AOC 15/50

WIND TURBINE GENERATOR

TECHNICAL BRIEF

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1. General Overview

The designation 15/50 refers to the 15 m diameter rotor and its rated output of 50 kW. This rated output is achieved at 12 m/s (26.8 mph) by the 50 Hz version and at 11.3 m/s (25.3 mph) by the 60 Hz version.

The AOC 15/50 includes the following design features:

- Downwind, passive yaw
- High efficiency NREL designed airfoils
- High strength to weight ratio fibreglass blades
- PLC controlled, aerodynamic tip brakes
- PLC controlled electro-dynamic brake
- PLC controlled multi-disk parking brake
- Single piece hub casting
- No slip rings
- Integrated planetary gearbox
- 3-phase induction generator
- Single piece cast tower top lattice tower interface
- Custom height lattice tower or tubular tower
- PLC based controller with adaptive features
- Optional tilt-up tower for remote locations

The wind turbine is based on a simple downwind design with no nacelle. The standard tower is a 30.5 m (100 ft) tall, self-supporting lattice structure (see Figure 1).

The two stage planetary gearbox is integrated in the single piece cast housing. See Figure 2 for a more detailed view of the drive train assembly. Note that the generator/parking brake assembly is flange mounted to the planetary gearbox.

Both turbine versions are designed to cut in at 4.6 m/s (10.2 mph). The 50 Hz reaches its peak continuous output of 55 kW at 15 m/s (34 mph); the 60 Hz achieves its peak of 65 kW (60 Hz) at 16 m/s (36 mph). Additional performance information can be gleaned from the summary specs in Figure 3 and graph in Figure 4.

Figure 1: AOC 15/50 on lattice tower (Gurteen College, Ireland).

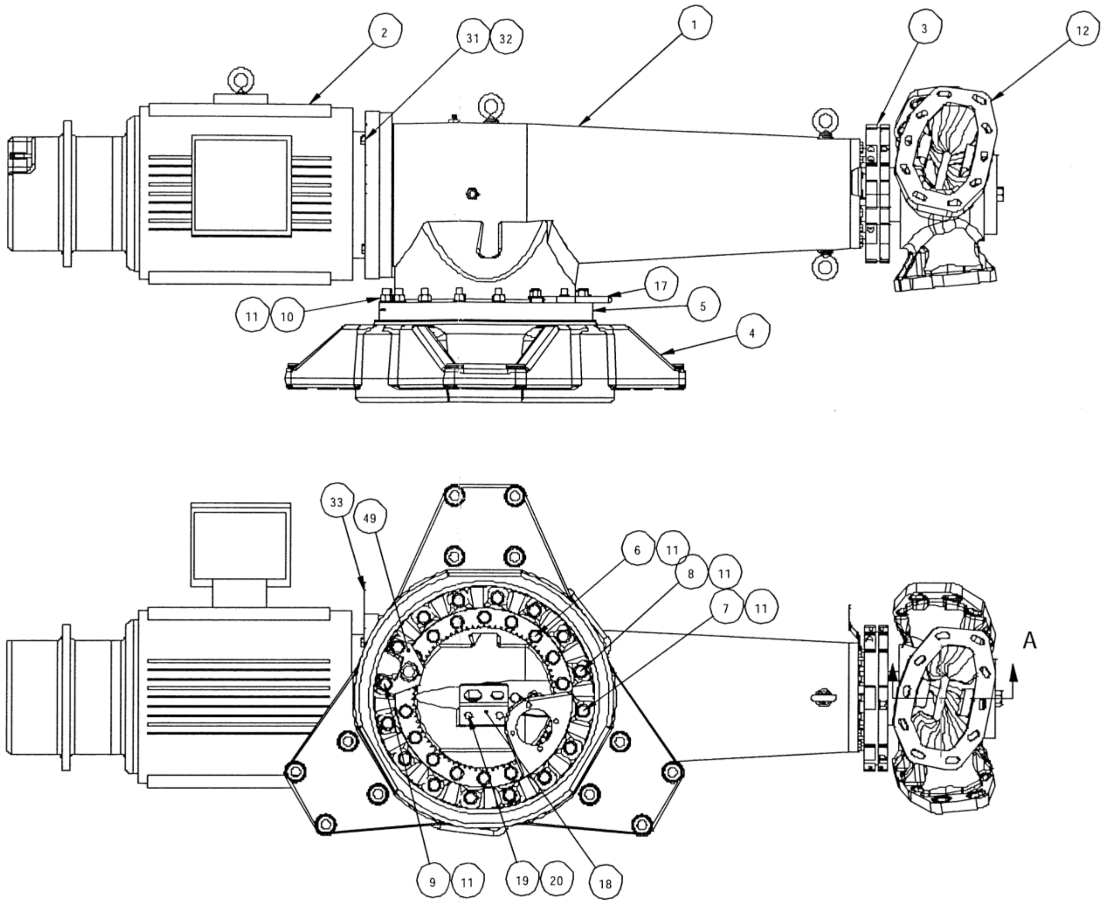

Figure 2: Wind Turbine Generator (WTG) Drivetrain Assembly

1. Gearbox Assembly & Location of Oil Fill Plug
2. Generator / Parking Brake Assembly
3. Rotary Transformer
4. Lattice Tower Top
5. Yaw Bearing Assembly
12. Rotor Hub Assembly
18. Twist Cable Suspension Bracket
49. Yaw Lock Assembly

Approximate Overall Length: 2.7 m (105 in)
Approximate Overall Height: 0.8 m (30 in)
Approximate Overall Width: 1.0 m (40 in)

SYSTEM

Type	3-Phase Grid Connected
Inverter/Converter	None
Configuration	Horizontal Axis, 3 Blade, Downwind
Rotor Diameter	15 m (49.2 ft)
Turbine Design Class	IEC Class II

PERFORMANCE PARAMETERS

Rated Power	50 kW @ 11.3 m/s (480 Vac/60 Hz)	
	50 kW @ 12.0 m/s (400 Vac/50 Hz)	
Cut-In Wind Speed	4.9 m/s (11 mph)	
Cut-Out Wind Speed	22.4 m/s (50 mph)	
Peak (Survival)	59.5 m/s (133 mph)	
IEC 61400 (NREL) Calculated Annual MWh		
@ 100% Avail; Rayleigh Distribution	Avg Wind	60 Hz
	5 m/s	42-60
	6 m/s	83-102
	7 m/s	128-147
	8 m/s	172-191

ROTOR

Type of Hub	Machined Cast Iron, Fixed Pitch
Rotor Diameter	15 m (49.2 ft)
Swept Area	177 m^2 (1902 ft^2)
Number of Blades	3
Rotor Solidity	0.077
Rotor Speed at Rated Wind	65 rpm (60 Hz), 62 rpm (50 Hz)
Orientation	Downwind
Cone/Tilt Angle	6 deg / 0 deg
Rotor Tip Speed	51 m/s (114 mph) @ 60 Hz
	48.6 m/s (109 mph) @ 50 Hz
Design Tip Speed	61 m/s (136 mph)

BLADE

Length	7.2 m (23.7 ft)
Material	GRE Composite
Airfoil	NREL,Thick Series, Modified
Twist	7 deg, Outer Blades
Root Chord	457 mm @ 4% (279 mm)
Max Chord	749 mm @ 39% (2925 mm)
Tip Chord	406 mm @ 100% (7500 mm)
Chord Taper Ratio	± 2:1
Overspeed Device	PLC Controlled Tip Brake
Hub Attachment	Embedded Female Thread Anchors
Approx Blade Mass	140 kg (308 lb)

GENERATOR

Type	3-Phase Induction, Asynchronous
Make	Baldor
Part No.	14E897X457G1
Volts; Frequency	480/400-415 Vac; 60/50 Hz
Rated Power	66/55 kW
Full Load Current	84 Amps
Nominal Speed	1800 / 1500 rpm
Winding Config.	Ungrounded Wye
Insulation	Class F
Rating – Duty Cyc	50 Deg C – Continuous
Enclosure	TEAO (Totally Enclosed Air Over)
Frame Size	365 TC
Mounting	Direct Mount to Gearbox
Lubrication	Electric Motor Bearing Grease
Options	Arctic Low Temp Shafting (-40 deg C)

GEARBOX

Type	Custom Two Stage Planetary
Ratios	28.25:1 @ 60 Hz
	24.57:1 @ 50 Hz
Housing	Ductile Iron Custom Integrated Casting
Lubrication System	Oil Bath Splash
Lubricating Oil (Examples)	Synthetic (Wind Turbine) Gear Oil
	Petro Canada Harnex 320 (Factory Fill)
	or Equivalents
Options	Arctic, Electric Heater
	Arctic, Lighter Viscosity (150) Oil

BRAKING SYSTEMS

Aerodynamic Brake	Tip brakes on each blade. PLC Control
Electrodynamic Brake	Two-stage resistor/capacitor
Mechanical Brake	Generator mounted, Stearns Series 81,000

YAW SYSTEM

Standard	Free Yaw
Bearing Type	4-Point Contact Ball Turntable Bearing
Bearing Grease	EP1/EP2 Depending on Temperatures
Wind Direction Sensor	None

DRIVE TRAIN to TOWER INTERFACE

Monopole Tower	Bearing Inner Race Bolted to Tower Top
Lattice Tower	Custom Tower Top Casting to Tower Top
Electrical	Separate Twist Cables for Power and Control

TOWER

Standard 3-Legged Lattice	30.5 m (100 ft) Self Supporting, Galvanized
Standard Monopole	30.5 m (100 ft) Self Supporting, Galvanized and Painted.
Options	Other Tower Heights
	Tilt-Up with Gin Pole Erection

FOUNDATION

General Type	Reinforced Concrete Pier
Anchors	Certified ASTM A193, Grade B7, Final Anchor Layout Site Dependant
Design Details	Site Dependant

CONTROL SYSTEM

Type	PLC Based, Koyo Direct Logic 205 Series
Control Inputs	Wind Speed (2 Redundant Anemometers)
	Generator RPM (2 Redundant Sensors)
	Power Output (Power Transducer)
	Utility Grid (Frequency, Voltage, Etc.)
	System Critical Temperatures
Control Outputs	Grid Connect, Braking Systems
Communications	Serial, Modbus, Ethernet
Enclosures	NEMA 4
Soft Start	Optional (Switched Resistor Bank)

ROTOR SPEED CONTROL

Power Production	Blade Stall Regulation
Normal Start-Up	PLC Controlled, Aerodynamic
Normal Shut Down	PLC Controlled (Electro-Dynamic Brakes & Aerodynamic Tip-Brakes ; Parking Brake)
Back-Up Overspeed Control	Centrifugal Force, Deployment of Tip-Brakes

APPROXIMATE MASS

30.5 m Lattice Tower	4000 kg (8800 lb)
30.5 m Monopole Tower	8600 kg (19,200 lb)
Drivetrain and Blades	2500 kg (5500 lb)

DESIGN LIFE

30 Years

DESIGN STANDARDS

IEC 61400-2

PENDING CERTIFICATIONS

CE, MCS, IEC, CSA, AWEA

Figure 3: AOC15/50 Summary of Specifications

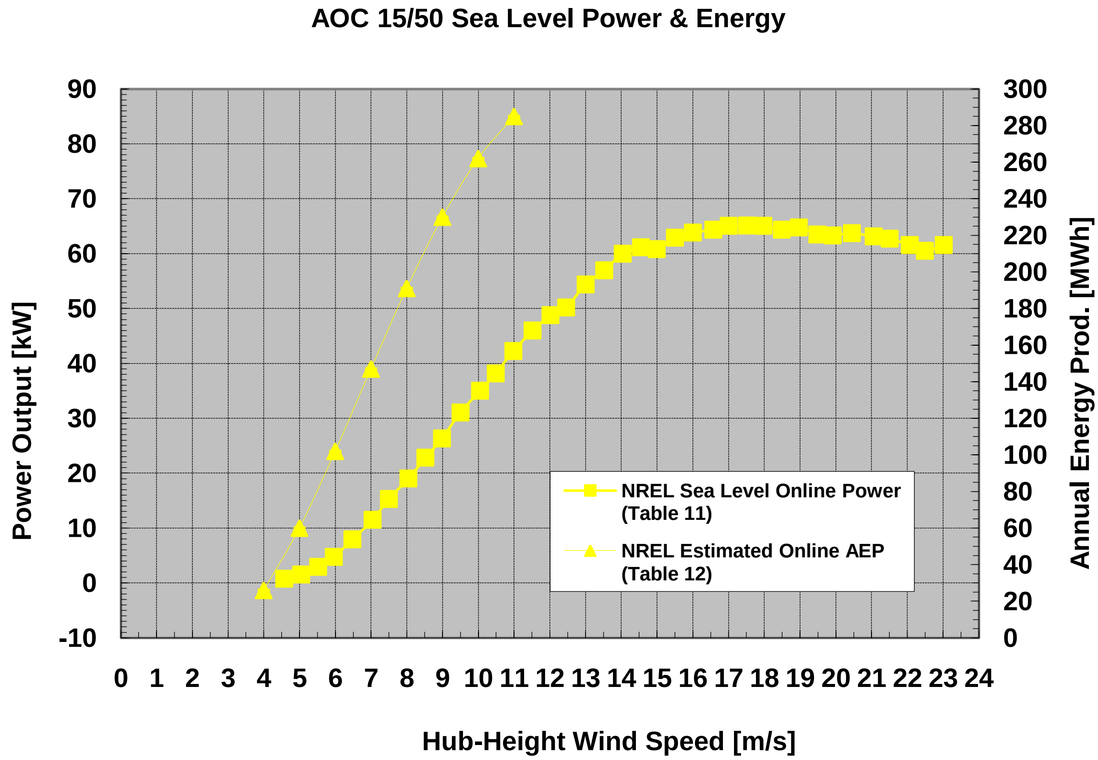

Figure 4: **Estimated Power and Energy Production at 60 Hz and 480 Vac (Reference: NREL Power Performance Test Report for the AOC 15/50 Wind Turbine, Test B. Revision 3. 8 August 2003).**

2. System Operation

The following parameters are monitored by the wind turbine's PLC based control system, which initiates safe shutdowns when faults have been detected to protect the wind turbine from mechanical and electrical damage. Faults are categorized as follows:

Utility Network:

- Over/under voltage
- Phase loss/reversal
- Over/under frequency

Turbine:

- Generator over temperature
- Rotor over/under speed (redundant speed sensors)
- Over/under power
- Parking brake current

Environment:

- Wind speed (redundant anemometers)
- Ambient temperature switch (optional)

The AOC 15/50 is a downwind turbine, i.e. its blades rotate downwind of the drive train assembly. It has no active yaw control and depends on its blades to track the wind. In winds outside of the operational wind band, the PLC (Programmable Logic Controller) disconnects the wind turbine from the grid and parks it. While the parking brake is applied, the turbine will still freely yaw to align itself with the wind direction.

This wind turbine has three main modes of operation: TEST, OFF and ON. TEST is used for commissioning and diagnostic purposes. When switched OFF, the turbine is parked and the PLC monitors grid faults. Once the turbine is switched to the ON position, the PLC begins evaluating wind speed and generator shaft speed data. The wind speed is measured using two (redundant) anemometers and generator shaft speed is measured using two (redundant) shaft speed sensors. Once the wind speed reaches 4.6 m/s, the parking brake is released and the blades start to rotate. As soon as the generator reaches synchronous speed, the wind turbine is brought on-line and begins producing power.

As long as no faults are detected and the wind speed stays between 3.6 and 22.3 m/s (8 –50 mph), the wind turbine will continue to produce power. Power production is continuously monitored to ensure that the turbine does not produce more or less than expected.

If a fault is detected, the PLC will initiate a shutdown. In order to avoid unnecessary shutdowns, each fault is monitored for a set period to confirm that it is not due to a temporary deviation but to a definite change in the operating conditions. Since faults impact the system with varying degrees of severity, monitoring periods differ. The wind turbine will park itself, in a specific sequence of steps. First the tip brakes are deployed, followed almost simultaneously by the dynamic brake. The parking brake is deployed last, after a 4 second time delay. After any deployment of the brakes, the wind turbine will enter a 15 minute cooling cycle. During this cool-down period, the turbine will not re-start.

3. Electric Interface to Utility

The utility interface is site specific and must be coordinated with the local utility or other responsible party. A kWh meter for each machine is recommended.

The wind turbine may be interfaced with a pre-existing low voltage 480V 60Hz (400V 50Hz) supply or it may require its own step up transformer to the system distribution voltage.

- Interface at the 400/480 VAC level:

  For single wind turbine installations the wind turbine can be interfaced directly with the 480/400 VAC utility system, if sufficient transformer capacity exists (75 kVA per turbine). This also applies to commercial and industrial installations with an adequately sized 480/400 VAC panel and distribution system. The wind turbine should be on a dedicated circuit breaker/fuse of proper capacity rating.

- Interface at voltage levels greater than 480/400 VAC:

  For single or multiple wind turbine installations it may be necessary and/or desirable to install a step up transformer between the 480/400 VAC wind turbine and the higher voltage utility system. For example, in a single unit installation interfacing with a 13.8 kV utility system, a minimum 75-kVA transformer with a 13.8 kV/480V ratio would be necessary. Since wind turbine output is variable, care must be taken to properly size the step-up transformer. The winding configuration may also affect system performance. The AOC 15/50 generator is (ungrounded) WYE connected. The interfacing transformer is typically connected with WYE primary and DELTA secondary.

Figure 5 illustrates the simplest form of a utility interface. The utility interconnection should be specifically engineered for each site, and all applicable national and local codes must be followed. Careful research and consultation during the planning stage can avoid expensive and dangerous mistakes. A licensed electrician will be required to install all interconnection wiring per applicable national and local codes.

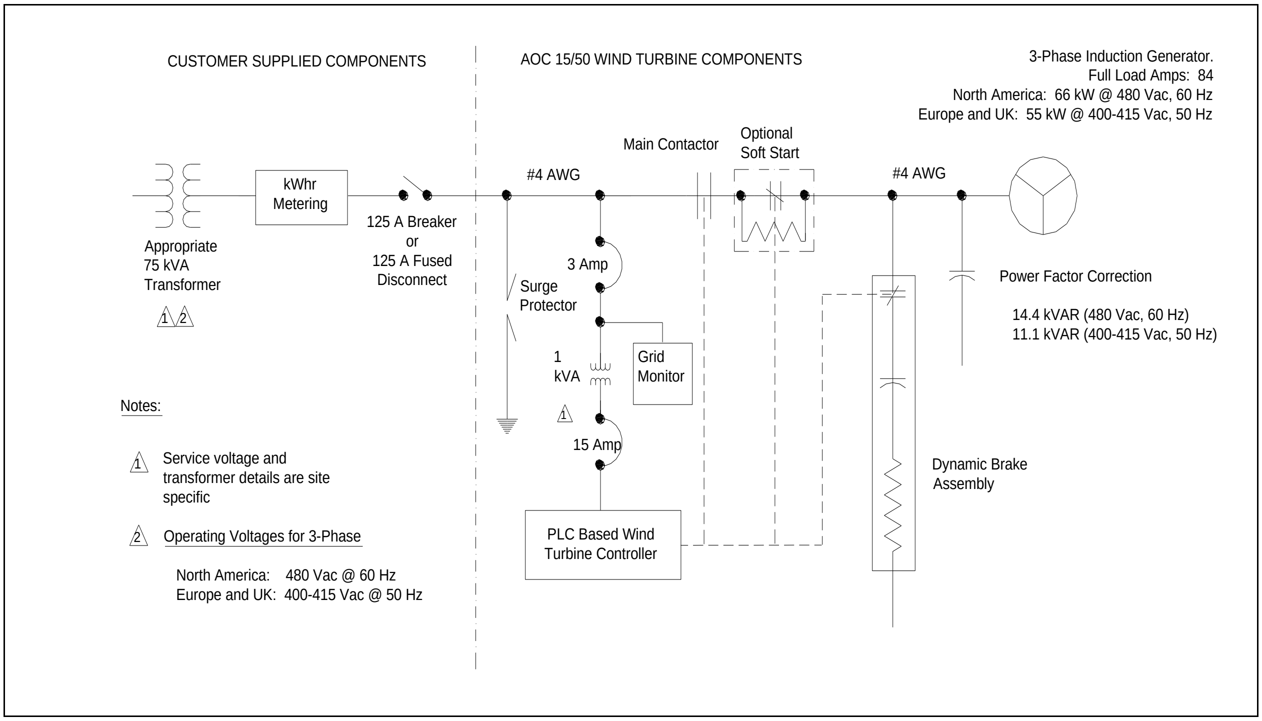

Figure 5: Generic single line diagram for electrical connection to grid.

4. AOC 15/50 Certification

The Underwriters Laboratory in the USA has verified compliance to the IEC 61400 Series of standards and has issued the corresponding Type Certificates for the following products:

Manufacture	Type of Certification	Turbine Model	Certificate No.
Atlantic Orient	Type Testing - Loads AOC	AOC 15/50	ZGYW-01002
Atlantic Orient	Type Testing - Acoustic	AOC 15/50	ZGYW-01002
Atlantic Orient	Type Testing - Power Performance	AOC 15/50	ZGYW-01001

European systems are CE compliant.
MCS Certification (UK) is being pursued.