EMS Annual Meeting Abstracts
Vol. 7, EMS2010-350, 2010
10th EMS / 8th ECAC

High resolution climatology
- towards climate change services

A methodology for optimization of wind farm allocation under land restrictions: the case of the Canary Islands

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Wind farms authorization and power allocations to private investors promoting wind energy projects requires some planification strategies. This issue is even more important under land restrictions, as it is the case of Canary Islands, where numerous specially protected areas are present for environmental reasons and land is a scarce resource. Aware of this limitation, the Regional Government of Canary Islands designed the requirements of a public tender to grant licences to install new wind farms trying to maximize the energy produced in terms of occupied land. In this paper, we detail the methodology developed by the Canary Islands Institute of Technology (ITC, S.A.) to support the work of the technical staff of the Regional Ministry of Industry, responsible for the evaluation of a competitive tender process for awarding power lincenses to private investors.

The maximization of wind energy production per unit of area requires an exhaustive wind profile characterization. To that end, wind speed was statistically characterized by means of a Weibull probability density function, which mainly depends on two parameters: the *shape parameter* K, which determines the slope of the curve, and the *average wind speed* $\widehat{\mathbf{v}}$, which is a scale parameter. These two parameters have been evaluated at three different heights $(40, 60, 80\ m)$ over the whole canarian archipelago, as well as the main wind speed direction. These parameters are available from the public data source *Wind Energy Map of the Canary Islands* [1].

The proposed methodology is based on the calculation of an initially defined Energy Efficiency Basic Index (EEBI), which is a performance criteria that weighs the annual energy production of a wind farm per unit of area. The calculation of this parameter considers wind conditions, windturbine characteristics, geometry of windturbine distribution in the wind farm (position within the row and column of machines), and involves four steps:

- Estimation of the energy produced by every windturbine as if it were isolated from all the other machines of the wind farm, using its power curve and the statistical characterization of the wind profile at the site.
- Estimation of energy losses due to affections caused by other windturbine in the same row and missalignment with respect to the main wind speed direction.
- Estimation of energy losses due to affections induced by windturbines located upstream.
- EEBI calculation as the ratio between the annual energy production and the area occupied by the wind farm, as a function of wind speed profile and wind turbine characteristics.

Computations involved above are modeled under a System Theory characterization perspective, which leads to a simple but robust model for the objectives of the analysis. Nevertheless, it is important to point out that although an estimation of the annual energy production is involved in the EEBI calculation, the goal is only to compare different wind farm projects in order to classify them as a function of efficiency under land restrictions. Hence, numerical computation of EEBI introduces some fictitious penalization to the estimation of annual energy production, whenever row disorientation with respect to the main wind speed direction is higher than a given threshold or whenever excessive separation between rows are found.

However, if these penalizations are not taken into account, this methodology also behaves as an elegant estimator of annual energy production of a wind farm, as demonstrated by our results. In addition, the methodology offers the

advantage of its simplicity compared to heavy numerical simulations to determine affection between surrounding windturbines and the induced energy losses.

References

[1] Cartografía del Recurso Eólico de Canarias. http://www.itccanarias.org/recursoeolico, April 2007.