e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:04/April-2023 Impact Factor- 7.868 www.irjmets.com

AIRBORNE WIND ENERGY

Mahesh Gadwantikar*1, N. Sumanth Reddy*2, M. Mahesh*3, K. Shiva Nagendra*4, D. Tharun*5

*1Assistant Professor, Department Of Mechanical Engineering, J.B Institute Of Engineering And Technology, Hyderabad, India.

*2,3,4,5Student, Department Of Mechanical Engineering, J.B Institute Of Engineering And Technology, Hyderabad, India.

DOI : https://www.doi.org/10.56726/IRJMETS37176

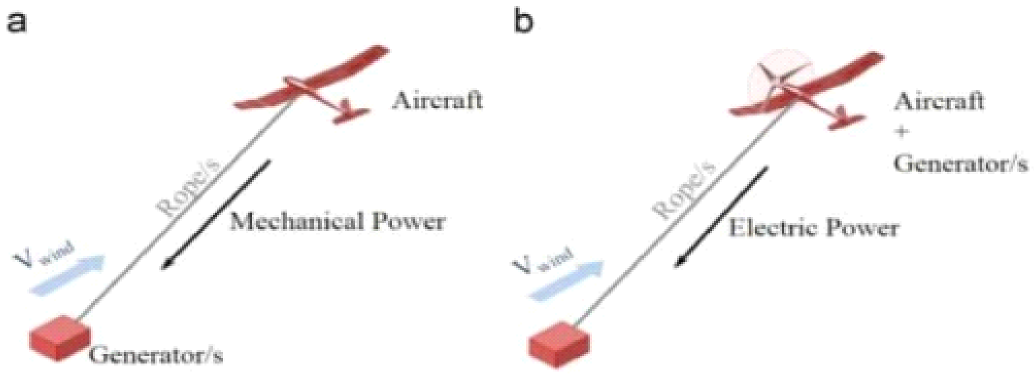
ABSTRACT

Among novel technologies for producing electricity from renewable resources, a new class of wind energy converter has been conceived under the name of Airborne Wind Energy Systems (AWES). Airborne wind energy (AWE) "is the conversion of wind energy into electricity using tethered flying devices." The essence of airborne wind energy is to replace material constraints (passive) by control algorithms (active). This is the great potential but at the same time also the challenge of the technology. Using a light weight tether in place of tower and its foundation remove most of the mechanical constraints of the system.

Airborne Wind Energy Systems have undergone major advancements in the last 15 years. Starting From theoretical concepts, more and more sophisticated prototypes have been developed and tested. A number of systems based on radically different concepts have been analyzed and tested. This provides a review of the different technologies that have been conceived to harvest the energy of high-altitude winds, specifically including prototypes developed by universities and companies. Today, a thriving community is fostering the industrialization of AWES.

I. INTRODUCTION

Airborne wind energy (AWE) is the conversion of wind energy into electricity using tethered flying devices. Some concepts combine onboard wind turbines with a conducting tether, while others convert the pulling power of the flying devices on the ground. Replacing the tower of conventional wind turbines by a lightweight tether substantially reduces the material consumption and allows for continuous adjustment of the harvesting altitude to the available wind resource. The decrease in installation cost and increase in capacity factor can potentially lead to a substantial reduction of the cost of wind energy. Wind at higher altitudes is also considered to be an energy resource that has not been exploited so far. Advancement of societies, and in particular in their ability to sustain larger populations, are closely related to changes in the amount and type of energy available to satisfy human needs for nourishment and to perform work. Low access to energy is an aspect of poverty. Energy, and in particular electricity, is indeed crucial to provide adequate services such as water, food, healthcare, education, employment and communication.



To date, the majority of energy consumed by our societies has come from fossil and nuclear fuels, which are now facing severe issues such as security of supply, economic affordability, environmental sustainability and disaster risks. To address these problems, major countries are enacting energy policies focused on the increase in the deployment of renewable energy technologies. In particular: Since 1992, to prevent the most severe impacts of climate change, the United Nations member states are committed to a drastic reduction in greenhouse gas emissions below the 1990 levels. In September 2009, both European Union and G8 leaders agreed that carbon dioxide emissions should be cut by 80% before 2050.

RELATIONSHIP TO TRADITIONAL WIND ENERGY

By using wind as its energy source, AWE may appear, at first glance, to be in direct competition with traditional wind energy technology (defined as wind turbines built on towers. To assess if this assumption is valid or could reduce the scope of the value proposition associated with AWE, this study aims to address the following questions when reflecting upon the congressional request:

Is AWE in direct competition with traditional wind energy? Influencing factors may include:

- Desired access to identical and mutually exclusive installation locations.
- Significant direct or secondary technology cost implications, such as raw material consumption.
- Strongly different cost implications on foundations and support structures (such as in offshore floating wind), respectively, or other reasons to be identified. Is AWE complementary to traditional wind energy? Influencing factors may include:
- Temporal characteristics of the wind resource
- Capacity-factor-related characteristics of either technology
- Possibilities of co-location, with levels of system integration, or other reasons to be identified.

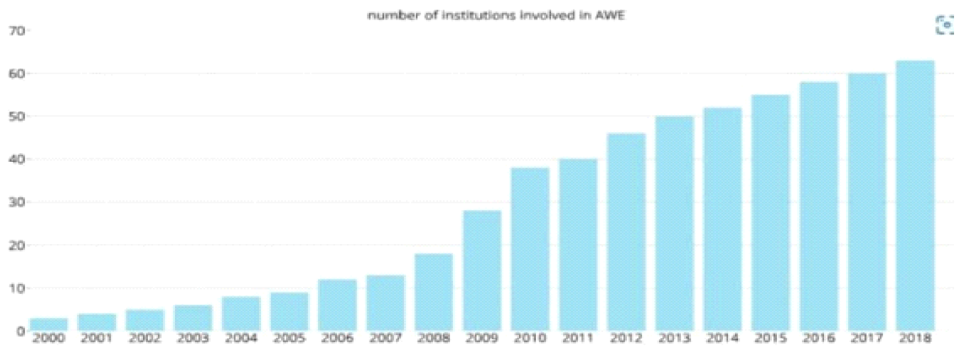
Is AWE independent of and thus supplementary to traditional wind energy? Influencing factors may include:

- Capability to access different wind resources. Reasons may be associated with location, level of resource intensity, and inherent access to resource at different heights above ground
- Type of markets and applications targeted (e.g., microgrid, distributed wind, deployment speed, plant operational duration, adaptability, visual impact, social benefit)

Independent supply chains or other reasons to be identified.

DEVELOPMENT AS AN INDUSTRY

Just before the turn of the century, TU Delft professor and former astronaut Wubbo Ockels presented a high altitude wind energy concept based on a cable loop that was running from a ground station into the sky. Driven by kites attached at regular intervals, the mechanical net pulling power in the loop was to be converted into electricity at the ground. Although this "laddermill" was only a conceptual idea the persistent effort of Ockels would lead to the establishment of a research group in 2004, spinning off two pioneering companies, Ampyx Power (2007) and Kitepower (2016). The increasing number of institutions involved in AWE worldwide is illustrated in the following diagram.



SURVEY ARTICLES

In response to language set forth in The Energy Act of 2020, the U.S. Department of Energy's (DOE's) Wind Energy Technologies Office (WETO), working with the National Renewable Energy Laboratory (NREL), explored the potential for, and technical viability of, airborne wind energy (AWE) technologies, which convert wind energy into electricity using tethered flying devices. As part of its inquiry, WETO drew on findings and insights gained from a synthesis of existing literature, NREL internal analysis, and outreach through interviews of AWE industry leaders. Supported by WETO, NREL hosted a technical workshop on U.S. Airborne Wind Energy in March 2021, attended by more than 100 experts and interested parties.

II. METHODOLOGY

Design of turbine shaft using Solid works. The purpose of the shaft is to transfer the mechanical energy of the turbine blades to the selected permanent magnet generator (DC12 V/24V, 350W, 2700 rpm). Various materials were taken into consideration for the shaft. Since one of the major objectives of this project is to lift the entire system with the help of a helium balloon, it is important for the selected material to be light weight. Aluminium-2024 T3 was selected on Solidworks.

The purpose of the turbine blades is to convert wind energy to kinetic energy. The design of the turbine blades was considered after doing research on various possible designs and their efficiencies where it is concluded that it has good aerodynamics properties due to its air foil profile, low noise in the wings during its operation and is feasible to fabricate. Also, the ease of fabrication has been taken into account. It is necessary that enough torque is generated to rotate the turbine shaft. It is also very important that maximum wind energy is extracted within the weight and size limitations of the design. It will be designed as a hollow member and is included with stiffeners for strength. Three symmetrical air foil shaped straight blades have been selected for the design.

The connector assembly is designed for the purpose of connecting the blades to the rotating shaft. It is said to consist of two parts, a flat plate and a circular plate. The flat plate is connected to the blades using riveting method. The circular plate is welded to the rotating shaft. Bolting of the flat plate to the circular plate was selected which enables the disassembly of the blades and also replacement of the blades. The circular plate area enables the secure attachment of the flat plate.The combination of all three cases have been considered in this project.

	Traditional Wind	Airborne Wind
Concept	Spinning rotor comprised of composite blades, a tower mounted nacelle & drivetrain	Self-supported airborne system tethered to a ground station, with an airborne or ground mounted drivetrain
Response to a Failure	Rotor blades pitch to stop rotation and the turbine waits for remote diagnostics or on-site technician	Airborne system must land safely and autonomously, while avoiding personnel/property
Installation / Maintenance	Crane lift and elevated assembly of major components. Inspection and maintenance also performed at height (80+ meters)	All installation and maintenance performed near ground level
Market Convergence	Upwind, 3-bladed configuration dominates, developed over 40+ years with trusted international standards	Dozens of configurations, little market convergence, and no international design standards or requirements
Operating Altitude	Typically below 250 meters Constant altitude	Typically 200–800 meters Variable altitude
Operational Strategy	Annual OpEx ≈ 2–3% of CapEx Designed for 25+ year operational life	Annual OpEx ≈ 3–20% of CapEx Major components may be replaced or upgraded often
Support Structure	Tower and foundation must resist significant overturning moments	Minimal overturning moments, tether tension is dominant load on foundation
Overland Transportation	Blades and towers are currently size constrained by the limits of highway and rail transportation	Kites may disassemble or compress for easier transportation. Larger rigid wings may become transportation size constrained in the future
Unit Capacity	0–6 MW Onshore 6–15+ MW Offshore	0–2 MW Onshore (notional) 2–5 MW Offshore (notional)
Wind Farm Integration	2D placement (Lattitude, Longitude)	3D placement (Lattitude, Longitude, Altitude) Location depends on wind direction and speed

Fundamental differences between Traditional and Airborne wind energy

III. DESIGN

AWE systems can be classified into two basic approaches: fly-gen and ground-gen,
defined here (shown in Figure 6 in an offshore setting):

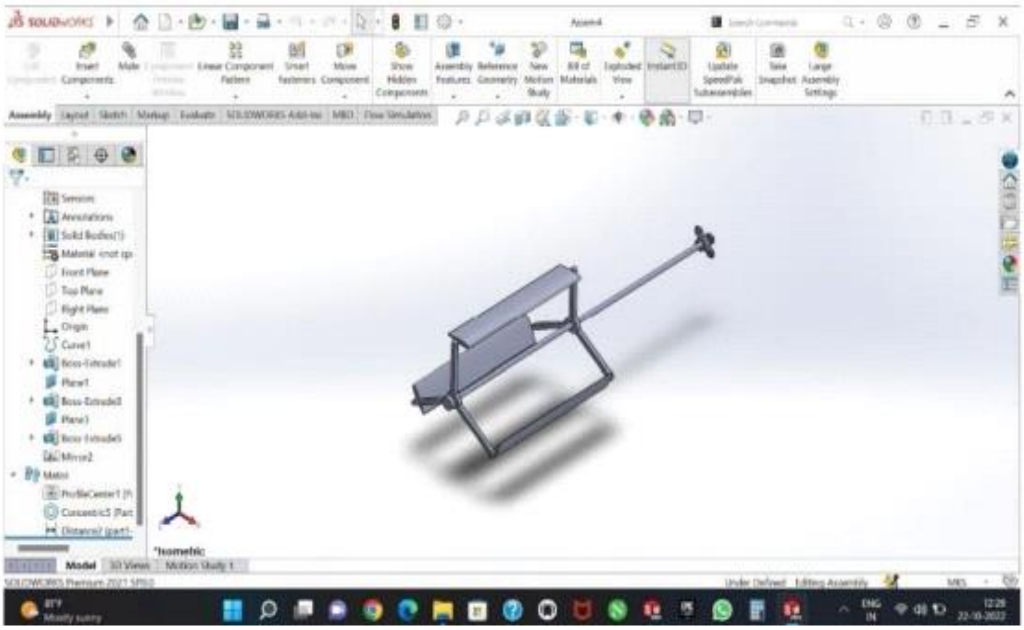
• Fly-gen AWE systems fly onboard turbine-generator units that are connected to an airframe along figure-eight or circular crosswind trajectories defined by the tether length. Electricity is generated onboard the kite. The onboard-generated electrical power is transmitted to the ground station through a conductor in the tether. The system is designed to achieve high relative velocity on the flying wind turbines.

• Ground-gen AWE systems generate electricity by flying in figure-eight or circular crosswind trajectories while spiralling upward and reeling out the tether that connects the kite to a winch-generator unit on the ground station. Electricity is generated on the ground. Once the kite reaches its maximum operational altitude, it is retracted, and the tether is reeled in. The system is designed to achieve high lift on the wing for maximum mechanical power transmitted through the tether.

Generator placement

The first design choice is where to place the electrical generation equipment. If placed onboard (called fly-gen), the airborne device generates power continuously but must transmit the electricity to the ground over the tether connecting the airborne device to the ground. If the generator remains on the ground (called ground-gen), the airborne device can be simpler and lighter, but many designs only generate electricity in one phase of flight—called “reel out,” as a tether is spooled from a drum—and consume energy during “reel in.” Ground-gen devices can have a stationary or moving generator, though the former is more commonly proposed.Wing structure Second, the structure of the airborne device can be either rigid like most aircraft or soft and compliant like a parafoil kite. Rigid wings can have higher performance and durability but may be heavier.

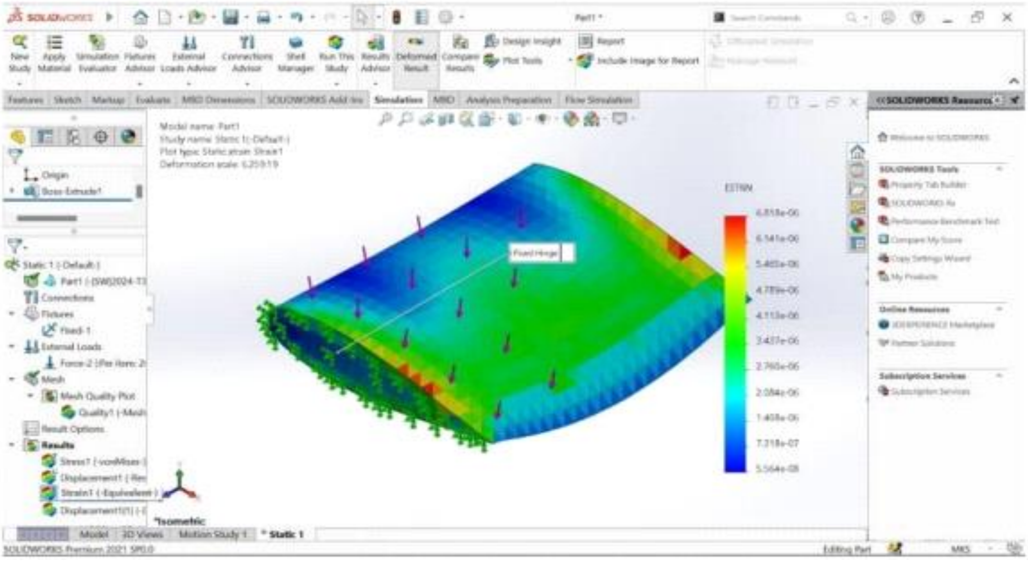
IV. RESULTS



The design was chosen to be kept hollow, since studies show that the strength to weight ratio of a hollow shaft is 44.4% higher than the solid shaft. The designed shaft is chosen to be 600 mm long with an outer diameter of 30 mm and an inner diameter of 25 mm, i.e., 2.5 mm on each side. This turbine setup is a version of the Darrieus

VAWT. Three symmetrical air foil shaped straight blades have been selected for the design. This design has been selected because it can provide good efficiency, has good aerodynamics properties due to its air foil profile, low noise in the wings during its operation. And the figure 8 is the final assembly of wind turbine in solid works.

Wind turbine model using Solidworks



Strain analysis of turbine blade (Aluminium 2024T3) of wind turbine using Solid works (Force given is 100N and the deformation value obtained is 0.625mm)

V. MERITS AND LIMITATIONS

MERITS: On comparison with alternative energy source, wind energy is clean energy.

There is no form of emissions of gases and other harmful substances. The system once installed gives free energy and is worth the initial cost. The use of airborne wind turbines saves installation and material costs, also these turbines can reach more height than conventional wind turbines. Airborne wind turbines can be moved from one location to another in case of seasonal change. The cost of the project is low as materials like aluminium are cheap and easily available. They are light in weight and have anti-corrosion properties.

LIMITATIONS: Severe weather conditions may require the system to be unlaunched for the particular time period and hence no power is generated if the wind turbine setup is retracted during bad weather. Initial cost for the helium balloon is high. The balloon requires regular refilling as it has a leakage of approximately 10% per 24 hours. It is difficult to get accurate readings of wind velocity as at high altitudes anemometer cannot be used.

VI. CONCLUSION

The design shaft orientation was decided to be kept horizontal for the purpose of stability after it is lifted. Vertical orientation may cause the system to sway and can be less stable. The overall weight of the system can further be reduced by using materials like carbon fibre. Although carbon fibre is an expensive material, its properties like light weight and greater strength. An aerodynamic self-aligning balloon can be designed. Also, airflow around the system can be studied and design can be improved. High altitude wind energy is currently a very promising resource for the sustainable production of electrical energy. The amount of power and the large availability of winds that blow between 300 and 10000 meters from the ground suggest that Airborne Wind Energy Systems (AWESs) represent an important emerging renewable energy technology. In the last decade, several companies entered in the business of AWESs, patenting diverse principles and technical solutions for their implementation. In particular, all existing AWESs have been briefly presented and classified. The basic generation principles have been explained, together with what could provide the reader with a perception on which and how crucial parameters influence the performance of an AWES. In the next years, a rapid acceleration of research and development is expected in the airborne wind energy sector.

VII. REFERENCES

[1] Dodge, D., 2006, "Illustrated History of Wind Power Development," Telos Net Web Development, Littleton, Colorado.

[2] John K. D. Zafirakis, "The wind energy (r) evolution: A short review of a long history", Lab of Soft Energy Applications & Environmental Protection, TEI of Piraeus, Greece, 2011

[3] Global Wind Statistics, "Global Wind Energy Council", 2017.

[4] Alexander Bolonkin, Using of High Altitude Wind Energy V. P. of Consulting and Research Co., Brooklyn, USA, 2011, PP 75-85. Moritz Diehl, "Airborne Wind Energy: -Basic Concepts and Physical Foundations",

[5] KULeuven, Electrical Engineering Department, ArenbergKasteelpark10, 3001 Leuven, Belgium.

[6] NykolaiBilaniuk, Ph.D., P.Eng. CEO, LTA Wind power, Ottawa, Canada," Generic System Requirements for High Altitude Wind Turbines", volume 1, 2009.

[7] W. T. Chong, A. Fazlizan, S. C Poh, W. P. Hew, F. B. Siao, "The design, simulation and testing of an urban vertical axis wind turbine with the Omni-direction-guide-vane* , Applied energy 2013-2012.

[8] U. Zillmann, P. Bechtle, Emergence and economic dimension of airborne wind energy, in: R. Schmehl (Ed.), Airborne Wind Energy e Advances in Technology Development and Research; Chap. 1, Green Energy and Technology, Springer, Singapore, 2018, pp. 1e25. https://doi.org/10.1007/978-981-10-1947-0_1

[9] A. Cherubini, A. Papini, R. Vertechy, M. Fontana, Airborne wind energy systems: a review of the technologies, Renew. Sustain. Energy Rev. 51 (2015) 1461e1476, https://doi.org/10.1016/j.rser.2015.07.053.

[10] M. Diehl, R. Leuthold, R. Schmehl (Eds.), The International Airborne Wind Energy Conference 2017: Book of Abstracts, University of Freiburg & Delft University of Technology, Freiburg, Germany, 2017. https://doi.org/10.6094/ UNIFR/12994, 5e6 October 2017.