ASPECTS OF AN EXPERT SYSTEM FOR ON-LINE EOLIAN SITES DESIGN

Octavian Căpăţână, Rareş Cazan, Mihaela Drăgan

IPA - R&D Institute for Automation - Cluj Subsidiary

Abstract: Our aim is to present the necessity and the objectives taken into account in the development of an ON LINE expert system, with free access, for the eolian sites designing process. The expert system is based on a set of rules and metric relations, and also on a Romanian patent. By eolian site design, we assume:

1. approximation of average and annual eolian potential, using terrain data, and
2. offering a blueprint for eolian plant project. This blueprint contains: potential technical solution, recommended installed power, optimal pillar height, approximation of capital costs, data about the providers for eolian plants, etc.

Keywords: Eolian energy, expert system, assisted design.

1. MOTIVATION

1.1 Eolian energy

It is estimated that from the overall solar energy at the level of our planet, a percentage between 1 and 3 is transformed in wind, and a percentage between 0.01 and 0.06 is transformed in biomass (by photosynthesis).

Production costs for one MWh, in USA, in 2006, produced based on wind, coal, or natural gas are approximately even, in case of production costs comprising all costs including investment absorption, loan interest and risk costs. In USA, these costs vary between 52 and 55 $/MWh (EIA).

A comparison made in between costs for different clean energies, leads to the conclusion that among the future solutions, the eolian energy must be taken into consideration (see table 1).

Table 1 Comparison in between costs for different clean energies

Energy type	Effic %	Usage factor	Cost./ invest. $/W	Life time	Cost prod/ KWh cUSD
μhydro	70	>55%	4	50	4-9
hydro	90		2		
wind		<30%	1,6*	20-25	6-12
solar		15	6-24	15-25	60-200
geothrm			70	25	5-9
biogas		27	8	20	4-5

Data source for table 1

BHA – British hydropower association
BC Hydro – British Columbia – Canada
BWEA – British wind energy association
Kapa System Antena – Geothermal comparison
Other (Ordean, *et al.,* 2006)

(*) A correction has to be done, if the cost for 1 installed W is 1.6 $, in eolian industry; we must emphasize the fact that the real cost for 1 W disponibile for utility, is in fact $\frac{1.6\$}{F_c} \cong 5\$$.

This viewpoint is confirmed by the dynamic registered by the eolian power growth: plus 25% in 2002 compared with 2001, plus 38% in 2003 compared with 2002, plus 41% in 2005 compared with 2004.

1.2 Eolian emplacement

Generally speaking, eolian emplacement comprises three distinct phases: eolian region, eolian site layout and generator/ generators emplacement. The first phase is referring to the ***brutish emplacement***, in a geographical area, limited by the coastal and hilly zones.

Currently, there are wind maps (in Romania, in 1992, ICEMENERG has created a map of this kind, representing eolian potential), more or less general (ICEMENERG).These maps aren't giving any other information beside the following rule:
RULE 1: Wind generators are practical in the coastal and hilly regions. In its metric form, this rule suggests that wind generators are to be taken into consideration where the average wind speed is at least 4,5m/s (16km/s). Consequently, we are considering the eolian potential maps almost useless.

The second phase consists in delimiting an area in which the eolian potential justifies an investment, or, inversely considered, in area X (property, chartered) an investment is worth it. The question being raised is if the eolian potential justifies an investment of Z funds in the considered area?

The third phase is referring to the final emplacement, meaning that we already know the exact area (several ha) and we want to establish the foundation of the eolian generator pillar. This phase is conducted, usually, by measurements. A single measurement consists of data acquisition (intensity, direction associated with time and calendar) conducted in a period of at least one year. Such a measurement, by means of few data, may cost up to 100.000 euro. A measurement conducted in an area, does not imply the fact that the measurement was taken in the optimal point, and for an investment raising up to several millions of euro (1.6 euro/installed W) it must be found the optimal point. Regarding the reduction of the measurement points' number or regarding the eolian potential assessment in a given area based on a measurement point, it exists at OSIM, a licence request - A00302/3 on May 2007.

2. ON-LINE ASSISTED DESIGN OF EOLIAN SITES

An investor has an established area within the regions with eolian potential and would like a more precise assessment of the eolian potential inside his area; an area, with the sense given here, regardless of the relation with the site's geography, may be estimated between 1 ha and several ha. Based on the cumulated knowledge, we develop an expert system which will assist an investor in assessing the eolian potential of an area.

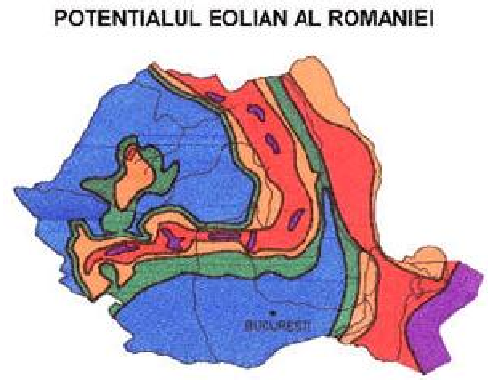

Fig. 1. Romanian eolian potential map elaborated by ICEMENERG

As presented, the first phase is superfluous. The expert system, being on-line, in case of GSM coverage, the investor located in the desired area, may succeed the second phase (see figure 2), arriving in the third phase, the last one, in which it is established the exact eolian generator/generators pillar/pillars foundation/ foundations.

2.1 Approximation of eolian potential based on terrain data

The expert system consists of an inference engine based on a set of rules and metric relations, some of the rules being listed below:
RULE 2: The increase of wind speed with increasing height in a proportion of 1/7th root of altitude (wind profile power law) (Exception – the case of coastal areas).
RULE 3: A wind turbine can extract at most 59% of the energy that would flow through the turbine cross section (Betz law)
RULE 4: An eolian farm is more economical than several eolian isolated generators with the same installed power.
RULE 5: A generator is emplaced in an area without obstacles in at least 250 m.
RULE 6: The smallest distance between a residential area and an eolian turbine is 250 m.
RULE 7: The turbine has to be emplaced at minimum 12 m above any obstacle located on a radius of 250 m.
RULE 8: The cost for one installed W off shore is double than the cost for one installed W on shore. etc.

The metric relations comprise the following ones:

1. $$v_{off-shore} = 1.1 \cdot v_{on-shore} \quad (1)$$

2. $$P_{vant}[W] = 0.5 \cdot \rho_{aer} \cdot S \cdot v^3 \quad (2)$$

where:
- P_{vant} – total wind power pass through swept area S
- ρ_{aer} – air density [kg/m^3]
- S – swept area of rotor wings [m^2]
- v – wind velocity [m/s].

Fig. 2. Interactive ON LINE form of the solicited eolian terrain data

$$3.\quad P_{eol-turbina}[W] = \eta \cdot P_{vant}[W] \qquad (3)$$

where:
- η – turbine and gear efficiency

$$\eta = \eta_{turbine} \cdot \eta_{gear} \qquad (4)$$

where:
- $\eta_{turbine} =< 0.59$ - (Betz Law)
- η_{gear} - efficiency that counts the losses in the gear mechanism.

$$4.\quad P_{medie}[W] = F_c \cdot \eta_{over} \cdot P_{eol-turbina}[W] \qquad (5)$$

where:
- F_c – capacity factor (<30%)
- η_{over} - efficiency that counts the losses in the short periods of time when the production has no utility load (and must be lost by dump load).

Other metric relations, regarding costs assessment are, among others, the following:
5. The cost of one installed W on shore is in between 1.6$ - 2$.
6. The cost of one km of low voltage electrical network is 25.000 $.

The set of rules and metric relations allow the approximation of 4 fundamental elements of an eolian project: i) cost approximation; ii) annual or multi-annual average eolian potential; iii) installed power; iv) generator's pillar height. Generation of questions to which the potential investor should offer answers, is automatically adjusted – considering the anterior answers. In case of essential questions not being answered, the process is interrupted and the client is apprised that he should document himself previously, and that he must take on the responsibility for provided data without factual coverage.

In cases in which the solicitant has the chance to be located in an area/situation in which exists, and could be indicated a general deformation grade related to the trees within the area, this exercise – ON-LINE assessment of eolian potential - may exclude, in a high proportion, direct measurements within the region.

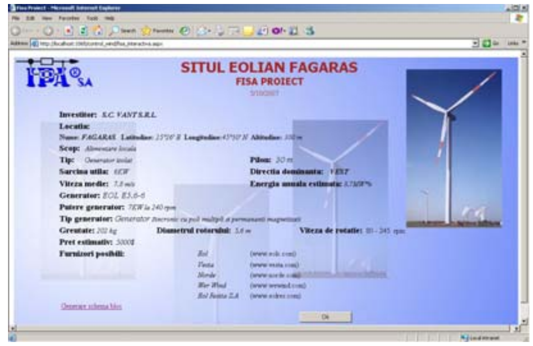

Fig. 3. Eolian site project blueprint

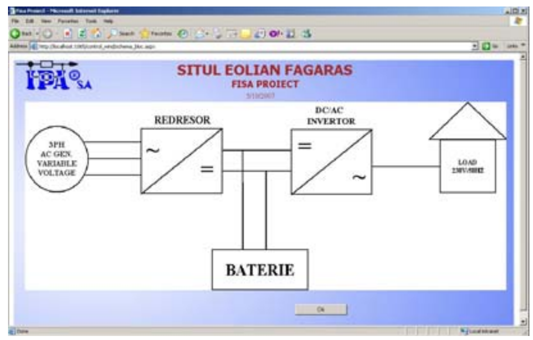

Fig. 4. Eolian site project blueprint. The case of an individual small wind generator

In cases in which the data provided to the expert system are poor or insufficient in order to apply the rules or metric relations, the next step is excluded.

Based on the answers given by the solicitant, summarized in the interactive form, the inference engine based on twelve rules and seven metric sizing relations, will generate the blueprint of the eolian site project (see figure 3).

In order to generate this blueprint, we used both the results from the interactive form, and, directly, the answers from the form. In certain cases, the expert system assumes a block diagram of the eolian generator and of the annexed installations (see figure 4).

Also, by the blueprint of the eolian site, in some cases, it is estimated an investment cost, according as in other cases, to direct measurements being imposed in order to determine the eolian potential.

3. CONCLUSIONS

In an analysis SWOT ENERO – Center for Promotion of Clean and Efficient Energy in Romania, the technical barriers are inventoried, being stated the following facts (Țânțăreanu, 2002):
"There is no precise knowledge of the wind potential since no substantial wind audit has been conducted in the country. Only a general analysis was attempted during the 1990's. There are no specific Romanian norms and standards relating to wind energy".

The proposed expert system is intended to reduce and cover these shortcomings; moreover the ON LINE implementation method will communicate, by free access, the eolian potential of the location of each solicitant.

REFERENCES

BWEA *report on onshore wind costs*. On the web: http://www.bwea.com/pdf/briefings/target-2005-small.pdf

EIA Energy Information Administration. *International Energy Outlook*. On the web: http://www.eia.doe.gov/oiaf/ieo/pdf/0484(2006).pdf

ICEMENERG - *Institutul de cercetări şi modernizări energetice*. On the web: www.icemenerg.ro

Ordean, M., D. Chiorean, I. Rogoz, C. Lehene, I. Stoian, E. Stâncel, (2006). SCADA Systems – Support for The Maintenance Management of Hydro Power Plants. In *International Conference on Automation, Quality and Testing, Robotics*, Tome **1**, pp. 238-242, Cluj-Napoca.

Ţânţăreanu, C. (2002) A Swot Analyses on the wind energy development in Romania On the web: http://www.enero.ro/ro/doc/Ebulletin4-01-ENERO_SWOT.pdf