Tandem Wind Energy GmbH

Small Scale Wind Turbine

WindStream5

Technical Description

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Figure 1: WindStream5

1. Challenge

Renewable energy technologies are undoubtedly poised to make a substantial contribution to addressing energy and environmental challenges. Over the past decade, there have been significant advancements in the development of large-scale wind turbines for grid-connected operations. In contrast, small wind turbines designed for decentralized energy generation have received relatively less attention during this period. To date, the leading companies in the wind energy industry have not undertaken any significant activities in this specific area.

The introduction of the WindStream5 (WS5) marks a notable shift as it brings a small-scale wind turbine to the market. What sets it apart is the adoption of methods and processes akin to those utilized in the development of large wind turbines. This includes the implementation of systematic construction procedures, aeroelastic simulations, wind tunnel measurements, Finite Element Method (FEM) component investigations, and Failure Mode and Effects Analysis (FMEA) system analyses in the design phase. A key focus during development has been on enhancing robustness, reducing maintenance requirements, ensuring user-friendliness, minimizing noise emissions, and addressing safety considerations within the system.

2. Design Concept

The WS5 is a robust, passive stall-controlled small wind turbine with a rated power output of 5kW, designed for both grid-connected and island-grid operation. All key mechanical components, including the generator, gearbox, shaft, and bearings, are integrated within a central aluminium casting.

Electricity generation is achieved through a two-stage, pole-changing 3-phase asynchronous generator with 1.5 kW and 5.5 kW. This generator is driven by the rotor via a gearbox. The rotor blades are aerodynamically optimized and set at a fixed angle of attack. They operate at fixed speeds to generate three-phase power at a frequency of 50 Hz.

The 3-blade horizontal axis system, when connected to the grid, employs active wind direction tracking to optimize its alignment with the wind. The WS5 has a cut-in wind speed of approximately 3.5 m/s and a cut-out wind speed of 18 m/s. For installation, two mast options are available: a 12 m high free-standing mast and an 18 m high guyed lattice mast.

3. Key Components

3.1. Rotor

The WS5 rotor is equipped with three blades, which can be crafted from either wood or a GRP profile (glass fibre-reinforced plastic). Both materials exhibit outstanding fatigue resistance, high abrasion resistance, and excellent UV resistance.

To ensure the necessary power limitation at higher wind speeds, the rotor blades of the WS5 incorporate a unique aerodynamic profile designed for passive stall operation. This feature allows for effective power limitation at the rated level without the need for rotor blade adjustments. The aerodynamic profile underwent specialized development and optimization through flow calculations and extensive field investigations.

3.2. Brake and Safety Concept

In addition to the power limitation at high wind speeds achieved through the specially designed stall properties of the blade profile, the WS5 is equipped with two electromagnetic safety brakes. Whenever the control unit detects that predefined parameter, such as nominal power, wind speed, or grid stability, exceed critical thresholds, the two brakes are automatically engaged to bring the system to a safe stop.

Furthermore, the WS5 is equipped with a safety chain. In case of a control unit failure, these safety mechanisms enable the brakes to be activated directly, either through a speed switch, a temperature switch, or a vibration switch. This ensures a reliable means of stopping the system, thereby enhancing overall safety.

3.3. Gearbox

The WS5 features a gearbox equipped with a single-stage spur gear with noise-optimized helical gearing. The rotor of the system is directly mounted on the drive shaft of the gear in the machine housing.
Within the lower section of the machine housing, ample space is allocated for an oil reservoir, which guarantees the long-term functionality of the gear teeth and roller bearings. Remarkably, an oil change, requiring only 0.5 litters of oil, is necessary just once every 5 years.
The low-friction seals ensure even at low wind speeds a smooth system startup.

3.4. Generator

The WS5 employs a three-phase asynchronous generator, specially engineered for high efficiency, as its power generator. All parts of the generator are constructed with a high insulation class and are fully enclosed within the machine housing, effectively shielding them from external weather conditions.

The pole-changing generator switches between two speeds based on the current power input. The first stage operates at 1.5 kW, while the second stage reaches 5.5 kW. The exceptional efficiency in the low-power range is especially beneficial for the wind turbine's design, as most energy yields are attained at moderate wind speeds.

3.5. Yaw Control

In the 5kW wind turbine market segment, the WS5 distinguishes itself as one of the few turbines equipped with a wind direction tracking system. This feature includes a motor and gearbox that accurately align the rotor with the wind direction. This advanced technology notably enhances energy production from the wind turbine and diminishes the fatigue stresses attributed to yaw errors.

3.6. Nacelle

From a mechanical point of view, the key components are integrated into a central cast aluminium structure. This highly compact design has been meticulously optimized to satisfy demands for rigidity, strength, heat dissipation, and manufacturing efficiency. Within the machine block, you'll find the rotor bearings, gearbox, generator, safety brake, vertical bearing, and elements of the yaw system.

Figure 2: Single frame concept

3.7. Housing

To attain an aesthetically pleasing appearance, the WS5 features a housing made of Glass Reinforced Plastic (GRP), which was meticulously designed by an industrial designer, taking both aesthetic and functional considerations into account. The housing shields the entire machine block from direct sunlight and adverse weather conditions while also facilitating optimized airflow across the generator's cooling fins.
Furthermore, it provides a range of possibilities for individualized design, including various colour options.

3.8. Tower

During the tower development, particular attention was placed on weight considerations for transportation and installation. In this context, a lattice tower was chosen as it offers the most advantages.
Depending on site conditions, various tower sizes are available. For the WS5, you can opt for either a 12-meter freestanding tower or an 18-meter guyed lattice tower. These towers are constructed using 3-meter segments that can be telescoped for ease of transportation.

3.9. Anemometer

At the top of the nacelle, there is an anemometer designed to measure both wind speed and wind direction. The data collected by this instrument is utilized by the controller to accurately orient the WS5 with respect to the wind using the yawing system.

3.10. Control System

The controller plays a pivotal role in ensuring the efficient and secure operation of the wind turbine. It oversees and manages the system as well as its integration with the grid. Its responsibilities encompass a range of tasks, such as controlling the generator switchover, engaging the brakes, establishing connections with the power grid, monitoring wind speed and direction, and managing additional loads. Importantly, the system can be remotely monitored through an Internet connection, allowing additionally the installation of new software updates.

4. Technical Data Sheet

General

Nominal Power Output (4-pole/6-pole)	1,5 / 5.0 kW
Cut-In Wind Speed	3.5 m/s
Rated Wind Speed	12.5 m/s
Cut-Out Wind Speed	18.0 m/s
IEC Type Class	TK 3
Operating Temperature	-20° C to + 50° C

Rotor

No. of Blades	3
Rotor Diameter	5.0 m
Rotor Area	19.76 m²
Blade Material (Optional)	1. Wood 2. Glass Fiber Reinforced (GRP)
Nominal Rotational Speed	122 / 184 min^{-1}
Power Regulation	Passive Stall
Yaw Control	Active Yawing System

Generator

Design	Asynchronous Generator, 2 Levels
Nominal Power	1.5 / 5.5 kW
Nominal Speed	1010 / 1520 min^{-1}
Number of Phase	3 Phase
Generator Voltage	400 V
Generator Frequency	50 Hz

Gearbox

Type	Single Stage Spur Gearbox
Transmission Ratio	8.27
Output Torque	117.4 Nm

Yaw Control

Design	Upwind Drive with Active Yawing System

Safety System

Power Control	Passive Stall
Braking System	Two Electromagnetic Safety Brakes
Safety Chain	Temperature-, Centrifugal-, Vibration Switch

Tower

Hub Height	12m/18m
Type	Lattice Tower
Construction Type	Freestanding (12m) or 18m (guyed)
Material	Steel

Mass

Nacelle without Rotor	174.7 kg
Entire Rotor	68.2 kg
Tower	613 kg (12 m) / 1002 kg (18 m)
Control Unit	37.8 kg
Total Weight	903.7 kg (12 m) / 1295.7 kg (18 m)