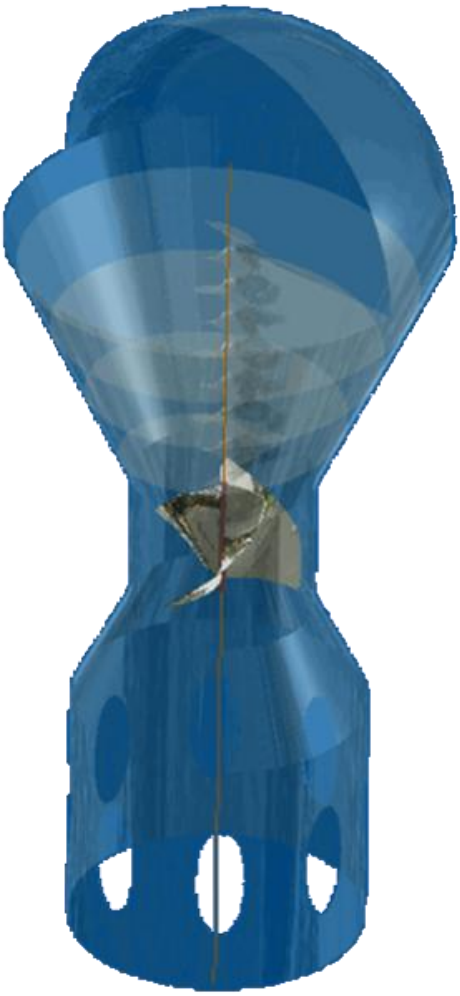

AVENTUS TURBINES

TECHNICAL NOTE

ABSTRACT

This technical note presents a comprehensive analysis of a novel screw-type wind turbine design, emphasizing its innovative Shroud design, inverse helical blade geometry and operational efficiency. Key methodologies include theoretical calculations of the maximum power coefficient (Cp), performance at low wind speeds, noise reduction strategies, and mechanical stress mitigation, demonstrating the turbine's capacity to adapt to variable wind conditions while ensuring ease of construction.

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RENEWABLE ENERGY

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1. Introduction

The need for renewable energy has become paramount as global energy consumption has been rising due to international innovation and development. Global energy consumption reached an all-time high of 620 exajoules in 2023 alone, marking a 2% rise in energy consumption from the previous year. This upward trend substantiates the escalating need for renewable energy globally.

1. Why Renewable Energy?

Fossil fuel usage has sustained humanity since time immemorial. Archaeological evidence suggests that coal was used for heating and cooking as early as 3,000 BCE, however, amplified combustion of these fossil fuels, particularly during the industrial revolution, catalysed greenhouse gas emissions. These gases trap the sun's heat in earth's atmosphere, preventing them from escaping back into space. This contributes to rising global temperatures, extreme weather, melting glaciers and rising sea levels. Hence, a more sustainable form of energy harvesting is required for reduced environmental impacts.

2. Why Wind Energy?

Wind energy offers high energy efficiency and scalability with faster and easier deployment while remaining cost-effective compared to other renewable energy sources. As of 2023, the capacity of all installed wind turbines amounted to 906 gigawatts (GW). The popularity of wind turbines is rising as wind energy made up 7.33% of global electricity generation in 2022. Countless countries including India, Japan and South Korea are making the shift towards onshore and offshore wind energy usage due to its high economic efficiency backing the low-carbon transition. Illustratively, China leads global wind energy capacity with over 365 GW installed, followed by the US and Germany with 144 GW and 67 GW respectively.

2. Design and Methodology

1. Concept and Innovation

The Aventus Turbine implements an external shroud to direct wind velocity to the rotor blade, seamlessly bringing the wind to the turbine instead of the turbine to the wind. Aventus' revolutionary design increases wind velocities by 825% on average, as backed by our Computational Fluid Dynamics (CFD) analysis using CFD software provided by Autodesk.

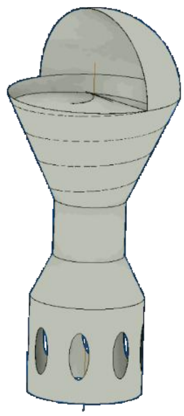

Figure 2-2: Aventus Turbine Shroud design outside view

This is achieved by shaping the Turbine outer shroud to combine the Venturi effect and vorticity. The conical shape of the shroud makes use of Bernoulli's Principle and the Venturi effect to increase wind velocity by decreasing pressure. The shroud entrance also features a spiral which uses vorticity to further increase wind speed. As air flows through the spiral, it gains centripetal acceleration, which works towards increasing wind speeds.

The rotor is positioned at the most optimal location as per the CFD analysis and use custom blade design to capitalize on both low and high wind speeds. The Aventus design also features a dome structure at the top of the turbine, designed to direct horizontal wind flow into the shroud. This dome is rotatable to adjust for varying wind angles. The dome also protects the Turbine blade and motor in adverse weather conditions such as Storms.

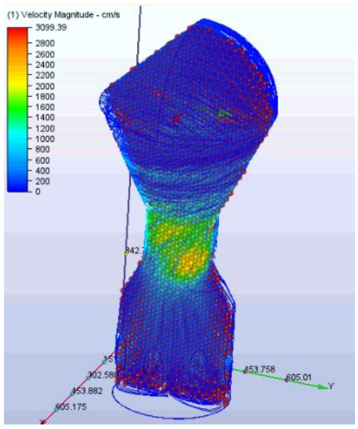

Figure 2-1: CFD Analysis result on Aventus Turbine design

Aventus is currently working on a proprietary AI model which once deployed will be able to predict location-specific wind patterns based on the metocean data from the turbine location. This would enable customers to capitalize on everchanging wind patterns and directions to generate as much power as possible.

3. Theoretical Calculations

The wind power equation calculates the power output of a wind turbine dependent upon air density, rotor area, wind speed and efficiency coefficient. Simply put, the equation is as follows:

$$P = \frac{1}{2}\rho A V^3 C_p$$

Where

- P describes the power extracted by the wind turbine,
- ρ is air density at sea level (usually 1.225 kg/m^3),
- A describes the area swept by the rotor blades (given by $A = \pi r^2$),
- V talks about wind speed in m/s and
- C_p is the power coefficient (with a maximum value of 0.593 due to Betz's Limit).

When consider this equation in scope of wind turbines, it is critical to note the kind of rotor used as this influences the parameters used in calculation.

4. Concept selection Considerations

When designing an innovative wind turbine, particularly one that utilizes an Inverse Helical blade geometry, several key factors must be taken into account to ensure optimal performance and sustainability. Here's a detailed breakdown of these considerations:

1. Maximum Power Coefficient (Cp Max)

The power coefficient, often denoted as Cp, is crucial in determining how efficiently a turbine converts wind energy into mechanical energy. While the theoretical maximum (known as the Betz limit) is around 0.593, practical turbines typically operate at lower values. For a screw-type turbine, achieving a Cp in the range of 0.35 to 0.45 is realistic. This design captures wind from various angles, allowing for consistent energy generation without needing to pivot toward the wind direction.

2. Startup and Operation at Low Wind Speeds

Many traditional turbines require a minimum wind speed of 4 to 5 m/s to begin generating power. However, screw-type turbines are designed to start operating at much lower wind speeds, often around 2 to 3 m/s. This capability makes them particularly suitable for urban environments or regions where wind conditions are less predictable.

3. Rotation Speeds

The rotation speed of a turbine significantly impacts its efficiency and durability. Screw-type turbines generally operate at lower rotational speeds, typically between 50 and 200 RPM. This is advantageous because it reduces wear and tear on the components compared to conventional turbines that may spin at over 500 RPM.

4. Noise Reduction

Noise generated by wind turbines is a common concern, especially in residential areas. The lower rotational speeds of screw-type turbines contribute to reduced noise levels, often below 45 dB. Additionally, the helical design helps smooth airflow around the blades, minimizing turbulence and associated sound.

5. Mechanical Stress Reduction

Mechanical stress on turbine components can lead to premature failure and increased maintenance costs. The axial load distribution in screw-type turbines helps mitigate these stresses, as the design allows for even force distribution along the helical structure. The reduced rotation speed also significantly decreases centrifugal forces acting on the blades.

6. Capacity to Operate in Variable Winds

Wind conditions can be unpredictable, with gusts causing fluctuations in power output for many turbines. The omnidirectional design of screw-type turbines enables them to capture wind from any direction without needing to reposition themselves constantly. This feature ensures stable energy output even during turbulent weather conditions.

7. Orientation to Changing Wind Directions

Traditional turbines often struggle with changing wind directions, leading to inefficiencies as they adjust their position (yaw). In contrast, the screw-type turbine is to be placed vertically and therefore can effectively harness wind from all angles making them more effective during stormy weather when winds shift rapidly.

8. Ease of Construction

The construction process for screw-type turbines can be simpler than that of traditional designs. Their modular nature allows for components to be manufactured using various methods, including extrusion or 3D printing. This flexibility can reduce costs and construction time while maintaining structural integrity.

In summary, selecting an Inverse Helical blade geometry screw wind turbine involves careful consideration of various factors that influence performance and safety. By focusing on maximizing efficiency while minimizing noise and mechanical stress, these innovative designs hold promise for sustainable energy generation in diverse environments.

Further, it is proven with earlier wind testing results done by a competitor that at similar wind conditions, a shroud around a Spiral Wind Turbine increases the power production of the spiral wind turbine, being able to extract more energy from the wind.

The reason being that the shroud produces a Venturi effect in way of the rotor plane, thereby increasing the mass flow rate through the rotor plane as well, thus increasing the C_p in that plane. Additionally, the shroud suppresses the tip vortex formation thereby decreasing the energy loss from the turbine blades.

5. Calculation Results

A calculation table for the power calculation is presented below:

Description	Input/Formula
Wind speed at the Turbine face from CFD (m/s)	18
Turbine diameter at the inlet (m)	1.5
Air density (kg/m^3)	1.225
Power coefficient (Cp)	0.4
System efficiency (η)	0.9
Swept area (m^2) = π*(D/2)^2	**1.77**
Power output (W) = ½ρAv^{3}Cp*η	**2272.47**
Revolutions per minute (RPM)	600
Torque (Nm) = (Power (Watts) × 60) / (2 × π × RPM)	**36.17**

Table 1: Power Generation Calculation

6. Conclusions

A table below shows the proposed solution which has far better wind power generating efficiency and other parameters in comparison with other type of Turbine generators as follows:

Description of Comparison Parameters	Savonius	Spiral Bladed Wind Turbine enclosed in Shroud	Darrieus (and Variants)	Tri-Bladed Horizontal Axis
Cp max	-2	-1	1	2
Start up and operation at low wind speeds	1	1	-1	-2
Rotation speeds	2	1	-1	-2
Noise reduction (due to rotation speeds)	1	1	-1	-2
Mechanical stress reduction (due to rotation speeds)	1	1	-1	-1
Capacity to operate at variable winds (gusty winds)	1	1	1	-1
Capacity to orientate to winds that change directions regularly (stormy days)	2	2	2	-1
Easy to construct	1	-1	-1	-1
Prevention of bird deaths and safety in case of destructive failure	-1	2	-1	-1
Total points on each parameters	6	7	-2	-9

Table 2: Comparison between various turbine types with advantages and disadvantages