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TECHNO-ECONOMIC ANALYSIS OF A HYBRID PV-WIND ON-GRID ENERGY SYSTEM IN A RURAL AREA IN THE STATE OF RIO GRANDE DO NORTE USING HOMER GRID SOFTWARE

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Abstract. The aim of this work is size and analyze the techno-economic viability of an on-grid PV-wind hybrid system located in a rural settlement. HOMER Grid software was used, which allows the system modeling and economic optimization based on local solar irradiation and wind speed, costs of components and the system load curve. The locality chosen was the rural settlement Santo Antônio, located in the district of Touros, in the interior of the state of Rio Grande do Norte. After the simulations, comparisons were made among three systems: wind-solar hybrid, solar and wind. The results showed that, among the three systems, the hybrid stands out as the lowest configuration cost between the systems, totaling an NPC (Net Present Cost) of R$ 245,482 over a 25 years project lifetime. In addition, the COE (Levelized Cost of Energy) of the hybrid system was the lower among the systems and also in relation to energy tariff, with a cost of 0.226 R$/kWh. Thus, it can be concluded that the on-grid system is the viable solution to the proposed systems.
Keywords: hybrid system, pv-wind, homer.

1. INTRODUCTION

The growing consumption of energy implies a greater use of fossil fuels and, consequently, an increase in environmental problems. It is expected that this energy consumption will increase by 50% in the year 2030 compared to that of 2011, and that the dependence on fossil fuels will be 82%. (Acuña et al., 2017).

In 2014, the power generation sector in Brazil was responsible for the emission of 479.1 million tons equivalent carbon dioxide (mt CO2e), being characterized as one of the main sources of greenhouse gases in the national economy according to data from the Observatório do Clima (2015).

Therefore, to reduce environmental impacts and the use of fossil sources, renewable energies are a solution. Examples of these are solar thermal energy, biomass, geothermal, etc. Among these are wind energy and solar photovoltaic energy, which are more attractive by economic criteria. (Buonomano et al., 2018). Although there is an increasing development of these technologies, there is a great disadvantage in their use and this arises because of their indeterminate behavior, as there is time dependence. Favorable climatic weather is required for the use of solar panels, considering that sun is needed; and wind turbines, because wind is needed (Acuña et al., 2017).

According to (Lima, 2016), the state of Rio Grande do Norte has characteristics favorable to the use of energy wind-solar hybrid, having regions with large amounts of wind and solar radiation. Therefore, the use of a hybrid system with both technologies, solar and wind, becomes attractive since it allows to achieve greater stability in electrical production when compared to only solar or only wind systems.

The technical and economic analysis of a hybrid system is essential for the efficient use of renewable energies (Sinha and Chandel, 2014). To deal with the complexity of the system, it is necessary to use optimization tools, such as software that analyzes its economic viability. Among the software, the HOMER (Hybrid Optmization Model for Electrical Renewable) developed by the National Renewable Energy Laboratory (NREL) is widely used.

In this context, this work aims to present the technical and economic feasibility of an on-grid wind-solar hybrid system located in the interior of the state of Rio Grande do Norte. The location chosen for the study was the Santo Antônio settlement, located in the municipality of Touros. The HOMER Grid software was used to simulate the best possible system configurations. Electric consumption data were also obtained from houses close to the region to simulate the load curves used in the software, in addition to market research with national manufacturers to obtain real prices for the equipment used in the system. After all the simulations, the feasibility between the wind-solar hybrid system and the isolated wind and solar system was discussed.

2. MATERIALS AND METHODS

To achieve the objective proposed in this study, the Homer Grid software is used, which allows simulating distributed generation systems based on data from the equipment, climatic data, economic data, and the load curve of the houses. With the data, the software performs iterative processes to provide the best configuration proposed for the system.

The location chosen for the analysis was the region of the municipality of Touros, in the state of Rio Grande do Norte, Brazil. The region, a rural settlement, is characterized by being a space for both housing and work, housing dozens of families of rural workers.

2.1 System model

The main model studied was a hybrid system connected to grid composed of photovoltaic modules, wind turbine and inverter DC/AC. The system works with two circuits, the DC circuit connects the photovoltaic module to the inverter and the AC circuit is responsible for connecting the inverter, wind turbine and the grid to the houses.
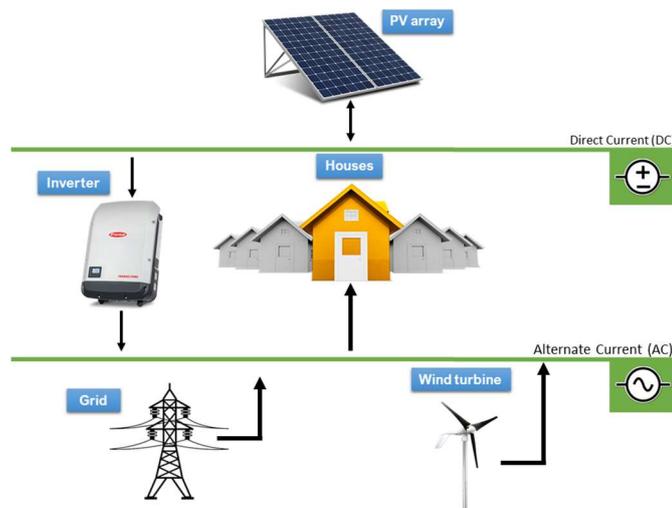

Figure 1. Proposed model for the hybrid system.

2.2 Climatic data

The climatic parameters used for the software simulation are the monthly averages of wind speed, monthly average of solar irradiation and monthly average of ambient temperature. The region was the municipality of Touros, located in the semi-arid region of the state. To obtain the climatic data the NASA Surface meteorology and Solar Energy database was used. The database provides the average monthly data made over a period of 10 years for wind speed and 20 years for horizontal irradiance and temperature.
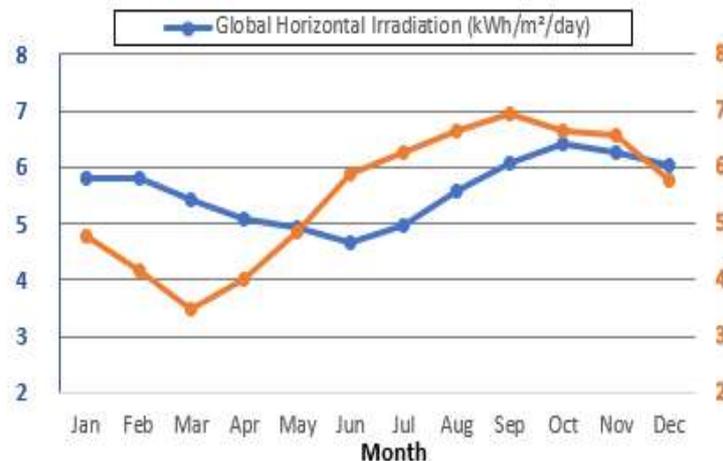

Figure 2. Solar irradiation and wind speed measured monthly in the Santo Antônio settlement, in the municipality of Touros.
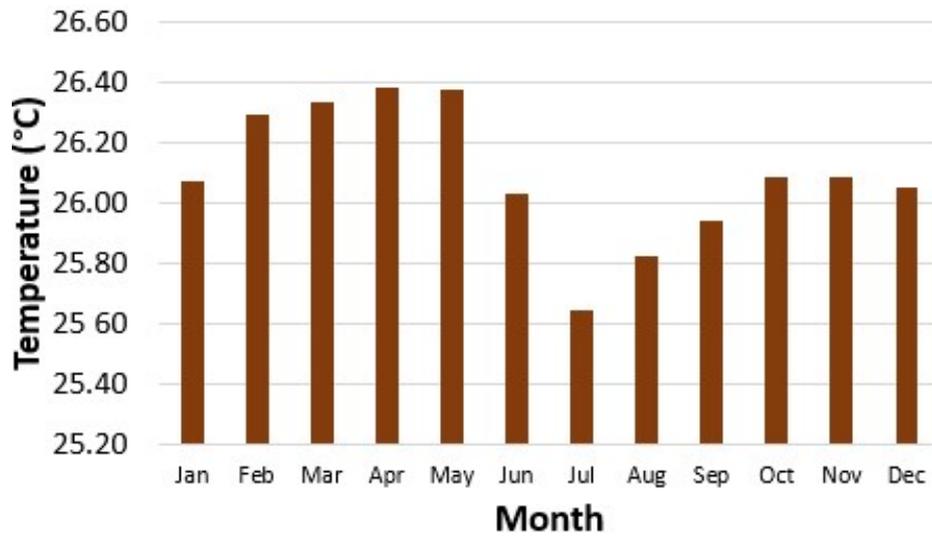
Figure 3. Average monthly temperature.

2.3 Load curve

Through contact with residents of the settlement, information was obtained on the consumption of household appliances present in the homes and the respective times of use. In addition, the electricity bills provided the average monthly consumption of the respective homes. Such information made it possible to estimate the daily electrical consumption and create the load curve. The values obtained are a daily average of 4.37 kWh for each house in the project.

The Fig. 4 shows the daily load curve composed of 20 houses, with an average load of 87.32 kWh and a peak load of 8.4 kW.
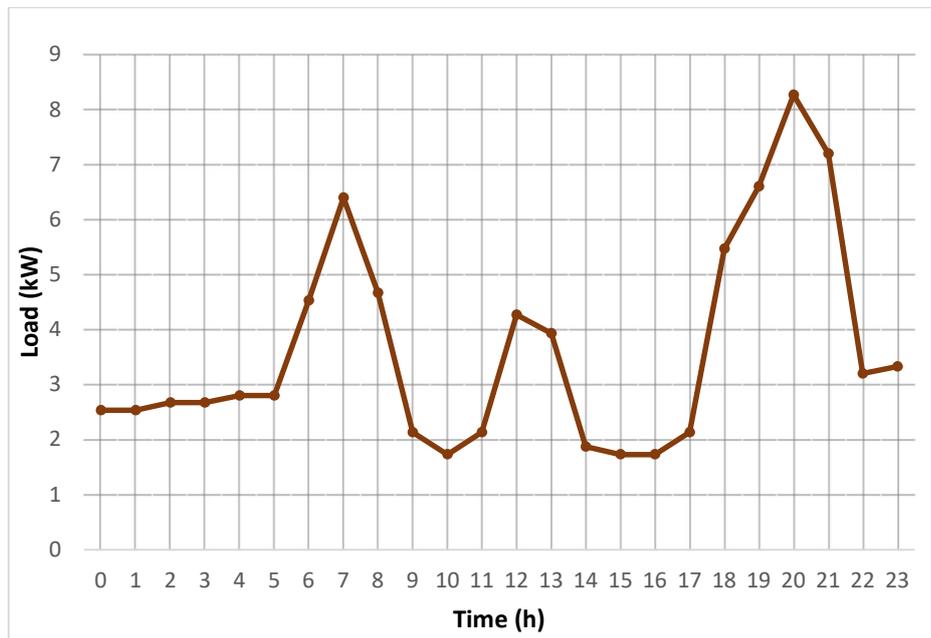

Figure 4. Load curve of the 20 houses

2.4 Equipment costs and energy tariff

To calculate the prices of the equipment used in the system, a market survey was carried out among the national suppliers of the components. Thus, an average price was obtained for the photovoltaic panel and the inverter and wind turbine. Costs are shown in Tab. 1.

Table 1. Economic data and technical specifications of the equipments.

Equipments	Data	Values
Photovoltaic painel	Model:	Generic
	Capacity:	250 W
	Cost:	R$ 850.00
	Lifetime:	25 years
Wind-turbine	Model:	Eletrovento HLV 6.4
	Capacity:	5 kW
	Cost:	R$ 90,000.00
	Lifetime:	25 years
Inverter	Model:	Generic
	Capacity:	1 kW
	Cost:	R$ 1,200.00
	Lifetime:	15 years

In addition to equipment costs, the tariff applied by the energy distributor to rural consumers is 0.504 R$/kWh, with government taxes already applied.

2.5 HOMER economics

The software simulates the operation of the system by performing energy balance calculations in each daily time interval (usually per hour) and compares the electrical demand in the given time interval with the energy that the system can supply, and thus performs the calculation of the required energy flow of each equipment. Through iterative processes, the software determines whether the configuration is feasible (that is, whether it can meet the electrical demand under the specified conditions) and estimates the cost of installing and operating the system over the life of the project, with the objective of selecting the best model from an economic point of view.

To calculate the best system model, the software uses the NPC (Net Present Cost) as a base, which includes all costs throughout its useful life minus the revenue generated by the resale of equipment during the entire project and also the sale of energy to the company.

$$NPC = C_{total} - C_{revenue} \tag{1}$$

C_{total} includes initial capital, replacement, maintenance, and other costs.

Another important parameter is COE (Levelized cost of energy), which is the average cost per kWh of electricity produced by the analyzed system. For the COE calculation, the total annual cost of the system is divided by the total energy served.

$$COE = \frac{C_{annual,total}}{E_{served}} \tag{2}$$

$C_{annual,total}$ is the total annualized cost of the system (R$/year) and E_{served} the total energy served during the year. Both parameters (COE and NPC) are fundamental for the evaluation of the systems. The $C_{annual,total}$ it is a function of the annual interest rates and the project time, calculated by Eq. (3).

$$C_{annual,total} = CRF(i, T_{proj}) * NPC \tag{3}$$

Where i represents the interest rate and T_{proj} is the total lifetime of the project. The $CRF(i, T_{proj})$ (Capital Recovery Factor) is the function that returns the capital recovery factor. This index is used to calculate the percentage of the total cost paid annually. The function is calculated using the Eq. (4).

$$CRF = \frac{i(1+i)^N}{(1+i)^N + 1} \tag{4}$$

with the variable N being the lifetime of the project.

The software also provides another important parameter for the economic analysis of the system, the $C_{operational}$. It provides system maintenance costs over its lifetime.

3. RESULTS

After the simulations, the software provides optimized results from the three systems analyze. Tab. 2 presents all data related to the cost and information of the equipment of each system during the period of 25 years of the project. Note that in the hybrid system there is a lower total net cost (NPC) and also a lower cost operational for each year.

Table 2. Simulation results containing the economic values of each system model

System	PV (kW)	Number of wind turbines	Inverter (kW)	NPC (R$)	COE (R$/ kWh)	Operating Cost (R$/year)	Initial Capital (R$)	Renewable Fraction (%)
Hybrid	10	1	7.78	245,482	0.226	4,555	133,331	61.5
PV	10	-	7.76	292,987	0.311	10,140	43,313	40.3
Wind	-	1	-	348,010	0.414	10,479	90,000	34.2
Grid	-	-	-	395,515	0.504	16,063	-	-

In addition, it is possible to see that the hybrid system is also advantageous in comparison to the value of the energy utility.

The monthly electrical production of the hybrid system is shown in Fig. 5. It can be seen in the figure that the wind turbine is responsible for 26% of the energy produced and the voltaic plates produce 36.3% and the rest of the electric consumption is supplied by the energy utility, being responsible for 37.7%. In addition, energy production is high in the second half, due to the higher incidence of winds as seen in Fig. 2. In total, the hybrid system is capable of producing 27,986 kWh/year.
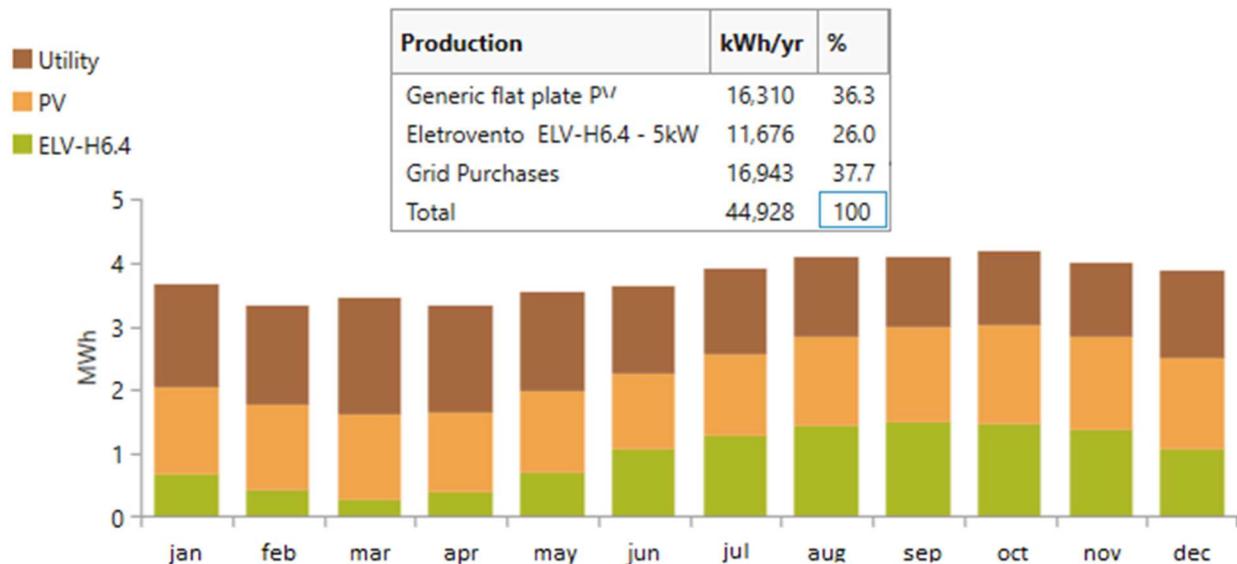

Figure 5. Monthly Electric Production of the hybrid system.

4. CONCLUSION

The results show that for on-grid systems the hybrid system presents itself as the viable solution compared to the others systems. The result is seen through the *Net Present Cost* (NPC) with the cost of R$ 245,482.00 and from the *Leveled Energy Cost* (COE) with the value of 0.226 R$/kWh. In addition, the hybrid system also becomes more viable than the energy utility with a 55.16% cost reduction in relation to the grid tariff.

However, compared to the electric grid, the proposed hybrid system becomes less attractive due to its high initial cost, because it is necessary a high investment in equipment, mainly the wind turbine, which is responsible for 67.5% of the initial cost of the system, but the initial cost ends up being recovered by selling energy to the energy utility.

It is expected that in the near future, hybrid systems will become more economically viable, because as technology advances, it is expected to reduce the production costs of the equipment used in addition to increasing efficiency.

5. REFERENCES

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6. RESPONSIBILITY NOTICE

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