WIND FARM VIABILITY ANALYSIS EMPLOYING COMPUTATIONAL FLUID DYNAMICS

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Abstract. *The present work aims to evaluate the project of a wind farm allying fundamental principles of the wind energy projects methodology to computational programs. Therefore, after choosing the region which the project parameters allow a favorable prospectus, technical procedures for the micrositting detailing are made. The proposed methodology intends to estimate, with high level of refinement and based on fluid mechanics, the wind regime in the region where the wind farm will be installed. Using the commercial software CFX and a statistical analysis of wind measurements, complete information was obtained about the wind behavior in all over the chosen site allowing the flow characterization at this region. Once the results were obtained from the numerical simulations employing standard k-ε model, suggestions for a better arrangement of the wind turbines will be presented in order to obtain the best possible energetic utilization. It is also shown an economic analysis of the project, where are selected aerogenerators of different manufacturers with different nominal powers for the discussions of the necessary investments in order to compose the wind farm under the established criteria by the "Programa de Incentivo às Fontes Alternativas de Energia Elétrica (PROINFA)".*

Keywords*: Wind Turbines, Micrositting, Computational Fluid Dynamics, Economic Analysis*

1. INTRODUCTION

The renewable energy term has been playing a fundamental role in a scientific ambit, incorporating several technological advances and related research, as well as the fields linked to discussion of ambiental, politicial and economics aspects. The main factors which allow the utilization of this energy source are its clean and renewable derivation. In the ambiental field, great part of the consumed energy has been generated significant climatic instability in many places around the world. For this reason, interests in the global warming causes have taken many countries to introduce technologies directed to the use of the renewable energies.

In Brazil great part of the energy sources comes from the hydrical resources, becoming the energy matrix highly dependent and consequently susceptible to any changes of the hydraulic regime. In the sense to certify a major trustworthiness and security in the supply, it was chosen a new energetic model which proposed a diversification of the energy system. Thus, this action stimulated the creation of new programs that had been encouraged researches in the renewable energy field.

The Incentive Program for Electrical Energy Renewable Sources (Programa de Incentivo às Fontes Alternativas de Energia Elétrica - PROINFA) – established by the Law N° 10.438, of April 26th 2002, and co-ordinated by the Energy and Mines Ministery (Ministério de Minas e Energia - MME) which set the energy purchase of 3.300 MW in the National Interconnected System (Sistema Interligado Nacional – SIN), produced by eolics, biomass and micro hydro systems (1.100 MW for each source). There will be a contract for the energy created during twenty years by the Brazilian Electrical Centrals (Centrais Elétricas Brasileiras – Eletrobrás) for the installations which start to work until December 30th 2006. In a world-wide avaliation, the Kyoto Protocol aims to reduce the emissions of carbon dioxide and five other greenhouse gases. This treaty has stimulated some projects that invest in a clean energy production.

The renewable energy concept will be represented in this study by the wind energy. This source is characterized by the eletrical energy generation acquired from the kinetic energy brought by the wind. This one intercepts the blades converting it in mechanical energy (rotational).

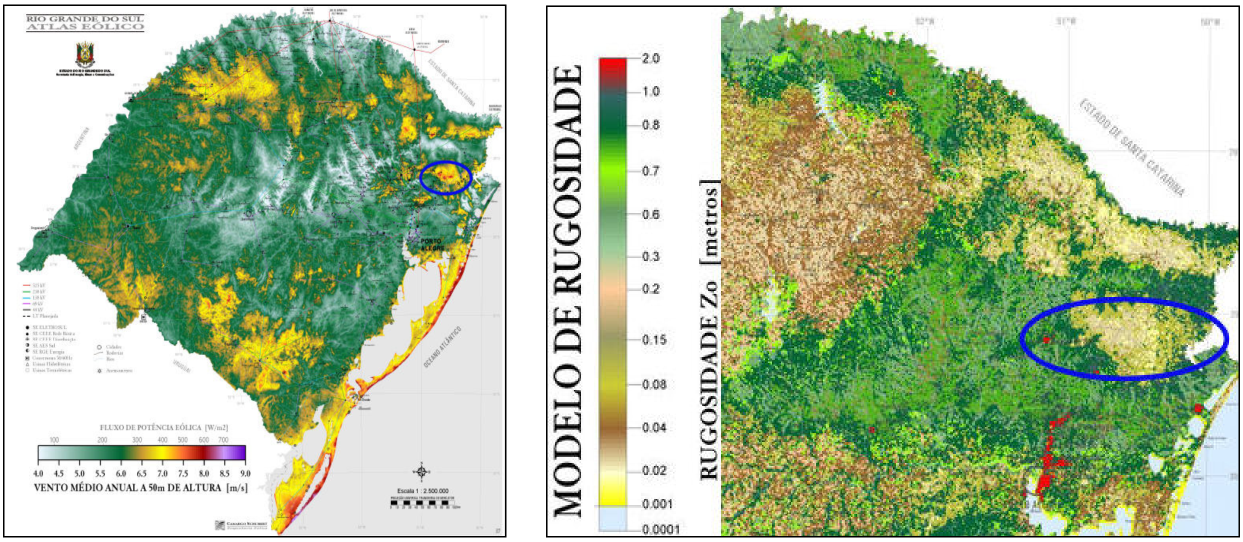
2. METHODOLOGY

The present work aims to evaluate a wind farm installation employing criteria commonly used in wind power projects. This methodology evaluates since the microsltting selection, where the aerogenerators will be arranged, until a discussion about the project costs in order to verify its viability. An increment in this study is the utilization of computational tools which show up a new alternative to solve engineering problems. This approach allows a high level of data refinement with a consequent wind motion characterization through the study domain resulting in a larger energetic utilization.

2.1. Mricrositting choice

Initially some regions in the state of Rio Grande do Sul were evaluated for a hypothetic wind turbines installation based on local parameters. Among these terms, the most important subject to consider is the wind annual average speed in the domain, since the wind power is proportional to its cube. Also geografic informations about roughness and topography will be essential in this work. These previous remarks were obtained from the Rio Grande do Sul Wind Atlas and other references about the chosen land. The micrositting chosen was Várzea do Cedro located at 985 meters of altitude and near to the cities of Tainhas and São Francisco de Paula, as can be seen in Figure (1a). The geographic coordinates are: 29º21´27´´S of latitude and 50º46´67´´W of longitude. This choice was mainly based on the annual averaged speed map analysis for 50 meters height, which is commonly used because it is the same of rotor installation. The observed velocity in this region was, approximately, 7.5 m/s. According to Hirata (2000), for the utilization of isolated wind generators and connected to the electrical grid, the wind speed must be higher than 7 m/s.

Other decisive factor for the micrositting choice was the observation of low values of terrain roughness. High levels of this parameter exert important influence in the wind regime, thus reducing the speed and consequently the output power. The terrain roughness value obtained was 0.02 meters, as can be observed in Figure (1b).



(a) (b)

Figure 1. Representation of (a) the annual average wind speed for 50 meters height and (b) the terrain roughness in the chosen micrositting (Source: Rio Grande do Sul Eolic Atlas, 2002)

2.2. Wind measurements

The speed and direction wind measurements are usually collected in the place of the wind turbine installation in a period long enough to guarantee meteorological variations. In this work, measurements data from the study domain had been obtained using the Rio Grande do Sul Wind Atlas. According Mattuella (2005), some places can be overestimated in 20% and according Molly (1998), an error of 10% in the wind speed could cause a wrong prognosis in the annual energy with until 20% of deviation. This affirmation shows the importance of the wind data collection "in loco" before the wind farm installation.

2.3. Wind data treatment

It is really important to perform a statistical data treatment to determine the wind potential. The wind regime presents important and non deterministic variations in relation to space and time being the speed its main characteristic. Therefore, this study was elaborated based on probabilistics analyses.

In order to manipulet the wind data collected from the Rio Grande do Sul Wind Atlas, it was utilized the free software ALWIN (www.ammonit.de). This program is, at first, fed with wind data for annual average speed. When extracted from Atlas, this information must be inserted togheter with the height measurement.

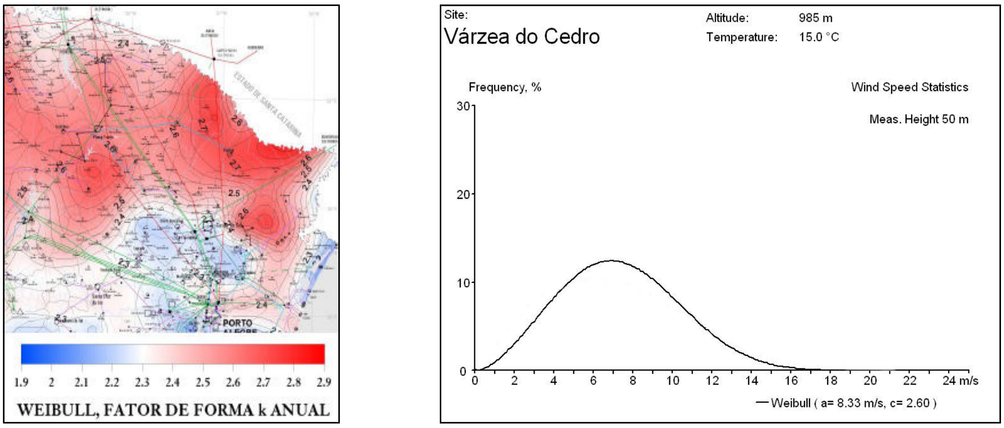
In order to obtain the frequency of the wind distribution, the Weibull distribution function brings the most similar relation to the wind behaviour. This function is showed in Equation (1).

$$F(V)=\frac{k}{c}\left(\frac{V}{c}\right)^{k-1}e^{-\left[\frac{V}{c}\right]^{k}} \qquad (1)$$

Where V is the wind speed, expressed in m/s, *k* is an adimensional shape factor and *c* a scale factor related with the local average speed, defined in speed units [m/s]. The *k* obtainment was taken from the annual shape factor curves map which was extracted from the Rio Grande do Sul Wind Atlas (Figure 2a). The scale parameter *c* appers from the Eq. (2) where $\overline{V}$ is the wind annual average speed.

$$\overline{V}=(\sim 0.90\pm 0.01)\,c \qquad (2)$$

Thus, knowing the annual average speed (7.5 m/s), measurement height (50 m), maximun speed in the micrositting (50 m/s), terrain roughness (0.02 m), shape factor k (2.6) and the scale factor c (8.33 m/s), it was achieved the wind speed distribution frequency to Várzea do Cedro city, showed in Figure (2b).



(a) (b)

Figure 2. Representation of the (a) shape factor *k* in the micrositting (Source: Rio Grande do Sul Eolic Atlas, 2002) and (b) the wind speed distribution frequency to Várzea do Cedro city

2.4. Wind direction

Another significant factor is the knowledge of the wind regime direction in the micrositting. According to the wind incidence, the right aerogenerators layout will be adjusted. Therefore, it was observed that most of the wind course in the site comes from northeast region.

2.5. Wind potential avaliation

In order to obtain the output energy in a wind farm, it is very important the parameters valuation to predict the operating point and to confront different projects.

The energy extracts from the air flow which intercepts the wind turbines rotating blades can be defined by its power, (in a specific speed V(i)) associated to an occurrence time T(i). For Eq. (3) calculation, it was used the period relative to one year of energy production, this way resulting in the estimation of Generated Annual Energy (GAE).

$$GAE=\sum_{i=1}^{i=n}P(i).T(i) \qquad (3)$$

Where:

GAE – Generated Annual Energy [kWh];
P(i) – aerogenerator power [kW];
T(i) – annual occurrence time [h].

The avaliable power in an eolic system, represented by the Eq. (4), varies linearly with the density "ρ" and with the swept area "A"of the rotor, increasing with the cube of the wind speed "V (i)".

$$P_a(i) = \frac{1}{2}\rho.A.V(i)^3 \tag{4}$$

However, the kinetic energy carried by the wind could not be transformed integrally into mechanical work (rotational). The aerogenerator rotor reduces the wind speed *v1,* without disturbances and frontal to the rotor, into a subsequent speed *v2*. This downstream wind speed makes evident the impossibility to integrally gain the available wind power.

The highest power which a rotor will be able to extract from the air flow is defined as maximum of Betz, or Betz coefficient and represents 16/27 (≅ 59.3 %) of the available power. In fact, this value does not exceed 40% of the available total power and commonly is known as power coefficient C_p, changing for each equipament. This coefficient will determine the blades aerodynamic efficiency and can be represented by the relationship between the effective power available and the power in terms of kinetic energy. Thus, the output power of a wind turbine will be represented by the Equation (5).

$$P(i) = \frac{1}{2}C_p.\eta.\rho.A.V(i)^3 \tag{5}$$

Where:

$P(i)$ - wind turbine power [W];
C_p - power coefficient [adimensional];
η - wind turbine efficiency [adimensional];
ρ - density [kg/m3];
A - swept area of the rotor [m^2];
$V(i)$ - wind speed [m/s].

The Parameter CF, called Capacity Factor, represents the project quality in terms of wind potential. This term reflects how much time the equipament works on its full power. An inadequate wind turbines arrangement or electric transmission losses can reduce this factor intervening negatively in output energy (Mattuella, 2005). Acording Custódio (2002), this adimensional factor can be determined by the Equation (6).

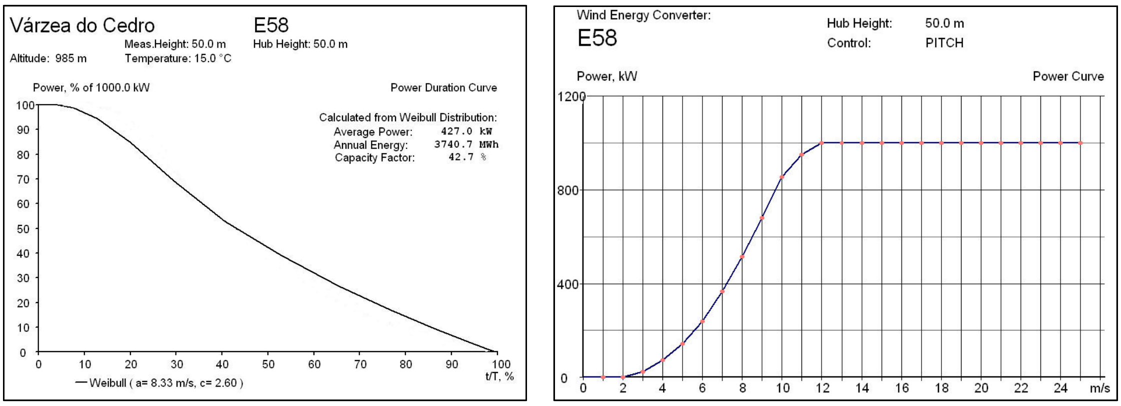
$$CF = \frac{GAE}{8760 * P(i)} \tag{6}$$

For the generated annual energy, average power and capacity factor analyses in the study site, it was chosen some aerogenerator models which were inserted in probabilistic analyses using its respective power curves. These curves estimate the aerogenerator extracted power in different wind speeds. The criterion used for the equipament selection was a rated power higher than 600 kW in order to avoid an eventually sub-utilization in the micrositting. Another preponderant factor in the selection process was the possibility to choose a national aerogenerator which would prevent costs with transports, involving long distances, and importation incubencies. In Table (1), results are listed for the parameters previously quoted. Beyond the national models – represented by the aerogenerators of the Enercon Company - equipments from other countries were selected in intention to evaluate the quality of the wind turbines and justify the equipment choice that offer the best relationship between cost and benefit.

Table 1. Comparative table beetween aerogenerators to Várzea do Cedro windiness.

Wind Turbines	Control	Hub Height (m)	Rotor Diameter (m)	Rated Power (kW)	Capacity Factor (%)	Average Power (kW)	GAE (MWh)
Enercon E-40	PITCH	50	40	600	32,4	194,6	1704,8
Nordex N43/600	STALL	50	43	600	28,3	175,2	1534,8
Enercon E-48	PITCH	50	48	800	42,1	341,1	2987,8
Nordex N50/800	STALL	50	50	800	28,5	228,4	2000,6
Enercon E-58	PITCH	50	58	1000	42,7	427	3740,7
Neg Micon 1000	STALL	50	60	1000	30,3	319,2	2795,8
Enercon E-82	PITCH	50	82	2000	36,4	745,6	6531,6
REpower MM82	PITCH	50	82	2000	33,4	667,4	5846,2

Evaluating the listed aerogeradores, it was verified that the wind turbines of Enercon Company present the capacity factor greater than other equipments with the same rated power. This result represents a higher exploitation of the wind potential in the study locality. In real terms, analyzing the aerogerador Enercon E-58 in a period of one year (equivalent to 8760 hours), this equipament would present full functionality in approximately 3740 hours, the greatest among the selected equipments. Together with this beneficial aerodynamic efficiency offered by the national equipment, it was verifyed exemption expenditures with freights and importation decreasing this way, the final cost of the product. In Figure (4), can be seen results for (a) the Enercon E-58 turbine and (b) the power curve inserted in the program.



(a) (b)

Figure 4. Results from ALWIN program: (a) average power, generated annual energy and capacity factor and (b) Enercon E-58 power curve

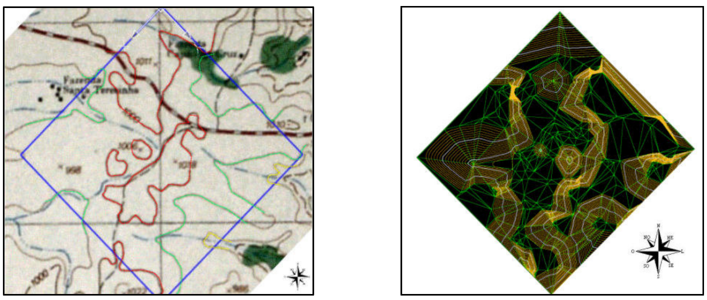
2.6. Numerical simulation

In order to characterize the wind behavior during the study domain, it was used numerical simulation as work tool. This methodology aims to evaluate the best aerogenerators layout based on the knowledge of the wind speed fields. The computational numerical analysis is based on the Finite Volumes Method and on the Reynolds Average Navier Stokes Equations (RANS). The average equations of mass and momentum are shown in the Eqs. (7) and (8), respectively.

$$\frac{\partial U_i}{\partial x_i}=0 \tag{7}$$

$$U_j \frac{\partial U_i}{\partial x_J} = -\frac{1}{\rho}\frac{\partial P}{\partial x_i} + \frac{\partial}{\partial x_j}\left(\nu\left(\frac{\partial U_i}{\partial x_j}+\frac{\partial U_j}{\partial x_i}\right) - \left(\overline{u_i u_j}\right)\right) \tag{8}$$

Where x_i is a spatial component (i = 1, 2 and 3), U_i is the speed in x_i direction, P is the pressure term and $\overline{u_i u_j}$ designed Reynolds Stresses. The solution was obteined with a convergence criterion (RMS) of 1.0E-5. The chosen domain covers an area of 4 km^2 in the immediacy of the Várzea do Cedro city. For the attainment of the micrositting topographical characteristics, it was acquired the geographical map relative to the micrositting contour lines at the 1ª Survey Division General Augusto Tasso Fragoso. This survey allowed a local mapping, as can be observed in the Figure (5a). Therefore, a three-dimensional domain was generated using the free software TopoCal (www.topocal.com), Figure (5b). The geometry was obtained based on linear interpolation between the contour lines



(a) (b)

Figure 5. Representantion of the (a) countour lines and (b) the topographical construction

The interest effects are located in the region called Atmospheric Boundary Layer (ABL). In this region, the velocity profile is highly disturbed by the terrain roughness extending its effects until the free atmosphere layers, where the wind is called geostrofic. Thus, in order to obtain all the possible alterations in the wind behaviour, the domain height utilized was 1 km, approximately equivalent to the height where de wind is “undisturbed”.

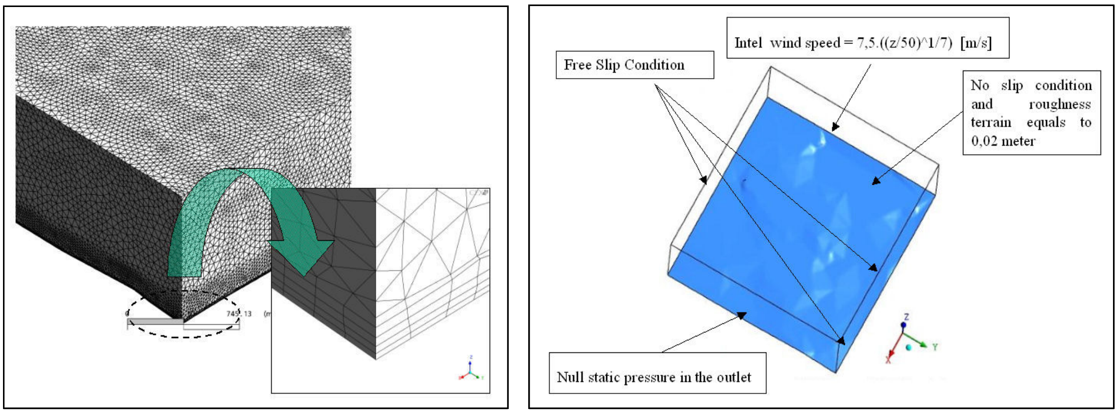
In the grid confection was used the mesh generator ICEM CFD 10. The created volumes are tetrahedral and have, as important characteristic, a fast configuration of complex geometries**.** In the study site, it was opted a less size tetrahedral configuration near the ground (region of intricated formation) followed of prismatic elements which allow a better physical modeling near the wall, Figure (6a). The mesh utilized contains, approximately, 1.300.000 elements.

The boundary conditions were inserted in software CFX 10.0 - program based on the Computational Fluid Dynamics (CFD) – using the wind regime direction in the micrositting. In the region that presents the highest annual frequency of wind incidence, the northeast direction, it was attributed the inlet condition. The boundary condition in the entrance was applied in direction "x" using the Power Law profile. According to the Rio Grande do Sul Wind Atlas, this law is conducted by the exponential profile, Equation (9), that determines the wind variation in relation to the height. In the other cartesian directions, "y" and "z", the wind speed was neglected.

$$V(z) = V(z_r).\left(\frac{z}{z_r}\right)^{\alpha} \tag{9}$$

Where $V(z_r)$ and z_r correspond to the reference speed and the reference height, respectively. Thus, we can get the speed V(z) in the desired height z considering a parameter α associated to the terrain roughness (traditionally, it is used α = 1/7). In this case, it was used the speed $V(z_r)$ equal to 7,5 m/s and 50 meters for the measurement height, both values extracted from Rio Grande do Sul Wind Atlas.

For the discharge region, it was inputted the static pressure null as outlet condition (atmospheric pressure). In the micrositting terrain was insert the wall condition and the no slip condition. In these criteria, the velocity close to the wall is equal to zero. The program also allows the roughness lenght arrangement. For the present study, it was utilized 0.02 meter. In the other domain regions, the free slip condition was attributed since prevents the wall interference in the fluid dynamics. In Fig. (6b), the boundary conditions of the problem are visualized.



(a) (b)

Figure 6. Representation of the (a) created mesh and (b) the boundary conditions in the study domain

In the present work, the turbulence model k-ε was adopted. This model derives from the RANS standard turbulence model. Although to supply inefficient results in some situations, this model can be used to obtain a first turbulence field. According to Lun et al (2003), the k-ε model presents damages in overestimating the term relative to the turbulent kinetic energy *k* around impingements regions. The k-ε modelling can be observed in Wilcox (2002).

2.7. Simulation results

For the results evaluation, it was segmented the problem in three heights which would be able the aerogenerators installation. The number of chosen equipments (four aerogenerators) will be argued in the economic analysis. Thus, in the hatched area of the 0, 20 and 40 meters levels, Figure (7), we can observe the regions with predominant terrain heights in the micrositting.

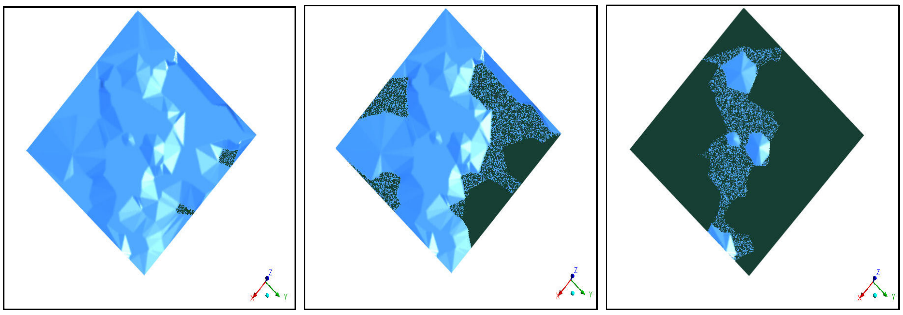


Figure 7. Terrain levels of 0, 20 e 40 meters, respectivelly

After defined the study regions, the wind speed fields at 50 meters upper than the study levels were examined. This distance between the terrain level and the wind speed fields was chosen based on the rotor cube height installation, in which the efficiency analyses of wind turbines are usually made.

Initially, for each terrain level, the speed will be analyzed since 3 m/s (cut in wind speed) up to 13 m/s (rated speed). After that, in intention to investigate the study site, the interval between the velocities was restricted for a better visualization.

As can be observed in Figure (8), in the first level, the lowest in the domain, the installation space for the wind turbines is small. Another negative point in this plane is the low velocity values. In this situation, the priority in the choice moment will be given to the other levels.

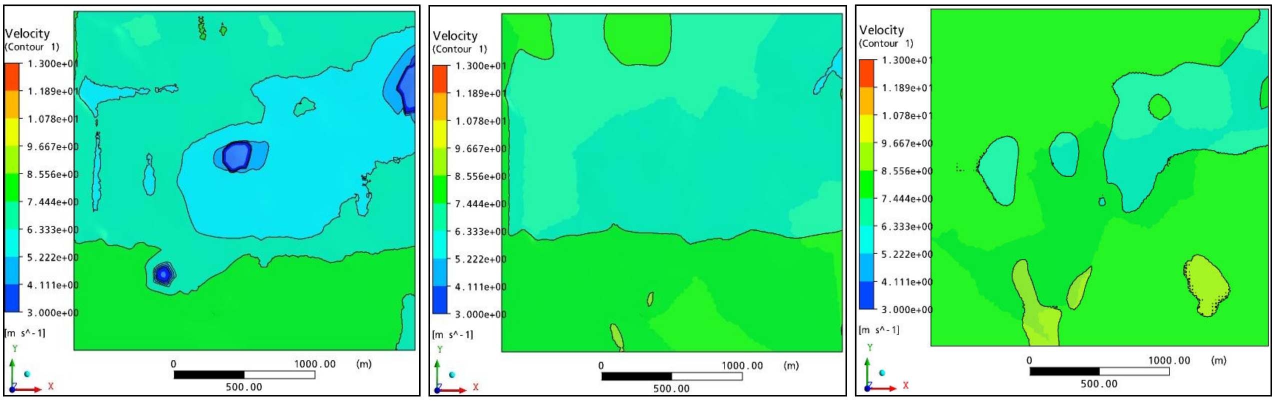
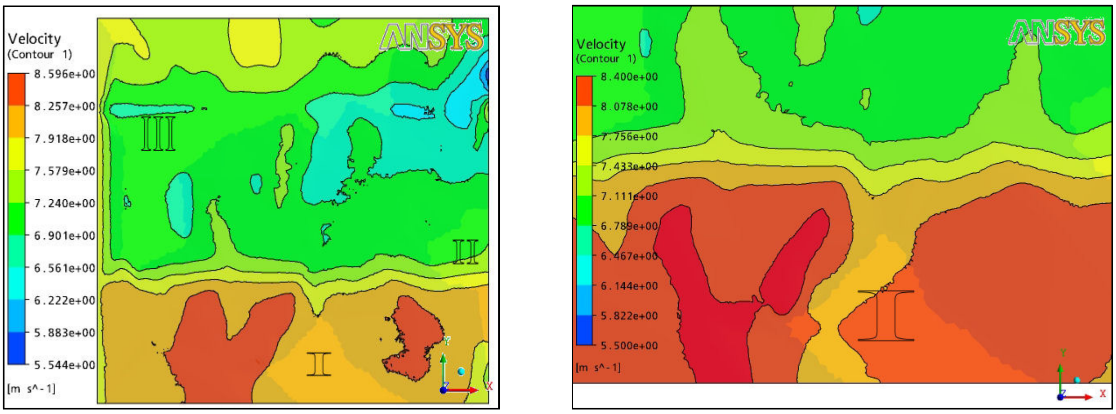


Figure 8. Wind speed fields to 0, 20 e 40 meters levels, respectivelly

The 20 meters level, according to the Figure (9a), shows the biggest extension for the wind turbines configuration. The region called I, responsible for the highest wind speeds in this level, presents fields with approximated velocity around 8.5 m/s. In this situation, the aerogenarator would work close to the rated power.

The aerogenerators layout in a wind farm is limited by the minimum distance necessary between the equipments. This restriction occurs mainly because the vortexes wake presence at the downstream equipment. This effect has as characteristic, the reduction of the wind potential available. An erroneous dimensioning of this parameter can reduce the wind farm efficiency as well as the useful equipment life (Custódio, 2002). Minimum distances of five times the rotor diameter (5D) in a direction and ten times in the other one (10D) must be respected.

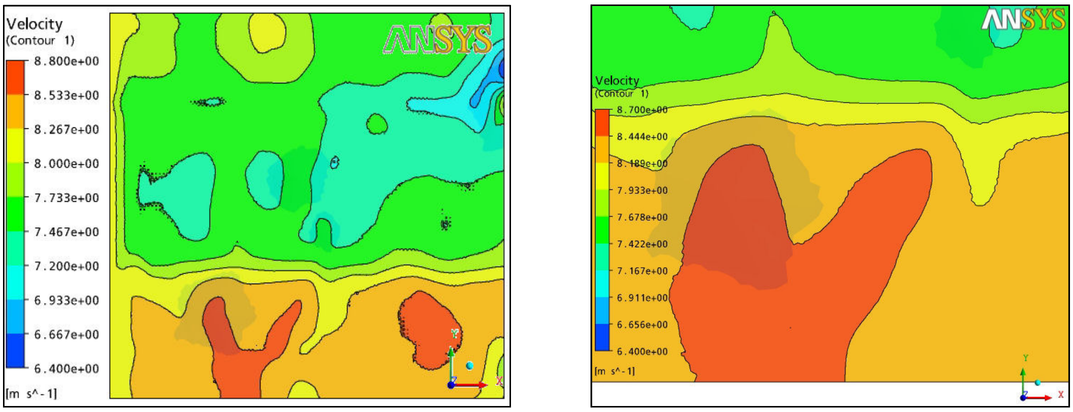
Thus, analysing the site I, as can be observed in Figure (9b), it was checked that this land could house two of the four wind turbines evaluated in the project. These aerogenerators would be installed in a rotor cube height of 50 meters in the region with speeds around 8.4 m/s.



(a) (b)

Figure 9. Wind speed fields to 20 meters level: (a) in all domain and (b) in site I

In the Figure (10a) is evaluated the speed fields for the level relative to the 40 meters height. In this region are distinguished sites where the wind is accelarated due the mounts (or hills) presence. According to Custódio (2002), the wind that circulates in the obstacle's top presents in this way high speeds due its heights which are less affected by the terrain roughness in upstream areas. Another advantage of these topographical elements is the deriving of its inclination that, due the air lines concentration on the top, acts in fluid acceleration way.



(a) (b)

Figure 10. Wind speed fields to 40 meters level: (a) in all domain and (b) next to the hill

Thus, as can be seen in the Figure (10b), it was observed an increase of the wind speed in the mount downstream and thus, generating a region with speeds around 8.8 m/s. The area that covers the region after-obstacle allows the installation of the two remains wind turbines.

3. ECONOMIC ANALYSIS

In the fiancial analysis, it was used a costs spreadsheet developed by Mattuella (2005). Its creation is related to the Proinfa's laws and visualizes payments and expenditures of diverse origins in the period of twenty years. For the wind farm project availability, the program demands a cash flow with an Internal Rate of Return (IRR) of 15%. This index is commonly used in financial calculations and equalizes the present value of one or more payments with the present cost of one or more receptions (Sobrinho, 2000).

In order to find the IRR factor, it was used the hypothesis of four machines acquisition fixed in the purchase price per kilowatt. Thus, according to Molly (2005), adding the equipament price to the installation costs, the price per installed kilowatt can be R$ 2900/kW (minimum price), R$ 4400/kW (maximum price) and R$ 3400/kW (average price). However, the presented values can be overestimated since these costs not compute the cambial variations due to the dollar indexation, indicator which the costs per kilowatt are divulged. Beyond the cost of the wind farm per kilowatt, another important factor to be analyzed in the project viability calculationt is the reference energy. This term represents the energy produced annually in a wind farm and is indexed, among other parameters, to the aerogenerator capacity factor. The last one is obtained, firstly, by the probabilistic data inserted in ALWIN program.

As can be observed in Table (1), it is verified that the equipament Enercon E-58, with rated power of 1000 kW, presents the highest capacity factor. In other words, the aerogenerator E-58 presents the biggest exploitation of the wind potential in the micrositting. Thus, for the cash flow calculation, the utilization of four national aerogenerators E-58 is defined using the installation average price of R$ 3400/kW and a rotor hub height of 50 meters, delivering in this way, a capacity factor of 42.7%. The spreadsheet used for the IRR calculation can be observed in Figure (11).

		Valor Unitário	Unidade	1 -2 ano	3 - 11ano	11 - 20ano
Receita Bruta.............				3.102.200,26	3.102.200,26	3.102.200,26
	Energia de Referência-ER		MWh	13.787,56		
	Preço de Compra da Energia	225	R$/MWh			
	Potência do Parque	4000	2400kW			
	Invest equip e planta	3.400,00	R$/kW			
	Financiamento Projeto-BNDES		70%			
(-) Perdas..........			1%	31.022,00	31.022,00	31.022,00
(-) Impostos sobre a Receita....						
	PIS......		1,65%	51.186,30	51.186,30	51.186,30
	COFINS.		7%	217.154,02	217.154,02	217.154,02
	CPMF......		0,38%	11.788,36		
(-) Custos / Despesas Operacionais........						
	Operação e Manutenção 1 - 2 anos	50	R$ /kW	200.000,00		
	Operação e Manutenção 3 - 10 anos	100	R$/kW		400.000,00	
	Operação e Manutenção 11 - 20 anos	120	R$/kW			480.000,00
	Custo de arrendamento		1,0%	310,22	310,22	310,22
	Custo do Seguro Operacional		0,5%	68.000,00	68.000,00	68.000,00
	Custo na Transmissão da Energia	2,5	R$/kW/mês	120.000,00	120.000,00	120.000,00
	Custo de recultivação	3,5	R$/kW/ano	14.000,00	14.000,00	14.000,00
	Depreciação		5,0%	68.000,00	68.000,00	
(-) Financiamento BNDES						
	Juros............		9%	856.800,00	856.800,00	856.800,00
	Amortização do financiamento					
(-)	Imposto de Renda..................					
(-)	Contribuição Social.............					
Fluxo de Caixa..........						
			-13600000	1.463.939,36	1.275.727,72	1.263.727,72
TIR	7%					

Figure 11. Spreadsheet used in the financial analysis

As can be seen in Figure (11), the achievement got an IRR value of 7%, in other words, too much below of 15% established by the PROINFA. An alternative in order to make possible the project is to raise the tower and consequently the height where the cube of the rotor will be installed. This raise will allow that the rotor swept area would be intercepted by high wind speeds increasing its capacity factor. The new IRR values for 60, 70, 80 and 90 meters of rotor hub height are presented in Table (2).

Table 2. Intern rate of return (IRR) to 60, 70, 80 and 90 meters of rotor hub height based on the probabilistic analyses

Rotor Hub Height (m)	Capacity Factor (%)	IRR (%)
60	44,4	8
70	45,8	9
80	47,0	10
90	48,1	11

With the raise of the tower, it can be seen that the capacity factor and the IRR factor had gotten a significant addition, however still not reaching the necessary criteria for the achievement availability.

Another alternative to obtain a favorable financial result would be to use the wind speed fields from the numerical simulation. This alternative has the important advent to possibilte the attainment of the major wind extraction, in other words, from the knowledge of the possible places to wind turbine installation in a micrositting, we can obtain the highests wind speeds and consequently a better output energy.

For this calculation, in the probabilistic analyses, it was inserted two numerical results for different measurements height of wind speeds in order to create a velocity profile, and in this way, to refine the output data for the generated annual energy, average power and capacity factor analyses. This process was made utilizing the wind speed of 8.4 m/s, for the two equipaments situated in the region I of the 20 meters level, and 8.8 m/s wind speed for those in the 40 meters level. The table (3) shows the capacity factor and the intern rate of return (IRR) values based on numerical simulation results.

Table 3. Capacity factor and the intern rate of return (IRR) based on numerical simulation results

Rotor Hub Height (m)	Capacity Factor (%)	IRR (%)
50	48,1	11
60	50,8	12
70	53	15

Based on the acquired results, it is observed that the achievement would become viable with a tower height of 70 meters. Limitations derivated from the numerical simulations associated to the absence of project costs relative to the increase of the tower would come to modify the IRR values and, consequently, making possible or impeding that the project reached the stipulated criteria by PROINFA program. However, the computational simulations allowed a better approach to the demanded values, stimulating in this way, wind energy projects and justifying investments by the narrow criteria of the PROINFA.

4. CONCLUSION

The observed results during the work evidence the importance of the wind flow characterization in the micrositting which the wind farm will be installed. The geographic accidents show a decisive influence in the wind behavior, revealing in this way, regions where the wind speeds diverge of those collected in specific points of the land. However, the methodology based on the Computational Fluid Dynamics still offers some deficiencies in the evaluation of parameters related to the pressure variation and temperature, beyond not computing the rotation effect of the Earth. The employment of CFD programs as a work tool allows a good approach of the results related to the wind behavior and can verify regions with the biggest output energy.

Analyzing the project viability, it can be concluded that the criteria established by the PROINFA still are too much narrow, impeding that many energy wind projects are glimpsed. Analyzing the results gotten in the present work, the computational simulations had represented an important tool in order to obtain an intern rate of return next to the requested by the program. Thus, despite the numerical results not representing the physical reality integrally, they can be considered as indicative to revel regions with highest wind speeds.

In the moment where the numerical simulations could represent all the important aspects of the wind regime, it will be able to define the wind farm layout from the evaluation of the wind speed fields as well as, supply a data refinement destined to the IRR calculation to eolic projects, allowing their availability conform PROINFA requirements.

An alternative to future works is the utilization of different turbulence models, for example, the Large Eddy Simulation (LES) which could refine the results and improve the energy output.

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