ARE WE REALLY BUILDING THE BEST WIND TURBINES?

A new turbine design uses old-fashioned know-how to reduce total capital costs, generate more power, and lower maintenance costs. Is this the future of wind turbine technology?

By Glen Lux and Marko Yanishevsky

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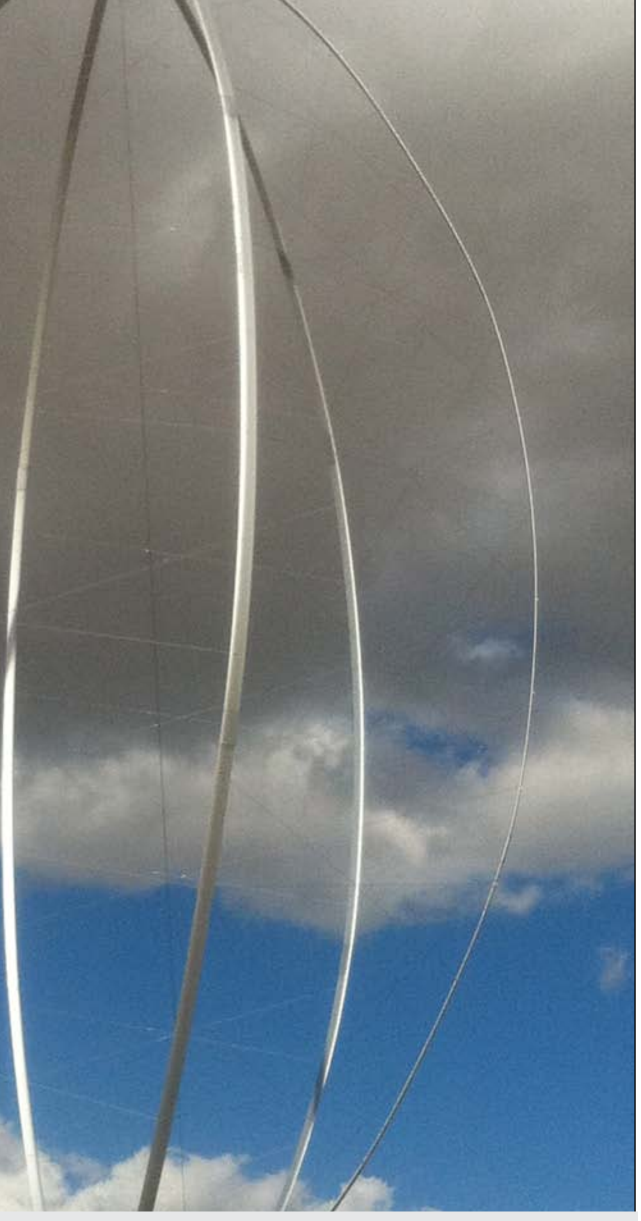
EVER SINCE THE WRIGHT BROTHERS USED cables to strengthen the wings on their early planes, this approach has been perceived as outdated, or simply put, old fashioned. However, the Glen Lux designed, built, and patent pending Vertical Axis Wind Turbine (VAWT) is unique in that it uses this highly effective technology to reinforce its multiple blades. For example, the Lux VAWT design with a one-megawatt power generating capacity has one-third the total weight of a comparable Horizontal Axis Wind Turbine (HAWT), mainly because it does not rely upon a tower or central column. The Lux VAWT also uses the same blade profile along the entire blade length, thus the reduced construction inputs drastically reduce the capital costs.

The Lux VAWT has six evenly spaced blades that are curved into an elliptical shape. The chord length of the blades is shorter than previously used blades, but the structural part of the rotor is reinforced by the use of several small diameter cables. By strategically attaching the cables to the blades, the aerodynamic drag is minimized. The cables follow a near circular path between their blade-to-blade connections. This results in a small amount of lost power; however, the structural integrity of the rotor, which consists only of blades and cables, is significantly enhanced. There is no need for an expensive central column or struts.



Previous Vertical Axis Turbines vs Lux Vertical Axis Turbine		
Feature	Previous	Lux Turbine
Vibration Problems	Yes	No
Torque Ripple Problems	Yes	No
Central Column	Yes	No
Struts	Yes	No
Guy cable tension	High	Low
Cross Cables	No	Yes
Life expectancy	Short	Long (beyond 20 years)

From the 1970s to the 1990s researchers from Sandia Labs in Albuquerque New Mexico, and the National Research Council in Ottawa, Canada worked on VAWT or Darrieus-style turbines, with two or three blades rotating around a vertical axis. The more common type of wind turbine is the HAWT that rotates around a horizontal axis. At that time it was unclear which style was more economically feasible. Both types had their limitations.

As these two organizations experimented with two and three bladed turbines, they tried different blade profiles, adjusting solidity ratios, height/diameter ratios, and blade curvature, offset blade angles and strut positioning. The power outputs were comparable to the HAWT, however, several of these demonstrator prototypes, including the largest VAWT ever built, a four-megawatt turbine in Quebec, encountered structural problems. A five hundred kilowatt turbine located in Prince Edward Island had a premature structural failure, primarily due to fatigue and corrosion issues. In addition, these two bladed designs suffered from large fluctuating torque excursions that caused poor power quality.

For the past few years Canada's National Research Council analyzed a Lux Turbine model with a diameter of 40-meters and a height of 65 meters with a one-megawatt power output. The Aerodynamic Lab used the Double Multiple Stream Tube Model computer program to predict the power output and wind loads along the entire length of each blade as the VAWT was rotated. These aerodynamic lift and drag loads, along with the centrifugal and gravitational forces were then applied to the six blades of a Finite Element Model of the Lux VAWT by the Structural and Material Performance Lab. The computer simulation program was used to determine the locations with the most damaging stresses and deformations. From the operating range of rotational stress data and using rainflow analysis they were able to predict the levels of damage to the blades, caused by these forces. The analysis performed by NRC, was for an International Electrotechnical Committee class II wind regime. Using a simulated annual wind spectrum, NRC predicted a life expectancy for the modeled blades to be measured in centuries instead of years. Deformations, even at extreme wind speeds that would be encountered once in 50 years, were exceptionally small. Further analysis on blade natural frequencies, temperature gradients, extreme wind loads and buckling were also achieved without any concerns to their long-term performance. The multiple blade design eliminated the torque excursions, a major source of structural fatigue loading, and achieved minimal torque ripple resulting in improved power quality.

The NRC also scaled the turbine to a remarkable 160-meter diameter with an approximate output of 16 MW. Surprisingly, the blade stresses remained relatively constant. It appears the maximum turbine size is only restricted to the economies of scale. As an added plus, large VAWTs are able to take advantage of the higher winds

Horizontal Axis Turbines vs Lux Vertical Axis Wind Turbine (2MW and larger)		
Feature	Horizontal	Lux
Overall Cost	X	0.5X
Overall Weight	X	0.3X
Total Blade Weight	X	1.2X
Total Blade Cost	X	0.6X (See note 1)
Rated Power	X	X
Annual Power Production	X	X
Swept Area	X	1.07X
Rotational Speed	X	0.7X
Hub/Equator Height (>2MW)	X	X
Peak Efficiency - Cp	High	Moderate
Mechanical	Gearbox or Direct Drive	Friction Drive (See note 2)
Main Shaft & Bearings	Large	Small
Tower	Yes	No
Pitch System	Yes	No
Yaw System	Yes	No
Hydraulic System	Yes	No
Moving parts within the Rotor	Yes	No
Concrete Volume for Foundation/Anchors	Large	Small
Size of Assembly Crane	Large	Small
Transportation Costs	Moderate	Small
Assemble Costs	Small	Moderate
Accessibility for Maintenance	Difficult	Easy
Costs for Offshore Installation	High	Low
Amount of Land Required/Turbine	Small	Large
Watts/sq.m. of Wind Farm	2 to 3	30 (See note 3)
Money Spent on Previous Research	Large	Small
Possibility for Technical Improvements	Small	Large

The Institute of Aerospace Research (IAR) in Ottawa, Canada, used computer models to analyze the aerodynamic and structural properties of the Lux turbine. The following information is a combination of the IAR report and from observations and data collected from several prototypes.

Notes

1 - Includes Splices and Cross Cables.

2 - The Friction Drive consists of a large diameter driving wheel and several small diameter driven wheels. This friction drive system is similar to the system used on railroads to transfer 6000HP from the locomotive wheels to the rails on a railroad system.

3 - VAWT's May Be Solution to Power Density Challenges - a study of modern wind farms comprised of (HAWTs) and counter-rotating (VAWTs) by John O. Dabiri, Ph.D, published in the *Journal of Renewable and Sustainable Energy*, July 19, 2011.

above the earth's surface without the use of towers, making them ideal for use off shore.

VAWTs built in the past have certainly had their problems. The government program in Canada was folded in the late-1980s and Sandia suffered a similar fate with their vertical wind turbine program. Compared to the horizontal wind turbines, the vertical turbine has had relatively little research; however, in our opinion, it has far greater potential. In the quest for the perfect turbine, the vertical axis model has been overlooked. Some of the advantages of the Lux VAWT turbine include:

- Lower capital cost
- High power output
- Low maintenance with few moving parts
- Low overall center of gravity
- Easy access to ground level power generation
- Gearboxes and generators can be contained in sound proofed ground level facilities to reduce external noise
- Higher power output/land area by using counter rotating turbines in close proximity
- A simple Friction Drive system reduces or eliminates gearbox problems

VAWT are wind direction independent and the turbines offer uncomplicated scalability to smaller or larger sizes with excellent longevity. These are important issues, especially since the warranty period for newly designed and manufactured HAWTs has been decreasing in recent years, despite the fact that the bulk of research money over the years has been put into complex HAWTs. Isn't it time to rethink the direction we are headed?

Predictions for a 2.6MW Lux Wind Turbine	
Operating Data	
Rated Power	2.6MW
Cut-in wind speed	4.0m/s
Rated wind speed	15m/s
Cut-out wind speed	25m/s
Rotor	
Diameter	80m
Height of blades	130m
Equator Height	70m
Total Height	140m
Swept Area	7680m2
Operating Interval	5 to 10 rpm
Speed Increaser	Friction Drive
Blades	
Number	6
Chord Length	1.2m
Material	Auminum extruded 6063 T5
Length (each)	150m
Weight	48kg/m
Rotor Weight	
Blades	43,200kg
Cross Cables	8,000kg
Guy Cables	9,000kg
Top Hub	9,000kg
Bottom Hub (Part of Friction Drive)	N/A
Total Rotor Weight	69,200kg