Airborne Wind Energy Technology

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Abstract –Wind energy is one of the energy resources that is used for generating electricity under the classification of renewable energy resources. Among the traditional technologies for generating electricity from renewable energy resources, a new class of wind energy harvested method has been launched under the name of Airborne Wind Energy Systems (AWES). Under this new concept, researchers' expert in overcoming the problems associated with conventional methods and produce more power as well. For the conversion of high altitude wind energy into electricity, this method is applied, and it has another name as Kite energy concept. In this study hope to briefly discuss the concept of airborne wind energy and other related branches.

Index Terms— Airborne wind energy, Conventional wind turbine, High altitude, Kite energy, Wings

1 INTRODUCTION

Today wind power is a significant and growing source of renewable energy. In power distribution networks, large wind turbines are widely installed. Wind energy is viewed as a low – cost pathway to achieving minimization in greenhouse gas emissions and addressing other environmental impacts associated with traditional non - renewable power generation technologies [1]. Wind energy generates due to some environmental factors. Uneven solar radiation, Coriolis force and atmospheric pressure variation are some of them. The energy harvest from this generated wind. When considering the traditional wind energy harvested turbine systems, mostly they are installed in the land areas of particular countries. These systems are difficult to see in mountains and high altitude areas. The high-speed wind flows through high elevation atmospheric layers, and the energy of that wind flows cannot harvest by using traditional wind turbine systems. Therefore a new concept should be introduced to harvest energy from high-speed wind flows because it contains much energy.

The wind speed typically increases with the elevation above the ground surface, at the height 05m, 500m – 1000m, the mean wind power density is about 4 times the one at 50 – 150m, and at 1000m it is about 40 times higher. This situation suggests that a breakthrough in wind energy generation can be realized by capturing wind power at altitudes over the ground and conventional wind turbines cannot harvest that. Therefore several technologies focused on converting high – altitude wind into electricity, and finally, the researchers introduced a new concept that can apply in high altitudes wind sources [2]. That is the Airborne Wind Energy (AWE) concept. This AWE concept aims to capture the wind energy at significantly increased altitudes. The machines that extract this kind of energy can be referred to as Airborne Wind Energy Systems. The persistence of the energy carried by high – altitude winds that blow in the range of 200m – 10km from the ground surface. Since the beginning of the eighties, several research communities had been attracted their attention for this AWE concept [3].

When considering about the AWE systems, all AWE systems use tethers to connect an airborne device to a ground station, which could be mounted on land, an anchored buoy, an offshore platform or a boat. By using strong, lightweight, durable, synthetic fibers, the tethers are constructed, and some tethers also include a conductive material, such as aluminium [4]. Airborne wind harnesses energy without the cost of large, material – heavy foundations and towers, minimizing its financial and environmental impact. Significantly reduces capital expenditure on platforms and subsea structures due to the massive weight reduction.

Although AWE is a proven concept and over 100 AWE related patents have been filed, no commercial airborne wind energy system is available on the market as of mid – 2013. When considering about the current situation, the AWE community has been developed rapidly in the past five years, and it consists now over twenty startups worldwide with a different design, energyoutputs and flying altitudes [4]. Under the present paper, discuss the technology concept of the airborne wind energy system, what are their classification and main components, and what are the advantages and limitations associated with this new concept.

2 TECHNOLOGY CONCEPT OF AIRBORNE WIND ENERGY

The concept of airborne wind energy is use wings, linked to the ground surface by using cables, to extract energy from the wind blowing at higher heights. By using an automatic control unit, the flight of the wings is suitably driven. By turning the traction forces acting on the wings lines into electrical power with the use of suitable rotating mechanisms and electric generators placed on the ground, wind energy is collected at ground level. The wings can exploit wind flows at higher altitudes than comparing with traditional wind towers. By using this airborne concept, high altitude wind energy can be extracted with minimal effort in terms of land occupation, cost and generator structure.

To understand the concept of airborne energy, imagine to remove all the bulky structure of a traditional wind tower and keep the outer part of the blades, which becomes a lighter wing flying fast in crosswind conditions, mounted to the ground by using the cables. The rotor and the tower of the conventional wind technology are replaced in airborne wind technology by the wings and its cables, realizing a wind generator that is lighter and cheaper. When considering about 2 – MW wind turbine, the weight of the rotor and the tower is usually about 300 tons. An airborne wind energy generator of the same rated power can obtain by using a 1000m long cables and 500m^2 – size wing, with a total weight of about 2 – 3 tons only [5].

3 CLASSIFICATION OF AIRBORNE WIND ENERGY SYSTEMS

Fig.01 shows the full picture about the classification of airborne wind energy systems [6].

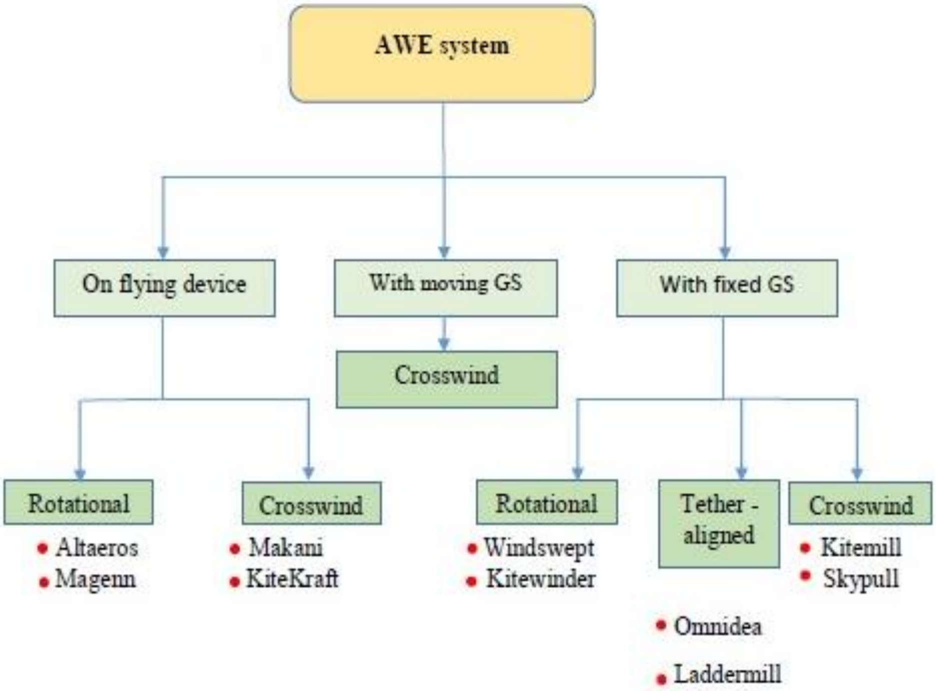

Fig.01 The classification of the AWE system [6]

Anyway, airborne wind energy devices can mainly categorize into two categorizations. The static and crosswind are them [7]. The static device can access the higher, more persistent wind resources. Using lighter – than – air balloons to stay aloft, these lift their turbines high above the ground surface and are linked to the ground surface mechanically and electrically by using one or more cables.

By flying across the wind, the crosswind devices stay in the air, producing enough lift to stay aloft and generate electricity. The crosswind movement allows higher relative wind speed; therefore, when considering about crosswind devices, they can produce between three and five times more power than static airborne devices at the same height. As well as they,

- Maximize the effective swept area of the device.
- Maximize the capture area.
- Maximize the potential power output.

The crosswind devices can be fabricated by using either soft material like kites or hard composites like wings. The electricity generation by crosswind devices can happen according to On-Board Generation (OBG) or Ground-Based Generation (GBG).

On – Based Generation (OBG)

When considering On – Board Generation devices, they generate electricity by having added drag on the wing through rotor blades that generate continuously while flying in a crosswind motion. In this phenomena, the lift coefficient is enough to compensate for the device plus the added drag. The high lift – to – drag ratio requires a hard wing that results in maximized performance when moving across the wind. The power generated On – Board has then transmitted down a cable connected to the ground surface [7]. Fig.02 shows the crosswind device with On-Board Generation.

Fig.02.The crosswind device with On-Board Generation [7]

Ground-Based Generation (GBG)

The lift of the device is used by Ground-Based Generation devices to pass mechanical power via the tether, winding and unwinding a ground-based winch. When the device files in a high – power crosswind motion, the power is generated. This device will be fabricated by using both hard and soft materials, and the Ground-Based generators allow a heavier and more bespoke design than On – Board Generation. When comparing with On – Board, more researches are launched in Ground-Based Generation devices than On – Board [7]. Fig. 03 shows the crosswind device with Ground-Based Generation.

Fig. 03. The crosswind device with Ground-Based Generation [7]

4 MAIN FUNCTIONAL COMPONENTS OF AWE SYSTEM

In here, consider about functional components of Ground-Based type airborne wind energy system.

Wings

An inflated tubular frame and fabric canopy are included in the wing; which combines a bow-shaped leading edge tube with several mounted strut tubes. By using a bridle system, the distributed aerodynamic loud acting on the flying wing is transferred to the tether. This particular structure is derived from leading-edge inflatable kites that are in smaller sizes, are popular for kite boarding. To maximize the maximum wing loading of the flexible membrane structure, the rigid chord wise reinforcements have been added. The both an aerodynamic and a structural function are included in the leading edge tube. During the flight, by the geometry of the bridle line system, the wind deforms substantially, and its shape is mainly controlled. Generating the traction force is another main function of wings. The wing also operated as morphing aerodynamic control surface. Asymmetric actuation, on the other hand, by adjusting the pitch angle of the wing, modulates the traction force. By the depower setting, the degree of symmetric actuation is quantified [8].

Bridle line system

By using the front bridle lines, the leading edge tube and the front sections of the strut tubes are supported. The major part of the aerodynamic load is transferred by the left and right line branches and mount to the left and right power lines. By the rear bridle lines, the trailing edge of the wing and its tips are supported. The two-line branches connect through the pulley to the two steering lines. Depending on the kite system, the bridle line system will consist of additional pulleys at bridle split points to reach the line geometry to passively adjust to varying load distribution and shape of the wing. The tether connects a weak link and a separate cable cutter, below the bridle point. To avoid possible damage and overload of the system, while the weak link breaks at a predefined tether force and in the emergency situation on command, the cable cutter servers the tether. In case of such an active or passive separation of the kite from the tether, to land the kite in tethered parachutes or paraglide mode, the safety line is used [8].

Kite control unit

The actuation drive trains comprising depower motors and steering, gearboxes, tape drums, and depower break are the central components of the Kite Control Unit (KCU). Instead of lines, tapes are used due to the better reeling behavior and lower layer build up on the drums. The kite control unit relies on three separate wireless links for redundant communication with the ground station. The kite control unit uses two onboard computers. A micro mint electrum motherboard I used for the objective that is not too time-critical, like communication. By using a faster motherboard, motor control is performed. In an aluminum chassis, all components are mounted and that chassis enclosed by high – density polyethylene covers, an additional foam padding and an outer fabric hall.

Tether

The transfer of the traction force of the kite to the ground station is the function of the tether. There is a special coating that is sprayed on the tether for its durability. When considering this component, the tether is a major safety-critical system component. Why is that, it is not redundant, it is constructed according to a safe – life philosophy, and when reaching a certain number of load cycles or a certain age has to be replaced. In commercial 100 – kW system, the typical diameter of the tether is 14mm, and it transfers a nominal traction force of 50kW.

Ground station

A drum or generator module is used in the ground station to convert the traction power of the outbound, powered kite into electric energy and to retract the depowered kite, consuming some of the generated energy. The tether connects the ground station via a fixed swivel head and pulley guiding system. The entire winch is connected on a sled that is moved transverse to the incoming tether. To the rotational motion of the drum, the alternating linear motion of the sled is coupled directly.

Distributed sensor network

To measure the environmental conditions and operational parameters of the system, a network of the distributed sensor is used. Some of these details is required for automatic operation and development purpose. The sensor data that is very useful for fault detection. The wind direction and speed is measured by a sensor connected at the tip of a mast by using wireless technology. The traction force and the elevation and azimuth angles of the tether are measured at the swivel head. For both the steering and depower motors, the KCU is equipped with potentiometers and temperature sensors.

Winch controller

To increase the energy output and at the same time ensure reliable and safe operation of the system, the winch controller modulates the reeling speed of the tether. In here, use set values for both reeling speed and maximum tether force, to avoid overloading of the airborne wind energy system due to natural fluctuations of the wind speed. The set value is tracked during the reel out unless the maximum tether force is exceeded [8].

Flight controller

The flight controller is in charge of the motion aspect transverse to the tether. It consists of three specified functional things. The flight direction planner, flight direction controller and course controller are them. The guidance of an aircraft is the flight path planner. As well as the flight path planner supports control on pumping cycle level. The flight path controller is active during system states with more than one target point. Its task is to switch to points when certain conditions are met. To allow the optimal pulling force in varying wind states, to calculate the desired elevation angle, the prevailing wind speed data is used. For optimizing the pulley force, the flight path controller has the authority to add a specific offset elevation to the fixed target points. When considering the course controller, its task is to steer the kite towards the unit sphere's target points. For this purpose, by using great circle navigation on the unit sphere, the course controller calculates the desired course.

Distributed software architecture

For the fact that hardware components of the control system are distributed over the different parts of the kite power system, the modular software architecture is accounted. When considering about an example, the two computers in the kite control unit are connected with the three computers in the ground station through wireless links. Accurate timing of the communication between the distributed hardware components is of crucial importance for this reason [8].

5 ADVANTAGES OF AWE SYSTEMS

When comparing with the Wind Energy Conversion System (WECS), the airborne wind energy system has some advantages, and some of them can mention below [9].

- **Power variation due to inconsistent wind** – Due to inconsistent and unpredictable wind conditions, conventional WECS produces varying power. However, high – altitude wind systems face continuous wind all the time. When comparing with the ground version, the availability of wind is far more predictable.

- **Easy installation** – Due to the absence of tower and foundation, a greater cost saving is achieved in the AWE system. As well as about 90% material saving is obtained as compared to the wind turbine. Due to the small apparatus size, transport is also cheap.

- **Easy maintenance** – Easy maintenance is guaranteed, as the generator is on the ground. Very low downtimes are required for maintenance in altitude windmills as well as airborne wind generators are largely scalable due to lesser costs involved in design and development.

- **Noise and pollution** – When comparing with conventional WECS, AWE systems have significantly less sound and visual impact. Significantly lower material usage is enough for the production process of the airborne wind generators. It is accounted to be less than 90% lower than in the production of wind turbines and resulting in minimal usage of scarce natural resources. So, as compared to WECS with large structures, the carbon signature is less in AWE systems.

- **Effect on wildlife** – Due to fast-moving wind turbine blades, more accidents are taking place in conventional wind turbine system. It is seriously injured sometimes especially birds (vultures, eagles and bats), have to die due when flying at heights comparable to wind turbines. When considering about the airborne system, they have soft and flexible wings and tether attached to them without any sharp edges. So, even if birds come into contact with these flying kite, they will be got very few injured.

- **Cost comparison** – When considering about AWE system, the net cost per megawatt-hours is about three times less than as compared with a ground-based wind turbine is Australia.

6 DISCUSSION

The need for fuel increases the main fold with the rapid increases in demand. Earth's crust will not be the only source for producing energy furthermore. There is a new tendency for alternate sources of sustainable energy worldwide, and wind power is gaining importance across the world. Currently, wind energy accounts for nearly half of the clean energy produced globally and is predicted to grow 25% each year. But researchers could identify some issues associated with conventional wind energy systems and as a result of that, the airborne wind energy system has been introduced. When considering about this method, AWE systems are flying wind turbines that combine several known, and technologies, several innovative into a unique method of collecting clean and renewable energy. Their flexibility and design allow them to be deployed in areas that are otherwise unsuitable for conventional wind turbines [10].

The effective evolution of AWE system was during 2008 – 2009, though airborne wind technology innovations started during the 1970s. AWE technology innovations recorded a remarkable growth of 35% in the year 2010, compared to 14% in the previous year's [11]. Currently, many research centers, technological organizations and universities, especially Delft University of Technology, have been introduced research groups and conference to promote and develop the airborne wind energy concept [5].

When considering about all engineering systems, they maximum performance bounds and limitations. So, that thing is similar to AWES. Following limitations can identify in the development of AWES technology [9].

- The tether weight and drag are one of limitation for driving maximum power from AWE system. When increasing the altitude to harvest wind energy, more tether length is required.
- There will be another power loss due to the elevation angle of the tether.
- AWE system may obstruct air traffic due to operation at high altitude, no-fly – zones should be selected for their operation during the planning phase.
- The electrical circuit of transmission tethers must be grounded via a drum to which the tethers are wrapped on. The tethers are influenced by strong impulsive electric field under cloudy weather and lighting condition. To avoid the high accumulation of charges which can ever destroy the generator and associated electronics, polyethylene polymer tether is found to exhibit high strength to bear large currents which can be grounded before entering the generator. However, this method is costly due to great demand in AWE system industry today.
- When using hard wings to fabricate the airborne system, they are more expensive and more massive.

Though the limitations mentioned above have, the airborne wind energy system is the most suitable solution to overcome problems associated with conventional wind energy turbine system. So, this paper has discussed the technological concept of airborne wind energy systems, their classification and components and their advantages for understanding the future tendency and future direction of the wind energy field.

7 CONCLUSION

In recent years, tapping the higher altitude wind for renewable energy is gaining momentum. The objective of this paper is to provide some fundamental ideas about the airborne wind energy concept. In a relatively short time, AWE technology may contribute to a significant reduction of the global dependence on fossil sources. The industrialization of this new technology may require from 3 to 5 years since no breakthrough is wanted in any of the involved engineering fields to apply this technology. The new technological innovations, for example in the field of high – efficiency airfoils and wings may support to increase the performance of this AWE system and it will take advantage of the different power zones to maximize the power output the AWE system from higher altitude wind.

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