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Numerical Analysis Of Savonius Wind Rotor: A Review

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Abstract—this paper deals with testing of power and torque coefficient of savonius rotor using numerical analysis. Numerical analysis least costly quick time response so that it is better than experimental method. Due to poor aerodynamic coefficient of savonius rotor, many people perform analysis. Some factor like as TSR, overlapping condition, geometry of rotor etc. affects the coefficient. Numerical method is very effective for testing of rotor geometry for extracting more power from wind. Numerical analysis can be done as steady and transient analysis, where steady analysis in which time is steady and transient analysis time is varying. Using this flow of wind can be analyze complicated phenomenon of flow can be observed. Aim of this paper, brings all informations in to discussion.

Keywords— Numerical analysis, torque, power, aerodynamic coefficient.

I. INTRODUCTION

In world many of countries are developing countries among them India is one of the developing country. Due to rapid growth of human population and industrial development, So that energy consumption increases day by day such a huge demand of electricity cannot be fulfill by energy sources as coal petroleum oil, nuclear energy, which has highly dangerous emissions which causes severe problems mankind and environment. To avoid such a problem it is need of use some source of non conventional energy such as wind energy. It is clean and no harmful emission. Chiefly available everywhere

ENERGY SCENARIO OF INDIA

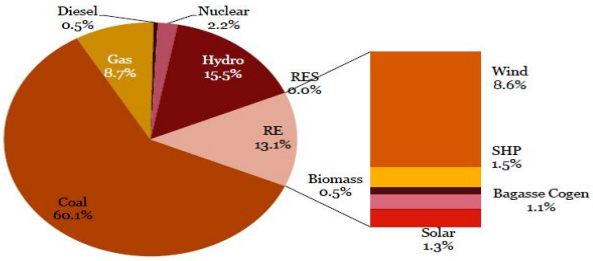

Fig 1. Utilization of Energy in India [1]

This fig clearly indicates that maximum utilization of coal for electricity generation nearly 60% fig shows various utilization energy sources for electricity production among the 13% utilization of renewable energies sources which are inexpensive and available in huge amount.8.6%of use of wind power for electricity generation which is nearly equal to 7% of total electricity generation.

II. CATEGORY OF VERTICAL AXIS WIND TURBINE

Due to rich availability of wind the different kind of vertical axis wind turbines are invented, but among them there are two main types of rotor such as savonius rotor and darrieus rotor, but problem deals with darrieus is unable to quick start. Savonius rotor has plus point ability to quick start and quick response at poor wind speed. Savonius rotor has s shape cross section this rotor rotates due to maximum drag offered by concave side and less drag offered by convex[2].

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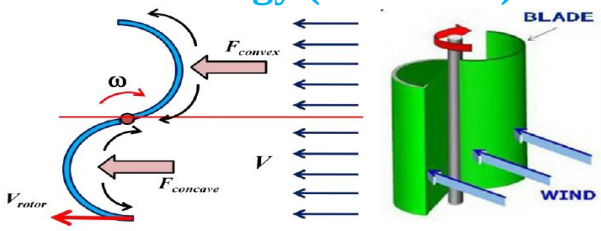

Fig 2. Savonius rotor [2]

III. REASON FOR STUDY

Raising demand of electricity cannot be fulfilled by coal, like energy sources. They will vanish in few years. Savonius rotor can be fulfilling the demand of electricity for domestic purpose. India is divided in many village where the electricity unable to reach due to geographical problem such as mountains, forest. It is necessary to give an attention on savonius rotor which small power generation unit which will cover the demand of individual houses. But the problem with savonius rotor is less efficient. Many people have worked on improve the geometry of rotor which will give efficient performance .by using numerical analysis.aim of paper is to bring them into discussion:

IV. METHOD

Numerical analysis is also called as CFD analysis. Different analysis software are available in market. Main advantageous of CFD is complicated flow visualization using some governing equation by solving differential equation. Using some problem computes the results in computer. CFD contains 3 basic steps preprocessing in this stage rotor geometry called up placed inside the domain generates mesh by means of finer near to rotor for getting better result. It necessary to define all required boundary conditions, Property of flow also defined.

Solver this stage deals with various solver specifically in fluent pressure based solver another is density based solver are used for solving flow governing equation manipulated iteratively

A. Preprocessing

In this stage rotor geometry called up placed inside the domain generates mesh by means of finer near to rotor for getting better result. It necessary to define all required boundary conditions, Property of flow also defined.

B. Solver

This stage deals with various solver specifically in fluent pressure based solver another is density based solver are used for solving flow governing equation manipulated iteratively

C. Post Processing

There are many post processing software are available in market .Ansys has CFD post module for representing the visualization of result in the form of contour plot. Contour plot contains pressure contours, velocity contours. Vector plot which contains velocity vectors, streamline which shows the path of flow around the rotor.CFD post have many result showing tools such as force moment. Numerical analyses are two types' steady state and transient analysis.

V. STEADY ANALYSIS

In steady state analysis time parameter remain steady but the rotor will not be rotate.

B.wahyudi [3] They perform an analysis on three different configuration it savonius rotor such as type-1(overlap),type-2(symmetrical),type-3(convergence), while dealing with this different rotor. In 2d space with pressure based solver, inlet as 1m/s, outlet as pressure outlet. Sides of domain as no slip wall, blades as stationary wall such a boundary conditions have defined.type-3(convergence) has maximum pressure from inlet side to outlet side.

S.Mctavish[4] they perform steady and rotating simulation on geometry of Aeolum Harvster and simple savonius rotor with dia of 1.8m and 1m major radius, inlet as 7m/s having zero outlet pressure .wall of domain as free slip, they found that Aeolun Harvesters has good result in terms of torque as compared with SSR.

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VI. TRANSIENT ANALYSIS

In this analysis the time parameter is not steady but rotor will rotate according to TSR as well as time.

S.Mctavish [4] conclude that single stage 3d geometry of Aeolum Harvster placed rotating cylinder this rotating cylinder surrounded by non rotating rectangle as domain. Using level of turbulence 5%in this study they conclude that when TSR increase torque of Aeolum Harvester decreases quickly than SSR. Due to convex portion of which blocks the flow of wind so that stagnation of wind occurs.

Wanlong tian[5] they studied that using transient analysis of different modified geometry of sr. In 2d space with rotating inner region, which including modified different blade fullness geometry are placed, rotating zone is surrounded by wake zone and again wake zone is surrounded by outer zone both wake and outer are fixed. In this study it is found that blade fullness equal to one has maximum. Power coefficient.ssr has 10.98% less power produce blade fullness equal to one.

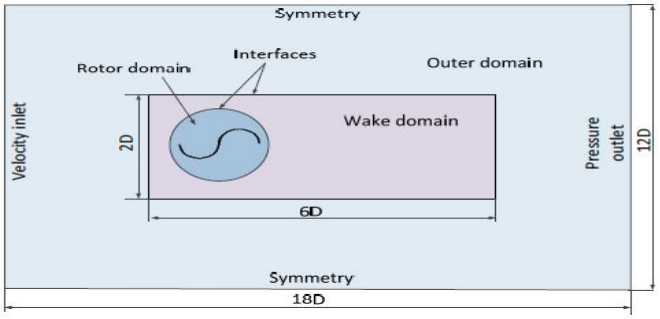

Fig 3. 2d Unsteady Numerical Analysis[5]

Formulae for Calculation

$$C_p = \frac{P_t}{P_a} = \frac{P_t}{\frac{1}{2}\rho A V^3} \quad \text{.....1}$$

$$P_t = T\,\omega \ \ (Watt) \quad \text{.....2}$$

$$A = H*D \quad \text{.....3}$$

$$TSR = \lambda = \frac{V_{rotor}}{V} = \frac{\omega.d}{V} \quad \text{.....4}$$

$$C_t = \frac{T}{T_w} = \frac{4\,T}{\rho\, A_s\, d\, V^2} \quad \text{.....5}$$

Where cp power coefficient
P_t -actual power in w
p_a –theriotical power in w
V – wind velocity m/s
A – area , A= H*D m^2
TSR- Tips speed ratio
T –actual torque in NM
T_w – theriotical torque in NM
C_p- power coefficient
C_t- torque coefficient

VII.FACTORS AFFECTING AERODYNAMIC CO EFFICEENT

Many of people had work on SWR for enhancing the power and torque coefficient according to different research many factors are identified and brought into discussion for future work these factors are as follows

A. TSR

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Yan Fei Wang[6]using software they perform analysis on different profile of rotor in section wise results of CFD and experimental are putting side by side they observed that 0.6 TSR has maximum power coefficient.0.12 was observed for helical bladed rotor power coefficient. For semi cylindrical rotor has 0.10 power coefficient. But for semi circular has power coefficient between of them 0.11.TSR is a function of power and torque.

Ivan Dobrev[7] they carried out study of unsteady flow analysis using rotor has equal dia.and hieght. Unsteady simulation performed and cross checked by it results using wind tunnel using PIV.Some effects such as vortex shedding and wake effect .they observed that TSR 0.8 has maximum power coefficient. Of 0.18 for experimental and 0.20 for CFD

As TSR increases aerodynamic coefficient are decreases. So that TSR is function of power and torque coefficient. The optimum TSR gives better coefficient

B. Stator Design

For enhancing the coefficient of power and torque, Curtain arrangement are introduced by burcin deda Alton[8] using practical and numerical analysis they found that torque exerted on convex part of rotor reduce the static torque. Flow of wind concentrated on concave part of rotor using curtain arrangements which improved coefficient of power and torque.

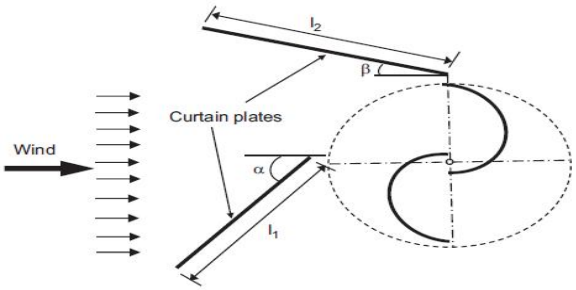

Fig 4. Curtain Arrangement [8]

W.El-Askary[9]using CFD they conclude that by manipulating wind flow aerodynamic coefficient can enhance. So that by using harvesting designs elimination of wind striking to convex part. On this basis they conclude that elimination of negative value of torque can possible. Increasing value total torque takes places.

C. Shape Of Rotor

Zhojong Mao[10] they perform analysis on various arc angle for rotor they conclude that act angle has influence on torque and power coefficient. At arc angle of φ=160°shows high value of coefficient as 0.28

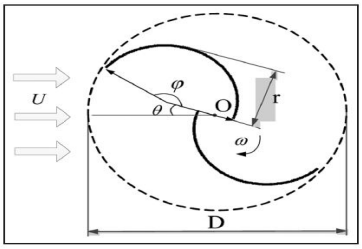

Fig 5 Arc Angle of Savonius Rotor [10]

Mariano Tartuferi[11] using new shape design of airfoil such as SR3345 and SR5050 shows better results than SSR.SR3345 has coefficient of maximum value of torque an power at TSR is less than 0.5 and SR5050 has at 0.5 to 0.9.

A. Faruk[12] they proposed new design of SSR which inlet at the bottom for hot air and where the spitted shaft is attached to near the hole at bottom. This design shows power coefficient for 0.12 at TSR of 0.58 which is 85.5% higher than SSR.

H.gad[13] they studied that V shape rotor using various v angles among them modified Rotor 4 has better performance in terms of power coefficient. 0.27 at TSR 0.8,it is seen that convex part of v shape rotor offers less drag.

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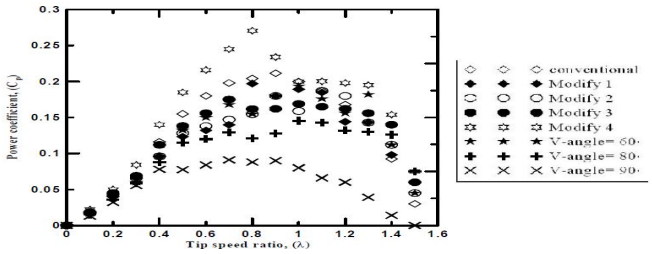

Fig 6 v shape power coefficient characteristic [13]

D. Overlap Conditions

When partially concave part covered by convex part this condition is named as overlap condition.

R.Gupta[14] they conclude that using three bladed SR using different overlap ratio such as 12.37%, 19.8%,21.37% and 25.8%. They conclude that using 19.8 % overlap ratio has optimum overlap ratio. It is shown by using pressure contour for pressure variation and velocity variation.

Sukanta Roy[15] they carried out numerical analysis of five types of overlap condition as 0,0.5,0.10,0.15,0.20,0.25,0.30 among theses overlap conditions of rotor. It observed that 0.20 has good results than all other, this rotor prevents negative value of torque good performance seen at velocity =10.44.

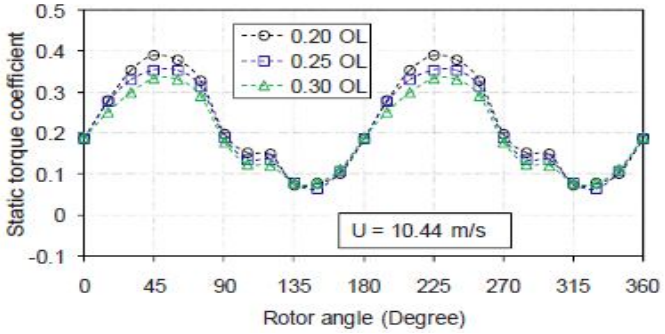

Fig 7 Static Torque Characteristic [15]

VIII. CONCLUSION

Numerical analysis provides good results but boundary conditions should properly define. From literature survey it is seen that many of people were worked for enhancing performance of SSR with different configuration has been proposed. On this basis some conclusion are highlighted as follows.

A. 2d simulation results shows over Predictions of results. 3d provides better results as compared to 2d,but 2d takes less time for computation and 3d requires more than 2d computation.

B. Flow always consider as turbulent and unsteady which show artificial flow behavior because natural wind is always turbulent due to wind flow is uncertain.

C. Aerodynamic coefficient depends on TSR, geometry of rotor, overlapping conditions, stator design, etc.

D. As TSR increase coefficient decreases the optimum value of TSR show high aerodynamic coefficienticientcient.TSR is a functions of torque and power coefficient.

E. Proper rotor geometry can extract more power from wind

F. Overlap position increases then wind get escaping from space between rotors so that performance decreases the optimum overlap shows good result as well negative torque value can be avoid.

It is necessary to improve the design of savonius rotor for domestic purpose so that individual houses stand alone for power generation and this power can be utilized houses

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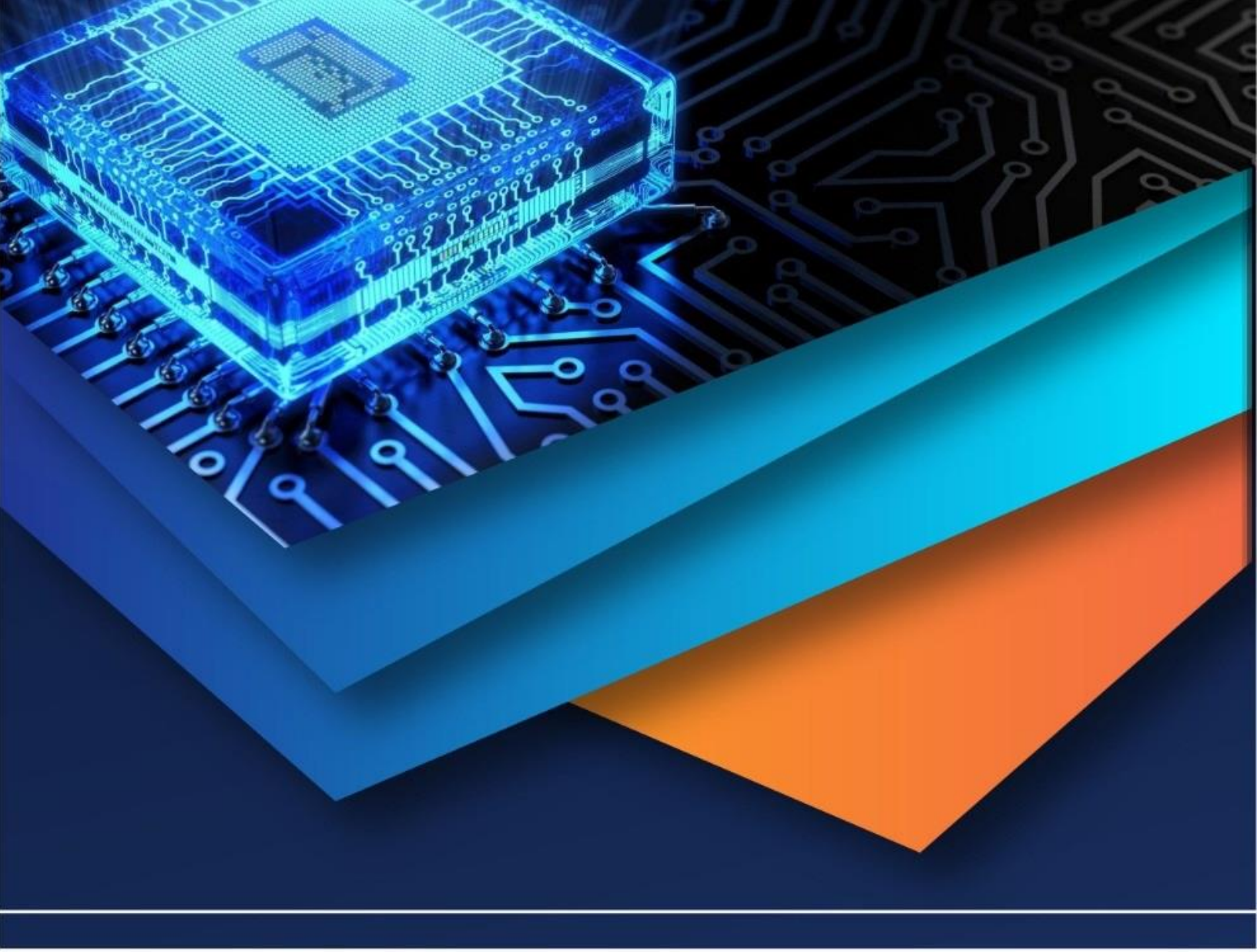

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