DEVELOPMENT AND TESTING OF ADVANCE HYBRID SAVONIUS AND ARM GEAR BASED STRUCTURE FOR ELECTRIC POWER GENERATION

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ABSTRACT

Wind energy is becoming the most important renewable source in terms of globally installed capacity, after solar and hydro power. China is experiencing a rapid expansion in the wind power industry. This paper provides a good overview of the current status and future development of wind generation. As per the technical evolution and technical trends consideration so we have created a “Advanced Hybrid Savonius and arm gear based effective Mechanical Structure for Multi-Station Optimized Power Generation. This system uses an advanced savonius hybrid turbine which will rotate over multiple natural resources water force, wind power and related parameters having efficiency greater than aerodynamic turbine. The advancement of this turbine is that, this turbine not only rotate over multiple natural resources and artificial resources but also having capability of resources settlement into it according to multiple savonius blade structure. This is advanced technical structure created specially taken vision over multiple natural resources and artificial resources. This structure having natural resources settlement and reutilization capacity, that means this structure not only uses multiple resources i.e. wind power, water force and other but also settle them to reutilization so that this turbine rotate with more toque and able to create more output so that we can able to charge battery within minimum time. Also this paper discusses medium and long-term planning goals of wind energy.
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**Keywords:** Savonius Turbine.


1. **INTRODUCTION**

This is not a simple structure like simple turbine. This is advanced technical structure created specially taken vision over multiple natural resources and artificial resources. This structure having natural resources settlement and re-utilization capacity, that means this structure not only uses multiple resources i.e. wind power, water force and other but also settle them to reutilization so that this turbine rotate with more torque and able to create more output so that we can able to charge battery within minimum time.

The Savonius turbine is one of the simplest turbines. Aerodynamically, it is a drag-type device, consisting of two or three scoops. Looking down on the rotor from above, a two-scoop machine would look like an "S" shape in cross section. Because of the curvature, the scoops experience less drag when moving against the wind than when moving with the wind. The differential drag causes the Savonius turbine to spin. Because they are drag-type devices, Savonius turbines extract much less of the wind's power than other similarly-sized lift-type turbines. Much of the swept area of a Savonius rotor may be near the ground, if it has a small mount without an extended post, making the overall energy extraction less effective due to the lower wind speeds found at lower heights.

![Schematic Drawing Showing the Drag Forces Exerts on Savonius Blades](image)

**Figure 1** Schematic Drawing Showing the Drag Forces Exerts on Savonius Blades

Most anemometers are Savonius turbines for this reason, as efficiency is irrelevant to the application of measuring wind speed. Much larger Savonius turbines have been used to generate electric power on deep-water buoys, which need small amounts of power and get very little maintenance. Design is simplified because, unlike with horizontal axis wind turbines (HAWTs), no pointing mechanism is required to allow for shifting wind direction and the turbine is self-starting. Savonius and other vertical-axis machines are good at pumping water and other high torque, low rpm applications and are not usually connected to electric power grids. They can sometimes have long helical scoops, to give smooth torque.
2. LITERATURE REVIEW

Mustafa Tutar et al. (2014) studied Performance analysis of horizontal axis 3-blades savonius turbine in an experimental wave flume, in which increasing wave height at the specified wave period leads to higher average rotational speed and the torque for each experimental case regardless of which submergence level is adjusted. However, it is well observed that the relative effect of wave height on the rotational speed or the torque is higher than that of wave period and/or of submergence level over the investigated ranges of the parameters for the present intermediate water depth conditions. The effective (rms) rotational speed and the torque tend to increase with increase of the wave height and wave period regardless of which submerge level is adjusted. The best performance of these values are obtained at the wave height of 200 mm and the wave period of 3.0 s, where the intermediate water depth conditions are satisfied, at a submerge levels of 0 mm and 50 mm. Due to the present experimental wave conditions of discontinuous and overtopping wave flow in the wave flume and the low mass moment of inertia of the rotor structure, without external, dynamically control of the rotational speed by using a proper dynamic braking system, the rotor will undergo a clockwise and counter clockwise varying rotational motion, outside of the maximum optimized speed range during the most of the wave cycles, which in turn leads to lower effective wave-to-mechanical ECE. Therefore, possible design optimization studies of such systems should be concentrated on dynamic control of rotational speed.

Zied Driss et al. (2014) studied Numerical analysis and experimental validation of the turbulent flow around a small incurved wind rotor, in which velocity fields, pressure and turbulent characteristics, are presented in different longitudinal planes of the wind tunnel, considered as a control volume. According to the obtained results, the incurved savonius wind rotor has an effect on the local characteristics. In comparison with a circular Savonius rotor, the fluid flow circulation of this rotor is improved. Experimental results were conducted on an open wind tunnel equipped by a small incurved Savonius wind rotor and compared to the numerical results, which validated the numerical model. Use of this knowledge will assist the design of packaged installations of incurved Savonius wind rotor

N.H. Mahmoud et al. (2012) studied An experimental study on improvement of Savonius rotor performance. In this experiment various rotors with two, three and four blades; with single and double stages; with end plates and without end plates; with aspect ratios of 0.5, 1, 2, 4 and 5 and with different overlap ratios from 0 to 0.35 are investigated experimentally to determine the optimum geometries of Savonius turbine. It was found here that, the two blades rotor is more efficient than three and four blades rotors. The rotor with end plates gives higher efficiency than those without end plates. Double stages rotor have higher performance than single stage rotor. The rotors without overlap ratios are better in operation than those with overlap. The results show also that the power coefficient increases with the rise in aspect ratio .The conclusions of the measurements from the static torque for each rotor at different wind speeds make verification of the above concluded results of this work.

Jend Sudirman et al. (2008) studied An experimental study on the performance of Savonius wind turbines related with the number of blades. In this experimental study the three blades wind turbine model has the highest tip speed ratio. In general the three wind turbine models have significant tip speed ratio at lower wind speed and more stable at wind speed of 7 m/s. It means that the wind turbine models has optimal
rotational speed at the wind speed above 7 m/s. Tip speed ratio is related with the performance of rotational speed of wind turbine rotor. Wind turbine with higher rotation will result in higher tip speed ratio. Three blades wind turbine model has the highest tip speed ratio at 0.555 with the wind speed of 7 m/s.

R.D. Maldonado et al. (2011) studied Design simulation and construction of a Savonius wind rotor for subsidized houses in Mexico. In this work, a study of velocity as a function of overlap ratio (R) in a Savonius type rotor was proposed. The implementation of the R factor in Savonius wind turbine allows an air flow pass in the opposite direction to the convex blade, this cause a torque in favor to the Savonius rotor. Likewise, the implementation of curtains in the Savonius rotor increases the torque to the rotor. When flow of air has a different direction from the angles of the window, the system will operate as a conventional Savonius. An analysis was made in the Savonius rotor speeds as a function of incident angle of the flow air on the blades. It was observed that for angle 120° yielded a maximum speed of 9.049 m/s with a pressure of 40.58 Pa, while the maximum of pressure was obtained at 69.1 Pa with a speed of 8.18 m/s for angle 0°. Finally, a study of speeds and maximum pressures as a function of incidence angles in the windows proposals for the Savonius rotor was proposed. The maximum speed with maximum pressure were found for the angles α=30° and β=40°. The proposed input configurations in curtains increase the speed of the Savonius rotor and consequently increase the Cp thereof. It was observed that for different configurations raised, the configuration α =30° and β=40 ° can increase the speed of entry to the Savonius rotor of 5 m/s to 8.18 m/s i.e, increases by 62% the input speed with the given conditions, quadruples the input power to the rotor. The simulation results will allow obtaining the best setting of blades for the optimal Cp of the Savonius rotor.

Fewderikus Wenehenubun et al. (2014) studied An experimental study on the performance of Savonius wind turbines related with the number of blades. He found the relationships between wind speeds and tip speed ratio or actual torque which shows that the three blades wind turbine model has the highest tip speed ratio. In general the three wind turbine models have significant tip speed ratio at lower wind speed and more stable at wind speed of 7 m/s. It means that the wind turbine models has optimal rotational speed at the wind speed above 7 m/s. Tip speed ratio is related with the performance of rotational speed of wind turbine rotor. Wind turbine with higher rotation will result in higher tip speed ratio. Three blades wind turbine model has the highest tip speed ratio at 0.555 with the wind speed of 7 m/s. This experiment gives the relationship between the actual torques of the shaft of wind turbine models for different wind speed. Four blades wind turbine model has higher torque than that two or three blades wind turbine. Wind turbine model with four blades has more drag force at any position when the wind rotor is in rotational position. Wind turbine rotor with more number of blades will deliver higher torque for the shaft of the turbine. Number of blades related with the solidity of wind turbine, higher solidity will give also higher torque for the wind turbine.

Ahire Vaishali et al. (2014) studied Optimization of Savonius rotor for wind turbine. Flow analysis for the modified Savonius rotor is done for the range of wind velocity from 2 m/s to 8 m/s, and the computational domain is 5m x 5m x 15m for the internal flow analysis. In this paper from the calculations and analysis we can see that the power generation capacity of modified Savonius rotor is more as compare to conventional Savonius rotor. The theoretical power generated by the conventional Savonius rotor is 21.24 watt. And for the modified Savonius rotor the theoretical power is 42.48 watt.
power generated is 97.26 watt power generation calculated by analysis of modified Savonius rotor is 31.75 watt which is much greater than the power generated by conventional Savonius rotor.

**Jeff Whalley et al. (2013)** studied Effect of turbulence on Savonius rotor efficiency. He found a correlation between turbulence and power generation of a Savonius rotor. The location of the rotors led to distinct decreases in power on our test rotor, with several strong trends emerging. Result shows, several predictable patterns were observed. In relation to the baseline power output, the least loss in power generation occurred while in the Far Center configuration Contrary to predictions of Far Split being the best configuration, the Center rotor was the superior choice. The strange behavior of several rotor configurations in the initial two data points’ worth of testing is the result of some configurations starting to rotate and others not at these 30-40% wind tunnel settings, essentially creating infinitely greater/lesser percentages. At 30%, several of the configurations produced sporadic power generation without constant revolution. The exception to this was the Far Center configuration, which actually started the test rotor at 30%. He believe this was due to a funneling of wind speed and pressure to the test rotor, causing it to start. In general, having the rotors further away was better than closer, which is expected based on the flow reorganizing into less turbulent flow over time and distance. The eddies and vortices being shed by the rotor decreased in strength with distance, negating the effects of the rotors further away. The Split configurations had a 24% decrease over the baseline power generation, which was a full 10% better than the next best configuration, Center. The configurations of Center Left and Center Right were far worse on a performance basis, on average 52% less than the Baseline power generations, due to the sheer volume of turbulence causing material in the way of the path.

**Mohammed Hadi Ali et al. (2013)** studied Experimental Comparison Study for Savonius Wind Turbine of Two & Three Blades At Low Wind Speed. This experiment's was carried out and tested in the wind tunnel and the required measurement were obtained to study the performance of the two blades and three blades savonius wind turbine and makes the comparison between them to see which one is better in performance than the other. The performance [the dimensionless parameters torque coefficient (Ct) and power coefficient (Cp)] was evaluated as function of the dimensionless parameter the tip speed ratio (λ) at low wind speeds in terms of starting acceleration and maximum no-load speed. Graph shows the plot between the wind (air) speed and the rotor revolution (rpm) for both two and three blades savonius wind turbine, it appears that as the wind speed increases from [(0 m/s) upto (3 m/s)] where the savonius wind turbine is initiated and starts to move. The wind velocity where the wind turbine starts to move, the wind velocity is called the cut in speed, the low cut-in speed for this type of wind turbine which is about (2.5 m/s) and two blades savonius is a little bit lesser than three blades. The static torque for both two and three blade is found to be positive at any angle, high enough to obtain self-starting conditions. The reason is that increasing the number of blades will increase the drag surfaces against the wind air flow and causes to increase the reverse torque that leads to decrease the net torque working on the blades of savonius wind turbine. Figure shows the power coefficient for both two and three blades savonius wind turbine, it appears that the power coefficient for two blades has a noticeable increasing values than the three blades. It appears that the two blades savonius wind turbine has it highest value of (0.21) at the tip speed ratio of (0.8), the three blades has a value of (0.17) at the tip speed ratio of (0.8).
Marco Torresi et al. (2013) studied Performance and flow field evaluation of a Savonius rotor tested in a wind tunnel. A two-bucket Savonius rotor prototype, obtained from a PVC pipe, has been tested inside the closed loop, subsonic, wind tunnel at the Department of Mechanics, Mathematics and Management (DMMM) of the Politecnico di Bari. Results have been given in terms of turbine performance and flow-field analysis. In a wide range of tip speed ratios (from 0.3 up to 1.5), the torque coefficient shows a linear dependence with respect to the tip speed ratio, with the highest value at the lowest \( \lambda \). When considering the polar diagram of the phase-averaged shaft torque, this evidences its typical bilobed shape. However, even if the rotor is characterized by a geometrical symmetry of 180\(^\circ\), this is not the case for the shaft torque coefficient characterized by a lack of periodicity every half revolution due to the complex interaction of the vortex shedding with the rotating buckets. Averaged flow field analyses upstream and downstream the rotor have been performed. Furthermore, the wake downstream of the Savonius rotor has been described. From phase-averaged visualization, the main flow characteristics have been described and the lack of a perfect 180\(^\circ\) periodicity in the turbine behavior has been again put in evidence.

Norzanah Rosmin et al. (2014) studied Experimental study for the single-stage and double-stage two-bladed Savonius micro-sized turbine for rain water harvesting (RWH) system. From the obtained results, it can be concluded that the electrical generation using the proposed RWH system depends highly on the efficiency of the ability of blade rotor’s rotation. When the speed of rotor rotation is increased, the output power can be increased as well, as has been proven from the executed experimental. The height between the bottom storage tank from the mounted rotor also influence the rotor performance. When the height is shorter, water will strike the rotor shortly and thus, the rotor can automatically spin faster compared to the condition when longer height is set. The single-stage two-bladed Savonius rotor can rotate up to 1280 rpm when 60 litres water in the tank is stored before released the water to flow into the pipeline. In terms of performance, single-stage rotor produced better performance than double-stage rotor. Power can be generated almost double than the double-stage rotor when single-stage rotor is used, thus supplying a 0.3 watt LED lamp successfully. Based on the findings that have been observed and obtained from the executed study, it can also be concluded that the proposed RWH system is project may give a good potential to be used and commercialized for home application if the designed system is further upgraded to increase the entire system performance and reliability. Also, it can be conclude that the Savonius rotor is applicable to be used as the RWH’s turbine since this rotor manage to rotate fast, simple and easy to be designed and employed.

Bagus Wahyudi et al. (2014) studied Optimization design of Savonius diffuser blade with moving deflector for hydrokinetic cross flow turbine rotor. The use of pressure difference between the upstream and downstream as a parameter that represents the torque of rotor allows us to predict performance through optimization based on CFD simulation. An optimization design of savonius diffuser blade using CFD simulation shows that the selection procedure of radius tandem relying on RSM method can be employed for a quantitative optimize of the performance provided in a range of tandem radius. The best design of deflector can choice by plotting both models in range of diameter (Dtp) and the velocity ratio on narrow gap (Rcv) on graphics aerodynamic performance. The savonius diffuser blade rotor with moving deflector improves the velocity ratio on narrow gap (Rcv) for almost all
configurations and improves the torque due to forces in the return blade which generated by “jet effect” through the narrow gap in the middle of rotor. Meanwhile the Savonius convergent tandem blade turbine without deflector shows there are negative values for the static moment in some range, by using the deflector leads to a positive static moment value at any tip diameter for both angle deflector designs with radial direction (model 2) and tangential direction (model 1). The best size result of diffuser design using convergence model with hub diameter D = 68 [mm] is obtained Rt = 27 [mm] or 0, 4 D; e = 2.75 [mm] or 0.04 D; and using Tangential Moving Blade (moving deflector) with Tip diameter Dtp = 140 mm or 2.06 D that is capable to generate maximum power shaft or minimum pressure drop on CFD simulation.

3. CONCLUSION

Literature survey shows the improvement in power generation by using savonius turbine. However only little work is done with combination of savonius unit and arm gear based structure for multistation power generation. The present study is carried out to produce maximum power in low rpm of air also. This system uses an advanced savonius hybrid turbine which will rotate over multiple natural resources water force, wind power and related things having efficiency greater than aerodynamic turbine. The advancement of this turbine is that, this turbine not only rotate over multiple natural resources and artificial resources but also having capability of resources settlement into it according to multiple savonius blade structure. Advantages of advance hybrid savonius as compared to other system is that, on one single Savonius structure unit we can able to rotate multiple power substation and other power station uses single turbine which will rotate only single generator.

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