International Journal of Research in Engineering, Science and Management
Volume-2, Issue-1, January-2019
www.ijresm.com | ISSN (Online): 2581-5792

Experimental Investigation of Modified Savonius Rotor: A Review

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***Abstract*: The world adopts a policy of energy transition, which refers to the substitution of fossil fuels by renewable energies to reduce CO2 emission, however the major issue is to develop a wind turbine which has a simple design, a relatively low operating speed and independent wind directions. Savonius rotor is a vertical axis wind turbine which is characterized as cheaper, simpler in construction and low speed turbine. In the blades, there is a cut slot is provided and it is provided with the door shaped plate which is made up of with the same material used for the rotor. In the study of Savonius rotor the single stage rotor has less efficiency than double stage rotors. Initially, two blades are used for the inspection and checking. These slots are provided in all the blades of the rotor and it will reduce the loss of energy. This setup is now forwarded to the checking through the wind tunnel at different wind flow and to check the performance of the developed model of Savonius rotor. Wind flow is measured for both the types of blades and stages of the rotor system. The conclusions will be obtained through different stages of the rotor system and blades.**

***Keywords*: conventional electricity semicircular, vertical axis machines**

1. Introduction

Wind energy is one of very important energy producing resources in the world. Wind rotors are a very important tool to obtain the energy from wind. Through the wind energy is obtained by two types of a vertical axis and horizontal axis wind turbines. The vertical axis wind turbine is also known as the Savonius rotor. It is very simple in its structure and energy production method. A Savonius rotor has different types of blades and stages of the rotor system. The performance of the Savonius rotor has been studied since 1997 by various researches in order to increase the performance of the rotor system. In recent years, power production through wind energy has been given the interest to maximize. Various researches have attempted for the improvement of cost-effective, reliable wind energy conversion systems through all over the world. Several cases occur from various types of developed designs and it is also studied and concluded through a different equation to solve the issues. Since where a lot of people do not have access to conventional electricity service until, but in an urban people can make up a space for future generation. This project was undertaken to optimize the cost of Savonius rotor by the design configuration that this is simple vertical axis machines.

2. Literature survey

U.K. Saha, et al., [1] they have been tested a three-bladed twisted rotor system at low speed and compare its performance with semicircular blades. Performance analysis has been made basics of the static torque, starting characteristics and rotational speed. Three bladed semicircular Savonius rotor has good self-starting characteristics but it has been improving by increasing the twist angle of the blade. Semicircular blades have zero angles of twist, by increasing the angle the performance of the Savonius rotor is increased. And also larger twist angle is preferable for low wind velocity. A.J. Alexander, et al., [2] have been tested the number of Savonius rotor configurations in a wind tunnel in wind speed of 6-9m/s. Those variables were tested were aspect ratio, overlap, gap and the effect of adding extrusions. For low aspect ratio without addition gave the lower efficiency. But for the high aspect ratio with optimum blade configuration and shielding gave the higher efficiency. And also three and four-bladed configurations gave the very low efficiency. M.A. Kamoji, et al., [3] they tests on Savonius rotor with a shaft and without shaft rotor in an open jet wind tunnel. A coefficient of static torque, static torque and coefficient of power for each rotor has been measured. Helical Savonius rotor without shaft also compares with the conventional type Savonius rotor. The result indicates the rotor without shaft has the higher coefficient of power than the rotor with a shaft. Savonius rotor without shaft with an overlap ratio 0 have the same coefficient of power compared with the conventional Savonius rotor.

S. Thotla, et al., [4] they tests the aerodynamic performance on the single, two, three-stage Savonius rotor in the wind tunnel. Both semicircular and twisted blades used in each case. Experiments were carried out to optimize the number of stages, the number of blades and the geometry of blades. And also measure the performance of the two-stage rotor with the valve on the concave side on the blade. The tests were conducted in the speed range of 6-11m/s. The result indicates the two-bladed two stage rotor gave the higher performance than the single and three stage rotor. And also twisted geometry is well in performance compared with semicircular blades. Valve aided Savonius rotor gave the better performance compared with a conventional type Savonius rotor. R. Gupta, et al., [5] they tests the combined Savonius - Darrieus type vertical axis wind

turbine for testing its advantages over individuals. In here, one simple Savonius and the other combined Savonius-Darrieus wind rotors were designed and fabricated. Three bucket Savonius and three bladed Darrieus rotors were tested in subsonic wind tunnel. The overlap variations made in the Savonius rotor only. From this investigation increase of overlap ratio decrease the power coefficients. The efficiency of a combined rotor without overlap condition is higher than the efficiency of the Savonius rotor without overlap conditions. T. Hayashi, et al, [6] they tests wind tunnel on a different three stage of Savonius rotor. They decreased the torque variation of a Savonius rotor and improve the characteristics of the rotor. They were to make a smooth rotation of three stage rotor at one revolution as compare to one stage. They also measure torque characteristic with guide vanes. The guide vane increases the torque coefficient on the low tip speed ratio but decreased on the high tip speed ratio. The present three stage rotor need to improve the aspect ratio in each stage. The three-stage rotor with the guide vane had better torque characteristics than one stage rotor. M. Zemamou, et al, [7] they reviewed the Savonius wind turbine design and performance. The major reason for the development of the wind energy system is due to the world's energy transition, which equals the energy of fossil fuels for the reduction of co2 emission. A Savonius rotor has a simple design and independent wind direction but has major problems of low efficiency and high negative torque. This review is to make a new design to improve the performance of the Savonius rotor by making a new design. They noted that the range of power coefficient values for the conventional Savonius rotor is (0.1-0.25). They have set the installation of a new set of different components can achieve an improvement in coefficient of (27.3%) compare to the conventional rotors. Their review has resulted that the different set of extra changes in Savonius turbine will make major drawbacks between the rotor efficiency and make the system complex, but these reviews will be helpful for the future researches.

Chat Chai Promdee, et al., [8] they two of them made the tests (Double wind tunnel test) on the Savonius wind turbine with the DC Generator to know the reading and graph the efforts of wind angles and wind speeds on voltage generation. The test has made and found that the highest voltages of (7.28-11.28) volts generated at the wind angles of 30 degrees and the wind speed of (4.86-6.41). But without wind tunnels the voltage generation only in the degree of (60-75degree). At last the results shows that the proposed wind turbine generate a higher voltage of all wind angles than compared to the conventional Savonius wind turbine. Sobhi Frikha, et al, [9] they have tested the five configurations with different stage number and particularly invested in visualizing the velocity field static pressure, dynamic pressure, vorticity, turbulent kinetic energy, dissipation rate, and viscosity. The software Solid works flow simulation has been used to present the local characteristics in different transverse and longitudinal planes. The wind tunnel experiment was compared to numerical results in term of velocity, torque and power coefficient. W. A. EL. Askary, et al, [10] they have made a work of three-way controlling the wind directions to increase the performance of Savonius rotor. Their concept is to control the incoming wind to generate a wind jet at a concave side and prevent the convex side of the blade from the coming wind upstream. A different design has made in controlling the wind directions of the concave side to eliminate negative torque an increase the positive torque. Their result suggested that the newly implemented design of the real performance on Savonius rotor operations. They remarked that one has reached a power coefficient peak of (0.52) operation range with tip speed ratio of $\lambda \leq 0.2$. A. A. Abdel-Hamid, et al, [11] they have made an evaluation of static and dynamic studies of Savonius rotor performance. This evaluation has made with the aspect of overlap ratios which help in a numerical analysis using turbulence models. The static and dynamic test has performed different angles with the five rotors which having two semi-circular blades with different overlap ratios. The resulted readings compared with the other turbulent models and found that the pressure recovery effect created when the aspect ratio changes the torque co-efficient also leads to changes as increase by increasing. N. H. Mahmoud, et al, [12] they have made an experimental study on improvement of Savonius rotor performance for solving and managing the world problem of reduction of fossil fuels. Now everyone has turned to renewable energy especially wind energy. In this wind energy is cheaper and simpler energy works is from the Savonius rotor with the vertical axis wind turbine. Experiments have made in this and found that rotor with two blades is more efficient than three or four. The efficiency is higher with the construction end plates and the double stage rotor has higher performance than a single stage. The result shows the aspect ratio is increasing as the measure of static torque of each rotor confirms that.

Rajan Pudur, et al, [13] has made a scheme of the grid-connected Savonius rotor of hydrokinetic power generation with the asynchronous generator. For this generator, the Savonius rotor acts as a prime mover. The system provides the power input variable wind energy conversion system. An AC-DC-AC converter is used to convert the input power generation of the effect of changes in the performance. They test in various load condition with multiple inputs in various components, filters and converter especially by d-q control method and observed performance from that is satisfactory. A. Damak, et al, [14] they have been attempted a optimization of the helical Savonius rotor through wind tunnel experiments. They made the test on the combination of helical rotor and back rotor of a helical back rotor. The back rotor has the high value of CP, but it has negative static torque coefficient, the negative values also helpful to start of its own in certain rotor angle. The helical rotor has a low value of Cp but has high static torque coefficient. The new design of combination is attempted to evaluate the power coefficient, static torque coefficient. The result shows that the helical back rotor obtained at (0.2) CP which is more than the helical rotor power coefficient of (0.18). Miguel Angel Rubio-

Paramio, et al, [15] they have been tested a new rotor adopted from a Savonius rotor with the parametric model to the dimensions and geometry of product design this transforms initial cylindrical buckets into the topological surface with an organic shape. The new modified Savonius rotor based on the product design requirement and the conventional Savonius rotor has the same aspect ratio is tested in the open jet wind tunnel to find the effect of product design parameters on rotor performance by means of Cp, torque coefficient. The experimental results coincide with (3.5%) error. The results are analyzed by the angle of rotation of turbines of the angle at (45^o) the Cp is 32% improved compared to the angle at 0o. The new rotor designed is aimed to require a moderate energy generation by new product design easy manufacturing and maintenance at equally a dap table as the conventional Savonius rotor. Roberto Romagnoli et al, [16] they have made the experimental study on a Savonius wind rotor for a street lighting system. They investigate the aerodynamic performance of the Savonius rotor for a lamppost. The major aim is to find the changes or effect of Savonius rotor performance based on the different construction and they found by using the wind tunnel test. Tests made at different velocities and different constructions. The result of test range (2-3.3*105) is obtained that increases power coefficient. The better configuration gives the better results for the lighting systems. Rajesh Kumar Sharma, et al, [17] they have made the investigation CFD (Computational Fluid Dynamics) measure the effect of multi miniature blades on the performance of Savonius rotor. The numerical simulation software is used to measure the improvement of COF of a basic configuration of the conventional Savonius rotor. The modified configuration made by a miniature blade of Savonius rotor. Many studies like validation and grid convergence studies, shear stress transport turbulence model is used for numerical calculations. At last, they found an improvement in the coefficient of performance between 8.1%-11.34% is achieved with modification of miniature blades with an achievement of grid refinement through the grid convergence study.

Olfa Mlayah, et al, [18] they have been made the numerical simulation and experimental validation of the turbulent flow around an incurved Savonius rotor. This test has been made by the use of the wind tunnel to know the performance of incurved Savonius rotor compared to a formal Savonius rotor. The "Solid works Flow Simulation" software is used to present the local characteristics. The numerical models are considered on the basis of Navier Stokes equation and solved by the finite volume discretization method to validate the calculated numerical method results. The experimental results made on the small incurved Savonius rotor in a wind tunnel. In comparison with the circular Savonius rotor, the fluid flow circulation is improved. Slah Driss, et al, [19] they have been made a study on the incidence angle effect on the aerodynamic structure of an incurved Savonius wind rotor. This test has made in wind tunnel. The numerical simulation is made on the basis of Navier Stokes equation and solved by finite volume discretization. The "Solid works Flow Simulation" software is used to know the flow characteristics. The experimental has done in wind tunnel with the help of testing they found that the incidence angle on incurved Savonius rotor has a direct effect on the local characteristics. The effects are a large recirculation zone form action (θ=45o) and two recirculation zone at (θ=90o). The maximum velocity values are generated and compared with the numerical and experimental result confirms the validity of the numerical method.

3. Conclusion

Thus the Savonius rotor has increased the performance of power generation by the modified turbine blades with cut slot of compartment. Although it may use to generate energy by wind it can't be replaced with Horizontal axis wind turbines. This test attempt is conducted to resolve the power loss by rotor vibrations and similar ones. Thus the modified Savonius rotor which provides the more performance as compared to normal Savonius rotor by eliminating the vibration of blades and reduce loss of energy.

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