March 2016

# Powerhouse Wind Ltd

## Document 1000037

## Technical Summary for Thinair 102.

| **Thinair 102 Mechanical Specification** | |
|---|---|
| Turbine type | downwind, variable speed, stall regulated, direct drive, passive yaw |
| Rotor diameter, area | 3.6 m,10.2m$^2$ |
| Rated electrical power | 2000W at 10 m/s at 320 rpm |
| Max. electrical power | 2500 W with bursts to 3000 W |
| Operating wind speed | cut in 2.5 m/s, rated power at 10 m/s, shut down at 18 m/s |
| Operational rotor speed | generation begins at 170rpm, max rotor speed 345 rpm |
| Braking | 1. Control system brakes turbine based on rotor over speed or over voltage condition.<br>2. Independent system in the turbine and located before the slip ring operates based on over voltage. |
| Chassis construction | composite epoxy fibreglass/carbon fibre hybrid with integrated tower fairing |
| Turbine tower top weight | 75kg |
| | |
| **Rotor specification** | |
| Rotor type | fully teetering hub with 1 blade and 2 counterweights at 120° intervals |
| Wing type | fixed pitch –Rotor Cp = 0.35 |
| Wing construction | Carbon/epoxy – one piece molding with central shear web |
| Control strategy | Turbine senses wind in standby and starts at 3 m/s.<br>Between 2.5 and 10 m/s runs in 'cubic control' optimizing tip speed ratio to for maximum efficiency.<br>Above 10 m/s: controls to a speed target.<br>Above 18 m/s: shuts down and furls wing |
| | |
| **Bearings Specification** | 1. Main rotation axis – 2x sealed deep groove ball bearings<br>2. Teeter axis – sealed deep groove ball bearings<br>3. Yaw axis – upper deep groove ball bearing, lower plain plastic bush. |
| | |
| **Alternator Specification** | |
| Alternator type | modular, 3 phase, axial flux, 6 stators arranged in pairs, 16 neodymium magnets |
| Alternator voltage, current, frequency | 100 – 380VAC, 8 A max., frequency dependent on rotor speed |
| | |

| **Electronic Specification** | |
|---|---|
| Rectifier type | 3 phase rectifier using IGBT'S and PWM to control power |
| Rectifier voltage, current | 110 – 480 VDC, 9.5 A max |
| Controller | MSP430 running Powerhouse Wind control software |
| Inverter | Enasolar 3kW grid tied, designed and manufactured in NZ, wireless data interface, AS4777 certification |
| Inverter input voltage, current | 120 – 495 VDC, 16A max. |
| Inverter output voltage, current | 202 – 258VAC, 15A max. |
| Battery Charge controller | Enatel WM2048 or Morningstar Tristar 600V |

| **Tower Specification** | |
|---|---|
| Standard Tower | Spunlite monopole, 3 piece modular steel, 3mm wall thickness, folded and welded, galvanized, hub height 11.8m high, designed to AS/NZS 4677:2000 |
| Flange connection to tower | A/S A150 2 ½"using 4x M16 bolts to attach turbine to tower |
| | |
| **Corrosion Protection** | |
| Tower | galvanized to AS/NZS 4680: 1999 |
| External steel components and fasteners | stainless steel or nickel plated steel |
| Aluminium components | CC601 T6, clear anodised |

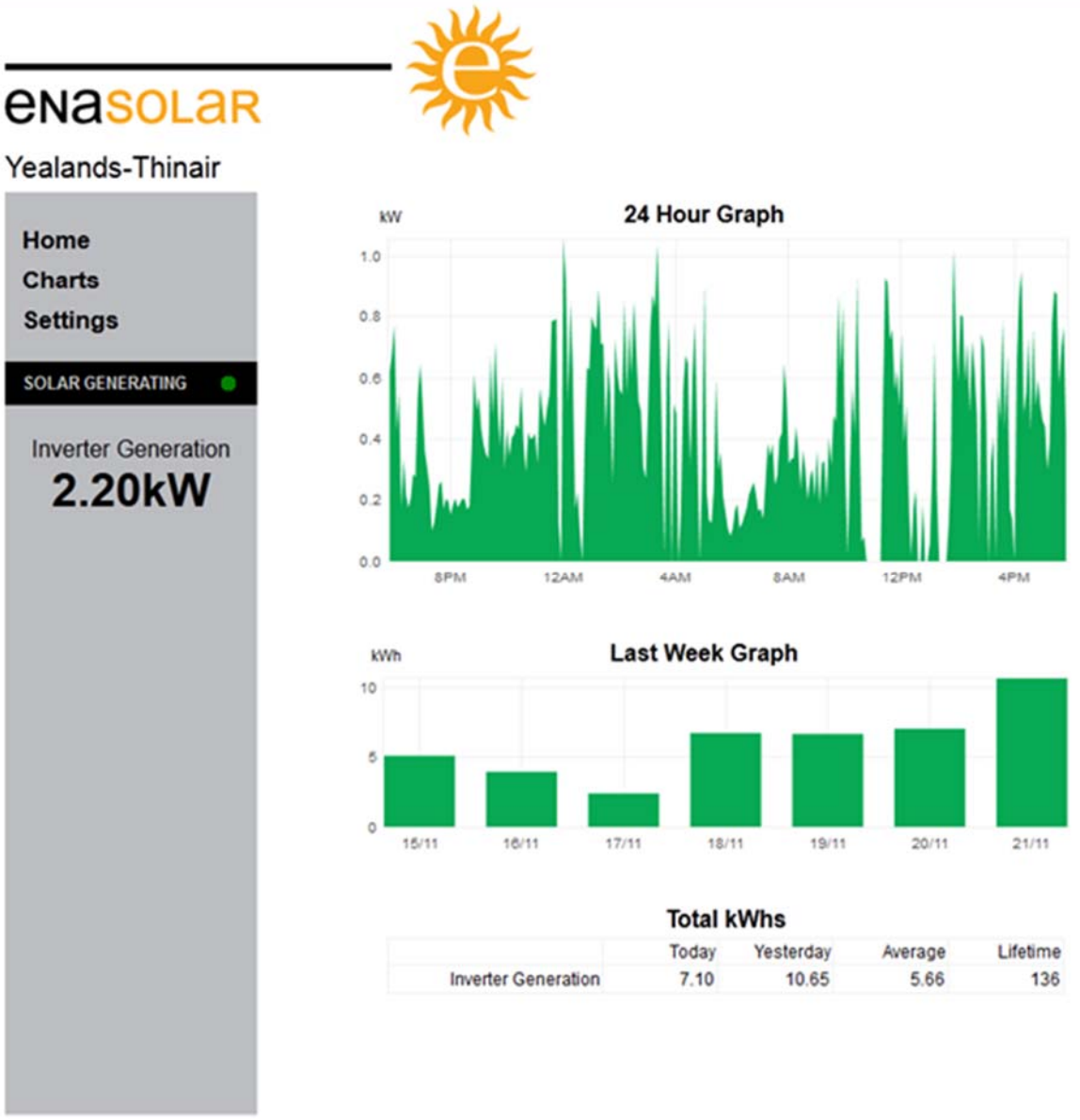



**Image 1: Inverter output screenshot**

**Image 2: Thinair turbine running**

**Image 3: Thinair installation on Southland farm**

**Image 4: Stayed installation for high wind site**

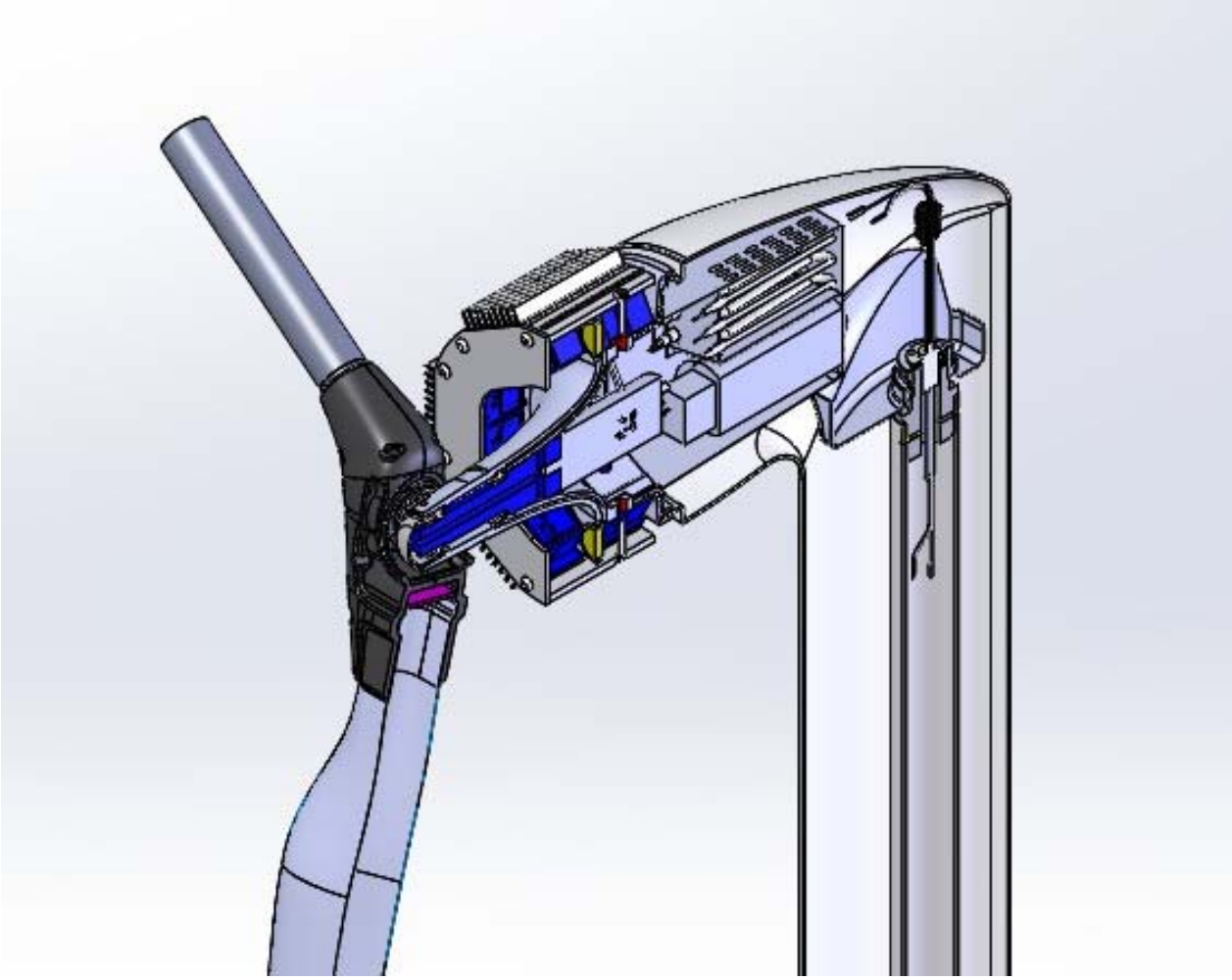


**Image 5: Thinair main assembly CAD cross section**

**Image 6: Thinair turbine**

# Turbine Performance Model - Thinair 102

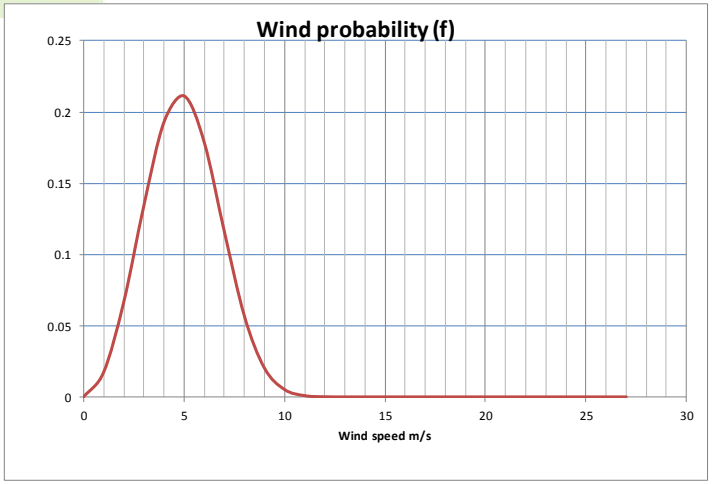
| Inputs: | |
|---|---|
| Average Wind m/s | 5 |
| Weibull k | 3 |
| Site Altitude m | 0 |
| Wind Shear Exponent | 0.143 |
| Anem. Height m | 11.8 |
| Tower Height m | 11.8 |
| Turbulence Factor | 1.0% |
| gamma | 0.9 |

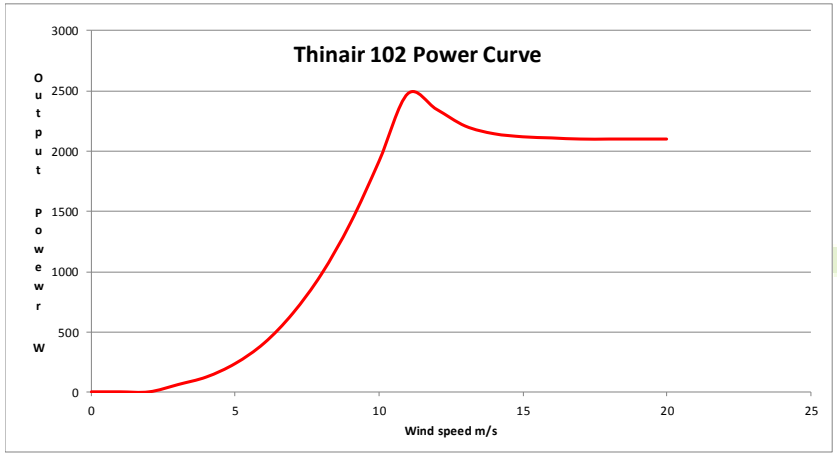
| Results: | |
|---|---|
| Weibull C | 5.56 |
| Hub Average Wind Speed m/s | 5.0 |
| Air Density Factor | 0.0% |
| Average Output Power W | 325 |
| Daily Energy Output kWh/day | **7.8** |
| Monthly Energy Output kWh/month | 238 |
| Annual Energy Output kWh/year | 2,850 |
| Percent Operating Time | 78.1% |

8760 0 0

## Weibull Performance Calculations

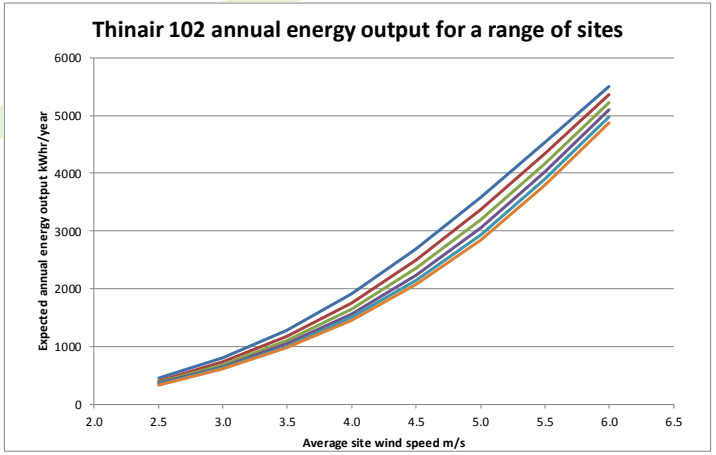
| Wind Speed Bin (m/s) | Power (W) | Wind probability (f) | Cumulative prob. | Power@ V | Energy kWh/year@ V | Cumulative energy kWh |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0% | 0 | 0 | 0 |
| 1 | 0 | 1.7% | 1% | 0.0 | 0 | 0 |
| 2 | 0 | 6.7% | 5% | 0.0 | 0 | 0 |
| 3 | 60 | 13.5% | 15% | 8.1 | 71 | 71 |
| 4 | 124 | 19.3% | 31% | 23.9 | 209 | 280 |
| 5 | 236 | 21.1% | 52% | 49.7 | 436 | 716 |
| 6 | 404 | 17.9% | 72% | 72.2 | 632 | 1,348 |
| 7 | 652 | 11.6% | 86% | 75.7 | 663 | 2,011 |
| 8 | 978 | 5.7% | 95% | 55.3 | 484 | 2,495 |
| 9 | 1,399 | 2.0% | 99% | 28.2 | 247 | 2,743 |
| 10 | 1,916 | 0.5% | 100% | 9.8 | 86 | 2,829 |
| 11 | 2,475 | 0.1% | 100% | 2.2 | 20 | 2,848 |
| 12 | 2,346 | 0.0% | 100% | 0.2 | 2 | 2,850 |
| 13 | 2,208 | 0.0% | 100% | 0.0 | 0 | 2,850 |
| 14 | 2,143 | 0.0% | 100% | 0.0 | 0 | 2,850 |
| 15 | 2,119 | 0.0% | 100% | 0.0 | 0 | 2,850 |
| 16 | 2,109 | 0.0% | 100% | 0.0 | 0 | 2,850 |
| 17 | 2,099 | 0.0% | 100% | 0.0 | 0 | 2,850 |
| 18 | 2,099 | 0.0% | 100% | 0.0 | 0 | 2,850 |
| 19 | 2,099 | 0.0% | 100% | 0.0 | 0 | 2,850 |
| 20 | 2,099 | 0.0% | 100% | 0.0 | 0 | 2,850 |
| 21 | 0 | 0.0% | 100% | 0.0 | 0 | 2,850 |
| 22 | 0 | 0.0% | 100% | 0.0 | 0 | 2,850 |
| 23 | 0 | 0.0% | 100% | 0.0 | 0 | 2,850 |
| 24 | 0 | 0.0% | 100% | 0.0 | 0 | 2,850 |
| 25 | 0 | 0.0% | 100% | 0.0 | 0.0000 | 2,850 |
| 26 | 0 | 0.0% | 100.000000% | 0.0 | 0.0000 | 2,850 |
| 27 | 0 | 0.0% | 100% | 0.0 | 0.0000 | 2,850 |
| | Totals: | 100.0% | | 325.4 | 2850 | |




Site average wind speed m/s

| Weibull k | 2850 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 |
|---|---|---|---|---|---|---|---|---|---|
| | 2.0 | 449 | 802 | 1287 | 1919 | 2692 | 3577 | 4530 | 5506 |
| | 2.2 | 407 | 732 | 1176 | 1762 | 2498 | 3369 | 4341 | 5364 |
| | 2.4 | 379 | 684 | 1099 | 1648 | 2346 | 3196 | 4171 | 5227 |
| | 2.6 | 359 | 651 | 1045 | 1565 | 2231 | 3054 | 4022 | 5099 |
| | 2.8 | 344 | 627 | 1006 | 1504 | 2143 | 2940 | 3895 | 4982 |
| | 3.0 | 333 | 610 | 977 | 1458 | 2076 | 2850 | 3789 | 4877 |




**Inputs:** Use annual or monthly **Average Wind** speeds. If **Weibull K** is not known, use K = 2 for inland sites, use 3 for coastal sites, and use 4 for island sites and trade wind regimes. **Site Altitude** is meters above sea level. **Wind Shear Coefficient:** For perfectly smooth (calm water) use 0.1. For flat grassland or low shrubs use 0.2. For trees or hills, buildings in area use 0.3. Close to trees or buildings use 0.4. Very close to trees or buildings use 0.5. Surrounded by trees or buidings use 0.6. **Anemometer Height** is for the data used for the **Average Wind** speed. If unknown, use 10 meters. **Tower Height** is the nominal height to the hub centreline. **Turbulence Factor** is a derating for turbulence. Use 0.00 (0%) - 0.05 (5%) in most cases.
**Results: Hub Average Wind Speed** is corrected for wind shear and used to calculate the Weibull wind speed probability. **Air Density Factor** is the reduction from sea level performance. **Average Power Output** is the average 24-hour power produced and includes all deratings and is the primary performance parameter. **Daily, Annual** and **Monthly Energy Outputs** are calculated from the Average Power Output . **Percent Operating Time** is the percentage of time the turbine should be producing power.