

Our dream at Zephyr is to transform the ever-changing movement of wind into clean electric energy, and to make this energy available at any location in the world. To realize our dream, we launched Japan's most ambitious small wind turbine technology project in history — Project Z<sup>1</sup> — unifying the research and intelligence of Japan's leading experts in government, academia and private industry.

Project Z spent six years combining the most advanced 21st Century wind turbine technology with Japan's world-renowned manufacturing craftsmanship, to successfully develop the Airdolphin wind turbine — a next-generation, low-mass wind turbine which instantly adapts to changing wind conditions, from slight to stormy.

Through extensive testing in windy sites<sup>2</sup> around the world, Airdolphin wind turbines have proven to be tough and efficient. Airdolphins instantly respond to the vagaries of wind, while delivering over 150 kWh per month at average winds speeds of 6 m/s (13.4 mph).

In 2009, Zephyr Corporation launched its newest model, Airdolphin Pro, 48 VDC, specifically targeting industrial off-grid applications, and established American Zephyr Corporation to better serve a "green energy" conscious society.



Tarifa, Spain



A mountain lodge at Mt. Yatsugatake, Nagano, Japan (elevation: 2,722m / 8,930ft)



CIEMAT-CEDER test facility in Soria, Spain



SEPEN: Small Wind Turbine Field Test Site in Narbonne, France



Cape Erimo, Hokkaido. One of the windiest areas in Japan.

<sup>1</sup> Project Z members: Toray Industries, Inc. (in charge of blade molding); Hitachi Metal Co., Ltd. (neodymium iron boron magnet); Yokogawa Electric Corp. (communication system and maintenance); NTN Corp. (rotating parts, including bearings); Unitec Corp. (motor); Nitto Kako Co., Ltd. (vibration control system); Moriyama Giken (body); Oume Denshi (electronic circuit board); The University of Tokyo, Graduate School of Engineering (observational study and basic engineering of the blade); National Institute of Advanced Industrial Science and Technology (basic engineering and practical experiments for the blade). Development was supported by the Ministry of Economy, Trade and Industry, and the (National) New Energy and Industrial Technology Development Organization.

<sup>2</sup> Test sites and permanent installations: Akadake Tenbo-so at Mt. Yatsugatake; Miyagijima island, Okinawa pref.; Ashikaga Institute of Technology, Tochigi pref.; Ocher Plateau in China (by Yulin College); Kyushu University; a house exhibition space at Sakura Josui, Tokyo; reclaimed land from Tokyo Bay in Odaiba (a test site operated by The University of Tokyo); Tarifa, Spain (a site facing the Strait of Gibraltar); Soria, Spain; Rimini, Italy; Shetland Islands, UK; Aberdeen, UK; Erimomisaki, Hokkaido; Tappisaki, Aomori pref. (by Department of Commerce, Industry and Labour from Aomori prefectural government); Ulan Bator, Mongolia; Takashimaya department store at Takasaki, Gunma pref.; Takashimaya department store at Yokohama, Kanagawa pref.; "Eco no Hotori" in Tokushima pref.

## Specifications

|                                      |   |               |                 |                |
|--------------------------------------|---|---------------|-----------------|----------------|
| Model Name                           | Airdolphin Pro  |               |                 |                |
| Model Number                         | Z-1000-48   |               |                 |                |
| Wind Turbine Type                    | Horizontal axis, up-wind  |               |                 |                |
| Rotor Diameter                       | 1,800mm (5'10-7/8")   |               |                 |                |
| Mass                                 | 17.5kg (38.5 lbs)   |               |                 |                |
| Tower Diameter                       | 48.6mm (1-15/16")   |               |                 |                |
| Number of Blades                     | 3   |               |                 |                |
| Blade Construction                   | Carbon fiber laminate over solid foam core  |               |                 |                |
| Blade Mass (per piece)               | 380g (13 oz)  |               |                 |                |
| Blade Method                         | Interlock hub mounting  |               |                 |                |
| Body Material                        | Aluminum diecast  |               |                 |                |
| Body Construction                    | Bolt-less joints (based on traditional Japanese craftsmanship)  |               |                 |                |
| Product Finish                       | Anti-corrosion Teflon-based paint   |               |                 |                |
| Power Generator                      | Synchronous-type, three-phase power generator with permanent neodymium iron boron magnet  |               |                 |                |
| Control Systems                      | Built-in original Intelligent Power Management with:<br>1. Power-assist function, 2. Two mode control functions, 3. Safety Control, 4. Battery Charge Management, 5. Data Communication |               |                 |                |
| Protection Circuit                   | Built-in  |               |                 |                |
| Data Logger                          | Built-in  |               |                 |                |
| Yaw Control                          | Free yaw (360 degrees)  |               |                 |                |
| Direction Control                    | Original Swing-Rudder System  |               |                 |                |
| Start-up Wind Speed                  | 0m/s (Power-Assist Function)  |               |                 |                |
| Cut-in Wind Speed                    | 2.5m/s, 5.6 mph   |               |                 |                |
| Peak Power                           | 2.3kW (20m/s, 44.7 mph)   |               |                 |                |
| Maximum Rotor Speed                  | 1,000rpm (20m/s, 44.7 mph)  |               |                 |                |
| Mass per Watt                        | 17.5g (1 oz)/W (at rated power)   |               |                 |                |
| Power Generation Amount*             | Avg. Wind Speed (m/s)   | Per Day (kWh) | Per Month (kWh) | Per Year (kWh) |
|                                      | (m/s)   | (mph)         | (kWh)           | (kWh)          |
|                                      | 3.0   | 6.7           | 0.7             | 22             |
|                                      | 4.0   | 8.9           | 1.8             | 54             |
|                                      | 5.0   | 11.2          | 3.4             | 103            |
|                                      | 6.0   | 13.4          | 5.6             | 167            |
|                                      | 7.0   | 15.6          | 8.2             | 245            |
|                                      | 8.0   | 17.9          | 10.9            | 327            |
|                                      | 9.0   | 20.1          | 13.5            | 405            |
|                                      | 10.0  | 22.4          | 15.7            | 471            |
|                                      | 12.0  | 26.8          | 18.4            | —              |
|                                      | 15.0  | 33.5          | 18.9            | —              |
|                                      | 20.0  | 44.7          | 15.9            | —              |
| Output Voltage*                      | 50 VDC  |               |                 |                |
| Braking System                       | Regenerative electromagnetic braking system   |               |                 |                |
| Communication System (Signal Output) | RS-485  |               |                 |                |
| Recommended Battery Capacity         | Deep cycle lead acid battery of at least 250 Ah.  |               |                 |                |

\* Power generation figures are based on field test measurements and calculations from Rayleigh wind speed distribution.  
\* Power generation varies with installation site, wind quality, mounting framework, and other conditions. These figures should be used as a guide only.

\* 24VDC version is also available.

## Options

|                |             |   |             |
|----------------|-------------|---|-------------|
| Remote Monitor | RM-1000 Pro | Monitor for accumulated generated output (daily, monthly, total) display. Real-time generated output display, wind direction/wind speed display, battery voltage display, PC connection by wired LAN, flash memory slot, AC adapter or 48/24 VDC converter, analog output (synchronizes with Airdolphin's rotation frequency)<br>Dimensions (W x H x D): 240 x 152 x 45mm (9-7/16 x 6 x 1-3/4 inches), weight 850g (1 lb 14 oz)<br>Options: PC software program | RM-1000 Pro |
|----------------|-------------|---|-------------|



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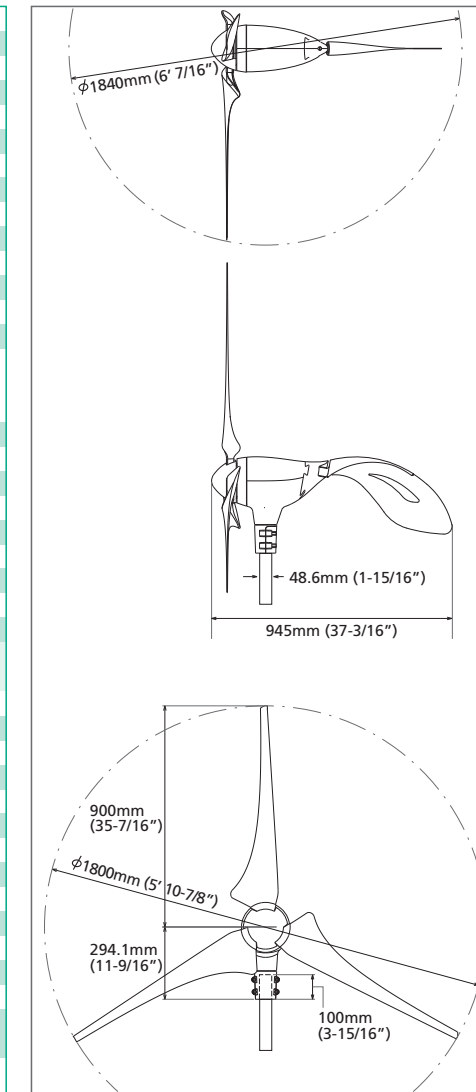
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Design and specifications subject to change without notice.

Product colors may differ in photographs from actual appearance, due to effects of printing and photography.

All information in this catalog is current as of July 2009.

## Outer Dimensions



Front, Side, and Top Views



Ultra-light Next-Generation Small Wind Turbine

# AIRDOLPHIN PRO

Industrial Grade – Ready to Work.



# AIRDOLPHIN PRO

**Empowering the Wind to Energize the World™**

The Airdolphin Pro, while small in size and mass, is no lightweight when it comes to capturing the power of wind. From the gentle breezes that inspired our company's name to the raging gales that threaten the very existence of structures, the Airdolphin Pro declines no challenge. Here's why Airdolphin Pros reliably generate electrical energy under even the most trying of wind conditions:

## Ten State-of-the-Art Technologies Inside Every Airdolphin Pro

### 1 Extremely Low Mass

The total weight of the Airdolphin Pro is only 17.5 kg (38.5 lbs). Turbine weight per generated watt is only 17.5 g (0.6 oz.) — one fifth that of large mega-class wind turbines. Unlike larger turbines, the Airdolphin Pro's low mass allows it to be mounted on existing structures like remote telecommunication towers, transmission line pylons and billboards, as well as near roads, railways and airports. Even factory and urban rooftops can become cost effective locations for producing usable electrical power. Most importantly, its low mass allows the Airdolphin Pro to respond quickly to the continuously changing turbulent nature of wind — thus increasing the total daily amount of power production. We call this feature the Airdolphin Pro's "Dynamic Wind Capturability".

### 2 Swing Rudder System — Our Patented Innovation

Wind is not constant, neither in strength nor direction. The rudder on the Airdolphin Pro uses our patented Swing Rudder System, a directional control system inspired by the tailfin movement of fish, to indirectly control the rotor's heading. This allows the turbine to instantly respond to the subtle nuances of shifting winds, while ultimately improving power generation.



### 3 Seamless Response Rotor

The rotor system on the Airdolphin Pro seamlessly responds to various wind conditions from the slightest breezes to the strongest gusts, offering a high wind-to-power conversion factor by utilizing technology commonly found in the aerospace industry, including: (1) ultra low mass, stiff blades constructed of laminated carbon fiber skins over a special foam core, (2) a multi-stagger blended airfoil blade that provides superior lift efficiency from its root out to the tip, and (3) a dynamically balanced blade and hub system to insure vibration free operation. Together these elements allow the rotor speed to be constantly controlled for maximum power output.



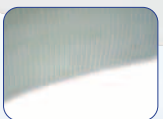
Rotor

### 4 Patented Noise Reduction Innovation

The blades of each Airdolphin Pro are created with Zephyr's patented SD blade technology (noise reduction ridges). Our designers were inspired by the feather patterns of owl wings, which allow owls to fly in silence. This technology applies a series of thin ridges to the surface of each blade, creating micro vortices to keep the airflow attached to the airfoil longer than conventional blades, thus reducing decibel count.



Owl Wing



SD blade

### 5 Robust Body Structure

Bolt-less self-fitting body inspired by Japanese traditional block puzzle craftsmanship. This technique ensures an exact fit and provides superb resistance to adverse weather conditions, greatly minimizing maintenance requirements.



Body Joints



Blade and Hub Cover

### 6 Power Assist Function

Throughout each day, small thermal breezes waft across the land. While each by itself offers little power potential, they represent a substantial amount of power potential when accumulated. If there is no wind, the Airdolphin Pro self rotates for ten seconds every minute, allowing it to catch all these small wind events. As an additional bonus, when the turbine is regularly rotated in this manner, icing in calm cold conditions is greatly minimized.

### 7 Intelligent Power Management System

The intelligent power management system incorporated in the Airdolphin Pro is the outcome of our continuous R & D work in the maximization of power generation efficiencies. The power management system, controlling fixed-pitch blades, incorporates unprecedented technology in the wind power world, offering power output comparable to or even surpassing variable-pitch blade systems. By realizing constant blade rotation speed, operation of the wind turbines has been made much more silent and secure. This newly developed system uses our original and patented technologies of maintaining uniform rotor spinning speeds while encountering turbulent gusts found in cities or raging winds at remote locations. Even in hurricanes, the Airdolphin Pro can still deliver stable output power after its peak output of 2.3 kW at 20 m/s (44.7 mph) wind speed has been reached. These attributes, specifically for small wind turbines, are very crucial because, unlike large wind turbines, they are often installed in cities where turbulence is caused by tall buildings.

When the wind speed increases beyond 20 m/s (44.7 mph), the Airdolphin Pro continues delivering output power at a reduced rpm eliminating the need for cut-out entirely. The intelligent power management system inside the turbine achieves its outstanding performance by software driven microprocessors including control firmware, an internal battery charge controller monitoring voltage and charging rates in a variety of climatic conditions, a web interface and data logging functions. The Airdolphin Pro also has various safety features enabling it to sense adverse conditions like over-heating, excessive blade rpm, and blade strikes, and automatically shut itself down. Airdolphin Pro with its excellent dynamic wind energy capturability is ready to set new industrial small wind turbine standards.



Generator and Control Boards

### 8 Generator

The generator weighs only 7.5 kg (16.5 lbs.). It achieves remarkable high power density with tightly wire wound coils and powerful neodymium iron boron magnets. These two features combine to implement the optimum duty cycle by electronically damping the rotor.

### 9 Data Communication System

Every Airdolphin Pro comes equipped with an RS-485 protocol wiring harness thus allowing it to be monitored both on-site and remotely via our RM-1000 Pro unit and, optionally, with a dedicated IP address.

### 10 Life Cycle Assessment

Not only does the Airdolphin Pro provide clean energy, it also quickly recoups its own manufacturing carbon footprint. We conducted an extensive survey over a period of one and half a years, and the study showed that an Airdolphin Pro requires less than three months of operation at an average wind speed of 4.5 m/s (11.2 mph) to offset the entire carbon footprint of its manufacturing process. (Data source: The University of Tokyo's Hirao Laboratory, IEA.)

## Wide Applications

With its high power, low noise, and superior reliability, the Airdolphin Pro serves a broad range of application possibilities. It can be used in various off-grid applications\* in urban as well as remote places, such as islands, ocean or mountainous areas.



Remote Telecommunication System



Electric Car Plug-in Charging System



Urban Telecommunication System



Urban Weather Monitoring System



Remote Areas

\*Off-Grid (Stand-Alone) Use: residences in remote areas; for pumping water; fishing boats, yachts, etc.; repeater stations; remote monitoring sites (web cameras, GPS receivers, wireless applications); streetlights (no need for utility electricity); public facilities (dams, weather observatories, etc.)

## Off-Grid Hybrid System

Remote locations needing electrical power often necessitate the use of several renewable energy sources. In some installations wind is complementary to PV. In remote areas, wind may not only be blowing but raging with turbulent gusts and even typhoons that can defeat all but the most robust wind turbines. Airdolphin Pro was designed specifically for these conditions and readily goes to work capturing the power of wind. In many offshore applications PV is not practical because of fog and roosting birds. In these locations Airdolphin Pro is the ultimate power generator because of its life-like movement, toughness, and ability to operate maintenance-free for many guaranteed years. The Airdolphin Pro can quickly pay off its investment cost when the high maintenance expenses of servicing diesel gensets are factored in.

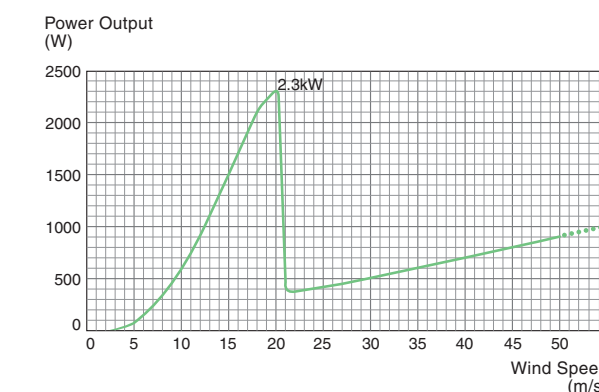


Remote hybrid wind/PV telecommunication system in Turkey



Twenty one Airdolphin Pro form an AC power micro-grid on an unmanned off shore gas rig.

## Power Output Characteristics



## Intelligent Power Management System

The intelligent power management system has succeeded in truly seamless power generating performance for a broad spectrum of wind energy ranging from 2.5 m/s (5.6 mph) upwards, never cutting out. The system instantly responds to sudden changes in the wind speed and adapts by creating the most suitable power point production. At its upper potential, by incorporating sophisticated software algorithms, the Airdolphin Pro can deliver 2.3 kW output when capturing 20 m/s (44.7 mph) gusts and winds. It then shifts to a more gradual power curve slowly increasing output as the wind strength increases.