Design of a Model of Power Generation System using Kites

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Abstract— most people associate wind power only with conventional wind turbines, but research has led to a yet new source of renewable energy, kite power. Kite power has the potential to be more economical than using wind turbines because kites can fly higher than turbines can operate. At higher attitudes, wind speeds and available power are increased. In order to bring this new concept to a higher state of public awareness, a kite power demonstrator was considered ideal. The work here will include a way of adopting two kites to harness power by alternately changing their angle of attack. The kite angle of attack will be changed in such a way that the force in one of the kite will be higher which pull the power line to its side rotating the turbine. Then the angle of attack will be reversed so it gives a churning effect. Reducing friction proved to be a challenging task. Using of bearing V pulleys is of great advantage to reduce friction.

Key words: Frequent Pattern Mining, High Utility Itemset Mining, Transaction Database

I. INTRODUCTION

Since a couple of years the world is beginning to realize that there is an energy crisis. The second problem is that electrical power is not available at all places. Examples of this fact are the less industrialized African countries. Crosswind kite power systems (CWKPS) characterized by a kite system that has energy harvesting parts that fly transverse to the direction of the ambient wind, i.e.,to crosswind mode; sometimes the entire wing set and tether set is flown in crosswind mode. These systems at many scales from toy to power-grid-feeding sizes may be used as high altitude wind power (HAWP) devices or low-altitude wind power (LAWP) devices without having to use towers. Flexible wings or rigid wings may be used in the kite system. A tethered wing, flying in crosswind at many times wind speed, harvests wind power from an area that is many times exceeding the wing's own area. Crosswind kite power systems have some advantages over conventional wind turbines: access to more powerful and stable wind resource, high capacity factor, capability for deployment on and offshore at comparable costs, and no need for a tower. Additionally, the wings of the CWKPS may vary in aerodynamic efficiency; the movement of cross winding tethered wings is sometimes compared with the outer parts of conventional wind turbine blades. However, a conventional traverse-to-wind rotating blade set carried aloft in a kite-power system has the blade set cutting to crosswind and is a form of crosswind kite power. [1]

The idea is to generate power using kites linked together by lines forming a 'ladder'. By changing the AOA (Angle of Attack) one can change the lift coefficient of the kites; a large AOA will create more lift for the up going kites, and a small AOA will decrease the lift of the kites creating a circular motion of the ladder. In order to prove and show that it is possible to generate power using kites, the assignment was to design a small-scale demonstrator/toy. Using this small-scale demonstrator, it is possible to create public awareness for this new energy source. Also, when sold as a toy, the ladder mill project can be funded with its profit. In order to design a good prototype a lot of testing of different concepts has to be done. Most of the testing will be trial and error of varying concepts. Failures in concepts will mean going back to the basics and re-engineer the concept or discard it as a final option, leaving only one promising concept. This concept can then be further engineered to a final design for the prototype. [2]

II. LITERATURE SURVEY

High altitude winds are one of the largest untapped renewable resources in the world. High altitude winds are more consistent and average around twice the velocity, with five to eight times the power density, than those found near ground-level. In the U.S. alone, over 60% of potential wind sites for tower-mounted systems were found to be uneconomical. The advent of airborne wind technology holds the potential to bring affordable wind energy to these sites. [3]

The early 1800s witnessed George Pocock using control of kite system wings to crosswind to good effect. In early 1900s Paul Garber would produce high speed wings by two-line controls to give targets for aircraft gunners. Crosswind kite power was brought again into focus when Miles L. Lloyd carefully described the mathematics and potential of crosswind kite power in 1980. In 1980 it was not possible to create an economical automatic control system to control the wings of a kite system, though passive control of cross winding kite systems had been ancient.

With the advance of computational and sensory resources fine control of the wings of a kite system became not only affordable, but cheap. In the same time significant progress was made in the materials and wing construction techniques; new types of flexible kites with good L/D ratio have been invented. Synthetic materials suitable for the wing and tether became affordable; among those materials are UHMWPE, carbon fiber, PETE, and rip-stop nylon. Multiple companies and academic teams work on crosswind kite power. Most of the progress in the field has been achieved in the last 10 years. [4]

Currently wind power is experiencing an enormous boom. Although most people associate wind power with conventional wind turbines, airborne wind energy conversion on the basis of kites has a number of substantial advantages. Lightweight, mobile and flexible in application. Future kite power systems will be capable to exploit the almost unlimited potential of high-altitude wind. [5]

Kite Power is a cost-effective renewable energy solution with a low environmental footprint. The inflatable wing and the traction tether are made from strong but flexible lightweight materials. In contrast to conventional wind turbines, this tensile structure is not obstructing the view. It is an ideal basis for a highly mobile wind energy system. The heavy generator is positioned at ground level, which facilitates servicing and also minimizes structural forces. The direct force transmission into the ground station removes the need for bending-resistant foundations, which is particularly interesting for deep-water offshore deployment. The technology demonstrator of Delft University of Technology uses a tele-operated airborne unit for the flight control of the kite, which can access altitudes far beyond the limit of conventional wind turbines (200 m). Wind at these altitudes is stronger and steadier which increases capacity factors of the system to about 60%. Conventional wind turbines presently achieve values of 20-35%.[6]

Originally conceived by David Lang, research is being performed by Dr. Wubbo Ockels, a former ESA/NASA astronaut, at Delft University, Netherlands. A low tech approach to high altitude energy, this alternative envisions a stable kite with hard, steady pull. The kite is simply reeled out, then in, using a capstan connected to a generator. During the reel-out or power stroke, the kite is at a high angle of attack and pulls at maximum load. It is then depowered by lowering the angle of attack and reeled back. Power is harvested from the net energy gained during reel out, less than required to reel in. Electrical and mechanical components required are simple. The concept is scalable by increasing kite area and by stacking kites. It is considered to be the most likely to succeed of the many high altitude energy concepts that have been proposed due to its simple nature and higher technology readiness level. [7]

Kite gen concept uses a large number of computer-controlled kites to turn a large rotating structure connected to a central generator. Kites would fly at 800 to 2000 meter altitude. Analysis has shown potential to generate up to 1 GW per generator. This concept is currently being developed in Italy by Dr. Massimo Ippolito. Recent prototypes demonstrate sophisticated automatic kite control technology for single kites which will be required for the full-up multiple kite system.

The Magenn concept uses a lighter than air helium balloon that is shaped to act as a horizontal Savonius rotor. The generators are located on the balloon which limits their size. The design is mainly for local small-scale power production and is geared toward use in developing countries.

III. Methodology

The pull force given by the kite is harnessed here to run the generator.

- The tethers connected to the kite transmit the tension (force) to the rollers or gear system which will make the dynamo to run.
- The mechanism for power generation from "to and fro" motion will be adopted.
- Anemometer will be used to take the wind readings.
- There will be a control system adopted to control the kite i.e. engaging and disengaging.
- Two kites will be adopted here to pull it back instead of a motor so that more or less it will contribute a constant power output Main/power lines will be used to transmit pull and brake lines to control (engage or disengage) the kite during its operation.

The mechanism here is engaging one of the kites for the strongest pull and making it to power the generator as well as pull the disengaged kite. This cycle will be made to repeat for continuous power generation by switching the kites. The design here adopted is the improved version of the previous work. They faced the problems of friction and tangling of the ropes. There was even necessity to use brake for the control of towing line (to change AOA).

IV. Conceptual design

A. Kite

The kite used here is the Eddy Kite. It is known to be most stable kite for various types of winds. Though the power output of this kite is low, it is best for demonstration purpose.

B. Lines

There are two lines connecting the kite to the ground station i.e. power line and brake line. The power line is used for the transfer of power to generator. Brake line is used to control the kite, to change the AOA of kite.

Ground station

- Vertical Bar: It is the support for the towing lines of the kite, pulleys attached to it help in the reduction of friction by easing the motion of towing lines.
- Generator: It is unit which produces electrical energy from the mechanical rotation of it by power line.
- Brake line controller: it consists of a motor attached to a spindle of brake line rope. The motor either pulls or leaves the brake line to change the AOA.
- Switch board: It is the electrical circuit which is connecting the battery terminals to the brake line controller.
- Bottom Bearing: It is the roller bearing fitted to the vertical bar for its alignment according to the kite pull direction in order to avoid friction.

For construction reasons of the kites, the wind speed should not exceed 4Bft and has a minimum of 2Bft. At the top of 4Bft the kite will be too difficult to handle, e.g. the kites will become unstable and tend to dive in maximum AOA. This is most likely caused by the increase in force, causing the resultant force vector on the kite moving over its equilibrium, realizing a dive. At wind speeds of 3 to 4Bft nervous behavior (e.g. diverging oscillation) of the kites occurs. By adding a tail the system will be damped in such a way that the kites will oscillate converging or harmonically. This is a phenomenon of tail addition is most likely realized due to the dynamic change of inertia and aerodynamic forces. This was proven while testing a commercial Eddy kite.

C. Forces In Towing Lines

Here the AOA is assumed to be 45 deg. However, testing with an Eddy kite showed that a F max = 7.5N and a F min = 3.5N was realized at a wind speed of 4Bft. This can be justified due to the fact of varying wind speeds and a different CL value of the kites. The surface area of the kite used is 0.72m2.

V. OPERATION

- Initially both the kites are oriented at an angle approximately 45o to the horizontal. Equal wind force will be acting on both the kites hence there will not be any power generation since there is no churning action.
- To generate power we need to simultaneously engage and disengage the kites so that unequal wind force acts on the kites. The engaged kite will have more wind force acting on it and gets pulled away resulting in churning action of dynamo caused by the motion of the power line.
- Engaging and disengaging of a kite depends on its angle of attack (AOA).
- In order to change the AOA, of kite 1 we simply have to switch to position 1 on the switch .This activates motor 1 which pulls the brake line for kite 1
- which creates difference in length ratio between the brake line and power line, forcing the kite 1 to change its AOA.
- Simultaneously motor 2 will be rotating in the opposite direction releasing the brake line for kite 2. Now kite 2 will change its AOA to 45o and has more wind force acting on it.
- This causes the powerline to be pulled with kite 2 and due to this the dynamo is rotated, generating power.
- The dynamo has a pulley attached to it, and the power line rotates the pulley therefore the dynamo.
- The power generation is continued by alternatively engaging and disengaging the kites.

VI. ADVANTAGES AND DISADVANTAGES

- Simple in design.
- Higher wind energy per unit area at high altitudes.
- Higher winds are more stronger and steady compared with low altitude winds. This helps in giving higher capacity factor for power generation.
- Larger scope for its harnessing ability - Though many locations are unfit for wind turbines as there is no sufficient wind at ground level, but at higher altitudes winds are stronger which facilitates power generation
- Cheaper compared to conventional wind turbines.
- Less prone to corrosion.
- Power is lost due to friction of tethers.
- Cannot be used during rainy seasons.
- Falling of the kites will create problems.
- High turbulent wind can destroy the system.

VII. CONCLUSIONS

- During the time of testing, the wind speed varied from 8km/hr to 14km/hr
- The kites were flying without stability issues and we were successful in achieving the objective.
- The power output ranged from 0.3watt to 3 watt according to the variation in wind speed. The main issue for the low output of power compared to the theoretical was the loss due to friction. The loss is nearly 40% - 60%.
- The kites were stable during the changing of angle of attack.
- Maximum power is obtained when kite is at 45 deg orientation with the horizontal. At the time phase between the change of AOA from 0 - 45 deg power output reduced marginally.
- The use of bigger surface area and better kite will fetch more power than current kite.

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