Aerostatic Way of Harvesting High Altitude Wind Energy

S Rajasekhar, G R S naga Kumar, Pravallika, Anjana Kumari

Abstract*: Renewable energy system in electrical power generation is one of important field of electrical engineering due to its source is natural, reusable and environmental pollution free and cost free. There are renewable energies such as wind, solar and so on. The wind is a free, clean, and inexhaustible energy source. It has served mankind well for many centuries by propelling ships and driving wind turbines to pump water. It has become one of the most attractive energy system in several decades due to rich availability. The important proposed contribution in this work is to enhance the efficiency of renewable energy using AEROSTATIC WAY OF HARVESTING WIND ENERGY that allows turbines to capture as much as possible wind by increase in the altitude at which is the turbine is placed. Which is done by attaching the turbine to aerostat and the aim of the study is to extract maximum energy of the turbine and transmit it to grid, storage device with suitable converters and controllers.

Keywords*: High altitude wind control (HAWC), Power electronic converter (PEC), and cost of power (COE).

I. INTRODUCTION

With increase in population and industrialization, the generation of power was really a challenge today. The overall power generated in INDIA is about 65% from non-renewable sources such as coal, natural gas and petroleum. Only 20% is from nuclear sources. The other 15% is generated from renewable sources like wind, solar, hydro[1]. The conventional ways of generating power should be improved in order to escape the power crises. Solar harvesting can only be done during day time. And hydro methods are during periods of time only. But wind energy can be extracted at any place any time. More efficient ways are to be developed to improve wind harvesting techniques. Wind is air in motion and it derives energy from solar radiation[2]. About 2% of the total solar flux that reaches the earth's surface is transformed into wind energy due to uneven heating of the atmosphere. During daytime, the air over the land mass heats up faster than the air over the oceans. Hot air expands and rises while cool air from oceans rushes to fill the space, creating local winds. At night the process is reversed as the air cools more rapidly over land than water over off-shore land, causing breeze, on a global scale low pressure exists near the equator due to greater heating, causing winds to blow from subtropical belts towards the equatorial air masses to the upper atmosphere, causing deflection of winds.

The common wind power generation uses low altitude and high mechanical arrangements. This not only increasees the cost of installing but also reduced the ability of production. The base of the pole and turbine have large surface area restricting them to only some coastal areas and away from human life. The common production involves high ecological effects. Usually, power generation capacity on normal or convention methods can be increased by increasing swept are of the rotor. From 1980 the size of the rotor is increased from 9 to 140m in diameter and generation capacity has increased from 25kw to 10mw [1]. As the rotor size increases the holding tower size need to be increased to absorb high jerking of the wind and torque. For a 1000 kw generating system the diameter of the rotor is 60m, rotor weigh 20 000kg, nacelle weight 36000kg and height of the hub is from 56 to 63m. This large construction and conventional wind energy generation system uses heavy turbine which drives an electrical generation with or without gear box arrangement using suitable (PEC) power electronic converters.

The generated power can be increased by increase in rotor diameter or by increasing the altitude. If the rotor diameter is increased the base of the tower and as well as size of the turbine are to be increased[3]. As the surface area of the turbine increases the production increases making it more difficult and very costly for installing. The other way is by increasing the altitude. The altitude of the system can be increased by reducing the weight of the system and connecting it to a aerostat. Suitable (PEC) are used in order to convert energy at generating station and as well as distributing station. The speed at which winds are blown are very high at high altitude. The rate of increase of speed of wind is directly proportional to increase in altitude[4]. At high altitude if the speed of wind is high then the speed at which the rotation is also high producing high torque than normal conventional turbines. So we propose that high amount of energy can be extracted from the wind by increasing the altitude using a balloon or aerostat device.

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Relation between wind speed and altitude The helix is taken to the air by means of an air ship. The airship is made of high tensile strength material that can hold gas at high pressures[5]. The balloon is filled with gas that is lighter than air i.e. Hydrogen or helium. The mass of the both gases is very less compared to air, hydrogen is highly inflammable.
Thus helium is used instead of its high cost for the safety reasons[6]. For 1m3 of hydrogen 1kg of weight can be lifted. This involve weight of balloon, weight of grimmer and payloads. The amount of gas to be filled in balloon is given by

$$v_g = \left[\frac{v_e p_a g - m_e g - m_a}{\frac{a+g}{p} - \frac{p_a}{pg} g}\right]$$

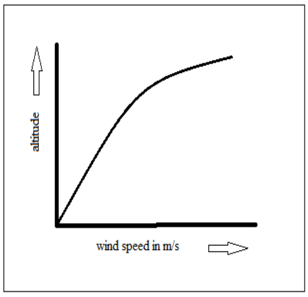

Fig1.1 shows the relation between wind speed and altitude Relation between energy produced and speed of the wind

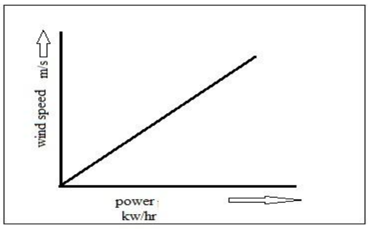

Fig 1.2 shows the relation between energy produced and wind speed

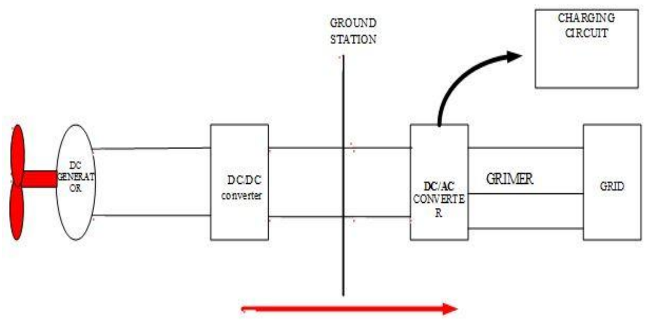

Fig 1.3 Block diagram

The high altitude wind power extraction is done as shown in fig (1.3). The energy is first generated at the helix or generating station. As, the proposed system is a DC system, the boost circuit is present at the generation side[7]. The generated power is transferred to ground by a connecting system called theatre (or) grimmer. The power thus generated and transmitted will be received at the ground station by a rectifying circuit at the ground state. The energy will be used to store in a battery (or) is sent to the grid circuit.

II. CONVERTER TOPOLOGY

As the generator used in the construction is a DC generator (PMG). The generated voltage needs to be converted into medium level DC voltage the airborne PEC is designed to convert low voltage DC to medium voltage DC. The aerostat has an advantage of making the system to work in only one direction so, there is no need of bidirectional power flow [12-17].

Generating side rectification:

At the generation side the power generated is transmitted by means of a boost converter, by which the power generated will be transmitted at high level, due to capacitance, and resistivity the generated power obtained at the ground station is very low. So to reduce this and boost PEC is introduced at the generating side. This boosts the generated voltage, and transmits to the ground station. For an AC generator, the generated power is converted from AC to DC by means of a converting device (or) arrangement. The convert different levels of voltage. The converter arrangement at generation is made using power electronic devices. The generated voltage is dc voltage can be transmitted directly through conductors, to base station (or) ground station by means of PEC. The generated voltage is to be stored in a storing device (or) cell circuit. But the generated voltage is transmitted by a diode rectifying circuit for any fluctuations [18-25]. The single way electronic device only transmits dc power by filtering all other wastes from the supply and supplied to ground. Then the stored energy is utilized by using an inverter for an AC devices and for dc by using a controlled circuit.

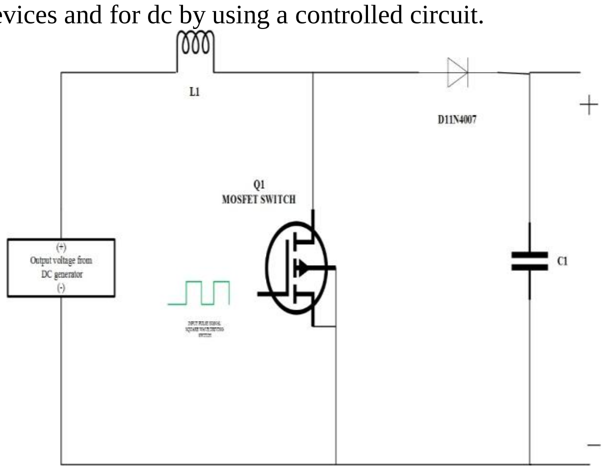

Fig 1.4 representing boost converter

The generated voltage is stored using the above mentioned circuit

Boost converter output equation:-

$$Vout = \frac{Vout - Vin + Vd}{Vout + Vd - Vtrans} \quad (2)$$

Duty ratio:-

$$D = \frac{Vout - Vin + Vd}{Vout + Vd - Vtrans} \quad (3)$$

Voltage drop:-

$$Vout = \frac{Vin}{1 - D} \quad (4)$$

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Ground station or base station rectification:

Here the output is DC so the power is converter to AC then we get AC output waveform. From the DC, There are two types of categories they are Current source inverters and voltage source inverters. The Current source inverters control the ac output current waveforms and voltage source inverter control the ac output voltage waveforms. In single phase and three phase applications we use voltage source inverters. To produce Ac output current from DC current supply we use current source inverters. For high quality voltage waveforms in three phase applications we use current source inverters. This inverter output is given to transmission line and here due to capacitor there are some losses [26-32]. This is connected to transformer which step up or step down the voltage. Transformer works on the Faraday's principle. In transformer there are two coils they are primary coil and secondary coil. And connect this transformer to grid and on grid side the power is observed.

Charging circuit:-

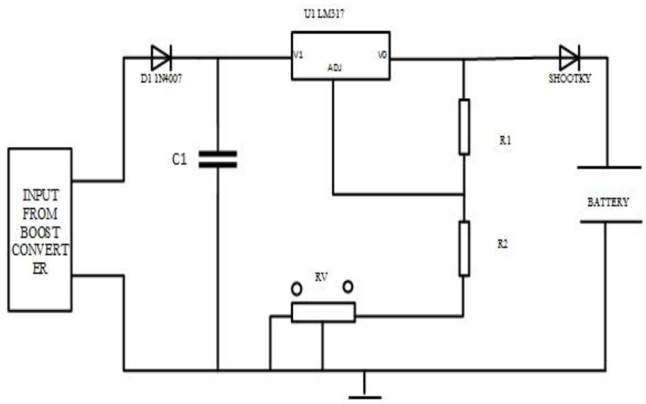

Fig 1.5 charging circuit

The energy that is produced is used to charge a battery of 5v-16v, as the out of the dc generator is small. The circuit is designed to charge the battery under non stable output voltages. As the generated voltage is not stable because of the speed of the wind is not stable

III. DESIGN OF HARDWARE

Fig 1.6 air borne wind turbine

This project requires a stable structure to bear the pressure in air and as well as should be less in weight as the weight of the structure(helix) increases, the amount of volume of gas required to take the helix increases. To main the structure at a steady state we have to go for an grad rant structure which contains four legs and two wings like structures called small blimps. These blimps help the lift and drag of the air onto the turbines. The turbine carrying structure is designed by four beams of identical size.

Two beams of rods are made to form an "L" shaped structure and two of them are made to make a window structure. The arrangement is made to sit the generator in between the window structure. The window is balanced by adding balancing rods on the four sides of the window structure. The size of the balancing rods is identical to each other.

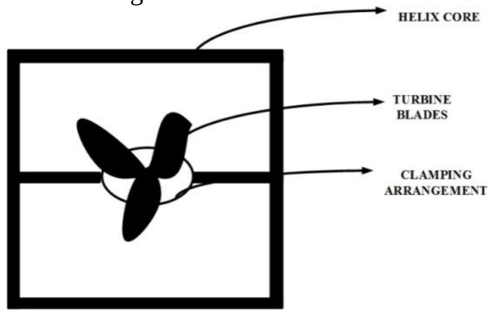

Fig.1.7 showing the structure of helix

Connecting helix to balloon (or) aerostat:

The helix hangs in air with the help of a balloon carrying hydrogen. The volume of hydrogen is directly proportional to weight it can lift. The helix and balloons are attached to each other by using strings and bearings arrangement. The bearing arrangement in between helix and balloon acts as a system which only transfer the kinetic motion of balloon to helix but not the direction. The direction of the balloon is irrespective of the helix. The lift and drag forces acting on balloon and helix can be reduced by using Bernoulli's principles of aerodynamics.

The buoyance force that the balloon exert is given by

$$f = v_a g(\rho_{a-}\rho_g) \qquad (5)$$

Where, VA is volume of the blimp,ρ_a is density of air,ρ_g is density of filled gas.

Thus for 1m3 of hydrogen gas it can lift up to 1kg mass. This includes the weight of the balloon gas itself and mechanical/electrical payloads.

Grimmer core (or) theater:

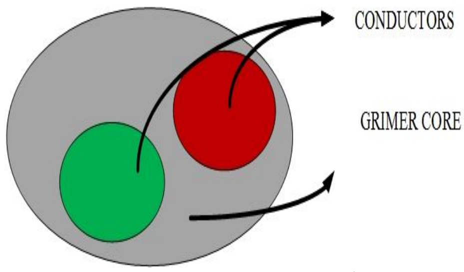

Fig 1.8 showing internal section of theater

The generated voltage is transferred to the ground by a structure containing. The resistance offered by both the conductors is (or) transmission line is given as 4.2ohms. Whereas the transmission drop is given by multiple of square of current and resistance.

1. Two conductors and
2. One Grimmer

The conductors are made of "AL" conducting material they are insulated from each other the weight of the conductors also acts on the weight lifted by the balloon. The weight of the positive conductor and negative conductor and weight of the grimmer.

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Table.1 representing weight of materials intheater

s.no	Name of conductor	Weight
1	+ve conductor	4.18kg
2	-ve condutor	4.18kg
3	Theater	16kg

The grimmer not only helps the structure to stay balanced in air but also to connect it to the ground, so the grimmer should be so strong and does not affect the conduction of the system. The helix can only brought down by using this grimmer so a strong material should be used to tie the helix to the ground.

$$r = \sqrt{\frac{pl}{(1-\omega)\sigma_c \pi v^2}} \quad (5)$$

Overall weight of the conductor depends on the weight of the dielectric and grimmer cable.

$$w_{cab} = p_{con} r_c^2 \pi l + p_{di} \pi r_c^2 t_{ins} \quad (6)$$

Arranging the turbine and generator into the helix:
The generator is placed in the helix, in between the clamps that are arranged for the generator to be placed. The clamps hold the generator tight, so that it will not be displaced during the generation which considering the system weight, There are two masses present in the system. The first mass is the generator and the second mass is the turbine. The weight of the turbine should be counter weighing the weight of the generator.

Power extraction from the turbine:
The power extracted from the turbine depends on the velocity of the wind, and as well as on the surface area (or) swept area of the turbine.

$$p = 1/2 \rho C_p A_t v^3 \quad (7)$$

Where c_p is the coefficient of power extraction from turbine, A_t is the swept area of the rotor in m^2.

Connecting to the grid:

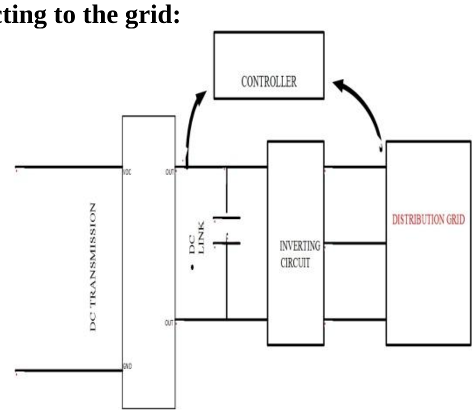

Fig 1.9 representing the whole system connecting to grid.

The system connecting to grid is shown in the above fig 1.8, the dc power is transmitted to the dc link by means of a controller. Then an inverting circuit inverts the dc signal into an AC signal. The inverted signal is given to the connecting grid. Here the output dc signal is inverted by using any of the phase converters

IV. Output and Results

In frequent sampling and testing the output voltages vary from time to time and speed of the wind as well. The output voltages that are given by the generator are boosted by a boost converter. The converted voltages are stored in a n battery or storage device by using an charging circuit for frequent intervals of time reading have been taken. The output graph denote the voltage at generator. Voltage after boosting, and voltage at the charging circuit, and voltage at grid. The output can be observed after the rated voltage

Plot showing curve between Generated voltage and boosted voltage:

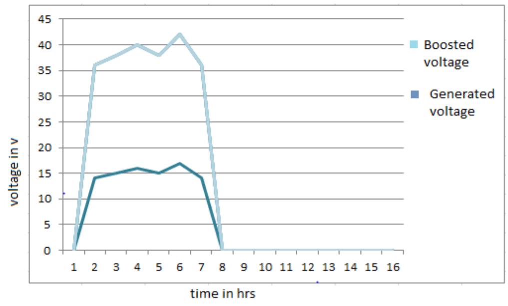

Fig 1.10 shows the relation between the generated voltage and boosted voltage in v along with time

Curve between generated current and time:

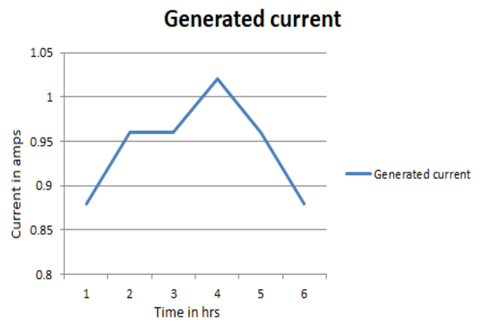

Fig 1.11 shows the current in Amps at load

Curve between generated voltage and Rpm

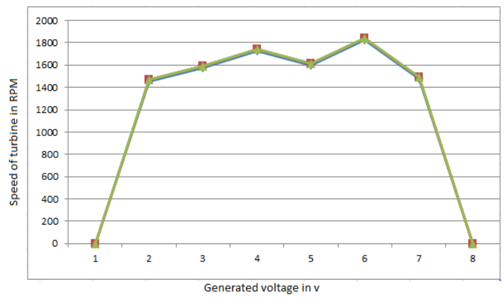

Fig 1.12 shows the relation between generated voltage in v and speed of turbine in Rpm

From the above curves the output of the system, gives an efficiency of 53%, which is greater than the normal or traditional way of wind harvesting. The mechanical factors are reduced. With low gearing and high altitude using aerostat we can produce large amount of power

V. Conclusion

From all the practical results, the plots indicate that generated voltage is directly affected by the change in swept area, wind speed, and as well as altitude. This project clearly presents an idea of air borne system being more efficient than normal system.

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By using proper generating units and converting units more power can be produced as well as transmitted to distribution system. Comparing with common wind power harvesting, high altitude harvesting is more efficient. The generating units produce power only if the wind comes at the direction at which turbines can catch the air, by additional equipment like position controlling and direction controlling more power can be produced. Specialized converters are to be used to increase the efficiency, of the transmission. Specialized structure should be developed to increase the air flow onto the turbine.

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