BUOYANT AIRBORNE TURBINE – THE NEXT GENERATION OF WIND POWER

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Abstract:Climate change concerns, high volatile fossil fuels prices, and increasing government support, accelerates the growth of renewable energy sector. With nations pledging to reduce the carbon emission to counter global warming, the need for systems that generate renewable energy has been on a rise. "Buoyant" means "to be able to float" and "Airborne" means "in flight." An Airborne Turbine is a wind turbine with a rotor supported in the wind without a tower. It is connected to the ground via high strength conducting tethers. The main objectives of the project is to develop a system that can reach high altitudes as high as 500 meters & above where winds are more consistent and strong. With this system, a solution for the future energy (fossil fuels) crisis which can already be seen in present day can be provided and it's clean energy from an endless source.

***IndexTerms* - Airborne, Altaeros, Altitude, Buoyant, Helium, Shell, Tethers, Turbine.**

I. INTRODUCTION

An ever growing population means an ever growing requirement for energy. Nowadays, enormity of energy cannot be denied. It is essential in every walk of life. Energy sources can be broadly classified as renewable and non-renewable. Knowing the dreadful fact that non-renewable sources will eventually deplete, the importance of renewable sources cannot be underestimated. The most important aspect while utilizing them is their impact on the environment.[1]

1.1 RENEWABLE ENERGY

Renewable energy is the energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable. The forms of renewable energy are solar, wind power, hydroelectric energy, biomass is the term for energy from plants, hydrogen and fuel cells, geothermal power and other forms of energy. Climate change concerns, high volatile fossil fuels prices, and increasing government support, accelerates the growth of this sector. In 2008, about 19% of global final energy consumption came from renewable sources. With nations pledging to reduce the carbon emission to counter global warming, the need for systems that generate renewable energy has been on a rise.Applications of renewable energy are broadly classified as "on-grid" and "off-grid". A grid is basically an integration of generation, transmission and distribution system which supplies energy to several consumers. [2]

1.2 NEED FOR WIND ENERGY

Wind power is growing worldwide as a major source of renewable energy. To meet the demand for alternative energy sources, large numbers of wind power generators are being deployed on wind farms both at land and sea. Our energy needs are changing, and so is the way we are meeting them. Energy production is the biggest current source of Greenhouse emissions. Not only does burning fossil fuels emit greenhouse gases, but fossil fuel reserves are a finite resource and increasingly need to be imported from overseas. The wind, in contrast, is freely available and endlessly renewable. As onshore wind technologies have matured, onshore wind has also become the lowest cost form of new large-scale electricity generation cheaper than gas and almost half the price per kWh of new nuclear power stations.

Whilst energy efficiency is increasing, changes such as the growth in use of electric cars and the increasing use of electricity as a source of heat are also likely to increase the need for electricity into the future.

1.3 WIND POWER

Wind power is the conversion of wind energy into a useful form of energy. Wind energy has been the world's fastest growing source of electricity during the past decade, with over 20% annual growth. Energy production from wind was 340 TWh, which is about 2% of worldwide electricity usage.

A wind turbine, or alternatively called as a wind energy converter, is a device that converts the wind's kinetic energy into electrical energy. A wind turbine is a rotary device that extracts energy from the wind. Types of wind turbines: Horizontal Axis Wind Turbine (HAWT), Vertical Axis Wind Turbine (VAWT), Small Wind Turbines, and Airborne Wind Turbines (AWT). Wind farms and wind turbines are built onshore as well as offshore.**Figure 1** shows different types of wind turbines.

Horizontal axis:

Horizontal axis wind turbines are the most common type used. All of the components (blades, shaft, and generator) are on top of a tall tower, and the blades face into the wind. The shaft is horizontal to the ground. The wind hits the blades of the turbine that are connected to a shaft causing rotation. The shaft has a gear on the end which turns a generator. The generator produces electricity and sends the electricity into the power grid.

Vertical Axis:

In vertical axis turbines the shaft the blades are connected to is vertical to the. All of the main components are close to the ground. Also, the wind turbine itself is near the ground, unlike horizontal where everything is on a tower. There are two types of vertical axis wind turbines; lift based and drag based. Lift based designs are generally much more efficient than drag, or 'paddle' designs.

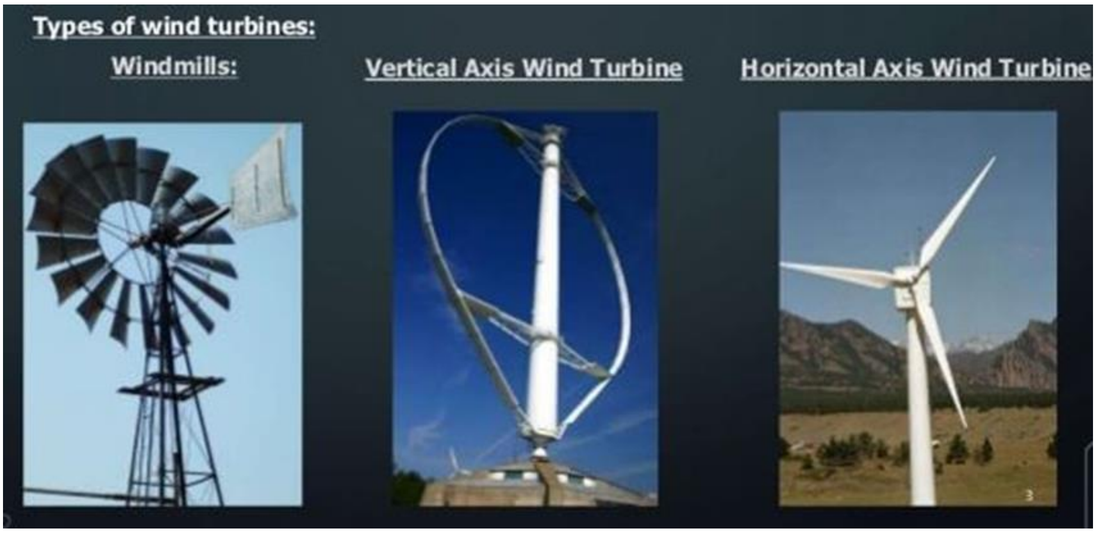

Figure.1: Types of Wind Turbines

Present day wind turbines have certain constraints which are considered as problem statements in this paper, they are:

- Generation of power by traditional wind turbines are not consistent
- Space constraints
- Utmost efficiency has not reached yet
- Present day wind turbines are not portable for remote areas
- They cannot supply off-grids or isolated communities.

This paper explains how all the above mentioned constraints can be solved by using Buoyant Airborne Turbine.

Abbreviationsand Acronyms

BAT-Buoyant Airborne Turbine.

II Theoretical framework

2.1Energy at High Altitudes

- The primary reason for seeking wind at high altitude is that the wind tends to blow faster and more constantly the higher you go.
- Power output from a wind turbine is proportional to the cube of wind velocity and to the square of the rotor diameter. Thus going a little higher may produce a lot more power.

i.e, $P \propto V^3$ ………….. *(1.1)*

$P \propto d^2$ ………….. *(1.2)*

- Over most of the land surface of The Earth, average wind speeds at surface are below 5 m/s, well below the velocity required for conventional ground-based wind turbines to operate. Hence traditional wind turbines can only be deployed in selected areas where surface winds regularly blow strongly and steadily.
- AWTs makes energy harvesting possible even at inaccessible locations, but at lesser installation cost.

Tethered airborne turbine that fly in a crosswind direction have the ability to highly concentrate the abundant wind power resource in medium and high altitudes, and promise to make this resource available to human needs with low material investment.

2.2Airborne Wind Energy

Airborne wind energy regards the generation of usable power by airborne devices. In contrast to towered wind turbines, airborne wind energy systems are either flying freely in the air, or are connected by a tether to the ground, like kites or tethered balloons. It turns out that all airborne wind energy systems with significant power output are mechanically connected to the ground in order to exploit the relative velocity between the air mass and the ground.

The three major reasons why people are interested in airborne wind energy for electricity production are the following:

- Like solar, wind power is one of the few renewable energy resources that is in principle large enough to satisfy all of humanity’s energy needs.
- In contrast to ground-based wind turbines, airborne wind energy devices might be able to reach higher altitudes, tapping into a large and so far unused wind power resource. The winds in higher altitudes are typically stronger and more consistent than those close to the ground, both on- and off-shore.
- Airborne wind energy systems might need less material investment per unit of usable power than most other renewable energy sources. This high power-to-mass ratio promises to make large scale deployment of the technology possible at comparably low costs. [4]

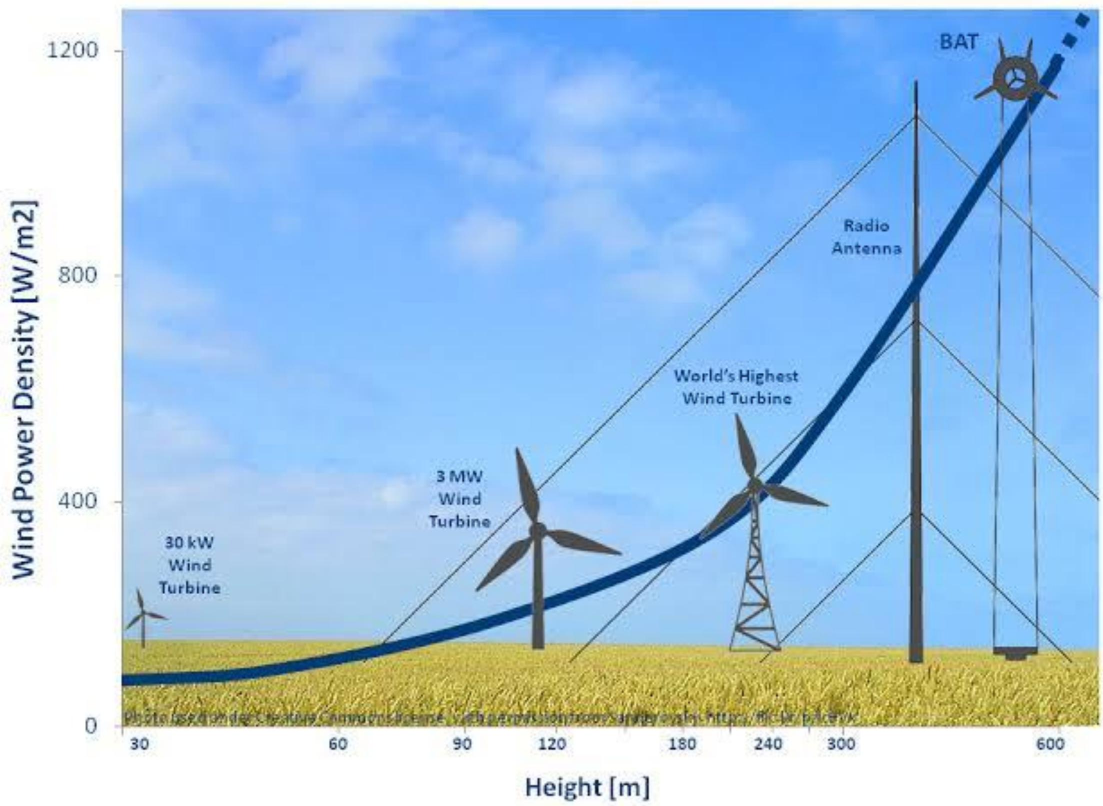

Figure 2: Wind Power Density V/S Height

Airborne Wind Energy can be harnessed by using any of the systems shown in **Figure 2**.

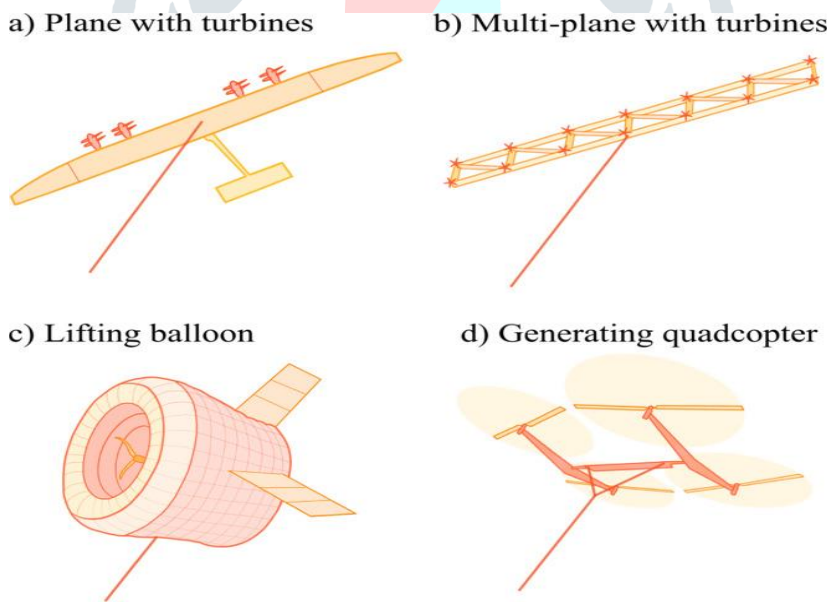

Figure 3: Airborne Wind Energy Systems

III Lighter than Air Systems

While most airborne wind energy systems rely on aerodynamic lift in one form or the other in order to keep the system airborne, a few systems rely on aerostatic lift to stay aloft, i.e. the airborne part of the system is lighter than air. The advantage is that they can stay airborne in the absence of wind indefinitely, and without power consumption. On the other hand, they need a considerable volume to compensate the weight of the rest of the airborne system – this volume is typically filled with Helium. An interesting fact is that power generation comes along with significant tether tension and when the wind blows and power is produced, the tether force, which is partly directed in vertical direction, largely dominates the weight of any airborne wind energy system; thus, the advantages of lighter than air systems become obsolete when they do generate power. Two of the lighter than air systems that have been realized in recent years, the systems by Magenn power and Altaeros Energies mentioned earlier, both use on-board power generation with the additional weight burden of the electrical generator. To the best of the present knowledge no crosswind kite power systems exist in this class; their large volume constitutes a fundamental design limitation for achieving high lift-to-drag ratios.

3.1 Helium gas:

Helium is a chemical element with symbol He and atomic number 2. It is a colorless, odorless, tasteless, non-toxic, inert, monatomic gas, the first in the noble gas group in the periodic table. Its boiling point is the lowest among all the elements. After hydrogen, helium is the second lightest and second most abundant element in the observable universe, being present at about 24% of the total elemental mass, which is more than 12 times the mass of all the heavier elements combined. Its abundance is similar to this figure in the Sun and in Jupiter. This is due to the very high nuclear binding energy (per nucleon) of helium-4 with respect to the next three elements after helium. This helium-4 binding energy also accounts for why it is a product of both nuclear fusion and radioactive decay. Most helium in the universe is helium-4, the vast majority of which was formed during the Big Bang. Large amounts of new helium are being created by nuclear fusion of hydrogen in stars.
In order to get a balloon or the shell to float, a gas which is as light as possible required. Helium is quite a lot lighter than air weight. It's about a eighth of the density of air. Hydrogen is about a sixteenth the density of air. Helium is safer than Hydrogen because it is a noble gas, which means that it is chemically unreactive or inert and therefore safer from burning and "explosive" accidents (other than those related to pressurized transport and handling). However, Helium is also rare on earth, with few known deposits, and essentially non-renewable. This makes it expensive and relatively precious.

3.2 Properties of Helium:

Helium has many unique properties: low boiling point, low density, low solubility, high thermal conductivity and inertness, so it is use for any application which can explioit these properties. Helium was the first gas used for filling balloons and dirigibles. This application goes on in altitude research and for meteorological balloons. The main use of helium is as an inert protection gas in autogenous welding. Its biggest potential is found in applications at very low temperatures. Helium is the only cooler which is capable of reaching temperatures lower than 15 K (-434ºF). The main application of ultralow temperature is in the development of the superconductivity state, in which the resistance to the electricity flux is almost zero. Other applications are its use as pressurizing gas in liquid propellants for rockets, in helium-oxygen mixtures for divers, as working fluid in nuclear reactors cooled down by gas and as gas carrier in chemical analysis by gas chromatography.

3.3 Helium in Environment

Helium is the second most abundant element in the known universe, after hydrogen. Helium constitutes the 23% of all elemental matter measured by mass. Helium is formed in The Earth by natural radioactive decay of heavier elements. Most of this helium migrates to the surface and enters the atmosphere. It could be logical to think that the helium concentration in the atmosphere was higher than it is (5,25 parts per million at sea level). Nevertheless, its low molecular weight allows it to escape to space at the same rate of its formation. There is an about 1000 km layer in the heterosphere at 600 miles where helium is the dominant gas (although the total pressure is very low). Natural gases contain higher helium concentrations than the atmosphere. Helium is the 71st most abundant element in the Earth's crust where it is found in 8 parts per billion (109). [3]

IV RESEARCH METHODOLOGY

4.1 Buoyant Airborne Turbine

Buoyant Airborne Turbine (BAT) is one of HAWP which integrates proven aerospace and wind turbine technology. The BAT lifting platform is adapted from tethered aerostats, which have reliably lifted heavy communications and motoring equipment high into the air or decades. BAT integrates three main components.

- Shell: A proprietary helium-filled shell made from high performance, industrial fabrics that lifts the turbine up and stabilizes it in the air.
- Turbine: A lightweight conventional three-blade, horizontal axis wind turbine fixed within the shell.
- Tethers: The light weight, high strength tethers hold the turbine in place in all-weather conditions and transmit power to the ground.

Apart from above, there shall also be some Ground works, which include the setup of tethering control mechanism.

4.2 Block Diagram

The aim of the paper is to show that BAT is a system that can reach high altitudes such as above 500 meters where winds are more consistent and strong andgenerate over twice the energy output of similarly rated wind turbines. Thus the general block diagram is as shown in **Figure 4.**

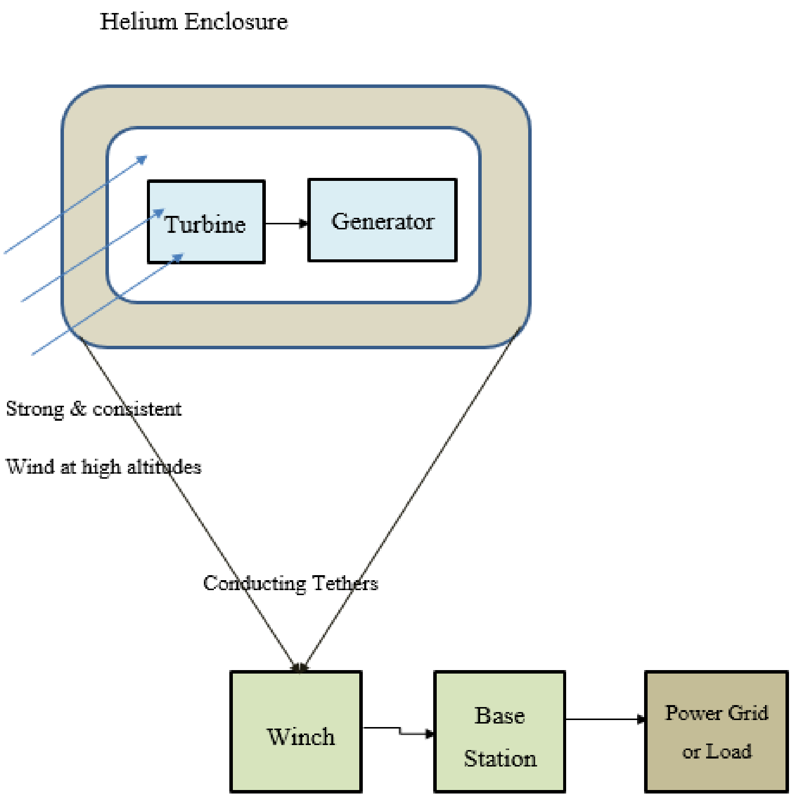

Figure.4: Block diagram of Buoyant Airborne Turbine

The Floating Airborne Turbine uses a helium-filled, inflatable shell to lift the rotor-based turbine to high altitudes where winds are stronger and more consistent than those reached by traditional tower-mounted turbines. High strength conducting tethers hold the aerostat steady and send electricity down to the ground. A power station on the ground controls the winches that hold the tethers and pulls in the power from the turbine before sending it on to a grid connection.

4.3 Altaeros' Buoyant Airborne Turbine:

Altaeros Energies have developed a buoyant airborne turbine (BAT) which has a standard wind turbine rotor fixed within a helium filled shroud. The system is attached to ground through three tethers one located at the fore and two located at the aft-starboard and aft port respectively. One tether facilitates the transfer of electrical energy to ground. The tether lengths are regulated through three DC motors located on a rotating base station. The Altaeros system is shown in **Figure.5.**

Figure.5: Altaeros Energies System during Testing

V Advantages and Disadvantages

5.1 Applications and Advantages

- Towers are often too low to catch the best winds. By flying wind turbines where winds are stronger and more consistent, a lot more energy can be harvested, and it's clean energy from an endless source.
- They are portable for remote areas, isolated communities or places that are off grid.

- They can be deployed in the required area within a few hours.
- No expensive infrastructure, such as electrical grids or power stations, is required.
- This turbine generates consistent, low cost energy for the remote power and microgrid market, including remote/ far-flung villages and island communities; oil & gas, mining, agriculture, and telecommunication firms; disaster relief organizations; and military bases.
- Can also be deployed at ground level.

5.2 Disadvantages

Since we are using helium filled shell to lift the turbine into the air, if the tethers get damaged & cut off, the shell keeps moving higher & higher until the weight of helium is lesser than that of the total weight of the shell & turbine together. But, this can be taken care of by using sensors to detect tension of the tethers & induce leakage automatically when the above mentioned condition occurs.

VI Conclusion

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. Buoyant airborne wind turbines are capable of harnessing stronger winds at higher altitudes and with their automated and rapidly deployable system they are suited to niche applications such as emergency power generation. Since we are harvesting clean energy from an endless source, Buoyant Airborne Turbine is the Next Generation of Wind Power.

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