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PERFORMANCE ANALYSIS OF SAVONIUS HYDROKINETIC TURBINE IN ARRAY BASED AT SAME INPUT VELOCITY AT DIFFERENT SPEED

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ABSTRACT

River current generation uses a generator to produce energy, changing the kinetic energy of current into a turning force by setting a water turbine in the river current. Savonius hydrokinetic turbine is designed in software CATIA V5R19 and CFD used in ANSYS 15.0 for analysis. Analysis is done by the method Fluid Flow (Fluent) in SIMPLEC method. In this velocity is constant at 1 m/s and speed is varying in rad/s as k and epsilon method used in turbulence keeping it constant in non-uniform flow. Power generated by the turbine is maximum when four turbines are used, coefficient of power is maximum when one turbine is used and turbulent intensity is almost same in array.

***Keywords:** CFD, Coefficient of power, Power, Savonius hydrokinetic turbine and Turbulent Intensity.*

I. INTRODUCTION

Savonius Hydrokinetic Turbine (SHKT) is used as it is simple and low cost design. The advantage is outweighing its low efficiency and slow running speed makes it an ideal economical choice to meet small-scale power requirement. Experimentally work is done by the Norzanah Rosmin et al [1] in 2014 they studied on the single-stage and doubled-stage two bladed Savonius micro-sized turbine for rain water harvesting (RWH) system it was found that the designed and built system have good performance in terms of producing a constant voltage and current. The single-stage produced better performance than double-stage rotor, where power can be generated almost double. Rotor can rotate up to 1280 rpm when single-stage two-bladed Savonius rotor is used, compared to the double-stage rotor. The single-stage two bladed Savonius micro-sized turbine also capable to light the 0.3 watt LED lamps. Rami Malki et al [2] 2014 had done his work on planning tidal stream turbine array layouts using a coupled blade element momentum- computational fluid dynamics (BEM-CFD) model which is used to simulations of groups of tidal steam turbines. Simulations of single, double and triple turbine arrangements are conducted first to evaluate the effects of turbine spacing and arrangement on flow dynamics and rotor performance. Due to the computational efficiency of this modeling approach, particularly when compared to transient computational fluid dynamics simulations of rotating blades, the BEM-CFD model can simulate larger numbers of devices. It compared to a regular staggered configuration, the total power output of the array was increased by 10%. N.K.Sarma et al [3] 2014 has done Experimental and computational evaluation of Savonius hydrokinetic turbine for low velocity condition with comparison to Savonius wind turbine at the same input power. Its result shows that in both experimental and computational the variation of torque and power extracted by the turbine represents an increasing trend with increase in free stream velocity. When the comparatively analysis of power extracted by the Savonius water and wind turbines from the flow with respect to the maximum wind power. The maximum power extracted by the Savonius hydrokinetic turbine (for the same input wind power) is increased by 61.32%. This paper works on the same input of velocity 1 m/s and varying the speed in rad/s and finds the maximum value of upstream and downstream of velocities of the turbine in array finding by the numerical technique by SIMPLEC method in fluid flow (FLUENT) on ANSYS 15.0. After this it is put on the equation. Then it's finding that power extracted by the turbine, coefficient of power and turbulent intensity. It compares in array and find its how much number of turbine is giving maximum output.

II. COMPUTATIONALLY MODELLING

2.1. Design of the Savonius Hydrokinetic Turbine

The simple or convectional Savonius Hydrokinetic turbine is designed for the analysis. The parameters used for designing in CATIA V5R19, the rotor diameter (D) is 200 mm, the end plate diameter (D_0) is 220 mm, the height of the rotor (H) is 180 mm, Overlap distance (e) is 30 mm, blade thickness (t) is 10 mm and shaft diameter is (d) 20 mm as shown in fig.1.

2.2. Formulation

The amount of maximum power (P_{max}) depends on the fluid velocity, rotor area and the density of the fluid as expressed in equation 1:

$$P_{max} = ½\rho A U^3 \quad (1)$$

The torque generated by the turbine (T) in the upstream and downstream of the velocities in equation 2:

$$T = ½\rho A R (V_1^2 - V_2^2) \quad (2)$$

The power extracted by the turbine (P_{rot}) can be expressed in equation 3:

$$P_{rot} = T\omega \quad (3)$$

The Tip Speed Ratio (TSR) is non-dimensional number that the turbine performance data can be evaluated against can be evaluated in equation 4:

$$TSR = 0.5\omega d/U \quad (4)$$

The coefficient of power (C_P) determines the fraction of power that is extracted by the turbine is expressed in equation 5:

$$C_P = P_{max}/P_{rot} \quad (5)$$

The turbulent intensity (I) is an important parameter and is vital in the computational simulation of the design. The turbulent intensity of the flow at a specific position can be determined in equation 6:

$$I = 1/U \sqrt{\{⅓ (u^2+v^2+w^2)\}} \quad (6)$$

III. RESULTS AND DISCUSSION

3.1. Turbine arrangements

Turbines are arranged in rectangular box whose dimension is 0.3 m * 1 m * 1 m. Distance between two turbines is 20 D i.e. 4000 m. Two and Four turbines are arranged in longitudinal spacing. Three turbines is arranged in

45 degree angle and their between distance is 20 D i.e. 4000 m. The input velocity of flow stream is 1 m/s which is constant and speed is varying from 3 rad/s to 7 rad/s. All arrangements of turbines are shown in fig. 2 to fig. 5.

3.1.1. Single turbine

With different speed from 3 rad/s to 7 rad/s analysis is done and keeping velocity constant at 1 m/s. After the analysis is done the values are put on the equation where we get power at the rotor on different speed where we see in fig. 8 that it increases and at same time coefficient of power and turbulent intensity also increases as shown in fig .6 and fig 7 respectively

3.1.2. Two turbines

Distance between the two turbines is 20 D i.e. 4000 mm and it is laterally spaced. The input velocity is kept 1 m/s as keeping it constant. The SIMPLEC method is used to analysis the upstream and downstream of the velocities and coefficient of power, turbulent intensity and power generated by the turbine is increasing with respect to speed which is varying as shown in fig. 9, fig. 10 and fig. 11 respective

3.1.3 Three turbines

The turbines are arranged at an angle of 45 degree with distance 4000 mm. Distance between them is same. The coefficient of power and power generated by the turbine at some speed it is increasing and decreasing as shown in fig. 12 and fig. 14. Its arrangement can be changed for better performance. Power generated by the turbine gives maximum at 5.5 rad/s which is 645.6924 W, coefficient of power is 0.488795 and turbulent intensity is 3.268018. But turbulent intensity is increasing with speed as shown in fig. 13.

3.1.4. Four turbines

The turbines are arranged is square in equal distance between them. Here coefficient of power, turbulent intensity and power generated by the turbine is increasing with speed as shown in fig. 15, fig. 16 and fig. 17 respectively.

3.1.5 Comparisons of all turbines

As we compare all the turbines for performance analysis we see that the coefficient of power is more in one turbine it is more efficient as compared to other turbines in array as shown in fig. 18.The power generated by the turbine is maximum in four turbines as compared to other turbines in array. It is increasing with speed when speed is increasing as shown in fig. 20. The turbulent intensity of the turbine in array as compared to all turbines it gives almost equal values. They're not so much difference between them as shown in fig. 19.

VI. CONCLUSION

A detailed study of computational study of the Savonius Hydrokinetic Turbine in array is done. It is very useful in small scale for power generating. Its design is simple and low cost. Maximum power is generated by the rotor on the four turbines which gives 995.6184 W at a speed of 7 rad/s. Maximum coefficient of power is on one turbine which value is 0.682623 at a speed of 7 rad/s. And the turbulent intensity is almost equal in all turbines which are maximum at one turbine whose value is 4.121123 at a speed of 7 rad/s. As we concluded that the further we can analysis on more turbines on changing its arrangement and distance and making any parameters is constant or varying. We can check it maximum efficiency.

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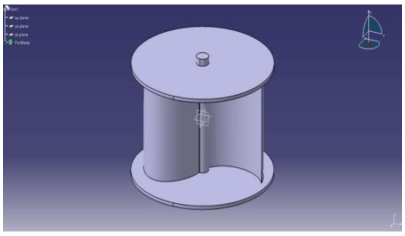

Fig.1 Design of Savonius Hydrokinetic Turbine

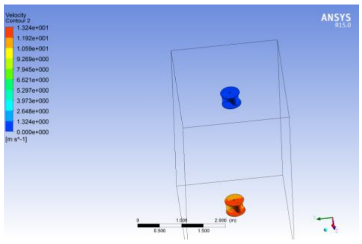

Fig. 2 Arrangement of one turbine

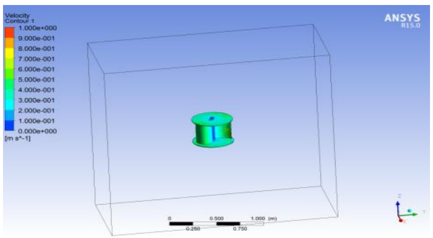

Fig. 3 Arrangement of two turbines

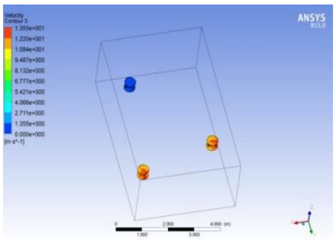

Fig. 4 Arrangement of three turbines

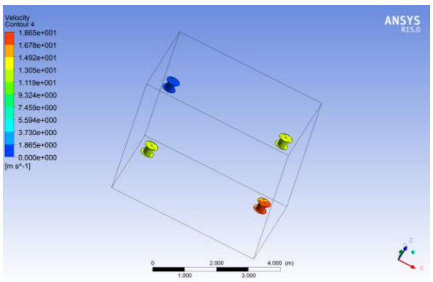

Fig. 5 Arrangement of four turbines

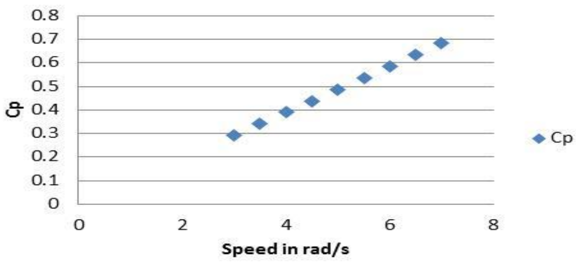

Fig. 6 Coefficient of power w.r.t speed for 1 turbine

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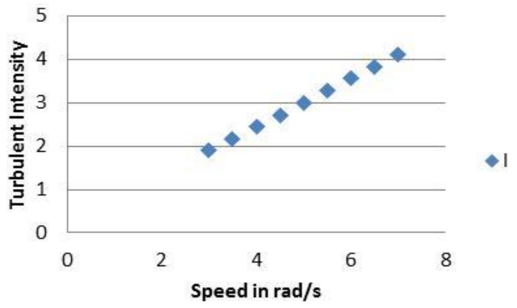


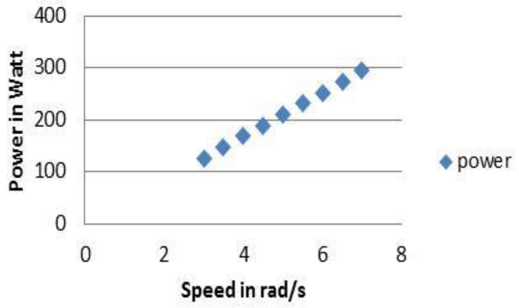
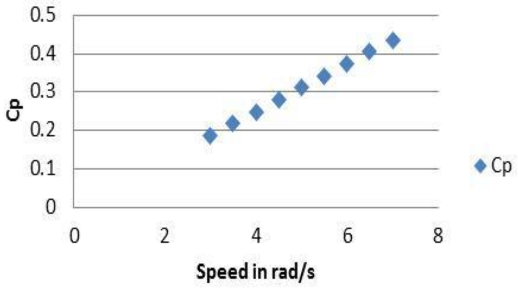


Fig. 7 Turbulent intensity w.r.t speed for 1 turbine Fig. 8 Power generated w.r.t speed for 1 turbine



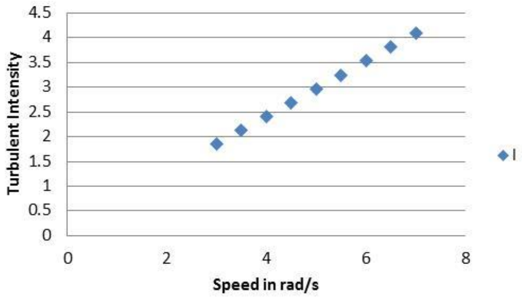
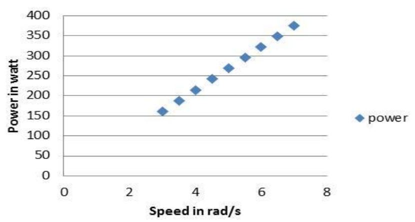


Fig. 9 Coefficient of power w.r.t speed for 2 turbines Fig. 10 Turbulent Intensity w.r.t speed for 2 turbines



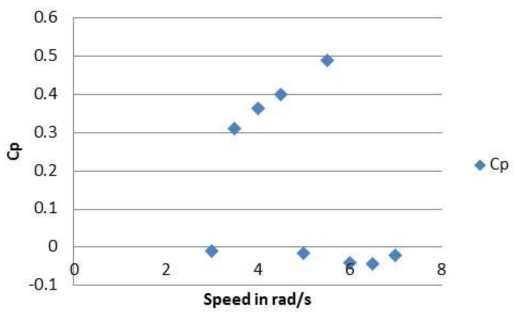
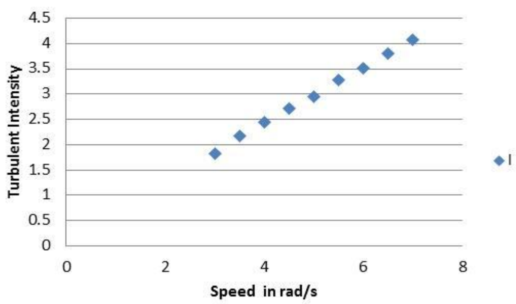


Fig. 11 Power generated w.r.t speed for 2 turbines Fig. 12 Coefficient of power w.r.t speed for 3 turbines



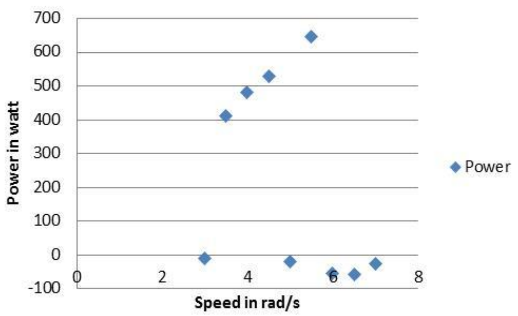


Fig. 13 Turbulent intensity w.r.t speed for 3 turbines Fig. 14 Power generated w.r.t speed for 3 turbines

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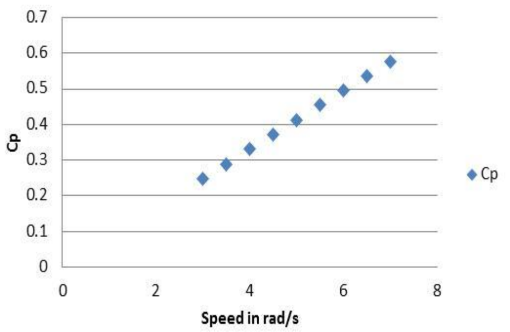


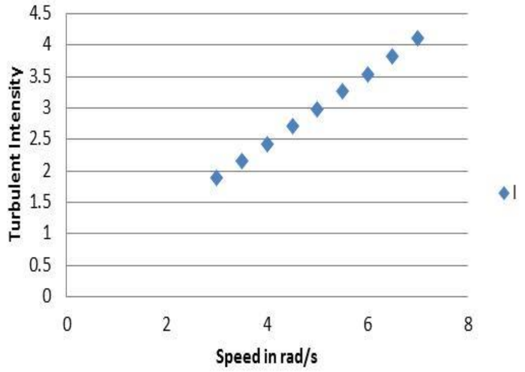
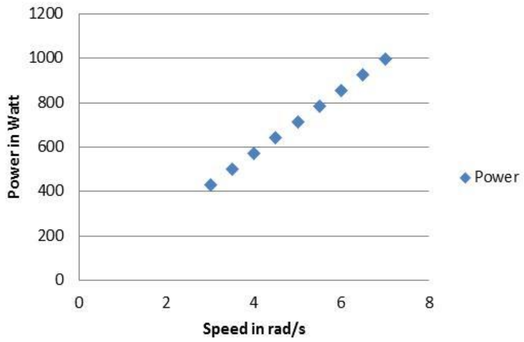


Fig. 15 Coefficient of power w.r.t speed for 4 turbines Fig. 16 Turbulent Intensity w.r.t speed for 4 turbines



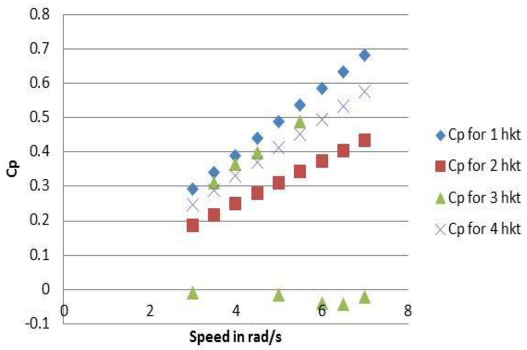
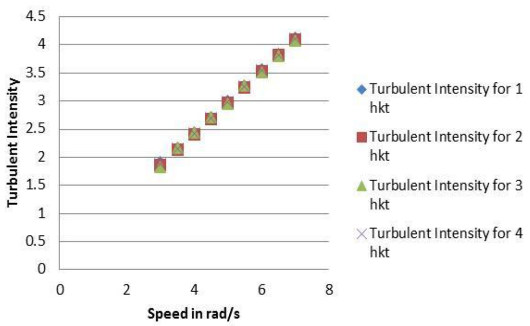


Fig. 17 Power generated w.r.t speed for 4 turbines Fig. 18 comparing all turbines for coefficient of power w.r.t speed



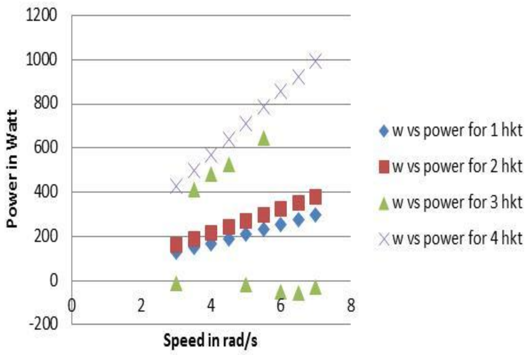


Fig. 19 comparing all turbines for turbulent intensity w.r.t speed Fig. 20 comparing all turbines for power generated w.r.t speed