LTA Windpower Inc. – PowerShip

Peter Lobner, 9 October 2023

1. Introduction

The Ontario, Canada firm LTA Windpower Inc. was founded by Dr. Nykolai Bilaniuk, the former Chief Engineer of the Ottawa airborne wind turbine firm Magenn Power Inc., and Asphodel Norwood. Their goal was to develop and commercialize their concept for an airborne wind turbine generator known as the PowerShip, for which Bilaniuk filed patent applications in 2009.

A PowerShip is a tethered, semi-rigid, variable buoyancy, hybrid airship comprised of a non-rigid, blimp-style lifting gas envelope that is attached amidships to a rigid straight wing with two large-diameter wind turbines driving generators in streamlined nacelles at the wingtips. The tall, fixed main landing gear under the wings enables the PowerShip to take off and land on the ground. The multi-element tether attached under the wing includes a load-bearing component, a data cable for control and monitoring functions and a power cable for delivering electric power via an anchored ground station.

Canada's LTA Windpower designed a hydrogen-filled, winged-blimp airborne wind turbine generator called the PowerShip. Source: CNN Business (2014)

LTA Windpower anticipated using hydrogen as the lifting gas. In a 2014 CNN article, Nykolai Bilaniuk acknowledged that using hydrogen, which is flammable, “is potentially dangerous.” However, he said, “we have to decide what would be sufficient to mitigate the risk.” A specially designed outer envelope surrounding the hydrogen would act as a barrier and protect the gas from ignition sources. Also, Bilaniuk says that hydrogen is cheaper than helium and can be created on-site. “You can electrolyze water using some of your own electrical output from the generator,” he said.

The business case for the PowerShip is based on the established principle that wind speeds increase with altitude above the prevailing ground level, resulting in more energy available for extraction at higher altitudes. That's why the industry trend has been toward taller wind turbines, both on land and offshore. On land, many wind turbines are sited in high, remote places that are exposed to higher winds than the surrounding countryside. Unlike the non-linear cost of building taller wind turbines, airborne wind turbines can operate at higher altitudes by lengthening the tether, the cost of which increases approximately in direct proportion to length.

The basic PowerShip design was intended to be scaleable. Writing for MWPS in 2019, Sarah Dinola noted:

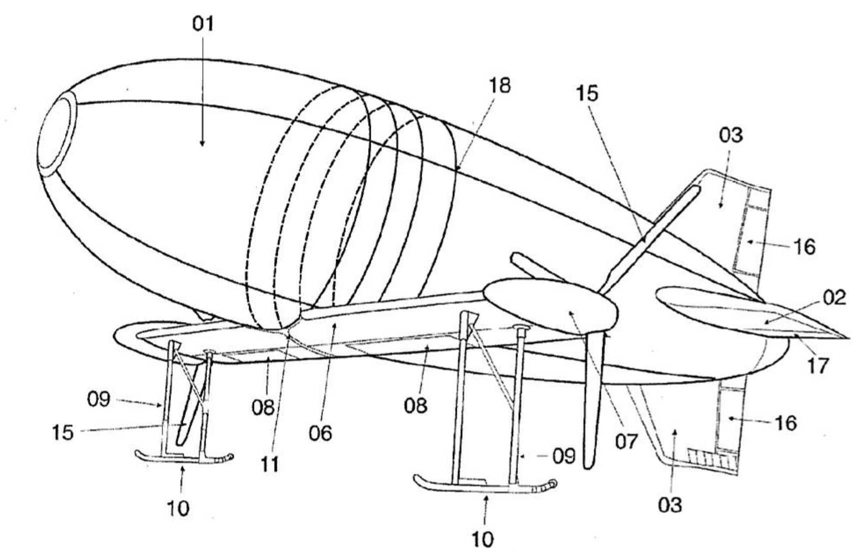
- Units up to 50 kW would be designed for off-grid use. These models would have non-grid-synchronous, permanent magnet generators and they would supply power to isolated micro-grids.
- Larger grid-connectable units may use AC synchronous generators and variable-pitch rotors.

No PowerShip was ever built and the firm LTA Windpower Inc. no longer is in business.

2. PowerShip Design

International patent application WO2010/006433A1, published in January 2010, and US patent application US2011/0101692A1, published in May 2011, provide the following description of a PowerShip:

> “A wind powered generator … that may take advantage of the strong wind present at higher altitudes above terrain than can feasibly be reached by traditional tower-mounted wind generators. It makes use of a combination of lift sources. The generator comprises an envelope filled with a lifting gas (helium or hydrogen) that enables the system to rise in little or no wind, and wings that provide additional lift when there is wind, to thereby prevent the wind from blowing the tethered generator to the ground. The airborne wind powered generator is able to both rise aloft and land unattended. Power is extracted from the wind by means of turbine rotors that drive electric generators.”



Legend: *The PowerShip is comprised of an aerostatic lifting gas envelope (01), with cruciform vertical tail fins and rudders (03, 16), and horizontal tail planes and elevators (02, 17). The gas envelope (01) is attached via suspension cables (18) to a main wing (06) assembly, which has a tether attachment point (11), aerodynamic flight controls (08) and tip-mounted nacelles that can rotate vertically (07), each containing a generator that is mechanically driven by a large-diameter wind turbine (15). Landing gear (09, 10) prevent the wind turbine blades from contacting the ground when the PowerShip has landed.*

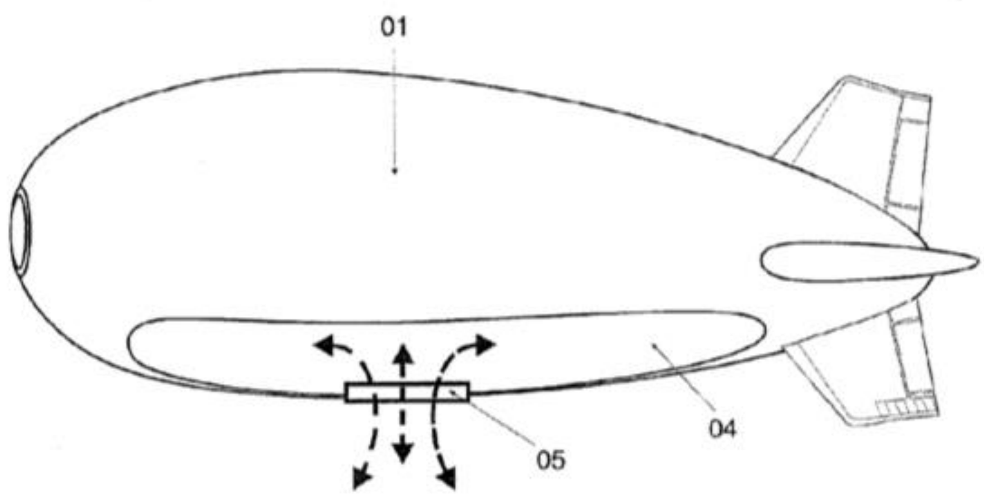
General exterior arrangement of a PowerShip.
Source: Patent US2011/0101692A1, Fig. 4

Gas envelope-to-wing interface

Circumferential wing suspension cables (18) shown in the general exterior arrangement drawing are looped around the gas envelope (01) and fastened to the rigid wing (06) in order to secure the wing in place, with the center-of-mass of the wing/turbine assembly directly beneath the airship's center-of-aerostatic lift, and to distribute the loads from the wing/turbine assembly through a large surface area of the gas envelope. To avoid abrasion of the gas envelope, reinforcing fabric may be applied to the surfaces that contact the wing suspension cables (18).

Operation of the air ballonet for buoyancy control

The patent application describes the air ballonet (04) as an expandable chambers located ventrally, inside the bottom of the non-rigid gas envelope (01), that can be inflated or deflated as required with outside air. If fore and aft ballonets are provided, they can be operated in coordination for pitch trim control without affecting gas envelope pressure or overall buoyancy.



PowerShip ballonet system.
Source: Patent US2011/0101692A1, Fig. 2

Turning on the ballonet inflator (05) inflates the ballonet by pressurizing external ambient air into the ballonet. This inflation increases the air pressure in the ballonet, thus displacing some of the volume previously occupied by the lifting gas and compressing the lifting gas to a higher equilibrium pressure. The resulting increased density of the lifting gas, coupled with the added mass of the air within the ballonet leads to a decrease in the overall aerostatic buoyancy of the airship.

Likewise, the ballonet can be vented to the atmosphere via the “inflater” (05) to reduce ballonet pressure, thereby allowing the lifting gas to expand and establish a lower equilibrium pressure inside the gas envelope. Now with a lower net mass, the overall aerostatic buoyancy of the airship increases.

In this way, the ballasting system allows for the controlled modulation of the aerostatic lifting force acting upon the airship. This is a feature that can be used to raise of lower the airship during takeoff or landing, or for station-keeping purposes in actively maintaining or seeking a given operational altitude under changing wind or weather conditions.

Using the ballonet as a variable ballasting system serves two main functions.

- **Compensates for changes in the temperature of the lifting gas**: As the lifting gas is heated or cooled, for example as a result of changes in the amount of solar radiation incident upon fuselage, the density of the lifting gas and hence its buoyancy relative to air will vary. The ballonet may be inflated or deflated as required to compensate for this lift variation and maintain overall system buoyancy within a target range, consistent with envelope operating pressure limits.
- **Allows for the deliberate modification of the overall buoyancy of the airship in order to effect either a takeoff or landing of the airship:** The ballonet is designed with a volume capacity such that, when the ballonet is maximally inflated, the airship will have a slightly negative buoyancy, and will land gently with or without wind. Conversely, with the ballonet deflated to or beyond a critical volume, the airship has enough positive buoyancy to lift off by itself and drag the tether aloft.

Flying the PowerShip

In equilibrium tethered flight, the airship is at its assigned operational altitude, its attitude is horizontal and the rotors are perpendicular to the incident wind, as shown in patent Figs. 9 and 10. The horizontal component of the force along the tether (Fth) balances the aerodynamic drag on the airship (Fda) plus the rotor drag (Fdr). The downward forces of gravity plus the vertical component of the force along the tether (Ftv) are balanced by the upward forces of aerostatic buoyancy (Fbu) plus the aerodynamic lift generated by the wings (Fbe).

Figure 9

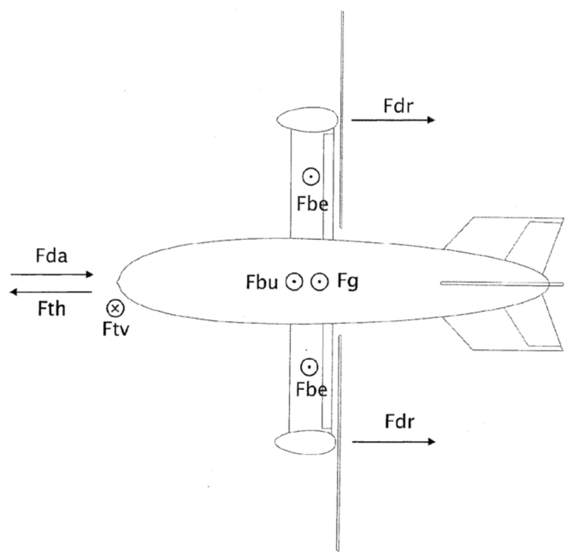
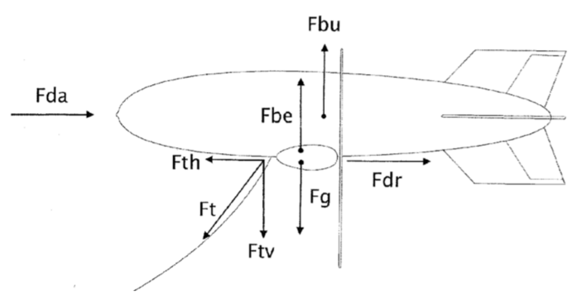


Figure 10



Legend: *Fbu = static buoyant lifting force, Fbe = aerodynamic lifting force (primarily from the wing), Fg = force of gravity, Ft = force along the tether, with Ftv being the vertical component of that force and Fth being the horizontal component. Fda is airship drag force and Fdr is rotor drag force.*

Forces acting on a tethered PowerShip in horizontal equilibrium flight

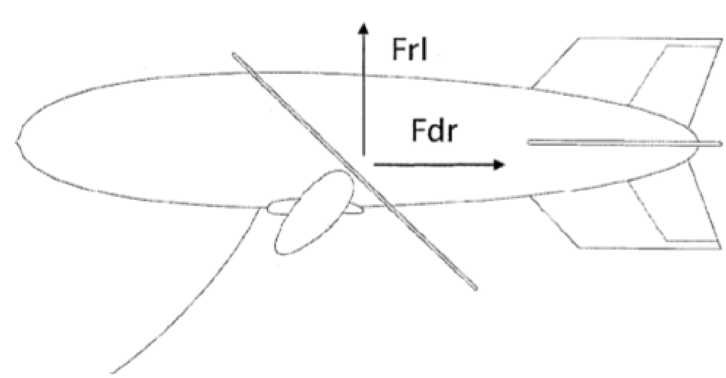
The nacelles can pivot vertically from their normal horizontal position. This provides useful capabilities for changing altitude (up or down) and modulating energy generation.

Patent Fig. 11 shows the PowerShip flying with the generator nacelles tilted above their normal horizontal position, in a mode that allows the rotors to trade drag for lift as a function of the angle of nacelle rotation. When the generator nacelle is in its normal horizontal position, the rotor is perpendicular to the incident wind, presenting the greatest (circular) cross-sectional area for energy extraction, and, consequently, generating the maximum rotor drag (Fdr).

As the nacelle rotates up, the rotor generates a new dynamic lift force (Fri). The rotor also presents less cross-sectional area (now an ellipse) for energy extraction from the incident wind and, consequently, generates less power and less rotor drag.

This adjustable lift-to-drag ratio may be used to modulate power output in high winds or as an additional option for altitude control.

Figure 11



Legend: *Frl = dynamic lifting force from the rotor,*
Fdr = diminished rotor drag (due to reduced vertical cross-section),

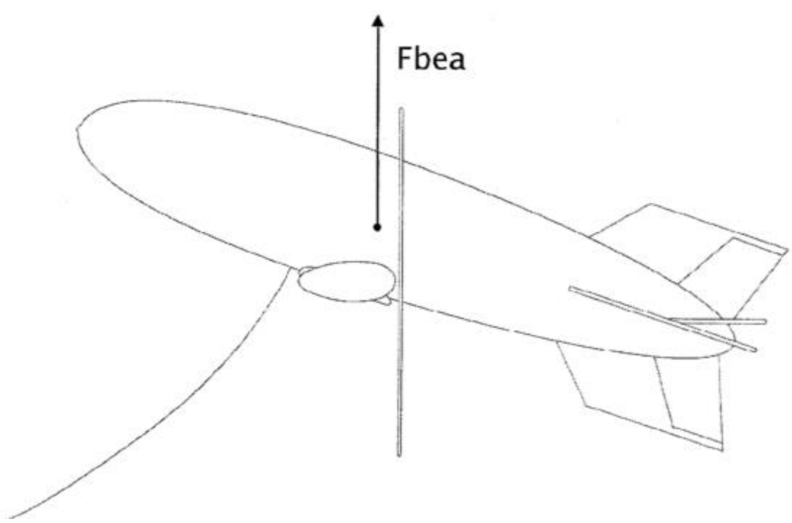
Additional forces arising when PowerShip nacelles are rotated up.

Patent Fig. 12 shows the PowerShip flying in a nose-up attitude, as it might when ascending to its operational altitude after takeoff from the ground. The nose-up attitude is achieved by operation of the tailplane elevators or by differential inflation of front and rear ballonets to bias the tail heavier.

With a positive angle-of-attack, the gas envelope acts as a lifting body and generates a new aerodynamic lift component, Fbea. In order to maintain the turbine rotors' plane of rotation perpendicular to the incident wind, the nacelles are rotated upwards to compensate for airship's pitch angle.

Upon reaching the desired altitude, the nacelles are rotated back to the horizontal position, and the airship establishes itself in equilibrium tethered flight.

Figure 12



Legend: Fbea = aerodynamic lift generated by fuselage angle-of-attack.

Additional forces arising when PowerShip fuselage pitches up.

3. For more information

- Thom Patterson, “Meet the BAT, an airborne wind turbine,” CNN Business, 12 May 2014: https://www.cnn.com/2014/05/12/tech/innovation/big-idea-airborne-wind-turbines/index.html
- Sarah Dinola, “A hydrogen-filled wind turbine,” My Wind Power Systems (MWPS), 4 May 2019: https://www.mywindpowersystem.com/2019/04/05/a-hydrogen-filled-wind-turbine/

Patents applications

- US2011/0101692A1, “Airborne wind powered generator,” Inventor: Nykolai Bilaniuk, Filed 16 July 2009, Published 5 May 2011: https://patents.google.com/patent/US20110101692A1/en
- WO2010/006433A1, ““Airborne wind powered generator,” Inventor: Nykolai Bilaniuk, Filed 16 July 2009, Published 21 January 2010: https://patents.google.com/patent/WO2010006433A1/en

Other *Modern Airships* articles

- *Modern Airships - Part 1*: https://lynceans.org/all-posts/modern-airships-part-1/
- *Modern Airships - Part 2*: https://lynceans.org/all-posts/modern-airships-part-2/
- *Modern Airships - Part 3*: https://lynceans.org/all-posts/modern-airships-part-3/
  - Airbine™
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  - Aeerstatica