HYDRO-EOLIAN ENERGETICAL ENSAMBLE

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Abstract: Considering both wind power drawbacks and the well known benefits and advantages of hydropower, and taking into account a general rule that stated that the power of wind plant is a fraction (30%) of wind power turbine, we proposed a hybrid eolian-hydro system for large utility system as a fine solution that has an overall integrated capacity factor better than those on we could trust before (30%). We had introduced a new efficiency factor for a better dimensioning expression of losses on dump loads in alone standing wind power plant. Finally we look for the solution on national scale, where hydro power represents a small part, fewer than 10%, as in Romania.

Keywords: Energy storage, Hybrid, Wind, Hydroelectric systems

1. MOTIVATION

1.1 Social, economic and environmental dimension of eolian energy

Social benefit that results from the development of eolian power is directly linked to the social welfare of the region in which the system is implemented. The social aspect implies avoiding money leakage of the region, and also leads to qualified employment, and employment growth. More important, involvement of the local community represents the first step to a more conscious energy use.

A renewable energy system (RES) has an important economic dimension. RES exploitation is a solution more economically feasible, considering the growth of fossil fuel prices. Diversification of energy sources is expected to reduce considerably the final electricity prices.

More important these days, is the environmental aspect of including RES systems. Renewable energy applications are much more environmental friendly than the systems based on fossil resources or nuclear power. But the implementation of a RES leads to other important environmental aspects. An important issue becomes the selection of locations and RES to be harvested, in cases where environmental damage could determine the extinction of some species or could imply fundamental impact on society's economy or culture. (Warmburg, 2006)

Shortly, we can state that the advantages of wind energy are: its renewable character, non-polluting type of energy, and free of charge.

1.2 Wind power drawbacks

The intermittent and non dispatch able nature of eolian power raises problems related to its usefulness.

The annual load factor (capacitance factor or availability), running typical between 25-30% is very low.

The fluctuation in eolian power assumes very often rapid change in last load in order to maintain grid system frequency.

Windiness varies, and an average value of wind speed for a given location does not alone indicate energy that can be produced there. In order to asses the amount of energy that can be produced in a certain location assumes the fact that we already know the distribution in time of wind speed.

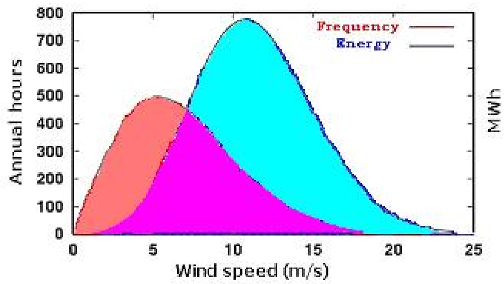

Fig. 1. Eolian resources - generally

In figure 1 one can see the number of hours with a certain wind speed (the frequency curb) and the equivalent energy produced at a certain speed (the energy curb). If we relate the two curbs the conclusion is: most of the average wind turbine comes in short bursts!

Another drawback, which represents actually a consequence of the already mentioned disadvantages, is the growth of polluting emissions generated by the thermal power stations within the energetic system; system which should cope with the variability of eolian energy.

These drawbacks are responsible for the low level penetration of eolian energy into national electric grid. Increasing eolian power penetration demands for power storage issues.

1.3 Other drawbacks

There are other protests regarding esthetic issues and regarding the ecological aspect (birds' habitat).

2. THE SOLUTION - HYBRID SYSTEMS

All the drawbacks marked with eolian power don't exist in the hydro power. Not only from an economic point of view (the cheapest energy), or ecological point of view, but regarding availability, hydropower is the most desirable energy source. So, if we combine the wind and the hydropower, the eolian drawbacks can be transformed into benefits.

An eolian-hydro power system can be seen and treated in 3 ways based on its size varying between: small sizes (local), medium sizes and large sizes. The differences among these types of systems will be discussed shortly in the following paragraphs.

The benefit from hydro/wind synergy has been exploited at several levels of site dimensions. On global scale, hybrid systems implementations are site specific and depend directly upon the available resources and the load demand of the region.

Regarding *small-scale hybrid systems*, the energy consumption being reduced, it is not mandatory to use expensive equipment and large capital in order to produce power. In such cases, the hybrid energy systems commonly used in hybrid configurations include small wind turbines, photovoltaic systems, micro hydro, diesel generators, etc. For energy storage are usually used batteries, but there are other options to consider like flywheels or hydro energy storage systems (Tarta, *et al*., 2006).
The purpose of these small-size systems is to supply energy for households for example; in which case, the power consumption registered for a single-family house is relatively small (used only for cooking, and space and water heating). The optimal hybrid system configuration is dependent of the unique set of technical and economic conditions imposed by the selected site.

An example of small sized hybrid system is presented in (Ding and Buckeridge, 2000; Tariq Iqbal, 2002), and is designed to provide power for lighting pathways at nights.

Considering a *medium-sized hybrid system*, a typical example is the implementation of a system in an island environment. Islands characteristics provide several advantages as a laboratory case for studying such kind of systems. Islands small-scale renewable energy technologies represent a high percentage of the total energy production. Islands represent an isolated, independent, closed system, suffering from water scarcity, but with a high eolian potential, that has to be used. Solar, wind, hydropower and ocean energies are highly abundant sources of energy on all islands. In such case, renewable energy technologies integration is an economically feasible solution despite the high energy prices imposed (Papathanassiou, *et al.,* 2003; Protopapas and Papathanassiou, 2004).

2.1 Large hydro-eolian systems

The novelty introduced by this type of systems is that by combining the most attractive form of electrical energy generation with the most "capricious" one, the outcome isn't a system with medium qualities; the outcome is a valid green power system. We estimate that the number of these systems will increase rapidly and significantly, developing into a general type of system. Moreover, by re-pumping water into the upper reservoir, during the availability daily period is an actual fact in energetics, which leads to energetic optimization. With other words, by re-pumping water in the upper reservoir by the aid of eolian energy, we "tame" the wind's capricious energy, by smoothing it, and we make it available in the periods of necessity. Consequently, the hydro-eolian ensemble is extremely attractive in cascaded hydro-energetic sites (Somes, Cris, Hateg, etc), as long as they are already prepared; and it assumes as investment work only pumping stations mounting. Investments made in pumping stations are important, being mandatory in an energetic system like the Romanian one (see figure 2), (Institutul National de Statistica, 2006) or the continental Europe one.

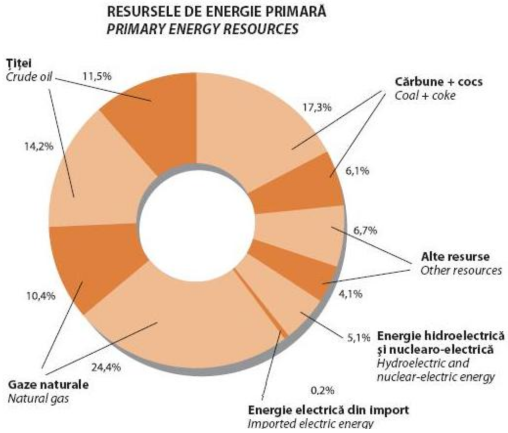

Fig. 2. Romanian energetic resources - 2003

2.1 Energetic balance-sheet and benefits

In order to pump a water flow Q from the downstream lake into the upstream lake (Δh), we need pumps with an installed power of:

$$P_{w-pump}[W] = \frac{\rho_{apa} \cdot g \cdot Q \cdot (\Delta h + h_f)}{1000 \cdot \eta_{pump}} \quad (1)$$

where:
- $P_{w\text{-}pump}$ – power [kW] of the water pump
- ρ_{apa} – water density [kg/m^3]
- g – gravity acceleration [m/s^2]
- Q – water flow rate [m^3/s]
- Δh – the difference [m] between upper and lower lakes (reservoirs)
- h_f – the head loss in the pipe [m]
- η_{pump} – pump efficiency [%].

The head loss is given by the Darcy-Weisbach equation:

$$h_f = f \cdot \frac{L \cdot v^2}{2 \cdot g \cdot D} \quad (2)$$

where:
- f – a numerical friction factor
- L – the pipe's length [m]
- D – the pipe's diameter [m]
- v – the water flow's velocity [m/s].

The wind power P_{vant} through a surface S with a speed v is:

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

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].

Only a part of this power is transformed into power at the turbine's rotor ax:

$$P_{eol-turbina}[W] = \eta \cdot P_{vant}[W] \quad (4)$$

where:
- η - turbine and gear efficiency

$$\eta = \eta_{turbine} \cdot \eta_{gear} \quad (5)$$

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

Starting from the fact that only for a fraction of time (30% at most) the average wind speed could be considered as v, and taken into account in dimensioning P_{vant}, then the average power we can count on is:

$$P_{medie}[W] = F_c \cdot \eta_{over} \cdot P_{eol-turbina}[W] \quad (6)$$

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).

So, we have:

$$P_{eol-turbina}[W] = \frac{P_{w-pump}[W]}{F_c} \quad (7)$$

Instead of:

$$P_{eol-turbina}[W] = \frac{P_{w-pump}[W]}{F_c \cdot \eta_{over}} \quad (8)$$

in a non hybrid ensemble or in a non storage situation, because $\eta_{over} = 1$ in an integrated wind-hydro power system. Here the dump load is the pump station that raises the water in the upper reservoir in order to be reused.
In other words

$$P_{eol-turbina\,/\,hybrid-ansamble} < P_{eol-turbina} \quad (9)$$

or in investment cost for the same utility we spent fewer money.

3. CONCLUSIONS

3.1 General conclusions

Eolian energy storage, in case of hydro-eolian hybrid systems, in this technical development stage, based on pumping water in cascaded hydro-sites, opens the road for eolian energy in order to be used on global scale. With efficiency growth caused by the water pumping process, we transform the most "capricious" green energy source into the most "desirable" one.

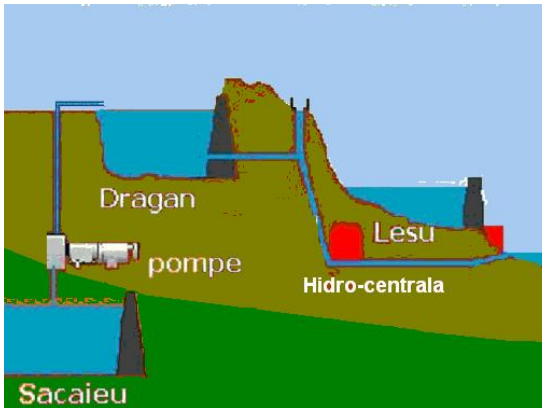

Fig. 3. Part of Crişuri hydro cascades. Sacuieu – Dragan pumping station

3.2 Particular conclusions

There are cases in which a hydro-eolian ensemble is very suited economically. For example, Crişuri hydro cascade (see figure 3), for which the pumping station is located in Săcuieu (the pumps' power is 5MW for each), or cases like Lăpuşeşti-Tarniţa, for which the pump station is in the development stage.

It must be specified that in case of Sacuieu-Dragan ensemble, in which the pumping station already exists, the investments for the hydro-eolian ensemble is reduced only at investments for the eolian turbine.

The closer we get to the hydro power plants located in the mountains, the closer we are to the electrical national grid, where there are good communication pathways. This involves a situation, in which conditions for combining hydro and wind power, leads to a superlative from an economic point of view.

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