POTENTIAL AND COST OF WIND ENERGY IN A TROPICAL ISLAND

Fabrizio CARLEVARO (University of Geneva, Fabrizio.Carlevaro@unige.ch)

Vincent DEODAT (University of Réunion, vincentdeodat@yahoo.fr)

Overview

The tropical French island Réunion presents a favorable context for the exploitation of renewable resources. Indeed, in a small overseas island the electric system is too small and decentralized to benefit from the economies of scale of large power plant. While renewable energy systems are usually used to achieve mitigation targets, in Réunion island such systems may be also more profitable than traditional fueled power plants. Furthermore, for an island which suffers from a lack of competitiveness in the Indian Ocean region, the transition toward a free-carbon energy system can also be seen as a powerful opportunity to reduce high unemployment and to develop exportable context specific knowledge. An ambitious public policy called GERRI (Green Energy Revolution: Reunion Island) use national and local skills to achieve an energy self-sufficiency by 2050.

For energy planning it is imperative to perform a reliable assessment of the productivity and generation costs for the renewable technologies available in the region. While solar systems are still expensive and land intensive, wind technologies adapted to cyclone areas seems to be more effective for power generation. Our analysis aims at assessing the potential of power generation of wind energy and evaluating its investment, operation and maintenance costs. The territory being scarce and the topography complex the impact of different level of anthropological and geographical constraints must also be taken into account.

Methods

Our assessment is based on three levels of analysis.

- At the first level we identify the “appropriate” sites of Réunion Island to locate wind power generators. This identification process is performed by first ruling out those sites which are incompatible with the constraints enforced by the regional development scheme and by the conservation of natural sites of high ecological and landscape values. Then, among the remaining sites, we consider as appropriate those having favorable wind characteristics for power generation (high average wind speed, acceptable annual, seasonal and daily variations, acceptable levels of turbulence and of extreme wind speed) and an appropriate topography to exploit this wind energy potentiality (ridges perpendicular to the main wind direction, sites sufficiently away from obstacles like buildings or big trees).

- At the second level we conduct a statistical analysis of the wind energy resource for each identified appropriate site. According to Justus (1978), we assess the wind energy potential of an appropriate site by distinguishing its “available wind energy” from its “recoverable wind energy”.
  The available wind energy refers to the maximum amount of energy that can be extracted from the wind using an ideal lossless wind turbine. The available power of wind is therefore proportional to the flux of kinetics energy of wind which is a cubic power of the wind speed. To determine this physical magnitude it is necessary to have relevant information about the wind resource. A suitable parametric model describing the spatial distribution of wind speeds can be derived from the statistical analysis of wind data collected at the weather stations of the island. To this purpose we use a Weibull probability density function with two parameters that is written as follow:

$$f(v;k,c)=\left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1}\exp\left\{-\left(\frac{v}{c}\right)^{k}\right\},$$

  where v is the wind speed in $[m/s]$, k a shape parameter of the density function, in $[1]$, and c a scale parameter, in $[m/s]$. The parameters of this model are estimated by means of wind speed data recorded during the last 10 years at 11 weather stations of Réunion using the maximum likelihood method. The measure taken at a height of 10 meters needs to be extrapolated to the height at which the wind turbine is installed, namely between 50 and 80 meters depending on the technology. The vertical extrapolation is done using a logarithmic law taking into account the kind of obstacles present at the level of the ground called roughness:

$$v_2 = v_1 \ln\left(\frac{z_2}{z_0}\right)\bigg/\ln\left(\frac{z_1}{z_0}\right),$$

  with v_1 et v_2 the wind speed at height z_1 and z_2, respectively and z_0, z_1 and z_2 the height of roughness, measurement and extrapolation, respectively. At the end of the day, roughness corresponds to the height at which the wind speed grows under a logarithmic profile, and the roughness length is given by land cover data of Réunion Island.

The recoverable wind energy refers to the amount of energy that can be extracted from the wind using an actual wind turbine which is intended to be installed in a given appropriate site. This physical magnitude is therefore obtained by integrating over all classes of speed with the help of a power function relating electricity production and wind speed for a particular technology:

$$\pi = 8760 \int_{1}^{25} Ps(v) f(v) dv \,,$$

where π is the annual quantity of electricity produced, $f(v)$ the probability density function of wind speed, 8760 the number of hours in the year, $Ps(v)$ the power function of the technology, expressing the power quantity produced at wind speed *v*.

- At the third level, to the technical potential identified over the territory of the island, a unit cost map is superposed to link the electricity produced to the investment cost of the technology installed and to the O&M costs specific to the region in order to look for the least cost solutions to generate wind power. The computation of the unit cost is obtained using a social costing method presented in Carlevaro and Gonzalez (2011), based on the following relation:

$$u\pi = aI^{i}P + H^{p}\pi \,,$$

where u denotes the unit cost, π the annual production of electricity, P the installed power, I^{i} the investment cost per MW of technology i, H^{p} the annual O&M costs per unit of installed power, a the coefficient allowing to compute a constant annuity for the investment costs over a lifetime of the technology of N years at a discount rate r, namely:

$$a = \frac{r}{1-(1+r)^{-N}} \,.$$

Results

This methodology is presently under implementation and results will be presented to the 13th IAEE European Conference.

Conclusions

Assessing the potential quantity of electricity generated by renewable energies and their relevant cost are key questions of energy planning in Réunion Island. It is then imperative to restrain the domain by imposing different level of geographical and anthropological constraints to determine the suitable sites and the total power to install. Indeed Réunion Island presents together with a complex topography due to its volcanic origin an important ecological wealth to preserve. If residential and infrastructure areas must be ignored as well as the UNESCO classified national park which cover 40% of the island, it is a matter of political decision to allow the implantation of wind power generation systems in less sensitive areas. The aim of this work is also to provide information to help policy makers on the impact of the constraints on the potential and the cost of wind electricity production.

References

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