Testing the Effect of Variation of Deflector Shapes on the Performance of the Three Blade Vertical Axis Savonius Water Turbine

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***Abstract*— Hydropower is energy obtained from flowing water and can be used for mechanical energy or electrical energy. Electrical energy is energy that is used to fulfill human needs in life. The need for electrical energy in Indonesia continues to increase by an average of 3.9% from year to year until 2050. There are various water sources in Kalimantan such as water ditches, as well as reservoirs that have low-speed water flow and the capacity to accommodate water levels that are not too high. The Savonius water turbine can be utilized in these conditions because it has the advantage of a simple turbine construction, and is suitable for relatively low velocity water flows. This study analyzes how well the Savonius water turbine is by applying different deflector shapes. The method applied in this experiment is an experimental study using a Savonius turbine. The conclusion in this study is that applying a deflector will improve turbine performance much better than not using a deflector. Experiments by applying deflectors, namely convex deflectors, flat deflectors, and concave deflectors, it was concluded that the application using a concave deflector resulted in the highest rotational speed produced by the turbine, the maximum value of turbine power and the Savonius turbine coefficient of 206.3 rpm, 0.196 Watt and Cp = 0.124.**

Keywords—deflector, electrical energy, water turbine, savonius turbine.

I. INTRODUCTION

Electrical energy is a source of energy used to meet human needs. Electricity is one of the important roles of mankind, especially the use of electrical energy for lighting and production process technology in industry [1]. Reducing electricity consumption is one of the efforts, efforts to save fossil energy. The use of technology and innovation to utilize renewable energy in the form of water is to use the Savonius water turbine. The Savonius turbine is a turbine invented by Finnish engineer Sigurd Johannes Savonius in 1922. The Savonius turbine is a drag type turbine that can be made with several blades including two, three and four blades. The Savonius turbine when observed from the top view of the turbine blade looks like the shape of the letter S because of its curvature [2].

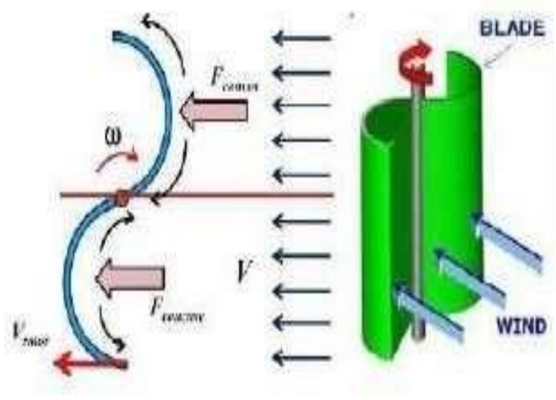

Fig. 1. Savonius turbine sketch

The Savonius turbine has a way of working, namely when the turbine rotates about a third of its revolution, the blade on the turbine which has a hollow shape like the letter S that is open will get fluid flow in the form of water or wind and the fluid will be in the back position, then the next blade will rotate and will get the same water fluid from the front, this process will continue to repeat as long as the water fluid hits the turbine [2]. There is a design tool that serves to increase the difference in the drag force of the turbine so that it causes the turbine rotational speed to increase by applying a deflector. In addition, the deflector can also increase the positive force when the turbine rotates. By installing a deflector in the upstream position of the turbine, it can increase the efficiency of the Savonius turbine [3].

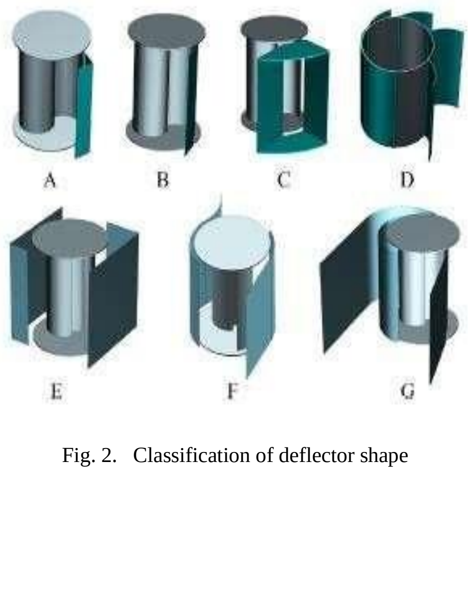

Fig. 2. Classification of deflector shape

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The performance of the Savonius water turbine has a benchmark that affects the performance of the Savonius turbine. Savonius water turbine performance can be calculated with several benchmarks, namely: Tip Speed Ratio (TSR), Weirs V-Notch, Turbine Mechanical Power, and Turbine Power Coefficient (Cp). Tip Speed Ratio (TSR) is the ratio of the speed at the tip of the turbine blade to the speed of the water flow. The tip speed ratio will affect the rotational speed of the rotor on the turbine [4].

$$\lambda = \frac{\omega.D}{2.V} \quad (1)$$

Weirs V-Notch is an equation used to measure the discharge from a reservoir or dam [5].

$$Q = 1{,}38H^{\frac{5}{2}} \quad (2)$$

Fluid Continuity is a fundamental equation of fluid mechanics. Incoming fluid flows into a volume that meets the scope of the volume at a certain point and can exit to another point. The fluid that enters the channel at the end of the pipe must be the same as the fluid that will come out even though the pipe line has an unequal radius, or the incoming mass is the same as the outgoing mass is constant [6].

$$Q=V.A \quad (3)$$

Turbine Mechanical Power is the torque obtained from the rotation of the turbine because there is a fluid in the form of wind or water hitting the blades on the turbine causing the blades on the turbine to start rotating or rotating which will produce turbine power [7].

$$P_t = T.\omega \quad (4)$$

Turbine Power Coefficient is the ratio between the power obtained from the torque obtained at turbine rotation with the power received at the turbine, namely the power coefficient. In principle, the power that the Savonius rotor can extract from water is less than the actual power available for water energy. In other words, the power generated by the turbine will not exceed the value actually available for water fluid power [8].

$$.C_P = \frac{2P_t}{\rho.HT.D.V^3} \quad (5)$$

II. RESEARCH METHODS

The research process begins with conducting a literature study to find references in the form of scientific publications or journals. The research steps are summarized in the form of a flowchart as shown in Figure 3.

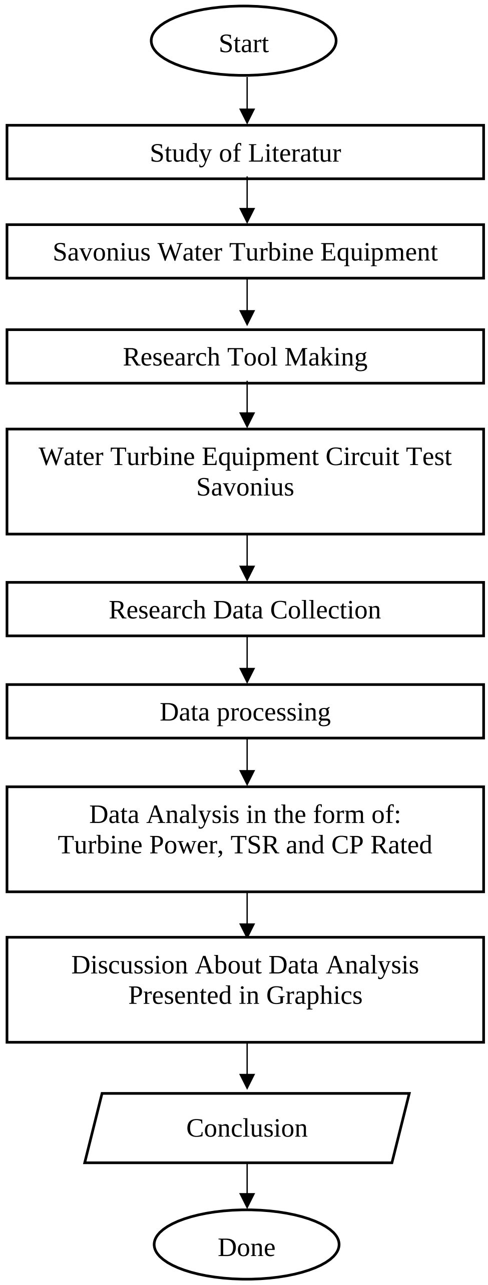

Fig. 3. Research flowchart

The method used is to conduct experimental studies supported by various reference sources of journals and scientific publications. The design model for the tool and turbine was obtained based on the relevant literature references. The Savonius water turbine is a turbine type that is simple in construction, made of acrylic on the endplate and the turbine blades made of PVC pipe. There are specifications on the Savonius water turbine, namely the turbine height of 100 mm and the turbine diameter of 100 mm with a turbine aspect ratio of 1.

In this study, there is an additional construction that is useful to increase the difference in drag force on the Savonius turbine which causes an increase in the rotation of the Savonius turbine by applying a deflector. The variation used in this study is to apply various forms of deflectors,

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namely the deflector with a convex shape, a deflector with a flat shape, and a deflector with a concave shape. Data acquisition is supported by several tools, namely a tachometer which functions to measure the speed of the shaft, a prony brake which functions to determine the measured load, and a scale to measure the load of the prony brake. After the test is complete, the data obtained from the Savonius turbine are then presented in a graph of the performance characteristics of the Savonius turbine. The last stage is to conclude the results of research and scientific articles. There is a set of tools research from the Savonius water turbine test which can be seen in Figure 4 as follows:

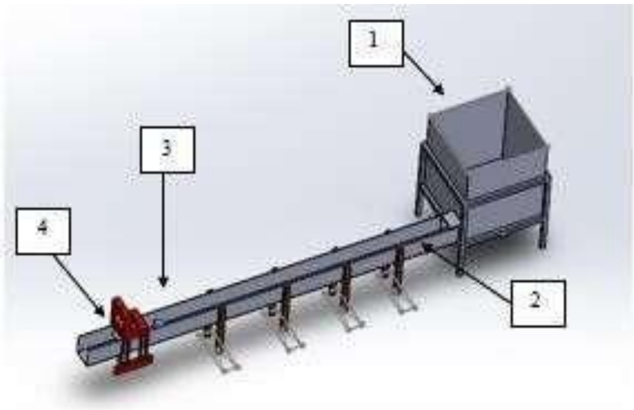

Fig. 4. Series of research tools: 1) water storage box; 2) gutters; 3) deflector; 4) savonius turbine

In addition, there are variations used in this study, namely the deflector can be seen in Figure 5 as follows:

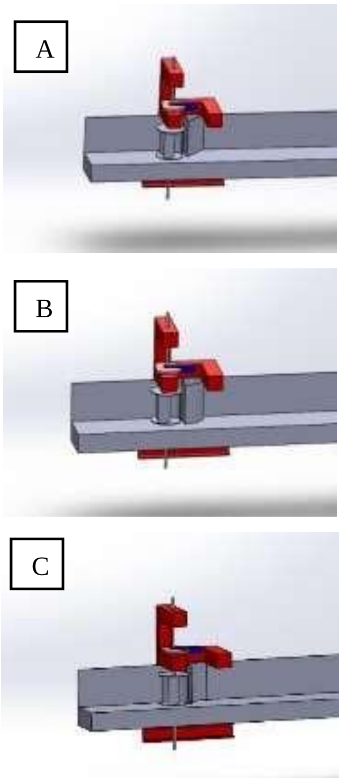

Fig 5. Variation of deflector used: A) flat deflector; B) convex deflector; C) concave deflector.

III. RESULTS AND DISCUSSION

Savonius water turbine by applying different deflector shapes with variations in the shape of flat deflectors, convex deflectors, concave deflectors, and without using deflectors. The test was carried out at a water velocity of 0.681 m/s. After processing the data, then the graph of the performance relationship of the Savonius turbine is obtained which can be seen in Figure 6 below:

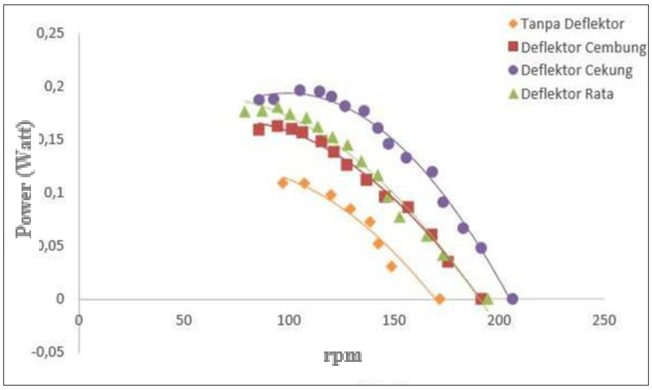

Fig 6. Graph of turbine power relationship with turbine rotational speed

Based on the results of the data converted into graphic form in Figure 6, namely the turbine that does not apply tool construction, namely the deflector produces the highest power value of 0.096 Watt at a speed of 95.3 rpm, the highest value at the speed generated from the turbine rotation is 171.7 rpm and the lowest value turbine rotation speed of 82.2 rpm produces a power value of 0.092 Watt. The application using a convex deflector produces the highest power of 0.153 Watt at a speed of 97.2 rpm, the highest value at the speed generated from the turbine rotation is 191.5 rpm and the lowest value for the turbine rotation speed is 78.6 rpm resulting in a power value of 0.146 Watt. The application using an average deflector produces the highest power value of 0.180 Watt at a speed of 94.6 rpm, the highest value at the speed generated from the turbine rotation is 194.5 rpm and the lowest value for the turbine rotation speed is 78.8 rpm resulting in a power value of 0.176 Watt. The application of the concave deflector produces the highest power value of 0.196 Watt at a speed of 105.1 rpm, the highest value at the speed generated from the turbine rotation is 206.3 rpm and the lowest value for the turbine rotation speed is 85.7 rpm resulting in a power value of 0.187 Watt.

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Fig 7.Turbine test using a convex deflector

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Testing a three-blade savonius water turbine using a convex deflector shown in Figure 7 is the part of the water flow marked with a blue arrow, it appears that the water in the channel is unstable because the water flow is hit by a convex deflector which causes the turbine rotational speed to decrease. The addition of a deflector with this shape will affect the flow conditions in front of the deflector, the fluid flow of water hitting the deflector produces a backflow wave. The flow of water that is not optimal is accompanied by obstruction of the flow of water by a convex deflector on the turbine which causes the rotation of the turbine to decrease.

Fig 8. Turbine test using a concave deflector

Testing a three-blade savonius water turbine using a concave deflector shown in Figure 8 is the part of the water flow marked with a blue arrow, it looks like the water flow is more directed and stable because the water flow directly passes through the concave deflector towards the blades on the turbine which causes the turbine rotation to increase. This is because the deflector can deflect the water fluid flow so that the water fluid flow can directly hit the blades on the turbine [3]. There is a visible buildup of water flow in the hollow part of the turbine so that the water turbine is slightly submerged by water which causes a better turbine rotation speed. accumulation of water that occurs but the water does not come out of the water channel so that the turbine rotation speed increases.

Fig 9.Turbine test using flat deflector

Testing a three-blade savonius water turbine using a concave deflector shown in Figure 9 is the part of the water flow marked with a blue arrow, it can be seen that the water flow is directed because the water in the channel directly passes through the flat deflector which causes the turbine rotation to increase. The existence of a deflector has an impact on the flow of water, namely increasing the speed of water flow and guiding the direction of water flow [4]. Without the buildup of water flow and there is no increase in water level which causes the turbine to not sink too much in the part after the deflector, causing the rotational speed to increase slightly.

The variation applied to the Savonius turbine by applying the shape of the deflector affects the rotation and the resulting power coefficient, it can be seen from the data results that using a concave deflector makes the Savonius water turbine produce a high power coefficient value. The application of a deflector on a Savonius water turbine is highly recommended because it can be seen from the results of the data that the use of a deflector produces better data than the data generated without using a deflector. The results of the data using the four variations have been obtained, namely testing the Savonius water turbine without using a deflector, using a convex deflector, a flat deflector, and a concave deflector stating that the best variation is the use of a concave deflector.

IV. CONCLUSION

The three-blade Savonius water turbine by applying a deflector produces better performance than the Savonius turbine that does not use a deflector. The application of a deflector with variations in the shape of a convex deflector, a flat deflector, and a concave deflector obtained the test results with the application of a concave deflector producing the best performance by obtaining a turbine rotation speed of 206.3 rpm, a maximum power of 0.196 Watt and a turbine power coefficient of 0.124.

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