oldest in their use with wind and biomass. Within these systems are:

  - For **direct heating** (window wells, greenhouses, solar ovens, ...)
    This is essential to optimize the solar radiation through proper orientation, creating reflective walls, mirrors or lenses.
    And the use of materials that permit the passage, recruitment and retention of heat rays (infrared) and its insulation to prevent heat loss of livestock. For example glass is used in greenhouses because it avoids the loss of infrared rays from the heated objects avoiding the loss by radiation.

This system has been used for home heating, cooking, fire, etc..

Figure 2: greenhouse that use direct heating from the sun

- **Deferred by heating** (solar thermal, Trombe walls, walls, floors, solar chimneys ...)
  The key in these systems is the thermal inertia which is the ability of all materials to store an amount of energy and subsequently returning it to the medium.
  Among the elements that are often used to get that momentum we have:

  - ✓ **Solid materials** (walls, floors ...) is the most widely used and by proper use is getting greater effects at lower cost. This is critical orientation, composition and design of different elements. A special type of this system is the Trombe wall that used to heat a greenhouse wall is then used to condition the house.

  - ✓ **Gels** are among the most widely used thermal gels are capable of absorbing and releasing the stored energy at a given temperature. Often used in conjunction with other renewable energy systems such as geothermal or wind directly.

  - ✓ **Fluids** from water at various compounds to avoid problems of evaporation and freeze (ammonia, lithium bromide). They are used to transfer energy from collection point to the place of use (flat thermal collectors, vacuum, ...).

- ✓ **Gases** such as air through the heating decreases its weight thereby generates an upward movement which is primarily used as ventilation system. This effect is achieved through solar chimneys. Can also use other forms of energy such as geothermal or biomass for conditioning the air flow.

- **Photovoltaic (solar)** is transforming the sun's energy into electricity through various systems, among them are:

Figure 3: photovoltaic panels installed in a roof

- ➢ **Photovoltaic panels**, panels that use the photoelectric effect (which allows the conversion of sunlight into electricity), these can be of different materials with different energy efficiency and production cost. Regardless of the material used efficiency can be improved by a constant orientation with motorized tracking systems and a greater surface concentration of sunlight on the solar cell itself using mirrors or lenses.
  Among the different materials used can be found:

  - ✓ **Doped silicon** is the most commonly used with a yield around 12%. There are three types according to their crystallization monocrystalline, polycrystalline and amorphous.
    To increase the voltage is doped silicon which is to replace some silicon atoms by atoms of other elements. To these latter are known as impurities. Depending on the type of impurity dope with which the

semiconductor pure or intrinsic semiconductor are two kinds of the N type and P-type

Currently, as of June 2009, in the European Union will get a low cost panel (1 € / watt) with an efficiency of over 16% Crystal Clear Project.

- ✓ **Organic polymers,** this technology is under enfoldment but has great potential because of its low price. Different teams and universities who are working in their development, Lee Kwang-hee at the Institute of Science and Technology Gwangju, Somenath Mitra at the New Jersey Institute of Technology

- ✓ **GaInP2/GaAs/Ge** efficiency is 29.9% using a system called Next Triple Junction (XTJ) developed by Boeing-Spectrolab. This same company claims to have obtained a new solar panel with 41.7% efficiency at a cost of 3 € / watt but have not yet revealed the materials used.

- ✓ **Alloys InN,** InGaN Nitrites group III study by the Lawrence Berkeley National Laboratories.

- ✓ **Zinc-Manganese-Tellurium** combined with atoms of oxygen, this system can be wound to get up to 45% efficiency. Kin Man Yu and Wladek Walukiewicz at Lawrence Berkeley National Laboratories.

- ✓ **Cadmium telluride** can achieve yields of 12% for 1 € / Watt developed by the company Abound Solar. This company does not sell to individuals.

- ✓ **Titanium dioxide** also known DSSC (Dye Sensitized Solar Cells) also known as DSC or DYSC, can be described as a kind of "artificial photosynthesis", in which an electrolyte, a layer of titanium dioxide pigment and a ruthenium, are placed inside a sandwich glass. Instructions to build it yourself.

✓ And various different combinations ...

- **Electric thermal systems**, thermal systems consist of solar through complementary systems generate electricity. They are of different types:

Figure 4: Solar termal power plant

  - Solar thermal power plant, are large areas of mirrors (heliostats) that orient the solar rays to a point where the heat a fluid moving a turbine which in turn generates electricity.
  - Wind-solar tower, is to accelerate as much as possible the air to pass it off as a wind generator. How to speed up the air using two systems together, first by heating the volume of air will pass through the tower and the other the pressure difference due to height.

- **Lighting (solar)** is the most widespread and used. The use of sunlight as a light source and contribute to a great saving light gives us a quality hard to match, including their therapeutic effects.

Figure 5: Room lighted from solar light. Free energy.

Wind Energy

Figure 6: Production of wind energy

Wind energy is used by the wind as a Source of Energy. The wind itself is produced by the thermal gradient generated on our planet due to heating from the sun, which could somewhat classifiable as indirect solar energy.

This energy like solar has been used since the beginning of time so that the systems currently used do not vary, at least in concept, of the ancients. An advantage to solar energy is its higher performance, since this energy is kinetic energy and much of our energy conversion systems are kinetic. In particular we have two large groups depending on their use:

- **Direct wind**, very widely used in architecture for both the thermal conditioning, clean the spaces (by improving ventilation by evaporation, convection, conduction, ...). Also traditionally been used for the thrust of ships at sea and on land.

Figure 7: The power that makes move this boat is wind power. Direct wind.

- **Wind through intermediate systems**, usually by mills of all types whose function was to transform the kinetic energy of wind energy in a usable (for power generation, to draw water from wells, ...)

Figure 8: Windmills. The power obtained in that case comes from intermediate systems, the windmills.

Its main drawback is the lack of consistency in the wind and some impressive differences in wind speed itself even in the same season (from total calm hurricanes), which requires the creation of system

Hydropower

Figure 9: River dam

The hydraulic energy is based on the energy potential of the water due to its altitude.

This goes back a long while was with the Industrial Revolution and especially in the nineteenth century began to take a great importance.

Figure 10: Canal lock

There are several ways to use this energy but we can classify according to use:

- **Direct use** by communicating vessels or locks to raise or lower heavy loads and ships.

- **Use mechanic**, was widely used in the industrial revolution. Use the potential energy stored in water for conversion into kinetic energy and thus can be used. From the old mills operated hydraulic machines hydraulic devices.

Figure 11: Millwheel. This is a mechanical method to obtain power from the river´s flow

- **Electricity generation**, widely used today, using the potential energy of falling water to drive a hydraulic generators. Its development requires the construction of reservoirs, dams, diversion channels, and the installation of large turbines and equipment to generate electricity. This entails the investment of large sums of money, so it is not competitive in regions where coal and oil are cheap. However, the weight of environmental concerns and low maintenance are required after running focus attention on this energy source. Importantly, the need for environmental impact studies of both the wildlife, flora and agricultural societies that depend on the normal flow of the river and that a sharp cutoff could generate a lot of damage.

Figure 12: Electrical power station in Hudson river, in Nevada (US). This power station gives all the electrical energy that Las Vegas needs

Tidal Energy

The sea has been the focus of some of the earliest civilizations that soon began to harness its power.

Figure 13: Power of the sea. The sea and the oceans has a lot of potential energy kept inside because there are a lot of mass in movement.

There are different types of energy that can be obtained from Sea tides, one of the oldest used, waves and even the thermal gradient in ocean waters.

- **Tidal energy**, is based on the difference in height of the sea at different times of day, moving in that transition a huge amount of water. We can find two ways to use this feature:

Figure 14: Machine that obtains energy from the tidal.

  - **The direct use** that joining the tide own buoyancy capacity of the bodies can raise large objects and weight. This principle has been used for a variety of jobs from refloating of ships to load ships or other objects on platforms.

  - The generation of electricity using turbines, whether included in a dam or free into the sea.

- **Wave energy**, waves in some seas is a constant, especially at certain times of year, making them very attractive for use as a Source of Energy. All systems used are based on the rhythmic movement of the sea driven mainly by wind and tides. There are many types with different efficiencies.

Figure 15: wave colector of energy

- **Ocean Thermal Energy**, is converted into useful energy the temperature difference between surface water and water that is 100 m deep. In the tropics this difference varies between 20 and 24 ° C, is sufficient for its use a difference of 20 ° C. There are two systems:

Figure 16: Prototype of ocean thermal energy plant

  - **Open circuit** which directly use the sea water evaporating the water at low pressure and so moving a turbine.

  - **Closed loop** fluid with a low boiling temperature (ammonia, Freon, propane) which evaporate on contact with hot water from the surface. This steam drives a turbine, is condensed with cold water from the depths and the fluid is again ready for evaporation. The fundamental problem is its poor performance on a 7% due to the low temperature of the hot and little difference in temperature between the cold and hot. It is also necessary to make an extra charge of energy used for pumping cold water from the depths to the condensate fluids.

Geothermal Energy

Figure 17: Geyser. The movement of the ground behind us makes a lot of heat, and this heat is energy that we can use.

This is the energy from the earth, and this can be classified into two groups, the internal heat produced by our own planet (usually through geothermal reservoirs are deep underground areas with layers and layers of porous rock impermeable rock trapping water and steam at high temperature and pressure), and on the other hand from the high thermal inertia which has the ground.

Thus we can observe the following classification with respect to the shape of said energy uptake:

Energy captured by geothermal fields

- **Direct use of geothermal water**, the temperature of these waters are in the range from 10 ° to 130 ° C and used directly for applications such as, that of sanitary, Spa, crops in greenhouses during the snowfall, to reduce the time growth of fish and crustaceans, for various industrial uses such as pasteurization of milk or even to implement whole district heating and individual housing among others.

Figure 18: Warm thermal lake. Example of direct use of geothermal energy.

- **Geothermal electricity in geothermal reservoirs**, here the steam produced by geothermal energy provide the force that spins the turbines to produce electricity. The condensed water is used subsequently injected into the well to be reheated, keeping the pressure of the reserve. There are three types depending on the temperature rise:

Figure 19: Electricity production in geothermal reservoir

- **Reserve "dry" vapor** produces steam but very little water. The steam is piped directly into a steam plant "dry" that provides the force to rotate the turbine generator.

- **Hot water tank**, produces mostly hot water is used in a central "flash". Water between 130 ° and 330 ° C is brought to the surface through the production well where, through the pressure of the deep reservoir, part of water immediately becomes steam in a "separator". The steam then drives the turbines.

- **Book temperatures between 110 °C and 160° C** does not have enough heat to quickly produce enough steam but can be used to produce electricity in a power "binary". In a binary system the geothermal water passes through a heat exchanger where heat is transferred to a second liquid which boils at lower temperatures than water. When heated, the binary liquid turns to vapor, that as the water vapor is expanded by moving the turbine. The vapor is then recondensed and become liquid is reintroduced into the cycle. In this closed cycle, no air emissions.

Energy collected by conduction

- **Use of closed systems of deep vertical pipes** for heating the liquid through the heat of the earth itself. Later this heated liquid is used for direct heating or use in heat pumps. Has the advantage of not being necessary to the existence of a geothermal reservoir. For use in a home would be necessary to create a pool of about 150m and that for every meter of depth is obtained an average of 50W.

Figure 20: Use of closed systems of deep vertical pipes.

- **Use of closed systems or open pipes at shallow depths**, these systems use energy mainly by thermal inertia owns the land and can be used both to cool to warm. Can be used for capturing both closed systems (heat pumps, heat exchangers, ...) and open systems through the air (for conditioning or preconditioning of the air itself).

The main advantage of geothermal energy is the constant temperature throughout the year without seasonal variations depend on something that makes it extremely interesting to be able to predict system behavior.

Figure 21: Lava in Hawaii. Example of the big heat inside the earth.

Organic

Biomass

Biomass energy is also defined as the set of organic matter of vegetable or animal origin, including materials processing from natural or artificial.

Depending on the use and origin of biomass can be distinguished:
Biomass combustion untreated domestic and industrial applications that run on direct combustion of biomass (wood, pineapple, olive pits, almond shells, ...). This type of application is one that has been used traditionally. Although it is now well advanced in higher efficiency furnace. The fundamental problem of this type of fuel is the large volume needed to meet energy needs.

Figure 22: Wood burning. Biomass burning. Humans obtain hot and energy from the fire since prehistoric times.

- **Biomass combustion treated** by various treatments is possible to obtain new fuels with higher energy content, lower storage volume or different properties that make it susceptible to use in different fields:

  - **Pellets** is a solid fuel pellets made by pressing one's acting wood lignin as a binder. As virtues versus untreated biomass has a higher calorific value, lower volume and can be transported in tanker and transfer deposits by pneumatic system.

    The pellets are usually done with the waste of pruning, felling or carpentry but also being investigated in Spain by the use of arable CENER to use the great potential of our country at this resort, and even the creation of energy crops this use.

    There are currently burning boilers or mixed pellets (pellets and other biomass) with high yields and automation at the same level as gas or diesel though prices of these facilities remain high.

Figure 23: Pellets. They has big heater power in small size

- **Biofuels** are an alternative to traditional fuels in the transport area, with a degree of uneven development in different countries. Under this heading reflects two entirely different lines, the bioethanol and biodiesel.

  - ✓ **Bioethanol**, its main applications are aimed at replacing gasoline or manufacture of ETBE (ethyl tertiary butyl ether, oxygenated additive of high octane that is incorporated in the gasoline). obtained from traditional crops such as cereal, corn and beets, which have high performance in ethyl alcohol.

  - ✓ **Biodiesel**, its main application is directed to the replacement of diesel. The technologies for producing biodiesel, now leave the use of common varieties of conventional species such as sunflower and rapeseed.

Figure 24: Picture of new biofuels.

- **The biogas** is produced by the action of a certain type of bacteria on biodegradable waste using anaerobic fermentation processes. This also allows for direct use in cogeneration installations use combined cycle for the production of electricity.

Figure 25: Tank of production of biogas.

- **Bio-Syngas** is a synthesis gas (mixture of carbon monoxide and hydrogen) produced by a gasification process (reaction of biomass-pellets, with steam and oxygen at high temperature and pressure in a reducing atmosphere). The combustion of this gas generates carbon dioxide and water vapor.

  The main use is given power generation in cogeneration plants (use of electricity and heat from)

Figure 26: Machine of Bio-syngas production.

The concept of biomass should not be included peat, that for purposes of CO_2 emissions equivalent to a fossil fuel, in addition, given the environmental impacts of the exploitation of peat, cannot be considered renewable energy obtained from this energy source .

Biological Energy

Biological energy, which directly produce the elements of life, has been available since the beginning of time but not the sole classified as a renewable energy.

A classification may be preferentially the source of this energy:

- **Plant** is the use of living plant elements for carrying out tasks that allow us to save energy or generate the energy needed to perform them. There are many utilities but the most used are divided into two main branches:

- **Lush green mass** that absorbs the excess of solar radiation and cool the atmosphere by evaporation and its shadow. Widely used in architecture for both urban plans with parks, gardens, street trees, etc., As in homes with woodland, pergolas, etc..

Figure 27: Lush green mass.

- **Algae and microorganisms**, many types able to perform many tasks like digestion of organic waste composting and biogas generating, generation of hydrogen and other gases used in other energy systems, water purification.

Figure 28: Algae that produces bioenergy

- **Animal,** at this point becomes relevant animal work both for transport or doing housework or agricultural. Currently the requirements of our society are very different relevance taking other uses as the use of animals in the detection of various substances, tumors and diseases, therapy, etc.

Figure 29: Animal traction. That kind of energy humans are using since centuries.

Humans as part of living beings on this planet is vital we integrate and interact with the natural world around us both to raise awareness of its existence and for our own survival.

About wind power

Definition:

Wind energy is the energy from wind, the kinetic energy generated by the effect of air currents, and is transformed into other useful forms for human activities.

Today, wind energy is mainly used to produce electricity through wind turbines. In late 2007, worldwide capacity of wind generators was 94.1 gigawatts. In 2009, wind generated about 2% of global electricity consumption, equivalent to the total electricity demand in Italy, the seventh largest economy in the world. In Spain the wind energy produced 11% of electricity consumption in April 2008. And 13.8% in 2009. In the early hours of Sunday 8 November 2009, over 50% of electricity generated in Spain mills wind, and the record-breaking total production, with 11,546 megawatts.
Wind energy is an abundant, renewable, clean and helps reduce emissions of greenhouse gases from power plants by replacing fossil fuel-based, which makes it a kind of green energy. However, the main drawback is its intermittency.

How to produce and get energy from the wind:

Figure 30: Wind farm

Wind energy is related to the movement of air masses move from areas of high air pressure into adjacent areas of low pressure, with speeds proportional to the pressure gradient.

Winds are generated because of the uneven heating of the earth's surface by solar radiation, between 1 and 2% of energy from the sun is converted into wind. By day, the air masses over the oceans, seas and lakes remain cold in relation to neighboring areas located on the continental masses.

Continents absorb a minor amount of sunlight, so that the air is on the ground expands, and is therefore lighter and rises. The cooler air and heavier than comes from the seas, oceans and large lakes is set in motion to fill the void left by the hot air.

To take advantage of wind energy is important to know the diurnal and nocturnal and seasonal winds, the variation of wind speed with height above the ground, the entity of the bursts in short periods of time, and maximum values occurred in historical data with a minimum of 20 years. It is also important to know the maximum wind speed. To use wind power, you need it reaches a minimum speed which depends on the wind turbine to be used but usually begin between 3 m / s (10 km / h) and 4 m / s (14, 4 km / h) speed call "cut-in speed", and not exceeding 25 m / s (90 km / h) speed call "cut-out speed".

Wind energy is used through the use of wind machines (or aero-) able to transform wind energy into usable mechanical energy of rotation, either to directly actuate the operating machines, as for the production of electricity. In the latter case, the conversion system (comprising an electric generator control systems and connection to the network) is known as wind turbines.

It is now primarily used to move turbines. In these wind energy and drives a propeller through a mechanical system rotates the rotor of a generator, usually a generator that produces electricity. To be installer profitable, tend to cluster at concentrations known as wind farms.

A mill is a machine that converts wind into usable energy, which comes from the action of the wind on a sloping blades attached to a common axis. The rotary axis can be connected to various types of machinery to grind grain, pump water or generate electricity. When the shaft is connected to a load such as a pump, called the windmill. When used to produce electricity is called wind turbine generator. The mills have a remote source.

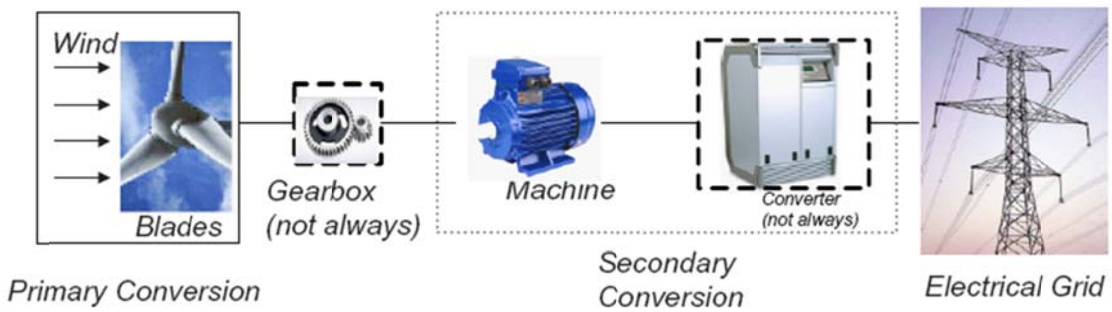

Figure 31: Scheme of the production of electrical energy from the wind power

History:

Wind energy is not new, is one of the oldest energy with thermal energy. The wind as a driving force there since ancient times and in all times has been used as such, as we observe. It originates from the sun. Thus, it has moved to boats powered by sail or machinery has operated the mill to move their blades. But it was not until the eighties of last century when this type of clean energy suffered a real boost. Wind power grows inexorably from XXI century, in some countries than in others, but certainly in Spain there is a high growth, one of the first countries behind Germany in Europe or the United States to worldwide. Its growth in wind farms is due to the favorable conditions of wind there, especially in Andalusia occupies a leading place among those who can point to the Gulf of Cadiz, as the wind resource is exceptional.

The first mills

The earliest reference we have is a windmill that was used to power an organ in the first century CE. The first mills were built for practical use in Sistan, Afghanistan, in the seventh century. These were mills vertical shaft with blades made rectangulares.8 apparatus 6 to 8 mill candles covered with cloths were used to grind wheat or removing water.

Figure 32: Old mill

In Europe

In Europe the first windmills appeared in the twelfth century in France and England and spread across the continent. They were wooden structures, known as mill towers, which were rotated by hand around a central pole to lift their blades into the wind. The tower mill was developed in France during the fourteenth century. It consisted of a stone tower topped by a wooden structure supported rotating shaft of the mill and machinery top of it. These first units had a number of common characteristics. From the top of the mill stood a horizontal axis. This axis departing from four to eight blades, with a length between 3 and 9 meters. The wooden beams were covered with cloth or wood. The energy generated by the rotation transmitting shaft, through a system of gears, machinery mill located at the base of the structure. The horizontal axis windmills were used extensively in Western Europe to grind wheat from the 1180s onwards. Just remember the now famous windmills in the adventures of Don Quixote. There are still mills that class, for example, in the Netherlands.

Pumping Windmills

In the U.S., the development of pumping windmills, recognizable by their many metal candle was the main factor that allowed agriculture and livestock over vast areas of North America, otherwise impossible without easy access to water. The mills contributed to the expansion of the railway around the world, supplying the water needs of the steam locomotives.

Figure 33: Pumping Windmill

Modern turbines

Modern turbines were developed in early 1980, although the designs continue to evolve.

Figure 34: Modern wind turbines

Use of wind energy

The wind energy industry in modern times began in 1979 with mass production of wind turbines Kuriant manufacturers, Vestas, Nordtank, and Bonus. Those turbines were small by today's standards, with capacities from 20 to 30 kW each. Since then, the size of the turbines has grown enormously, and production has expanded to many places.

Cost of wind energy

The unit cost of energy produced in wind power follows a fairly complex calculation. For evaluation should take into account various factors, among which include:

The initial cost or initial investment, the cost of wind affects approximately 60 to 70%. The average cost of a wind farm is today about 1,200 Euros per kW of installed capacity and variable depending on the technology and the brand that will be installed ("direct drive", "synchronous", "asynchronous", "generators permanent magnets "...;

Should be considered the life of the facility (approximately 20 years) and the amortization of this cost;

The financial costs;

The operation and maintenance costs (variable between 1 and 3% of investment);

The overall energy produced in a period of one year, ie the so-called factor plant installation. This is defined in terms of the characteristics of wind turbine and wind characteristics at the site has been located. This calculation is quite simple since it uses the "power curve" certified by each manufacturer and usually between 95-98% guaranteed by manufacturer. For some of the machines have been around for over 20 years has come to respect 99% of the power curves.

In August 2011 tenders in Brazil and Uruguay to purchase 20 had lower costs than U $ S65 the MWh.

Figure 35: World total Installed Capacity (MW). This picture show us that the wind turbine production increased each year in a logarithmic function

Wind power in the UK

The small wind could generate electricity cheaper than the network in some rural areas in the UK, according to research by the Carbon Trust. According to the report, mini wind turbines could generate 1.5 terawatt hours (TWh) per year in the UK, 0.4% of total consumption in the country, preventing the emission of 0.6 million tones of CO_2.

The UK ended 2008 with 4,015 MW installed with a token presence in its electricity production, yet it is one of the countries of the world's most wind power capacity is planned. The UK already has granted concessions to achieve the 32,000 MW wind farms on its shores:

Dogger Bank, 9000 MW North Sea Forewind * (SSE Renewable, RWE Npower Renewable, StatoilHydro & Statkraft)

Norfolk Bank, 7,200 MW; North Sea * Iberdrola Renewable (Scottish Power) & Vattenfall

Irish Sea, 4,100 MW; Irish Sea; Centric

Hornsea, 4,000 MW North Sea * Mainstream Renewable, Siemens & Hochtief Construction

Forth estuary, 3,400 MW; Scotland SeaGreen * (SSE Renewable and Fluor)

Bristol Channel, 1,500 MW South West Coast, RWE Npower Renewable

Moray Firth, 1,300 MW; Scotland * EDP Renewable & SeaEnergy

Isle of Wight (West), 900 MW, South Enerco New Energy

Hastings, 600 MW, South E.On Climate & Renewable

According to the British administration "offshore wind industry is a key route in the UK towards a low CO_2 emissions and should assume a value of about 75,000 million pounds (84,000 million) and sustain about 70,000 jobs until 2020. "

Advantages of wind energy

It is a type of renewable energy as it has its origin in atmospheric processes due to the energy that reaches Earth from the Sun

It is a clean energy, producing no atmospheric emissions or polluting waste.

It does not require combustion to produce carbon dioxide (CO2), so it does not contribute to the greenhouse effect and climate change.

Can be installed in areas unsuitable for other purposes, such as in desert areas near the coast, steep slopes and arid for cultivation.

Can coexist with other land uses, such as grassland for livestock use or low growing crops like wheat, corn, potatoes, beets, etc..

Create a high number of jobs in assembly plants and installation areas.

Installation is quick, between 4 months and 9 months

Inclusion in an inter-linked system allows, when wind conditions are suitable, save fuel in power stations and / or water in the reservoirs of hydroelectric plants.

Their combined use with other types of energy, usually solar, housing permits self-feeding, thus ending the need to connect to grids, autonomy can be achieved over the 82 hours without power from either of the 2 systems.

The current situation can cover the energy demand in Spain by 30% due to multiple location of wind farms on the territory, offsetting the low production of a lack of wind production with high wind areas. Systems can stabilize power system waveform produced in power generation by solving the problems that had the wind as energy producers at the beginning of installation.

Possibility to build wind farms at sea, where the wind is stronger, more consistent and the social impact is less, but increase the cost of installation and maintenance. Offshore parks are a reality in the countries of northern Europe, where wind power is becoming a very important factor.

Disadvantages of wind power

Technical aspects

Due to the lack of security in the presence of wind, wind can not be used as the sole source of electrical energy. Therefore, to save the "valleys" in the production of wind energy is indispensable support of conventional energy (coal or combined cycle, for example, and more recently, clean coal). However, when they support wind power, coal plants can not function at its best, which is situated about 90% power. They need to stay well below this percentage, to substantially raise production by the time they loosen the wind.Therefore, in the "backup" power plants consume more fuel per kWh produced. Also, by raising and lowering its output every time you change the wind speed, wears out the machinery. This problem goes back to Spain to try to solve through an interconnection with France to use the system to allow European and wind variability mattress.

In addition, variability in wind energy production has two important consequences:

To evacuate electricity from each wind farm (which are usually located well in natural sections) is necessary to construct high voltage lines that are capable of driving up electricity that is able to produce the installation. However, the average driving voltage to be much lower. This means putting cables 4 times thicker, and often taller towers to accommodate peak wind correctly.

It is necessary to meet the wind dips "instantly" (increasing the production of thermal power plants), because it is so produced, and widespread power outages do occur by low voltage. This problem could be solved through storage devices power. But the electricity produced can not be stored: is instantly consumed or lost.

In addition, other problems are:

Technically, one of the major drawbacks of wind turbines is called voltage sag. In view of these phenomena, the protections of the wind turbine with squirrel cage motors are disconnected from the network to avoid being damaged and, therefore, cause further disruptions in the network, in this case, lack of supply. This problem is solved either by changing the electrical switchgear wind turbines, which is quite costly, or through the use of synchronous motors is much easier but make sure the

network you are connecting is strong and stable .
One of the major drawbacks of this type of generation, is the intrinsic difficulty of providing for the generation ahead. Since power systems are operated by calculating the generation with a day in advance in view of expected consumption, the randomness of wind poses serious problems. Recent advances in wind forecasting has greatly improved the situation, but still a problem. Similarly, groups of wind generation cannot be used as a swing knot.
Besides the obvious need for minimum speed in the wind to move the blades, there is also an upper limit: a machine may be generating at full power, but if the wind increases just enough to exceed the specifications of the wind turbine is must disconnect the circuit of the network or to change the inclination of the blades to stop rotating, since wind speeds with the structure can be damaged by the efforts that appear on the shaft. The immediate consequence is an obvious decline in electricity production, despite having plenty of wind, and another factor of uncertainty when it comes to having energy in the consumer grid.
Although these problems seem only to wind power, are common to all natural energies:
A solar panel will only produce power when there is enough sunlight.
A hydroelectric plant dam will only occur while the water conditions and rainfall permit the release of water.
A tidal power can only occur while the water activity permits.

Enviromental aspects

Usually combined with power plants, leading to the existence of critics who do not really save too much carbon dioxide emissions. However, one must bear in mind that any form of energy production has the potential to cope with the demand and production based on renewable energy is cleaner, so its contribution to the electricity grid is clearly positive.
There are wind farms in Spain in protected areas as SPAs (Special Protection Area for Birds) and SCI (Site of Community Importance) of the Natura 2000 network,

which is a contradiction. While the possible inclusion of some of these wind farms in protected areas SPAs and SCIs have a reduced impact due to use natural resources, when human expansion invades these areas, thereby altering them without producing any good.

At the beginning of installation, the sites selected for it coincided with the routes of migratory birds, or areas where birds take advantage of slope winds, making conflicting wind turbines with birds and bats. Fortunately mortality levels are very low compared to other causes such abuses (see chart). Although some independent experts say the mortality is high. Currently the environmental impact studies required for the recognition of the wind farm plan takes into consideration the ornithological situation in the area. Furthermore, since wind turbines are of low current rotational speed, the problem of collision with the birds are being reduced.

The landscape impact is an important note because of the horizontal arrangement of the elements that compose it and the appearance of a vertical element such as wind turbine. Produce the so-called disco effect: This effect appears when the sun is behind the mill and the shadows of the blades regularly projecting over the gardens and windows, flashing so that people called this phenomenon "disco effect" . This, together with noise, can lead people to a high stress level, with consideration for purposes of health. However, the improved design of wind turbines has allowed it to reduce the noise produced.

The opening track operators and the presence of wind farms makes the human presence is constant in previously little-traveled places. This also affects wildlife.

About The software ANSYS

ANSYS is divided into three primary tools called modules: pre-processing (geometry creation and meshing), processor and post-processor. Both the pre-processor and post-processor are provided a graphical interface. This processor finite element for solving mechanical problems include: analysis of dynamic and static structures (both for linear problems and nonlinear), analysis of heat transfer and fluid dynamics, and problems of acoustics and electromagnetic. Usually the use of these tools is used simultaneously achieving mixing structures problems with heattransfer problems as a whole. This software is also used in civil and electrical engineering, physics and chemistry.

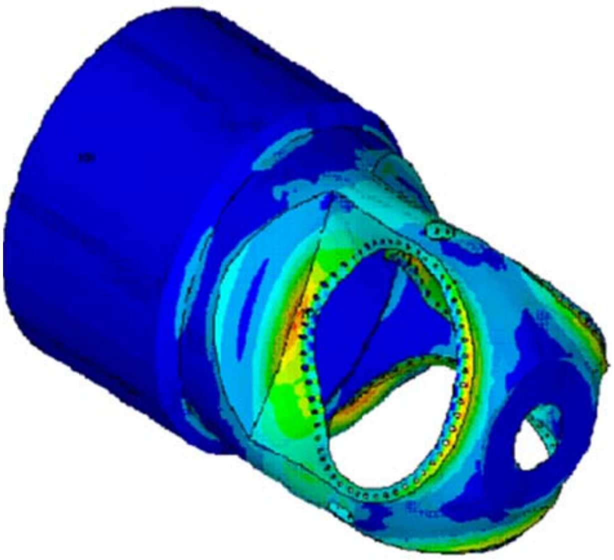

Figure 36: Hub analised by ANSYS

Features

Integrated

Allows the association of different technologies to develop a product without leaving a single platform. Besides its integration allows association with the most advanced CAD software. Finally, the integration system can easily be included in documentation systems of each company.

Modular

ANSYS allows customers to install a single application for solving a specific problem. As the user advances in the solution, this may require more complex analysis, until the validation process. The different modules allow ANSYS to solve the problems in parts.

Extensible

ANSYS offers "vertical applications" or more specific adaptations as required by the customer. These adaptations can automate processes that normally takes a client to more complex applications that are tailored to specific industries.

Disadvantages

Most of the errors and weaknesses of ANSYS, rather than relying on the program itself, are based on the finite element used by the program for analysis.
The solution given by the program is a complex mixture of discrete calculations. And efforts, temperatures and other properties represent continuous parameters. That said, the results obtained from ANSYS are approximations that depend on the number of elements used.
The geometry of the object to be analyzed, can cause errors in the solution because if the mesh made not maintain certain predetermined range parameters such as angles of the edges, and size relationships in the edges, the method can fail at a point which affects the convergence of the system.
The density of elements used must be entered manually. This means the user must run consecutively ANSYS increasing the number of elements used to achieve convergence to vary less than the stopping criterion used. This generates large computational cost and time by the user.
Due to the use of a discrete range as regards the properties of matter, it

should increase the number of points in the meshing of the object at the points at which the gradient of the analyzed property is too large for more accurate results. The element type as well as some properties are entered manually by the user. Which generates human-like errors in the use of ANSYS, sometimes the program does not display an alert on the ranges normally used.

Typical process of performing a calculation

Pre-processing

Establishment of the model, we construct the geometry of the problem, creating lines, areas or volumes. On this model will be established element mesh. This part of the pre-process is optional, since the location of the elements of the mesh can come from other design applications.

Defines the materials to be used based on their constant. Every element must be assigned a particular material.

Mesh generation, performing a discrete approximation problem based on points or nodes. These nodes are connected to form finite elements that together form the bulk material. The Maya may be generated manually or using automated tools or controlled mesh.

Process

Application of loads, boundary conditions are applied at the nodes and elements can handle values of strength, traction, displacement, time or rotación.7

Obtaining the solution, which is obtained when all the values of the problem are known.

Post-processing

Visualization of results, for example as a drawing of the deformed geometry of the problem.

List of results, just as data in a table.

Climate Study in Scotland

Figure 37: Image of the Wick castle

Figure 38: Wick in the map

Study of the wind made in the year 2011.

The town chosen I Wick in the north-east of Scotland. His high is 36 meters up the sea. It is near the sea.

The annual average of the wind says us that we can install a wind turbine because the range of working of a wind machine is between 6 Km/h and 90 Km/h. Some very windy days the machine will have to stop putting is blades to cut the wind, not to make resistance. This is normal because so many wind is dangerous for the wind turbine because it makes a lot of vibrations in the structure and that vibrations can break the machine.

Month	Monthly average (Km/h)	Maximum monthly (Km/h)	Minimum temperature (°c)
January	**16.38**	**74.08**	**-4.6**
February	**25.29**	**118.34**	**-2.2**
March	**20.15**	**96.49**	**-2.9**
April	**16.75**	**87.04**	**0.3**
May	**21.05**	**88.9**	**0**
June	**16.62**	**59.45**	**2.7**
July	**15.55**	**64.82**	**2.7**
August	**18.38**	**107.23**	**4.6**
September	**19.1**	**81.3**	**4.9**
October	**23.65**	**103.53**	**1.9**
November	**24.56**	**131.31**	**1.1**
December	**26.55**	**135.2**	**-3.1**
Average	20.03	95.64	-0.11

Table 1: Study of the weather in Wick

Simulation

The simulation has two parts:

1. Simulation of the wind turbine without ice in the blades with the tipical wind in Wick (20Km/h)
2. Simulation of the wind turbine with ice in the blades with the tipical wind in Wick (20Km/h)

Material Information:

The blade of the wind turbines are made of diferents materials, but I have choose the Fiberglass-reinforced epoxy resin because is very resitent and very light.

Is mass density is 2200 $N \cdot s^2/mm^3$ and is Dynamic Viscosity is 17.4 $N*s/mm^2$

[Customer Defined] (Part1) -Fluid 3-D

Material Model	Fluid
Material Source	Fiberglass-reinforced epoxy resin
Material Source File	
Date Last Updated	2012/04/02-14:46:42
Material Description	Customer defined material properties
Mass Density	2200 $N \cdot s^2/mm/mm^3$
Dynamic Viscosity	17.4 $N*s/mm^2$

Table 2: Parametres of the material used to made the blades of the wind turbine

Air –Fluid 3-D

Material Model	Fluid
Material Source	Autodesk Simulation Material Library
Date Last Updated	2004/09/30-16:00:00
Material Description	68 F, 1 atm
Mass Density	1.20761915536792e-012 $N\cdot s^2/mm/mm^3$
Dynamic Viscosity	1.79953165341156e-011 $N*s/mm^2$

Table 3: Parametres of the air used in the simulation

First we start designing the form of the wind turbine (for our study we only need the top part because all the tower are very similar and it doesn´t give us significant dates.

Figure 39: Windturbine design in Solid works

The design that I have made of the wind turbine is based in the form that has the wind turbines that are working all around the world.

Now the second step after the design in Solid works of the wind turbine is the mesh of the piece.

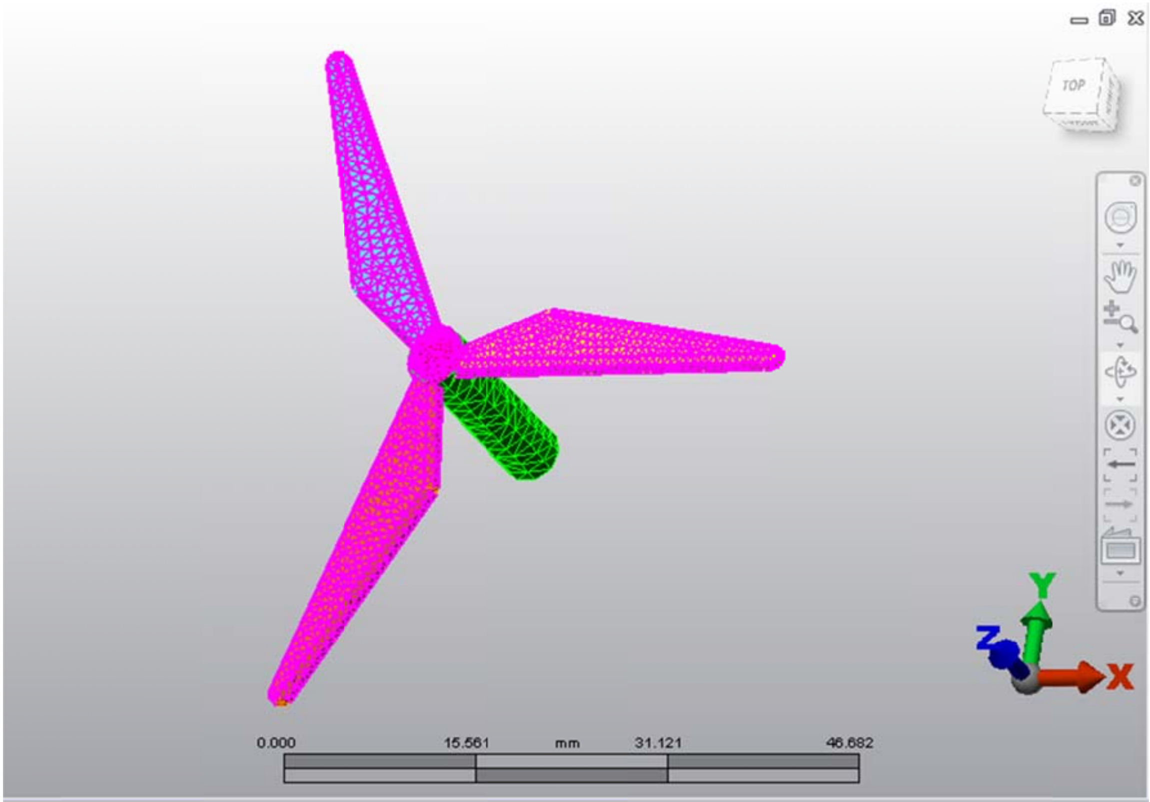

Figure 40 :Windturbine meshed

Now we put the charge of the wind on the blades, the force that the blades support.

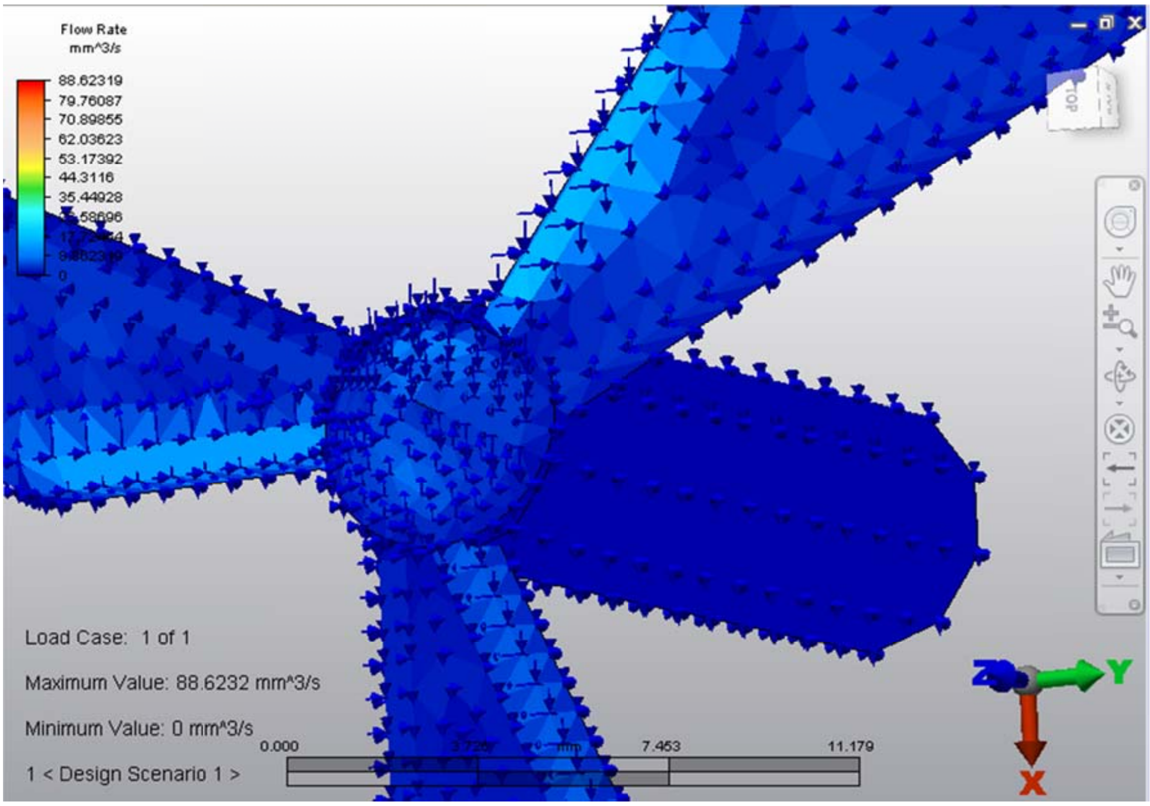

Figure 41: Flow detail of the wind turbine

We have the results of the flow rate, we can see that there are more charge in the attack face than in the back face

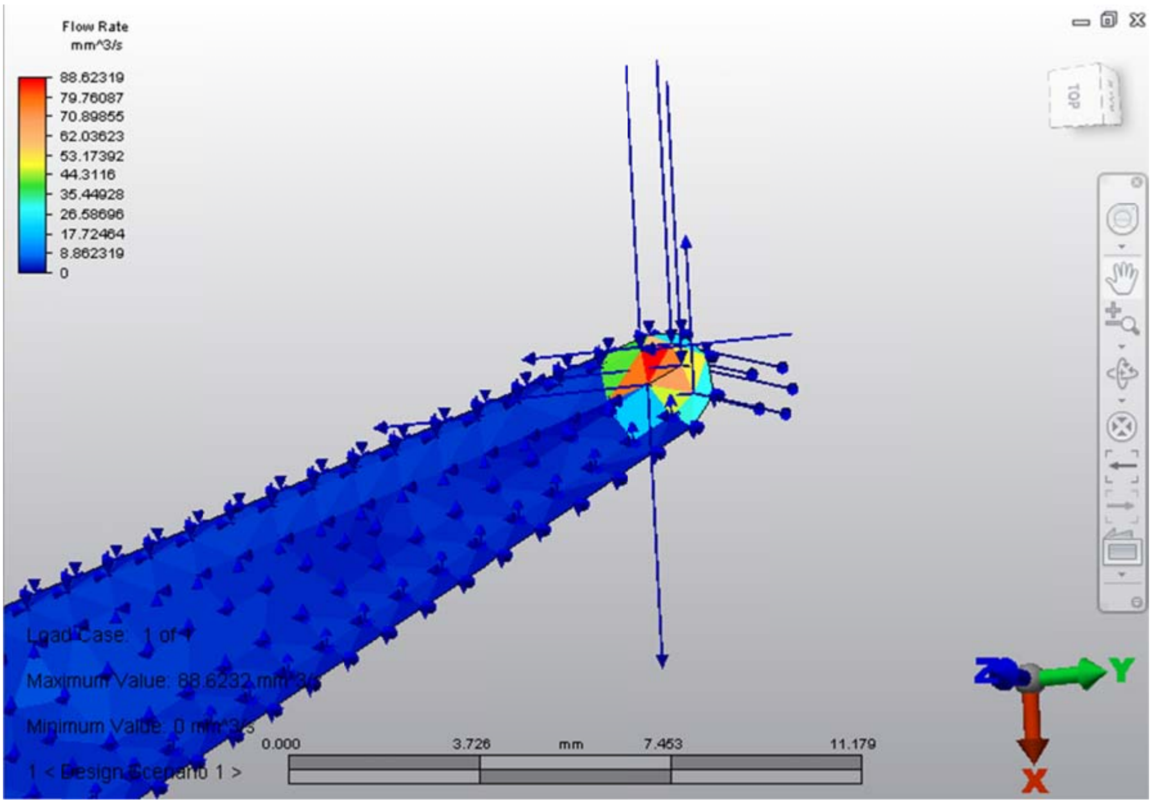

Figure 42: Detail of the turbulence in the end of the blade

Here there are a detail of the flow rate on the tail of the blade. Here we can see the turbulence that we have in that part of the blade. Different directions of the wind and different speeds in that part show us the turbulence.

Now we are going to see in more detail the fluent in de blade, we are going to do a study only of the blade.

As always, the first step is mesh the piece. I use the square mesh because is better than the triangle mesh. That kind of mesh is better because is more exactly and more flexible with the curves surfaces.

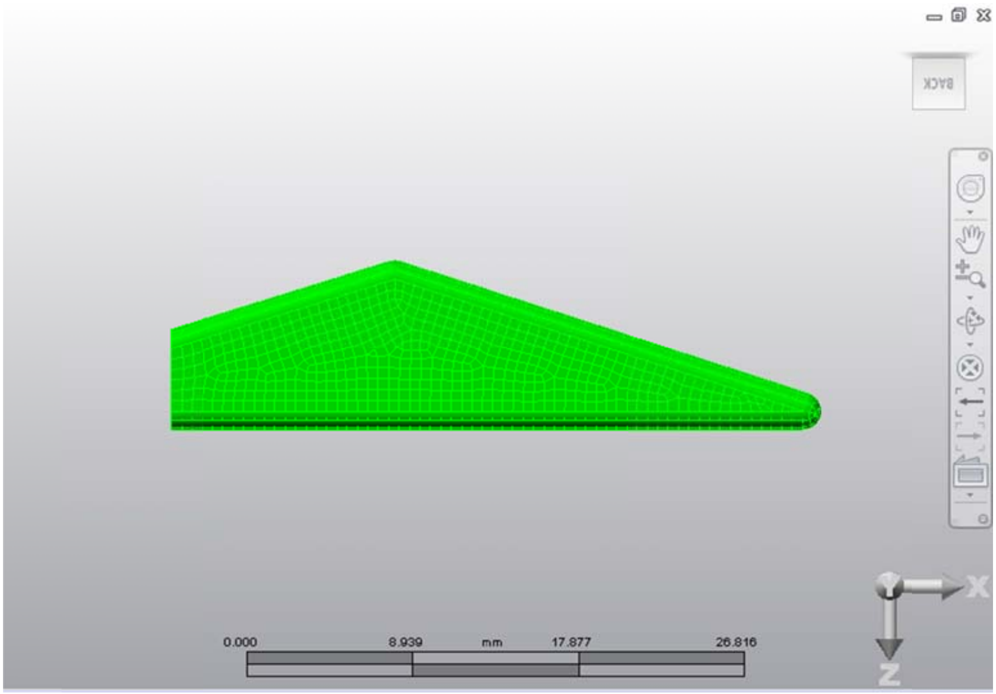

Figure 43: Picture of the mesh blade front view

And now we are going to put the charge of the wind in the attack face.

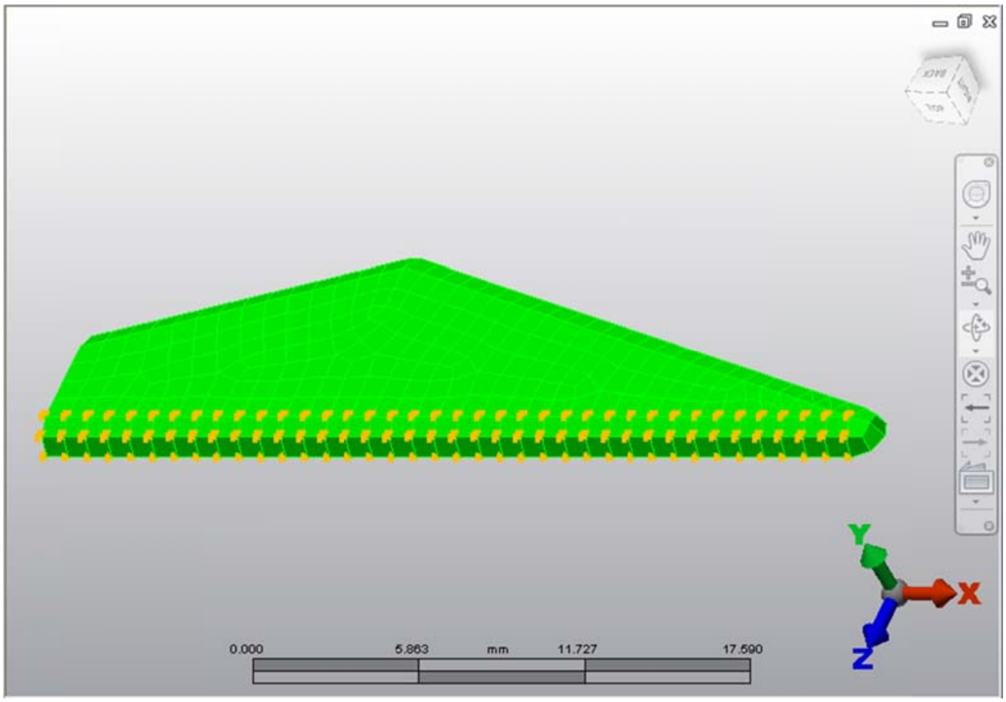

Figure 44: Picture of the mesh blade

The result show us that the velocity of the wind is very high in the attack face and after that the other faces of the blade stops the wind, that is the moment that the kinetic energy of the wind goes to de wind turbine.

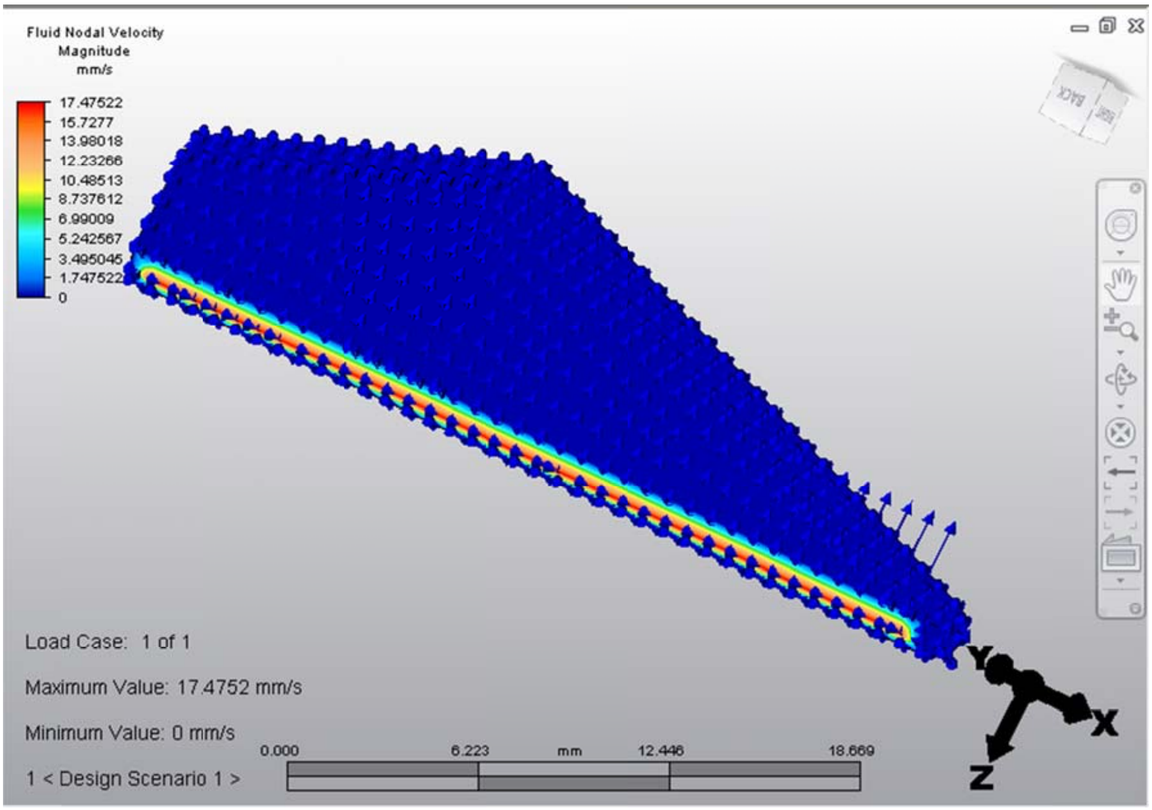

Figure 45: Direction and quantity of the wind in the attack section of the blade

In the following picture we have the flow rate all along the blade and we can see that we have different parts with more flow than others. That is because of the aerodynamic of the blade.

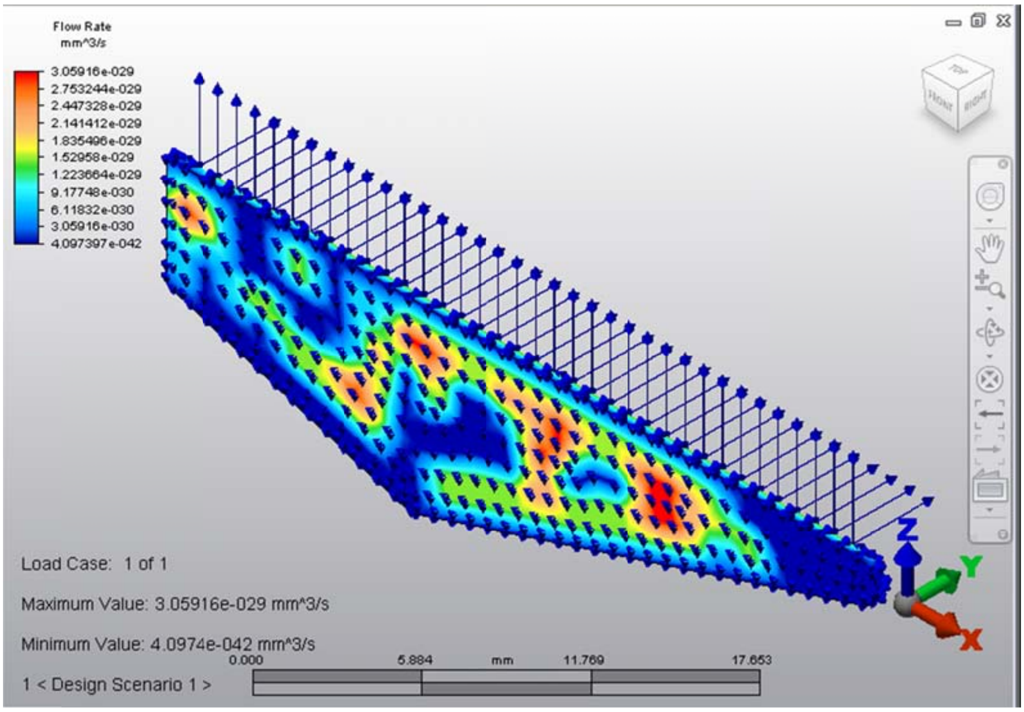

Figure 46: Flow rate of the wind through the blade surface

Here we have a detail of the flow rate in the attack face of the blade

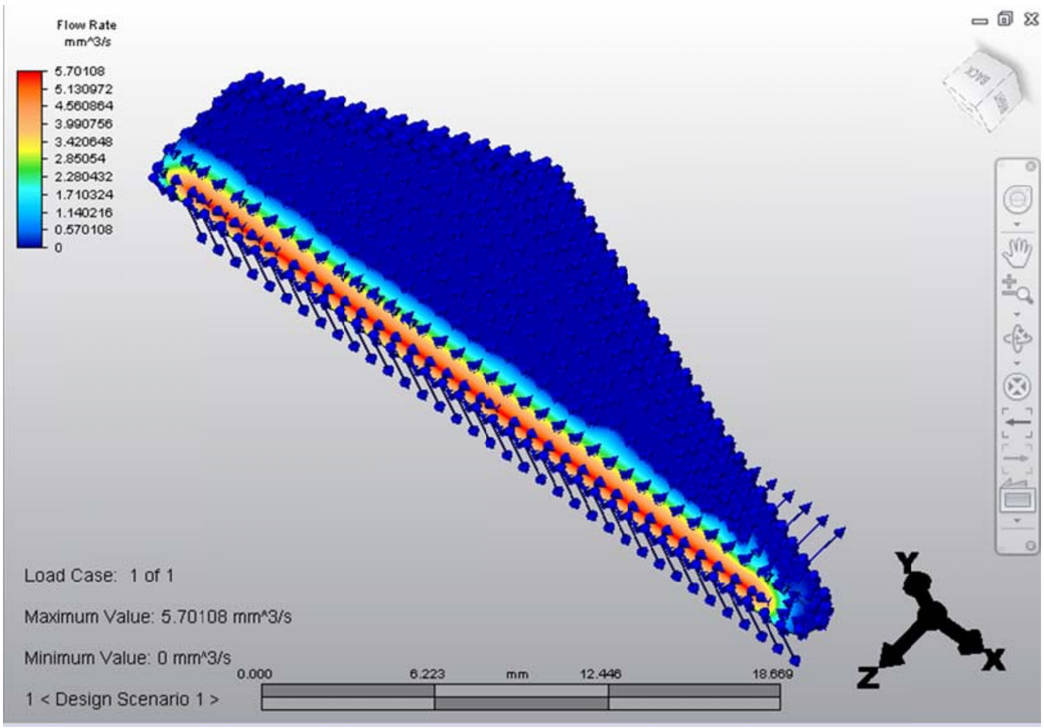

Figure 47: Flow rate through the attack face of the blade

Now we have the stress of the blade with the wind charge. We can see that the tail of the blade is the zone with more stress because that zone is always the part with more displacement and more vibrations.

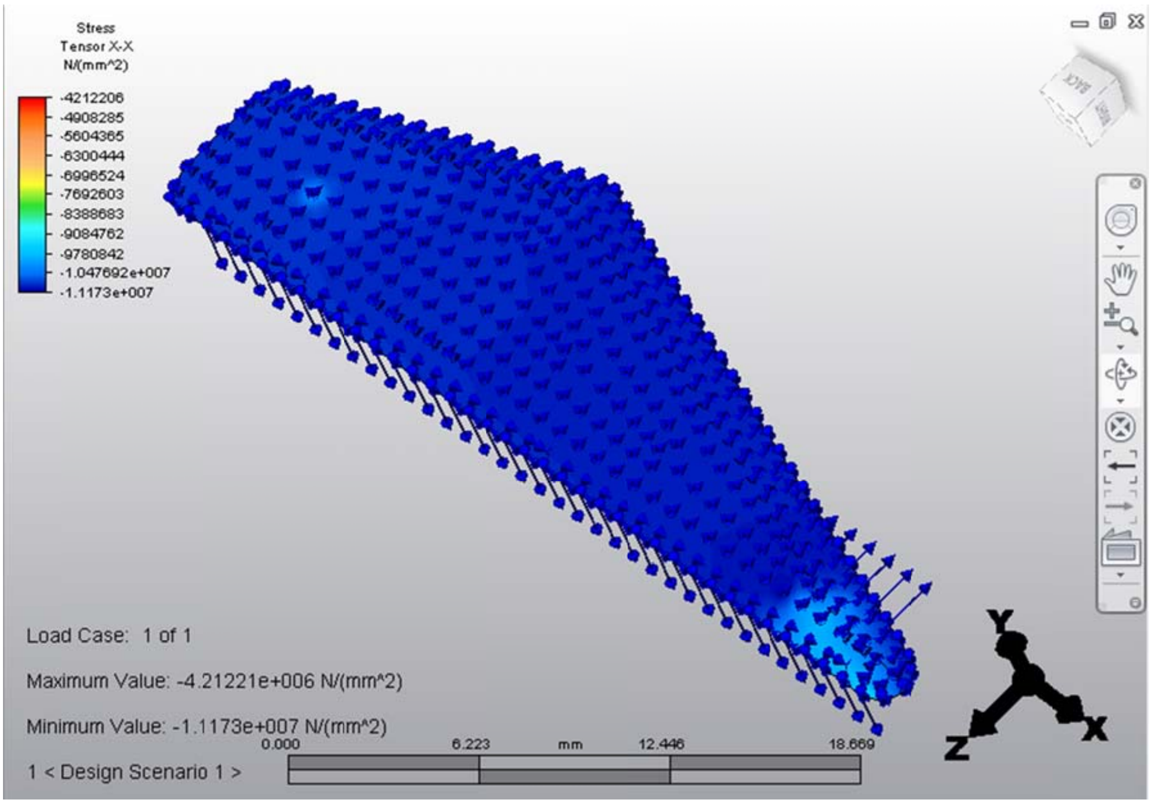

Figure 48: Stress range of the blade

In the picture of the pressure on the blade we can see that the pressure in constant along the face, but in the tail is less. This is all the face of the blade diverts the wind to the tail, making that pressure on the face, and when de air is near the tail, it doesn't have pressure force, only tangential velocity.

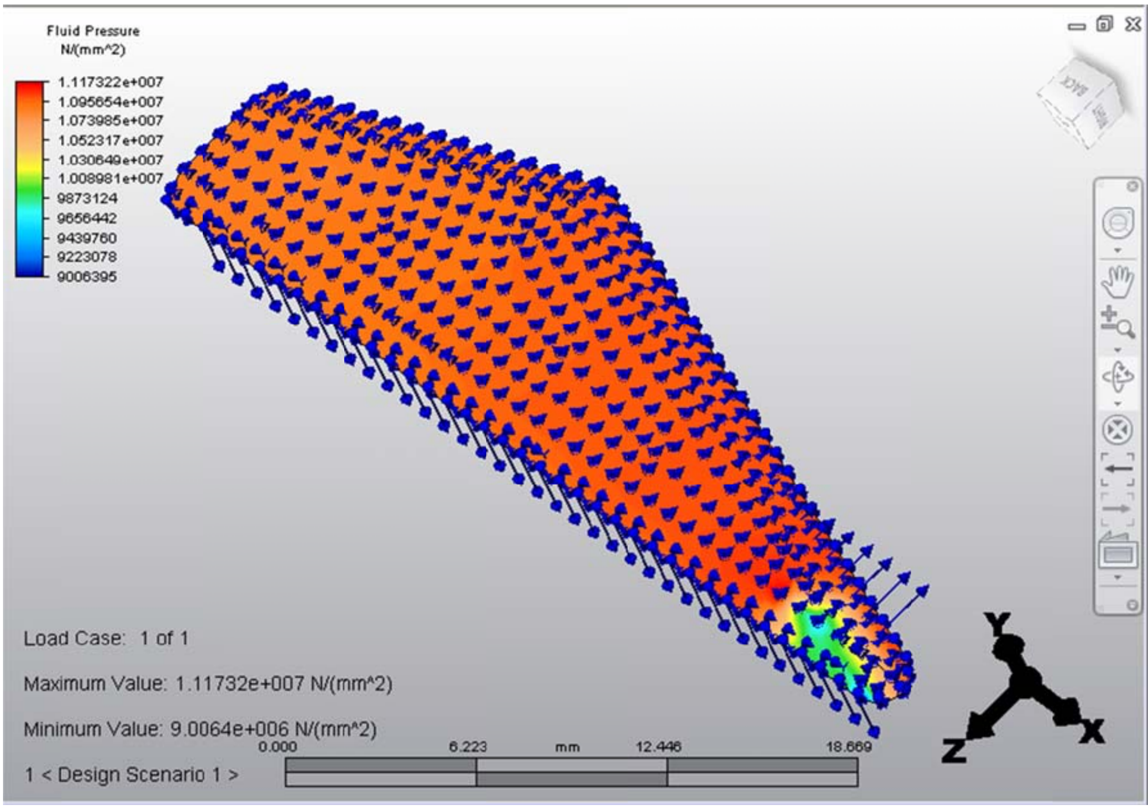

Figure 49: Fluid pressure along the blade

The second part of the analysis is to put normal wind from Wick, but with the typical temperature of Wick, so we meet ice in the blades. As we can´t design all the iced surface, we are going to make the attack face irregular to simulate an iced blade.

The first step is design the wind turbine in solid works. In that case, we must make de blades different.

Figure 50: Wind turbine with ice in the blades

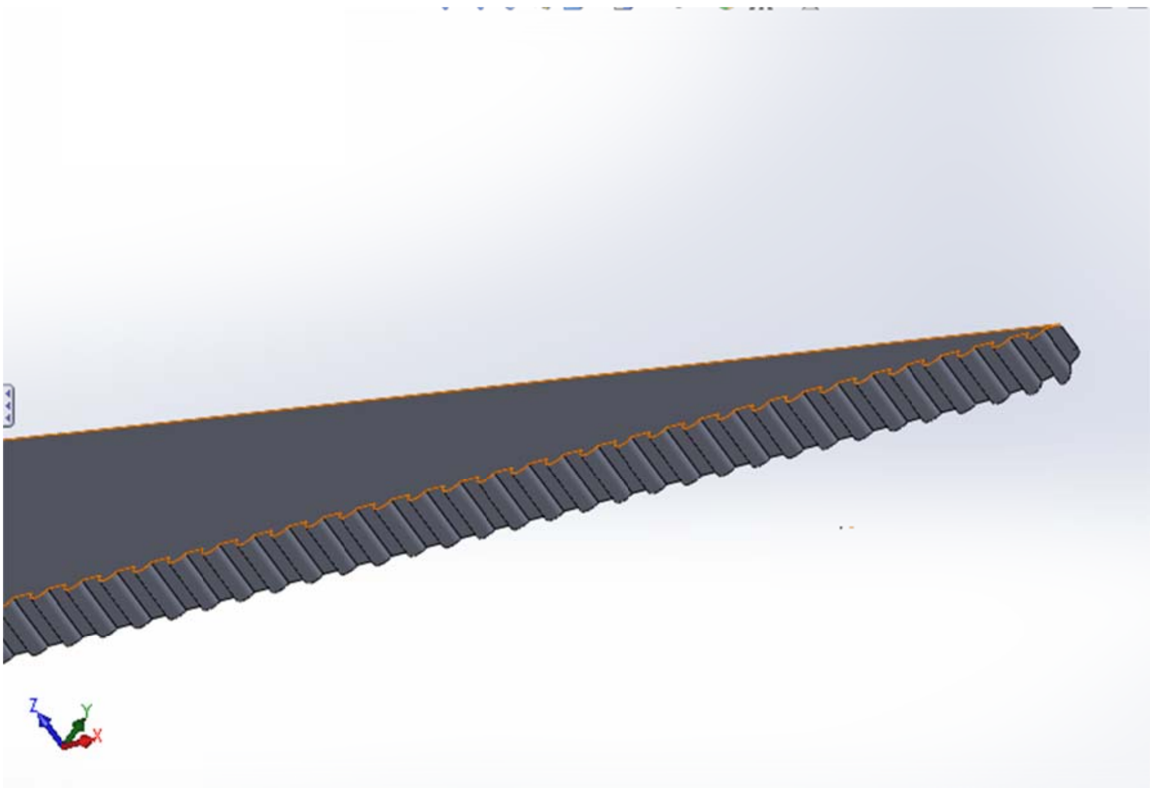

Figure 51: Detail of the blade with ice

Here we see the detail of the irregular surface in the attack face of the blade.

The second step is to mesh the windturbine.

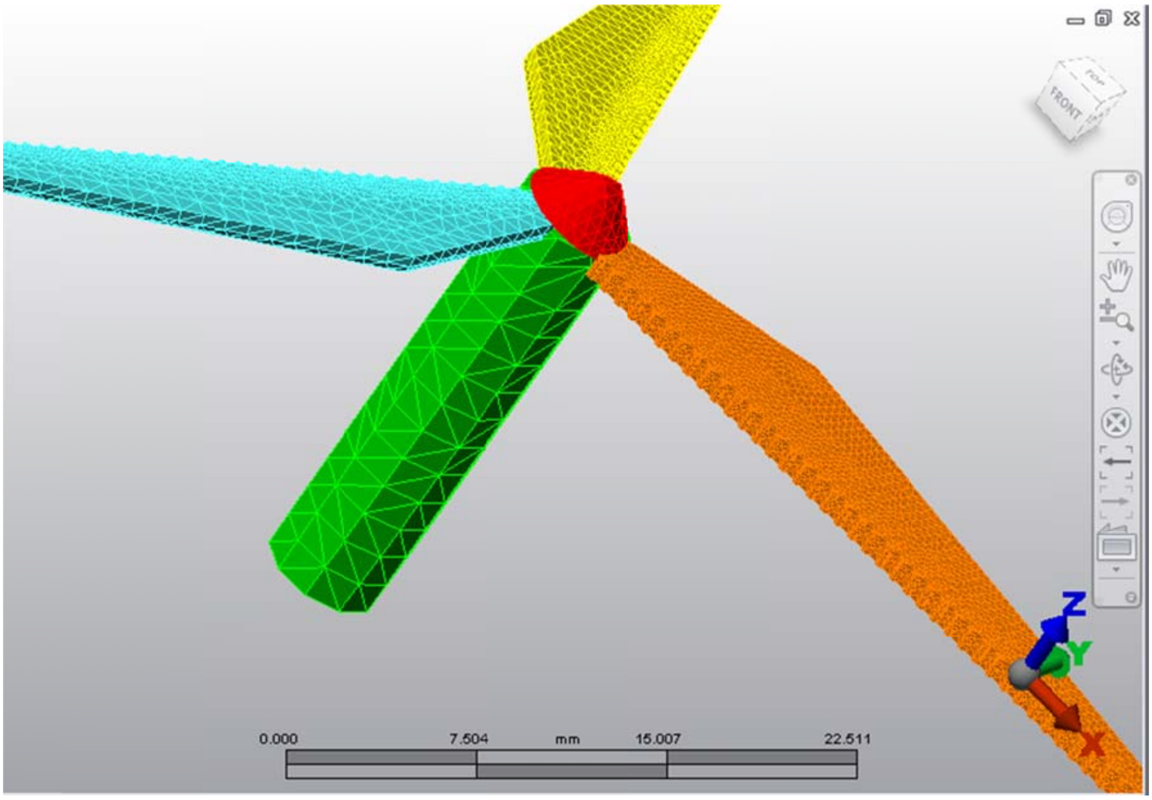

Figure 52: Windturbine with ice in the blades meshed

In that picture we can see the direction of the flow rate in the wind turbine with the iced blades. The direction of the flow rate is deviated outside the blade, so if we have ice in the blade the efficiency decreases a lot.

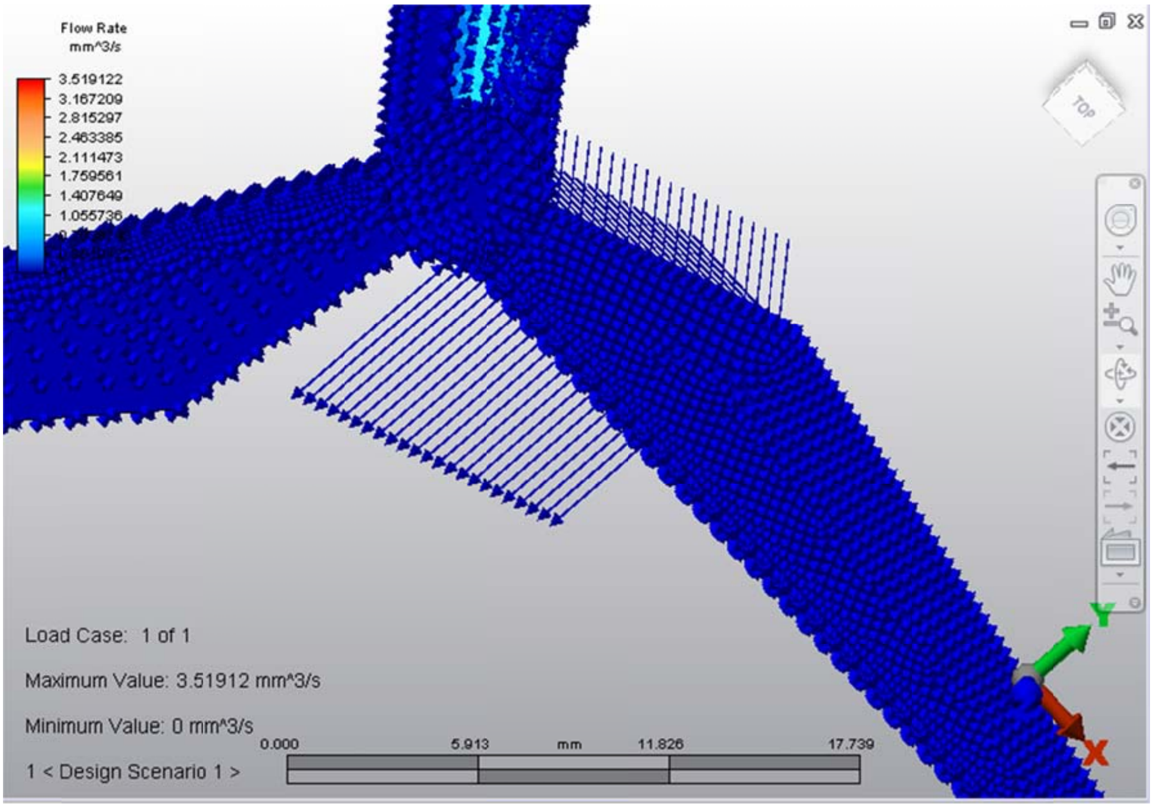

Figure 53: Detail of the flow rate in the blade with ice

Investigation about the ice in the blades

There are a disadvantage, being in an area of bad weather, we have a problem with the blades, and that low temperatures cause the water to the atmosphere to freeze and cause ice. The ice sticks to the blades and makes the aerodynamic of the blades is affected. Poor aerodynamics does not take advantage of the full force of the wind. This is seen in the efficiency of wind turbines. Companies currently detected the problem at low energy production. The cheapest solution is to stop the wind turbine and remove the ice. Other solution is to get warm the blades with a internal resistance, the electrical energy to get warm the resistances could come from the electricity produced by the wind turbine. There is another solution that increases the production of the electricity. This solution is projecting hot water to ice blades. This solution is more expensive, since you need an external water tank, a pump to bring water to the blades, and a heater. The latter solution is rarely used because it is more expensive.

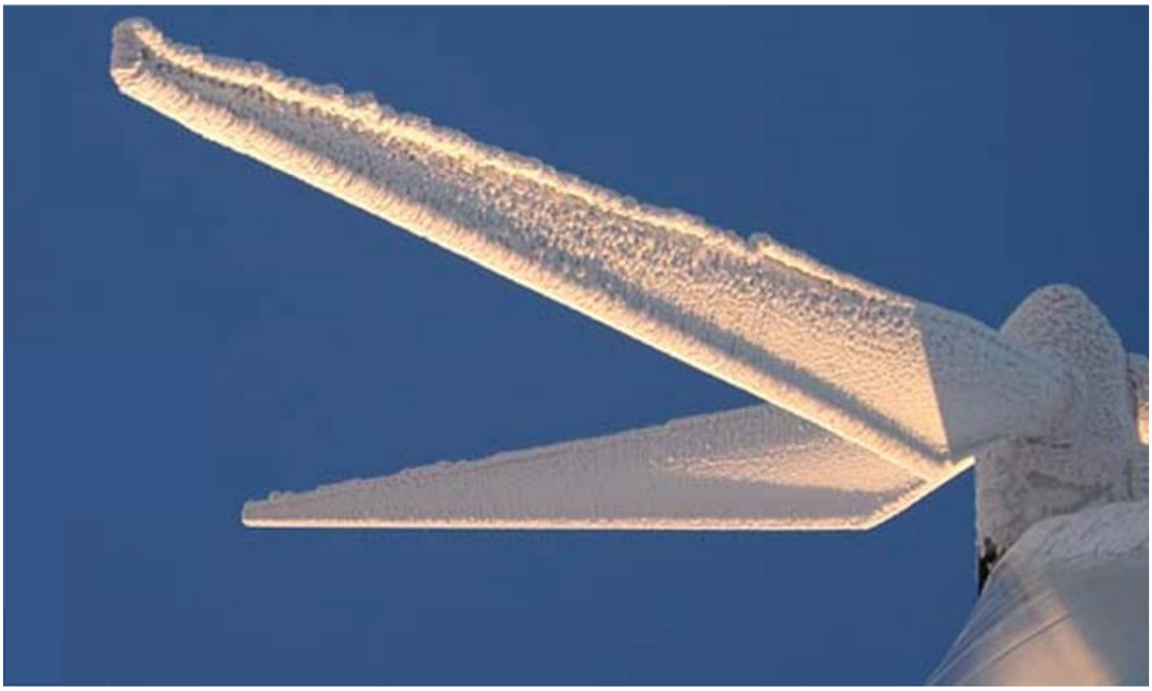

Figure 54: Iced blades. This picture shows how the ice can affect to the aerodynamic of the windturbines.

Conclusion

In this project I have investigated the practical renewable energies, and wind power in special. There are a lot of problems to get energy from the earth, because actually we found petrol in the deep of the sea, and is very difficult to obtain this. If renewable energies wants to substitute the fossil fuels, we can obtain that energies from all the places in the earth, as the fossil fuels are obtained. So, if we must put our renewable energies stations in difficult places, with bad weather, we must solve that engineering problem. In that project we study one of these problems, the ice in the wind turbines blades. With this study I try to help the renewable energies to substitute the fossil fuels all around the world.

The conclusion of that project is that the analysis without ice in the blades compared with the analysis with ice in the blades show us that the efficiency of the wind turbine ,and then the production of electricity, is much better when there are no ice in the blades. Knowing that we must fight with the ice in the blades and we must put it out of our wind turbines that are in cold zones of the planet.

Pd. In the end of the project, I couldn´t use the program fluent in the computers of Glyndwr, so, as good engineer I searched other solution. That solution was a finite elements program similar than ANSYS. The name of this element finite program is Autodesck simulation multiphisics. This program is from the company that develops Autocad.

References

Internet Pages:

- http://www.ibea.es/eco-02-tipos.htm
- **www.worldscibooks.com**
- www.clima.tiempo.com.

Books:

- Erich Hau. Wind Turbines: Fundamentals, Technologies, Application, Economics. Birkhäuser, 2006
- Robert Gasch, J. Twele. Wind Power Plants:
- Fundamentals, Design, Construction and Operation. Solarpraxis AG, 2002.
- Olimpo Anaya-Lara, Nick Jenkins, Janaka Ekanayake, Phill Cartwright. Wind Energy Generation: Modelling and Control. John Wiley and Sons, 2009.
- Godfrey Boyle, Open University. Renewable Energy. Oxford University Press, 2004
- Godfrey Boyle, Bob Everett, Janet Ramage, Open University. Energy Systems and Sustainability. Oxford University Press. 2003.
- Bryan J. Mac Donald. Practical Stress Analysis With Finite Elements.
- Alexandre Ern,Jean-Luc Guermond. Theory and Practice of Finite Elements.

Wind turbine electric generation simulation and optimizations

Universidad Pública de Navarra
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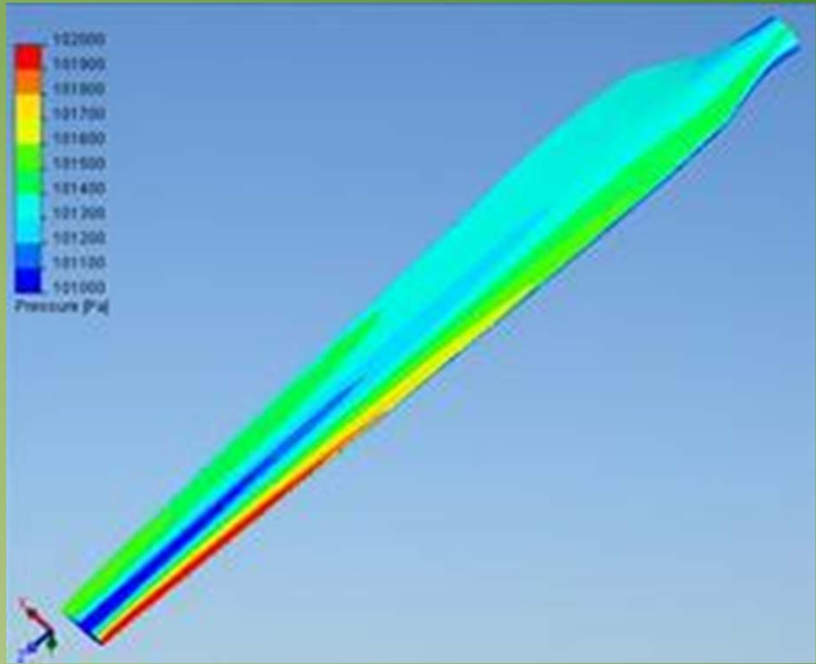
ITI Mecanica.

Supervisor: Pablo Sanchis

Koldo Sasal Diaz de Cerio.

Introduction

- This project is about a simulation of a wind turbine under different environmental conditions.



Project´s Objectives

- Climate study of a bad weather place
- Simulation With a finite elements software
- Simulation has to be with iced blades and normal blades
- Discussion of the results and possible solution of the problems

Climate study in Wick

The bad weather town chosen is Wick.

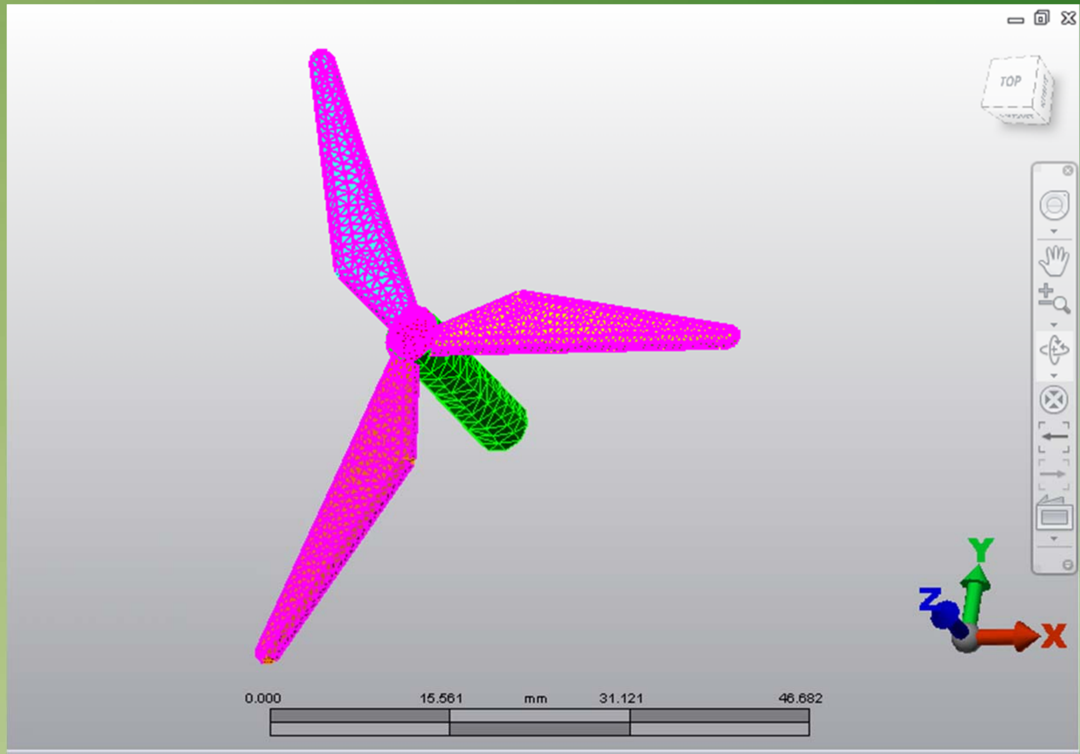
Wick is perfect for my wind turbine, because the winter months are very hard, and the annual wind average is high

Description of the simulation

First step in the simulation, is design the wind turbine. In that case is made with solid works

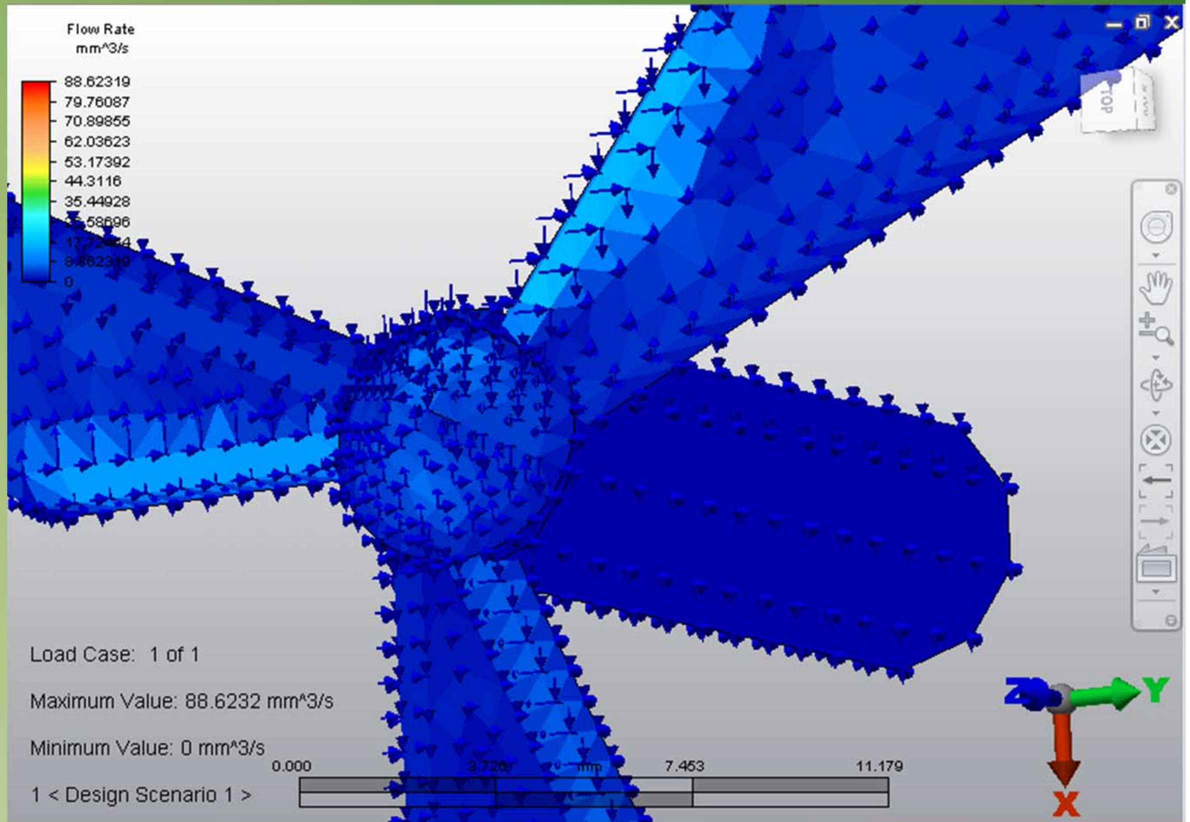
Meshing

Second step Is meshing the wind turbine with a finite elements program

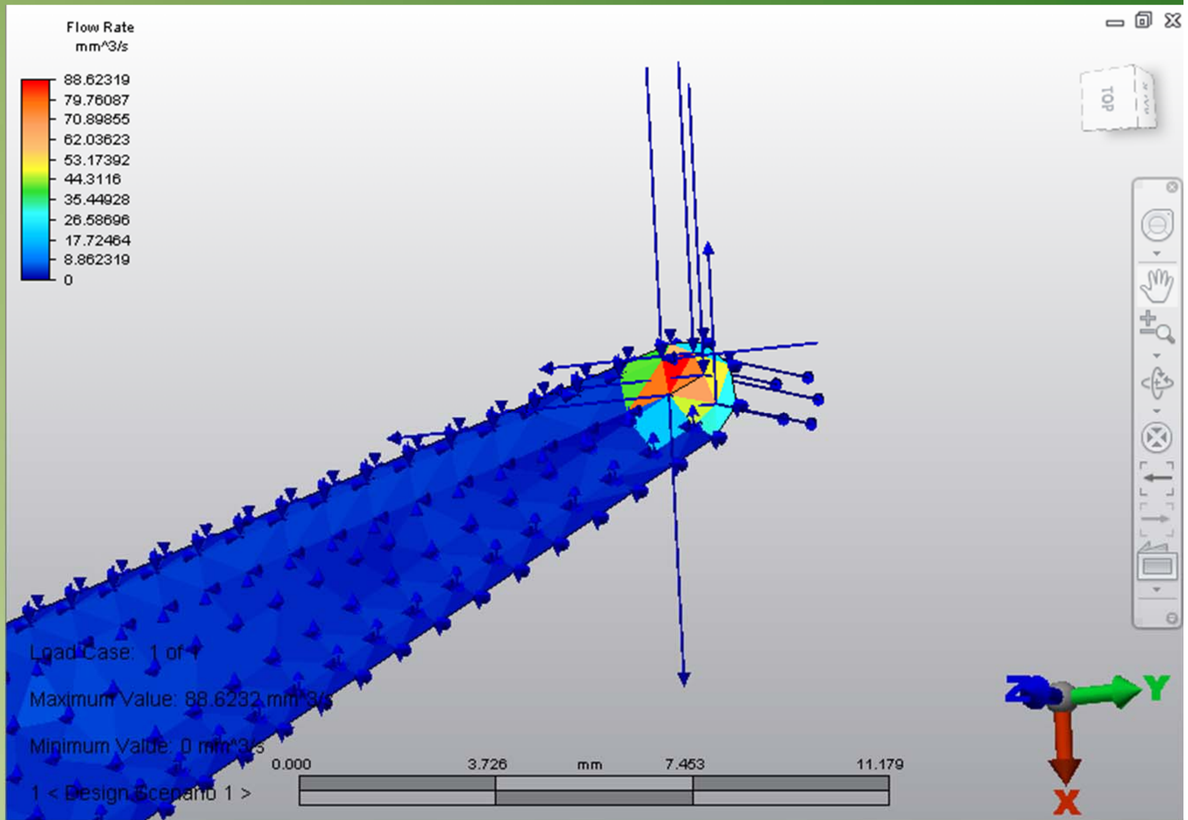


Wind forces

Third step is to put the wind forces on the wind turbine. The forces have to be the same as in a normal windy day in Wick

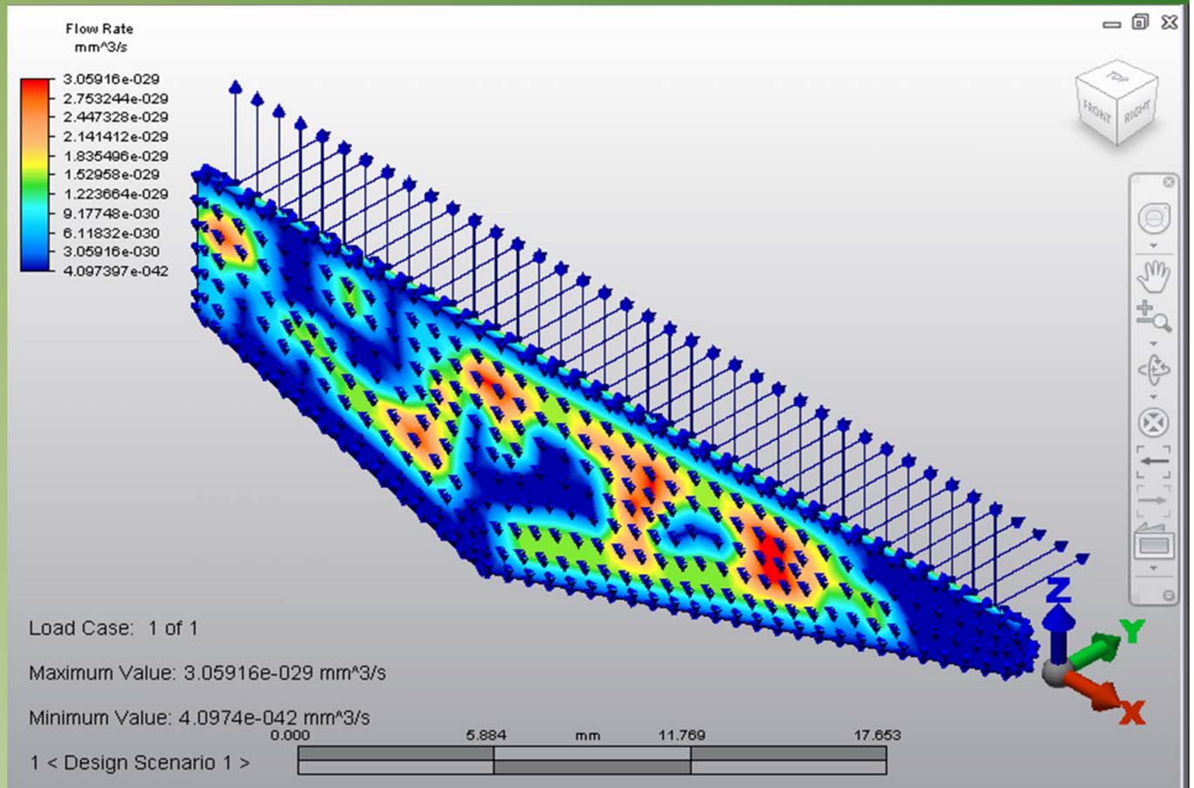


Detail of the end of the blade. Turbulences in that zone



Flow rate throw the blade

The colours show the flow rate through the blade. In the red zones there are a lot o air mass flowing.

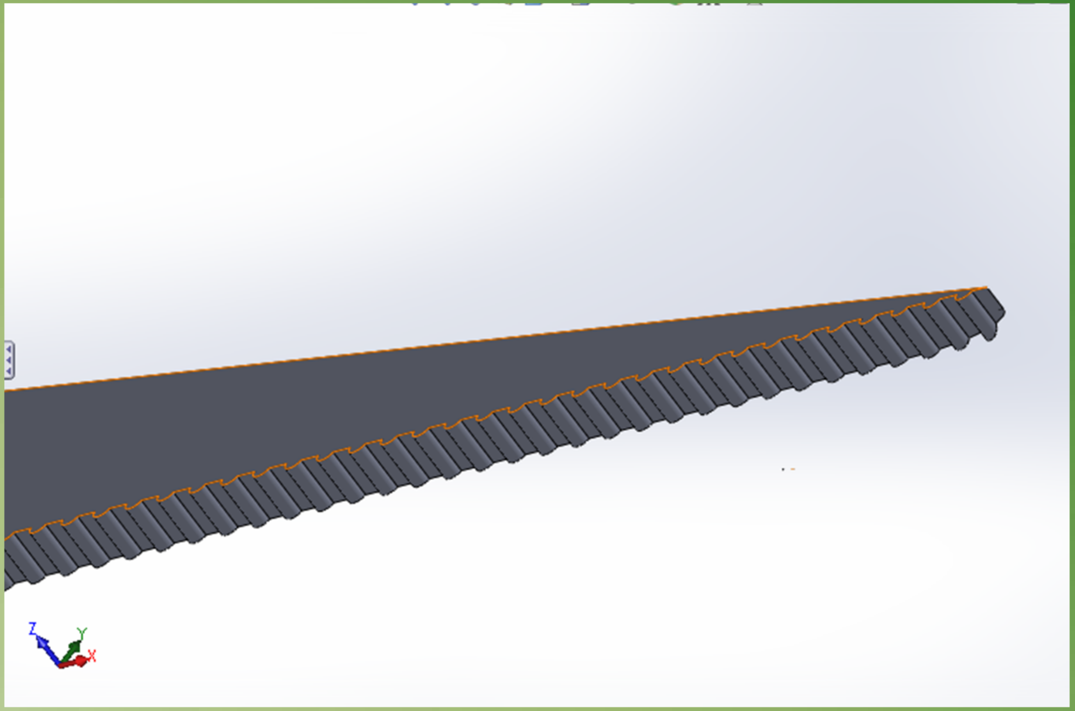


Iced blade

Is very difficult to make an iced surface with a cad software, so I have made a rough surface in the attack face to simulate the ice.

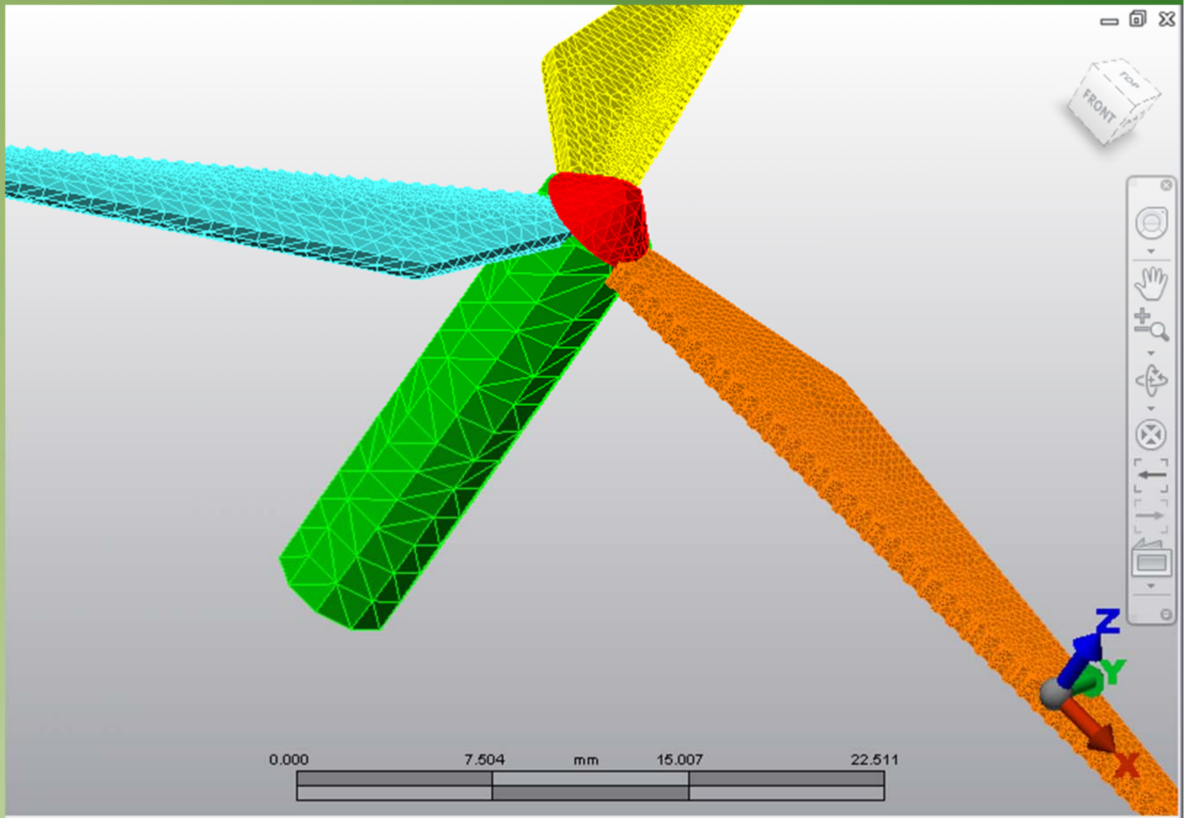
Blade design

This is the iced blade designed in solid works. The form is very similar to a iced surface



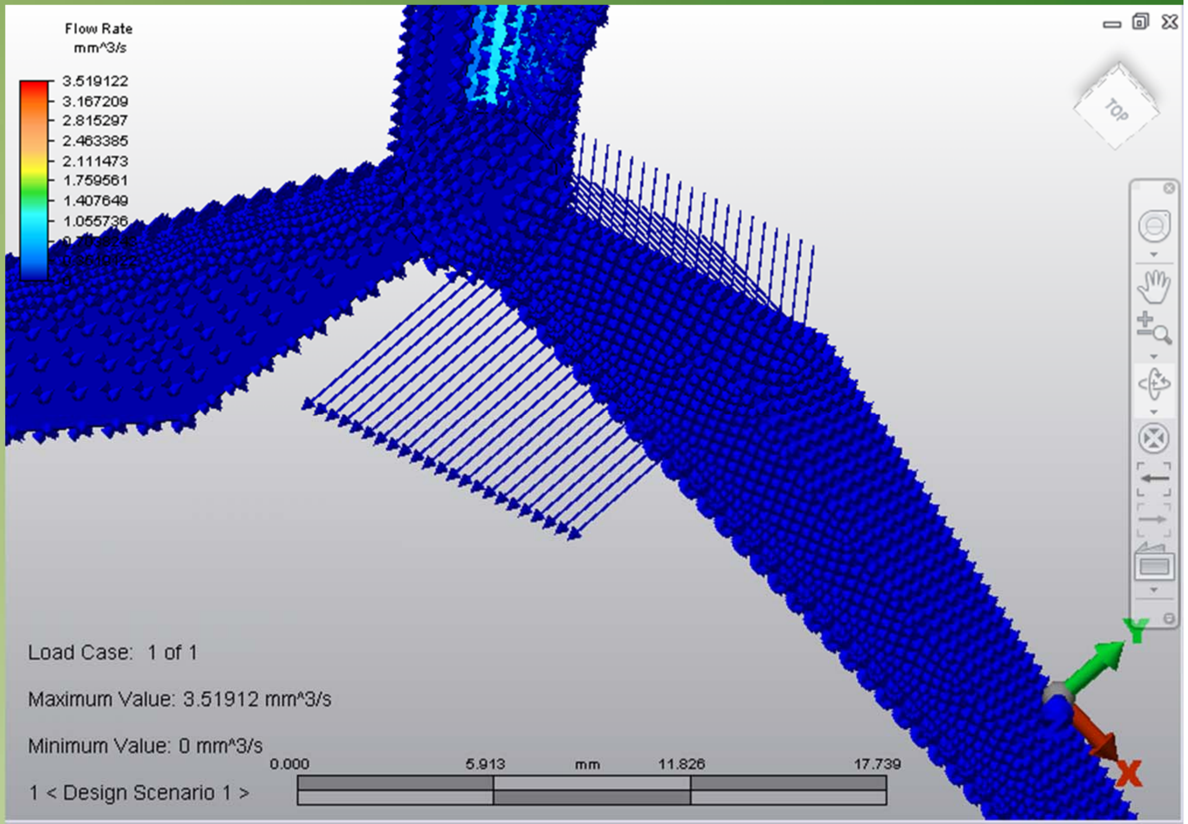
Iced blade meshed

As the other wind turbine this one has to be meshed with the finite elements software.



Flow rate of the iced blade

In the iced blade there are less flow rate than the normal blade, so, we lost efficiency



Results

We have a problem when is winter and the blades is ice, because we lost efficiency and it means money

Solutions of the problems

- 1: Stop the machine and put out the blades
- 2: Install a pump and a heater and throw hot water to the blades to quit the ice (expensive)
- 3: Resistances that get the blades hotter and convert the ice in water

Conclusion

- The best solution for the iced blades is the resistances inside the blades, using the electrical power from the wind turbine production.
- Before spend a lot of money making a wind farm only looking for hard annual wind average we have to think how it can be more effective.

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Thanks for your attention

I hope you enjoyed

Any question?