RESEARCH NEWS

# Artificial Tornadoes: A Novel Wind Energy Concept

Wind power and other unconventional energy systems have until recently been bereft of the kind of engineering study and research attention that have been lavishly applied to petroleum and nuclear energy sources. So it is not too surprising that a host of heretofore unexploited opportunities are now coming to light in the form of more efficient solar collectors and improved wind generators. A novel entry is a recently disclosed wind system that would utilize intense vortices, not unlike miniature tornadoes, inside large circular towers. This tornado-like wind system, preliminary results indicate, is capable of generating far more power than conventional wind turbines of similar size, and it is attracting considerable interest among aerodynamicists and energy researchers.

At the root of the new concept is the use of the tornado-like vortex and the tower in which it is generated to effectively collect and concentrate wind energy from a far greater volume than the air immediately around the turbine blades. Tornadoes, of course, are among the most destructive atmospheric phenomena on the earth, deriving their deadly efficiency not only from high winds but also from the extremely low atmospheric pressure within the core of the vortex. (Buildings over which tornadoes passed have been known to literally explode from the pressure difference inside to outside.) And in the concept proposed by James Yen of Grumman Aerospace Corp., it is the pressure difference between the core of the vortex and ambient air, and not the wind field itself, that drives the power-generating turbine.

Wind energy is collected by a stationary, open-top tower; wind enters through vertical slots or ports that are open on the windward side but that are otherwise closed by means of movable vanes (Fig. 1). The air flowing into the tower spirals in toward the center to form a vortex and moves upward. As the air moves inward it gains velocity, through conservation of angular momentum, and as the vortex becomes more intense, atmospheric pressure at its core decreases rapidly. Eventually the flow emerges from the top of the tower as a rapidly swirling mass of air which interacts with the wind blowing over the tower. The wind blows away the top of the vortex, restoring atmospheric pressure at the top of the tower and enhancing the low pressures achievable within the tower; in the process, the wind passing above the tower is slowed down, indicative of the fact that energy is being extracted from a large region. In effect the tower converts a low velocity wind into a vortex in which much higher velocities and low atmospheric pressures are achieved.

To tap the vortex energy, a turbine is placed in the tower floor beneath the low pressure core. The pressure difference between the ambient air beneath the tower floor and the low pressure core within the vortex drives a flow of air through the turbine and up the core of the vortex. This secondary flow of air, as it turns out, actually enhances the stability of the vortex. And because the wind energy has been concentrated, a much smaller and presumably less expensive turbine can be used than would otherwise be necessary.

The power generated by a turbine in constant temperature conditions depends on both the pressure drop across it and the kinetic energy of the fluid, a quantity which depends on the square of the wind velocity. For ordinary wind speeds (less than 100 kilometers per hour), however, the effect of pressure is theoretically very much larger. The vortex concept is a method of capitalizing on this difference, and it has other advantages as well. Because the wind is continuously slowed in passing through a conventional wind turbine, only about 0.6 of the kinetic energy can be extracted; in the vortex, however, this condition does not apply, since the wind is decelerated only after it leaves the tower. The result, according to Yen's calculations and wind tunnel experiments, is very high power output from the turbine.

The turbine itself would seem to be easier to build in Yen's design. Because it would not be high in a tower, vibrations that could interact with the tower would be less of a problem; because the turbine would not be directly exposed to incoming winds, damage from high winds would be less likely. Both considerations would ease the mechanical constraints on turbine materials and design. Moreover, according to Yen, the turbine could operate at much higher rotation rates than a conventional wind turbine, thus reducing the extensive gearing needed to couple it to electric generators. And the turbine would be near the ground, facilitating maintenance, with a vertical shaft that could be readily coupled to flywheels for energy storage.

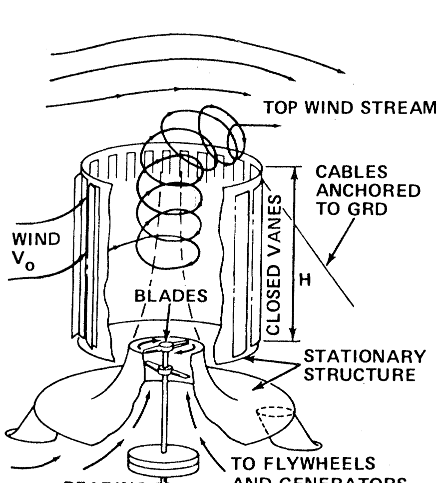


Fig. 1. Schematic of a tornado-like wind generator [Source: James T. Yen, Grumman Aerospace Corporation]

A number of questions, such as the design of the entry ports into the tower and their movable vanes or shutters to facilitate growth of the vortex, the stresses to which the tower itself would be subjected, the environmental effects of the vortices, and, overridingly, the cost of such a system, remain to be explored. But Yen's estimates of their capabilities, borne out by his admittedly preliminary experimental results, are such as to encourage further consideration. He suggests that it may be possible to obtain as much as 1 megawatt of power from a turbine less than 2 meters in diameter in a tower perhaps 60 meters tall and 20 meters across. Conventional wind turbines, in contrast, would have to approach 65 meters in diameter, nearly the limit of their size with materials of ordinary strength, to reach equivalent power. And although economic considerations may limit the practical size of tornado-like wind generators, Yen sees no inherent technical limit and talks speculatively in terms of individual units as large as 100 to 1000 megawatts. Thus, whatever the eventual size of such generators, their potential for greater power from smaller turbines, and thus for lower costs, would appear to be considerable. Yen believes the system may prove competitive with coal-fired power plants in some regions.

Interestingly enough, Yen attributes his idea to the serendipity effect—he was not working on wind generators directly when the concept occurred to him. In fact, he is employed not in the energy section of his organization but in its basic research division. However, he happened to see a diagram for an advanced wind generating system that a colleague was working on and it set him to thinking about the properties of vortices. The incident is evidence, perhaps, that the limits of the possible are not yet really known for many unconventional (or simply underinvestigated) energy sources, and that R & D programs broad enough to include basic studies may yield some fruitful surprises.—ALLEN L. HAMMOND