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Economical Feasibility study of a wind system interconnected to the grid for the self-supply at the Isthmus University

Estudio de viabilidad económica de un sistema eólico interconectado a la red para el autoabastecimiento de la Universidad del Istmo

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Abstract

Wind energy is one of the renewable energy sources that has experienced a constant growth worldwide. Currently, this source of energy is part of electricity markets in many countries, being China, United States and Germany the leading countries in installed capacity. In México there have been important advances and the total installed capacity already exceeds 4 GW, being the self-supply scheme one of the most used. The region of Isthmus of Tehuantepec is the main scenario for wind projects in the country, due to the great wind potential available. In this region, UNISTMO is located, an institution of higher education that has three university campuses: Tehuantepec, Ixtepec and Juchitán. This university is currently supplied with the electric power supplied by CFE, however, it has resources such as wind and solar that could be used to produce part or all of the energy consumed. For this reason, in this work the simulation, optimization and study of sensitivity of a wind system interconnected to the electric network at Campus Juchitán are carried out, considering variations in certain technical-economic variables.

Renewable energy, Electrical markets, Economical study

Resumen

La energía eólica es una de las fuentes renovables que ha experimentado un constante crecimiento a nivel mundial. Actualmente, esta fuente de energía forma parte de los mercados eléctricos en muchos países, siendo China, Estados Unidos y Alemania los países líderes en capacidad instalada. En México se han dado avances importantes y la capacidad total instalada ya supera los 4 GW, siendo el esquema de autoabastecimiento uno de los más utilizados. La región del Istmo de Tehuantepec es el principal escenario de los proyectos eólicos del país, debido al gran potencial eólico con el que dispone. En dicha región se encuentra localizada la UNISTMO, una institución de educación superior que cuenta con tres campus universitarios: Tehuantepec, Ixtepec y Juchitán. Esta universidad se abastece actualmente de la energía eléctrica que le suministra CFE, sin embargo, cuenta con recursos como el eólico y el solar que podrían aprovecharse para producir una parte o la totalidad de la energía que consumen. Por dicha razón, en este trabajo se realiza la simulación, optimización y estudio de sensibilidad de un sistema eólico interconectado a la red eléctrica en el Campus Juchitán, considerando variaciones en ciertas variables técnico-económicas.

Energías renovables, Mercados eléctricos, Estudio económico

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Introduction

Recently the demand for energy has reached very high levels, the main reason for this is the rapid increase in urbanization, neighborhoods, the built environment, public transport and services. Nowadays, due to the economic and political conditions of the modern world, there is a rapid development of the renewable energy system in Mexico and even though it is not so good, it is around 0.74% of the total generation (AMDEE, GWEC 2017). But the goal of the Mexican government is to generate 25% by 2018, 30% by 2021 and 35% by 2024 of total energy by renewable system. As a result, Mexico installed the 478 MW capacity to reach a total of 4,005 MW by the end of 2017, supplying approximately 4% of the country's electricity (GWEC, 2017). As far as wind energy has shown a rapid growth in recent years, and today is the technology with the most competitive price in most markets around the world.

Several countries are showing a boom in this technology, such as Argentina, or in South Africa, which has a surprising return. For its part, Mexico is experiencing spectacular growth. This development behavior is due to several factors, mainly to energy policies (SENATE) which mandates the execution and coordination of the Special Program for the Use of Renewable Energies (SPURE) that is being promoted worldwide to generate electricity through clean energies, the objective of reducing environmental damage, incentives, and the technical maturity that this technology has obtained (Dennis *et al.*, 2012; Wais, 2017).

Regarding renewable policies, in many countries they are ceasing to be tariffs established by the government and are beginning to be competitive auctions with long-term energy purchase agreement (PPA) for public-scale projects. (https://www.iea.org/renewables/).

One relevant fact is that the Energy Reform of Mexico introduced the tender for wind energy and other renewable energies, the last of which resulted in a record price of US $ 0.017 / kWh for projects, which has already attracted more than US $ 7.6. Investment bn The auctions held so far are historically lower prices, setting new world records and demonstrating the competitiveness of wind power in the country.

In addition, the Mexican wind market is not only about long-term auctions, since there are also new regulations that allow contracts with large consumers in the private sector. This helps extend the social and economic benefits of renewable energy development throughout the country.

The trend in prices is improving, which is why the use of wind turbine technologies is motivated in places where energy demand is really important, so much so that nowadays the economic viability of several sites for the production of electricity at low cost, either for electricity supply or for sale to the network.

The development of wind energy in Mexico has been complex and controversial; The great increase in wind energy in Oaxaca has created social conflicts, which could even stop the development of wind projects in the region (Huesca-Pérez, 2016; Juárez-Hernández et al., 2014). Within this sector, Oaxaca is the best-known state in the country because of the wind power that is delivered to the country every year (AMDEE), thanks to the wind potential of the Isthmus of Tehuantepec, particularly in La Venta, which has become a stage of the wind projects, despite the controversies and the public resistance to the wind developments that have taken place when planning the projects (Pasqualetti, 2011).

In this work the economic study is carried out using the software HOMER PRO (Hybrid Optimization Model for Electric Renewables), whose main interest is to analyze the profitability of the installation of a wind turbine or wind turbine of 660 kW or Gamesa of 2 MW for the purpose to supply electricity to the Juchitán campus or, if necessary, the three campuses of the Universidad del Istmo (UNISTMO) located in Santo Domingo Tehuantepec, Ixtepec and Juchitán de Zaragoza. After making various analogies regarding various variables such as: wind speeds, interest rate, initial capital, costs by O & M, etc., the conclusion of this investigation is expressed.

Methodology

The study was conducted using the HOMER PRO (HOMER) model. HOMER (http://www.nrel.gov/homer/) is a program for the optimization of hybrid electric power generation systems based on renewable sources (Türkay, 2011, Sahoo, 2015).

The program can optimize hybrid systems composed of photovoltaic generator, batteries, wind turbines, hydraulic turbine, AC generator, fuel cell, electrolyser, fuel tank and bidirectional AC-DC converter. The charges can be AC, DC and / or hydrogen charges, as well as thermal loads.

This model performs three fundamental activities: **simulation, optimization and sensitivity analysis**. In the simulation process, it models the operation of a particular system configuration every hour of the year, to determine its technical feasibility and its cost in the useful life. In the optimization, it simulates many different configurations in the search for the one that satisfies the technical constraints at the lowest cost. In the sensitivity analysis, it performs multiple optimizations under a range of assumed changes in input variables (costs, average demand, average wind speed, interest rates, life of the project or components, height of the wind turbine hub, others), to measure the effects that these changes cause on the functioning of the system. The optimization determines the optimal values of the variables over which the system designer has control, such as the combination of components that make up the system and the size or quantity of each. In contrast, the sensitivity analysis helps to assess the effects of uncertainties or changes in variables over which the designer has no control, such as those mentioned above. (Lambert et. al.).

Figure 1 shows the scheme of the wind system studied, which included the possibility of installing either Vestas wind turbines of 660 kW or Gamesa of 2 MW. This was done for comparative purposes, in such a way that one could choose between one and the other through the optimization process; the previous subject to restrictions in the power sale capacity to CFE.

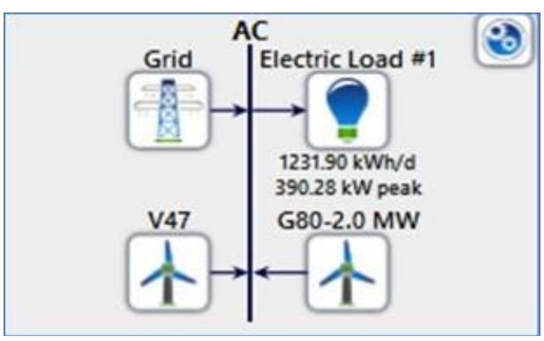

Figure 1 Scheme of the wind system studied
Source: HOMER PRO

The idea of including several values for the capacity to sell energy to CFE (sensitivity), is to see how this affects the level cost of the energy produced. This analysis is justified by the fact that, in Mexico, CFE does not pay for surplus energy that the system delivers, but under the self-supply scheme only makes a balance between what is delivered and what is purchased from the network (charges the difference between said amounts). Therefore, this analysis seeks to minimize surplus energy as it does not imply additional income for the university.

Table 1 shows all the sensitivity variables used: sales capacity; discount rate; rate of inflation; and daily energy consumption. The values of daily energy consumption consider: a university campus (1232 kWh / d); two campuses (2460 kWh / d); and three campuses (3700 kWh / d).

The value of a campus' consumption is derived from load studies conducted at the Tehuantepec campus, using a Fluke brand energy quality analyzer. The other two values are estimated.

Sensitivity variables			
Capacity to sell to the network (kW)	Nominal discount rate (%)	Rate of inflation (%)	Daily energy consumption (kWh)
25	8	6	1232.00
50	6	4	2460.00
100			3700.00
			500.00

Table 1 Sensitivity variables used
Source: Data taken from HOMER PRO

The meteorological information used consisted of wind speed data, recorded at 32 m SNS every hour, in an anemometric station located next to the Juchitán campus.

Regarding the sale and purchase prices of electric power to CFE, these were considered equal. It was taken into account that UNISTMO pays its electricity service to CFE under the HM tariff, which differentiates consumption in three periods: base, intermediate and peak. The prices for each period change by season of the year and apply to certain periods of the day. For this reason, a series of 8760 data were constructed with the prices of electricity for each hour of the year.

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This series was imported from the HOMER and it is visualized in figure 2.

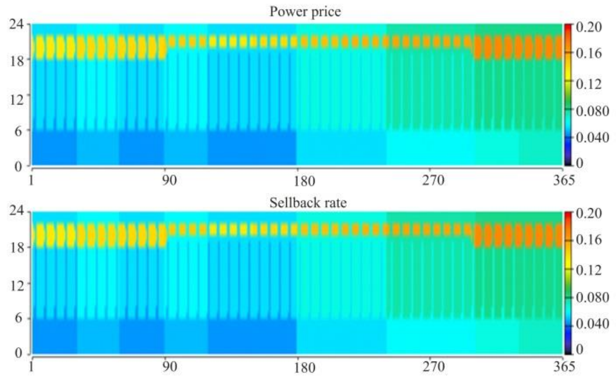


Figure 2 Variation in energy prices according to the HM tariff
Source: HOMER PRO

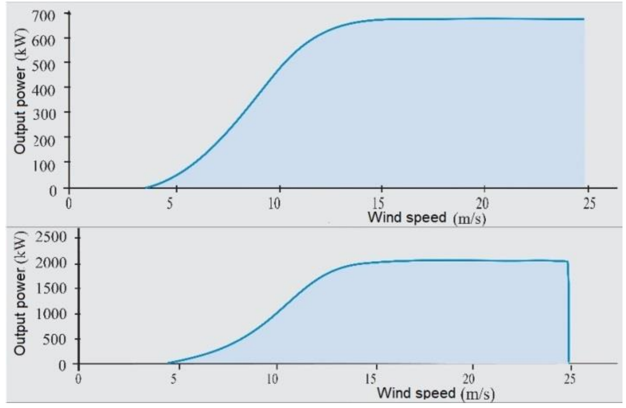
The costs considered for the wind technologies were the following:

1. Capital cost: 800 USD / kW.
2. Annual operation and maintenance costs: 2% of the capital cost.

The duration of the project was considered equal to the life time of the wind turbines (25 years), with which the residual value of the same is zero.

Figure 3 shows the proposed site for the installation of the wind turbine, at the Juchitán campus of UNISTMO. This campus was chosen because it is located in one of the most important wind resource sites in the country; where the largest Mexican wind farms are installed.

Figure 3 Place of location of the wind turbine on the Juchitán campus of the UNISTMO
Source: HOMER PRO



Graphic 1 Power curves of the Vestas V47-660kW and Gamesa G80-2MW wind turbines
Source: HOMER PRO

As can be seen in Table 2, the configuration that includes a Gamesa G80-2MW wind turbine is located behind the one that considers only the electricity grid. That is, in the life cycle of the project (25 years) it would be preferable to continue consuming 100% of the electric power from the network instead of interconnecting a 2 MW wind turbine.

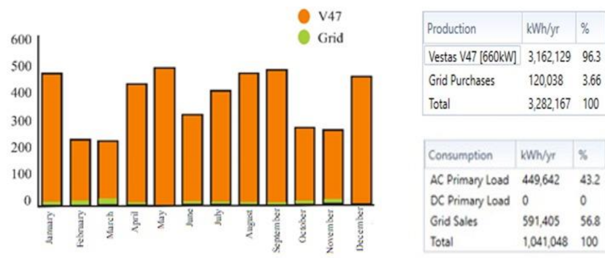
This is because the scheme that has been evaluated is self-supply, where the surplus energy does not imply additional income.

Architecture	Costs				System
Wind turbine	COE ($)	NPC ($)	cost of operation	Initial capital	Renewable fraction
Vestas 660kW	0.0065	0.13M	-26,595	0.66M	88.5
Red	0.0722	0.64M	32,486	0	0
Gamesa 2MW	0.0608	1.36M	-12,234	1.60M	92.6

Table 2 Results of the optimization
Source: Data taken from HOMER PRO

If it were the case of an independent production system or another where additional income is obtained by selling energy, then the behavior would be different and surely the G80 wind turbine would be preferable instead of the network or the V47 wind turbine.

However, under the conditions already described, a Vestas V47-660kW wind turbine would be enough to generate 100% of the consumption of the Tehuantepec campus.



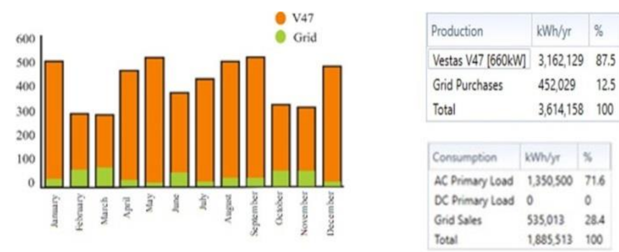
Graphic 2 Monthly energy balance produced by the wind turbine and purchased from the network (case of a university campus)
Source: HOMER PRO

The Vestas wind turbine would have a capacity factor of 54.7%, which is very high due to the potential of the available wind resource (9.57 m / s at 32 m SNS). The annual energy delivered would be 3162.13 MWh, while that purchased from the grid would be 120.04 MWh. It would be necessary to buy this amount of energy to the grid even though the total wind production is higher than the annual consumption, which is 449.64 MWh, due to the intermittency of the wind (not in all the hours of the year the production of the wind turbine equals or exceeds consumption).

However, since the energy sold to the grid (591.40 MWh) exceeds the power purchased, then the wind turbine would be supplying 100% of the demand and would also have an excess of production.

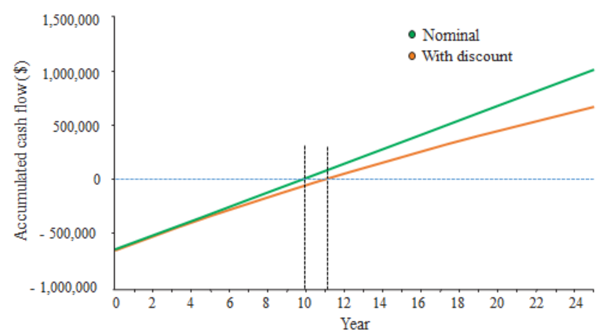
For those cases in which the electrical demand of the other two university campuses would also be met, the optimal system would continue to be wind power interconnected to the grid with a V47 wind turbine. Only by adding one or two more campuses, then it will be necessary to buy more energy from the network.

For example, for two campuses the total annual energy consumed (898 MWh) continues to be less than the annual production of the wind turbine; and for the three campuses the total annual consumption (1350.5 MWh) would also be lower. In all cases the production of the aerogenreador exceeds the demand.



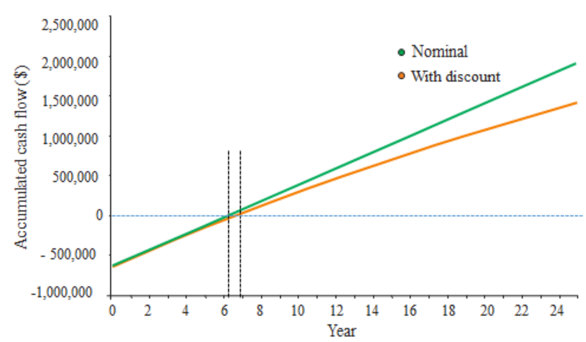
Graphic 3 Balance of monthly energy produced by the wind turbine and purchased from the network (case of the three university campuses)
Source: HOMER PRO

If we compare graphs 2 and 3 we can see that the amount of energy purchased from the network is higher in the second case, but the amount of energy sold continues to exceed the amount purchased.



Graphic 4 Accumulated cash flow (case Tehuantepec campus)
Source: HOMER PRO

The accumulated cash flow in figure 4 shows that the period of recovery of the investment would be 11 years if only the supply of electricity to the Tehuantepec campus were considered. However, if the system considers the self-sufficiency of the three campuses, the recovery period would be approximately 7 years (figure 5).



Graphic 5 Accumulated cash flow (case of three campuses)
Source: HOMER PRO

Regarding the sensitivity analysis, the influence of electricity consumption and sales capacity on the network was analyzed in the optimal system type (figure 4). As can be seen, most of the area is occupied by the wind system interconnected to the network (wind turbine V47-660 kW).

However, for small values of sales capacity and lower consumption than the Tehuantepec campus (1232 kW / d), the optimal system is the electricity grid. The latter would also happen for consumption slightly higher than those of said campus and network sales capacities below 40 kW.

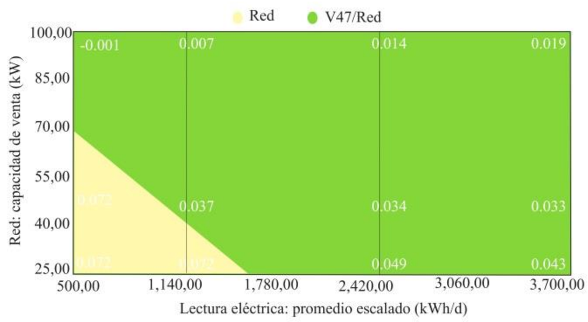


Figure 4 Optimal system type for different consumption values and capacity to sell energy to the network
Source: HOMER PRO

It should be noted that the Gamesa G80-2 MW wind turbine was not optimal for any of the possible combinations of the two sensitive variables of Figure 4. It should also be noted in Figure 4, that for the same value of energy consumed (horizontal axis) the level cost of energy (values superimposed in the area of the graph) decreases with the increase in sales capacity (vertical axis). The latter is because the increase in sales capacity would imply more energy sold to CFE.

What is indicated in the previous paragraph indicates the need to establish public policy measures in the energy sector that facilitate the commercialization of surplus energy that takes place in systems distributed under self-supply schemes.

Conclusions

The study shows the technical-economic feasibility of interconnecting wind turbines to the electric grid in the Juchitán campus, to supply the entire UNISTMO with electricity.

The existing wind potential allows to obtain wind turbine capacity factors above 50%, which means that wind turbines even lower than the MW of power are capable of supplying large amounts of electricity to the UNISTMO.

The sensitivity analysis carried out demonstrates the need to implement public policy measures that encourage the use of wind technologies for energy self-sufficiency. Low levels of electric power sales capacity can make systems such as those studied unprofitable, compared to the conventional electricity grid.

It should be noted that this study is preliminary, since there has been no optimization in the selection of the wind turbine most suitable for the site; Take into account, for example, aspects of turbulence and wind gusts that could reduce their useful life. This should be part of later studies.

Acknowledgement

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