FLYWHEEL: JURNAL TEKNIK MESIN UNTIRTA

Homepagejurnal: http://jurnal.untirta.ac.id/index.php/jwl

Effect of Deflector Angle Into Various Blades Configuration of Single Stage Vertical Axis Savonius Hydro Turbine Performance

Gad Gunawan[1*] , Doddy Suanggana[2], Yun Tonce Kusuma Priyanto[3]

[1]*Dept. of Mechanical Engineering, Institut Teknologi Kalimantan, Balikpapan 76127, Indonesia.*
[2]*Dept. of Mechanical Engineering, Institut Teknologi Kalimantan, Balikpapan 76127, Indonesia.*
[3]*Dept. of Electrical Engineering, Institut Teknologi Kalimantan, Balikpapan 76127, Indonesia.*

*Corresponding author: gad_gunawan@lecturer.itk.ac.id

ARTICLE INFO

Received 29/8/2020
Revision 9/11/2020
Accepted 17/11/2020
Available online 23/11/2020

ABSTRACT

Today, the exploitation of energy leads to renewable energy. One of the renewable energy is water flow energy. The Savonius Hydro Turbine is a type of water turbine which is suitable for low flowing velocity. One method for increasing the performance of the Savonius Turbine is by using a deflector. This study aims to see the effect of using a deflector on the Savonius Hydro Turbine's performance. The methodology used in this research is testing with variations in the number of turbine blades and deflector angle. The number of turbine blades used was two, three, and four blades, while the deflector angles used were 0°, 20°, 40°, 60°, and 80°. The result shows that using a deflector angle of 80° make turbine inlet flow is better. From the three blades Savonius Hydro Turbine, The best performance is obtained on 80° deflector angle with power 0.154 Watt and coefficient of power 0.132.

Keywords: *Savonius Turbine, deflector, blade, performance*

1. BACKGROUND

The potential for renewable energy that we can use from our nature is abundant, like a stream of water, wind, and sunlight. This research focuses on the utilization of energy from the water flow. Water's choice as an energy source is because water is relatively present in every corner of Indonesia, chiefly Kalimantan Island[1]. a water turbine is using to extract the water stream's energy.

River current energy conversion systems (RCECS) are electromechanical energy converters that convert river water's kinetic energy into other usable forms of energy[2]. The Savonius Turbine is One type of turbine which is suitable for low flow velocity. Sigurd Johannes Savonius first introduced the Savonius Turbine from Finland in 1922. This turbine has advantages because of its simple construction[3]. The Savonius Turbine is a Vertical Axis Wind Turbine (VAWT) which is suitable for providing small electrical power, for example, for powering electronic devices, charging cell phones, or lighting [4,5]. Initially, the Savonius turbine was used for wind energy utilization and also can be used for water flow[6]. Figure 1 shows the Savonius Hydro Turbine.

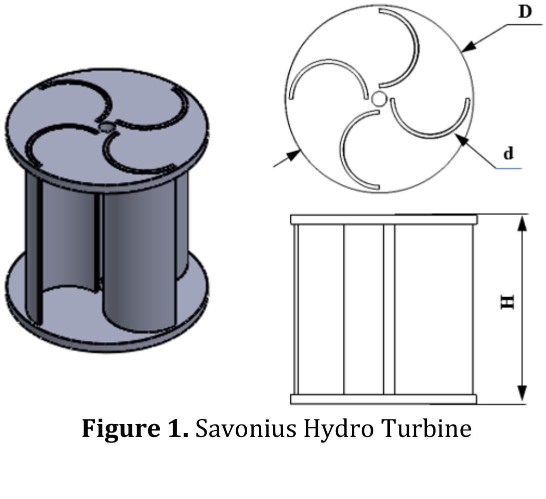

Figure 1. Savonius Hydro Turbine

The Savonius Turbine has a simple design, low operating speed, and can operate for any direction of the wind but has low efficiency and high negative torque[7]. The efficiency of conventional Savonius wind rotor is around 15%[8]. Investigation of the Savonius Turbine with a variation of the number of blades shows that the best performance is a turbine with three blades [9,10]. Modification blades for inside pipe application show improvement performance until five blades[11]. Many studies were done to increase the performance of the Savonius Turbine. Hadi et al.[12] investigated the effect of twisted semicircular blades of horizontal axis Savonius Hydro Turbine and show performance improvement compared with conventional blades, and by adding endplates[13] can also improve the efficiency.

Savonius turbines are a type of turbine called drag-type rotors[14]. The Savonius Hydro Turbine rotates because of the difference in drag on the blades[15,16]. Figure 2 shows that the water flow on the concave side of the turbine blade provides a more significant drag than the other blades so that the turbine rotates clockwise. The convex part of the other blade or returning blade moves in the opposite direction of flow, causing negative torque opposite the turbine rotation.

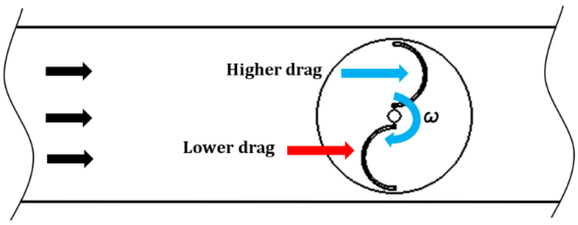

Figure 2. Savonius Hydro Turbine

For preventing the negative torque opposite the rotor rotation, curtain arrangement, or obstacle shielding was placed in front of the returning blade that shows increasing efficiency of Savonius Wind Turbine. A new metamodel-based optimization approach to determine the optimal shape of the deflector plates for vertical axis Savonius Wind Turbine was presented by Storti et al.[17]. Investigation place a deflector (Fig.3) in front of returning blade Savonius Hydro Turbine both on the vertical axis and on the horizontal axis. Several configurations of deflector show performance improvement compared to without deflector plate[18,19].

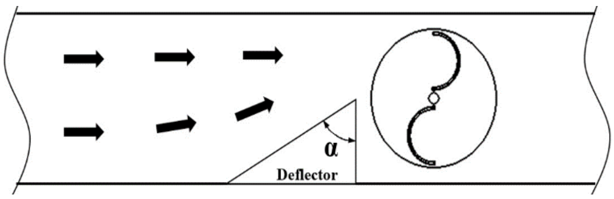

Figure 3. Savonius Hydro Turbine deflector

Another study, similar using a ducted nozzle as a deflector. A nozzle was made with a small section right in front of the concave turbine blade.

In this research, we use numerical simulation methods with variations in the nozzle inlet and outlet width ratio. The simulation results show that the increase in the power coefficient is 78% compared to the conventional modified rotor. In other cases, Thakur et al. [20] do CFD simulation using an impinging jet duct design to increase the Savonius Hydro Turbine's performance. Like that case, Antar et al. [21] made an optimal casing for Savonius Wind Turbine.

2. METHODOLOGY

Figure 4 shows The method used in this research. A literature review was conducted to see the studies that have been carried out before.

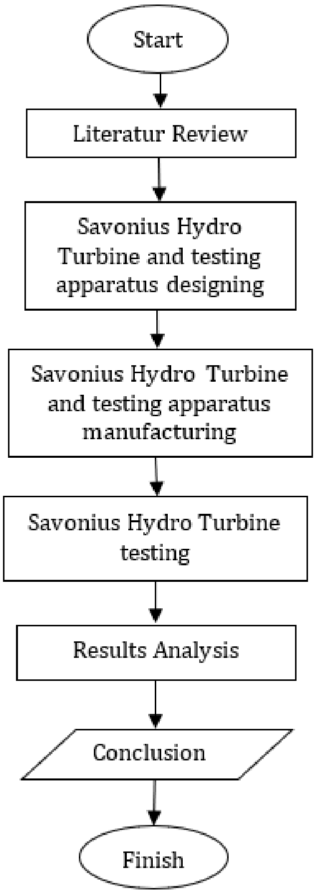

Figure 4. Research Flowchart

Figure 5. Savonius Hydro Turbine: (a) two blades; (b) three blades; (c) four blades

Based on the literature review results, the variations that will be carried out in the study were selected. This study used variations in the number of turbine blades, two, three, and four, as shown in Figure 5, and using a variation of the angle (α) of the deflector plate shown in Figure 3. Variations of the deflector angle are 0°, 20°, 40°, 60°, and 80°. The length of the side of the angle (α) is kept constant, which is 6 cm, while the front side and hypotenuse side vary depending on the angle (α) used.

The dimensions of the Savonius Hydro Turbine used are in Table 1.

Table 1. Turbine Dimensions

No.	Parameter	Symbol	Value	Unit
1	Turbine Diameter	D	10	cm
2	Blade Diameter	d	4.2	cm
3	Turbine Height	H	10	cm

Savonius Hydro Turbine testing apparatus as follow.

1. Water reservoir
2. Penstock/runner
3. Turbine and Prony Brake pedestal
4. Savonius Turbine
5. Deflector
6. Prony Brake

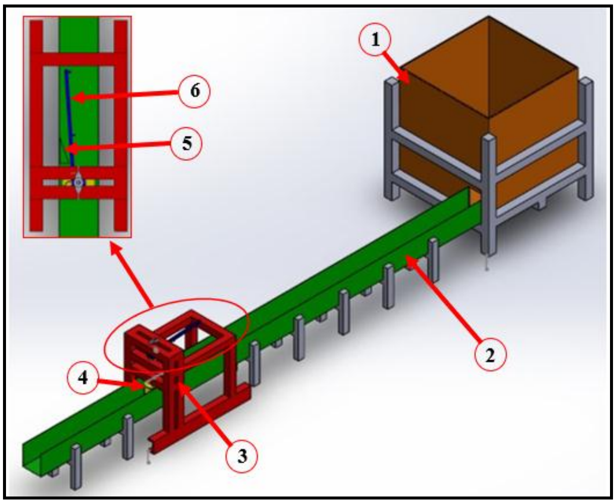

Figure 6. Testing Installation

The research was carried out using a water flow rate of 6 ls-1. Turbine rotation is measured using a tachometer, while the torque generated by the turbine is obtained using a prony brake. It weighs on the prony brake measured with a digital scale with a maximum measurement of 200 grams and an accuracy of 0.01 grams. The amount of mechanical power (P) was obtained from the product of Torque (T) and angular velocity (ω) as in equation 1.

$$P = T.\omega \quad (1)$$

The power coefficient (Cp) is the ratio between the amount of mechanical power generated by the turbine divided by the potential power contained in the flow, mathematically written in equation 2 with ρ is the density of the fluid. A is a crosssection of the flow, and v is flow velocity.

$$C_p = \frac{2P}{\rho A v^3} \quad (2)$$

Another parameter used for data analysis is the Tip Speed Ratio (TSR), which is the ratio between the linear velocity at the tip blade divided by fluid flow velocity. The next step in this research is to analyze the test results and conclude that relevant to the results.

3. RESULTS AND DISCUSSION

3.1. Two Blades

The results of the two blades Savonius Hydro Turbine test are showing in Figure 7, the relationship between TSR and power coefficient (Cp) with deflector angle (α) variations[22]. The graph shows that using a deflector increases the power coefficient of a two blades Savonius Turbine compared to without a deflector.

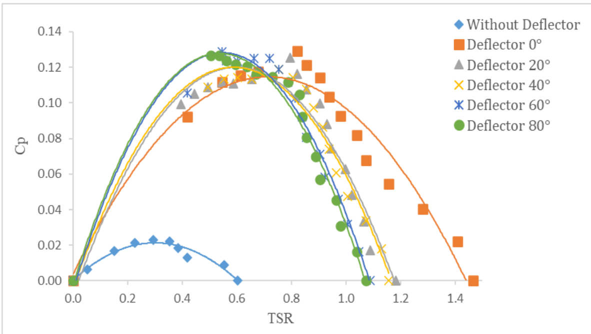

Figure 7. Relationship TSR and Power Coefficient (Cp) of two blades Savonius Hydro Turbine

Table 2 shows the maximum power coefficient for each variation from the experiment. The highest power without a deflector is around 0.027 Watt, a large increase to an average of 0.125 Watt with using a deflector. The use of this deflector is proven to reduce the flow drag on the turbine rotation. Based on the test results with the conditions described previously, the difference in power for each deflector angle variation for the two blades Savonius Hydro Turbine is not too large. The highest power is at an angle of 0° of 0.129 Watt, and the lowest power is using a deflector with an angle of 40°, which is 0.119 Watt or a difference of 8% from the lowest value.

Table 2. Power Coefficient of two blades Savonius Hydro Turbine

No.	Variation	Cp_{max}	Power (Watt)
1	Without Deflector	0.023	0.027
2	Deflector 0°	0.129	0.151
3	Deflector 20°	0.125	0.146
4	Deflector 40°	0.119	0.139
5	Deflector 60°	0.125	0.146
6	Deflector 80°	0.127	0.148

Figure 8 shows streamflow two blades Savonius Hydro Turbine. Figure 8a shows the turbine without using a deflector. The convex side of the turbine must oppose the water flow. As a result, the power received on the blade's concave side is used partly on the blade that rotates against the current, causing the power produced by the turbine to below. The deflector is used to direct the flow from the side of the blade that rotates against the current to the part that rotates in the flow direction. This method reduces the power of the turbine itself due to the blade rotating against the current.

a)
b)
c)
d)
e)
f)

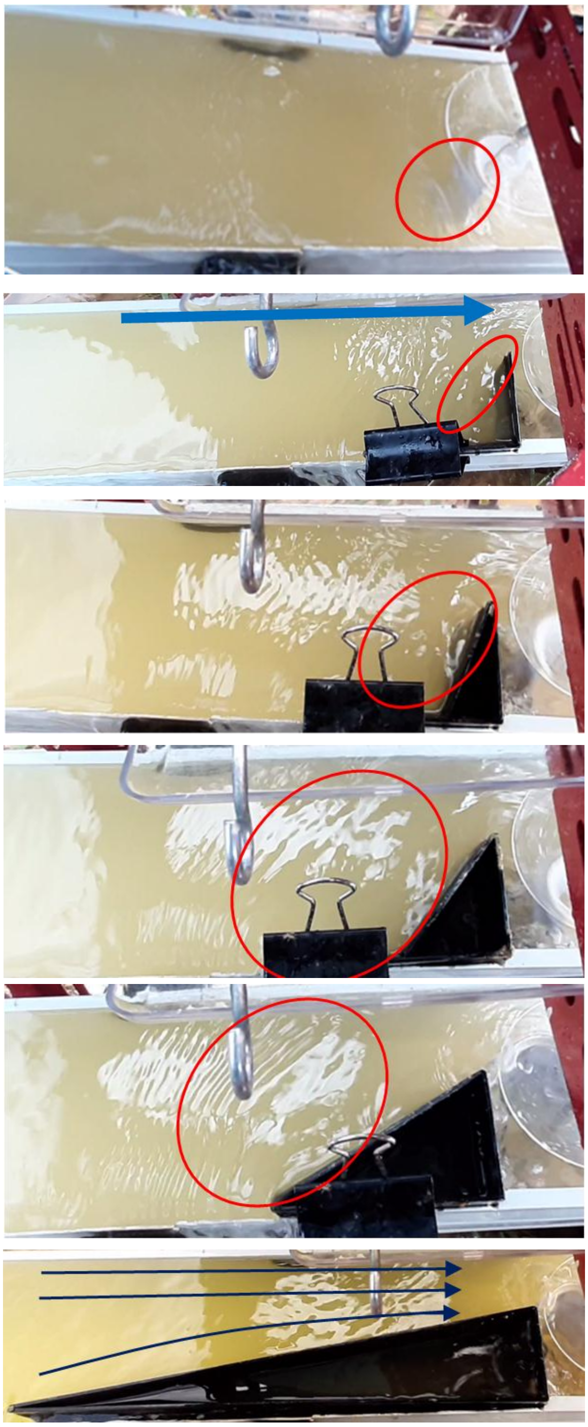

Figure 8. Streamflow two blades Savonius Hydro Turbine : (a)Without deflector; (b)Deflector 0°;(c)Deflector 20°; (d)Deflector 40°; (e)Deflector 60°; (f)Deflector 80°

However, adding a deflector for the conditions as in this test affects the flow conditions in front of the turbine. The flow hitting the deflector will create a back wave, which disrupts the water flow due to the flow momentum before hitting the deflector. We can see that the flow hitting the deflector at the 0° deflector slightly still interferes with the flow that will hit the blade. Things start to be different with deflectors with an angle of 20°, 40°, and 60°. At these three angles, the main flow that will lead to the turbine blade begins to be disturbed by the back wave from the water flow hitting the deflector and the turbine movement, as shown in Figure 8. As a result of the waves that are opposite to this flow's direction, the kinetic energy of the flow that will hit the blade diminishes. Based on the test data, there is a decrease in power at these three deflector angles compared to the 0° angle.

The deflector with an angle of 80° indicates the increase in the power of the turbine. Based on Figure 8, the flow at this angle tends to be more stable than the angle deflector of 20°, 40°, and 60°. The deflector with an angle of 80° with a long shape and sharp angle is in front of the flow. So that the flow hitting the deflector tends to be deflected according to the direction of flow. In contrast to 20°, 40°, and 60° angle deflectors with poor shape, this deflector's longer shape provides an opportunity for the flow to stabilize the flow streamline due to changes in the flow cross-section. The flow view at an 80° angle deflector shows no fluid movement against the direction of flow. This condition causes the turbine to receive a maximum flow of kinetic energy.

3.2 Three Blades

The three blades Savonius Hydro Turbine test results show in Figure 9, the relationship between TSR and power coefficient (Cp) with deflector angle (α) variations. The results are similar to the two blades Savonius Turbine; there is an increase in power using a deflector compared to without a deflector.

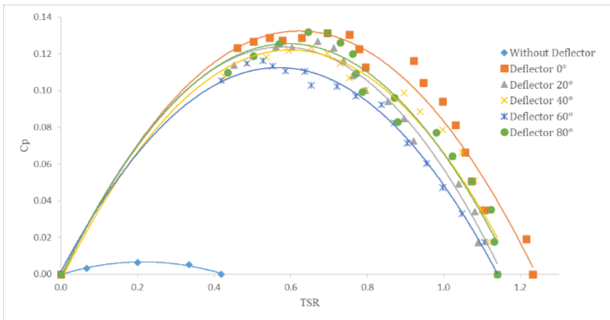

Figure 9. Relationship TSR and power coefficient of three blades Savonius Hydro Turbine

Testing the three blades Savonius Hydro Turbine using a deflector shows the highest power and power coefficient lies at the deflector angle of 80°, which is 0.154 Watt and 0.132. However, the difference is tiny compared to others, as can be seen in Table 3. Testing the three blades, Savonius Hydro Turbine also shows the same tendency as the two blades, the power decrease at the deflector angle of 20°, 40°, and 60°.

Figure 10 shows the same phenomenon as the two blades Savonius Hydro Turbine. There is a disturbance to the deflector's flow at angles 20°, 40°, and 60°, due to massive changes in the cross-section[23]. The flow deflected by the deflector creates a flow wave against the direction of the flow so that it can reduce the kinetic energy of the flow that will rotate the turbine. With an angle of 80 °, the deflector's flow view shows that the streamlines do not block each other as at the three angles mentioned before to have better power and power coefficient.

Table 3. Power Coefficient of three blades Savonius Hydro Turbine

No.	Variation	Cp_{max}	Power (Watt)
1	Without Deflector	0.006	0.007
2	Deflector 0°	0.131	0.153
3	Deflector 20°	0.127	0.148
3	Deflector 40°	0.124	0.144
3	Deflector 60°	0.116	0.136
3	Deflector 80°	0.132	0.154

a)
b)
c)
d)
e)

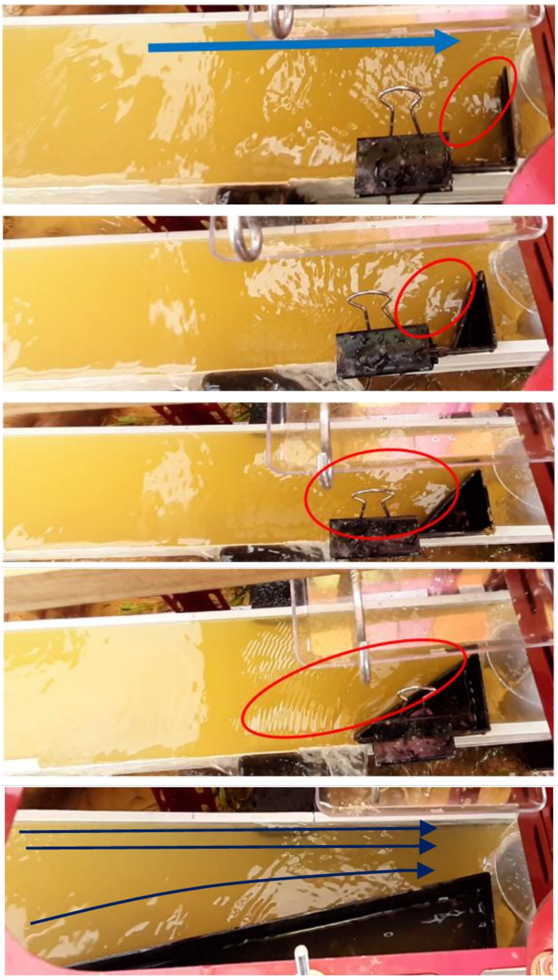

Figure 10. Streamflow three blades Savonius Hydro Turbine with a deflector : (a)Deflector 0°; (b)Deflector 20°;(c)Deflector 40°;(d)Deflector 60°; (e)Deflector 80°

3.3 Four Blades

The four blades Savonius Turbine test results are shown in Figure 11, the relationship between TSR and power coefficient (Cp) with deflector angle (α) variations.

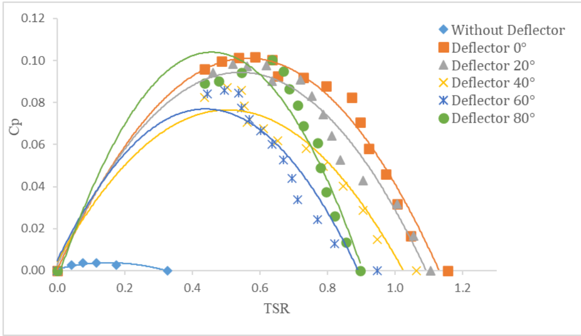

Figure 11. Relationship TSR and Power Coefficient (*Cp*) of four blades Savonius turbine

a)
b)
c)
d)
e)

Figure 12. Streamflow four blades Savonius Hydro Turbine with a deflector : (a)Deflector 0°; (b)Deflector 20°; (c)Deflector 40°; (d)Deflector 60°; (e)Deflector 80°

The results were similar to two and three blades; the turbine power coefficient increases using the deflector. Table 4 shows the turbine power increased from 0.004

Watt without a deflector to an average of 0.11 Watt in the presence of a deflector.

Table 4. Power Coefficient of four blades Savonius Hydro Turbine

No.	Variation	Cp_{max}	Power (Watt)
1	Without Deflector	0.004	0.004
2	Deflector 0°	0.102	0.119
3	Deflector 20°	0.098	0.114
3	Deflector 40°	0.087	0.102
3	Deflector 60°	0.086	0.100
3	Deflector 80°	0.100	0.117

The deflector angle variation test for two, three, and four-blade Savonius Hydro Turbines also shows the same trend. The difference between the highest and lowest power in the Savonius Hydro Turbine with a variation of the deflector angle is also not too large, namely 0.019 Watt. There is a slight decrease in power at deflector angles of 20°, 40°, and 60° due to changes in the flow cross-section as previously described. Figure 12 shows the flow pattern in front of a four blades Savonius Hydro Turbine with several deflector angles.

In this research, the highest power and power coefficient are on the three blades with a deflector angle of 80°, which is 0.154 Watt and 0.132. The second position is in the Savonius Hydro Turbine with two blades with a small difference in value compared to three blades, respectively 0.151 Watt and 0.129. The Savonius Hydro Turbine with four blades has the lowest power and power coefficient, 0.119 Watt, and 0.102.

4. CONCLUSIONS

Utilization of a deflector at the inlet turbine can increase the performance of the Savonius Hydro Turbine. The deflector angle influences turbine performance. The use of a deflector angle of 80° indicates better turbine inflow conditioning. Three blades configuration has higher power than the two and four blades Savonius Hydro Turbine. The best performance of the variation in the number of blades and deflector angle is the Savonius Hydro Turbine with several three blades with a deflector angle of 80°, with a power of 0.154 Watt and a power coefficient of 0.132.

ACKNOWLEDGMENT

The author would like to thank Institut Teknologi Kalimantan for providing financial assistance in carrying out this research.

REFERENCES

1. Statistik Potensi Desa Provinsi Kalimantan Timur 2018. 2018.
2. Khan MJ, Iqbal MT, Quaicoe JE. River current energy conversion systems: Progress, prospects and challenges. Renew Sustain Energy Rev. 2008;12(8):2177–93.
3. Savonius SJ. The Wing Rotor in Theory and Practice. Finland: Savonius & Co. , Helsingfors; 1925.
4. Abraham JP, Plourde BD, Mowry GS, Minkowycz WJ, Sparrow EM. Summary of Savonius wind turbine development and future applications for small-scale power generation. J Renew Sustain Energy. 2012;4(4):042703.
5. Nakajima M, Iio S, Ikeda T. Performance of Savonius Rotor for Environmentally Friendly Hydraulic Turbine. J Fluid Sci Technol. 2008;3(3):420–9.
6. Talukdar PK, Kulkarni V, Saha UK. Performance estimation of Savonius wind and Savonius hydrokinetic turbines under identical power input. J Renew Sustain Energy. 2018;10(6):064704.
7. Zemamou M, Aggour M, Toumi A. Review of savonius wind turbine design and performance. Power Energy Syst Eng. 2017 Dec;141:383–8.
8. Twidell JW, Weir AD. Renewable Energy Resources. 2th ed. London and New York: Tony and Francis; 2006.
9. Wenehenubun F, Saputra A, Sutanto H. An Experimental Study on the Performance of Savonius Wind Turbines Related With The Number Of Blades. Energy Procedia. 2015;68:297–304.
10. Hamzah I, Prasetyo A, Tjahjana DDDP, Hadi S. Effect of blades number to performance of Savonius water turbine in water pipe. AIP Conf Proc. 2018;1931(1):030046.
11. Payambarpour SA, Najafi AF, Magagnato F. Investigation of Blade Number Effect on Hydraulic Performance of In-Pipe Hydro Savonius Turbine. Int J Rotating Mach. 2019;
12. Hadi S, Purnama MST, Tjahjana DDDP. Pengaruh Sudut Puntir Sudu Pada Savonius Horizontal Axis Water Turbine Semicircular Blade Aplikasi Aliran Dalam Pipa. Flywheel J Tek Mesin UNTIRTA. 2016;2.
13. Jeon KS, Jeong JI, Pan J-K, Ryu K-W. Effects of end plates with various shapes and sizes on helical Savonius wind turbines. Renew Energy. 2015;79:167–76.
14. Hau E. Wind Turbines : Fundamentals, Technologies, Application, Economics. 2nd ed. Germany: Springer; 2006.
15. Iio S, Katayama Y, Uchiyama F, Sato E, Ikeda T. Influence of setting condition on characteristics of Savonius hydraulic turbine with a shield plate. J Therm Sci. 2011 Sep;20(3):224–8.
16. Kailash G, Eldho TI, Prabhu S V. Performance Study of Modified Savonius Water Turbine with Two Deflector Plates. Iqbal T, editor. Int J Rotating Mach. 2012 May;2012:679247.
17. Storti BA, Dorella JJ, Roman ND, Peralta I, Albanesi AE. Improving the efficiency of a Savonius wind turbine by designing a set of deflector plates with a metamodel-based optimization approach. Energy. 2019;186:115814.
18. Mohamed MH, Janiga G, Pap E, Thévenin, D. Optimal blade shape of a modified Savonius turbine using an obstacle shielding the returning blade. Energy Convers Manag. 2011;52(1):2011.
19. Putri NP, Yuwono T, Rustam J, Purwanto P, Bangga G. Experimental studies on the effect of obstacle upstream of a Savonius wind turbine. SN Appl Sci. 2019;1(10):42452.
20. Thakur N, Biswas A, Kumar Y, Basumatary M. CFD analysis of performance improvement of the Savonius water turbine by using an impinging jet duct design. Chinese J Chem Eng. 2019;27(4):794–801.
21. Antar E, Elkhoury M. Casing optimization of a Savonius wind turbine. Energy Reports. 2020;6:184–9.
22. Elbatran AH, Ahmed YM, Shehata AS. Performance study of ducted nozzle Savonius water turbine, comparison with conventional Savonius turbine. Energy. 2017;134:566–84.
23. Setiawan PA, Yuwono T, Widodo WA, Julianto E, Santoso M. Numerical Study of a Circular Cylinder Effect on the Vertical Axis Savonius Water Turbine Performance at the Side of the Advancing Blade with Horizontal Distance Variations. Int J Renew ENERGY Res. 2019;9(2).