Design and Development of Harmony Wind Turbine

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Abstract*-The wind is clean free and readily available renewable energy source. The Harmony Wind Turbine (HWT) is type of Vertical Axis Wind Turbine (VAWT), in which its blades are arranged in helix shape. Angle between two adjacent blades in adjacent layers is 60° and such arrangement of blades, irrespective of wind direction, wind turbine starts spinning. At high wind speed or turbulent wind conditions which are different for different size of wind turbines, and to prevent burning of generator the blades of turbine can furl into circle to maintain its speed. Due to use of furling mechanism, disk brakes eliminate which turns hot, causing fire in turbine. The aim of this paper is to prove that during cut off speed condition instead of braking system furling system activates which causes closing of blades due to which speed of turbine gets maintained and power curve is stabilized instead of drastic drop of power curve as in case of conventional wind turbines due to braking. The main objective is to replace breaking system by furling system effectively. The furling mechanism is implemented using RPM sensor, Arduino UNO, servo motor and furling gears. Protects against the breakage of blades and active protection against burning of generator or fire in turbine, works effectively irrespective of wind directions. The new type of blades which are called as scoop along with other components such as joining strip, furling gears and shafts are designed, assembled in solidworks 2016. Solidworks Flow Simulation Wizard is used to carry out flow simulation to generate flow trajectories and cut plots.

Keywords: Harmony Wind Turbine (HWT), VAWT, Furling system, Simulation.

I INTRODUCTION

The Christopher Moore came up with possible application idea of HWT. The purpose was to implement furling mechanism which activates at high speed condition. Furling mechanism is activate during high speed condition. The model was prepared and consisting of pairs of blades and each blade is equally aligned with 45° and look like helix shape (DNA). These turbine blade will be coupled by special generator design which will enable very high power output with low start up speed. In conventional wind turbine as velocity increases power also increases but at particular peak point the power gradually cuts down to zero. For this disc brakes are used but due to overheating of disc brake sometime turbine catches fire. To overcome this problem, furling mechanism was implemented. The cut off speed is the wind speed at which a turbine generator will shut off and stop generating power, usually to prevent damage to the turbine in cases of extra ordinarily high wind speed. Furling mechanism activates the furling motor due to which blades comes close and reduces swept area which reduces the speed of the wind turbine. Hence power output does not gradually fall down as compared to conventional wind turbine.

In this paper four different savonius rotor blade types viz. straight, curved, aero foil, twisted in helix form were tested and study. The straight blade is found to be least effective and best performance observed in twisted blade. This objective of this research was to design and modelling of a small-scale VAWT, which can be used to meet the power for low demand applications. Two new shapes of Savonius rotor blades were examined in terms of their rotational performances against the conventional straight and the curved blades. MATLAB/ Simulink Simulation was utilized to develop a mathematical model, which comprised of wind power coefficient, tip speed ratio, mechanical and electrical subcomponents. [1]. The study shows a combined turbine model with Straight Blade Vertical Axis Wind Turbine (SB-VAWT) and a Savonius rotor with two buckets was designed. Based on the wind tunnel tests data, the starting torque and power performance were simulated and analyzed, and the feasibility of the combination was discussed. [2]. Potential VAWTs models are numerically analyzed within virtual wind tunnels at low wind speeds by utilizing x-flow Computational Fluid Dynamics (CFD) software in Thailand [3]. The simulation results for VAWT revealed that, a new design of aeroleaf geometries generate less pressure drop near the center than the edges of aeroleaf blade and less pressure drop is produced till some radius of the of aeroleaf and as the radius of aeroleaf increased beyond the specified limit the pressure drops across the blade increases and hence minimum speed of 2.5 m/s is required to have acceptable output power taking in consideration

31~35% of efficiency between theoretical and experimental results. [4]. According to literature aerodynamic modelling, fabrication and the performance evaluation of VAWT also included some advantages of VAWT and suitable for low wind speed conditions, lighter weight, lower construction cost and low installation cost. [5]. Turbulence effect on wind turbine measured in experimental data at the coast of Norway over a 10 month period to measure the effect of turbulence intensity on power curves and Annual Energy Production (AEP) has been studied and power curve, power coefficient curves are plotted. [6]. The wind turbine performance under laboratory ideal conditions will always tend to be optimistic and rarely reflects how the turbine actually behaves in a real situation. [7]. A small data for commercial turbines are collected to set relationship between inertia and a rotor characteristic length, namely the radius. according to their study and experimentation VAWTs inertia is little higher than that of HAWTs characterized by the same diameter due to which, VAWTs response times are much greater at low wind speeds, prompting a severe limitation to an effective adoption of vertical axis rotor architectures within the urban setting, which is generally characterized by a low wind potential as well as rapidly varying wind conditions. [8]. Wind energy scenario in India is important to study in details of the fiscal incentives and development schemes offered by Indian government in expanding wind energy business. Wind energy policies of India have been keenly studied and obstacles to the success of these policies. [9]. A comparative review and mathematical dynamic models and electrical generators for Wind Energy Conservation System (WECS) are study. [10]. Maximum Power Point Tracking (MPPT) system to increase efficiency of Wind Energy Conversion System (WECS). [11]. This paper discussed about the design and analysis of HWT that can catch wind from any direction and start spinning and due to this kinetic energy of wind gets converted into electrical energy. Also to study wind energy and its conversion to useful power and implementing this knowledge for designing of small scale HWT. To minimize the chances of burning of wind turbine and its breakdown. To replace breaking system in conventional wind turbine by furling mechanism. To implement furling mechanism in HWT and activation of furling mechanism at cut off speed.

II THEORETICAL CALCULATION

i) Swept Area (S): The swept area is the section of air that encloses turbine in its movement. The shape of the swept area depends on the rotor configuration, in case of HWT the shape of swept area is rectangular. The total diameter of rotor is 0.412m and height of turbine =0.318m Swept area is given as follows.

$S = D \times H$

(1)

ii) Available power (P_a): Available power is maximum power that can be extracted from given shape and size of turbine if the turbine 100% efficient but in practical no turbine is 100% efficient. According to the lanchester-betz limit-“Maximum efficiency of vertical axis wind turbine can be up to 64%”. Since Kinetic Energy (KE) $= \frac{1}{2} \times m \times V^2$, particle of air have low mass so must look at mass flow in specific area,

$P_a = \frac{1}{2} \times \frac{dm}{dt} \times V^2 = \frac{1}{2} \times \rho \times A \times V^3$

(2)

Where, $\frac{dm}{dt} = \rho \times A \times V$, According to the lanchester-betz limit “Maximum efficiency of vertical axis wind turbine can be up to 64%”. Therefore, power extracted (P_e),

$P_e = 0.64 \times P_a$

(3)

iii) Furling Motor: Furling motor selection is done on basis of torque required for furling motion. The drag force on one blade is given as follows:

$F = A \times P \times C_d$

(4)

Where, using standard empirical relation, $P = 0.613 \times v^2$, couple, C= F× perpendicular distance between drag forces (acting on two couple due to drag force for 1 pair. Similarly, couple, C= F× perpendicular distance between drag forces (acting on two different scoops in pair).

iv) Gear Calculation: Let assume involute teeth profile with 20° helix angle therefore gear profile = 20° full depth involute. Since minimum number of teeth to avoid interference is 17. Assume Z_p=18.Considering reduction ratio = 2 Z_g, Where, since by using PLA (Polylactic Acid) as a material for 3D printing of gear and sector. For PLA material σ_y=37 N/mm^2. Considering factor of safety = 4. $[\sigma_y]$ = 37/4 N/mm^2. Lewis factor, $y_p = 0.154 - \frac{0.912}{Z} = 0.154 - \frac{0.912}{18} = 0.1033$.

$m \geq 1.26 \times \sqrt[3]{\frac{[Mt]}{y \times [\sigma_b] \times \varphi \times Zp}}$. [12].

(5)

Since for 1 pair 0.2207 N-m couple (from couple calculation for one pair) acting for overcoming it, consider 0.3 N-m opposing torque. M_t = 0.3 N.m = 3 kgf.cm, $y_p = 0.1033$, $\varphi = 15$, $\sigma_b = 37\ N/mm^2$. Below Table 1 shows the summary of calculated parameters values obtained after calculations.

TABLE 1

Summary of parameters needs to be designed for wind turbine.

1	Swept area, S	0.1310 m^2
2	Available power, P_a	27.94 W
3	Power extracted, $P_{extracted}$	18 W
4	Drag Force due to wind, F	0.6307 N
5	Couple for 1 pairs	0.2207 Nm
6	Couple for 3 pairs	0.662 Nm
7	Number of teeth on sector, Z_g	36
8	Module. m	2 mm

III FLOW SIMULATION CONDITIONS AND METHODOLOGY

Flow simulation is useful to understand behavior of fluid around the object or speciment, effect of flow of fluid on specimen surface and various forces, velocities, pressure intensities can be found out uing flow simulation by appling different boundary conditions. Flow simulation of HWT was carried out in wind tunnel with following considerations: wind tunnle size : (650×650×800)mm,Wind turbine size: 320 mm high, rotor diameter: 412 mm, Analysis type: internal, Reference axis: z axis, Fluid used: air (gases), Flow type: laminar and turbulent flow, Pressure: 101325 pa, Velocity: in z direction, 20 m/s. Turbulence intensity: 2%, Simulation type: flow trajectories simulation and cut plot simulation.

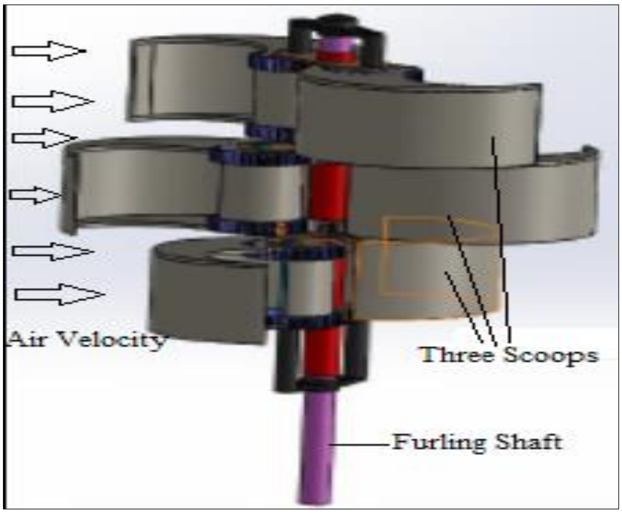
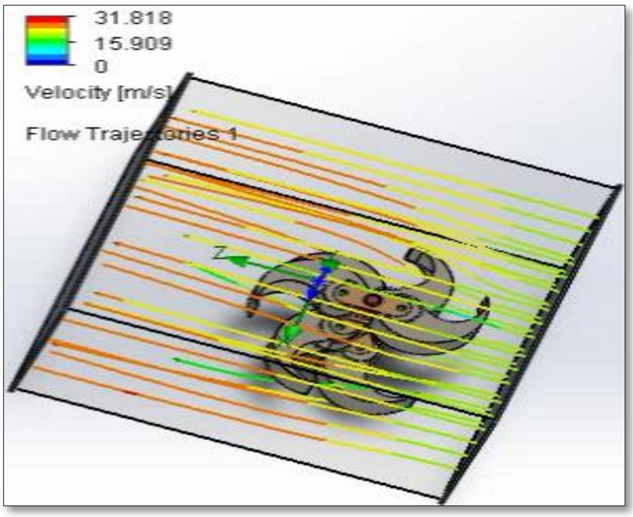


Fig. 1. View of Harmony Wind Turbine (HWT)

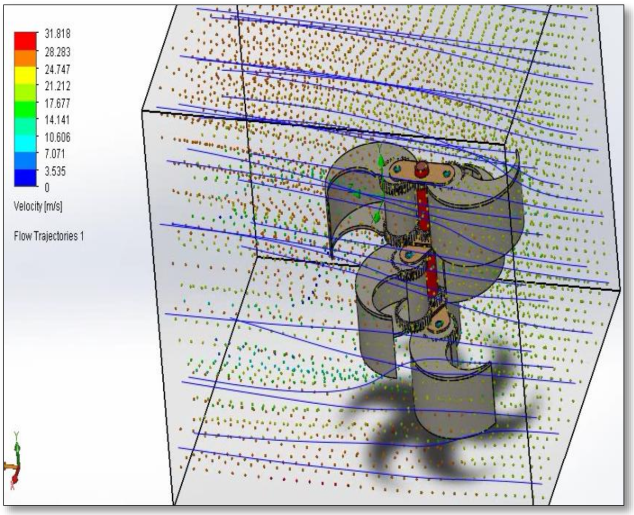
Flow simulation is carried out using following steps: Wind turbine model is assembled in wind tunnel. General setting of flow simulation wizard are done as mentioned above. Lids are created on both side of wind tunnel. Boundary condition at inlet is applied (i.e.velocity =20 m/s) Boundary condition at outlet (atmoshperic pressure101325 pa), Flow trajectories and cut plot are selected with goals such as velocity, pressure intensity and force in z direction and run the simulation.

IV FLOW TRAJECTORIES

Flow trajectories gives simple pattern of wind flow lines around the turbine shape from which defections of wind flow lines from the surfaces of scoops, changes in wind velocity after hitting the surface can be find out using color distribution etc.

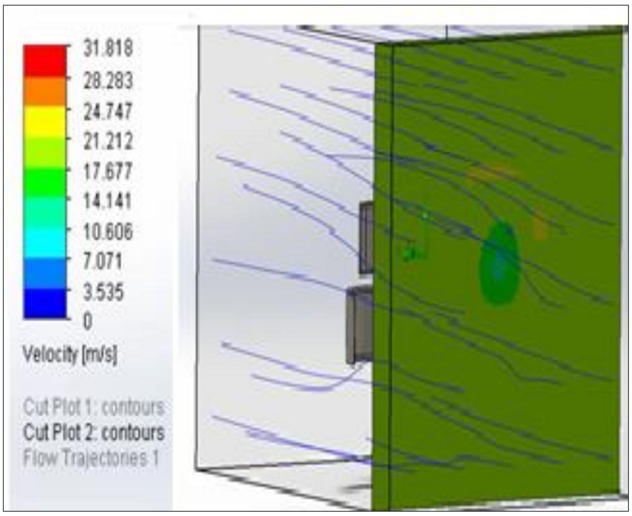


(a)

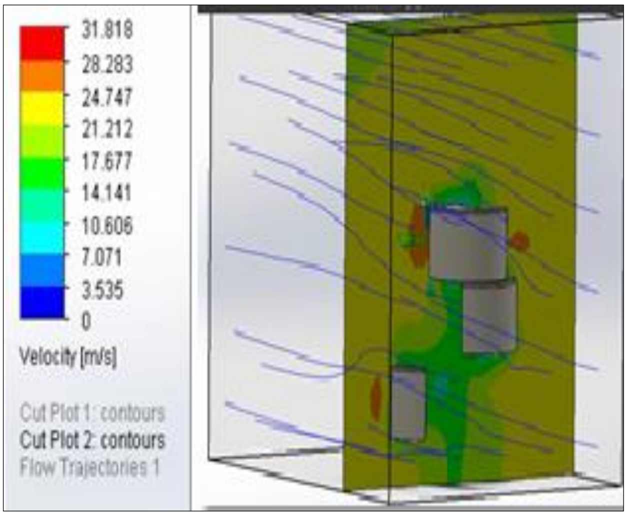


(b)
Fig.2 (a) & (b) Flow trajectories.

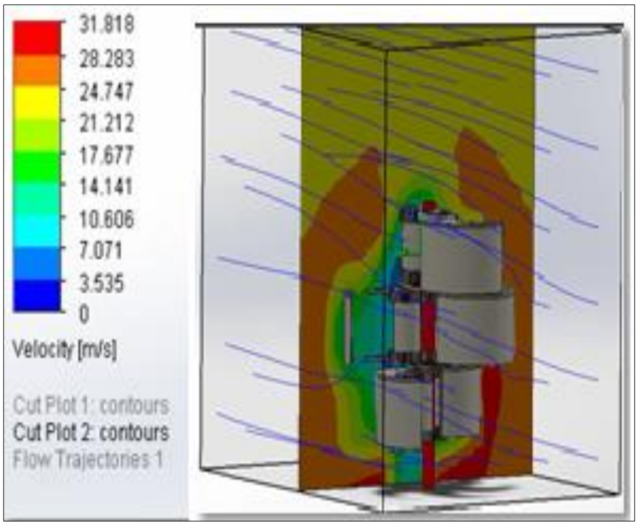
The Fig.2 (a) & (b) shows the flow trajectories view at different velocity. The cut plot is the plane traversing inside the wind tunnel from one end to other which gives information about planar velocity, pressure distribution along the plane at each instance of plane position. From this cut plot velocity distribution along the wind turbine can be easily found out by observation of color changes**.** From cut plots in Fig.3 (a), (b), (c) & (d), Flow trajectories, we came to know about increase or decrease of wind speed in scoop areas; if speed decreases in certain area means that amount of wind kinetic energy is utilized or vice versa.



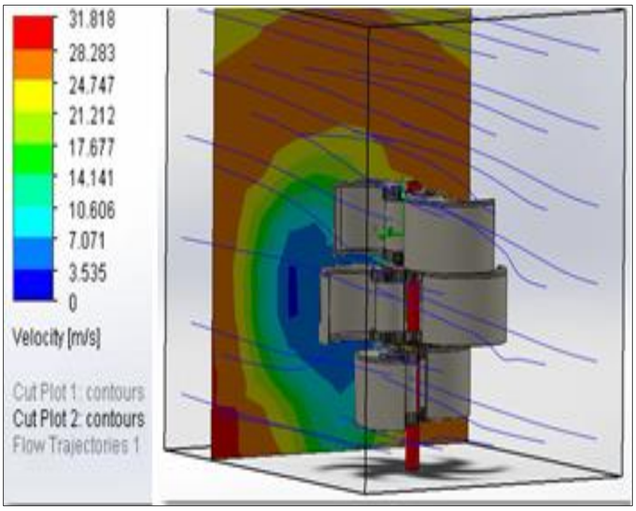
(a)



(b)



(c)



(d)

Fig.3 (a), (b), (c) & (d), different positions of Cut plots.

V RESULTS AND DISCUSSION

As per the calculations performed and betz limit the theoretical power output is 18W for wind speed 7 m/s (average wind speed in India). From the flow simulation we come to know that, at a time 2 blades gets maximum exposure to air flow if wind is flowing from one direction only. From the cut plot simulation we come to know about planar velocity distribution on and around the wind turbine. From this velocity distribution it is found that opposition by convex surfaces is very much lower as compared to excitation on concave surface of scoops and this thing is possible due harmonic arrangement of blades.

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NOMENCLATURE

A = area of 2D space that the air is hitting, m^2.
C_d = drag coefficient =1.05.
D = total diameter of rotor, m.
F = drag force due to wind, N.
H = height of turbine, m.
P = wind pressure, N/m^2.
P_e = power extracted, N/m^2.
P_a = available power, N/m^2.
S = swept area, m^2.
V = average velocity of wind in India, m/s.
Z_g = number of teeth on sector.
Z_p = number of teeth on gear.

GREEK LETTERS

ρ = density of air, kg/m^3=1.229 kg/m^3.