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TECHNICAL EVALUATION OF THE WIND RESOURCE IN VENEZUELA

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ABSTRACT

Venezuela is a country with large reserves of fossil fuels, and it's estimated that resources from renewable energies are also large enough. Nevertheless, the technical evaluation of the majority of these resources has not been sufficiently investigated, particularly wind resources. In this article, we present the analysis of the wind flow based on different climate data sources, as well as a preliminary technical evaluation of the wind resource, in order to identify those areas susceptible for the development and implementation of wind power. The results presented here are theoretical considerations of the technical potential of wind powered energy in the country, which might be considered as a preliminary study in order to formulate projects aimed at obtaining electrical power from wind energy. The results show that there are many places that have excellent wind resources; however, the major energetic potential of wind flows is located along the coast, with values in excess of 5500 MWh/km², mostly in the Falcon, Zulia, Sucre and Nueva Esparta states.

Keywords: wind energy, technical evaluation, wind resources, wind flow, electric power generation.

1. INTRODUCTION

The small or large scale use of wind-based energy represents a real economic alternative for supplying electricity to the main power grid as well as to isolated rural communities. According to experts from the German Wind Energy Association, wind energy is one of the cheapest energy sources when compared with conventional energies produced from fossil fuels. The price of 1 Kwh of wind energy in 2012 was 48% cheaper than the energy produced from coal, and 10% less costly than that produced from natural gas [9]. Additionally, as is well known, this type of energy source reduces environmental pollution, allows creating new jobs and may provide more energetic security for the country because most countries need to import the energy that they use, increasing the possibility that their electrical power grids be affected by failures and power interruptions due to high demand. With the use of wind-powered electricity, this possibility is reduced because this energy comes from a local resource, in theory inexhaustible, that assures energy supplies in the present and in the future, without energy dependence to other countries. In the case of countries that have large fossil fuel reserves, the development of wind energy is based essentially on the protection of the environment.

However, in order to achieve an efficient development and use of wind energy, a correct assessment of wind resources is required. It is suspected that great wind energy potential exists in Venezuela, but it has not yet been evaluated in an exhaustive way. Therefore, the objective of this investigation is to carry out an assessment of the wind resources in the Bolivarian Republic of Venezuela, as a contribution to the middle-term development of technical and economic projects that promote the optimum exploitation of this resource for the generation of electrical power [2].

2. MATERIALS AND METHODOLOGY

In Venezuela, the interest in evaluation and exploitation of the renewable resources began in 1999 with the first national energy meeting, which promoted the incorporation of sources of renewable and not conventional energies for power generation, through the pilot project Plan Operativo de Energías Renovables (PODER).

In 2004 PODER changed his name for Programa de Energias renovables (PER) and keep promoting the utilization of renewable energies in order to create power energy in applications, which are connected to the network or isolated from it.

About the energy assessment of renewable resources in the country, there are no records of energy atlas or otherwise calculation of energy potential of these resources. For the specific case of wind energy at the moment, there are three wind farm projects taking place in the country, located in coastal areas, but so far none of the parks is in phase of finalization. The evaluation of the energy potential of the wind resource published and which has been recorded until now is Wind-resource atlas of Venezuela based on on-site anemometry observation [7].

For this reason in this article, we present a technical assessment of the wind resource considering sources of reanalysis data, evaluation that considering the type of input data is so far the first in the country.

The models used to analyze the flow of wind currents in a particular region are grouped in two big categories: statistical models and numerical models. The most used ones are the numerical models, because they include in their analyses two factors that considerably influence the exploitation of wind resources, such as the orography and ruggedness of the zone [3, 6]. Most popular are the numerical model of mass conservation, the linear model, the mesoscale model and the non-linear model.

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The model of mass conservation was one of the first models of wind flow developed to calculate the spatial distribution of speed and wind direction from the extrapolation of wind speeds measured at different points within the areas being evaluated. Among these kind of models, the best known are NOABL and MINERVE. On the other hand, the linear potential flow models are based on the theory of Jackson and Hunt that solve in linear form the Navier-Stokes equations under the assumption that the terrain orography influences the variations in the flow of the wind currents. However, it does not model turbulence in complex terrains and does not consider the effects of thermal stability. Within this type of models are WAsP and MS-mike [10].

The mesoscale models were designed mostly for forecasting the weather, they solve the equations that describe atmospheric processes and offer great precision in the evaluation of the characteristics of the windo flow in complex terrains, because they represent well and with good resolution the terrain orography. Within this type of methods we can mention KAMM, MASS and WRF. Finally the non-linear methods or numerical methods of fluid dynamics (Computational Fluid Dynamics), usually abbreviated as CFD, are based on the complete solution of Navier-Stokes equations combined with models to simulate turbulence, allowing modelling of complex thermal effects.

Among this type of models is the Meteodyn model WT. Figure-1 shows the methodology for assessing wind flow using numerical methods [8, 11].

The WindPRO, METEODYN and WAsP softwares included in Figure-1 evaluate with great precision the potential contained in wind flows in areas with complex surfaces and forests. The input data necessary for any of these models are: climate variables (wind speed and direction, which can be measured using satellites, surface or reanalysis), orographical data and obstacles in the terrain [8].

On the other side are the statistical methods, which are based mainly on the modelling of the wind flow in the surface layer of the atmosphere in a specific geographical area, based on empirical measurements of the characteristics of climate phenomena and wind currents, defined by experimental data and which describe a statistical function.

The interpolation and extrapolation of this data is made by selecting statistical parameters of the wind flow in areas with similar topography and orography. Statistical methods can be combined with other methods of wind flow modelling, such as the numerical models, in order to obtain more precise results [11].

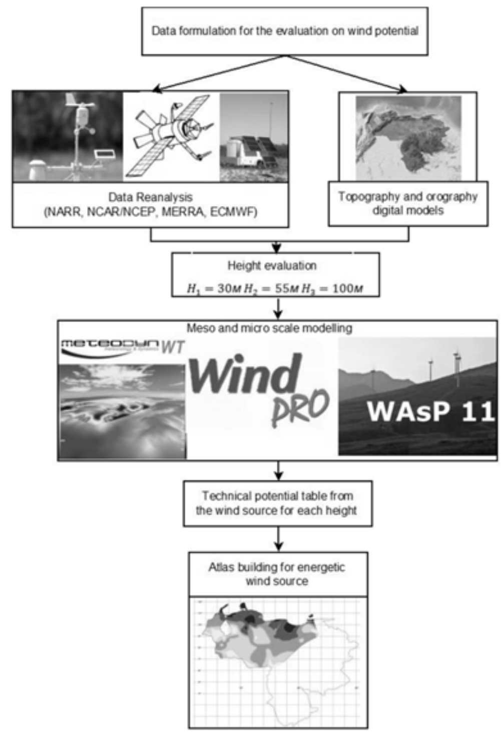

Figure-1. Methodology for calculating the technical potential of the wind resource in Venezuela, considering reanalysis data and models of meso and micro scale.

For the assessment of wind resources in Venezuela we considered a statistical method. However, when we want to evaluate the wind in complex terrains with abrupt changes in the topography or with significant ruggedness (obstacles, forests, mountains, etc.), statistical models are very limited, because they could lead to error when their results are extrapolated. Therefore, for areas with complex topography and a limited network of meteorological stations, this type of model only allows identifying the areas with better potential for the practical use of wind resources, but they require a more in-depth study of the wind characteristics [4].

With this evaluation of wind resources throughout Venezuela we want to identify the areas with the best potential for exploitation of wind resources. To achieve this we analyzed data from 35 meteorological stations located in rural and urban areas, airports and other facilities. As a complement to this analysis, we selected data from three different sources of reanalysis: the NASA Modern Era Reanalysis for Research and Applications (MERRA), the North American Regional Reanalysis (NARR) and the National Center for Atmospheric Research (NCAR). A comparative analysis of the information obtained from all the reliable sources for the evaluation of the wind system led to the selection of source that the best adapts to the climate and topographic conditions in Venezuela.

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For comparing data from the reanalysis sources, we selected as a reference point a meteorological station located at 10°0 ' 0 " north latitude and 67°30 ' 0 " west longitude. For the selected reference point we constructed the graph of the wind speed profile (Figure-2).

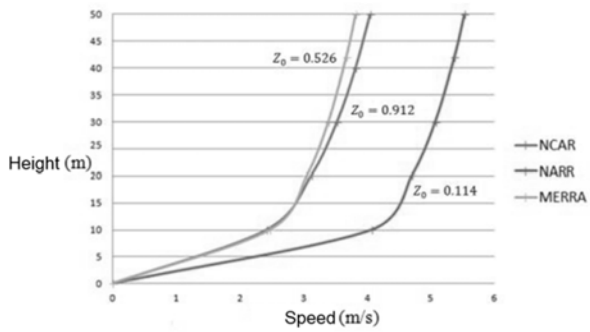

Figure-2. Specific wind speed data from different sources depending on the height under normal pressure and temperature.

The Figure shows that there are differences between the wind speed reported by each data source considered, something which seems related to the ruggedness value (Zo) considered by every source. From the graph it can be seen that the data from the MERRA and NCAR sources agree in the first meters, but start to differ at altitudes higher than 20 meters. On the other hand, the NARR data are very different from the other sources. Comparing the ruggedness value (Zor = 0.11) of the selected reference point with the Zo values considered by each source, we can concluded that the value of Zo considered by the NARR source coincides with Zo of the reference point.

Once the wind speed profile was known, we compared the wind speed data in a period of one week for the selected reference point, with same information for each of the other sources. We did not obtain any significant correlation between the data of the different sources, as can be seen in Figure 3. In this sense, in order to evaluate the potential of the wind resource we used data generated by the source that better adjusts to the topographic conditions of the area, that is to say, the one that considers a Zo value closest to the real value of the selected reference point. As mentioned previously, the NARR source has the Zo value closest to the real value. It is important to indicate that the ruggedness and orography of the terrain are basic factors for a precise evaluation of the wind behaviour, because they can influence directly the decrease or increase of wind speeds.

The technical potential of the wind resource can be calculated with a wind generator, fabricated by GAMESA, model AE61, with a nominal power of 1,320 KW, class I - A. This is used in Venezuela in one of the wind farms, currently under construction.

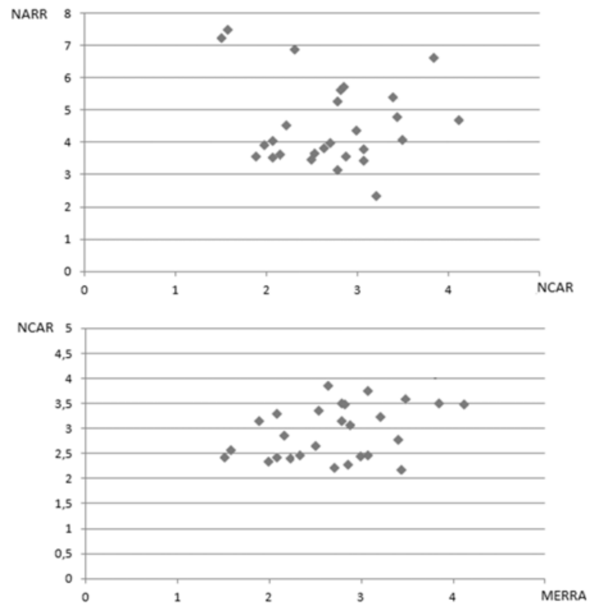

Figure-3. Correlation between each of the data sources of wind speeds over a period of one week to the selected point.

For a temperature of 15°C, standard air density of 1.225 kg/m³, and without turbulence, the wind generator yields the power curve shown in Figure-4. The graph shows that the wind generator begins operating at a speed of 4 m/s, generating 31 kW and reaching its maximum power (1350 KW) at a speed of 16 m/s.

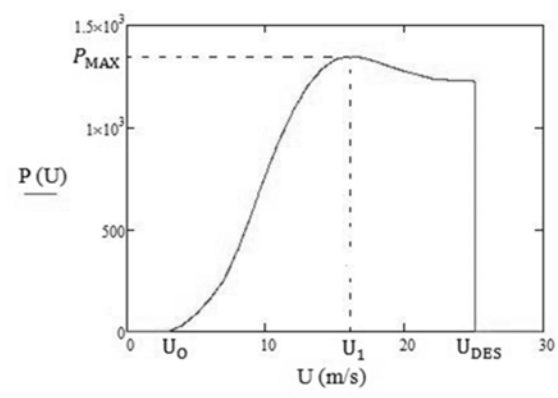

Figure-4. Power curve AE 61-1320 kW turbine to normal temperature, standard density and free of turbulence.

The technical potential of the wind resource in Venezuelan territory was calculated with the following equation:

$$E_{TEC(i)} = \int_4^{25} f(V,i).P(V)dV \qquad (1)$$

Where

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function:

$$f(V,i) = \frac{k_i}{a_i} \cdot \left(\frac{V}{a_i}\right)^{k_i - 1} \cdot e^{-\left(\frac{V}{a_i}\right)^{k_i}} \qquad (2)$$

3. RESULTS

In Figure-5 we show the spatial distribution of the points from the NARR source, which contain the meteorological information used to calculate the potential. It can be observed that the largest numbers of points are located in the west and middle of the country, which corresponds to the area where we will represent the preliminary map of technical potential of wind resources in the Venezuelan territory.

As is shown in Figure-6, the preliminary wind potential goes from values of 1000 MWh/km² up to values to 5500 MWh/km² for a height of 55 meters above the surface. The representation of the distribution of the technical potential of the wind resource throughout the country allows identifying areas with the best promise for the development of wind power facilities. As can be observed, the areas with highest potential are located in the north of the country, mainly along the coast. Comparing with the data from the weather stations located along the coastline, we find measurements of high wind speeds that vary from 6 m/s to 12 m/s. This confirms the great potential present in this area (Figure-7).

Figure-5. Point location data download speeds of wind NARR source (WindPro Source).

At the same time, there are additional areas that offer a considerable potential, but that because of the complexity of their topography make it necessary to carry out more detailed local studies, in order to define with better accuracy the usable potential. Nevertheless, the results of wind potential obtained in this article are sensitive to the height at which the wind generator is placed, and the type of wind generator, since this influences directly the usable wind speed and therefore the energy produced.

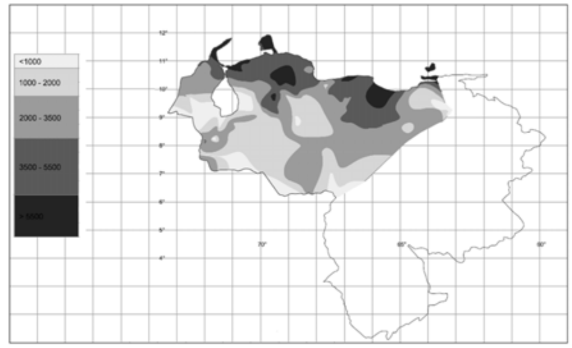

Figure-6. Technical potential of wind resource measured in (MWh / km²) of Venezuelan territory considering the data source NARR wind speeds.

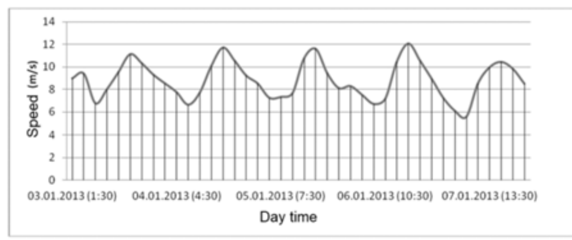

Figure-7. Frequency variation of wind speed for four days of January 2013, considering the NARR data source.

4. CONCLUSIONS

As noted, the wind potential obtained in the Venezuelan territory varies between 1000 and 5500 MWh/km² at 55 meters height, using a GAMESA model AE61 wind generator with a nominal power of 1, 320 kW and I-A class. To evaluate the potential we used wind speed data from NARR, obtained with the WindPRO software. For the particular case being evaluated in this article the NARR source was best adapted to the topography of the area; for this reason it was selected for the calculations of wind potential and the construction of a map to represent and determine the areas with best potential.

The results obtained show that in a large part of the Venezuelan territory, the wind resource has a high potential for both small and large scale development. However, a compilation and debugging of surface data is required in order to quantify exhaustively the actual potential, using one of the methodologies applied in this article. Likewise, it is necessary to improve the measurement of the climate variables associated with the wind resource throughout the national territory, especially the wind speed and direction, through the recovery of meteorological stations which are not currently operating, and the creation of new stations. Through the improvement of the data collection on wind behaviour in certain areas, we can achieve a more precise evaluation of the available wind potential.

To the extent that better surface data are available in surface, the results obtained in this article can be greatly improved.

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Table notation

Definition	Notation
the power density contained in the wind flow	P (V)
the probability function of the wind speed	$f(V,i)$
the form parameter, describes the wind speed distribution	K
the scale parameter, indicates how acute or how flat will the distribution be	A