EXAMINING THE FEASIBILITY OF WIND POWER GENERATION IN THE REGION OF PRE-SALT

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Abstract. *The pre-salt region is located far from any power generating plant and is not connected to the grid. However, the oil platforms that operate in this area will require a supplemental power. Typically, oil rigs have generators which consist of gas turbines and for emergencies, diesel, and this gas comes from reservoirs of the platform itself, after passing through a treatment process and transformation, and Diesel comes from the land by boats. Thus, large areas of deck and engine room of platforms are commonly used for the purpose of generating electricity to keep the platform running. This paper proposes the implementation of floating wind turbines in the region of the pre-salt to provide, albeit in part, the electricity needed in that area, which would reduce the footprint of these platforms and also its weight, continuing concerns for the designers of these units . Despite the fact that wind power plants offshore have advantages, like the wind to be more stable and get to be 90% stronger at sea than on land, and do not offer negative impacts that this would cause as pollution, noise or visual, and this plan fails to occupy space on land that could be being used for other purposes, this type of wind power is still rarely discussed in Brazil, despite growing demand in the energy matrix to enable the national supply of energy and reduce the environmental impact caused by conventional ways of generating electricity, and each day greater stimulus for this to be made from renewable sources. This country has definitely entered the world map of the producers of electricity from wind power through an auction in this specific sector, which handled more than 19.5 billion dollars, and the Proinfa, Incentive Program for Alternative Sources of Energy, already the wind stands out among these sources to be inexhaustible and its minimal carbon emissions. This article, using data provided by NASA, will make a study of emissions reduction, risks and viability of this proposal.*

Keywords*: Wind, power, Pre-Salt*

1. INTRODUCTION

Petrobras recently made the biggest oil discoveries in Brazil in the pre-salt layer located between the states of Santa Catarina and Espírito Santo, where major volumes of light oil were found. The Tupi accumulation alone, located in the Santos Basin, has recoverable volumes estimated at 5 to 8 billion barrels of oil equivalent (oil plus gas). Meanwhile, the society's resistance to the use of polluting fuels and technologies due to concern about global warming combined with projections that indicate that energy consumption will rise at rates higher in the coming decades than in previous causes around the world increasingly search to invest in an energy less dependent on non-renewable sources of energy, investing in renewable sources such as biofuels, geothermal, hydroelectric, solar, tidal and wind, and each of these has unique characteristics that influence how and where they shall be used. In Brazil, wind energy can present as an alternative to diversify the national energy matrix, which is currently based on hydroelectric production. The focus of this paper is to evaluate the possibility of generating electricity to power likely FPSO (Floating, Production, Storage and Offloading) that will be exploiting the oil in the region of Pre-Salt.

2. OFFSHORE WIND POWER GENERATION

The first windmill for electricity production was built in Scotland in July 1887 in the backyard of the House of Professor James Blyth, who had the first house in the world to have their lighting supplied by wind Power. Blyth offered the surplus electricity to the population of Maykirk for lighting the main street, but the offer was refused because it was thought that electricity was "the work of the devil." Since then, mainly due to interest in generating energy from non-renewable resources and have minimal impact on the environment, wind energy has been widely appreciated. The main advantages of wind power are linked to this area: environmental impact much smaller than that caused by traditional energy sources. Wind energy is clean, renewable and does not generate pollution that can contaminate the environment because there are no chemical processes involved in the generation, and thus no release of products, besides the fact that the winds are an inexhaustible source of energy. Wind energy can also be useful for people who live permanently or temporarily in remote areas where it can be difficult to transport electricity through wires. So instead of taking the power plant where it was produced, wind turbines can be mounted in such places.

However, there are also disadvantages to this type of energy generation, such as instability: Wind turbines do not always work with 100% power, because wind speed is variable. As the wind is an energy source relatively unreliable, operators of wind farms need to have a backup system with a small amount of reliable power and non-renewable, for the times when the wind speed decreases. Some people argue that the use of clean energy to sustain the production of clean energy outweighs the benefits, but the wind industry claims that the amount of energy needed to maintain a steady supply of electricity in a wind system is negligible.

The danger against birds is usually the biggest cause for complaints against the installation of wind turbines. An article in the British journal Nature in January 2007 indicates that each wind turbine kills on average 4.27 birds per year, a tiny number compared with other human activities such as automobile traffic, hunting, electric transmission and skyscrapers buildings heaven. A positive example is the power plant Peñascal located in Texas, USA, which is situated in the middle of a route for migratory birds, so use a radar aircraft originally developed by NASA for the U.S. Air Force to detect birds from 6 km away. If the system decides that the flock is in danger of colliding against the rotating blades, it shuts down the turbines and reconnects automatically after the birds are gone.

All manner of electric energy production presents threats to security. Failures in propeller and ice that has been attached to it when fall can cause death and injury. When the brake of a wind turbine fails, it can rotate freely until it disintegrates or catches fire. Electronic controllers and subsystems security monitor different aspects of the wind turbine and the environment to determine whether the facility is operating safely and within the prescribed limits. These systems can turn it off temporarily due to strong winds, unbalanced electrical charges and other problems. There is also the risk of leaks occurring lubricating oils or hydraulic fluids by the propellers of the turbine, which can be scattered throughout the area around the aero generators, and can even contaminate the water consumed in the region. There is also a claim about visual pollution and noise: The windmills can be noisy for people living near them. These people may also complain of a "shadow flickering" caused by the propellers turning. In addition, wind turbines require aircraft warning lights, which create an uncomfortable light pollution.

Onshore wind plants are generally subject to restrictions and objections, these based on their negative impact with visual and sound pollution, restrictions pertaining to obstructions (buildings, mountains, etc..), dispute of use of land where there is bit space available ... Furthermore, studies show that average offshore winds are even 90% stronger than the winds on earth. These reasons may explain part of each day greater importance of plants for wind power generation located offshore. Spite of this, onshore wind power plants have advantages over wind farms located in the sea, mostly relating to cost: foundations cheaper, cheaper integration with the local power grid, installation and cheaper access during the construction phase, access to operating and maintenance cheaper and easier...

Furthermore, smaller wind turbines (which necessarily are used in onshore applications) cover certain objectives that the ones offshore do not cover. That is, the ability to build these offshore wind turbines and their advantages will not eliminate the plants constructed on land, however, when the production occurs on a large scale, the energy generated offshore takes advantage. Therefore, most of the higher aims in renewable energy production systems are based offshore, involving a large number of huge wind turbines and large-scale resource and investment. In September 2009, Denmark, the country that made the wind an alternative for generating clean electricity, opened the largest field of offshore wind power in the world. The HornsRev2 has 91 turbines spread in an area of 35 square kilometers in the North Sea. When in full capacity, will produce 210 megawatts of electricity per year, equivalent to the energy consumption of a city of 200,000 inhabitants. The investment was of 469 millions of Euros. As important as the deed that this plant poses to the engineering, is the value it represents to those who believe in cleaner sources of energy.

2.1. Wind turbines in deep water

The wind farms at sea for power generation that are already in operation are embedded with wind turbines which column is buried in the sea floor, fixing and maintenance them in place. As a consequence, to be economically viable, they cannot be installed in very deep water, which means that, apart from being visible from the coast, causing problems with coastal landowners, will become a threat to the birds inhabiting these regions and are unworkable in the pre-salt region, where water depth is in ranges from 1000 to 2000 meters.

Has been developed a project that aims to enable the deployment in deeper water using concepts of floating platform for oil and gas, the Windfloat, as shown in Figure 1 (taken from the website pcouncil.org). This project will allow them to be installed in previously inaccessible places, where water depth exceeds 50 m and wind resources are higher. Furthermore, economic efficiency is increased by reducing the need for offshore operations during assembly and installation.

Figure 1. Windfloat: Floating wind turbines.

3. ELECTRICITY GENERATION IN OIL RIGS

With the increase in production capacity of oil and gas in Brazil and deployment of new technologies in the offshore sector, the complexity of the electrical system of the platforms has increased significantly. In this work, we take as reference the P-43, whose daily output is 150,000 barrels and is capable of exploiting deep water. The P-43 is a FPSO, type of vessel that can process and store oil and / or natural gas.

Figure 2. The FPSO P-43.

The electrical design of the FPSO P-43 was developed within the standards of PETROBRAS, in accordance with the basic design done by CENPES – *Centro de Pesquisas da Petrobras* (Petrobras Research Center) - and also taking into account the norms by IEC – International Electrotechnical Commission - and ABS – *Agência Brasil de Segurança* (Agency of Brazil Security). The generation consists of four main turbo generators, each with nominal power rating of 23 MW at 13.8 kV, 60 Hz. For operation under normal conditions three units are sufficient for the operation of the system, with the fourth drive as a backup. For these conditions, is expected to operate two gas compressors and three water injection pumps. The generation consists of two emergency diesel generators, each with nominal power rating of 1700 kW at 480 V, 60 Hz

The peak demand occurs when the operation of the three gas compressors is necessary, requiring that the four generating units be in operation. With the P-43 operating without gas compression and don't transferring oil onshore (Offloading) two main generators are sufficient to attend the demand of the system. In this condition, the system demand is slightly higher than the capacity of a main generator, and it is possible to even greater decrease of the load, operating with only two water injection pumps, P-43 can be attended only with one generator.

The main generators are installed in two modules on the main deck. To accommodate the electric equipment on the part of production there is the Module Electric, whose equipment is distributed on two lifts. The emergency generators and electrical equipment of the naval facilities are leased in the Electrical Equipment's room, being the normal system's room located in *Sala de Utilidades* (Room Furniture) and essential system located on the Main Deck. The BCS - *Bombeamento Centrífugo Submerso* – or centrifugal pump submerged is inserted in oil production as one method of artificial lift. In this method, the energy is supplied to the fluid through a centrifugal pump multistage installed into the well. This pump is powered by one electric motor which is fed from the surface.

4. POTENTIAL OF WIND POWER GENERATION IN THE REGION OF PRE-SALT

4.1. Parameters

The pre-salt is a huge reservoir of oil and natural gas located in the coastal region between the states of Santa Catarina and Espírito Santo. As these reserves are located below the salt layer, which can have up to 2 km thick, they are located five to seven thousand feet below sea level. If the estimates are confirmed, Brazil will become one of the largest producers and exporters of oil and derivatives in the world.

Aiming to make an initial assessment of project feasibility to implement a plan for wind power generation in the pre-salt area of Brazil to supply electricity to the FPSO that will be sent in order to explore this region, we use the program RETScreen Clean Energy Project Analysis Software, a support tool developed with the contribution of numerous experts from government, industry, and academia. The software, provided free-of-charge, can be used worldwide to evaluate the energy production and savings, costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies (RETs). The software also includes product, project, hydrology and climate databases.

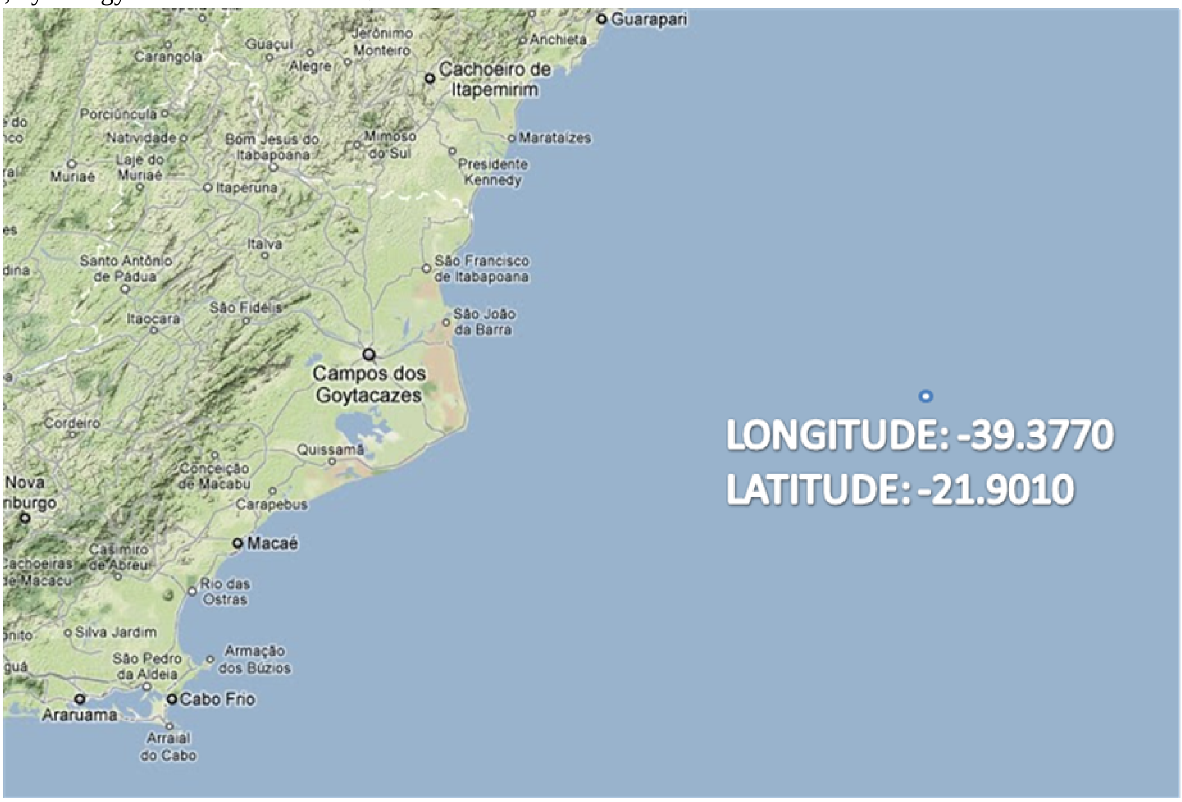

Figure 3.

The point chosen for theoretical simulation of the wind turbine was the one with longitude -39.3770 and latitude -21.9010, whose position is shown in Figure 3, taken from Google maps. This was a random coordinate within the region of the Brazilian pre-salt, since, as in the sea there are no major obstructions such as buildings or mountains and the roughness is constant, it can be assumed that for an initial analysis, this coordinate is satisfactory. According to satellite-derived meteorology and solar energy parameters, the monthly Averaged from 22 years of data provided online by NASA for these coordinates are:

Table 1.

Month	Air temperature (°C)	Relative humidity (%)	Atmospheric pressure (kPa)	Wind speed measured at 10 m(m/s)	Earth temperature (ºC)
January	26.0	79.2%	101.1	4.9	26.7
February	26.4	77.5%	101.1	4.3	27.5
March	26.4	77.1%	101.1	4.1	27.8

April	25.8	75.6%	101.3	4.2	27.3
May	24.9	72.2%	101.4	4.3	26.2
June	24.1	71.1%	101.7	4.3	25.1
July	23.2	71.2%	101.8	4.7	24.2
August	22.8	71.4%	101.8	4.9	23.7
September	22.9	74.2%	101.6	5.2	23.6
October	23.3	77.5%	101.4	5.1	24.0
November	24.1	79.7%	101.2	5.0	24.8
December	25.1	80.9%	101.1	5.1	25.7
Annual	24.6	75.6%	101.1	4.9	26.7

Additionally, will be analyzed the data provided by a wind atlas for this point too that are graphically presented following in this article:

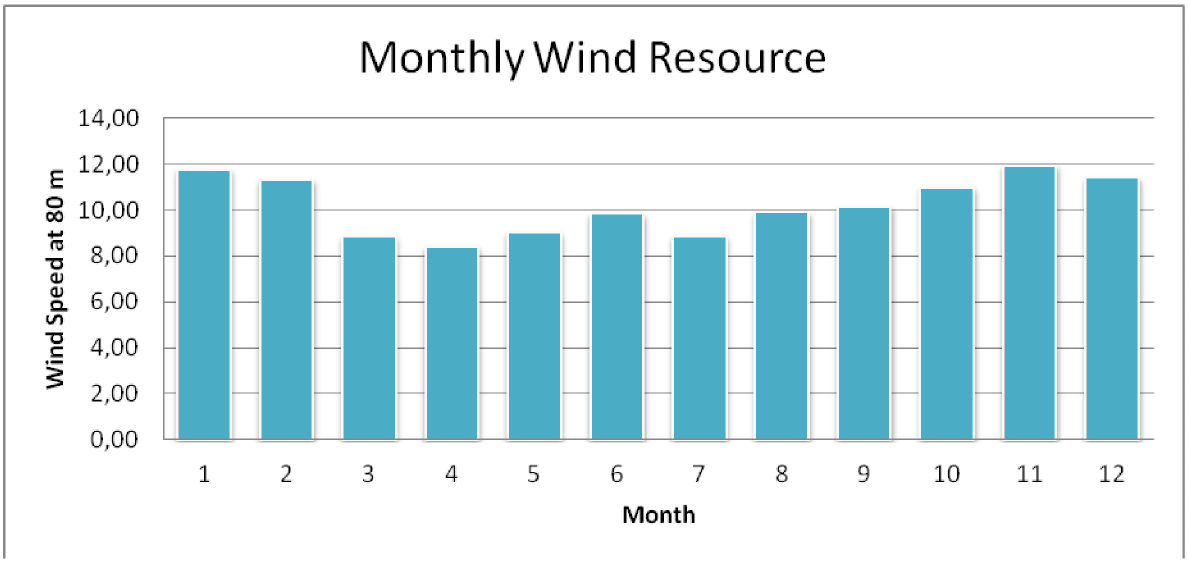

Figure 4.

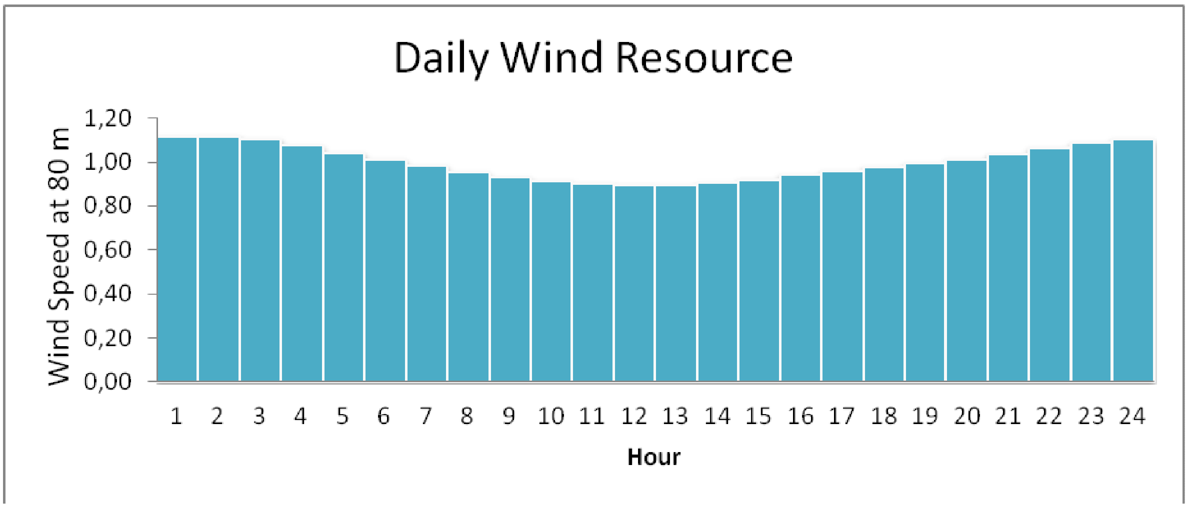

Figure 5.

For analysis, we use the technical specification of the wind turbine VESTAS V112-3.0MW, as shown in Figure 7 (taken from the VESTAS official website), with a hub height of 84 m, tip height of 104 m and a radius of 56 m.

Figure 7. The VESTAS V112-3.0MW.

The power curve for this Turbine considering a standard air density will be:

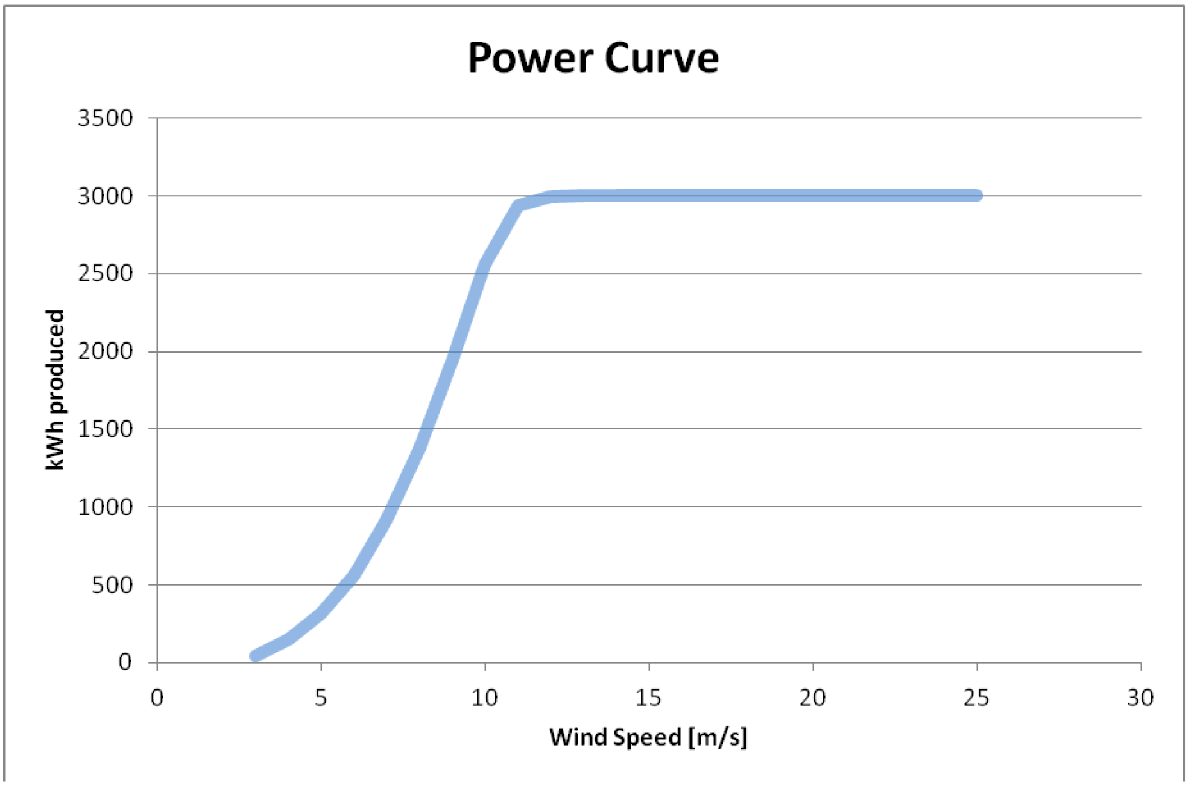

Figure 8. The VESTAS V112-3.0MW power curve.

4.2. Results

To simulate the park needed to generate the energy that feeds the platforms it will be used the WasP, a PC program for predicting wind climates and power productions from wind turbines and wind farms. The predictions are based on wind data measured at stations in the same region. The program includes a complex terrain flow model, a roughness change model and a model for sheltering obstacles. It will be simulated a park capable of generating 90 MWh. The analysis of the wind made by this program from the Weibull parameters on these coordinates is shown in Figure 9.

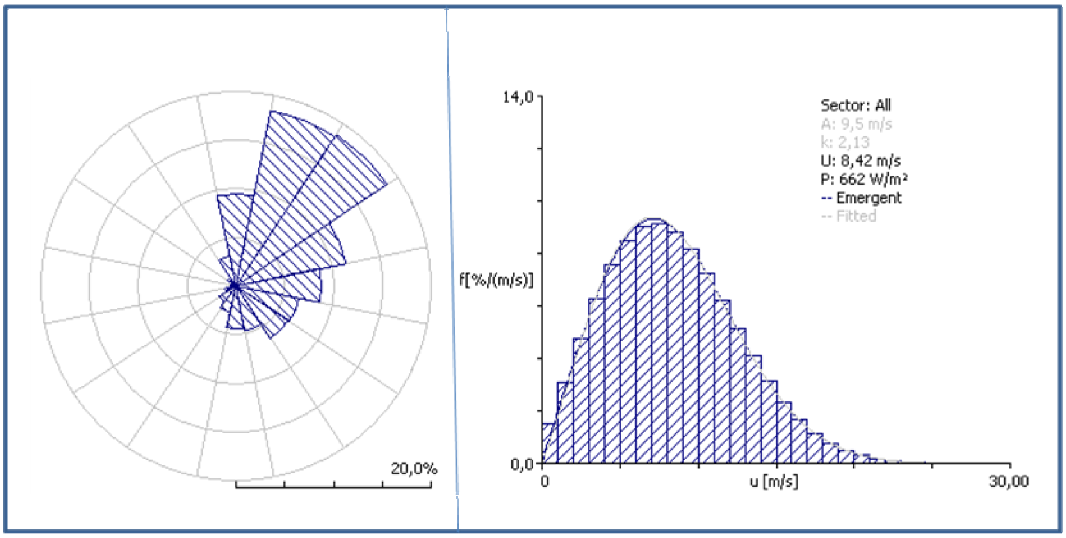

Figure 9.

The simulation with 30 wind turbines aligned can be seen graphically at figure 10 and numerically on table 2. The chart in each wind turbine indicates de power generated by them and the red portion the losses caused by the wake effect.

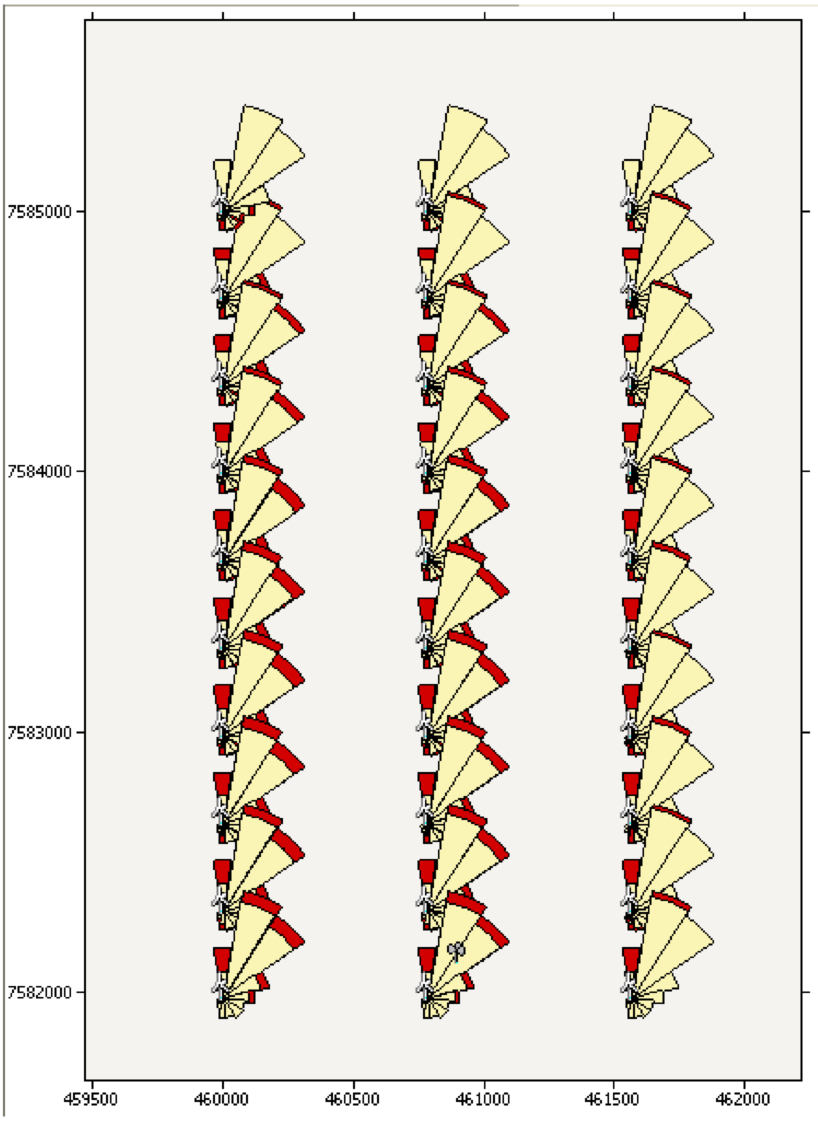

Figure 10.

Table 2.

Site ID	X-location [m]	Y-location [m]	U [m/s]	Grs [GWh]	Net. [GWh]	Loss [%]
1	460000	7585000	8.48	13.604	12.792	5.97
2	460000	7584664	8.48	13.604	12.139	10.77
3	460000	7584328	8.48	13.604	11.741	13.7
4	460000	7583992	8.48	13.604	11.524	15.29
5	460000	7583656	8.48	13.604	11.381	16.34
6	460000	7583320	8.48	13.604	11.315	16.83
7	460000	7582984	8.48	13.604	11.294	16.98
8	460000	7582648	8.48	13.604	11.327	16.74
9	460000	7582312	8.48	13.604	11.437	15.93
10	460000	7581976	8.48	13.604	11.702	13.99
11	460784	7585000	8.48	13.604	12.828	5.71
12	460784	7584664	8.48	13.604	12.198	10.34
13	460784	7584328	8.48	13.604	11.829	13.05
14	460784	7583992	8.48	13.604	11.623	14.57
15	460784	7583656	8.48	13.604	11.512	15.38
16	460784	7583320	8.48	13.604	11.455	15.8
17	460784	7582984	8.48	13.604	11.448	15.85
18	460784	7582648	8.48	13.604	11.496	15.5
19	460784	7582312	8.48	13.604	11.616	14.61
20	460784	7581976	8.48	13.604	11.881	12.67
21	461568	7585000	8.48	13.604	13.179	3.13
22	461568	7584664	8.48	13.604	12.73	6.42
23	461568	7584328	8.48	13.604	12.564	7.65
24	461568	7583992	8.48	13.604	12.474	8.31
25	461568	7583656	8.48	13.604	12.422	8.69
26	461568	7583320	8.48	13.604	12.396	8.88
27	461568	7582984	8.48	13.604	12.397	8.88
28	461568	7582648	8.48	13.604	12.422	8.69
29	461568	7582312	8.48	13.604	12.488	8.21
30	461568	7581976	8.48	13.604	12.671	6.86

And also with the WAsP we can obtain the capacity factor for the wind farm, that is 45.7%, a high value for a wind farm. The analysis of the amount of greenhouse gases emitted made by RETScreen can be seen below:

GHG emission	
Base case (tCO_2)	68316.9
Proposed case (tCO_2)	1366.3
Net annual GHG emission reduction (tCO_2)	66950.6

The net annual GHG emission reduction is equivalent to 12262 cars & light trucks not used or 28766808 liters of gasoline not consumed and 66.951 people reducing energy use by 20%.

5. CONCLUSIONS

Based on the data presented, we conclude that it would require a large number of wind turbines to generate energy for each platform, which would make the project very costly. Taking as comparison the HornsRev 2 mentioned, which has a production capacity of 160mw, had a cost of 270 million Euros. It is important to also consider that on this region of Denmark the waters are pretty shallower than in the pre-salt region of Brazil (6-14 m and 1000-2000 m), and floating wind turbines are not yet commercially available.

From the simulations of the wind farm, which has not yet optimal layout according to the wind direction, we obtained a high capacity factor, indicating a great potential for wind power generation in this region. So, the view of a wind farm in the pre-salt region is still futuristic, but it will take many years yet to the oil exploration on this site is at all your capacity too.

6. REFERENCES

RETScreen International Empowering Cleaner Energy Decisions. 9 Feb. 2010. <http://www.retscreen.net/ang/home.php>

NASA Surface meteorology and Solar Energy. 14 Jul. 2010. < http://eosweb.larc.nasa.gov/sse/RETScreen/>

PETROBRAS: Questions & Answers, understanding the Pre-Salt. < http://www.petrobras.com.br/minisite/presal/en/questions-answers/>

WindFloat Brochure, PRINCIPLE renewable energy delivered. < www.principlepowerinc.com>

ABCM, 2004."Journal of the Brazilian Society of Engineering and Mechanical Sciences".1 Feb. 2007, <http://www.abcm.org.br/journal/index.shtml.>

Bordalo, S.N., Ferziger, J.H. and Kline, S.J.,1989, "The Development of Zonal Models for Turbulence", Proceedings of the 10th Brazilian Congress of Mechanical Engineering, Vol.1, Rio de Janeiro, Brazil, pp. 41-44.

Coimbra, A.L., 1978, "Lessons of Continuum Mechanics", Ed. EdgardBlücher, S.Paulo, Brazil, 428 p.

Clark, J.A.,1986, Private Communication, University of Michigan, Ann Harbor.

MLA, 2004. "How do I document sources from the web in my works-cited list?" Modern Language Association.22 Feb.2007 <http://www.mla.org>.

Soviero, P.A.O. and Lavagna, L.G.M., 1997. "A numerical model for thin airfoils in unsteady motion". RBCM – Journal of the Brazilian Society of Mechanical Sciences, Vol. 19, No. 3, pp. 332–340. Sparrow, E.M., 1980, "Forced Convection Heat Transfer in a Duct Having Spanwise-Periodic Rectangular Protuberances", Numerical Heat Transfer, Vol.3, pp. 149-167.

Economia BR, "Indicadores Econômicos". <http://economiabr.defesabr.com/Ind/Ind_energia.htm>

General Specification V112-3.0MW IEC IIA Vestas.

Price, T.J.,2005, "James Blyth - Britain's first modern wind power engineer"., Wind Engineering, Multi Science Publishing.

Marris, E.; Fairless, D., "Wind farms' deadly reputation hard to shift", Nature.10 may 2007.

HORNS REV Official website <http://www.hornsrev.dk/nyheder/brochurer/Horns_Rev_GB.pdf>

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