Flying Electric Generator

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***Abstract:-*Flying electric generators (FEGs) are proposed to harness kinetic energy in the powerful , persistent high altitude winds. Average power density can be as high as 20 kW/m 2 in a approximately 1000 km wide band around latitude 30 ° in both Earth hemispheres. At 15,000 feet (4600 m) and above, tethered rotorcraft, with four or more rotors mounted on each unit, could give individual rated outputs of up to 40 MW. These aircraft would be highly controllable and could be flown in arrays, making them a large -scale source of reliable wind power. The aerodynamics, electrics, and control of these craft are described in detail, along with a description of the tether mechanics. A 240 kW craft has been designed to demonstrate the concept at altitude. It is anticipated that large -scale units would make lo w cost electricity available for grid supply, for hydrogen production, or for hydro -storage from large -scale generating facilities.**

Keywords:**-Wind power generation , Wind energy , Terrestrial atmosphere , Atmospheric measurements, Energy conversion, Power conversion**

I. INTRODUCTION

Two major jet streams, the Sub -Tropical Jet and the Polar Front Jet exist i n both Earth hemispheres. These enormous energy streams are formed by the combination of tropical region sunlight falling and Earth rotation. This wind resource is invariably available wherever the sun shines and the Earth rotates. These jet stream wind s offer an energy benefit between one and two orders of magnitude greater than equal - rotor -area, ground mounted wind turbines operating in the lowest regions of the Earth's boundary layer. In the USA, Caldeira and O'Doherty and Roberts have shown that average power densities of around 17 kW/m 2 are available. In Australia, Atkinson et al show that 19 kW /m 2 is achievable. These winds are available in northern India, China, Japan, Africa, the Mediterranean, and elsewhere. Various systems have been examined to capture this energy, and these include tethered balloons, tethered fixed -winged craft, tether climbing and descending kites , and rotorcraft. Our preferred option is a tethered rotorcraft, a variant of the gyroplane, where conventional rotors generate power and simultaneously produce sufficient lift to keep the system aloft. This arrangement, using a twin -rotor configuration, has been described and flown at low altitude by Roberts and Blackler. More recent developments have produced a quadruple rotor arrangement. Commercialization of the quad -rotor technology could significantly contribute to greenhouse gas reductions.Tetheredrotorcraft , with four or more rotors in each unit, could harness the powerful, persistent jet streams, and should be able to compete effectively with all other energy production methods. Generators at altitude also avoid community concern associated with ground-based wind turbine appearance and noise. Bird strike problem s are also less. However, tethered generators would need to be placed in dedicated airspace, which would restrict other aircraft. Arrays of tethered generators would not be flown near population centers unless and until operating experience assured the safety of such a configuration.

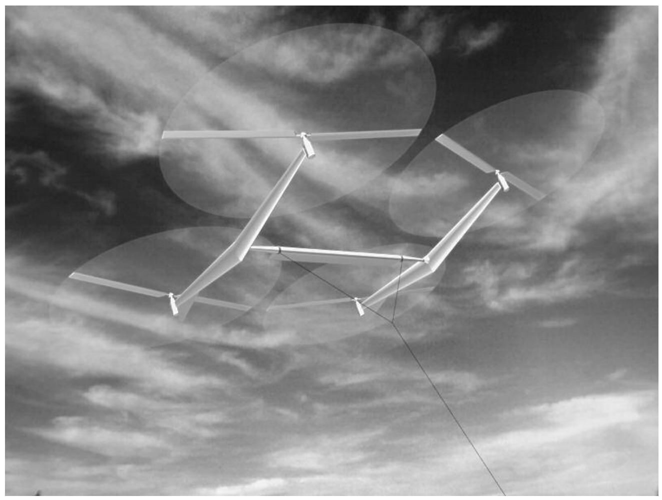

Fig. Rendering of Sky WindPower Corp.'s planned 240 kW, four-rotor demonstration craft.

II. DESCRIPTION OF THE PREFERRED ENERGY CONVERSION SYSTEM :

The currently proposed new tethered craft consists of fouridentical rotors mounted in an airframe which flies in the powerful and persistent winds. The tether's insulated aluminium conductors bring power to ground, and are wound
with strong Kevlar-family cords. The conductor weight is a
critical compromise between power loss and heat generation.
We propose employing aluminium conductors with tether transmission voltages of 15 kV and higher, because they are
light weight for the energy transmitted. To minimize total

perkWh system cost and reduce tether costs, the design allows higher per meter losses and higher conductor heating than does traditional utility power transmission. Depending on flight altitude, electrical losses between the tether and the converted power's insertion into the commercial grid are expected to be as much as 20%, and are included in energy cost estimates described in Section IX.The flying electric generator units (FEGs) envisioned for commercial power production have a rated capacity in the 3 to 30 MW range. Generators arrays are contemplated for wind farms in airspace restricted from commercial and privateaircraft use. To supply all U.S. energy needs, airspace for power generation is calculated to restrict far less airspace than is already restricted from civil aviation for other purposes. While similar in concept to current wind farms, in most cases flying generator arrays may be located much closer to demand load centers.In this particular four rotor assembly, craft attitude in pitch, roll, and yaw can be controlled by collective rotor pitch change. No cyclic pitch control is needed to modify the blades pitch as they rotate, as is needed in helicopter technology. This should help reduce maintenance costs. Rotor collective pitch variation then varies the thrust developed by each rotor in the format described below using GPS/Gyro supplied error signal data.

III. FLYING GENERATORS AERODYNAMIC PERFORMANCE :

The flying generator's side view in Fig. 3 is for a typical flight configuration in a wind of velocity V. A single tether of length Lc is attached to the craft at a point A on the craft's plane of symmetry. The aircraft's center of mass is at C. The tether is assumed, herein for simplicity, to be mass-less and non-extendible. For low altitude flight, around 1500 ft (< 500 m), theassumption of a straight, mass-less tether is reasonable. However, for higher altitudes, the analysis has been extended to included tether mass and tether air-loads. Roberts and Blackler and Roberts and Shepard have shown that higher altitudes are achievable using an aluminium-Kevlar composite or an aluminum-Spectra composite for the electro-mechanical tethering cable.

IV.CURRENT HIGH ALTITUDE WIND ENERGY CONCEPTS:

A)The "Pumping" Laddermill or Kite Reel :

Originally conceived by David Lang,research is being performed by Dr. WubboOckels, 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 reeledback. 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 bystacking kites. It is considered to be the mostlikely to succeed of the many high altitudeenergy concepts that have been proposed due to its simple nature and higher technology.

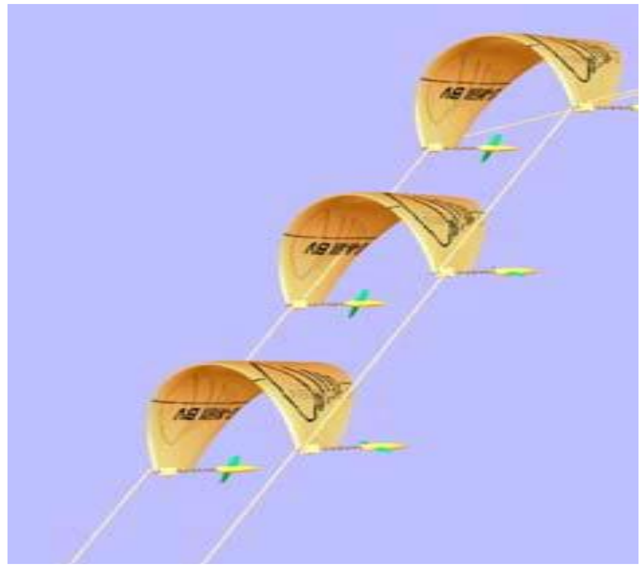

Fig. Laddermill

B) KiteGen :

This 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.

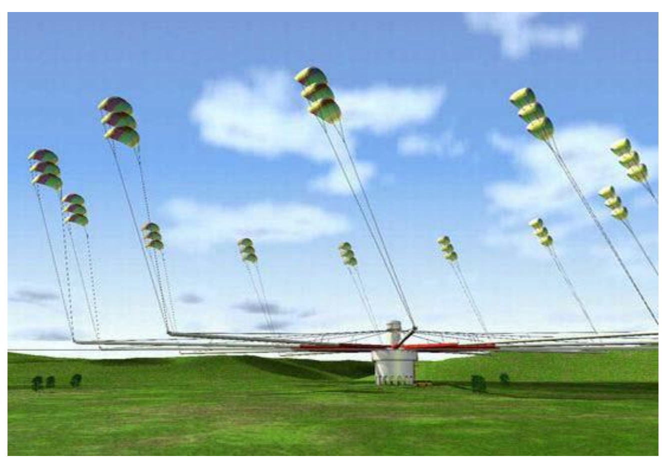

Fig. Kitegen

C) Magenn :

The Magenn concept uses a lighterthan- 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.

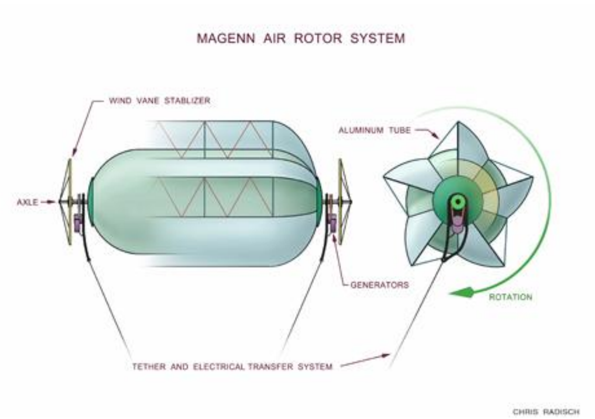

Fig. Magenn

V.ELECTRICAL SYSTEM DETAILS

Flying electric generators need to ascend and remain aloftfor short periods on grid-sourced energy. In low-wind conditions, only a small proportion of output rating as gridsourced energy is required to raise or maintain the craft aloft. Voltages at the terminals of both the generator/motor and at the grid interface need to be kept within designed tolerances and/or be adjusted by timely voltage regulation.

In a national regulated electricity market, such as that found in Europe and elsewhere, a System Impact Study (SIS) is required to connect a new generator to the grid if the generator's capacity is above a minimum level, e.g. 5 MW. Even non-dispatchable "embedded generators"require Grid System Impact Assessments. The generator proponent usually pays for the generator-to-grid network connection. Land and sea locations for generation from renewable energy sources, especially wind energy, are often remote from the existing grid, hence, connection costs are often 50% of the total investment for new generating capacity. Also where a renewable energy source generator is not n-1 reliable for availability, the Network Connection Contracts usually include the costs of back-up supply contingencies. These relate to network charges when the renewable generator is not supplying.

Flight control using gps –

Very accurate control is needed to precisely maintain a desired position in the sky. GPS with gyroscopes is an ideal way to provide the reference data necessary to provide this control.

The Global Positioning System (GPS) consists of a constellation of 24 satellites that provide a continuous navigation capability to users at any location on (or near) Earth in all weather conditions. With this system, currently operating with 29 satellites, real-time, three dimensional position information with accuracies on the order of 5-10 m can be achieved. Main error sources for the system include signal propagation effects through the atmosphere, satellite orbit and timing errors, and GPS receiver noise and signal reflection(multipath). When used in differential mode, where measurement corrections are computed at a GPS reference station sited on a known location, accuracies can be improved quite easily to within a few meters (DGPS).

VI. ADVANTAGES OF FLYING ELECTRIC GENERATOR :

1.Higher wind energy per unit area –

This is mainly due to the higher wind velocities available at high altitudes. As wind power is a function of velocity cubed, the higher velocities result in a much higher wind energy density. Available wind energy density at 10000 meters altitude can be 2 orders of magnitude higher thanthose at the current average turbine height of 50 meters.

2.Higher capacity factor-

Due to the planetary boundary layer, surface winds are turbulent, intermittent, and slow. These properties of low altitude winds pose major problems in the design of ground based wind turbines. Wind velocity intermittency and limited wind velocity operating range due to structural constraints for tower mounted wind turbines result in low capacity factors (average power output / rated power output) and unpredictable power supply to the grid, drawing into question the penetration capability of wind power. Some experts believe wind power market penetration can never exceed more than 20% of the overall electrical power supply (currently it is at 1%). High altitude winds are both strong and steady with much less turbulence and daytime to nighttime velocity variability. Several studies have shown that capacity factors for high altitude winds systems would most likely be in the 70-80% range vs. 20-30% for ground based wind turbines.

3.Lower cost –

Kites, being a simple tensile membrane structure with a tether, have thepossibility of drastically reducing the capital expenditure for wind power systems.Generator costs would be comparable to wind turbine generators, but weight constraints and maintainability are much improved for the kite/tether generator because it is mounted at ground level. Current best estimates for this type of system project a life cycle cost at 0.5 to 1.5 cents per kilowatt hour compared to current costs of 5 to 12 cents per kilowatt hour.

4. Siting –
Current wind power statistics at 50 meters altitude show that only a fraction of the land area of the United States is suitable for large scale wind farming. Most of these regions are in western states which are far from populated areas or are offshore. However, the subtropical jet stream which typically is found between latitudes of 30 to 50 degrees north covers large portions of the northern region of the U.S. including the densely populated areas of the Midwest and Northeast .

VII. CONCLUSION :

It has been shown that flying electric generators can harness the powerful and persistent winds aloft to supply electricity for grid connection, for hydrogen production or for hydro-storage. Globally, upper atmospheric winds provide an enormous resource for this application. The environmental impacts at altitude are minimal with virtually no visual, or noise intrusionand no bird strikes. The proposed systems lead logically to rural/remote area installations in regions of restricted airspace.High altitude wind power is not science fiction. It depends on currently available technologies and engineering knowhow, building on decades of experience with wind turbine and gyroplane technologies. Harnessing high altitude wind energy, using a combination of essentially existing technologies, appears to be thoroughly practical and suggests that this energy source can play an important part in addressing the world's energy and global warming problems.

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