First published at http://www.fe.up.pt/~feliz in 30 November 2006, and registered with the Portuguese Society of Authors

Double Convergent Wind Turbine: To Follow the Wind Direction

© J. Manuel Feliz-Teixeira

November 2006

Email: feliz@fe.up.pt
Url: http://www.fe.up.pt/~feliz

KEYWORDS: Renewable energy, wind power, "convergent" and "divergent" turbines, wind tracking systems, inexpensive solutions.

ABSTRACT

In a previous article we have introduced the concepts of "divergent" and "convergent" turbines (Feliz-Teixeira, 2006), and proposed a wider usage of the idea of "convergence" in wind systems. Here we present a double turbine for wind power capture which uses precisely this concept and naturally has the ability of aligning itself with the direction of the wind flow. Although the model presented here is an experimental prototype, it has been observed that it operates with very promising performances. In this article we show the turbines' structure and present a first model of a rotor a metre in diameter. One may get a better idea of how this system performs by watching two short videos at http://www.fe.up.pt/~feliz.

1. **Introduction**[1]

For centuries wind energy was used in the fields of transportation (sailing) and water pumping and grain grinding (mills), but since the last century it is also being used for electrical power generation (D.W.I.A., 2003), and, even if indirectly, for flying (in effect, airplanes fly due to the wind invoked when running at high speeds). In the last decades, however, with the development of new materials and the increase in generators' efficiency, and also due to the strong applause coming from a large and growing number of citizens arguing for cleanness and renewable, wind energy traversed from an initial period of uncertainty to a kind of modern trend. In each international oil crises, like in the *Iranian Revolution* (eighties) and more recently the Anglo-American *Iraq Invasion*, a generalised interest in renewable energies could also be observed, not only due to the economical advantages of such a move, but, as we said, also due to the development of a superior consciousness in the populations about the finitude of Earth resources. Renewable energies are therefore no longer merely a simple possibility, but they have become an approach to living, a philosophy of existing. In effect, although under the strong pressure of the crazy-consumption-style promoted by certain wealthy companies, populations seem to become more interested not only in using non-destructive processes for producing energy, but also in reducing the excessive consumption which have been installed in most of our societies, mainly in the West, during the last century's excitement age. "*The Earth is a finite system*", Lehoucq (2005) argues in a wise article regarding present energetic resources versus demand figures. Understanding the importance of opting for a renewable process shows, in particular concerning energy production, and in our opinion, an evolution to a superior mindset. After all, we may not forget that *Life* includes humans, and not the opposite, humanity being only a small part of overall existence. But another aspect to take into account is the climate change, which is right there in front our eyes, ready either to be understood or to be ignored, depending on our wisdom, of course.

The system presented in this article, in its almost

---

[1] We would like to state that any novel ideas presented in this article are to be considered anti-patent, that is, they are offered to the public domain by its author and anyone may implement them freely without the need for any special permission, other than a symbolic contribution in order to cover the author rights. Please contact the author, in this case.

naive simplicity, aims to contribute to the spreading of such a non-destructive-renewable-energy frame of mind, particularly concerning energy production. Throughout such a system, one may also wonder why one often get the impression that simple and inexpensive solutions are still ignored, while expensive systems systematically win the race. Could it make any sense that at a certain point energy *must not get cheaper*?

2. Divergent and convergent turbines

Most of the wind turbines currently in use are of the type we consider "*divergent*" (Feliz-Teixeira, 2006). A *divergent* turbine, schematically shown in figure 1, is considered a system which tends to enlarge the flow of the wind, therefore introducing not only a reduction in the wind speed but also a certain dispersion at the system's boundaries. Due to the tendency for moving the wind flow from the central region to the peripheral zones, and also due to the blades' design and the expensive technology used, these systems are alleged to be less efficient and much more expensive than certain easy-to-build *convergent* ones.

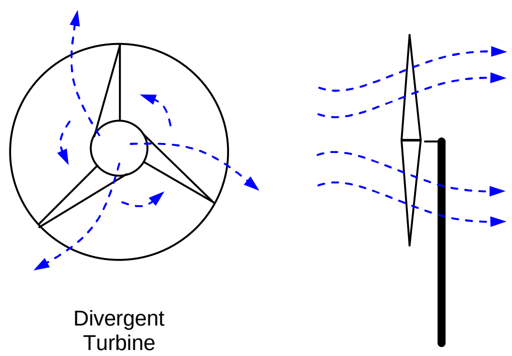

Fig. 1 Expected lines of force induced in the flow in a *divergent* turbine running to the left. Frontal and lateral views.

On the other hand, in *convergent* turbines, depicted in figure 2, we expect the wind behaviour to be substantially different, concentrating the flow instead of dispersing it, and therefore avoiding some of the effects that contribute to reducing the efficiency of the system. Besides, these systems have a transparent central spot where the wind can pass freely. It is believed that this will probably create a central low pressure which is responsible for sucking the peripheral wind to this central zone. And that is also believed to contribute to a higher efficiency than expected in usual turbines.

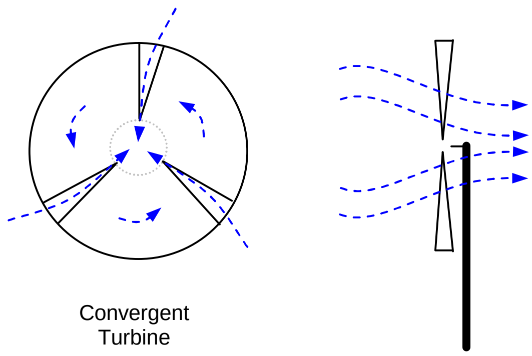

Fig. 2 Expected lines of force for the *convergent* turbine.

As mentioned earlier, the double turbine system presented in this article uses this last principle.

3. Why double turbines

When using the usual *divergent* wind turbines, it perhaps makes little sense to install two turbines in a row for receiving a higher quantity of wind power along the same axial direction. With the dispersive behaviour they have, and since they may easily enter turbulent regimens, this would probably produce only a few positive results, unless the turbines would be separated by a long distance. It is perhaps due to this fact that double rotors of divergent turbines are not usually seen in wind systems. Exceptions are the multi-rotor horizontal systems recently proposed by Douglas Selsam[2], in the USA (Wikipedia, 2006).

But when we think on using *convergent* turbines, it becomes somehow reasonable to think of trying to collect also the power of the wind that passes freely through the transparent central spot. Associating two turbines with a certain separation between them (we suggest that this distance can be of the order of the rotor's radius), will in principle let us capture torque in two sections of the flow. These two contributions will certainly add, and the total power captured by the system will increase in accordance. From the observations made with the *double convergent* system we have built, we may note that we had the impression that the wind passing through the central spot tends to "open" again after traversing the turbine, and may therefore also be captured by a similar turbine strategically located some distance away. This idea is better

[2] http://www.selsam.com

depicted in figure 3.

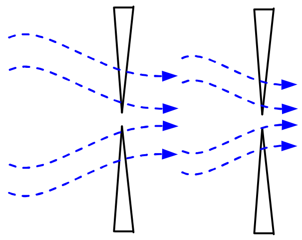

Fig. 3 Probable lines of force in an association of two *convergent* turbines.

If this is true, one may even build a static system with good efficiency by simply installing two *convergent* turbines attacking the same axis of rotation, for example, as shown in figure 4. We expect that, in places where the wind maintains a preferential direction, this can be an interesting solution, since its instalation is simple and there is no need to worry about any special control. In extreme situations, the system can be repositioned in accordance with, in order either to get the maximum power or for protection during storm conditions. Such a control could be made electronically and in the overall structure, for example.

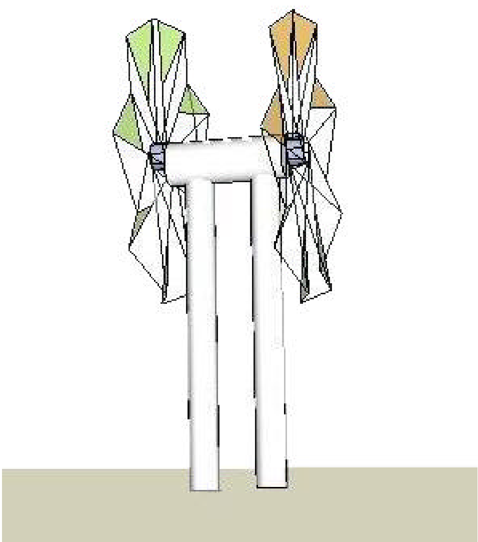

Fig. 4 A static double *convergent* turbine system.

Apart from these comments, we also believe that *convergent* turbines will probably resist strong winds much better than *divergent* ones, since they tend to be more "transparent" to the wind flow. That would also mean substantially less control.

4. On following the wind direction

Most of the actual wind systems which track the wind are based on the tail vane principle. Some of these systems use this principle also to protect the wind system from excessive wind speeds, turning it appropiately above a certain speed limit.

The usage of *convergent* turbines also led us to test other solutions for tracking the wind, and these solutions showed to work perfectly if the machine is properly designed. The physical principle is the same as that of the tail, but now the tail is replaced by the second turbine (fig. 5).

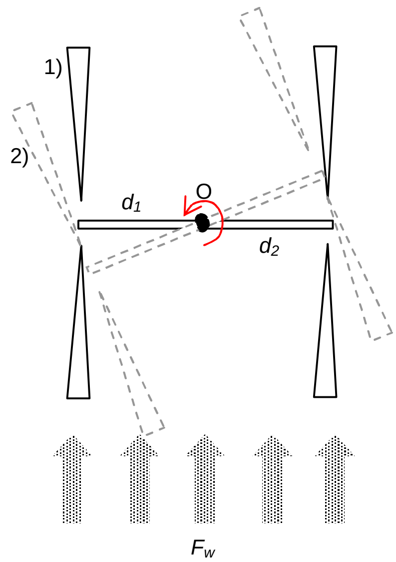

Fig. 5 Tracking the wind direction with a double *convergent* turbine (top-view).

Supposing that the system starts in the position 1), with the two turbines mounted around a common axis of horizontal rotation (O), and parallel to the wind flow (F_w), the structure will rotate acordingly to the difference in torque introduced by the wind force in the two parts of the system. If, for example, $d_2 > d_1$ and the exposed area of both turbines (A_j) are equivalent, then the system will rotate as shown in the figure. Care must be taken, nevertheless, to avoid deceptions, since what must be compared is not only distances, but torques, which are computed by the product $F_w \times A_j \times d_j$, where F_w is the force of the wind per unit of area. This means that there are two degrees of freedom in which the builder can act, considering F_w common to both turbines: the distances d_j and

First published at http://www.fe.up.pt/~feliz in 30 November 2006, and registered with the Portuguese Society of Authors

the areas A_j.

There are, however, some subtleties in this method which may result in a poor tracking performance, and induce a continuous horizontal rotation in the structure. In effect, the structure must be properly dumped in order to avoid this "excessive" rotation, and the distances (d_j) and areas (A_j) properly chosen. To avoid entering further mathematical details, we may say that using a larger blade area in the second turbine will surely help. If this is resolved, the system will perform perfectly.

Another important aspect to bear in mind is the *angular momentum* produced by the rotors at high speeds. As we know, by the law of conservation of angular momentum, the higher the rotational speed, the higher the momentum and the more difficult it is to rotate the structure horizontally. So, when one tries to force the turbines to change the plan of rotation, in order to adapt them to strong wind conditions, for example, stronger reactive forces are also induced in the support structure. If the turbine is quite light, this effect is reduced, but in systems for high power, with large areas of exposure to the wind, this effect must be studied before installing the machine. The *convergent* system shown in figure 6, for example, uses triangular blades mounted as "flags" in order to rapidly reduce the exposed area in high speed winds.

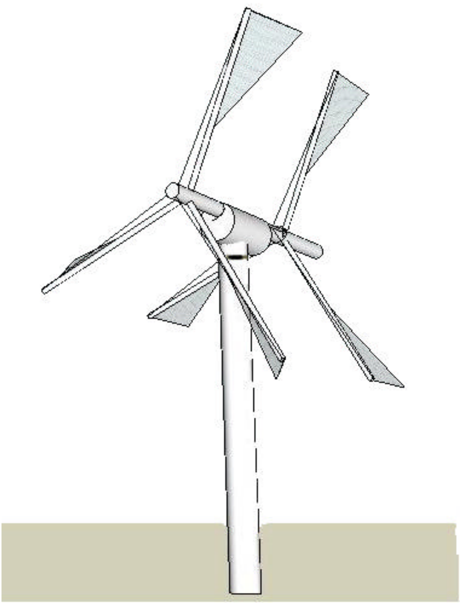

Fig. 6 Another example of a double *convergent* turbine, with the ability for tracking the wind direction and reduce the exposed area during high speed winds.

5. A first prototype

The prototype presented in this section (fig. 7) uses two turbines built with the technique exposed in Feliz-Teixeira (2006). Please refere to this article for any details about the turbine construction. This *convergent* system can also be seen running, and tracking the wind, in two short videos offered at the Internet address http://www.fe.up.pt/~feliz.

Fig. 7 Our double *convergent* turbine 1m in diameter, built of wooden sticks and blades made of TESA® adhesive tape. The system has the ability for tracking the wind.

This system uses two *convergent* turbines made of wooden sticks, and blades built of TESA® adhesive tape, a surprising resistant and light material. This tape can be used for making the blades of certain convergent designs, making them very attractive in terms of simplicity and costs. Even if one can hardly notice from the picture, each of these turbines has a tense wire around to confer rigidity to the structure. This method can also be seen in the typical Portuguese windmill, which inspired this turbine design.

The two turbines are then fixed onto a single horizontal shaft, separated by a distance of around 0,5 m. The shaft is then placed in a vertical support where it is able to rotate in the horizontal plan. With a diameter of 1,0 m, this rotor is expected to receive a direct power of around 450 *Watt* at wind speeds of 35 *Km/h*. Notice that the blades of the first turbine are thinner than the ones of the second, so that the system can better adapt to the wind direction. The efficiency of the system is still to be measured, and we would like to receive some feedback data from those readers who may be interested in helping to test this idea. We anticipate, anyhow, promising results, since this is a double system which is expected to capture the wind power in two plans and this way increase the total torque induced in the shaft.

This system has also been observed performing perfectly during a windstorm with winds in the order of 70 Km/h, and the tracking system previously disabled. In the end, the vertical support was broken but the turbine system remained completely unharmed. We could not record any videos of this situation, unfortunately, since we observed the storm during the night.

6. The Wind Forest

Somehow surprisingly, it is common today to find a strong inclination for taking into account aesthetic considerations when making the decision of which wind technology and system to use. In some way it is understandable, since machines like these are in certain conditions to be imposed for several decades on the natural environment; it seems a good idea to choose their design also in a way that it affects the tranquillity of nature as little as possible. The tranquillity of nature, however, is not properly our own tranquillity, since nature for instance feels the wind blowing and the shaking of its elements, like the trees, for example, as rich phenomena, while most of us choose to stay at home in moments like these. What seems good for us does not always have to be good for nature, we would say. In that sense, efficiency and reliability could be the universal measure instead, and perhaps the systems that we would install would simply be the best ones in terms of efficiency and reliability. That is, the ones which fit best with the natural laws. This issue is frequently touched apropos the type of tower that technicians and designers must choose for supporting the wind turbines, for example. Some people avoid the use of metal towers, which can be much more transparent to the wind than the usual single towers, simply because they do not look as nice as these ones. Our point is this: we believe that if a system is really good, the human mind will naturally adapt to it and recognize it as somehow making part of the laws of nature, even if it looks strange at first sight, perhaps. We must not forget that it is, somehow, of this strangeness that technology and science live. The best science and technology have always moved in the domain of the strangeness, and not in the opposite, the normal, the previously fitting and easy-to-absorb already "humanized" universe.

We have chosen this little introduction in order to present what we see as an interesting element of technology design, which we have named the *Wind-Forest*. The double turbines resemble trees (fig. 8), which will move as the other trees move when installed in the natural environment. If there is calm, they will move calmly; if there is storm, they will move fast, as it is normal for a tempest.

Fig. 8 Double *convergent* systems located near each other, resembling trees.

Since these turbines can, in principle, be located much nearer to one another than those of *divergent* systems, which must be separated by some hundred meters, probably it would be easy to build a wind park for electrical power generation resembling a kind of forest, a technological forest, the *Wind-Forest*. In effect, if the expected transparency of these systems will let us install them much closer than usual, this is possible. There is in this idea the consideration not only of more power per square metre of occupied land, but also more power generated by each double turbine. This, in conjunction, could perhaps allow the use of systems with smaller diameter located not as high as the ones of today, in order to get the same amount of energy. This is, of course, a little divagation, which would need to be studied in detail. It represents, however, a certain wish of seeing technology resembling the design of the natural structures too. That would be good. Or even superb.

Thus, instead of being planted solely at the top of the mountains obstructing our view of a clean and peaceful sky, these *Wind-Forests* could perhaps be planted along the slope of the hills, or in any plain landscape, in that way becoming part of nature. Blades may even be painted green, when needed, for example. We end this section with an artistic view of this idea, and with no further comments:

Fig. 9 The vision of a *Wind-Forest*.

7. Conclusions

We presented here a *double convergent* turbine for wind power capture. The results obtained by inspecting the system operating are stimulating and led us to believe that this can perhaps be a good solution to be used in practice, at least in systems of small and medium scale. The turbine structure proved to be reliable in terms of wind response and of rigidity, being perfectly rigid at wind speed in the order of 70 Km/k. With respect to its construction, this system is simple, flexible and inexpensive. Several systems of the kind could probably be installed as a dense area for collecting the wind power and transforming it into electrical energy, leading to something resembling a forest of wind systems, which we called *Wind-Forest*. Most of the ideas presented in this article are still to be confirmed in practice by means of some tests and experiments.

Author Biography:

J. Manuel Feliz-Teixeira graduated in Physics in the Faculty of Sciences of University of Porto, Portugal, and received an MSc and PhD from the Faculty of Engineering of the same university. His work has been related to various matters, from optical communications, solar energy and seismology to, more recently, the simulation of complex systems in management science, like warehouse and supply chain. His PhD thesis is on “Flexible Supply Chain Simulation”.

Corten, G. P. (2001). *Novel Views on the Extraction of Energy from Wind.* Paper presented at the EWEC 2001, Copenhagen.

D.W.I.A. (2003). *A Wind Energy Pioneer: Charles F. Brush*. Danish Wind Industry Association (online). from http://www.windpower.org/en/pictures/brush.htm

Feliz-Teixeira, J. M. (2006). Low-cost Convergent Turbine for Wind Power Usage. *Online publication at http://www.fe.up.pt/~feliz*.

Gorban, A. N., Gorlov, A. M., et al. (2001). Limits of the Turbine Efficiency for Free Fluid Flow. *Transactions of the ASME, 123*, 312-317.

Lehoucq, R. (2005). Contagem Decrescente. *Le Monde Diplomatique (portugese version)*, 11.

Wikipedia. (2006). *Wind turbine*. Wikipedia, the free encyclopedia. Retrieved November 2006, from www.wikipedia.org