

Effect of Variation in the Number of Blades on Turbine Rotation and Output Power at PLTPH (Picohydro Power Plant) Using a Kaplan Turbine

Arnawan Hasibuan¹, Asran², Sartika Yanti³, Misbahul Jannah⁴, Andik Bintoro⁵, Ari Nrartha⁶

^{1,2,3,4,5}Department of Electrical Engineering, Universitas Malikussaleh, Indonesia

⁶Department of Electrical Engineering, University of Mataram, Indonesia

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ABSTRAK

The turbine is an important component for converting mechanical energy into electrical energy in picohydro power plants (PLTPH). The Kaplan turbine is a type of reaction turbine with a head of 1.58 m. This study examines the effect of variations in the number of blades on turbine rotation and power output. This study aims to obtain a turbine runner with the number of blades that can produce the highest efficiency, so a variation of the Kaplan turbine runner was made with several blade runner variations, namely 4 blades, 6 blades, and 8 blades. The results showed that the addition of the number of blades produced the highest output with the number of blades 6 which produced a turbine rotation of 218.1 Rpm, a generator rotation of 2433 Rpm, a generator voltage of 19 volts, a generator power of 1900 watts, and a torque of 17.5 Nm. The resulting efficiency value is 26.62%. The results of this research are expected to become a reference and help increase human resources to develop power plants in rural areas, as well as open up opportunities for the community to develop small-scale power plants, namely pico-hydro power plants.

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Corresponding Author:

Arnawan Hasibuan
Department of Electrical Engineering,
Universitas Malikussaleh,
Bukit Indah, Lhokseumawe, Aceh, Indonesia.
Email: arnawan@unimal.ac.id

1. INTRODUCTION

Utilizing the potential of water wealth in nature can be useful for generating electricity using a picohydro power plant [1], many areas in villages or villages that have not been electrified, people in rural areas or villages that have not been electrified can utilize the potential of existing water as a power plant [2]–[5]. Picohydro or often called picohydro power plant (PLTPH) is a small power plant that uses hydropower as its driving force [6], such as irrigation canals, rivers or waterfalls by utilizing the height of the water fall and water discharge [7].

Water energy is an energy that is abundant in Indonesia because Indonesia is located on the equator and this energy is environmentally friendly [8][9]. Water energy is useful based on the kinetic energy of water flow created from the potential energy of water upstream or lakes and dams located at a certain height [10]. The amount of hydropower available from a water source depends on the

water velocity and water discharge. The speed of the water flow will produce rotation on the turbine which will produce electrical energy [11], [12].

Small-scale hydropower plants or picohydro can be said to be one of the power generation technologies whose utilization is very reliable, as well as relatively low manufacturing costs and environmentally friendly when compared to other large-scale power plants [13]–[15]. The main components of a picohydro power plant consist of water as an energy source, turbines and generators. generator [16].

Turbine as one of the most important components in a micro-hydro power plant (PLTMH), many types of turbines are used, one of which is the Kaplan turbine [17]. Turbine performance is influenced by several factors, including water flow rate, blade angle, rectifier vanes, blade dimensions, and number of blades [18], [19]. The number of blades and the speed of the water flow is one of the factors that affect the rotational and tangential performance [20]–[22], which determines the performance and efficiency of the turbine [23], [24].

Effect of variations in the number of blades of a waterwheel turbine with variations in the number of different blades (3, 5, and 7) with bowl-shaped blades carried out by Kriswanto in 2006, the result is that the number of blades is affected by turbine performance where at blade 7 with a flow rate of 30m³/hour has the highest power compared to blades 3 and 5 of 0.227 watts [25].

Wayan Arta Wijaya carried out the test on the number of blades on the PLTMH prototype with a Pelton turbine. The best measurement value was obtained for the impeller with a total of 22 blades, where the current voltage and output power produced by the generator were 15.72 volts, 2.14 amperes and 33.7 watts. The resulting turbine speed is 852.2 Rpm before it is coupled and 497.2 Rpm after it is coupled with the generator, while the generator speed is 2133.8 Rpm. The generator can rotate so that the generator can produce high voltage, high current and the highest power using a 22 blade rotor with a torque of 0.6Nm [26].

Tests were also carried out on the number of blades to optimize the performance of single wheel kinetic turbines. Based on the discussion and analysis it was found that the number of blades affects the performance of the kinetic turbine where the water discharge is 0.013 m³/s for 100 rpm rotation, the number of blades 5 has a power of 5.50 watts, blade 11 has a higher performance than the number of blades 5.7 and 9 especially the 100 rotation rpm the power generated is 20.41 watts at a water discharge of 0.016 m³/s the number of blades 11 the highest performance (power and efficiency) is at 100 rpm which is 20.41 watts and an efficiency of 71.42% the effect of water discharge on maximum torque occurs at blade 11 with a water discharge of 0.016 m³/s at 20 rpm rotation of 3.73 Nm while the minimum torque occurs at blade 5 with a water discharge of 0.013 m³/s at 100 rpm rotation which is equivalent to 0.53 Nm [27]. From the explanation above, the author takes the topic of the influence of variations in the number of blades by using a Kaplan turbine with a number of blades of 4, 6 blades and 8 angles [28].

2. RESEARCH METHOD

The following is a research flowchart (Figure 1):

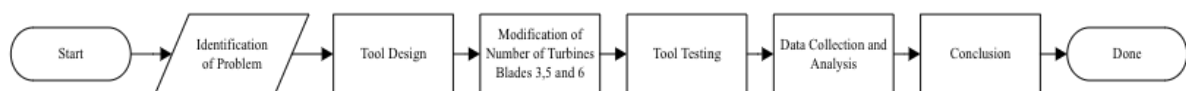


Figure 1. Research flowchart

2.1. Research sites

This research was conducted in Blang Pond, Kec. Nisam Between kab. North Aceh and the test location for the Picohydro Power Plant with variations in the number of blades. In November 2022.

2.2. Data Collection Method

After testing the prototype, the data obtained from the test results included turbine rotation speed, generator rotation speed, voltage and current. The data is then analyzed and used to explain

the effect of the number of blades on output characteristics such as voltage, current, power, turbine rotation, generator rotation, produced and the effect of the number of blades on the value of efficiency and output power generated from the prototype system of the Picohydro Power Plant. Analysis data in this study using quantitative data. This quantitative data is obtained from the results of each test where the test is carried out 5 times. Measurements were made with the number of blades on the Kaplan turbine, namely the number of blades 4, 6 blades and 8 blades to obtain a runner with the number of blades that produces the greatest voltage, current and power so as to produce efficiency of the Picohydro Power Plant prototype system. the highest.

2.3. Data Analysis Techniques

The analysis technique used is as follows

1. Water discharge

The water discharge is the volume of water flow in one unit of time, the water discharge in the river flow can be solved by the following equation:

$$A = I \cdot D \dots\dots\dots (1)$$

$$Q = VA \dots\dots\dots (2)$$

2. Flow rate

The speed of flowing water can be calculated using the following equation:

$$v = \frac{Q}{A} \dots\dots\dots (3)$$

3. Hydrostatic pressure

Hydrostatic pressure is the pressure exerted by water in all directions at the measuring point as well as due to the force of gravity;

$$Ph = \rho gh \dots\dots\dots (4)$$

4. Electrical output power

Is the output power of the generator obtained using the following equation:

$$PG = VI \dots\dots\dots (5)$$

5. Rotational Force Moment (torque)

Torque is a force in translational motion indicating the ability of a force to make an object rotate. Torque can be obtained from the quotient between the output power (watts) and the number of revolutions per second (rpm).

$$T = \frac{p}{2\pi \frac{N}{60}} \dots\dots\dots (6)$$

3. RESULTS AND DISCUSSION

In this chapter, testing of Pico Hydro Power Plants and observations are carried out which aim to obtain data that is in accordance with Pico Hydro power generation systems. Tests were carried out to determine the performance of each component in this PLTPH. The test results data obtained will later be analyzed to be used as a reference in drawing conclusions.

3.1. Measurement of water discharge

The water pressure used in testing the variation in the number of blades on this prototype can be calculated as follows:

$$H = \frac{P}{\rho \cdot g}$$

$$P = H \cdot \rho \cdot g$$

$$P = (1,58) \cdot (1000) \cdot (9,8)$$

$$P = 15,484 \text{ psi}$$

$$\Rightarrow 15 \text{ psi}$$

The water pressure value used in testing the PLTPH prototype with the Kaplan turbine is 15 Psi, the volume of the bucket used is 10 liters and the time needed to fill the bucket with 15 psi

pressure is 2.17 seconds. The discharge used in testing the variation in the number of blades on this prototype can be calculated as follows:

$$Q = \frac{v}{t}$$

$$Q = \frac{10}{2,17}$$

$$Q = 4,61 \text{ Liter/s}$$

$$Q = 0.00461 \text{ m}^3/\text{s}$$

So the water discharge that can be used to obtain the hydraulic power produced by the PLTPH prototype using the Kaplan turbine is 0.00461 m³/s.

3.2. The relationship between the number of blades and the turbine rotation

Based on the table of testing the effect of the blade on the turbine rotation above, the following Figure 2 can be obtained:

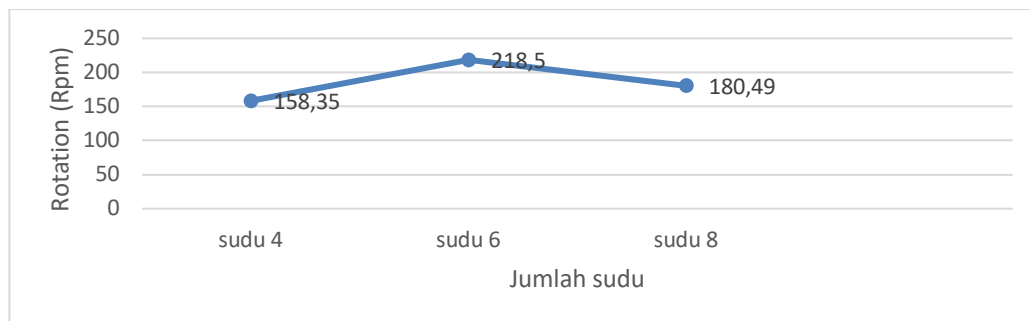


Figure 2. The effect of changing the blade on the turbine rotation

Based on Figure 1 above, it can be seen that an increase in the value of the turbine rotation speed occurs in the turbine with 6 blades, which is equal to 218.1 Rpm. This happens because blade 6 has the most ideal distance between blades so that the water energy hits the blade fully so that the rotation is maximum.

3.3. The relationship between the blades and the generator rotation

Based on the research, it can be seen that the graph of the results of the research on the variation in the number of blades on the generator rotation can be seen in Figure 3 below:

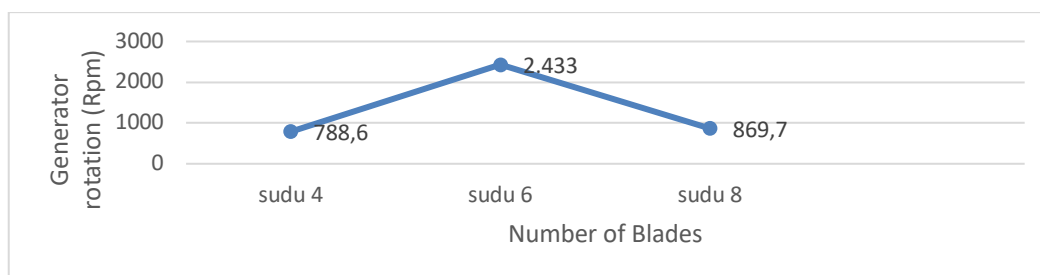


Figure 3. Graph of changes in the number of blades to generator rotation

Based on figure 3, it can be seen that the highest generator rotation speed occurs at blade 6 which is 2433 Rpm and the lowest generator rotation speed occurs at blade 4 which is 788.6 Rpm.

3.4. The relationship between the blade rotation and the generator

From the table above, it can be seen that the graph of measuring the change in blades to the voltage on the generator can be seen in Figure 4 below:

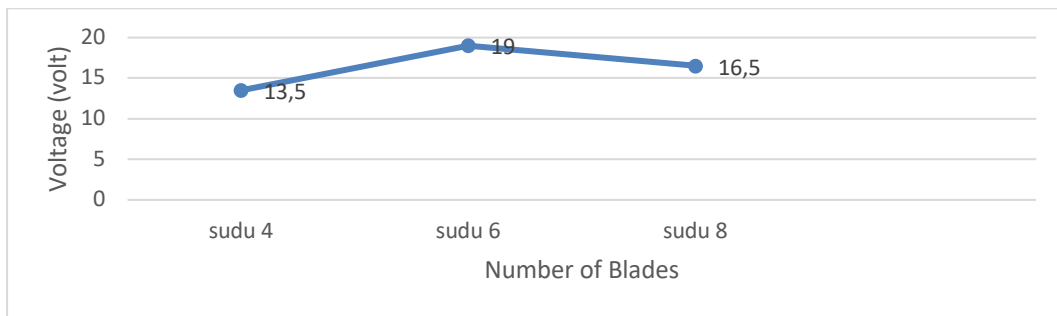


Figure 4. Graph of the change in the blade to the generator voltage

Based on Figure 4 above, it can be seen that at blade 4 the generator voltage is 13.5 volts, at blade 6 the generator voltage is 19 volts and when the blade is 8 the generator voltage changes to 16.5 volts, the highest generator voltage occurs at blade 6 which is 19 volt.

3.5. The relationship between the blades and the generator current

Based on testing the effect of changing the number of blades, the following graphical image of test relationship 4 is obtained:

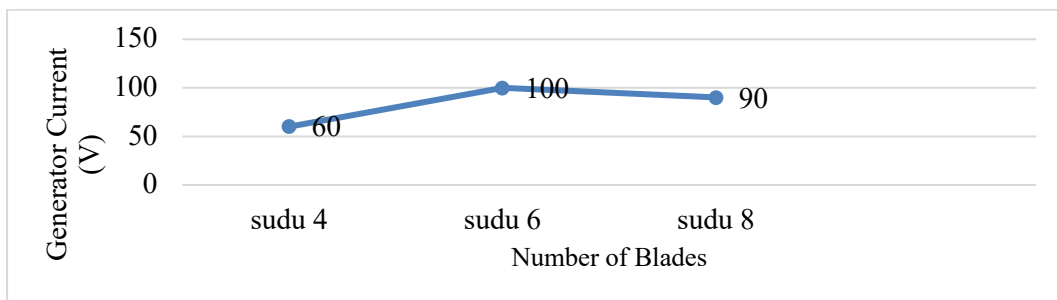


Figure 5. Graph of changes in the number of blades against the current

Based on Figure 5 above, it can be seen that there is an increase in the current value in the turbine with a number of blades 6 which is equal to 100 V when the number of blades exceeds 6 there is a decrease in current, this is because the current value of the generator depends on the rotational speed of the generator itself. At 6 blades the generator achieved the highest output current among the three variations in the number of blades tested.

3.6. The relationship between the number of blades and generator power

Based on testing the effect of changing blades on generator power, the relationship graph obtained can be seen in Figure 6 below:

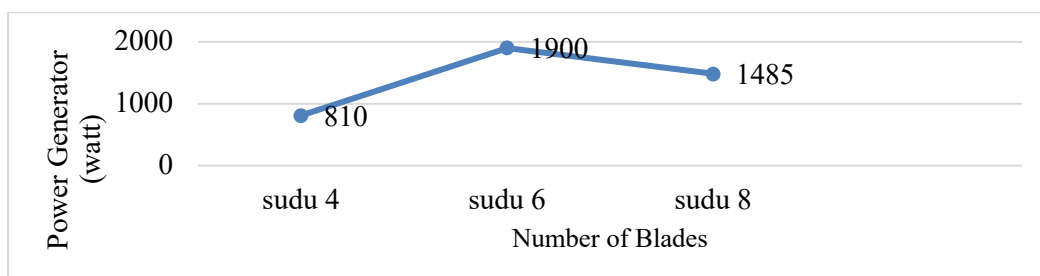


Figure 6. Graph of blade changes to generator power

From the graphic image above it can be seen that the highest output power is at blade 6 which is equal to 1900 watts and when the number of blades exceeds 6 then the output power decreases to

1485 watts this is because the value of the output power of the generator depends on the output voltage and output current itself. The greater the current voltage, the greater the output power generated, and vice versa.

3.7. The relationship between the number of blades and torque

The graph of the relationship between the number of blades and the torque value is obtained as follows:

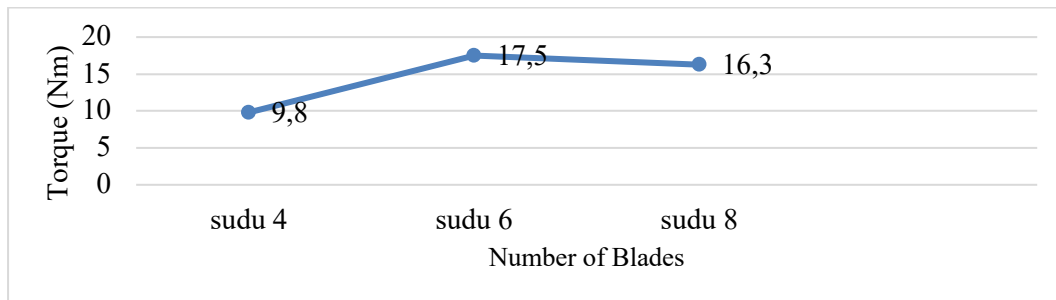


Figure 7. Graph of blade changes to torque

Based on Figure 7, it can be seen that there is an increase in the torque value at the 6th blade, which is 17.5 Nm.

3.8. Relationship of Number of Blades to Hydraulic Power

The graph of the calculation results from all the different blades can be seen in Figure 8 following:

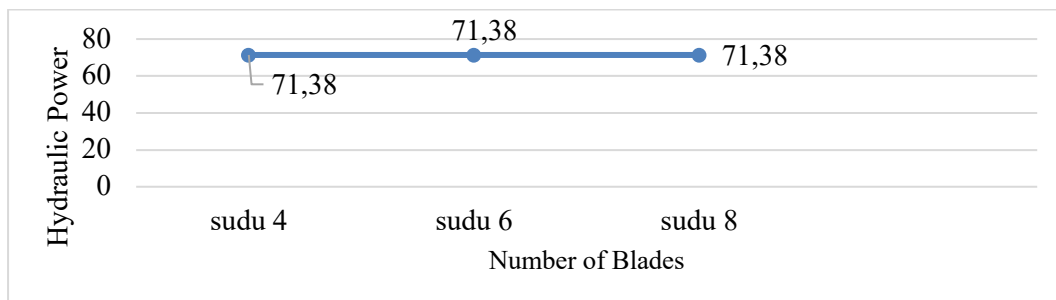


Figure 8. Changes in the number of blades to hydraulic power

Based on Figure 8 above, the addition of the number of blades does not affect the increase in hydraulic power, this happens because the hydraulic power is affected by the water pressure used which in the test uses only one pressure parameter which is equal to 15 psi with a water discharge of 0.00461 m³/s which causes the value of hydraulic power be constant.

3.9. Prototype System Efficiency Calculation

Calculation of the hydraulic power of the PLTPH prototype system can be solved with the following equation:

$$\eta_{\text{PLTMH}} = \frac{P_G}{P_H} \cdot 100\%$$

The graph of the relationship between the number of blades and the torque value is obtained as follows:

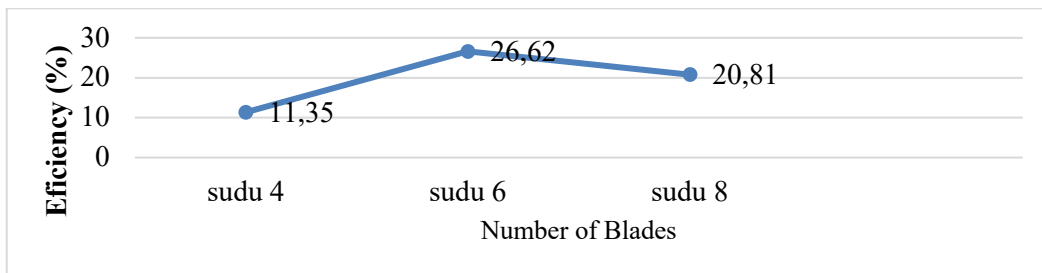


Figure 9. Graph of blade changes to system efficiency of the PLTPH Prototype

Based on the Figure 9 above, it can be seen that the turbine with the number of blades 6 produces the highest efficiency because the distance between the blades is the best so that the kinetic energy of the water fully hits the blade ridges which results in high generator output power, therefore the efficiency produced by the turbine is also of maximum value simum

4. CONCLUSION

The conclusions from this study are as follows:

1. The turbine rotation speed obtained in this study with the same amount of water discharge, namely 0.00461 m³/s and with the number of blades 4, 6 and 8 blades respectively, was 158.35 Rpm, 218.1 Rpm 180.94 Rpm. The highest turbine rotation speed occurs in a turbine with 6 blades, namely 218.1 Rpm and the lowest turbine rotation occurs in a turbine with 4 blades, namely 158.35 Rpm. This happens because the 6 blades have the most ideal distance between the blades so that the energy of the pressurized water hits the blades fully so that the maximum rotation.
2. Comparison of the power generated in this study with the same amount of water discharge, namely 0.00461 m³/s and with the same height of falling water, namely 1.58 m using the number of blades 4, 6 blades and 8 blades respectively is 810 watts, 1,900 watts, and 1,480 watts. The highest power produced is at blade 6 of 1,900 watts and the lowest is 810 watts at blade 4. This is because the output power value of the generator depends on the voltage and current itself, the greater the voltage current, the greater the output power produced vice versa.

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