Security Classification: 机 密

GOLDWIND

GOLDWIND 1.5 MW Technical Description

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Prepared by Elliot Zhu

Checked by

Reviewed by

Approved by

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金风科技股份有限公司
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受控(2)

Goldwind Science & Technology Co., Ltd.
www.goldwindglobal.com
info@goldwind.cn

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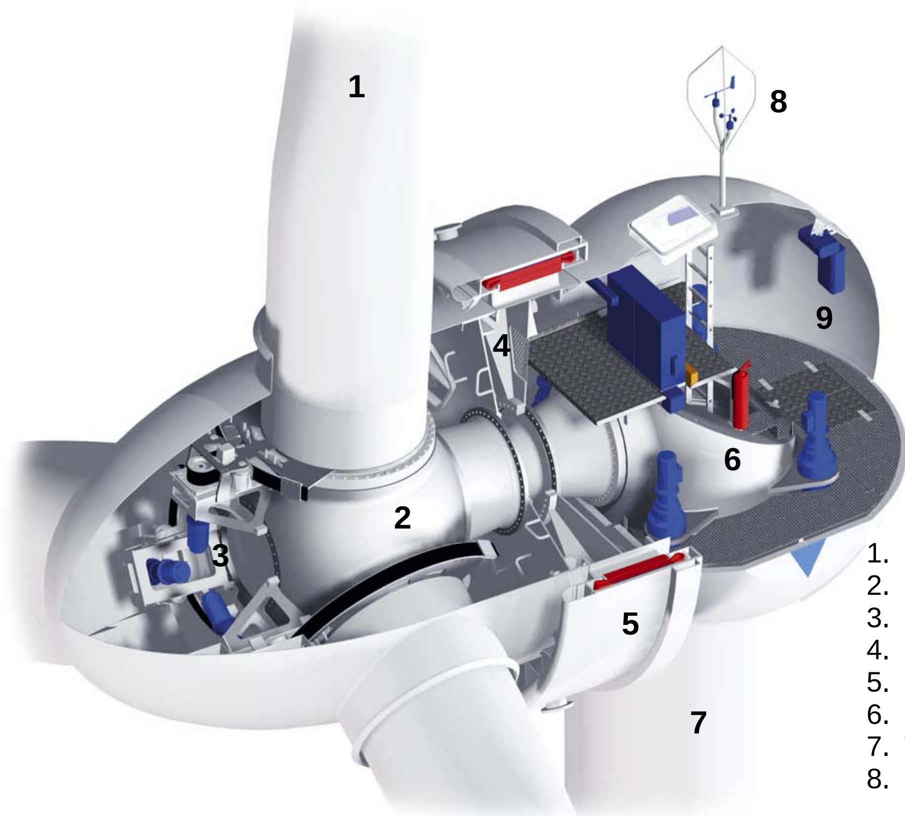
1. Introduction

The basis of the GOLDWIND 1.5 MW wind turbine (GW 1.5 MW) is its Permanent Magnet (**PM**) generator, which is gearless and Directly Driven (**DD**) by a **3-blade** rotor. The combination of the PM synchronous generator with its **full power converter** maximizes energy output, making the wind turbine highly efficient and reliable. These technologies specify the **turbine type**.
Wind turbines frequently operate at partial load, a range wherein PM generators reach their highest **efficiency**. Direct Drive (DD) is the ultimate concept for reducing turbine components as well as increasing its reliability. A unique feature of the GW 1.5 MW turbine is the direct cooling of the generator by the wind, utilizing the relationship between the generator cooling demand and wind speed to cool the generator efficiently. The full load IGBT converter allows an adapting rotor speed to achieve optimum aerodynamic efficiency at varied wind speeds. This converter system combined with the PMDD synchronous generator guarantees superior grid connection capabilities. **Tooth-belt driven blade pitch** systems combined with **ultra-capacitors** ensure precision, safety and low maintenance.
The product model is offered in several versions: GW 70/1500, GW 77/1500, GW 82/1500, and GW 87/1500 (70m, 77m, 82m, and 87m rotor diameters, respectively). These versions cater to different wind resources and are available at varying tower heights.



1. Rotor Blade
2. Casted Hub
3. Pitch System
4. Generator Stator
5. Generator PM Rotor
6. Base Frame
7. Tower
8. Wind Measurement Equipment
9. Auxiliary Crane

Figure 1: Goldwind 1.5 MW Turbine

Special Features:

- **Permanent Magnet “PM” generator**
    - ⇨ No energy loss through magnetic field excitation
    - ⇨ High generator efficiency, especially at partial load
    - ⇨ No need for slip rings for excitation of generator-rotor
- **Direct Drive “DD” multi-pole generator**
    - Direct flange connection between turbine-rotor and generator
        - ⇨ Gearless; no gearbox monitoring system
        - ⇨ No gearbox oil, no oil pumping, cooling or filtering
    - External generator-rotor concept
    - Passive air cooling system
        - ⇨ No active cooling systems needed; no energy used for cooling the generator
        - ⇨ Fewer components: high reliability, less maintenance, higher availability
- **PMDD generator is combined with full load IGBT converter**
    - ⇨ Wide range of speed control, optimum turbine-rotor efficiency
    - ⇨ Superior grid connection capabilities (ZVRT, LVRT, and HVRT)
- **Tooth belt driven blade pitch system**
    - ⇨ No backlash, more precise blade angle
    - ⇨ No grease lubrication needed for the tooth belt
    - ⇨ Easy to exchange compared to a pinion or whole pitch bearing
- **Ultra-Capacitors used in series with each pitch actuator motor power supply**
    - ⇨ No use of lead-acid battery, no energy loss at low temperature
    - ⇨ Long lifetime
    - No change in operating mode of pitch system during voltage drop or grid loss
    - Permanent control of energy storage
        - ⇨ Safely pitch each blade to a safe position after power loss or for an emergency stop

1.1 Product Versions

This Technical Description document is valid for the following versions of the GW 1.5 MW model:

Table 1: Goldwind 1.5 MW Turbine Versions

Version	Rated Power	Rotor Diameter	Hub Height	Rotor Blade	Wind Class	Certification
GW 70/1500	1.5 MW	70 m	65m	LM 34	IEC IA	TÜV
GW 77/1500	1.5 MW	77 m	65m 85m	LM 37.3	IEC IIA	TÜV
GW 82/1500	1.5 MW	82m	70m 85m 100m	LM 40.3	IEC IIIA	TÜV
GW 87/1500	1.5 MW	87m	75m 85m	LM 42.1	IEC IIIB	TÜV

*All versions currently hold certifications or are in the process of being certified

2. Rotor

2.1 Blades

The Goldwind 1.5 MW wind turbine rotor is equipped with 3 reinforced fiber glass blades (GRP) that are produced by qualified international blade manufacturers. The high aerodynamic efficiency of the rotor is based on the efficient design of the airfoils used in each blade. Different blade lengths are used depending on the wind class of the site that the turbine will be placed. This optimizes energy output and loads. The following table shows the respective blades used for each Goldwind 1.5 MW turbine model and the resulting swept area.

Table 2: GW 1.5MW Blade Characteristics

Blade Type	Blade Length	Rotor Diameter	Swept Area
LM 34P	34.0m	70m	$3886m^2$
LM 37.3P	37.3m	77m	$4649m^2$
LM 40P	40.3m	82m	$5325m^2$
LM 42.3P	42.1m	86.6m	$5890m^2$

2.2 Hub

The hub supports the three rotor blades via the blade bearings and connects them to the generator. The connections between the blades and hub, as well as the generator-hub connection are flange bolt connections. The hub is optimized for size and weight and is made of casted iron (EN-GJS-400-18U-LT / GGG 40.3). Additionally the pitch system, including the pitch motor, gear box, control box, and the nose cone support structure are integrated into the hub.

2.3 Pitch System

The pitch system is responsible for adjusting the pitch of the three blades. As the blades are pitched, the angle of attack of each blade is changed, either increasing or decreasing the lift force over the blades. All three blades are controlled collectively, with each blade acting independently.

The following components and connections are contained in each system.

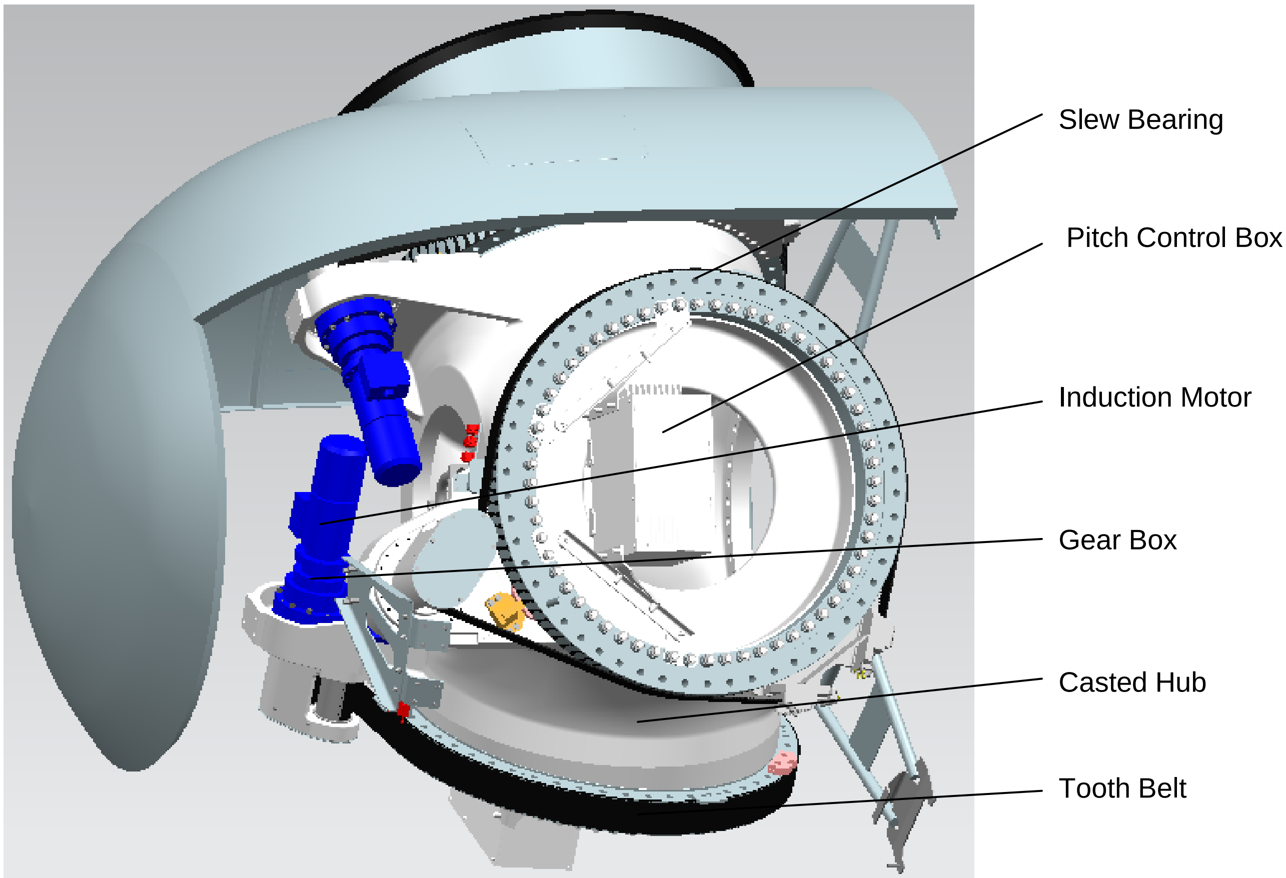


Figure 2: Pitch System and Rotor Hub

The blade is connected to the hub via a slew bearing. This is a double row ball bearing that allows the blade to rotate around its longitudinal axis with minimal friction.
Motion is actuated by a 3-phase induction motor. The simple design of induction motors means the system is reliable with minimal maintenance requirements. The motor is equipped with an independent cooling fan and a motor brake on the second end. The output of the motor is connected to a 3-stage planetary gear box.
A carbon fiber reinforced tooth belt transfers the output from the gearbox pinion to the outer ring of the blade bearing. This pre-stressed tooth belt adjusts the pitch angle with superior accuracy and no backlash. High stiffness carbon fiber material ensures minimal elongation over time. The ease of interchanging belts, and the lack of a need for lubrication, keeps costs at a minimum. The belt system used in the Goldwind 1.5 MW turbine is a patented technology.

The pitch system receives power from the main power supply in the nacelle by means of a slip ring at the center of the generator-hub connection. The power is rectified to DC to charge the ultra-capacitor and power the control circuits. The DC source is thus converted to AC to power the induction motor.

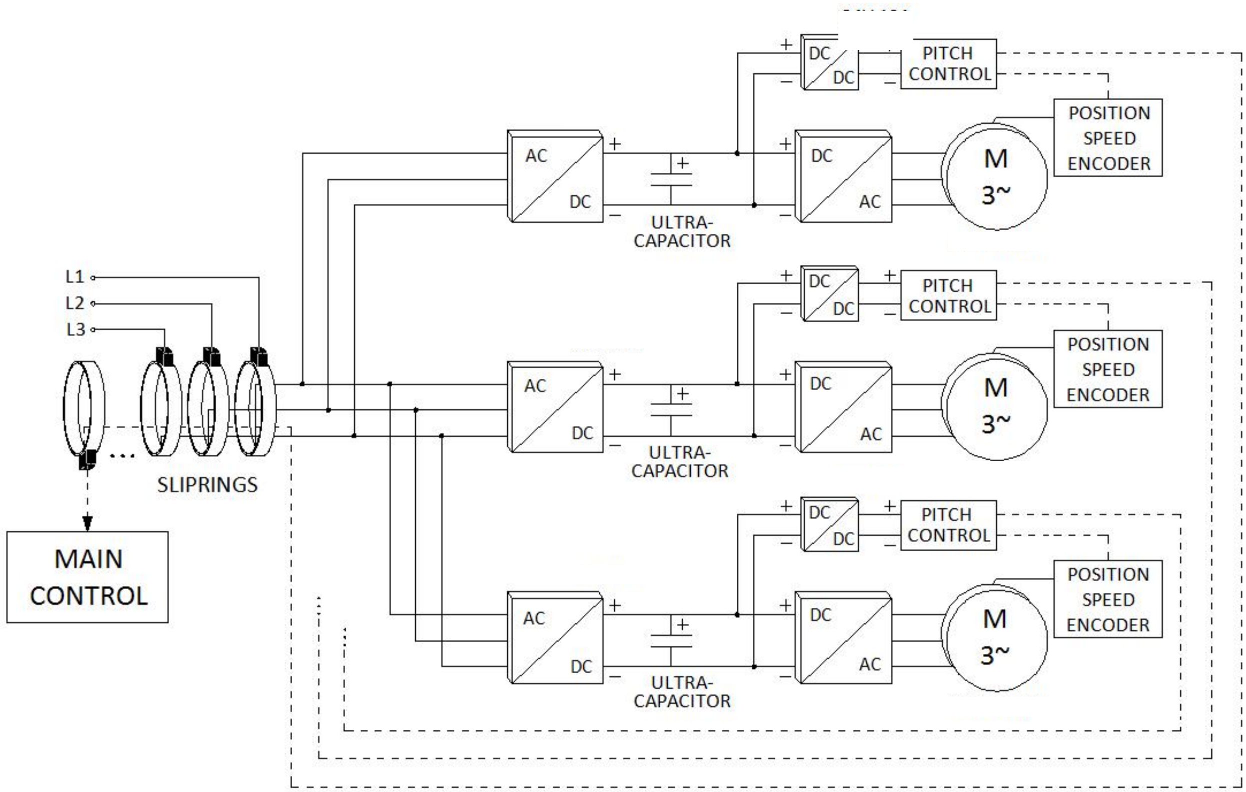


Figure 3: Pitch Control Electrical Diagram

The three pitch controllers receive identical signals from the main turbine controller and each blade subsystem responds independent of the other blades. The independent nature of the system means that if a single blade fails the other two blades can respond to slow the turbine to a safe speed. This is an inherent safety feature of the pitch system.
A position sensor on the second end of the motor reports the blade position and pitch speed to the controller. A central pitch controller compares the position of each blade and synchronizes them. A second position sensor is located on the blade bearing that checks the blade position and synchronization with the motor sensor for safety reasons.
The desired pitch angle is basically calculated on the difference between the actual generator speed and the desired generator speed. The desired generator speed is derived from the utility power demand and rotor output.

In the event of power loss (i.e. grid failure) the pitch system needs stored energy to re-pitch the blades to a safe position. By placing the ultra-capacitors in series with the power supply, they will always carry a charge, giving immediate action when needed. No change in the operation mode of the pitch system occurs during a voltage drop and "low voltage ride through." In addition there is no change in operating systems during grid loss. The continuous operation of the ultra-capacitors guarantees the permanent full control and functionality of this storage and safety system. Ultra Capacitors also have the benefit of a long lifetime and are not affected by high and low temperatures.

3. PMDD Generator

The generator of the Goldwind 1.5 MW turbine is a multi-pole Permanent Magnet Direct Drive (PMDD) Synchronous generator.

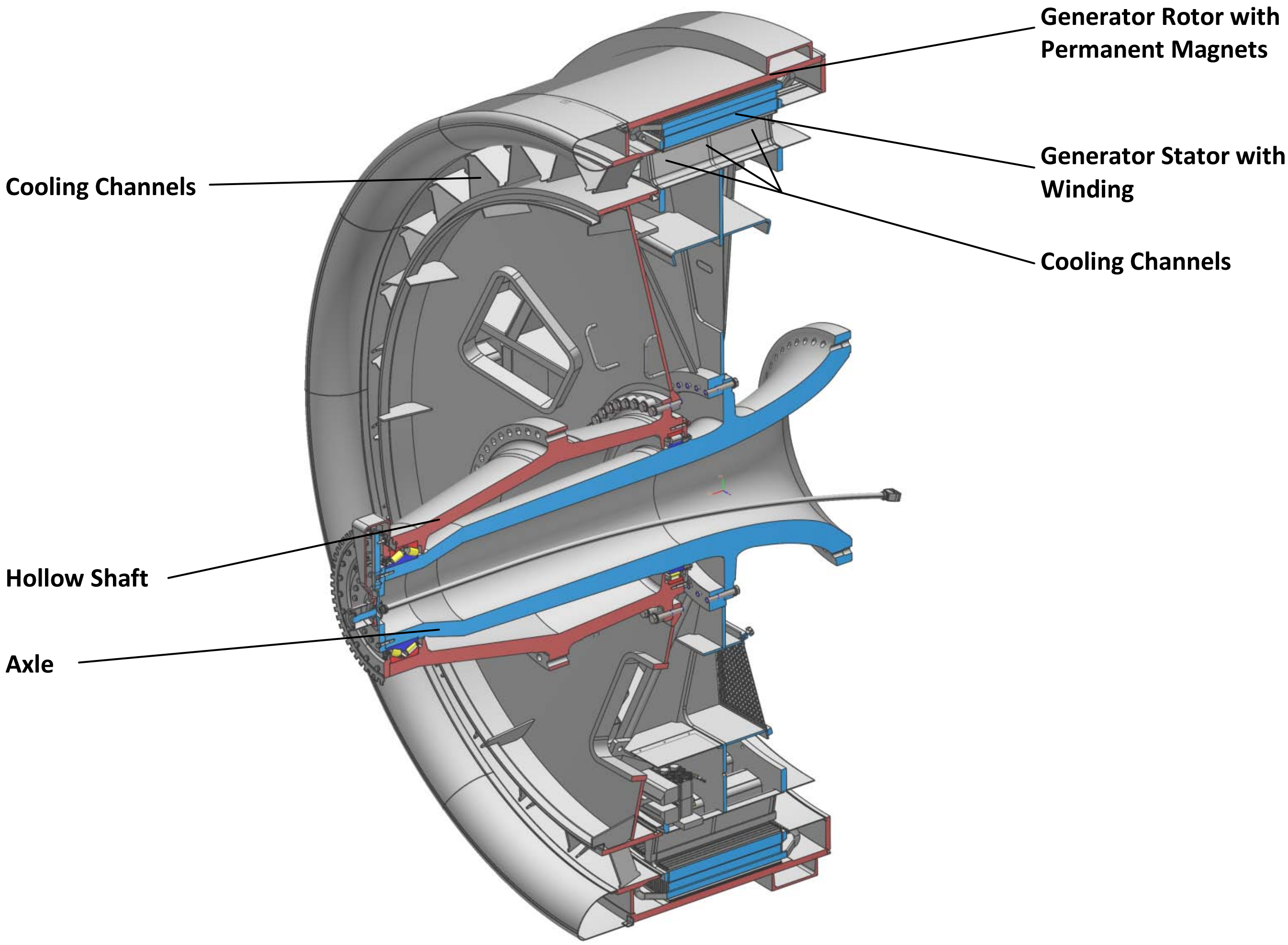


Figure 4: 1.5 MW PMDD Generator

The Permanent Magnet (PM) design maximizes efficiency with no energy loss resulting from magnetic field excitation and no slip rings.
The direct drive (DD) aspect of the turbine means there is no gearbox. As a result there are no couplings, gearbox oil, oil pumps, cooling, heating, filtering, and gearbox monitoring systems, minimizing components and costs.
The variable speed nature of the generator-converter system means that the aerodynamic efficiency of the turbine rotor can be maximized by adapting the rotor speed to the wind speed. The combination of this type of synchronous generator and full load converter, allows the system theoretically to be able to adapt to the full range of wind speeds from zero to rated output.

As a safety measure and for maintenance operations, a hydraulically actuated rotor brake will slow the rotor to a complete stop following the use of the aerodynamic brake if needed. A hydraulic lock then locks the rotor in place.

A special design feature of the GW 1.5 MW generator is the external rotor design.

Technical data

Outside diameter	5.002 (Including lifting points)
Air gap between rotor and stator	6 mm
Winding type	two layer fractional-slot winding
Slots and Coils	576
Frequency	13.9 Hz (GW 70), 12.7 (GW77/ GW 82), 12.17 (GW 87)
Number of phases	3 phase (x2)
Rated voltage	690 V

3.1 Generator Rotor

Permanent magnets are placed on the inside of the rotor cylinder in 22 blocks of 4 poles, resulting in 88 poles. The magnetic fields of the poles, rotating around the stator coils, produce the voltage in the stator. The rotor (entire rotating section of the generator, shown in red above) is manufactured using casted and welded components.
The magnets are fixed to the inside of the rotor cylinder and sealed with high strength glue. Additionally the magnets are covered by a fiber glass protective layering.

The rotor is an external rotor, meaning the rotor rotates around the outside of the stator. Assuming the same diameter of the air gap between rotor and stator, the use of a PM rotor as an external rotor, reduces the total diameter of the generator. This is due to small thickness of the permanent magnets compared to an electrically excited rotor.

3.2 Generator Stator

The generator stator (shown in blue above) is a combination of casted and welded components that support the stator core and the three phase copper winding. The copper winding utilizes rectangular copper wiring, which ensures optimal insulation covering. The stator is fixed to the base frame of the turbine by a bolt flange connection. It is a static component.

3.3 Rotor Bearing

The turbine rotor and generator rotor are connected to the hollow shaft by flange bolt connections. The hollow shaft rotates about the axel via a tapered roller bearing in the front (luff) and a cylindrical roller bearing in the rear (lee).

3.4 Passive Cooling System

The Goldwind 1.5 MW generator is passively cooled by air passing through cooling channels located in the stator and by air over the outside of the rotor. The relationship between generator cooling demand and the wind speed makes this cooling strategy possible.

This cooling system guarantees that the magnets cannot be demagnetized. The occurrence of demagnetization depends on a combination of high temperatures and large magnetic fields. The maximum magnetic field can be produced by a short circuit in the electrical system close to the stator. The cooling system of the turbine always keeps the temperature of the magnets so low, that a short circuit close to the stator cannot result in a demagnetization of the rotor.

4. Nacelle

The nacelle is an enclosure that sits atop the tower. It is made of three parts; a base frame, a walkable platform, and a fiberglass cover.

The base frame is connected to the axle (generator stator) by a vertical flange and to the yaw system by a horizontal flange. It is responsible for transferring all loads from rotor to the tower and is manufactured using casted iron (EN-GJS-400-18U-LT / GGG 40.3).

The platform is fixed to the base frame; it provides an area for maintenance personnel and for the systems that are housed in the nacelle.

The nacelle houses the yaw system, hydraulic system, auxiliary crane and the so called top boxes, which includes several electrical components, like the power supply and circuit breakers for the subsystems in the nacelle and rotor hub.

The meteorological equipment, anemometer and wind vane, and hazard beacons (Upon Request) are placed on top of the cover.

4.1 Yaw System

The yaw system turns the rotor / turbine head into the wind and adjusts its position as the wind direction changes. The wind direction is monitored by a wind vane on the nacelle cover, which sends a signal to the turbine controller to yaw the nacelle as the wind direction changes.

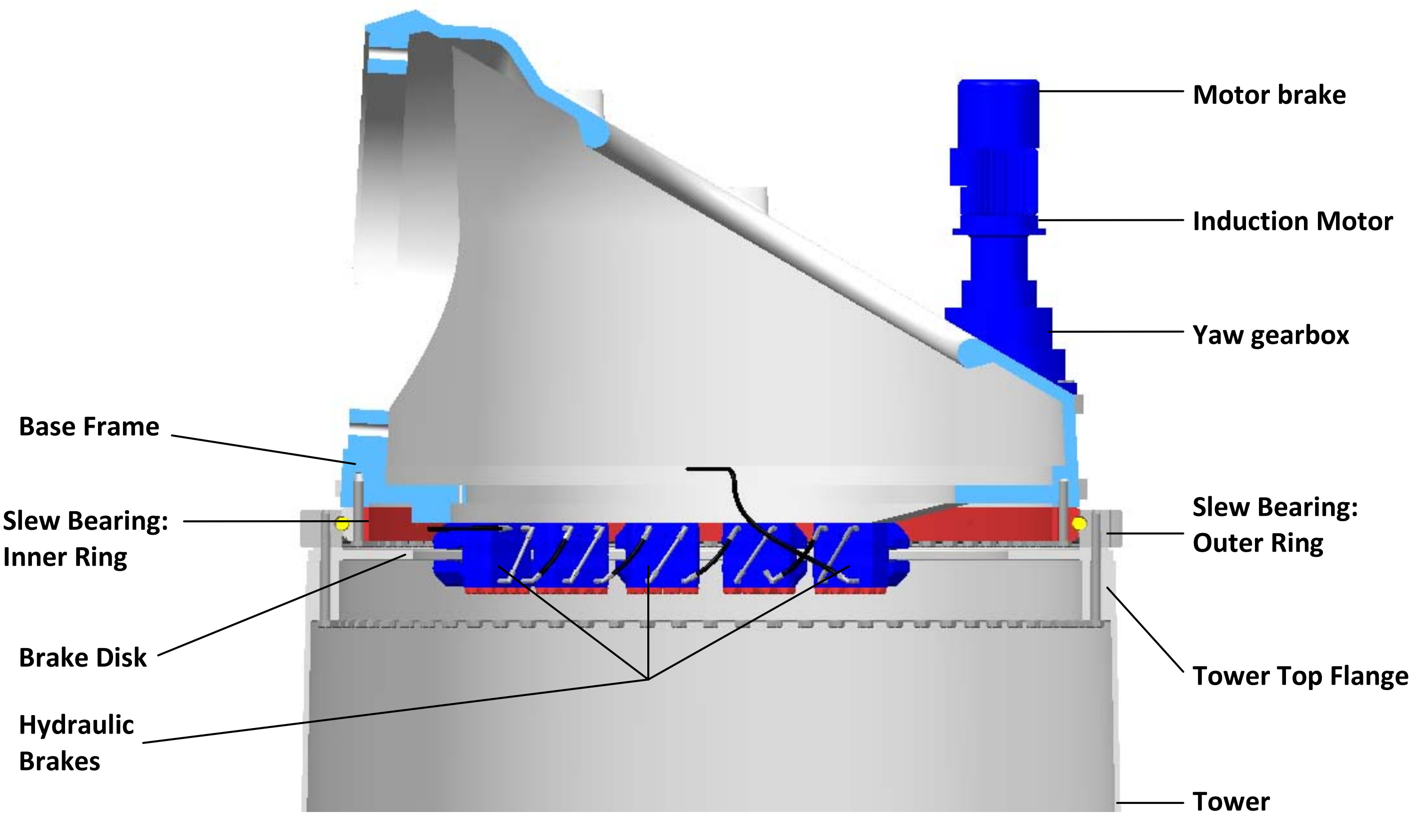


Figure 5: Yaw System

The system consists of a fixed system and a rotating system (blue). The fixed system includes the tower top flange (tower), static brake disk, and the outer ring of the slew bearing, which are all bolted to the tower. The rotating system contains all components bolted to the base frame of the nacelle. This includes three induction motors, a number of hydraulic brakes, and the inner ring of the slew bearing.

The induction motors are connected to a four stage planetary gear box. The output of the gear box drives a pinion aligned with the toothed outer ring of the slew bearing. The motors apply the actuation force to yaw the nacelle as the wind direction changes.

Hydraulically actuated brakes, located to the inside of the base frame and tower, apply pressure to the brake disk to keep the turbine head from yawing. Additionally motor brakes at the second end of the induction motors add brake torque. During yawing, several brakes are released, while others keep pressure to eliminate backlash between the gears, which could be induced by wind gusts.

After several full rotations, the turbine will return to its original position to untwist the power and data cables that run from the nacelle to the base of the turbine.

5. Tower

The tower is manufactured using high strength steel in three to five sections, depending on the overall tower height. Each section contains an inner flange on each end for connecting the segments. The bottom tower section is bolted to the foundation and the subsequent sections are bolted on top.

Towers are equipped with a ladder and safety rail. Upon request an assisted climbing system or an elevator can be included for maintenance access to the nacelle. Emergency lighting and platforms are installed throughout the tower in regular intervals.

6. Foundation

The foundation is made of reinforced concrete with an embedded “foundation steel section”. A flange on the top of the foundation steel section connects the first tower section to the foundation.

Standard foundations are designed for each rotor diameter, tower height and wind class of the GW 1.5 MW turbine that meet different standards and a variety of environmental conditions. However, local standards, soil conditions and other environmental conditions vary considerably from place to place and it is necessary to design a site specific foundation. Goldwind works together with local civil engineering firms with the specific local knowledge to design these foundations.

7. Electrical Systems

7.1 Converter

The GW 1.5 MW variable speed system is based on the combination of the PMDD synchronous generator and the full range frequency converter. It allows the generator to operate at the optimized rotor speed from cut in to cut out. Variable frequency AC power from the generator (linear to the generator rotational speed) enters the converter, and is converted to match the grid frequency, whether it is 50Hz or 60Hz. The converter thus decouples the generator frequency from the grid frequency. The converter system has its own controller unit (CPU), separate from the turbine controller.

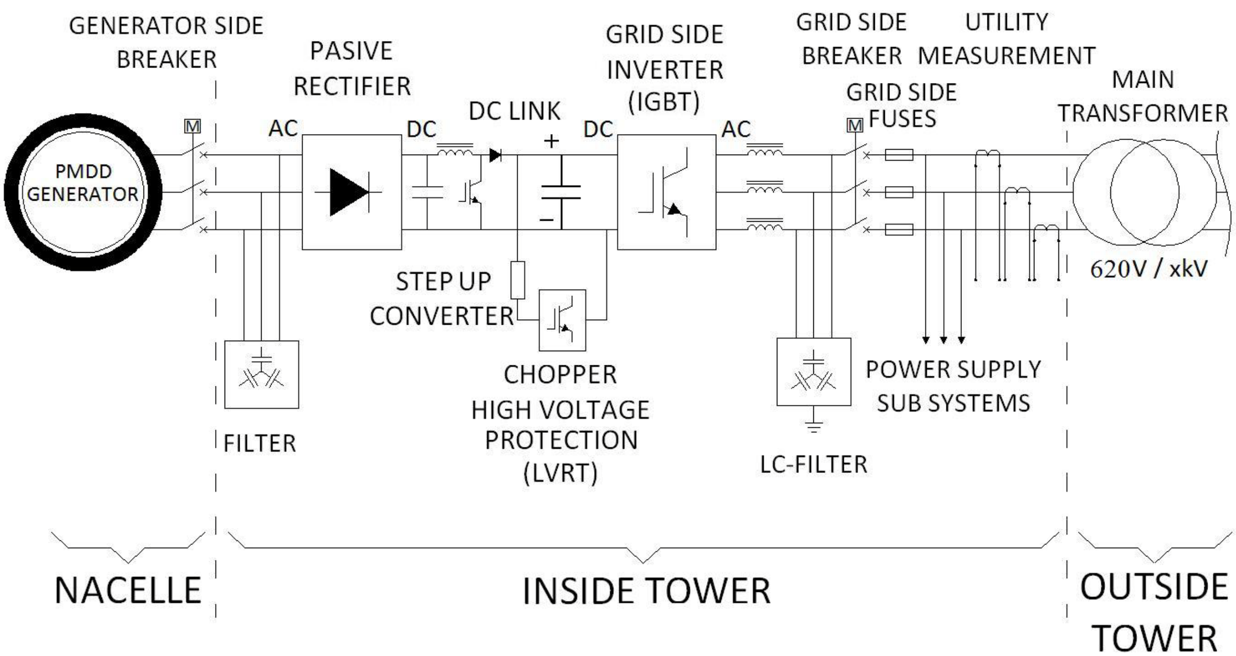


Figure 6: GW 1.5 MW Electrical Diagram

The three phase power output from the generator enters a passive rectifier (A series of diodes) that converts the AC generator output to DC. An IGBT inverter then converts the DC back to AC at the required grid frequency and supplies a sinusoidal current. The microprocessor controlled power electronics (IGBTs) allow the system to be adapted to various grid requirements by software adjustments.

The DC-Link and capacitor are responsible for maintaining the balance between the generated and output power. If the grid doesn't take the output of the rectifier (ex. grid fault), there will be a voltage increase in the DC link. To protect the IGBT modules and to allow the turbine to stay connected to the grid, for example during a "Low Voltage Ride Through" (LVRT), the high voltage protection circuit will limit the excess voltage by dumping the load through a resistor.

Harmonic filters are located on the grid side of the converter. They support the overall power quality of the system and ensure grid standards are met. Fuse boxes and circuit breakers are able to disconnect the converter from the grid.

To meet any present grid requirement and most future grid requirements the PMDD - full power converter system is a perfect base to be adapted, solely by software modifications.

The converter, located at the base of the tower, is a modular system that can be easily serviced.

The power supply to the subsystems in the turbine is taken directly from the grid. This includes the power supply for the main controller, which is backed up by an uninterruptable power supply (UPS).

7.2 Main Turbine Transformer

The transformer is located downstream to the converter and transforms the low voltage output of the turbine to medium voltage level. The standard is to place the transformer outside of the tower.

8. Turbine Controller

The turbine controller manages all functions and sub controllers of the turbine; it optimizes the loads and energy output, depending on utility and customer demand.

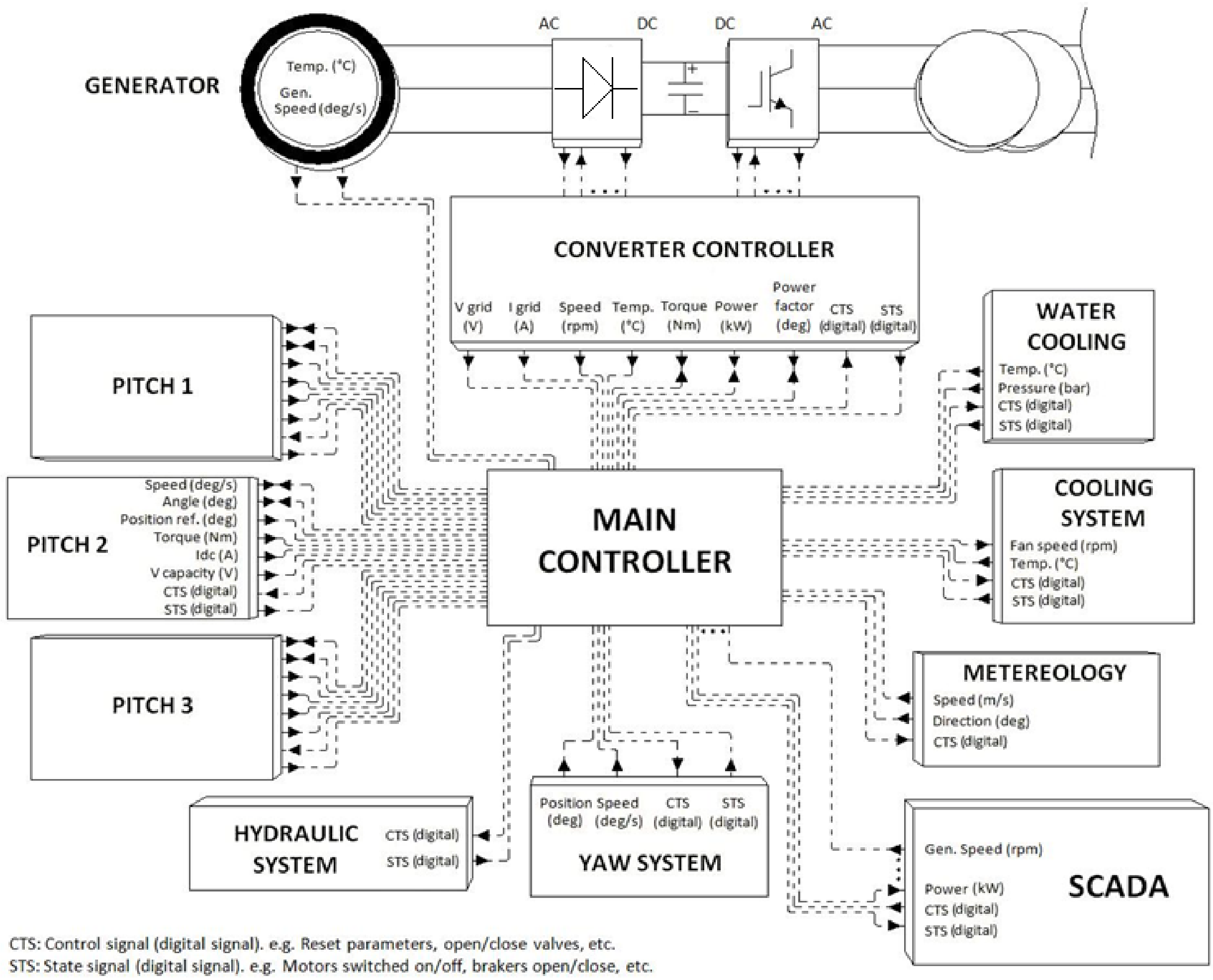


Figure 7: GW 1.5 Control Diagram

It receives signals from the converter and pitch sub controllers, as well as data from all sensors within the turbine, like the anemometer, wind vane, generator speed sensor, temperature sensors, yaw position sensor, vibration sensors, etc …
The turbine controller sends commands to the converter and pitch sub controllers, and activates the yaw system, hydraulic system, etc…

The main signals are transmitted by a DC-isolated profibus system.

The SCADA system is integrated into the turbine through the main controller. It can both send commands to the turbine controller and receive data from the controller via the wind park control system.

The turbine controller is placed at the base of the tower.

9. SCADA (Supervisory Control and Data Acquisition)

The turbine can be controlled and monitored externally through the wind farm control system at the wind farm. The turbine can be monitored by the Goldwind SCADA system via any computer with internet access. Both current and historical turbine operating data can be viewed from a SCADA terminal. Various levels of security exist within the systems, allowing the customer to choose specific access levels.

10. Goldwind 1.5 MW Series Technical Data

Technical Data	GW 70/1500	GW 77/1500	GW 82/1500	GW 87/1500
Power				
Rated Power	1500kW			
Cut-in Wind Speed	3m/s			
Rated Wind Speed	11.8m/s	11m/s	10.3m/s	9.9m/s
Cut-out Wind Speed	25 m/s (10 min avg.)	22 m/s (10 min avg.)		
Rotor				
Diameter	70.34m	76.94 m	82.34 m	86.6m
Swept Area	3886 m^2	4649 m^2	5325 m^2	5890 m^2
Speed Range	10.2-19rpm	9 -17.3rpm	9-17.3rpm	9-16.6rpm
Blades	3			
Type	LM 34P or similar	LM 37.3P or similar	LM 40P or similar	LM 42.1P or similar
Power Control	Collective Pitch Control / Rotor Speed Control			
Safety System	Independent Blade Pitch Control Hydraulic Disk Brake Hydraulic Rotor Lock			
Generator	Permanent Magnet Direct Drive Synchronous Generator			
Rated Voltage	690V			
Yaw System	3 Induction Motors with Hydraulic Brakes			
Tower	Tubular Steel Tower (Q345C/D/E)			
Hub Height	65m	65m, 85m	70m,85m,100m	75m,85m
Foundation	Flat Foundation (Other Options)			
Converter	Full Power Converter (IGBT Modular System)			
Transformer				
Input Voltage	620V	620V	620V	620V
Output Voltage	20kV (Others Possible)			
Control System	Microprocessor Controlled, DFÜ (SCADA) with Remote Monitoring			
Design Standard	IEC IA	IEC IIA	IEC IIIA	IEC IIIB
	TÜV Nord (Design Assessment)*			

*All versions currently hold certifications or are in the process of being certified

11. Goldwind 1.5 MW Series Performance Curves

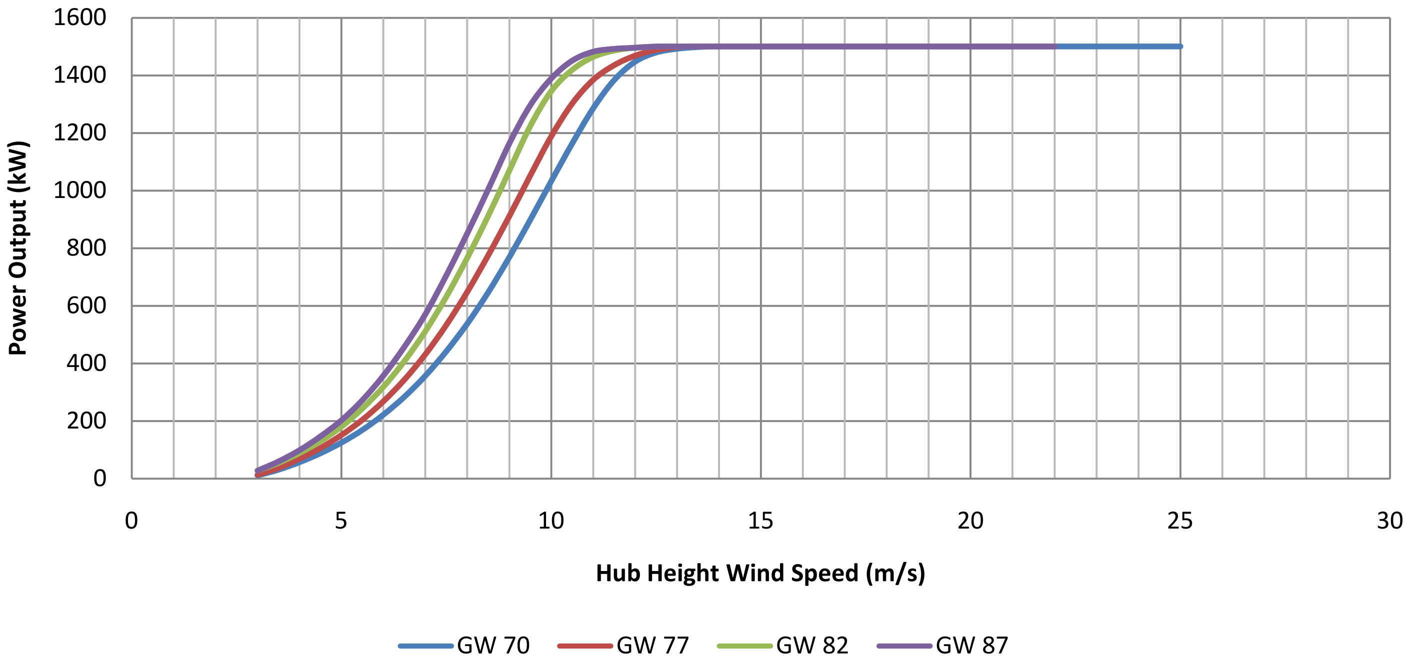


Figure 8: Goldwind 1.5 MW Series Power Curves*

***Calculated at standard conditions; Air density = 1.225kg/m3, Turbulence intensity = 10%. Please see Table 3 for numerical values.**

Hub Height Annual Average Wind Speed (m/s)	Calculated Annual Energy Production** (MWh/yr)			
	GW 70	GW 77	GW 82	GW 87
6	3,168.70	3,609.59	4,079.66	4,353.06
7	3,925.01	4,362.52	4,821.88	5,087.02
8	5,474.36	5,949.23	6,461.10	6,753.97
9	6,446.19	6,849.77	7,340.14	7,618.52

**** The ideal Annual Energy Production (AEP) for the Goldwind 1.5 MW series turbines has been calculated using a Rayleigh distribution.**

Table 3: Goldwind 1.5 MW Series Power Curves

Hub Height Wind Speed (m/s)	GW 70 Power Output (kW)	GW 77 Power Output (kW)	GW 82 Power Output (kW)	GW 87 Power Output (kW)
3	11	14	28	28
3.5	31	38	55	60
4	57	70	89	99
4.5	88	107	130	147
5	125	152	181	203
5.5	169	205	244	273
6	222	269	319	358
6.5	284	344	408	458
7	357	432	512	571
7.5	442	534	632	706
8	538	649	767	852
8.5	647	776	913	1005
9	768	911	1069	1163
9.5	898	1052	1224	1296
10	1032	1188	1345	1389
10.5	1163	1302	1419	1451
11	1285	1384	1464	1482
11.5	1383	1435	1486	1492
12	1447	1468	1496	1496
12.5	1479	1488	1500	1500
13	1492	1498	1500	1500
13.5	1498	1500	1500	1500
14	1500	1500	1500	1500
14.5	1500	1500	1500	1500
15	1500	1500	1500	1500
15.5	1500	1500	1500	1500
16	1500	1500	1500	1500
16.5	1500	1500	1500	1500
17	1500	1500	1500	1500
17.5	1500	1500	1500	1500
18	1500	1500	1500	1500
…	…	…	…	…
22	1500	1500	1500	1500
…	…			
25	1500			

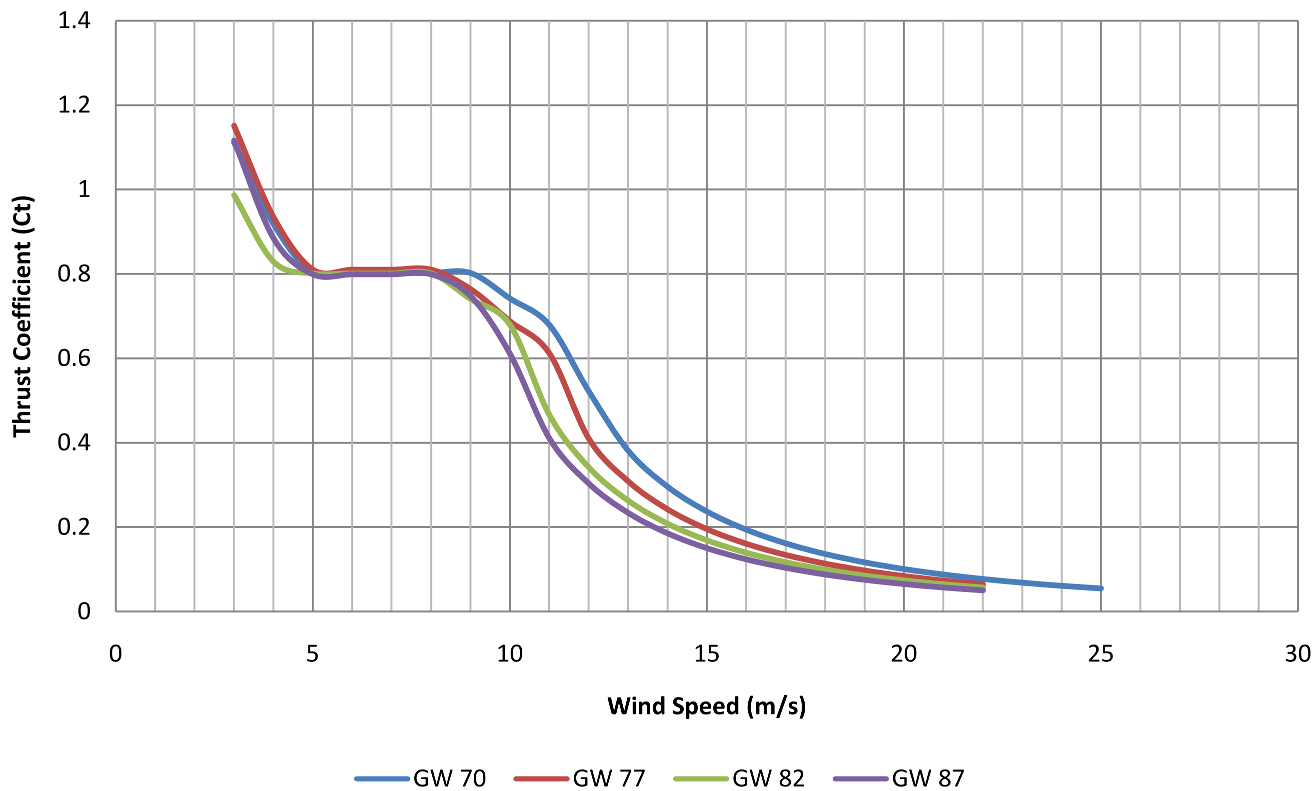


Figure 9: GW 1.5 MW Series Thrust Curves*

***Calculated at standard conditions; Air density = 1.225kg/m3, Turbulence intensity = 0%. Please see Table 4 for numerical values.**

Table 4: Goldwind 1.5 Series Thrust Curves

Hub Height Wind Speed (m/s)	GW 70 Thrust Coefficient	GW 77 Thrust Coefficient	GW 82 Thrust Coefficient	GW 87 Thrust Coefficient
3	1.1109	1.15066	0.986485	1.11651
4	0.918062	0.934016	0.828979	0.884595
5	0.802057	0.809703	0.800984	0.79926
6	0.802056	0.80972	0.800961	0.799345
7	0.802073	0.809629	0.80098	0.799318
8	0.802093	0.809716	0.801011	0.799319
9	0.802126	0.763506	0.740502	0.74772
10	0.741749	0.687529	0.679143	0.610908
11	0.679097	0.611321	0.465718	0.41053
12	0.522062	0.409339	0.341545	0.303546
13	0.381194	0.308251	0.262735	0.23399
14	0.295782	0.241931	0.208226	0.185597
15	0.236812	0.194989	0.168772	0.15041
16	0.19391	0.160307	0.139371	0.124002
17	0.161404	0.133866	0.116815	0.103822
18	0.13627	0.113323	0.099252	0.088047
19	0.116512	0.097002	0.085259	0.075537
20	0.100606	0.083897	0.073986	0.065482
21	0.087716	0.073221	0.064767	0.05729
22	0.077117	0.064438	0.057141	0.050528
23	0.068322			
24	0.060922			
25	0.054664			

Subject to Change:

The technical description of the Goldwind 1.5 MW (GW 1.5/70, GW 1.5/77, GW 1.5/82 and GW 1.5/87) wind turbine was updated on July 21, 2011. Future product development may result in differences in actual versus theoretical specifications and operating data. As such, this document is subject to change.

GOLDWIND