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COMPARATIVE STUDY OF RENEWABLE ENERGIES WITH SOLAR AND WIND SOURCES

Fritsch, A.R. [1], Dias, M.M. [1], Piber, P.R.V.[1], Borba, M.G.[2], Martins, R.M.[1], Aquim, P.M[1], Moura, A.B. D.[1]

[1] Instituto de Ciências Exatas e Tecnológicas (ICET) - Professional Masters in Materials Technology and Industrial Processes – Universidade FEEVALE - Novo Hamburgo/RS-Brazil-P.O. Box 3004, ZIP CODE 93510-250, Novo Hamburgo, Rio Grande do Sul, Brazil.

[2] Laboratório de Transformação Mecânica (LdTM) - Universidade Federal do Rio Grande do Sul, Centro de Tecnologia, P.O. Box 15021 – Campus do Vale, ZIP CODE 91501-970, Porto Alegre, RS, Brasil.

ABSTRACT

The objective of this work was to evaluate two renewable energy sources alternative with the purpose of comparing the energy generation of both, using geographic information from maps and climatic data collected from meteorological centers for energy generation with wind and solar renewable sources, analyzing which energy source is most efficient.

Keywords: Alternative energy, Renewable sources, Solar and wind energy

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1. INTRODUTION

1.1. SOLAR ENERGY

The energy that reaches the Earth in the form of solar radiation is called insolation. Approximately 19% of this radiation received by the atmosphere is absorbed by clouds and other gases, 31% of the radiation received is reflected by the planet and atmosphere. This fraction of light is called albedo. The remaining 50% of incident solar energy reaches the earth's surface and is almost completely absorbed, and only 3% is reflected. The amount of insolation reaching the earth's atmosphere is approximately 1360 W/m² or 430 Btu/ft/h, and this number is called solar constant. The insolation received at a particular location on the earth's surface can range from 0 to 1,050 W/m² or 330 Btu/ft/h, and this number depends on latitude, daylight hours, season and amount of clouds [1,2].

The most commonly used technology in the solar cell is the active layers composed of polycrystalline or amorphous thin films deposited on an electrically passive or active substrate. However, there is another technology, called monocrystalline, which has also several applications in the market, besides being the first generation produced for commercial use [3]. Silicon is an abundant semiconductor in nature, and even when it absorbs an incident photon, it generates an electron pair (negative) and a hole (positive) inside it, also known as a p-n junction. When this junction is connected to an electrical circuit by its terminals, it generates an electric current.

To make a solar cell, silicon oxide (SiO_2) is initially refined and purified. Next, it is then fused and solidified in such way that the arrangement of the silicon atoms is a perfect interlacing. One way to do this is to introduce a crystalline silicon seed into a pure silicon melted mass, then slowly drawing out the mass. This method is called the Czochralski process [1]. After the extraction of this mass, a cylindrical ingot is formed after slicing into wafers of approximately 0.5 mm thick that are doped to form the p-n junction.

The potential barrier at the p-n junction produces a voltage of approximately 0.5 V in the silicon monocrystal. The current generated by a solar cell is directly proportional to the amount of incident light and the area of the cell. Under sunlight of 1000 W/m², a current of 30 mA/cm² of surface cell will be generated from standard monocrystal cells. Then a cell of 10 cm in diameter, for instance, produces about 1 W under a insolation of 1,000 W/m² [1]. Figure 1 shows the types of silicon cells: monocrystalline (a), polycrystalline (b) and amorphous (c) [3].

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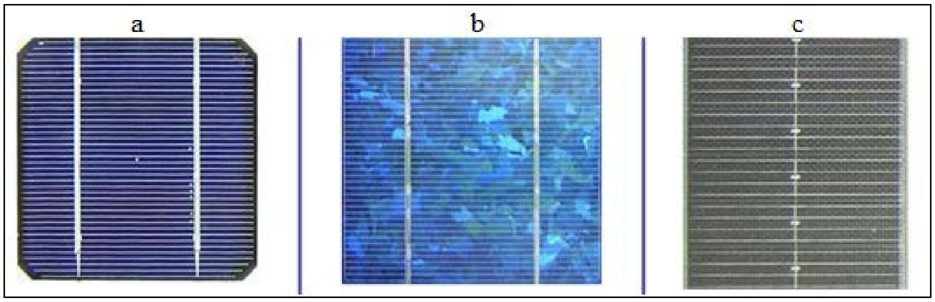

Figure 1 - Silicon cells (a) Monocrystalline (b) Polycrystalline (c) Amorphous [3].

1.2. WIND ENERGY

The use of wind energy occurs in regions where wind power reaches considerable values. This is necessary to know if there will be economic feasibility of energy generation, depending on the wind power given in W/m^2 [2]. Regions that have elevated buildings and higher buildings only achieve reasonable wind speeds, over 5 m/s, after several meters of altitude. Where there are not so many obstacles and only houses and small buildings exist, the height decreases and at a lower altitude, it becomes possible to verify satisfactory winds [4]. However, at sea level, the wind speed is satisfactory in coastal regions, different from previous situations, that is, without great heights, it is possible to obtain high wind speeds.

A basic wind system consists of a rotor, where the blades are coupled, which rotate with the wind pressure. This rotor is connected to a shaft which, in turn, is connected to an electric generator, by means of a system of gears [1]. The blades can be constructed of aluminum, fiberglass, steel, wood, among others materials and the rotor shaft can be tubular or latticed to improve aerodynamics. The support of a wind system is made by tower and stais, and the tower supports the rotor by means of rolling bearing. The multiplier box is required to couple the rotor to the generator, since the rotor can assume speeds ranging from 20 to 150 rpm and the generator from 1200 to 1800 rpm [2]. They also constitute a wind system for more sophisticated models, the control mechanism to avoid excessive speeds of the rotor and, also to brake when the wind speed is low, besides a transformer, that can be coupled to the electric network.

In ideal conditions, the maximum theoretical value of the energy contained in the air flow that can be extracted by a wind turbine is approximately 59.3%. This percentage is called the power coefficient (Cp). The power coefficient reaches no more than 50% under real conditions, because it includes all aerodynamic losses of the wind turbine, such as blade loss (drag), displacement and air buoyancy [4]. The equation that defines the power generated by a wind turbine is demonstrated when the wind speed is above 3.5 m/s, which is the starting velocity (Vp) and the nominal velocity whose value varies between 12 and 15 m/s [5]. Figure 2 shows some types of vertical axis wind turbines: model H-Darrieus (a), Darrieus (b) and Savonius (c).

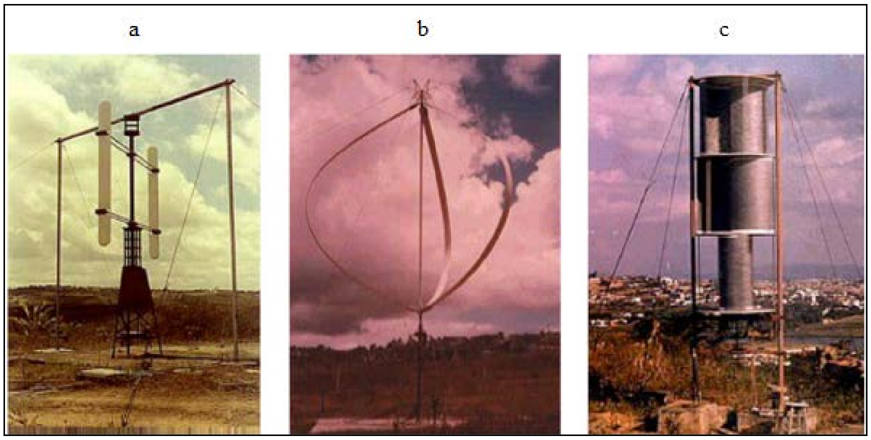

Figure 2 – Types of wind turbines with vertical rotors: model (a) H-Darrieus (b) Darrieus (c) Savonius [4].

2. MATERIALS AND METHODS

2.1. Proposed System

The production of energy depends directly on the incidence of wind and solar irradiation for the two generation options, i.e. if there is no wind above the required, according to the equipment manufacturer from 2.5 m/s to 3.5 m/s , there is no generation of wind energy, as well as for the generation of solar energy, there is need for solar irradiation (Solar panel receiving energy from the sun). To verify the required amount of wind or sun that meets a local demand, the energy sources can be compared to identify the generation behavior and which source will be the most appropriate. In order to compare with installed equivalent power, will be considered the power generated by 6 modules HAERON HR260P that add up to 1592 W (Figure 3-a) in relation to the RAZEC266 wind turbine that can generate up to 1500 W (Figure 3-b), i.e., to analyze the two power sources it is ideal to relate the nominal powers that are marketed considering losses as they vary from manufacturer to manufacturer and can result in a design error if disregarded. The solar and wind sources cited are installed on the roof of the electronic engineering building at Feevale University, and the control room where the data was collected is located on the top floor of this building, just below the installations.

In this work, the solar panel was been tested in practice, so the actual power is determined by the installation conditions and by the panel form factor. The slope of the installation and impurities that may be accumulated on the panels, reduce the efficiency by up to 20%, and generate only 75% of the power described in the manual, while the incidence of 1000 Wh/m² and controlled temperature of 25 °C only happen in laboratory. In real conditions the panel has its high temperature above 45 °C. In this condition, the solar radiation is variable, there is current limiting when connected in series, and there is voltage limitation for the lower efficiency cell when connected in parallel, causing the final efficiency to be at most 70% of nominal. The wind generator presents its limitations as to the linearity of the wind, because turbulent winds, wind gusts or periods of lull are not used for power generation. These conditions may compromise the structure of the wind turbine, which has a brake system. When weak winds turn the propellers, and they do not exceed the 3 m/s range, they do not generate enough energy for their use [5].

(a) (b)

Figure 3 – Installed Devices - (a) HAERON HR260P modules - (b) RAZEC266 wind turbine.

The comparison between the two sources through a graphical analysis, with trend curve for the two cases of electric power generation, is necessary to verify the efficiency of the wind system in relation to the solar system in the same place.

2.1. WIND SPEED

The values identified in the database of the meteorological station of the city of Campo Bom / Brasil [6] can be separated in a way that identifies the various wind speeds that precede the generation of energy and that meet a minimum value so that there is a profitable generation for use and storage in batteries. Table 1 shows the values separated by occurrence over the period of one year.

Table 1 - Occurrence of winds during one year [6].

Annual wind speed	
Wind (m/s)	Incidence %
<0.5	19.90
0.5 to 1.5	47.63
1.5 to 2.5	22.78
2.5 to 3.5	7.58
3.5 to 4.0	0.93
4.0 to 5.0	0.86
5.0 to 6.0	0.24
>6.0 m/s	0.05

Table 1 shows that most of the time during the year the average wind speed is between 0.5 m/s and 1.5 m/s, which represents approximately 48% of the total. Then, the most frequent wind speed is between 1.5 m/s and 2.5 m/s with approximately 23% of the total. Therefore, considering the time when the wind is less than 0.5 m/s or null, approximately 20%, more than 90% of the time with a lull period is added, below 2.5 m/s, when there is no usable power generation. From 2.5 m/s a small power generation is seen, in the order of a few Watts, and above 4 m/s energy generation is considerable, however, it represents less than 2% of the total time analyzed. Figure 4 shows the proportion of occurrence of wind.

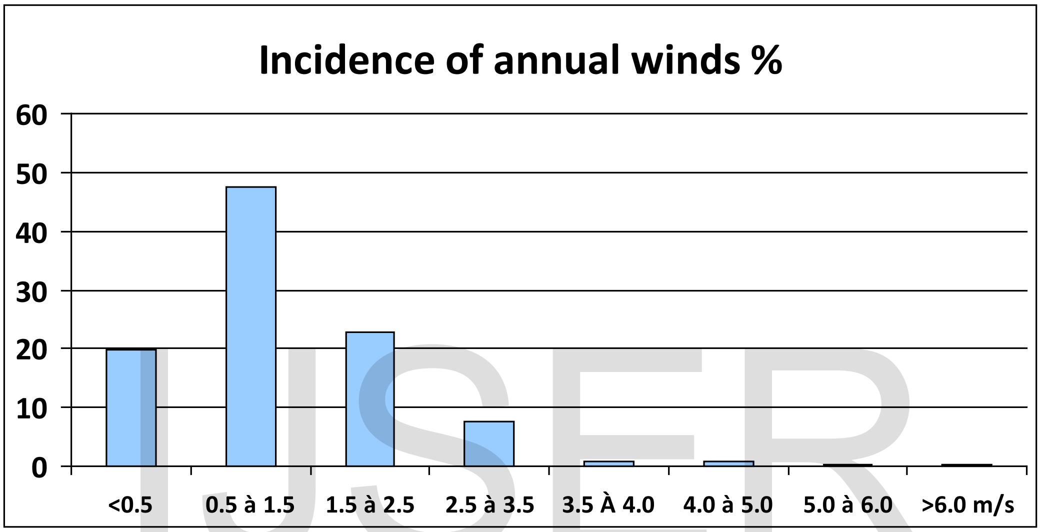

Figure 4 - Occurrence of winds in one year [6].

2.2. SOLAR IRRADIATION

In the same way that the wind-related climatic data were organized, i.e., by the seasons, a similar analysis can be made for solar radiation data. Table 2 shows the values obtained during one year for solar radiation.

Table 2 - Annual sun incidence% [6].

Annual solar radiation	
Radiation Wh/m^2	Incidence %
0.0	46.54
0 to 300	25.55
300 to 500	9.47
500 to 700	8.41
700 to 900	5.77
900 to 1000	1.97
>1000 Wh/m²	2.23

The use of the energy provided by the sunlight is different from the use of the energy provided by the wind. In terms of energy conversion, the solar panel can generate power in order of a few Watts from the beginning of solar incidence, which in wind energy happens from a certain wind speed. It is quoted that, by natural reasons, almost 50% of the time, there is no sun. During the night time at the measurement site, between 0 and 300 Wh/m² can be harnessed from the energy of the solar panels, which represents 25.5% of the total time. Larger powers can be obtained when the radiation is above 500 Wh/m², e.g., up to 1000 Wh/m² when the panel reaches its maximum power. From Figure 5, the period without energy generation can be visualized during nights and obstacles that can prevent solar irradiation on the panels.

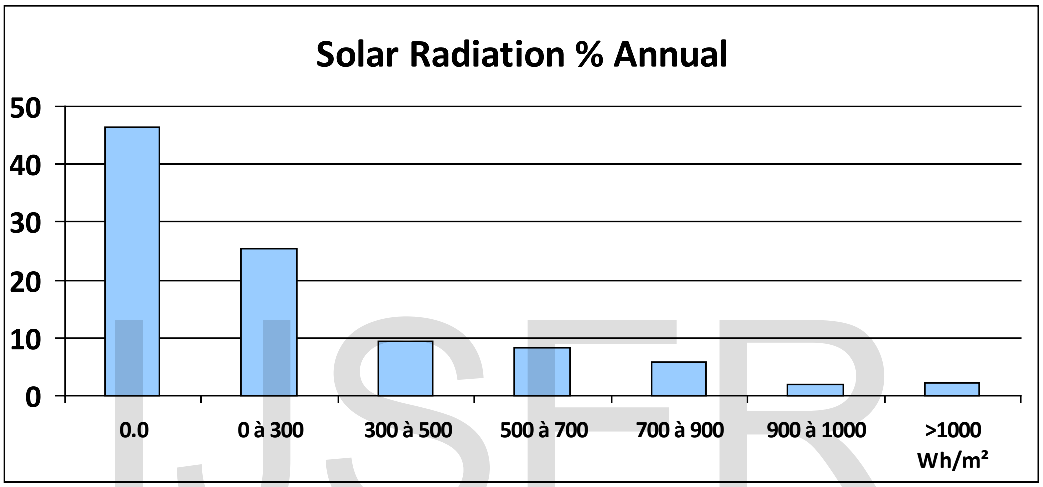

Figure 5 - Incidence of annual sun% [6].

3. RESULTS AND DISCUSSIONS

Figure 6 shows the behavior of six HAERON HR260 solar modules in series connection. Its final power is related to the installation conditions, and the yield from these conditions, with solar radiation values of 0 to 900 Wh/m² and power generated from 0 to 500 Wh.

Figure 6 - Power generated by 6 HAERON HR260 modules.

Figure 7 shows the power generated from 0 to 500 Wh by wind turbine, with winds from 0 m/s to 8 m/s.

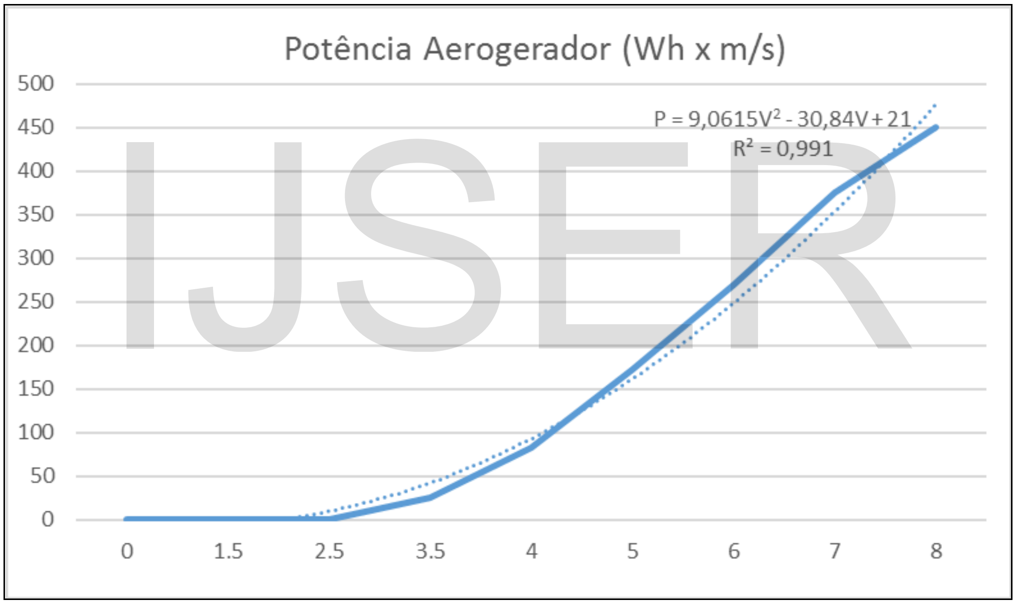

Figure 7 - Power generated by 1 wind turbine RAZEC266.

For an analysis of the technical feasibility of power generation through the potential of any locality, considering the equipment installed in the same way that the Feevale University project presents, it is possible to equate the power curves of both equipments, using the generated graphs for each one and obtaining a relation between the wind speed and the solar irradiation for the same power required. The two equations shown in the graphs can be equated according to Equation 1.

$$9.0615V^2 - 30.84V + 21 = 0.0006E^2 + 0.1332E \quad (1)$$

where **V** is the wind speed in m/s, and **E** is the solar irradiance in Wh/m².

Using the daily data of the meteorological stations of the selected city it is possible to obtain the mean values of wind speed and solar irradiation of each season of the year, as well as annual and compare the local values by the energy equivalence equation, e.g., for Novo Hamburgo / Brazil. Table 3 shows the values verified by Campo Bom / Brazil meteorological station.

Table 3 - Comparative table of Novo Hamburgo / Brazil.

NOVO HAMBURGO - RS			
Station	Medium radiation Wh/m^2	Wind Eq. Cal. (m/s)	Real Wind (m/s)
Summer	263,00	4,705	1,36
Spring	272,00	4,779	1,52
Autumn	143,00	3,71	1,23
Winter	153,00	3,79	1,09
Year	212,00	4,28	1,32

From the average irradiance, the equivalent wind speed is compared to generate the same power if the solar energy is used, then the value of the real wind speed is compared. With the equation of power equivalence, it is possible to generate a graph that facilitates the analysis according to the locality and its wind or solar potential. Figure 8 shows the relationship of the two power curves to the same power demand.

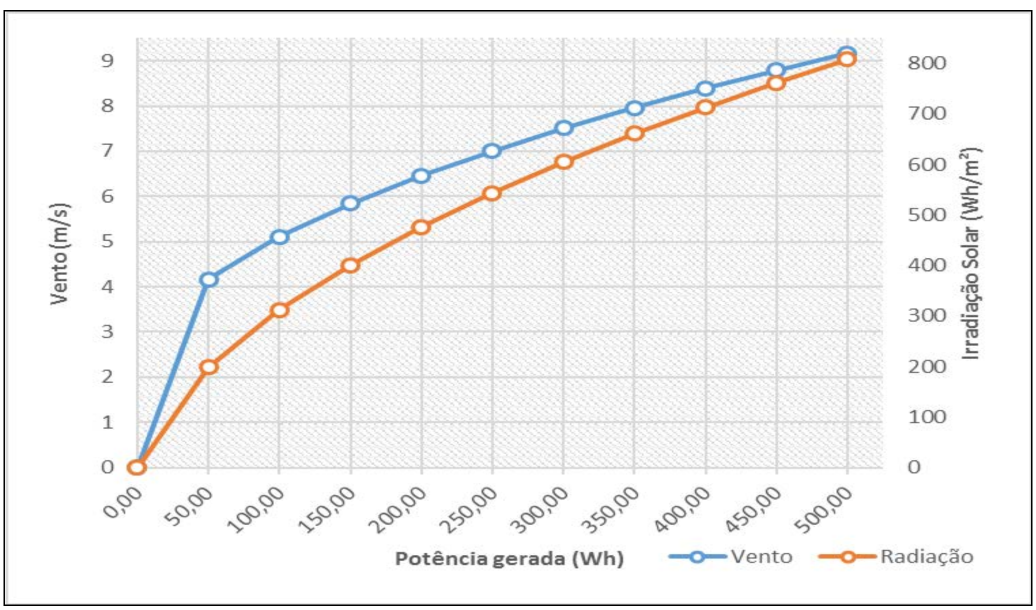

Figure 8 - Relationship between wind and solar radiation for electric power generation.

This graph enables a quick and practical analysis of which energy source (or both) has better conditions to generate energy for the locality in question. From this graphical analysis, an economic feasibility study and application of a hybrid system can be conducted using other sources together, such as Biogas to meet a *microgrid* system [7].

4. CONCLUSIONS

The analysis of these data becomes important for future installations and projects that wish to use the best relation of local power generation through parameters provided by public agencies and by specific softwares, as presented in this work. From the analysis of the data collected in practice, such as information on irradiation and wind speed at the site, using equipment installed in the laboratory of the Institution and help of information from the equipment manufacturers, it is possible to obtain the behavior of the energy generation for wind turbines and solar panels through graphs that present their respective power curves.

From the power curve of the equipment it is possible to check the technical feasibility for the place under analysis, even before starting an economic feasibility study, increasing the chances of choosing the best energy source for the application, such as for the city of Novo Hamburgo where wind energy is not viable due to the average wind speed but for solar generation there is sufficient incidence for the capture of electric energy [8,9].

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