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Implementation of the economic dispath to optimize the location of the wind parks

Implementación del despacho económico para la localización óptima de parques eólicos

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Abstract

The supply of electrical energy must be guaranteed in a sustainable way due to the depletion of non-renewable resources, as new alternatives for renewable resources, known as clean energies. As a concrete case, for the state of Tamaulipas, previous studies have been carried out that indicate its enormous potential for the installation of the wind parks. This paper presents an analysis of the efficient management of electricity production through the generation of clean energy, such as wind energy. This analysis is carried out under the economic dispatch scheme, proposed as a problem of minimization of energy at the time of transmission. The mathematical model, formulated through a linear programming scheme and considering the real variables, allows to find the optimal location of a wind park in order to maximize the generated energy, showing the real generation capacity. The analysis realized has the advantages of being a method that yields the best solution for the linear optimization model, unlike the heuristic methods that only look for a solution that is closest to the optimum.

Economic dispatch, Linear programming, Optimization

Resumen

El abastecimiento de la energía eléctrica se debe garantizar de una manera sustentable y debido al agotamiento de los recursos no renovables, se han buscado nuevas alternativas a partir de recursos renovables, conocidas como energías limpias. Como caso concreto, para el estado de Tamaulipas, se han realizado estudios previos que indican su gran potencial para la instalación de parques eólicos. En este trabajo se presenta un análisis de la administración eficiente de la producción de energía eléctrica mediante la generación de energía limpia, como la eólica. Dicho análisis se realiza bajo el esquema de despacho económico, planteado como un problema de minimización de pérdidas de energía al momento de la transmisión. El modelo matemático, formulado a través un esquema de programación lineal y considerando variables reales, permite encontrar la localización óptima de un parque eólico con el fin de aprovechar al máximo la energía generada, logrando mostrar la capacidad real de generación. El análisis realizado posee las ventajas de ser un método que arroja la mejor solución por el hecho de ser un modelo de optimización de programación lineal, caso contrario de los métodos heurístico que solo buscan una solución la cual es la más cercana a la óptima.

Despacho económico, Programación lineal, Optimización

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Introduction

Energy is the ability of a body or system to develop a certain work, these forms of energy can be kinetic, thermal, solar, light, hydraulic, wind, atomic, and electrical energy according to Roldan (2008). Currently, electric power is present in the daily life of the human being, and as fossil fuels are exhausted, as well as its high and increasing cost each day, they provoke the interest of searching for new alternatives to take advantage of resources energetics.

The methodology of the economic dispatch provides a way to supply the demand for electric power, optimizing the available generation resources. An administrative approach to the economic dispatch arises when dealing with the problem of locating a new generation plant through economic dispatch, resulting in an optimal location.

Theoretical fundament

Exhaustion of non-renewable resources

Electricity is of utmost importance in our society, due to the countless applications in all areas of life as mentioned by Hall (2013) is industrial, commercial, communications, and residential uses.

This electric power according to Villarrubia (2012) is generated from non-renewable resources and renewable resources, which must be guaranteed in a sustainable way in Mexico and is defined within the 2013-2019 development plan, which refers to to use in renewable energies, to increase competitiveness and have greater economic and social development. Currently, most of the energy consumed in the world is of non-renewable origin according to the report on Renewable Energies: The world situation: (2018), where it is mentioned that only 26.5% of the energy generated is through renewable resources.

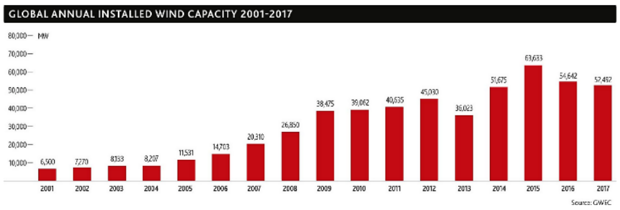
Studies of the energy sector, such as that of the International Energy Agency: World Energy Otlook (2006) and of the European Commission World Energy, Technology and Climate Policy Outlook WETO 2030 (2007), coincide in their projections of a depletion of resources not renewable as fossil fuels and coal for 2030 and uranium according to Dittmar (2011).

Due to the depletion of non-renewable resources begins to develop systems or devices for the use of alternative sources of energy known as renewable energy such as: solar, wind, biomass, hydraulic, geothermal, and obtained by the oceans according to Roldan (2013).

Wind energy: viable alternative in Mexico

Wind power, as defined by Spinadel (2015), comes from the sun due to changes in pressure and temperature in the atmosphere that cause the air masses to move and generate wind. This, allows to be taken advantage of by the wind turbines that transform the kinetic energy of the wind to produce the necessary mechanical work to generate electricity. In its beginnings it was used in irrigation and milling, as well as to operate water pumps at the beginning of the 17th century.

Until the early twentieth century was when the wind was used to produce electricity, but the low cost of coal and fossil fuels made them more in demand. As a result, the development of its technology was halted, and as a result of the oil crisis of the 70s, it promoted alternative energies such as wind power. According to Han (2005) and Fernández (S / F) the pioneering countries in the use of this technology were E.U and Europe. From the 21st century, wind energy has had great development as shown in Chart 1, with the main current producers China, U.S., Germany, India and Spain according to the Global Wind Energy Report 2018 (GWEC 2018).



Graphic 1 Evolución de la capacidad de energía eólica instalada en el mundo
Source: Global Wind Statistics 2017

In Mexico wind energy has advanced very slowly, currently there are several wind farms in different states with a total capacity of 4005 MW according to the Mexican Wind Energy Association in 2018 (AMDEE 2018). In Figure 1, the distribution of wind farms installed in Mexico reported until 2018 is shown.

Figure 1 Wind farms installed in Mexico
Source: AMDEE 2018

Different studies such as those of the Tech4 CDM Project (2009), Calderón (2008), Gorrochotegui (2006) and Coronado (2005), to name a few, have identified different areas with wind potential to produce electricity.

In particular, one of them is the coastal area of Tamaulipas, the mentioned references indicate that the points with the greatest potential are in Matamoros, Soto la Marina and Altamira as shown in Figure 2.

Figure 2 Wind power density in Mexico
Source: SENER 2014

The incorporation of new electric power generation centers to the central network; brings with it new challenges among them the efficient use of all resources, so it is important to resort to the implementation of optimization techniques that allow the strategic location of energy generation nodes to be identified.

Operations research

Decision making in real problems is complex, especially due to the large number of variables involved. For the resolution of these problems, the use of quantitative models is fundamental and, according to González A. and García G. (2015), this branch of mathematics is known as Operations Research.

A mathematical model can generate endless solutions, but the optimal solution that is generated will be one that improves feasible solutions.

Its main feature is that all the variables involved in the system must be represented by linear functions. The linear programming model consists of three basic components:

1. The variables of non-negativity.
2. The goal, which is the goal that is to optimize, either maximize or minimize resources.
3. The restrictions that must be met, these can be due to the limitation of resources.

Economic Dispatch

The operation of an electrical network involves several problems of technical order and economic order. The network must ensure, at all times and in all places, the coverage of energy demand, guaranteeing an acceptable quality of the power delivered, ensuring high food safety, at the lowest possible cost.

The high prices of fuels have given an important position to the optimal functioning of electric power systems in energy management. The problem that arises is then, the distribution of the total load of the system among the available generation units in order to optimize all resources.

The problem of the Economic Dispatch according to Barrero (2004), is a problem of linear programming and this begins when you have two or more central power supply and must supply a certain amount of demand, therefore, the form of divide the demand between the power stations in search of the optimization of the resources at the moment of connecting to the electrical distribution network.

Methodology

The problem of economic dispatch is proposed to modify and add a random variable containing the probability of Weibull density, which tells us the probable speeds that can be obtained in each of the probable locations in which you want to locate and thus get the powers and under the restrictions of the Economic Dispatch you can find the most efficient location in which it is more convenient to locate the wind farm.

The probability that the wind speed is between certain values according to Martinez (2011) is given by:

$$P(u_a \le u \le u_b) = \sum_{i=a}^{b} p(u_i) \qquad (1)$$

Where u_b can be as large as you want, so as to obtain the probability that a wind speed is above the value of u_a. For various reasons it is convenient that the model of the wind speed frequency curve is a continuous mathematical function instead of a table of discrete values. In this case, the probability p (u_i) is transformed into a probability density function of f (u).

The area below the function is unity, this is:

$$\int_0^\infty f\,(u)\,du = 1 \qquad (2)$$

While the cumulative distribution function is given by:

$$F\,(u) = \int_0^u f(x)dx \qquad (3)$$

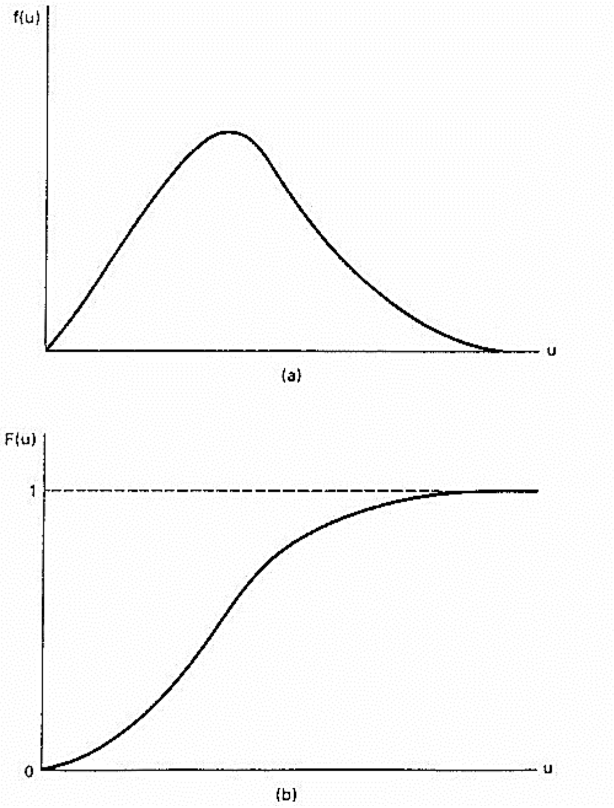
Likewise, the average value is expressed:

$$\bar{u} = \int_0^\infty u\, f\,(u)\,du \qquad (4)$$

And the variance for:

$$\sigma^2 = \int_0^\infty (u - \bar{u})^2\, f\,(u)\,du \qquad (5)$$

The probability functions f (u) and cumulative F (u) are represented graphically in Graphic 2.

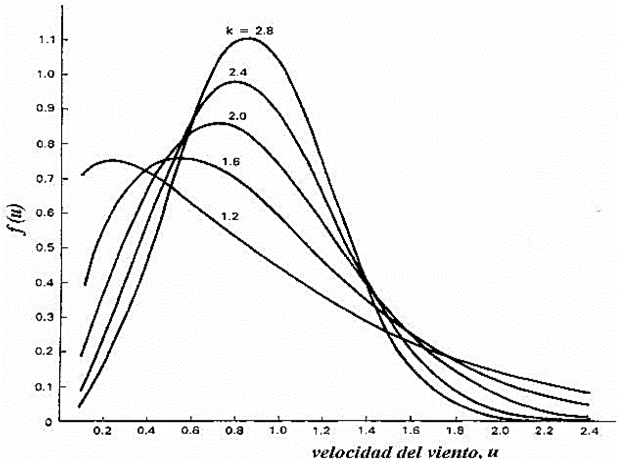


Graphic 2 Weibull distribution functions
Source: Martínez 2011

One of the functions that best fits to describe the distribution of wind speeds is the distribution of weibull which is the one with the highest precision is given by:

$$f(u) = \frac{k}{c}\left(\frac{u}{c}\right)^{k-1} exp\left[-\left(\frac{u}{c}\right)^{k}\right] \qquad (6)$$

This is a distribution of two parameters, where c and k are the scale and shape parameters respectively.



Graphic 3 Weibull distributions with parameter c = 1
Source: Martínez 2011

The integral over the entire domain of the f (u) is the unit, so that, for various values of k (form) the peak indicates the most frequent velocity as shown in Graphic 3. The determination of the k and c values they depend on the values of u registered in the case. Since f (u) is the Weibull distribution, the probability that the wind speed u is greater than or equal to u_a is:

$$P(u \geq u_a) = \int_{u_a}^{\infty} f(u)du = exp\left[-\frac{u_a}{c}\right]^k \quad (7)$$

Thus, the probability that the wind speed is within a range of 1 m / s in width, centered in u_a is:

$$P(u - 0.5 \leq u \leq u_a + 0.5) \cong f(u_a) \quad (8)$$

By implementing the probability of the Weibull density at the probable points of location of the wind farm, the approach of the economic dispatch is based on the following conditions.

Each line in the electrical network transmits the power from the supplying node to the receiving node. The amount of power sent is proportional to the difference of the angles of these. The power transmitted from node i to node j through line i - j is therefore:

$$B_{ij}(\delta_i - \delta_j) \quad (9)$$

Where B_{ij} is the susceptance called the constant of proportionality, of the line i-j; and δ_i and δ_j the angles of the nodes i and j, respectively.

For physical reasons, the amount of power transmitted through a power line has a limit. This limit is justified by thermal or stability considerations. Therefore, a line must work so that this transport limit is not exceeded in any case. The latter is formulated as:

$$P_{ijmax} \leq B_{ij}(\delta_i - \delta_j) \leq P_{ijmax} \quad (10)$$

Where P_{ij}^{max} is the maximum transport capacity of the line $i - j$.

It must be stressed that the transmitted power is proportional to the difference of angles and not to a given angle. Consequently, the value of an arbitrary angle can be set to 0 and considered as the origin:

$$\delta_k = 0 \quad (11)$$

Where k is an arbitrary node. A consequence of arbitrarily selecting the origin is that the angles are unrestricted variables in sign.

The power produced by a generator is a bounded positive quantity lower and higher. The lower bound is due to stability conditions (analogous to how a car can not move at speeds below a certain limit). The upper bound obeys to thermal considerations (as well as the speed of a vehicle can not surpass a certain superior level). The above restrictions can be expressed as:

$$P_i^{min} \leq p_i \leq P_i^{max} \quad (12)$$

Where pi is the power produced by the generator i $P^{min}i$ and Pi^{max} are, the maximum and minimum admissible output power for the generator i.

In each node, the power that arrives must coincide with the power that comes out of it (corresponding to the law of conservation of energy), which can be expressed as:

$$\boldsymbol{\Sigma}_{j\in\Omega i}B_{ij}(\delta_i - \delta_j) + p_i = D_i, \quad \forall i \quad (13)$$

Where Ω_i is the set of nodes connected through the lines to the node i and D_i the demand in the node i.

As indicated above, the power transmitted through each line is bounded, so

$$-P_{ijmax} \leq B_{ij}(\delta_i - \delta_j) \leq P_{ijmax}, \quad \forall j \in \Omega i, \forall i \quad (14)$$

Results

The implementation of economic dispatch in the region is shown in figure 3 where the main elements of this problem are:

- Parameters

VA_i = Random power variable i i= 1 Matamoros, 2 Soto la Marina, 3 Altamira.
P_i = Losses of electrical energy at point i. i= 1 Matamoros, 2 Soto la Marina, 3 Altamira.
B_{ij} = susceptance of the i - j line
P_{ij}^{max} = The maximum transport capacity of the line $i - j$

- Variables

δi= Phase angle in the location i i = 1 Matamoros, 2 Soto la Marina, 3 Altamira.
L_i= Binary 1 = If the location i is the most efficient to locate the wind farm.
0 = The location is not feasible.
for i = 1 Matamoros, 2 Soto la Marina, 3 Altamira.

- Objective Function:

$$Min\ z = P_1\ \mathrm{VA}_1 L_1 + P_2\ \mathrm{VA}_2 L_2 + P_3\ \mathrm{VA}_3 L_3 \qquad (15)$$

- Subject to conditions:

Law of conservation of energy

$$\delta_4 = 0 \qquad (16)$$

$$1.64\,X10^{-5}(\delta_4 - \delta_1) + \mathrm{VA}_1\mathrm{L}_1 = 0 \qquad (17)$$

$$0.02164\ (\delta_4 - \delta_2) + \mathrm{VA}_2\mathrm{L}_2 = 0 \qquad (18)$$

$$0.0374(\delta_4 - \delta_3) + \mathrm{VA}_3\mathrm{L}_3 = 0 \qquad (19)$$

Power transmitted through each line

$$-0.23 \leq 1.64X10^{-5}\left(\delta_4 - \delta_1\right) \leq 0.23 \qquad (20)$$

$$-0.4 \leq 0.02164\ \left(\delta_4 - \delta_2\right) \leq 0.4 \qquad (21)$$

$$-0.4 \leq 0.0374(\delta_4 - \delta_3)\ \leq 0.4 \qquad (22)$$

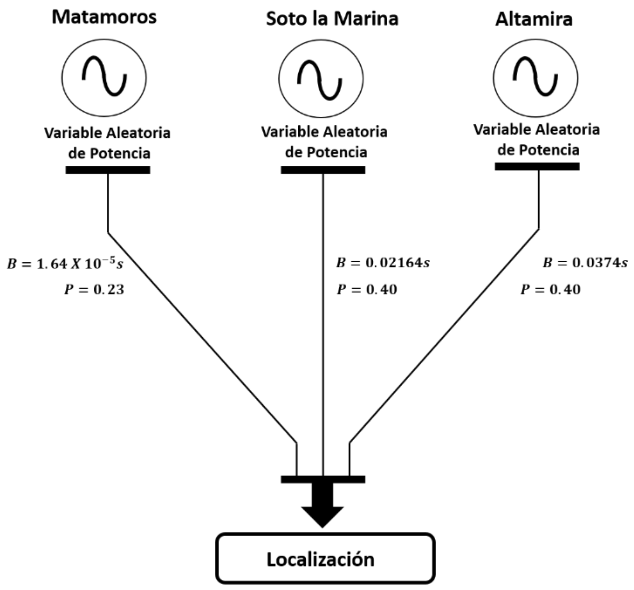
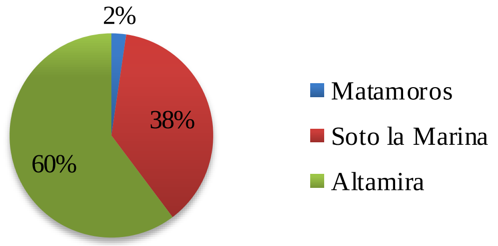


Figure 3 Approach of the proposed problem of the Economic Dispatch
Source: Own authorship

Conclusion

For purposes of this work, the modifications that were made to the economic dispatch show an optimal solution, and the use in the region is viable.

When running the problem of linear programming 385 times because the sample size was determined at a confidence level of 95%, with random power variables with Weibull distribution, of which 9 times was in Matamoros, 144 in Soto the Navy and 232 in Altamira as shown in Graphic 4.



Graphic 4 Frequency graph of location results
Source: Own authorship

From this same graph it is observed that 60% of the runs of the proposed Economic Dispatch method, Matamoros has a better Weibull probability density curve, but it has a great restriction because the transmission line to which it connects has lower transmission capacity, compared to Soto la Marina and Altamira, which prevents the wind farm from being located in that place. This can be seen in the equations (20), (21) and (22) that indicate the maximum power transmitted through each line.

This method developed in a problem which can be adapted to any situation not only focused on wind energy, but any type of clean energy that you want to minimize.

This minimization can be considered in transmission losses, generation and / or installation costs, as well as CO_2 emissions, among others. Additionally, this study allows to be a useful tool in the efficient location of electric generators.

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