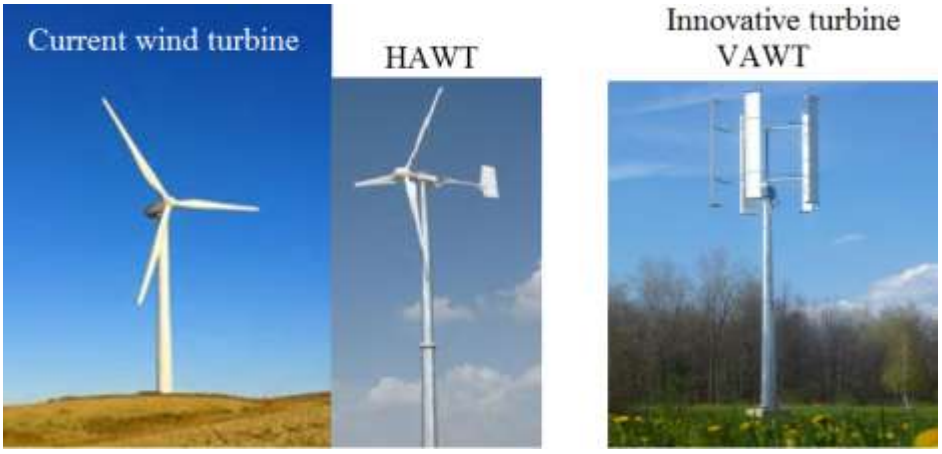
The development of vertical wind turbine technology

Preambles

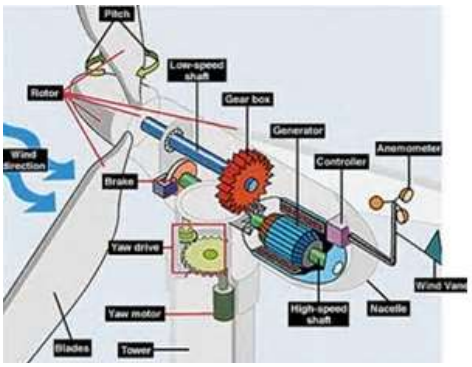
Wind turbine industry background introduction:

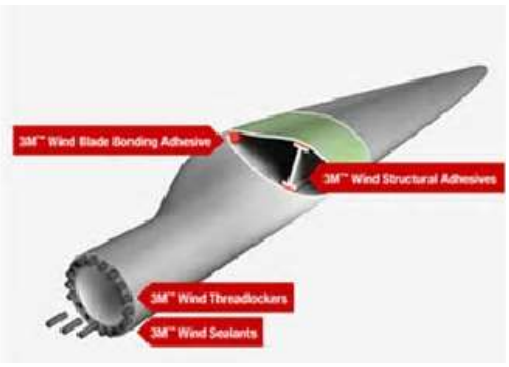
- The wind turbine industry consists of two sections, small and large wind turbines. They differentiate not only in sizes, but also in technical characteristics and market.
- The small wind turbine industry could be further divided into traditional horizontal wind turbine (HAWT) industry and modern innovative vertical wind turbine (VAWT) industry.



Current traditional wind turbine technologies

- Current HAWT technologies have been developed for more than one hundred years. The technologies are very mature. But based on Betz's Law, the HAWT's movement is a single desk movement in a two-dimensional space.
- HAWT technologies include blade technology & craft, gear box technology & craft, pitch angle technology etc.



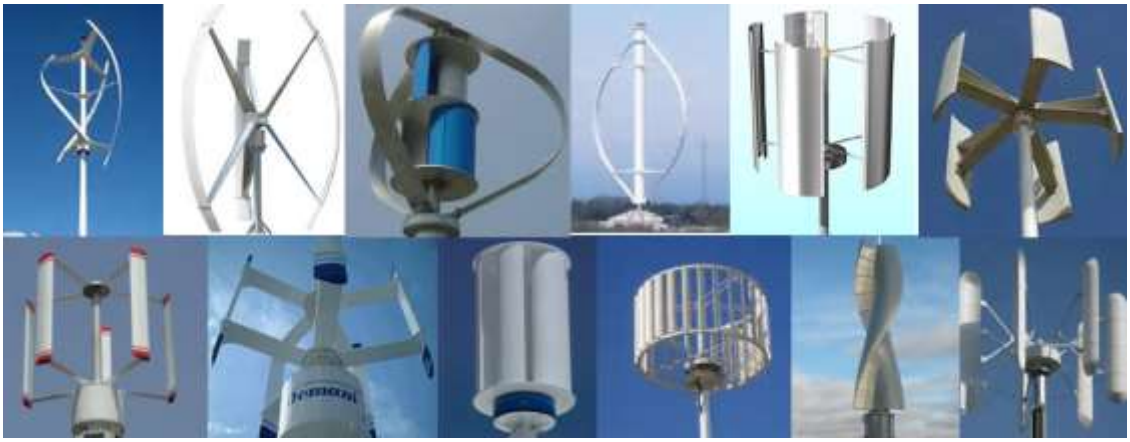


1. Small vertical wind turbine.

- In fact, small vertical wind turbine and middle and large vertical wind turbine are very different. Because the blade's driving force and direction are different when a blade rotation in the vertical wind mill. At some position the force is bigger and the direction are positive, some position the driving force will be smaller and also are positive, but at another positions, the driving force and direction are not only negative and the big and small. So if the diameter bigger, the negative force will more and more. So if the diameter of wind mill is bigger the blade's angle has to adjustable at real time. This is called "real time attached angle control regulation" technology.

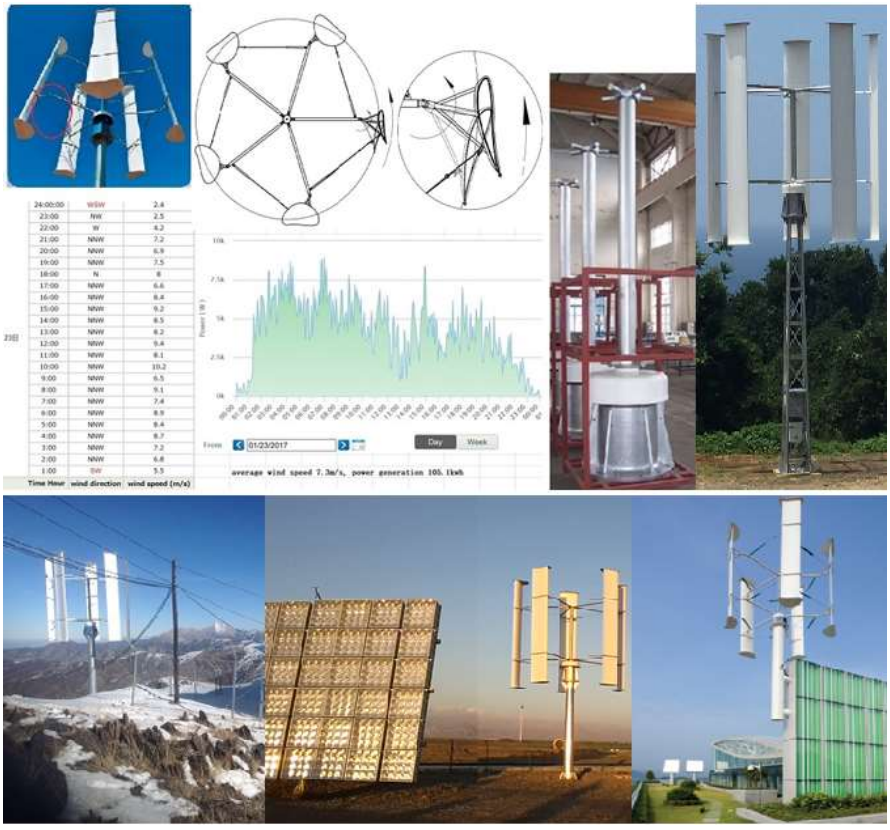
1.1 Current most vertical wind turbines have three major problems:

1. Low power generation performance.
2. A little power generation at lower wind speed and disintegration in strong winds.
3. Poor stability at rotation, make a turbine life shorter.



1.2 Solved the three problems.

SAWT solved above three kind of technical problems in vertical wind turbine industry. He designed the small vertical wind turbine that sold over 4000 units in around 60 countries from 2007, and set up technical barriers by patents pool.



A real-time monitoring of 10kw VAWT power generation 105.1kw/h at average wind speed 7.3m/s .

1.3 How to design a good small vertical wind turbine?

1.3.1 Different from HAWT, the core technology of VAWT is the wind mill structure with blades. Once the airfoil is chosen, concave orientation, angle, width, quantity, connecting way need to be calculated carefully as each of these factors determines the performance of VAWT. So the correct first step is to choice kind of low speed airfoils; the second step is that put the concave orientation to outside, the third step is choice a small blade angle and the blade width suitable, 8 degrees is better for the angle. The best blade quantity is five. And then the blade connecting way is important. The best solution is to use socket structure in order to easy installation and reduce the drug force. These factors determine the power generation performance of VAWT.

1.3.2 In HAWT, the turbine can yaw, but the VAWT can't yaw. So the "positive pitch attached angle regulation" has to be used. It is use the centrifugal force to control the blade angle, when the rotation speed is over the rated speed.

1.3.3 A good vertical wind mill has to stable when the wind mill is rotating, if not so, the mill will shake head when the mill is rotating. It will reduce the turbine's life and cause other problems such as noise, mechanical wear etc. So the best solution is to use the coaxial structure of wind mill and generator. The coaxial structure of wind mill & generator can ensure the reliably sealing, safety & stability, free of mechanical noise, reasonable bearing for windmill, longer life span.

1.3.4 It may cause destructive damage to wind turbines when wind speed is over 25m/s. So the vertical wind turbine has to an automatic brake system. Different from the car brake, the car brake is only braking the inertia, it has no kinetic energy when the car brakes. But the wind turbine start to brake, it not only overcome the inertia but also overcome the driving force from the high wind speed. It is the difficulty point. So the correct design ways is that you have to calculate how much the torque at survival wind speed and choose a suitable brake desk to balance the torque at survival wind speed.

2. Medium & large VAWT technologies

Though many other turbine manufacturers are developing medium and large VAWT, they have adopted the design approach from small VAWTs—simply enlarge a small turbine proportionally to become a "medium or large VAWT". They do not truly understand the characteristics of VAWT.

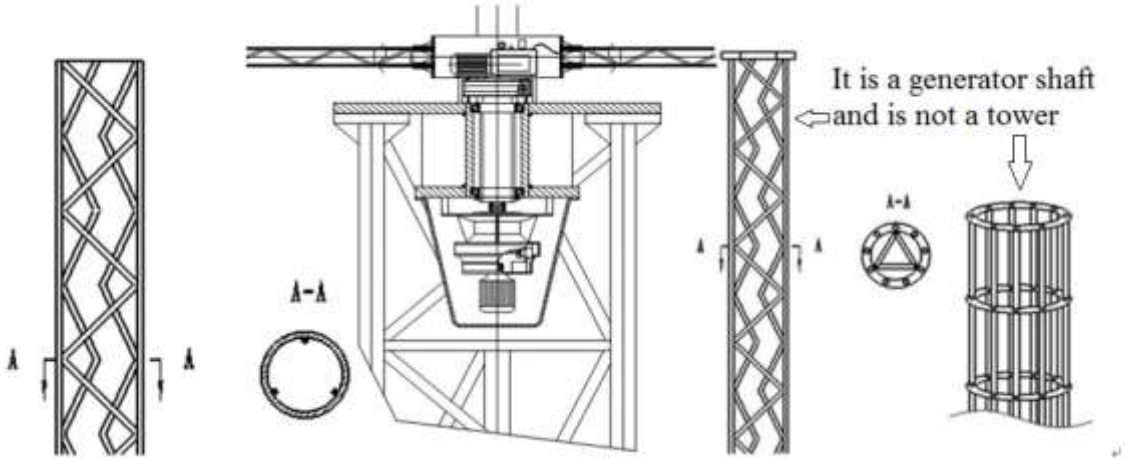
It is well known that VAWT is quieter, safer and do not need a tall tower. However, hardly any commercialized large VAWT has been launched in spite of the efforts of countless engineers. The reasons are obvious: the problems of aerodynamic efficiency, self-starting, structural stability and safety braking remain unsolved, and these problems have to be solved for any type of wind turbines (such problems have been solved in HAWT). These three problems are also solved with "active real-time pitch attack angle regulation" and "Truss Structure Shaft" technologies.

2.1 "Active real-time pitch attack angle regulation" technology

The core of "active real-time pitch attack angle" technology is to adjust blade angles while the wind mill rotation. The tested device is a 1m*1.36m VAWT in a wind tunnel at 2m/s wind speed. The torque is (0.9-1)N.M at 44 RPM. The conversion rate of wind energy to mechanical energy reaches 68%, surpassing the limit of 59.3% by Betz Law. This is not to say the Betz law is wrong. In his theory, windmill of HAWT is a single desk rotation in a two-dimensional space and the VAWT is a multiple desk rotation in a three-dimensional space. It is Equivalent two wind mill of HAWT.

2.2 Truss structure main shaft of large VAWT

The bending moment on the wind mill can be extremely large if the wind mill's diameter is big. The main shaft has to be large in diameter and strong, making commercialization even more difficult. Our solution is using a truss hollow main shaft inside since truss structure is strong and relatively light, meeting medium & large VAWT main shaft demand, as well as the demand for commercialization.



After over ten years R&D experience in the VAWT industry, the Super Turbine (a kind of huge wind turbine) invented in 2014. Super turbine has a very low power generation costs, easy installation and maintenance. The core technology is an extension of the "active real-time pith attack angle regulation" technology verified by experiments. It will lead a revolution in current large wind turbine industry.

3.1 Bernoulli's principle applied on sailing boats.

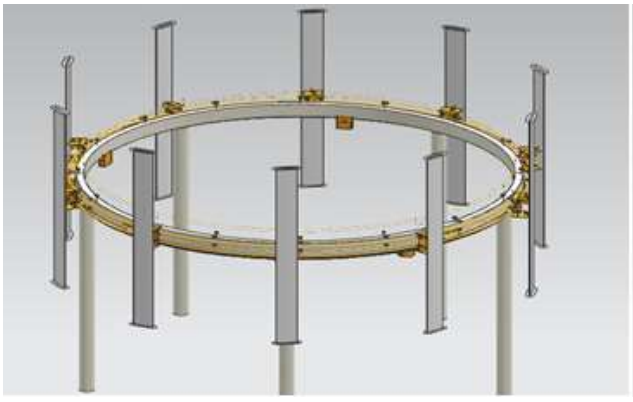
The Vestas Sailrocket 2 made its world record of the sailing boat speed in Walvis Bay of Namibia in 2012. Sailing speed reached 64.78 knobs (119.95kmh) at wind speed of 25 knobs (46.3kmh). Its averaged sailing speed reached 59.23 knobs (109.65kmh) in 500m straight channel. It is quicker than most non racing yachts. This sailing boat drive by the lifting force resulted from Bernoulli's principle and required no gasoline.

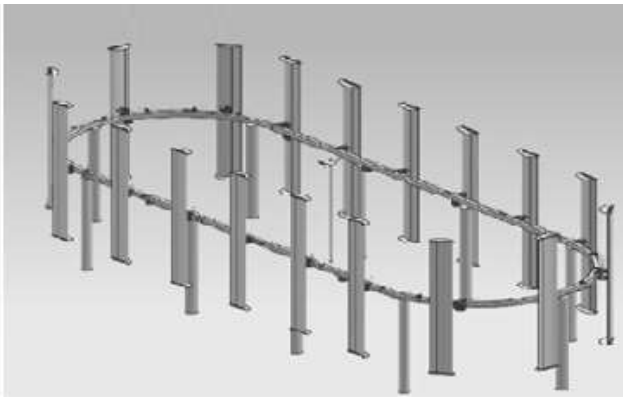
The pain points of traditional wind turbine industry

- High Power Generation cost than traditional energy.
- Manufacturing craft complex.
- Super parts difficult to transport.
- Need large volume foundation.
- Installation needs super crane.
- Noise pollution.
- Damage ecosystem.
- Chemical pollution.
- Electromagnetic radiation and interference.

3.2 What's Super Turbine & how it works?

- Hundreds of blades moved by lift force through the chain to drive the hundreds of generators fixed on the circular track to produce power.
- According to the wind direction, wind speed and the position of the blade on the track, the active real-time pitch angle regulation technology is applied to adjust the blades' angles and to gain the maximum lifting force, so that the Super Turbine can enhance the wind energy conversion rate and enable high efficiency power generation.
- The capacity of single Super Turbine can be designed to fit the wind farm condition and customer's requirements. One turbine is max 50MW to min 7MW.





3.3 Verified technologies by wind tunnel test

It is the extension and further application of "active real-time attack angle regulation" technology.

In the circular orbit, driven by the wind, the blades of different locations will produce the driving force with different sizes and different directions. In the driving force of the largest position, cut the circular track at this position, and extended into a straight line which is the prototype of super turbine. Like a sailing boat, in the upwind, the boat has fastest speed in the straight line.

A super turbine could be designed round, long, or even triangular shape, but the turning radius is the same according to the land and wind conditions.

In the circular orbit, driven by the wind, the blades of different locations will produce different sizes and different directions of the driving force. In the driving force of the largest position, the circular track cut, and in this position extended into a straight line, which is the prototype of the super turbine. According to the site conditions and the main wind design of the shape of the super fan, can be round, long or even triangular, but the radius of each arc are the same

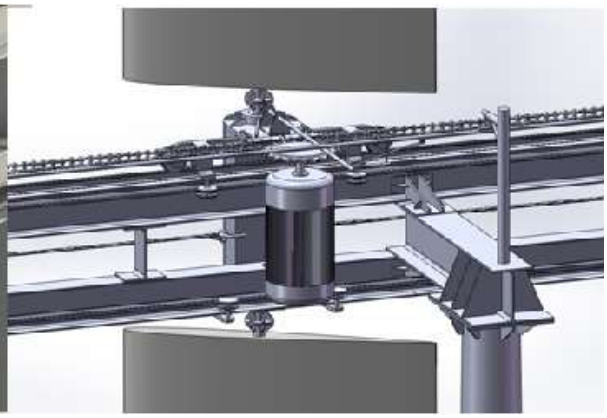
3.4 Features of Super Turbine

Fully use current mature technologies:

- Track technology
- Motion control technology
- Encoding technology
- Hydraulic technology
- Wireless positioning technology
- Wireless signal transmission technology

Major components:

- Central controlling unit
- Standardized tracks
- Standardized blades
- Standardized trolleys
- Standardized high speed PMG
- Standardized supporting parts



3.5 Super turbine solved these problems of large HAWT

Super Turbine

- Rated Power 40MW
- Track length 4400M
- Swept area 101,200M^2
- Cut-in wind speed 2m/s
- Cut-out wind speed 30m/s
- Small-scale foundations
- Middle size parts
- Transport by ordinary car.
- Use small crane
- Easy install
- Easy maintenance

Traditional large wind turbine

- Rated Power 3.3MW
- Rotating diameter 112m
- Swept area 9,852M^2
- Cut-in wind speed 3m/s
- Cut-out wind speed 25m/s
- Large-scale foundation
- Huge parts
- Difficulty to transport
- Need super crane
- Difficult to install
- Difficult to maintain

3.6 Lower equipments cost.

- Super Turbine use all current mature technologies, such as motion control technology, hydraulic technology, track technology, moving power technology. So it will be easy to manufacturer.
- A 40 MW Super Turbine user total cost is 15 million USD, low to $0.38 per watt.

40MW Super Turbine User cost list				
Item		Unit price thousand (USD)	Quantity (unit)	Total thousand (USD)
Blade	400kg/（2*11.5）m	5	440	**2,200.00**
Trolley		10	220	**2,200.00**
Generator	100KW/1500RPM	5	400	**2,000.00**
Pole	4000 kgs/unit	4.5	220	**990.00**
Cyclotron track structure	8500 kgs/unit	10.5	220	**2,310.00**
On grid inverter	500kw	40	80	**3,200.00**
Central controller, electrical, cable and other			1	**800.00**
Equipment cost				**500.00**
Foundation and installation cost				**800.00**
User total cost				**15,000.00**
Cost/per watt (USD)	**$0.38**			

3.7 Low power generation cost

40MW Super Turbine: Wind farm investment cost						
Average wind speed (m/s)	Annual production (Mw/h)	Total production in 20 years (Mw/h)	turbine & foundation & installation cost($ M)	Transformer substation & other investment ($ M)	Service fee in 20 year ($ M)	cost of Kw/h ($ cent)
5m/s	**40,300**	**806,000**	**18.60**	**1.8**	**6**	**3.3**
6m/s	**61,500**	**1,230,000**	**18.60**	**1.8**	**7**	**2.1**
7m/s	**81,800**	**1,636,000**	**18.60**	**1.8**	**8**	**1.6**
8m/s	**106,100**	**2,122,000**	**18.60**	**1.8**	**9**	**1.2**
9m/s	**139,800**	**2,796,000**	**18.60**	**1.8**	**10**	**0.9**
10m/s	**167,500**	**3,350,000**	**18.60**	**1.8**	**11**	**0.8**

Because of above advantages it will change the current large wind turbine industry structure. It makes the manufacturing of large wind turbine very easy, because it has terminated large blade, large gear box, large generator and huge tower.

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