1 New Concepts

Traditional horizontal wind turbines continue to evolve and become more efficient through a combination of improved rotor aerodynamic designs, introduction of active feedback aerodynamic control, and the use of better materials. Even with these improvements, such wind turbine designs are still constrained by the Betz limit, which specifies the maximum amount of energy that can be extracted from the wind to be 59.3% of the available energy. Thus there is an interest in developing new, less traditional approaches that might overcome the Betz limit, or otherwise offer other benefits. This section will discuss some of these possible concepts listing their potential benefits, as well as possible limitations.

1.1 Vertical Axis Wind Turbine

Vertical axis wind turbines (VAWTs) are receiving a second look as an alternative to HAWTs. The chief advantages are that individual VAWTs utilize less area, do not depend on the wind direction, and can be more closely packed in arrays in wind farms to provide a potentially higher energy density than wind farms made up of HAWTs. Because of their slow rotor spinning speed, VAWTs are also indicated to be more environmentally friendly, with virtually no aerodynamic noise, and with a much lower impact on flying species such as bats and birds.

An example of a modern VAWT is shown in Figure 1. This is a type that are based on a helical rotor shape. The one shown in the figure is a prototype known as "Windspire" that is advertised to produce 2000 kW-hrs per year for 12 m.p.h. average wind speeds. Such a system could be suitable for single homes as a supplemental power source.

Figure 1: Example of modern vertical axis wind turbine designs.

Another style of wind turbine that is marketed as a "home appliance" is shown in Figure 2. This wind turbine, referred to as the "Jellyfish", is 36 inches in height. It can generate approximately 40 kW-hr per month, which is enough to light a home that uses energy efficient light bulbs. It has a solid state controller and a variable induction generator that is designed to connect to the electric energy grid. The right part of Figure 2 shows a concept where a pair of Jellyfish wind turbines could provide supplemental electric power to a highway.

Figure 2: Less traditional vertical axis wind turbine design with a concept for use over highways.

A pilot concept for wind farms made up of groups of small VAWTs is shown in Figure 3. This pilot wind farm consists of 10 m. tall wind vertical wind turbines that each generate 3-5 kW of power. They are grouped in pairs where the two wind turbines in the pair rotate in opposite directions. The designers indicate that this minimizes the amount of drag on each wind turbine in the pair, enabling them to spin faster, and maximizing the power efficiency of the farm as a whole. A criticism of the vertical wind farm approach is that because of the use of smaller wind turbines, the number of wind turbines and the land area required, would significantly exceed that if larger conventional HAWTs were used.

An alternative to a wind farm of smaller VAWTs is the concept for a Gigawatt rated vertical wind turbine that is shown in Figure 4. This is a magnetically levitated (MagLev) wind turbine concept that would be scaled to be capable of providing power to 750,000 homes (notice the helicopter rendering at the top of the image for scale). The magnetic levitation would eliminate the friction on the bearing support at the base of the wind turbine. A criticism of the concept is that the electro-magnetic bearing requires a continuous amount of energy. Most likely this would utilize cryogenic cooling to minimize electric losses in the bearing. The concept was invented in 1981 and there are reported to be several of the MagLev wind turbines operating in China. The power rating of these is not however published.

1.2 Wind Focusing Concepts

The Betz limit results from having an open rotor disk about which the air can be deflected as a result of the blockage it presents. A number of concepts have emerged that are designed to address this. One approach is the addition of a duct that encircles the rotor. One of these is marketed under the name "Wind Lens". It was developed by a group at the

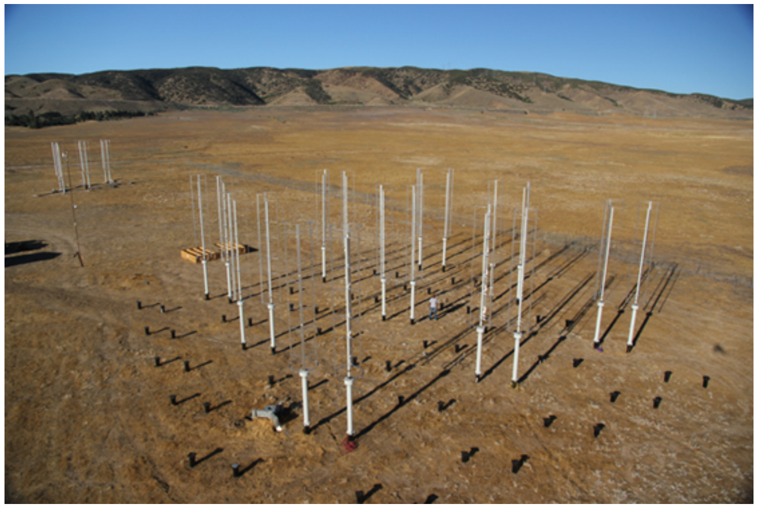

Figure 3: Photograph of a pilot test of a concept for wind farms made up of small VAWTs.

Figure 4: Concept of a giant vertical axis wind turbine mounted on magnetic levitating bearings.

Kyushu University Research Institute for Applied Mechanics (RIAM) in Japan. The wind lens consists of a circular contraction duct that fits around the rotor as shown in Figure 5. The air that enters the circular duct is accelerated and more importantly restricted from deflecting around the rotor disk.

Another concept aimed at directing the wind around a horizontal wind turbine is shown in Figure 6. This concept is marketed as the "Wind Donut". It consists of a passive concave mound that is placed at the base of a horizontal wind turbine that is intended to accelerate

Figure 5: Examples of horizontal wind turbine duct concepts.

the air approaching the rotor disk. The designers of this concept claim that it increases the turbine power output by 15-30%. They further highlight the low cost of implementation that can be retro-fitted to existing wind farms.

Figure 6: Artificial hill concept to accelerate air flow around wind turbines.

A concept that is a combination of wind orienting and rotor ducting is show in Figure 7. This consists of a funnel that collects the wind and then passes it through a duct in which a wind turbine is located. The system shown in Figure 7 was designed by SheerWind Inc. where they claim the wind turbine produces 600% more power than conventional wind turbines. This is a result of accelerating the wind speed by a factor of four through the duct. As a result of the funneling effect, they indicate that the system can generate electricity in wind speeds as low as 1 m.p.h.

The concept of focusing the wind for energy harvesting has also entered into building architecture. An example is shown in Figure 8. In this case the facade of the two building spires are curved and tapered to direct the wind in the space between the spires, where three horizontal wind turbine rotors are located. The wind turbines are 29 meters in diameter and are forecast to provide 11-15% of the electric power for the building.

Figure 7: Wind capture and duct concept to accelerate air flow around wind turbines.

Figure 8: Building design to incorporate wind capture and acceleration to drive wind turbines.

1.3 Bladeless Wind Turbine Concepts

Both horizontal and vertical aerodynamic wind turbines rely on converting aerodynamic lift on rotating wing sections into electrical work. The following are complete departures from these concepts that are categorized as "bladeless wind turbines". One of these developed by Saphon Energy in Tunisia is shown in Figure 9. It involves a flexible disk that oscillates and deflects in a wind stream. The motion of the disk drives hydraulic pistons that turns an impeller pump that drives an electric generator. The designers claim that the design overcomes the Betz limit.

Figure 9: Flexible wind disk bladeless wind turbine concept.

Another bladeless concept is referred to as the “Wind Stalk”. This consists of a flexible pole that is attached at its base to a stack of photoelectrically active disks. The flexible poles are designed to deflect and oscillate in the wind through a combination of their aerodynamic drag and wake instability. Their motion is converted into electric energy by the piezoelectric generators. Figure 10 shows a concept of hundreds of wind stalks in a wind farm that is intended to resemble a field of wheat.

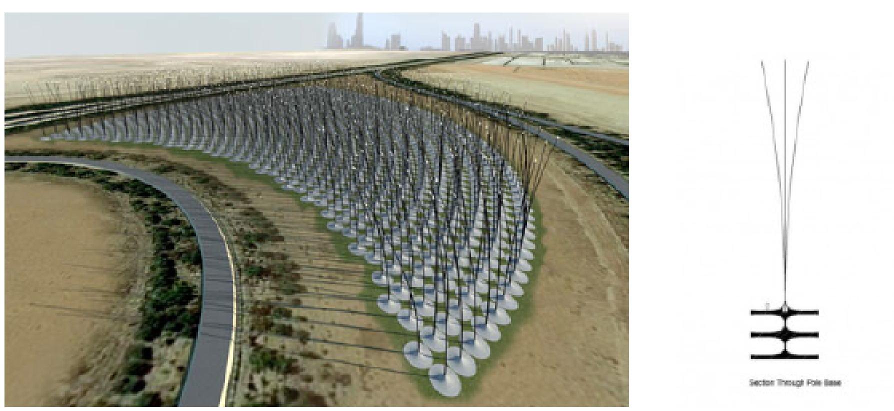

Figure 10: Flexible wind stalks bladeless wind turbine concept.

1.4 Airborne Wind Turbine Concepts

There are a number of airborne wind turbine concepts. The motivation for these is to place the wind turbines at high altitudes that are at the edge of the atmospheric boundary layer where the highest wind speeds occur. The concepts in Figure 11 are examples of helium-filled lighter-than-air flying wind turbines. These are tethered to the ground by a electric transmission line. The concept on the left part of the figure is designed as a duct that accelerates the air past horizontal rotor disk. In the concept on the right part of the figure, the lighter-than-air wind turbine rotates around a horizontal axis to generate electrical energy. Both concepts can orient themselves with respect to the wind direction.

Figure 11: Examples of lighter-than-air flying wind turbines.

An example of a rigid tethered flying wind turbine system is shown in Figure 12. This is referred to as an “energy kite” by the Makani designers. The design shown in the left part of the figure has a 30 foot wing span, and is intended to generate 30 kW of power. It will will use a strong flexible tether that will allow it to reach altitudes of 80-350 meters. As shown in the right part of Figure 12, it is designed to fly in a vertical oval that subtends these two altitudes.

Another type of tethered wind turbine known as the “Sky Serpent” is shown in Figure 13. This consists of an array of small rotors on a single flexible shaft that is attached to a generator. One end of the shaft is held aloft by helium balloons. The objective of the concept was to increase efficiency by insuring that each rotor catches undisturbed air. This requires achieving an optimal angle for the shaft in relation to the wind direction, and having an ideal spacing between the rotors.

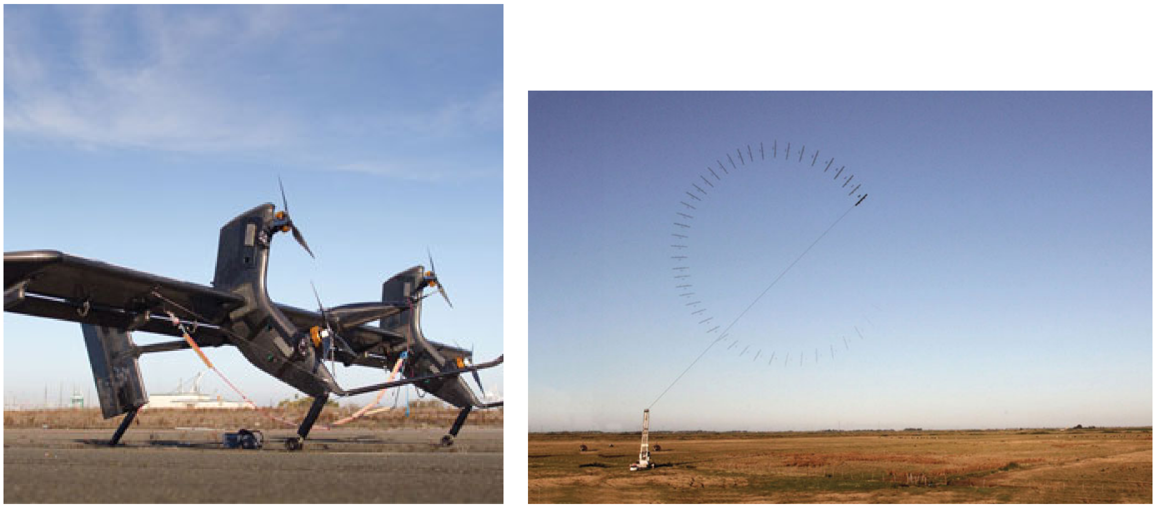

Figure 12: Rigid-wing tethered flying “energy kite” wind turbines.

Figure 13: “Sky Serpent” tethered flying wind turbines.

1.5 Other Concepts

There are a number of other wind energy concepts that have also emerged. The following summarizes a number of those.

Lateral axis wind turbine. The lateral axis wind turbine design shown in Figure 15 rotates on a horizontal axis similar to a Ferris wheel. The rotor blades rotate in an epicyclical path around the central shaft. The advantages are unclear.

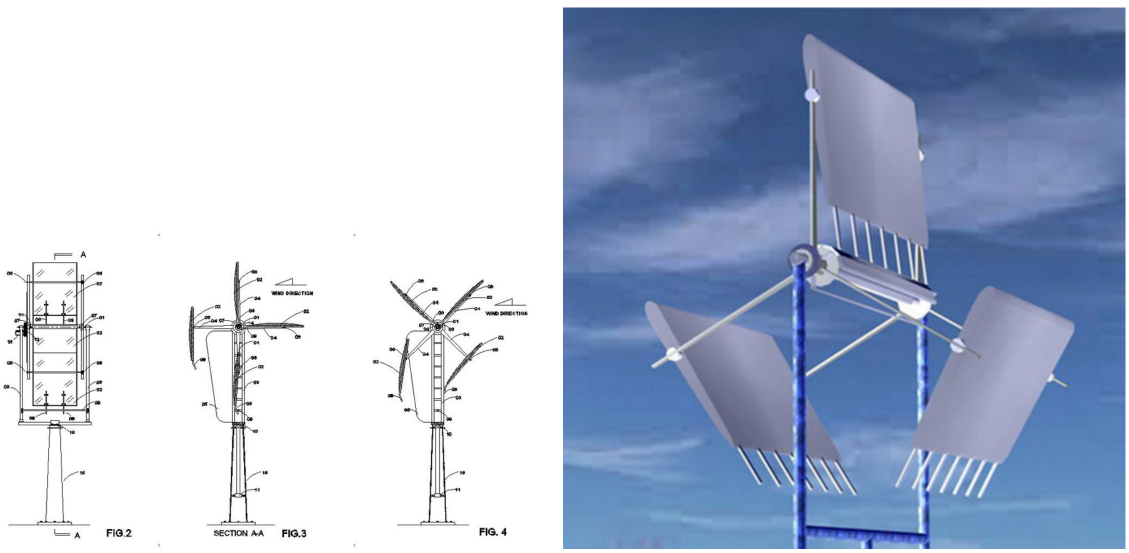

Figure 14: Lateral axis wind turbine design.

Tree-shaped wind turbine. The tree-shaped wind turbine is an esthetic approach to wind energy that can be placed in an urban environment where they can be used to exploit small air currents flowing along buildings and streets. They also could eventually be installed in backyards and urban centres. The 26 foot high trees use tiny vertical blades inside the "leaves". They can generate electricity in wind speeds as low as 4.5 m.p.h.

Wind turbine phone charger. The wind turbine shown in Figure 16 is a portable 12 in. tall cylinder three-bladed VAWT. It has a built-in 15,000 mA-h battery, a 15W generator, and a USB port. It can charge battery operated devices with USB ports, such as the pictured cell phone.

Figure 15: Tree-shaped wind turbine design.

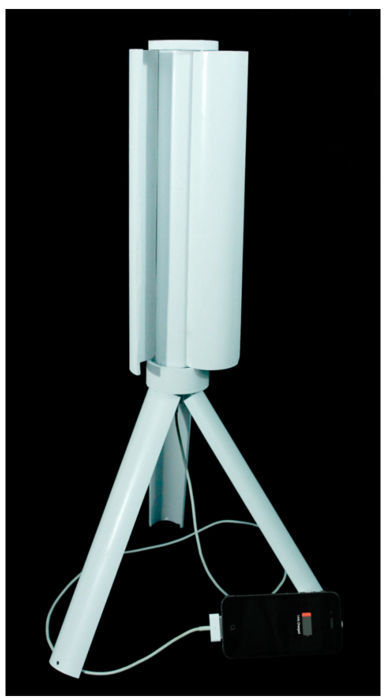

Figure 16: Wind turbine phone battery charger.

Miniature wind turbine. The researchers in University of Texas Arlington have designed an ultra-tiny micro-windmill shown in Figure 17 that they claim is capable of generating enough wind energy to recharge cell phone batteries. The scale of these tiny wind turbines is such that 10 of these can be mounted on a single grain of rice.

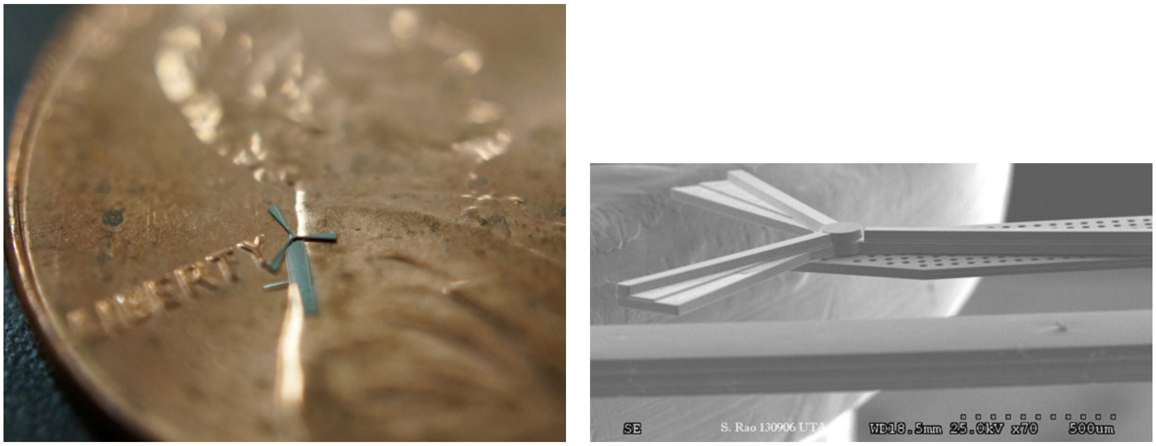

Figure 17: Ultra-tiny micro wind turbine design developed at the University of Texas Arlington.

Wind powered street border lights. A new concept for a wind generated road border lighting system is shown in Figure 18. These are VAWTs that rotate due to the wind generated by passing vehicles. The energy is captured and stored during the day time, and used to illuminate the core of the turbines at night, marking the edge of the roadway.

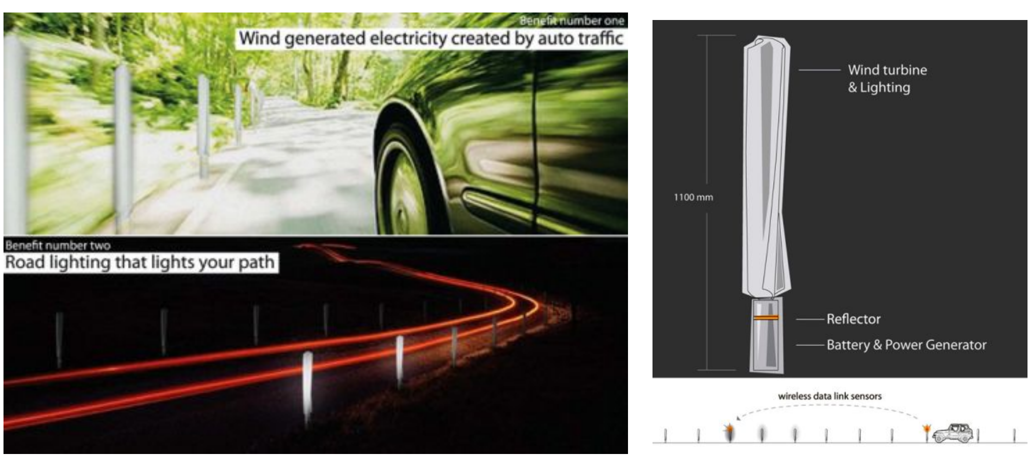

Figure 18: VAWT road lighting concept.