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# A New Approach for Classification of Airborne Wind Energy Generation Systems

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## ABSTRACT

To extract high altitude winds, several concepts have been proposed. But, there is a lack of a proper classification approach for classifying these concepts. In this paper, a classification method for classifying all types of airborne wind energy generation system has been proposed. This classification is proposed based on mechanism of flying. This classification can cover all types of airborne wind energy generations system.

**KEYWORDS:** Wind Energy, Airborne wind energy, High altitude winds, airborne wind energy generation systems

## INTRODUCTION

The energy consumption of word is increasing dramatically. The world energy demand is estimated about 13TW [1]. The major part of energy generation units are conventional type which consume fossil fuel, the main reason of global warming. Moreover, the fossil fuel resources are limited, which will be last considering the rate of world energy consumption, according to the International Energy Agency's (IEA) findings published in June 2006 by the Global Wind Energy Council (GWEC) and Renewable Energy Systems Limited (RES). On the other hand, there are several resources of clean energy which are originated in solar energy. This energy can be found in forms of solar energy [3], wind energy, biomass energy, such energy can be a proper alternative for the fossil fuels resources.

To harness wind energy we can benefit high altitude or low altitude winds. Recently high altitude wind energy conversion system which is mostly called airborne wind energy generation system has been attracted attention of researcher in this area since high altitude winds contain about 1000 TW energy, 100 times bigger than global energy demand [2]. Several airborne wind energy generation systems have been proposed in patent and research papers. However, a unique classification has not been proposed for classification of airborne wind energy generation system. Thus, in this paper we have proposed a novel classification for airborne wind energy generation system. This classification can cover all type of old airborne wind energy generation systems and future airborne wind energy generation system has not been proposed or invented yet.

Each classification should be established from only one point of view; the mechanism of flying of airborne wind energy generation systems or the mechanism of generation of wind power. For example, wind turbine concept is about the type of energy generation while wing concept refers to mechanism of flying. Any classification based on two points of view is not logical.

There are only four types of airborne wind energy generations concepts based on mechanism of flying: the concepts use lighter than air gas, the concepts benefit lifting force using a wing instead of lighter than air gas, the concept that use long towers, and the hybrid concepts. This classification can cover all type of airborne wind energy generations system.

In this view, this classification based on mechanism of flying is more logical. It should be noted that, classification based on generation of power is complicate and will is not clear for reader to understand.

The contribution of this paper can be summarized as follow: All the concepts of high altitude wind energy generation were classificated.

This paper has been organized all follows: In section 2, all types of wind energy generation system based on the chosen classification viewpoint has been presented. In section 3 a conclusion concludes the paper.

## AIRBORNE WIND ENERGY CONCEPTS

### 1- Airborne Wind Energy Generation System (AWEGS)

AWEGS is a system which extracts high altitude wind energy and convert is to electrical energy by working at altitudes. Conceptual representation of each AWEGS is shown in Fig. 1. A seen the AWEGS consists of two main parts of generation unit and transmission system.

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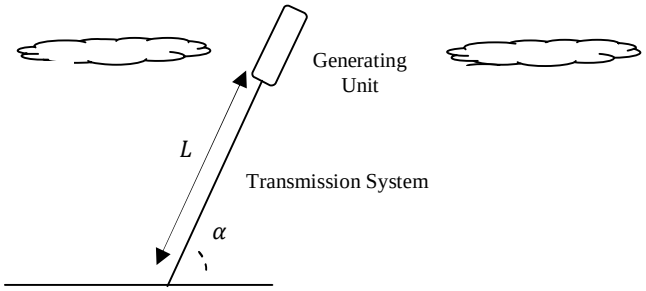


Fig. 1. Conceptual representation of AWEGS

**1-1-Generation Unit:**

The generation unit extracts the wind energy from the high altitude wind and converts it to electrical or mechanical energy. The generation unite can also presents the extracted energy in form of both the electrical and mechanical energies.

**1-2-Transmission Unit:**

The transmission system connects the generation unit to the ground-station, transmitting the generated energy by the generation unit to the ground-station. When the generated energy by the generation unit is in form of electrical energy the transmission system is a cable. If the generated energy by the generation unit was in form of mechanical power, the transmission system is a tether. Finally, in case that generation unit provides both the mechanical and electrical energies the transmission system is a reinforced cable which can transfer either the electrical or the mechanical energies to the ground-station. The received mechanical energy by the ground-station also will be converted to electrical energy.

**2- Concepts for Airborne Wind Energy Generation**

In point of view of flying mechanism of AWEGS, all the airborne wind energy generation systems can be divided to four main concepts including lighter than air gas concept, wing concept, tower concept, and hybrid concepts.

**2-1- Lighter than air concept**

In the lighter than air concept, the generation unit is supported at altitude using a light gas storage filled with lighter than air gas as shown in Fig. 2. The generation units in this concept only provide electrical energy. Consequently the transmission system is a cable transferring the generated electrical energy to the ground station. Moreover, in this concept, the lifting system and generation system are independent.

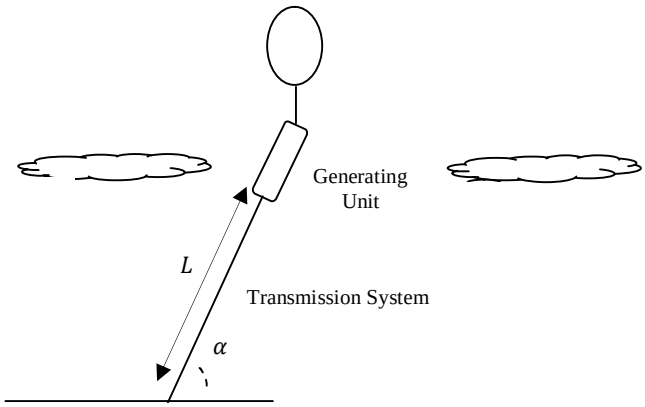


Fig. 2. Lighter than air concept

**2-2- Wing Concept**

In the wing concept, any lighter than air gas is not used for supporting of the generation unit at altitude. Instead, the generation unit benefits the lifting force which is created by special shape of the generation unit. The created lifting force supports the generation unit at altitude. In this concept the generation unit extracts the wind energy and represents it in from of electrical, mechanical energies, or in both forms.

2-2-1 High drag wing concept

In the low lifting force wing, the generation unit is in form of a thin and light weight plan with a high drag coefficient. The generation unit is connected to an electrical generator, positioned at the ground-station, using the transmission system. Wind provides a high drag force over the generation unit. Thus, the generated unit transmits the mechanical energy to the ground-station using the tether in order to rotate the electrical generator in the ground-station as shown in Fig. 3.

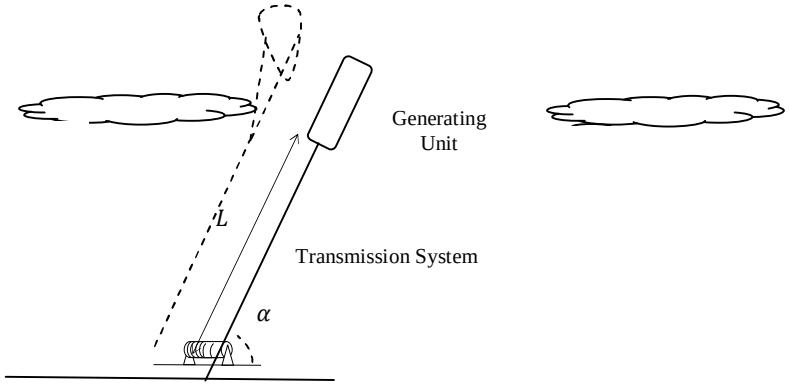


Fig. 3. High drag wing concept

2-2-2 High lifting wings concept

In the high lifting wing concept, during blowing the wind, due to the shape of generation unit, it represent a high lifting force which support itself at altitude as conceptually is shown in Fig. 4. In spite of the low high drag wing concept, the generation unit provides a small mechanical power because the drag coefficient of the generation unit is low. The generated power by the generation unit can be in form of mechanical or electrical power. For example, the in the Laddermill concept, the generation unit provides mechanical power. Also, in the airborne wind energy generation proposed by SkyWind Power Inc., the generation unite only generates electrical energy.

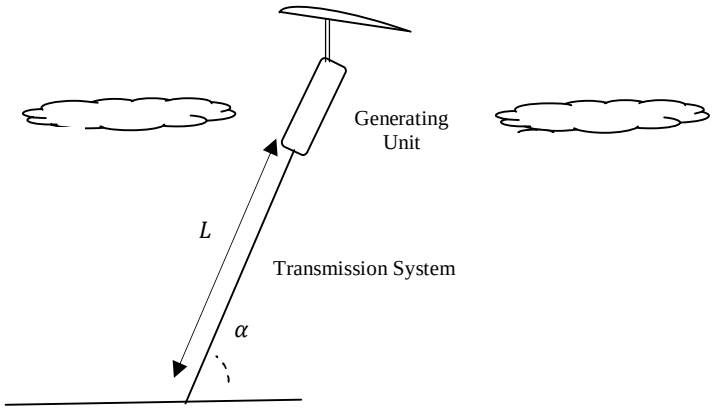


Fig. 4. High lifting concept

**2-3- Tower concept**

The generation unit can be supported at aktitude using a long tower, which are significalt larger than tower of ground mounted wind turbines as shown in Fig. 5. In this concept all or some part of transmission system will be inside the tower. The tower also can reduce the length of the tramission system. Both types of lighter than air gas and the wind concept also can be used with this concept which will be disscused in the hyrbied concepts.

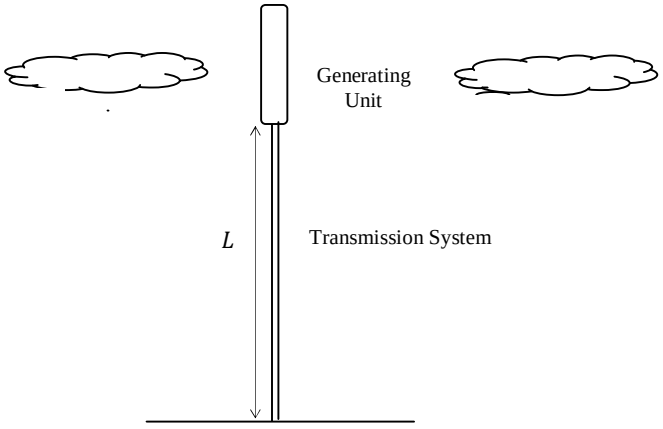


Fig. 5. Tower concept

**3. Hybrid concepts**

The hybrid concept implies that generation unites extract the wind energy using two or three numbers of concepts.

**3-1- lighter than air gas- wing concept**

Both the lighter than air gas and the wings are used for supporting of generation unit at altitude as seen in Fig. 6.

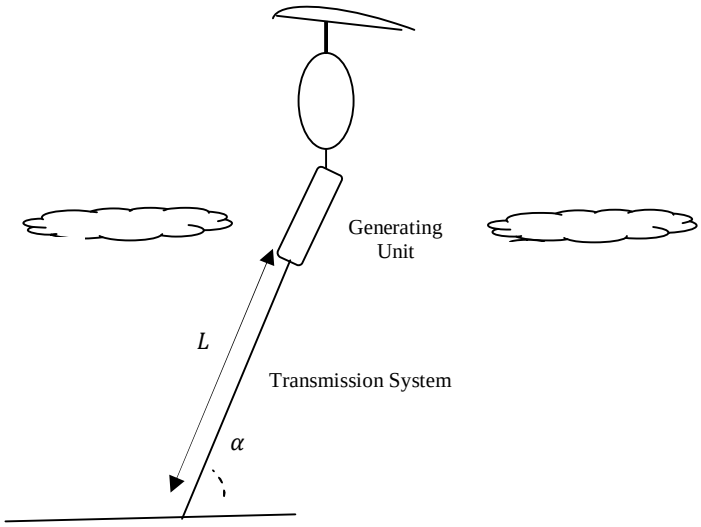


Fig. 6. Conceptual representation of AWEGS

The proposed floating kite in [5,6] benefit this concept for generation of wind energy.

**3-2-lighter than air gas-Tower concept**

In this concept the generated unit is tether to tip of a long tower using the cable. The two can significantly reduce the length of the cable. Such concept may not be economical since a high amount of structural material is required for construction of the tower.

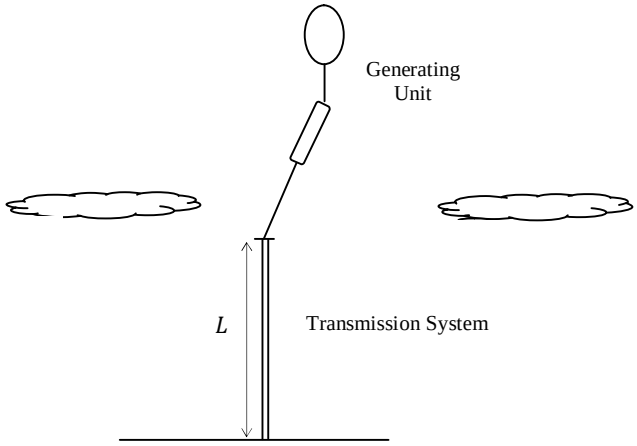


Fig. 7. Tower-lighter than air gas concept

**3-3- Wing concept-Tower concept**

Similarly, in this concept, the generated unit is tethered to tip of a long tower using the transmission system as seen in Fig. 8. The tower can reduce the length of the cable significantly. Such concept may not be economical since a high amount of structural material is required for construction of the tower.

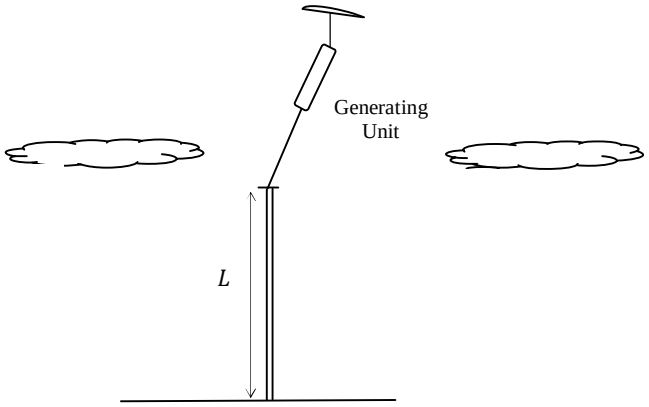


Fig. 8. High lifting wing-lighter than air gas concept

**3-4-lighter than air gas-wind concept-Tower concept**

Like two previous approaches, in this method, the generation unit will be tethered to tip of a, long tower. The generation unit extracts wind power based on the lighter than air-wing concept as seen in Fig. 9.

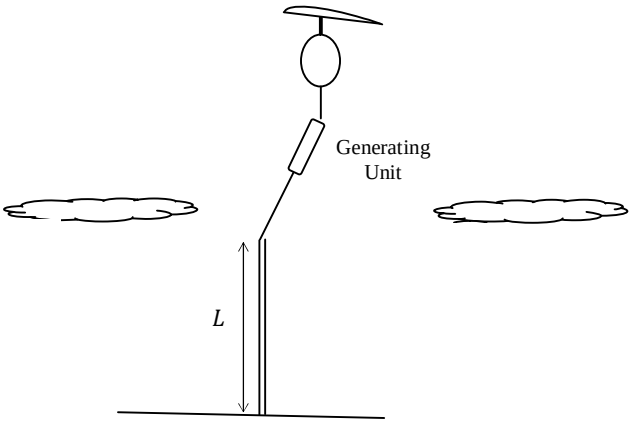


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Fig. 9. Lighter than air gas-wind concept-Tower concept

## CONCLUSION

In this paper an overview over all kinds of classification of airborne wind energy generation systems has been presented. Then, only one point of view has been chosen. Using the selected point of view, all types of airborne wind energy generation system has been classified and presented.

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