COMPUTATIONAL STATISTICAL ANALYSIS OF THE WIND AND SOLAR POTENTIAL FOR ELECTRICITY GENERATION

Ricardo Ezequiel Silva[1], Regiane Slongo Fagundes, Yurri Ferruzzi

ABSTRACT
This paper describes an application developed through scientific project initiation. The purpose is to provide information to assess the energy potential of renewable energy such as wind and solar radiation. The information submitted by the program is obtained from weather stations that collect data on temperature, wind speed and intensity of solar radiation. The data are processed using statistical techniques that allow summarizing a large volume of measurements. The result is information presented in tables, graphs and reports, which measure the energy output of these alternative sources in electricity generation.

KEY WORDS: Renewable. Energy. Electricity.

1 INTRODUCTION

The application of statistical techniques to meteorological data has the advantage of compressing the huge amount of data, measured, for example, in one season, in a simple table or an equation that can summarize all the information in order to make predictions about the data [1].

According to Morettin [2], the statistic is a collection of methods to design experiments, obtain data and organize it, summarize it, analyze it, interpret it and draw conclusions. The methods and statistical techniques are used in meteorology basically to analyze the time spent in order to estimate on the probable future behavior of some variable.

The assessment of wind potential of a region requires systematic work of collecting and analyzing data on speed and wind regime. Generally, an accurate assessment requires specific surveys, but data collected at airports, weather stations and other similar applications can provide a first estimate of gross potential or theoretical wind energy [3].

Solar radiation can be directly converted into electrical energy, through the effects of radiation (heat and light) on certain materials, particularly semiconductors. Among these, we highlight the effects thermoelectric and photovoltaic [5].

[1] Department of Telecommunication Engineering, Assis Gurgacz Faculty - FAG Cascavel-Pr, Brazil

The photovoltaic effect arises from the excitation of electrons in some materials in the presence of sunlight (or other appropriate forms of energy). Among the materials most suitable for the conversion of sunlight into electrical energy, which are usually called solar cells or photovoltaic, highlight the silicon [5].

The conversion efficiency of solar cells is measured by the proportion of solar radiation incident on the surface of cell that is converted into electrical energy. Currently, the best cells have an efficiency rate of 25% [5].

However, the need of methodologies and technologies in development assistance and use of renewable sources, has led to a more detailed analysis of climate information. However, analysis of collected data, often becomes difficult. The use of a computer resource suitable for collection, storage, analysis and presentation of such data is essential for this purpose.

2 MATERIALS AND METHODS

The computer program for meteorological analysis was developed for use in operating system Windows® XP, through object-oriented language Delphi® 7. The application is divided into independent modules, each module corresponding to a particular climatic factor.

2.1 Data collection

Data were collected from the anemometer model Vantage Pro2 ™, manufacturer of Davis Instruments, installed 2.36 m above the ground weather station at the Assis Gurgacz College (latitude 24 º 56 '49 ''N, longitude 53 º 30' 38'' W and altitude of 710 m).

The information is transmitted by radio signals with a frequency of 916.5 MHz and power less than 1mW, captured by a system of data acquisition from the same manufacturer, at a distance of 150 m from the station, storaging a record average each 5 minutes.

2.2 Application of Computing Statistical Techniques

In order to summarize a large volume of data collected at intervals of 5 minutes, algorithms have been developed that apply hourly, daily, monthly and yearly according to the type of analysis one wants to accomplish. For this techniques were used filters provided by the SQL programming language.

The group in certain periods allowed the use of other statistical resources as standard deviation, Pearson variation coefficient, maximum and minimum frequency distribution. Such information is presented through graphs, queries and reports in the application itself using a computer with a 2 GHz processor and 3 GB memory RAM.

3 RESULTS AND DISCUSSION

As a result of the project, we obtained an application with a graphical interface and easy handling. The composition of modules allows processing the data independently for each climatic factor, minimizing the use of computing resources.

The statistical data to monitor the variation and dispersion of wind data, radiation and temperature are located at the top of the application through a table. The charts to assess intuitively the summarization of information are located at the bottom. Thus, while processing data for a particular period, is generated automatically daily charts, monthly and yearly in the form of industry, row or column.

The pie charts show the relative frequency and direction of winds in the selected year. The classification of wind speeds is achieved by the Beaufort scale, which classifies the winds in twelve designations according to the speed. The analysis of the average per farm designation (type of wind) for the year 2006 in the city of Cascavel-Pr can be visualized by FIGURE 1.

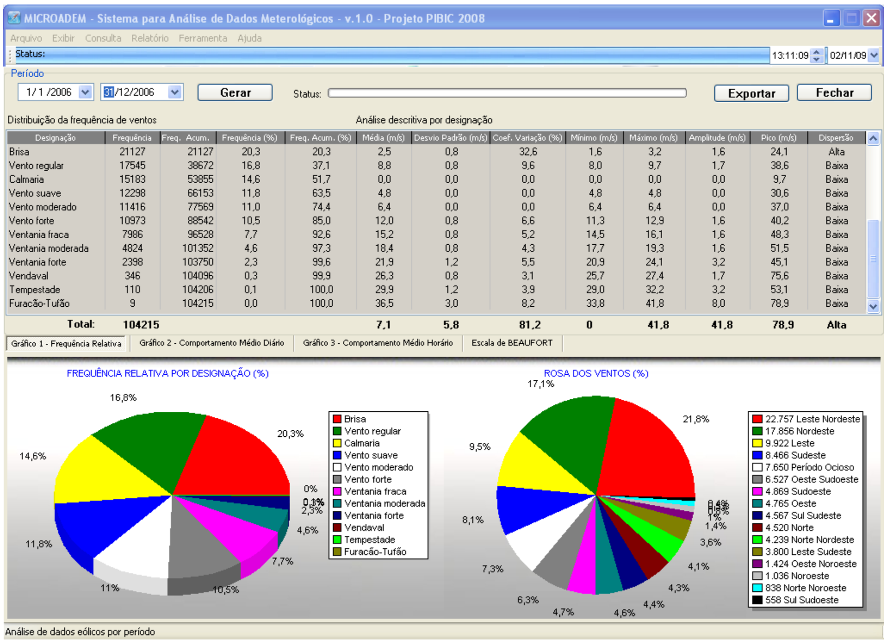

Figure 1 - Analysis of wind power by type of wind in 2006.

It is observed by the frequency of occurrences or measurements for each type of wind, totaling between 2006 an amount of 104.215 measurements. The relative frequency in FIGURE 2 obtained by the ratio between the number of occurrences in different scales and the total sample, with the percentage of occurrence of each type of wind out of the total.

The application allows for each assignment calculating the average wind speeds, and the standard deviation of the value as the sample data are dispersed from the average. The coefficient of variation that relates the mean and standard deviation, shows a percentage of the dispersion. Thus it is possible to identify the types of winds more conducive to exploitation of wind power, and to assess their stability or oscillation on a mean central value.

Distribuição da frequência de ventos					Análise descritiva por designação		
Designação	Frequência	Freq. Acum.	Frequência (%)	Freq. Acum. (%)	Média (m/s)	Desvio Padrão (m/s)	Coef. Variação (%)
Brisa	21127	21127	20,3	20,3	2,5	0,8	32,6
Vento regular	17545	38672	16,8	37,1	8,8	0,8	9,6
Calmaria	15183	53855	14,6	51,7	0,0	0,0	0,0
Vento suave	12298	66153	11,8	63,5	4,8	0,0	0,0
Vento moderado	11416	77569	11,0	74,4	6,4	0,0	0,0
Vento forte	10973	88542	10,5	85,0	12,0	0,8	6,6
Ventania fraca	7986	96528	7,7	92,6	15,2	0,8	5,2
Ventania moderada	4824	101352	4,6	97,3	18,4	0,8	4,3
Ventania forte	2398	103750	2,3	99,6	21,9	1,2	5,5
Vendaval	346	104096	0,3	99,9	26,3	0,8	3,1
Tempestade	110	104206	0,1	100,0	29,9	1,2	3,9
Furacão-Tufão	9	104215	0,0	100,0	36,5	3,0	8,2
Total:	**104215**				**7,1**	**5,8**	**81,2**

Figure 2 - For the table of frequency distribution and descriptive analysis.

FIGURE 3 shows through a pie chart the percentage of occurrence of each type of wind in 2006.

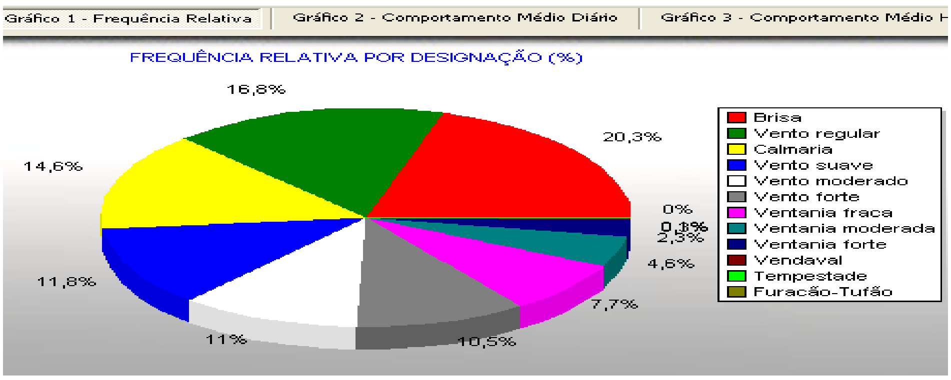

Figure 3 - Chart frequency distribution by type of wind in 2006.

FIGURE 4 shows the monthly wind power in 2006. Thus, one can evaluate and compare the monthly electric potential provided by a wind turbine every month of the year.

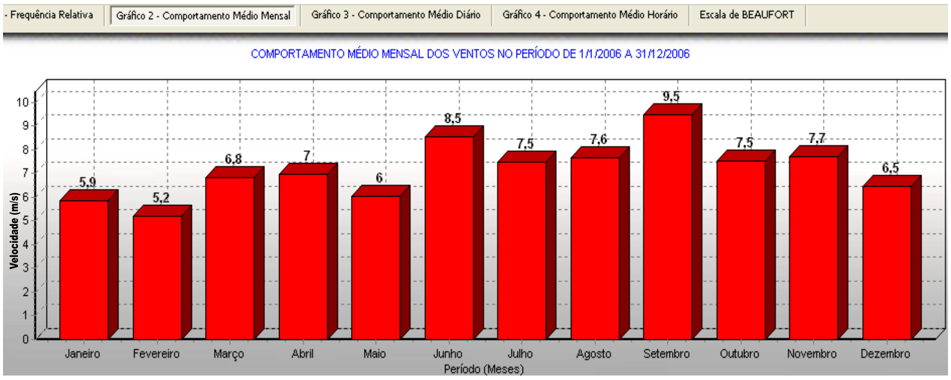

Figure 4 - Monthly review of wind power for the year 2006.

FIGURE 5 evaluate the variations of wind power in one month.

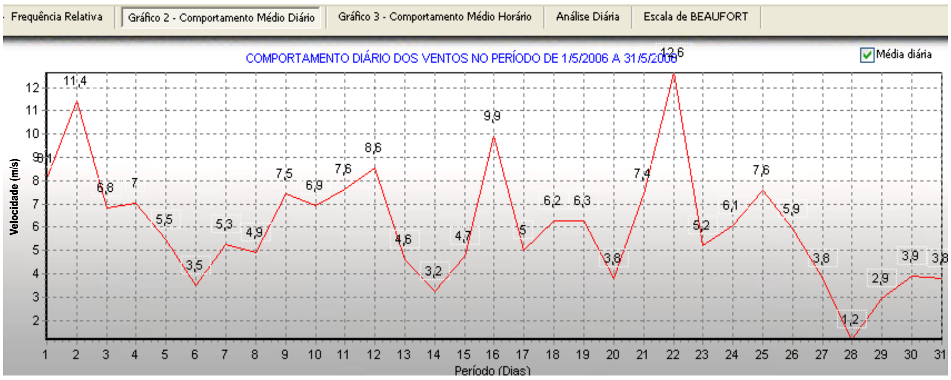

Figure 5 - Daily analysis of wind power in May 2006.

The evaluation of the potential energy of solar radiation is obtained through the same statistical techniques applied to data farms. The application processes and calculates statistical features as standard deviation, coefficient of variation of Pearson, maximum and minimum frequency distribution.

However, solar radiation can directly obtain the energy density in W/m2. FIGURE 6 shows the monthly intensity of solar radiation maximum, average and minimum for the year 2006, respectively.

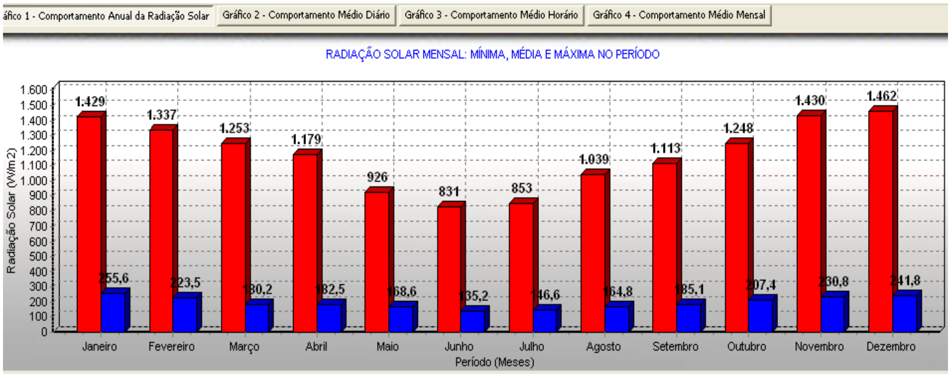

Figure 6 - Monthly review of solar radiation in 2006.

FIGURE 7 shows the intensity of daily solar radiation average for the year 2006. Data collected at intervals of five minutes are grouped by day, to be processed later through the middle. The average daily behavior is indicated by a line graph that shows the fluctuations of solar radiation in the selected period.

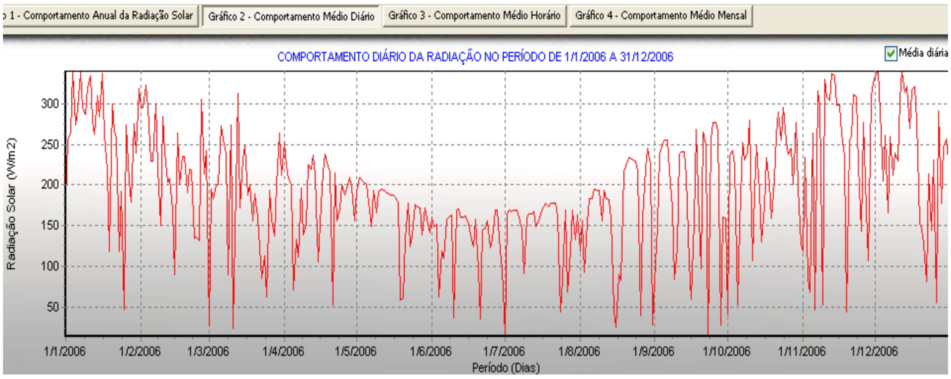

Figure 7 - Daily analysis of solar radiation in 2006.

FIGURE 8 shows the hourly radiation average for the year 2006. The application allows to estimate in a period of one year, the hours of the day when there will be more production of energy through a photovoltaic panel.

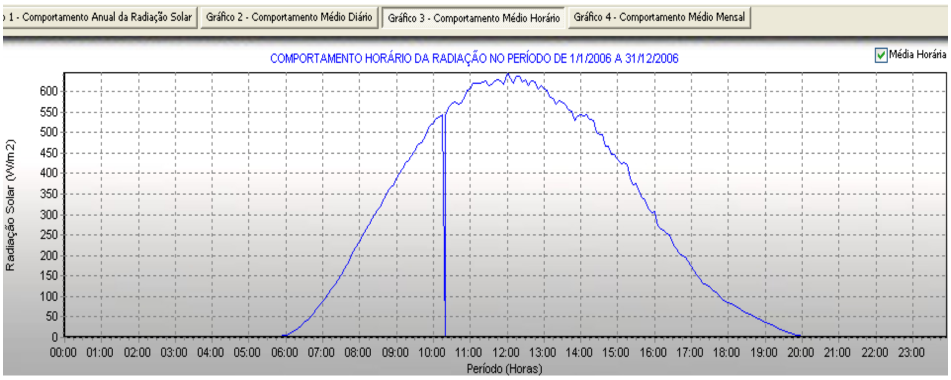

Figure 8 - Analysis of hourly solar radiation in 2006.

In case you want to use solar energy to generate electricity using equipment photothermal through heating liquids or gases, the predominant factor to be evaluated is the temperature. Thus, the application provides statistical information of temperature in degrees Celsius collected in a certain period.

FIGURE 9 shows the monthly average temperature for the year 2006. It can be observed from the graph the minimum, average and maximum temperature in the study period.

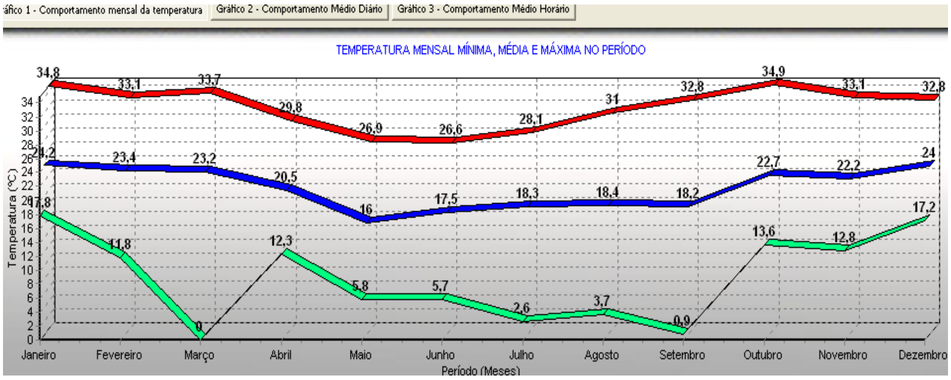

Figure 9 - Analysis of monthly mean temperature, maximum and minimum.

FIGURE 10 shows the average daily temperature for the year 2006. From the plot one can evaluate the fluctuation of temperature during the year and the potential energy equipment photothermal that convert heat into electricity. Thus, one can estimate the periods in which there will be more or less production of electricity.

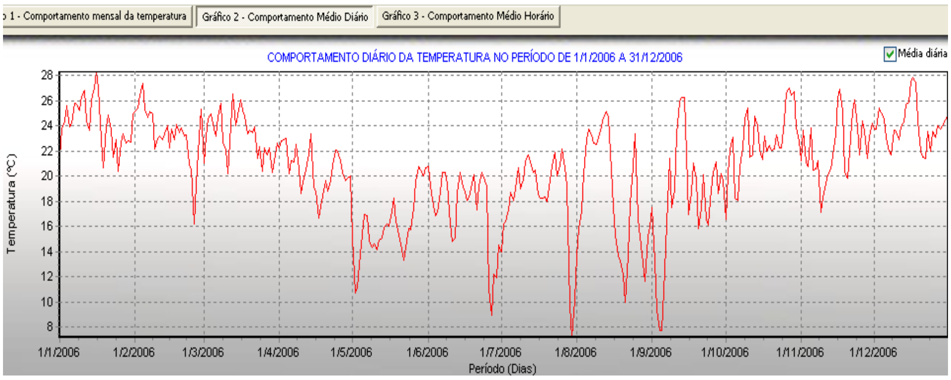

Figure 10 - Analysis of daily temperature in 2006.

FIGURE 11 shows the hourly average temperature in 2006. This feature is useful when you want to evaluate the production of energy during the day, mainly through thermoelectric devices can generate electricity at night.

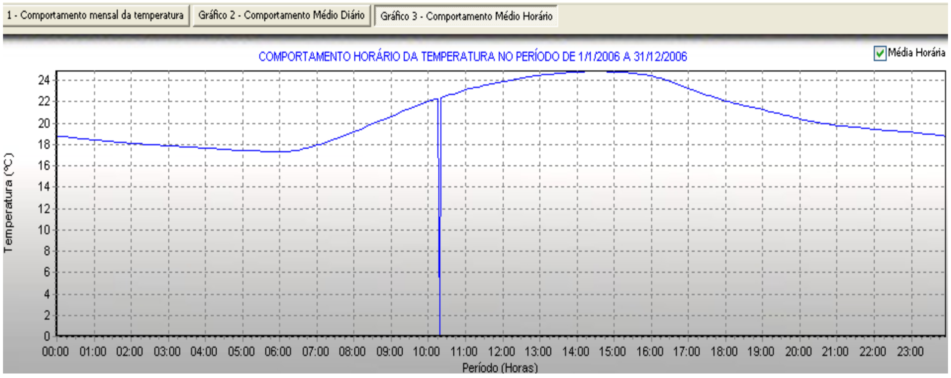

Figure 11 - Analysis of the hourly temperature in 2006.

4 CONCLUSIONS

The application developed for the analysis of potential wind and solar energy provides information to calculate the electric power density, using descriptive statistics (mean, standard deviation, Pearson variation coefficient, the maximum and minimum) and frequency distribution. Such informations called central tendency measures indicate how the collected data are concentrated around a value located in the center or middle of the data set. This allowed characterize the behavior of sources in a given period by estimating the stability or oscillation energy behavior.

The classification of wind speed through the Beaufort scale allowed group the data in wind types and obtain the wind behavior through the classification designation. The calculation of power density can so be achieved through the speed information. The predominant direction summarized by pie charts is of great importance in the leasing of wind devices in order to position them to better take advantage of prevailing winds.

Regarding the solar radiation potential, one can directly estimate the power density in W/m2, what allows the direct power calculation in solar panels on the incident area. Temperature information can provide a more detailed analysis of energy efficiency, especially in estimating the solar thermal panel's power.

The application of computational statistical techniques allow accurately estimate the energy behavior of a renewable source. Data collection in the exact location or near where one want to install the converter equipment, allows a more precise analysis of electric power that is generated by wind or solar radiation. In this context, the developed application is shown as a useful and agile, especially when one want to analyze the potential energy resulting from a large number of measurements.

The processing is useful for assessing changes in climate behavior in recent years, and thus, to deduce estimates for the future. It is intended for future studies to further enhance the computational techniques of this tool, including functions that permit direct electrical power in watts estimated period. Thus, in addition to provide information for effective analysis of the alternative energy potential, resources can be added to use it in other applications influenced by climatic factors, such as agriculture, civil engineering and telecommunications.

REFERENCES

[1] ASSIS, F. N, Applications of Statistics to Climatology, Pelotas: Universitária, UFPEL, 1996.

[2] MORETTIN, L.G. Basic Statistics-Probability. 4. ed. São Paulo: McGraw-Hill, 1992.

[3] ANEEL. (2009) National Agency of Electric Energy homepage on [Online]. Available: http://www.aneel.gov.br/aplicacoes/atlas/pdf/06-Energia_Eolica.Pdf

[4] ANEEL. (2009) National Agency of Electric Energy homepage on [Online]. Available: http://www.aneel.gov.br/aplicacoes/atlas/pdf/03-Energia_Solar (3). Pdf

[5] GREEN, M. A. Progress in photovoltaics: research and applications. Solar cell efficiency tables: version 16. Progress in photovoltaics: research and applications, vol. 8, pp. 377-384, 2000.

[6] GRUBB, M. J; MEYER, N. I. *Wind energy: resources, systems and regional strategies.* In: JOHANSSON, T. B. et. al. Renewable energy: sources for fuels and electricity. Washington, D.C.: Island Press, 1993.

ACKNOWLEDGMENT

Assis Gurgacz College for supporting and transfering the data used in this work.