Advanced Wind Energy Technologies

HIPA Designs

Wind Turbines

Two Megawatt Turbines

Upon undertaking a peer review of current wind technologies, Hydrogen Infrastructure Projects Australia (HIPA) has identified that the two Megawatt (2MW) wind turbine market can benefit greatly from its patented superior protective performance coating.

The current 2MW market includes terrestrial and offshore site developments (i.e. at present, the 2MW wind installations are a larger market than ultra large wind turbines). In addition, the 2MW turbine shafts are of a size (circa 750mm) that ensures cost effective asset deployment to terrestrial and/or offshore sites as specified by customer needs.

Whilst efficiencies are expected to increase with turbine size, it is the adoption of HIPA's suite of wind technologies that will allow rapid production, installation, low-cost maintenance, and longevity of the wind assets that will ensure a greater rate of return to investors.

The combination of market demand, low risk research and development, cost effective production and installation will position HIPA's Wind Technology Engineering Department as a world leader in provisioning innovative wind technology solutions.

Five Megawatt Plus

Because of the superior protective performance coating and its ability to withstand huge compressive forces, the large (5MW and over) wind turbine market with very large rotors (mass) hanging off a drive shaft is a perfect fit and a natural progression for the application of HIPA Bearings technology.

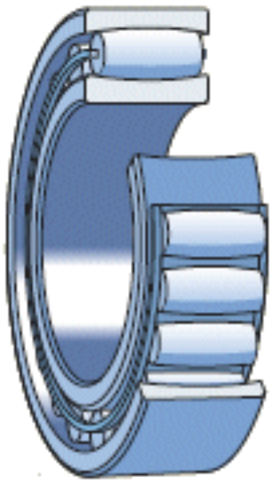
Larger wind turbines often mean greater noise generation during its operations. Once HIPA's superior protective performance coating is applied to a wind turbine and its components, the noise emanating from large wind installation can be reduced significantly. The superior protective performance coating exists as a native foam form and when combined with HIPA's Bearings technology may be reduced noises emanating from a wind turbine in excesses of 90% during its operations.

Specific world leading innovations HIPA will bring to the wind energy generation market includes but are not limited to the following:

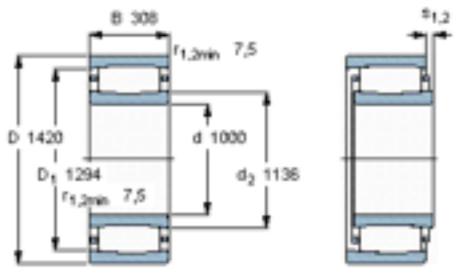
- Technological enhancement of current wind turbine design and operations,
- Light weight and durable down-wind design applicable to various wind turbine sizes,
- Superior protective coating that can cover each wind turbine and all its moving parts and will increase its durability and life of operation,
- Unique bearing sphere design will allow for greater wind turbine capacity and efficiency,
- Direct drive, gearbox less operation will increase efficiency, reduce maintence costs significantly and increase operational life significantly,

Wind Turbine Market & Impact

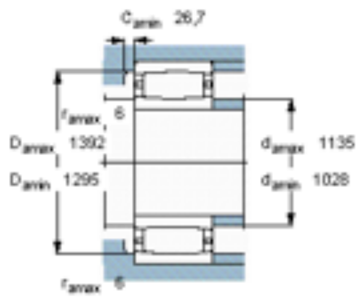
At present the 5 MW turbines in Europe use SKF Carb ™ (see figure to right) non locating bearings. An example of such a bearing is the c30/1000MB Carb ™ Toroidal roller bearing. This bearing has a shaft diameter of 1000mm and weighs 1570 KG.



The equivalent HIPA Bearings technology would weigh in at 820 kg (60% that of existing units) and would not require an intrinsic cooling system and other paraphernalia associated with operating such a large bearing.



The HIPA Bearings technology is life of type, meaning it is designed to last 50 years before replacement. This contributes significant cost savings in maintenance, which is particularly important in wind farms of any size. The technology is also "self lubricating" which increases the efficiency of the turbine by an expected order of magnitude of around 2 to 3%.



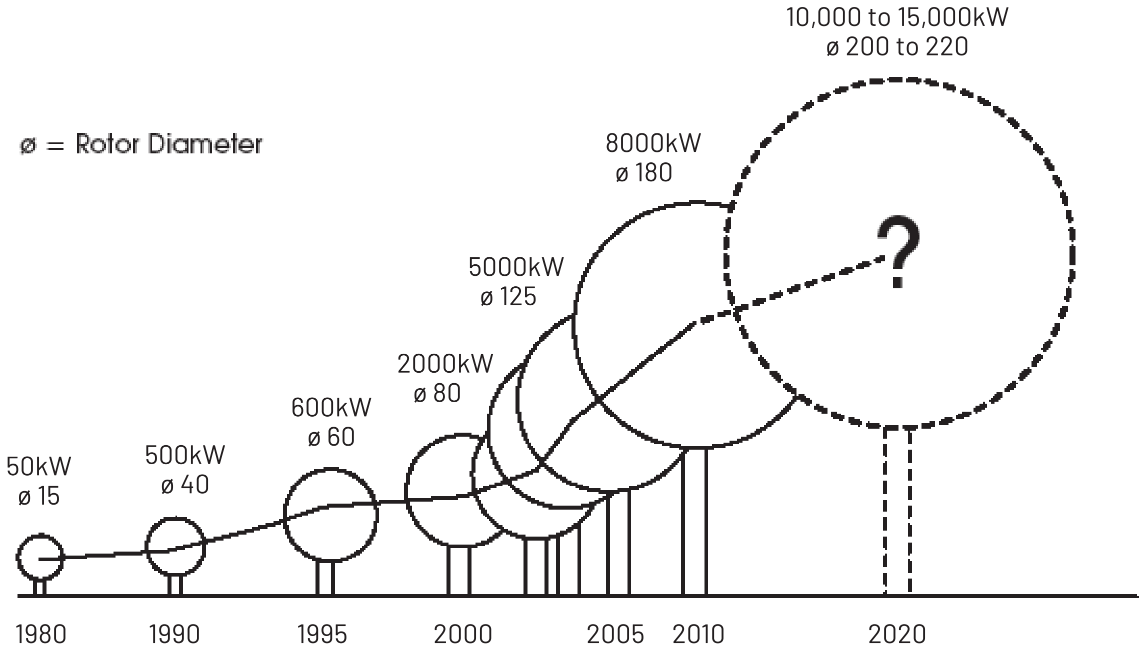
Lastly, HIPA Bearings technology can withstand huge compressive forces in the order of 7.2 Giga Pascals and greater. This makes the technology ideal for large hung masses associated with Megawatt sized wind turbines.

Axial displacement s_1	30
Misalignment factor k_1	-
Operating clearance factor k_2	0,114

Market & Impact

The European large wind turbine market alone is expected to expand to accommodate 12MW wind turbines in the near future (see diagram below).

This places HIPA Bearings in an ideal situation where coupled with the innovative technology of HIPA (down wind turbines) the company will be able to create an aggressive, unsubsidized and cost effective wind harvesting niche within the global energy market.



Growth in the size of commercial wind turbines.

Source: Directorate-General for Research Sustainable Energy Systems

High Efficiency Wind Turbines

Using Advanced Ceramic Switched Reluctance Generator and Bearings

Some of the key challenges for wind turbine design and scaling today are the structural limitations of larger and larger diameter blades and the speed/torque regulation of the rotor/generator coupling.

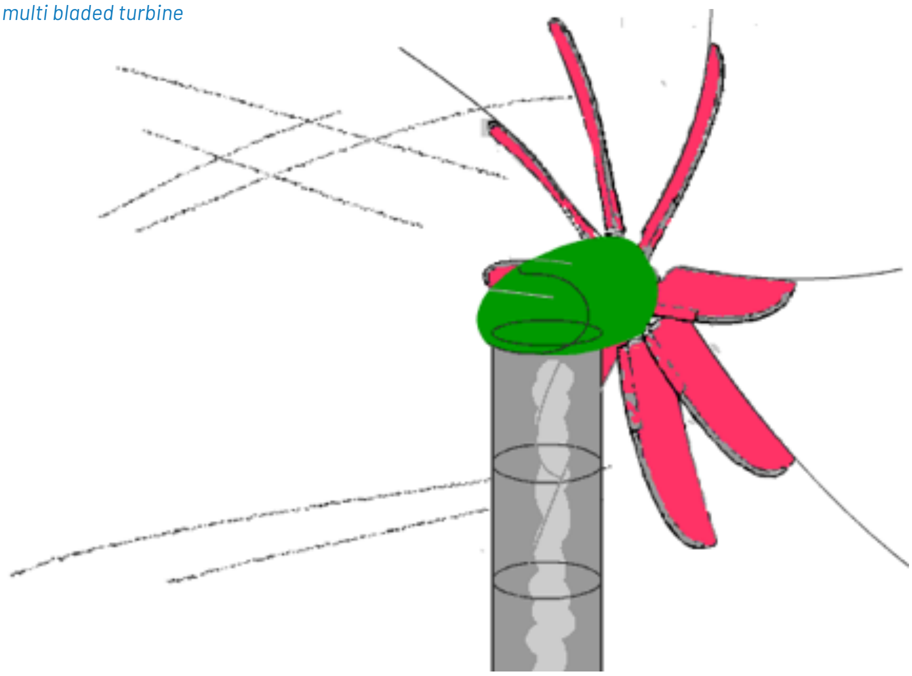
By using the superior protective performance material as a basis for the generator, bearings and gears, you can move the optimal design criteria into a different corner of the Betz Power Coefficient envelope that will allow for power coefficients higher than 0.5. That means a 5MW design can now be 20% more efficient or scalable in size up to 50% larger as required.

The illustration below shows a conceptual design that operates at a much higher torque than traditional wind turbines and uses a stall regulated rotor.
The key enablers to this design are:

1. A rotor design with a high activity factor (number of blades) which are joined at the hub using
2. High strength, low friction bearings made of the superior protective performance material, which drive a high efficiency Switched Reluctance Motor.

This use of high strength ceramics will allow for a wind turbine that does not require speed regulation, (staying within the sonic speeds) and will be able to convert grid suitable power at any speed. Additionally, start-up can be accomplished with very little power.

Figure 1: Fixed pitch multi bladed turbine



High Efficiency Turbines

This design shows a mast that is actually a 16/12 pole switched reluctance generator (SWG) of a cross section illustrated below made of the superior protective performance material for the rotor and foam for the casing. Since the This special material is conductive, it acts similar to a carbon steel or ferrite core. The stator poles on the casing can be doped more heavily to provide inductance form the coils around the poles while still offering ultra-lightweight performance.

The structural rigidity of this generator will prevent excessive flexure or breakage of the mast during high wind events, yet still be relatively light compared to traditional generator/mast designs. It may be possible to weld segments together for large masts using an RF welding procedure, thus allowing the turbines to be shipped worldwide in standard containers.

The two-foot diameter, two-foot tall segment shown below represents a 110kW generating capacity when turned at 200 rpm using 118 Nm of torque. Efficiencies are at least 93% at this speed and can go up to 98% at higher speeds. This design scales upward to full mast diameter and height relatively easily.

Figure 2. Superior protective performance material SRG Mast Cross Section

Figure 3. 2ft. Diameter SRG Segment

High Efficiency Turbines

The illustrations in figure four shows how SRG speed control will provide the synchronization to the power grid. This control will eliminate the need for speed control and pitch bearings on the rotor and the power can be extracted and regulated to design optimum based on torque stall of the rotor blades.

Most modern horizontal axis wind turbine rotors consist of two or three thin blades. These are known as "low solidity" rotors, due to the low fraction of the swept area that is solid. This arrangement gives a relatively high tip speed ratio in comparison to rotors with a high number of blades like this design which uses 8.

Using a switched reluctance motor, starting torque would only be needed to overcome friction losses and once rotation is started, then drag or torque required can be regulated using a phase controller, like the one depicted below, and then the phase can easily be matched to the power grid phase.

Figure 4. SRG Control Block Diagram

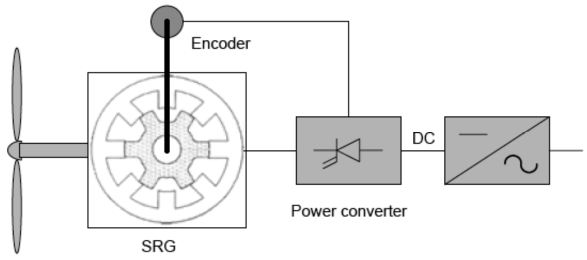
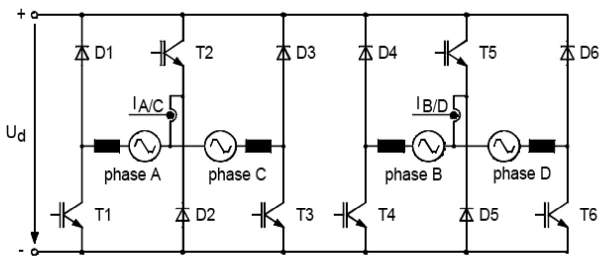


Figure 5. Four Phase Voltage Control Circuit for SRB



High Efficiency Turbines

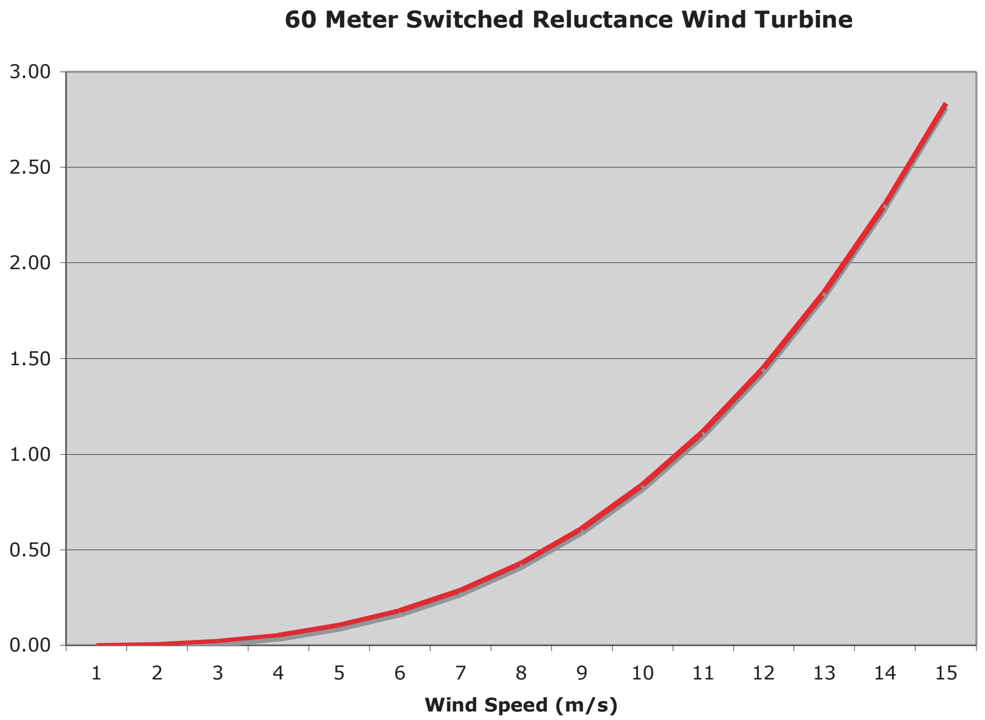
Figure six shows a power output expectation of the system. The overall power efficiency is better by up to 20% over a traditional induction generator

Assumptions:

$Pout = \frac{1}{2} \rho A V^{3}_{w} (\rho g \, \rho b \, Cp)$
Assume ρg = .98 For Switched Reluctance Generator
Assume ρb = .99 For Ceramic Squirm Drive
Calculated *Cp* = .50 Due to blade design

By using the superior protective performance material and some advanced concepts for power generation, you can simplify and reduce the overall cost to operate a wind turbine. This design is one approach that can be prototyped within 36 months of commencement of operations under HIPA Bearings.

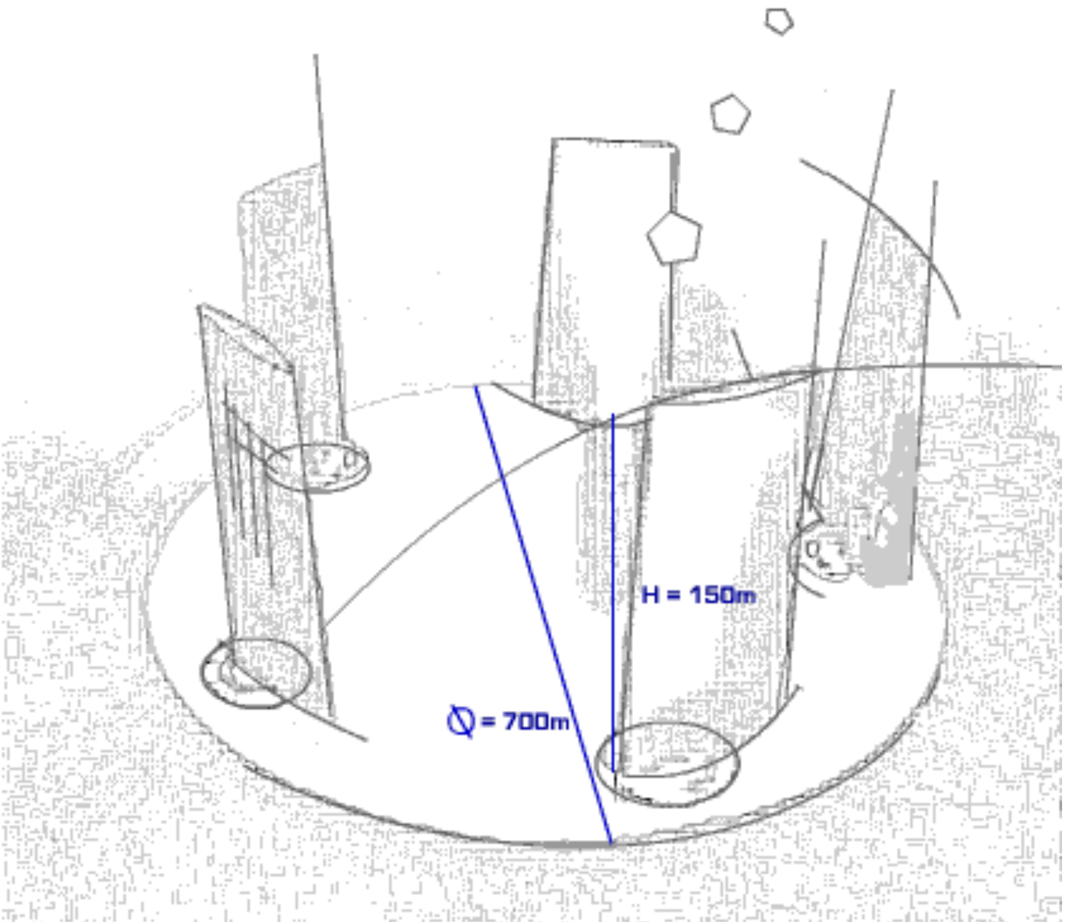
Figure 6. Sample Power Output Chart for 60 Meter Turbine (Rated Power is higher than depicted.)



Ultra Large Bearings and Switch Reluctance

The application of HIPA technologies have the potential to take the current 2MW wind turbine design to a more efficient design which incorporates switch reluctance technology.

When this concept is taken further to the design, production, and installation of ultra large architectural and engineering designs, it is possible to create energy self-reliant communities. (See figure below).



Ultra Large Bearings and Switch Reluctance

Slow speed, vertical axis, direct drive concept using 700mm diameter, switch reluctance ring and foundation disks with polymer matrix construction techniques, (please refer to previous diagram on page 9).

This design based on the proven Voith Schneider marine propulsive technique (but using switch reluctance instead of mechanical linkage) makes an excellent earthquake resistant structure because it is free floating in 3 axis and rests on bearings coated with HIPA's superior protective performance coating. This type of structure may also derive energy from daily seismic activity.

This type of structure would be ideal for a saltwater desalinization plant, because of its noncorrosive building material and due to its ability to be submerged beneath the surface of the water, taking advantage of both atmospheric and hydrodynamic currents. Water treatment is the first industry that comes to mind in the application of this type of technology, because the structure is dynamic (rotates) and the product is liquid (flows) and the process requires power.

For example: salt water could be pumped into the centre of the ring and the freshwater produced by the plant could simply be allowed to spill over the lip into a reservoir serving both productive and aesthetic functions.

Innovation necessary to the wind industry

There continues to be huge international demand for wind powered technologies.

The world wide order backlog for current wind technologies stands at two to three years, with 3,000 to 4,000 turbines needed to meet Australian targets.

Unfortunately, current wind technologies are heavily dependent on Government subsidies and protection tax incentives in USA, feed in tariffs in Europe, Renewable Energy Certificates (RECs) in Australia.

Wind energy technology is already proven and making progress. But innovation has become essential in reducing investment costs and increasing performance and reliability to reach a lower unit cost of energy.

HIPA's breakthrough wind turbine technology can reduce electricity production costs from wind by 30% or 40%, making this sustainable energy production option, more viable for the future.

The current situation

Traditional 3 bladed upwind anchored turbines

On shore

The majority of current, commercially available on shore wind farm turbines are traditional 3 bladed upwind anchored turbines. These initially started with kW capacities, but today range up to 15 GW.

They comprise fixed horizontal axis, fixed upwind blades onto the main shaft driving a stage up gearbox into a traditional step up generator.

Construction and installation costs are generally site dependant, ranging from US$2M - 4M/MW.

Maintenance costs range from US$100K to US$200K per annum. They typically require gearbox and main shaft bearing replacements at around the 2 to 5 year mark. General operational life is 15 to 25 years before complete replacement.

Key Specifications

Conventional 3 bladed upwind anchored turbines

Construction and Installation costs	$2M/MW - $4M/MW
Maintenance costs	100 - 200K per annum
Operational life	15 - 25 years

Off shore

Current conventional off shore installations are traditional 3 bladed, gearbox drive upwind turbines that are seabed anchored. Installations are very expensive and limited to areas that are close to shore in shallow seas.

Floating 3 bladed up wind turbine installations for deeper waters are in development, but these are difficult and costly to position, stabilise and anchor.

Construction and installation costs are projected to be 4 - 6 times more expensive than on shore installations. Maintenance and operational costs are also higher due to more hostile conditions and sea water erosion.

HIPA's breakthrough wind turbine technology

Innovation reduces wind electricity production costs by 30 - 40%

On shore

HIPA wind turbines are 2 bladed downwind direct drive turbines, with each blade being independently hinged to the main shaft. They can be stand alone, anchor supported, or guy-wired, requiring no anchor. Their capacity is flexible and can be tailored to each specific site.

The HIPA 2 bladed downwind turbine can also be designed for use in cyclone prone regions with feature that allows the turbine to be laid down, ground horizontal, during cyclonic conditions.

Typical construction and installation costs range between 40 - 60% of the traditional 3 bladed upwind anchored turbines. Maintenance costs are also typically only 10% of those of current wind turbines (site dependent).

Operational life is 50+ years, with no gearbox or bearing replacements required due to their innovative metal to metal protective coating.

As a result, electricity is generated at 30 - 40% below the cost of conventional technologies.

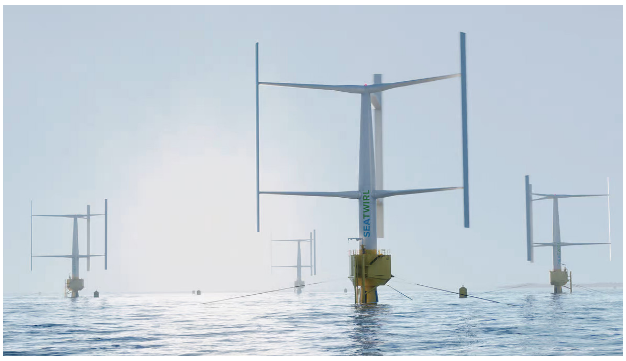
Key Specifications

Breakthrough 2 bladed downwind direct drive turbines

Construction and Installation costs	40 - 60% of conventional 3 bladed turbine costs
Maintenance costs	10% of conventional 3 bladed turbine costs
Operational life	50+ years

Off shore

The unique metal to metal protective coating intrinsic to the design of the HIPA 2 blade turbines means that they are better protected against sea water erosion, have lower maintenance costs and have an increased operational life in more hostile conditions.



HIPA breakthrough 2 bladed downwind direct drive turbines

Unique design

- 1.5 MW downwind turbine
- 2 flapping hinged blades
- Direct drive (no gearbox)
- Lightweight, permanent magnet generator
- Lightweight cable stayed tower (lower cost foundations)
- Generator relocated to tower base using special energy conversion drive

HIPA 2 bladed downwind direct drive turbines deliver a 10% increase in efficiency and a 30% reduction in capital costs over conventional three bladed designs. Expected electricity production cost reduced by further 10%

This is acheieved by its unique design, which encompasses reductions in tower weight, and hence capital cost.

Plus there is a significant reduction to maintenance costs - to less than 10% of conventional tower top generators.

There is also significant potential for lower cost off-shore floating turbine development; particularly below 1MW sized machines for cyclone and monsoon regions.

This technology will significantly assist the world to address climate change targets at commercially competitive rates.

Initial cost comparison

	Conventional 3 blade turbine	HIPA 2 blade turbine with 75 m/s tip speed	HIPA 2 blade turbine with 125 m/s tip speed
Rotor	$810,000	$482,436	$428,436
Rotor support structure	$391,500	$195,750	$166,050
Power transmission	$283,500	$267,300	$194,400
Fluid system	$40,500	$40,500	$40,500
Electrical system	$351,000	$351,000	$351,000
Nacelle enclosure	$27,000	$24,300	$24,300
Control system	$40,500	$48,600	$48,600
Tower	$540,000	$324,000	$324,000
Foundation	$135,000	$81,000	$81,000
Transportation	$54,000	$32,400	$32,400
Erection	$27,000	$18,900	$18,900
Total	**$2,700,000**	**$1,866,186**	**$1,709,586**

Quoted prices and costs are to be considered as general and turbine site dependent.

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