IOSR Journal of Engineering (IOSR JEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
PP 64-69

High Altitude Wind Power Generation

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Abstract:*The concept of High Altitude Wind Power (HAWP) is to supply clean energy at low cost and high capacity factor than the Conventional Wind Power (CWP) system. This is one of the new technologies deployed for harvesting high altitude wind power using airborne wind turbine - cum electric generator supported by light gas filled blimp/aerostat has been proposed in the project. An airborne wind turbine at high altitude extracts kinetic energy from the high speed streamlined wind using buoyancy provided by the blimp. Using a suitable power electronic converter (PEC), harvested electrical power is transmitted to the ground by using a tether. A Blimp is tethered to the ground and provides mechanical strength to hold the blimp and the same tether consisting of an electrical conductor is used for transmitting the generated power. In addition, a comparative study between conventional wind energy harvesting system and high altitude wind energy harvesting system shows that high altitude wind power is better in terms of capacity factor, Cost of Electricity (COE), ease of construction and power density than conventional wind power generating system.*

Keywords:*Airborne Wind Turbine - cum Electric Generator, Blimp, Conventional Wind Power (CWP), High Altitude Wind Power (HAWP), Power Density.*

I. Introduction

Sun oriented and Wind have developed as two noteworthy wellsprings of sustainable power source in the last two decades[1]. Sun oriented power creating framework has a lower control thickness (150-250 W=m2) when contrasted with the power thickness of customary warm power producing framework (1000-1200 W=m2). Though, a regular breeze control (CWP) creating framework requires immense common developments and experiences low limit factor (30-35%) [2] (Capacity factor is characterized as the proportion of real yield vitality over some stretch of time to potential yield vitality, in the event that it were feasible for it to work at the appraised power inconclusively) [3]. Because of these reasons, the infiltration of sustainable power sources has not fundamentally expanded in present power advertise [1]. In any case, genuine capability of wind power could be extricated utilizing high elevation wind. The speed of wind increments in the height from the beginning was communicated in the condition 1.1(a). What's more at higher elevations, the breeze stream is streamlined and steady in nature. Since the breeze control is relative to the 3D shape of the breeze speed and specifically corresponding to turbine zone AT, as referenced in condition 1.1(a), a lot of electrical power can be removed with diminished turbine measure.

$$P_{air} = \frac{1}{2}\rho C_P A_T v^3$$

$$v(h) = v_0 \left[\frac{ln(\frac{h}{z_0})}{ln(\frac{h_0}{z_0})}\right]$$

Equation (1)

Pair is appraised intensity of HAWP creating framework, AT is cleared territory of rotor sharp edge in m2, 0 is the known speed of wind in m=s at earth surface, (h) is the speed of wind in m=s at a height h in m above ocean level, 0 is the realized breeze speed in m=s at a known elevation h0 above ocean level in m, CP is the coefficient of intensity extraction by the turbine, and z0 is the Hellman's coefficient of the surface that relies upon the landscape.

Power created by the breeze turbine is a component of intensity coefficient (greatest estimation of 59.3%), turbine cleared region AT and wind speed v. To expand the produced power in the event of traditional breeze vitality age, cleared zone of the turbine can be expanded by expanding the distance across of turbine rotor. Interestingly, speed of wind increments with elevation over the earth surface as communicated in condition 1.1 (a). Speed of wind achieves limit of about 50m/s at an elevation of 9-10km above ocean level. Since wind control is directly corresponding to turbine cleared zone and relative to cubic capacity to speed of wind, cleared region of rotor can be essentially diminished to produce meet measure of intensity with slight increment in the breeze speed. Interestingly, speed of wind increments with elevation over the earth surface as communicated in condition 1.1(a). Speed of wind achieves limit of about 50m/s at an elevation of 9-10km above ocean level. Since wind control is sprightly corresponding to turbine cleared territory and relative to cubic capacity to speed of wind, cleared region of rotor can be altogether decreased to produce level with measure of intensity with slight increment in the breeze speed.

II. Problem Definition

Wind control should in any case contend with traditional age sources on a cost premise. Contingent upon how lively a breeze site is, the breeze ranch probably won't be cost focused. Despite the fact that the expense of wind control has diminished drastically in the previous 10 years, the innovation requires a higher beginning speculation than fossil-energized generators. Great breeze locales are frequently situated in remote areas, a long way from urban communities where the power is required. Transmission lines must be worked to bring the power from the breeze homestead to the city. In any case, fabricating only a couple of as of now proposed transmission lines could altogether diminish the expenses of growing breeze vitality. Wind asset improvement probably won't be the most beneficial utilization of the land. Land appropriate for wind-turbine establishment must rival elective uses for the land, which may be more profoundly esteemed than power age. Turbines may cause clamour and stylish contamination. In spite of the fact that breeze control plants have moderately little effect on the earth contrasted with ordinary power plants, concern exists over the clamour created by the turbine sharp edges and visual effects to the scene. Turbine cutting edges could harm nearby untamed life. Feathered creatures have been murdered by flying into turning turbine edges. The vast majority of these issues have been settled or incredibly diminished through mechanical advancement or by appropriately siting breeze plants.

III. Block Diagram

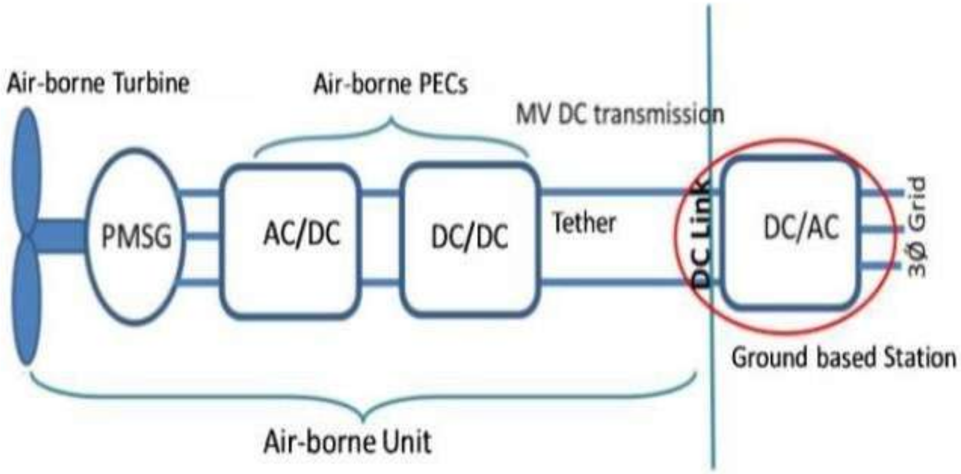

Fig. 1 Block Diagram of HAWPP

1.1 Air – Borne Turbine :

An airborne breeze turbine is a plan idea for a breeze turbine with a rotor bolstered noticeable all around without a tower,[5] in this manner profiting by progressively mechanical and streamlined alternatives, the higher speed and ingenuity of wind at high heights, while maintaining a strategic distance from the cost of pinnacle construction,[6] or the requirement for slip rings or yaw system. An electrical generator might be on the ground or airborne. Difficulties incorporate securely suspending and keeping up turbines many meters off the ground in high breezes and tempests, exchanging the gathered and additionally produced power back to earth, and impedance with aviation.[7].Airborne wind turbines may work in low or high elevations; they are a piece of a more extensive class of Airborne Wind Energy Systems (AWES) tended to by high-height wind power and crosswind kite control. At the point when the generator is on the ground,[8] then the fastened air ship need not convey the generator mass or have a conductive tie. At the point when the generator is high up, at that point a conductive tie would be utilized to transmit vitality to the ground or utilized on high or shot to recipients utilizing microwave or laser. Kites and helicopters descend when there is deficient breeze, kytoons and zeppelins may resolve the issue with different impediments.

Additionally, awful climate, for example, lightning or rainstorms, could briefly suspend utilization of the machines, likely expecting them to be conveyed down to the ground and secured. A few plans require a long power link and, if the turbine is sufficiently high, a precluded airspace zone. Starting at July 2015, no business airborne breeze turbines are in customary task.

1.2 Air – Borne Power Electronics Converter :

Permanent magnet synchronous generator (PMSG) gives better capacity to weight proportion in HAWPcreating framework [11]. The created AC voltage should be changed over into ideal medium voltage DCfor effectivetransmission. Along these lines, the power electronic converter is intended to change over low voltage

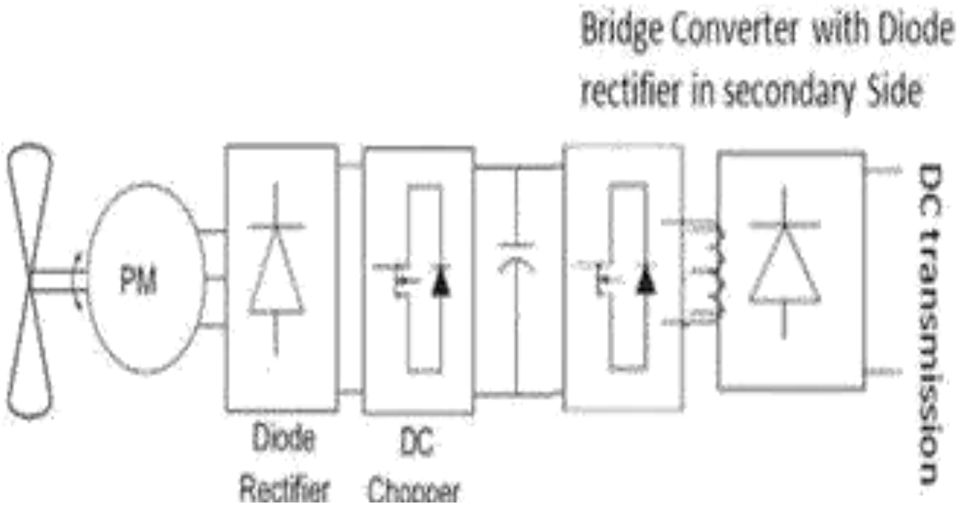

Figure 2 Block Diagram of Power Electronics Converter

AC to medium voltage DC proficiently. Flying electric generator bolstered by a zeppelin has an electric machine that works in age mode just, so the bidirectional power stream isn't a prerequisite. The proposed power electronic converter for gathering HAWP comprises of diode connect rectifier, DC chopper at the generator side and full scaffold confined DCDC converter in the transmission side appeared in Fig. Since the transmission voltage is high, diodes are associated in arrangement the auxiliary side of confined DC-DC converter. Lift chopper is utilized here for extricating the most extreme power from the given breeze condition, controlling the power factor at the age side (for single stage AC control age) and keeping up a steady DC interface voltage for DC-DC converter, that permits consistent obligation cycle exchanging of DCDC converter.

Three stage rectifier gives amended yield to a DC chopper which is controlled utilizing inductor current control. DC chopper can't make solidarity control factor at age side for three stage age however diode rectifier yield current is controlled to get greatest power from the given breeze condition and furthermore keeps up steady DC interface voltage at determined reference esteem. Detached DC-DC converter is utilized to venture up steady DC interface voltage to ideal medium voltage DC as determined in before subsection. Yield voltage for DC transmission as a component of HF transformer turns proportion is communicated in condition beneath.

$V_o = nV_{dc} D_{eff}$ ation (2)

Where Vdc is DC connect voltage, n is transformer turns proportion and Deff is powerful obligation cycle on square wave beat. Ventured up DC voltage is transmitted through an electromechanical tie to the ground based power station and the ground based power station changes the high height wind capacity to an appropriate structure.

1.3 Tether : Tether utilized for reaping HAWP has two essential targets:

1) To hold the airship at a given elevation.

2) Transmit the power effectively to the ground based station.

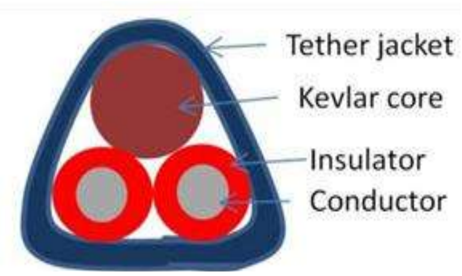

Figure 3 Tether Conductor used for transmitting power

Fig demonstrates the proposed tie for reaping HAWP. The tie ought to have adequate rigidity and adaptability to help the air-borne unit. It is furthermore used to drag the air-borne unit to the ground based station. Tie should offer least protection from the electric flow coursing through it to limit the general transmission misfortune. Furthermore, it ought to be physically impervious to radiation, dampness and other barometrical contamination. Real segment of the heaviness of an air-borne unit in HAWP framework is contributed by tie. In this way, the heaviness of tie ought to be limited without trading off the transmission proficiency. DC transmission gives preferable capacity to weight proportion over AC transmission and requires no pay. In this way, DC transmission is constantly favored over AC transmission for reaping high height wind control [11]. So as to diminish the conductor weight, the transmission voltage is expanded, yet additional augmentation in transmission voltage may prompt increment in load because of the expanded thickness of protection layer. Thus, ideal transmission voltage should be resolved to get the base weighted tie. Condition underneath gives the connection of transmission voltage and channel range and condition gives the connection between transmission voltage and the thickness of dielectric

$$r_c = \sqrt{\frac{P_{rated} L}{(1-n)\sigma_c \pi V^2}}$$

$$t_{ins} = r_c \exp[\frac{2V}{S r_e}] - r_e$$

Equation (3)

where $r_c$is conductor radius, P is power level of transmission system, L is length of tether, n is opted transmission efficiency, $_c$ is conductivity of the conductor and V is transmission volt-age level, t_{ins} is thickness of insulating layer, S is dielectric strength of insulator.Overall weight of a cable depends on the weight of conductor and weight of dielectric used for insulator. Equation 3 gives the weight of cable inside the tether as the function of transmission voltage.

$$W_{cab} = \rho_{con} \pi r_c^2 L + \rho_{di} \pi L t_{ins} (2r_c + t_{ins})$$

Equation (4)

Where $W_{cab}$is the weight of a single cable, t_{ins} is the thickness of insulator, $_{con}$ and $_{in}$ are the density of conductor and insulator respectively.

IV. Results

This paper discusses the simple concept of extracting wind power through high altitude turbines. This is a new concept and for the same we have designed a Doubly Fed Induction Generator (DFIG) which has certain advantages over other types / conventional turbine types. DFIG has low power to weight ratio and hence can be used at higher altitudes. Designing a DFIG / Generator is the most important part in HAWPP . The results obtained from the MATLAB simulation is shown below which are considered optimum for HAWPP.

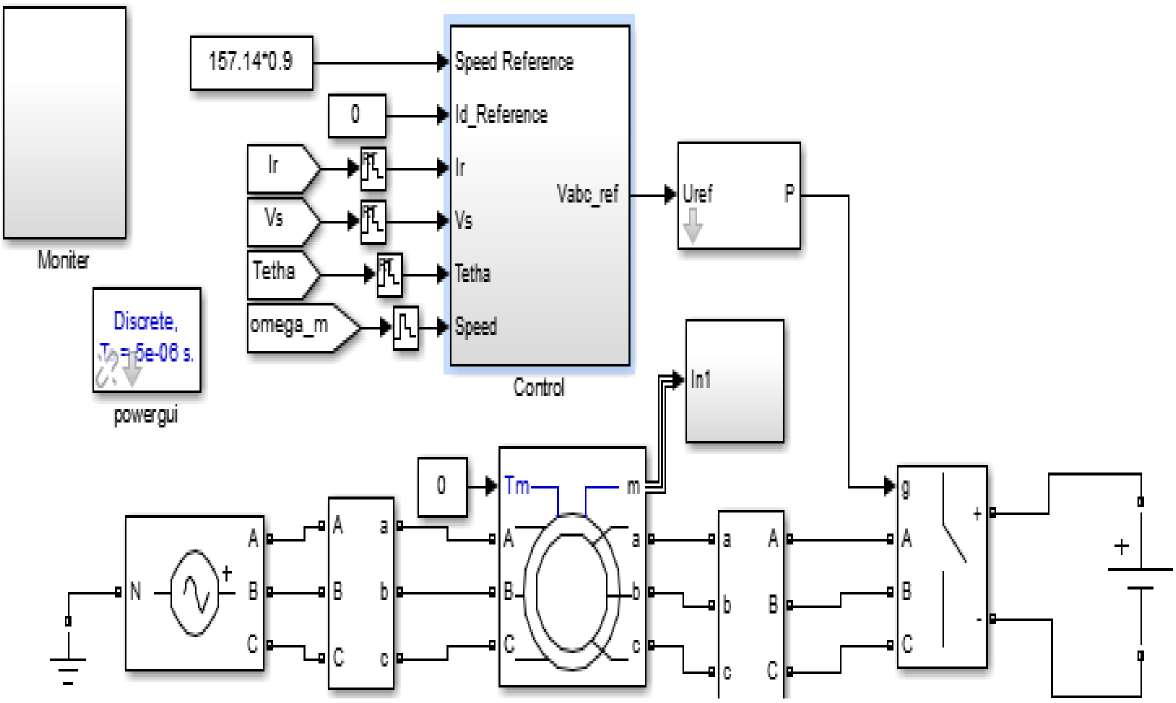

Figure 4 Block Diagram of DFIG

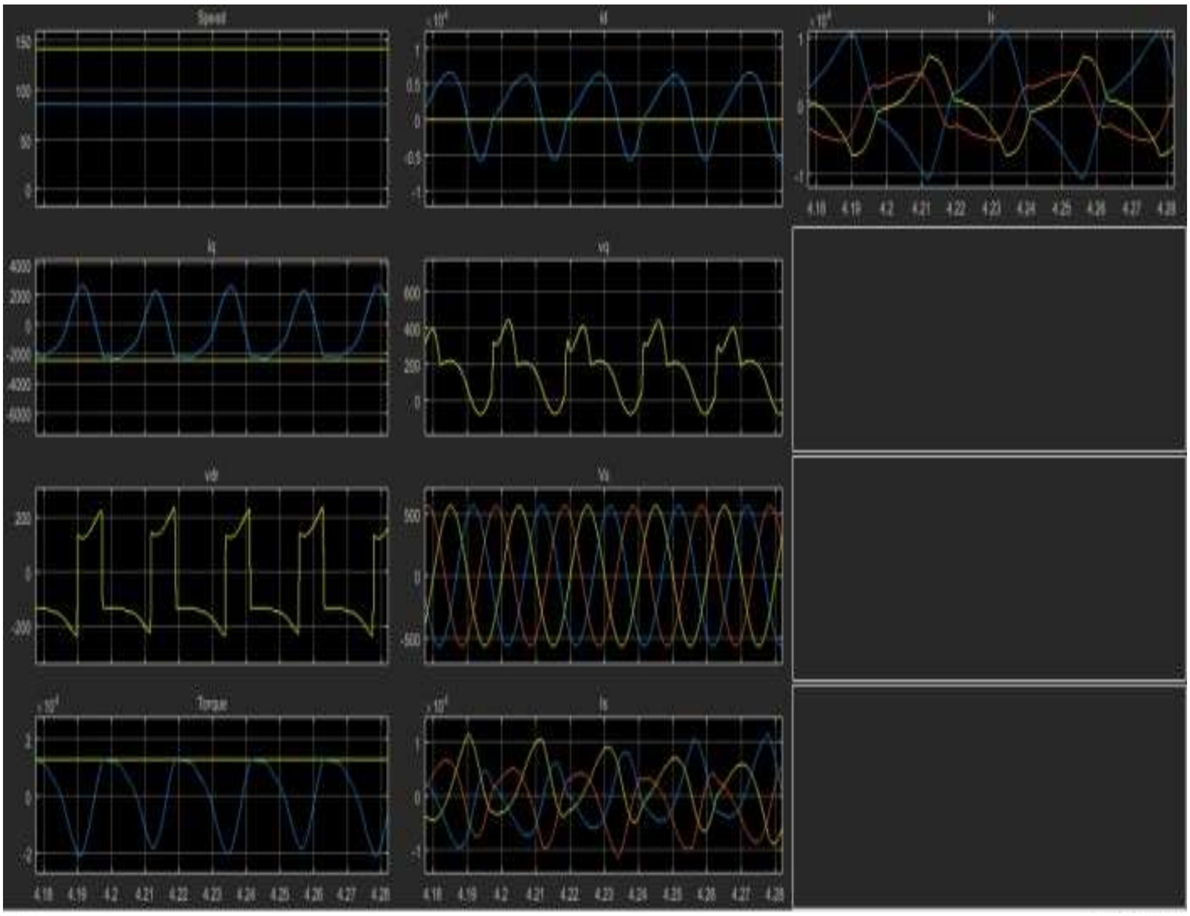

Figure 5. Output Waveforms of DFIG

V. Conclusion

This project presents a simple concept to harvest high altitude wind energy using air borne wind generator supported by light gas filled blimp. A blimp is an aerostat that remains stationary at high altitude holding an air-borne wind turbine and the electric generator at a particular height. An electromechanical tether is used to transmit power to the ground based station. Optimal transmission DC voltage is determined in order to reduce the overall weight of tether. So, a simple and light weight PEC is designed which converts generated low volt-age AC to optimal medium voltage DC for efficient power transmission. The designed converter consists of a rectifier and an isolated DC-DC converter in the air-borne unit and a grid connected PEC in the ground station. Isolated DC-DC converter and ground based PEC are designed and simulated for 100 kW application in the paper. Using this concept of harnessing high altitude wind energy; on grid power supply as well as off-grid power for underdeveloped countries, supply power during emergency condition can be provided with ease of tower construction. However, there are many challenges in harvesting high altitude wind energy using this concept. A blimp which uses light gas like Hydrogen and Helium for buoyancy is expensive. In addition, hydrogen is sensitive to ignition and Helium is a limited element in its existence on earth. Moreover, control of aerostat at high altitude to extract high energy is also challenging. Despite all these challenges, high altitude wind can be one of the best supplements to fulfil high energy demand in this decade for both on-grid, off-grid and emergency power requirements.

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