INTERNATIONAL JOURNAL OF INNOVATION IN MECHANICAL CONSTRUCTION AND ENERGY
Vol. 1 No. 3 (2024), 139-147

IJIMCE
https://ijimce.ppj.unp.ac.id/index.php/ijimce
University of Negeri Padang

International Journal of Innovation in Mechanical Construction and Energy

ISSN: 3046-9112 e-ISSN: 3046-9104

Effect of Discharge and Pressure on the Performance of Crossflow Turbine Simulation System

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Received 09 Agustus 2024; Accepted 04 November 2024; Available online 28 November 2024

Abstract

The demand for electrical energy is increasing. Electricity supply in Indonesia is not yet evenly distributed. Indonesia's electrification ratio is only 99.63%. Generally, areas that have not been electrified are rural areas. It is necessary to utilize water energy sources for power generation. This research was conducted with a simulation tool from a micro hydro power plant with a crossflow turbine. The use of this turbine is because it is easy in terms of cost and manufacturing. The research was given an input source from a pump with a double pump system and a single pump system. Each system is given a variation of 100%, 75% and 50% openings. From this research, it will be able to determine the type of turbine, the size of the opening and the electricity production process. Data collection time is carried out for 90 minutes on each system and opening. From the research results obtained current, voltage, and output power. In the double pump system with 100% opening is relatively greater than 75% and 50% opening in the same system and in the single pump system. The maximum output current obtained in this study is 0.09 amperes with a double pump system opening 100% and the minimum output value is 0.02 amperes in a single pump system opening 50%. The maximum output power obtained in this study was 1.81 watts with a 100% opening dual pump system and a minimum output value of 0.32 watts in a 50% opening single pump system. The maximum output voltage obtained was 21.5 volts at 50% opening of the dual pump system, and the minimum output voltage was 15.8 volts at 50% opening of the single pump system. A large discharge will provide a large current, voltage and power output because it is able to crush the turbine with a relatively large speed. Discharge will affect the pressure and flow that occurs in the pipe, because the amount of discharge will be linear with the amount of pressure. The use of double pumps will get high efficiency with a large discharge. The greatest efficiency occurs when the double pump system.

Keywords: Energy, turbine, pump, current, voltage, power.

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INTRODUCTION

The need for electrical energy continues to increase, in line with technological progress and development. Electrical energy is used in industry, transportation, households and activities that use other electrical devices. Data from the Ministry of Energy and Mineral Resources (ESDM) shows that the electrification ratio in Indonesia is only 99.63%. There are still some areas that have not been electrified. The difficulty of reaching network supplies to remote villages is a major challenge faced [1]. Generally, areas that have not been electrified are dominated in rural areas [2]. Efforts can be made by utilizing renewable energy sources [3]. This utilization has a complex relationship, and so it is strategic and very important for economic development and environmental protection of the country [4].

Energy sources that can be utilized include renewable energy and non-renewable energy. It is time to use renewable energy such as water, solar heat, geothermal, wind. This use is to maintain environmental impact [5]. From these sources, water energy has been widely used and developed. Because it is the most cost-effective way to generate electricity without pollution [6]. Through mechanical processes, water power can be utilized to drive turbines and generators that will produce electrical energy [7]. Indonesia already has a special hydropower plant in West Sumatra there is Singkarak Hydropower, Maninjau Hydropower. The potential for hydroelectric power plants is not in one place alone. Can be utilized on a small scale such as river flow and waterfalls. So that in its utilization needs proper planning.

Micro hydro power plant is a power plant by utilizing river flow, irrigation with a small source [8]. The basic principle of micro hydro power plants is to utilize the potential energy possessed by water flow at a certain height distance from the power plant installation [9]. Microhydro Power Plant is one of the alternative energy conversion tools that can be developed for rural areas [10], [11]. The advantages of this plant are environmentally friendly and low operating costs [12]. Microhydro power plants generally use crossflow turbines because of the small discharge and water drop point [13], [14]. The advantages of using crossflow turbines are considered simpler in construction [15]. The process of making crossflow turbines tends to be easier and the components are not complicated [16]. So that theoretically the calculation of incoming water discharge [17] can be calculated using the equation:

$$Q = V \times A \tag{1}$$

Q = Incoming water discharge (m^3/s)
V = Water flow velocity (m/s)
A = Surface area (m^2)

The size and size of the discharge that occurs will affect the results of the power that will be generated. Turbine speed is influenced by flow velocity [18], flow discharge, dimensions and geometry [19]. Turbine speed will affect the electrical energy produced. So that the calculation of the power generated can be calculated theoretically by using the results of equation (1). So the power calculation uses the following equation [20]:

$$P = \rho \times g \times H \times Q \tag{3}$$

P = Water power (Watt)
ρ = Density of water (kg/m^3)
g = Gravity ($g = 9.8\ m/s^2$)
H = Head (m)
Q = Incoming water discharge (m^3/s)

This study was conducted by comparing two input systems on the turbine. The input system uses a double pump system and a single pump. So that in the calculation of the power obtained, you can also get the value of the voltage and current produced. From this value can be used to find the value and efficiency of the turbine later [21]:

$$P_{\text{out}} = V \times I \tag{4}$$

P_{out} = Output power (Watt)
V = Voltage (Volt)
I = Current (Ampere)

Research activities were carried out at the Department of Mechanical Engineering, Faculty of Engineering, Universitas Negeri Padang. The main equipment used is a crossflow turbine simulation tool. This simulation tool is a development from the previous one which added sensors and features for data collection. This turbine simulation tool is equipped with a piping system, turbine and water input source using a pump. The test was carried out with two methods, namely a double pump system and a single pump system. Each system is given a variation of 100%, 75%, and 50% flow valve openings. This control aims to determine the performance of the turbine [22]. The purpose of this study is to determine the comparison of the output results obtained from the input with a dual pump system and a single pump. The output obtained is in the form of voltage, current and power and efficiency which can be used as a comparison. The calculation of efficiency can use the following equation [23]:

$$\eta t = \frac{P_{out}}{P_{In}} \times 100\% \tag{5}$$

ηt = Turbine efficiency (%)
P_{out} = Output power (Watt)
P_{in} = Input power (Watt)

The data results from the research will be made into a graph. From the graph, it will be seen how the influence of the discharge, on the output results of the turbine in the form of current, voltage, power and efficiency of each system.

RESEARCH METHODS

This research is quantitative research. Quantitative research uses a lot of numbers, starting from data collection, interpretation and results [24]. The type of research is experimental. Experimental research is the most reliable scientific research. Experimental research is carried out trials to prove a phenomenon. Conducted by strictly controlling the confounding variables outside the experiment. From the results, the cause and effect of a phenomenon will be obtained. In this study, the phenomenon that occurs is the effect of discharge on turbine performance.

This research will be conducted using a crossflow turbine simulation tool. This tool is designed like a power plant in general. It has an intake pipe line, penstock, inlet, turbine, transmission and generator [25]. The simulation tool is equipped with a flowmeter, sensor, water tank, LED display, and input pump. This crossflow turbine simulation tool has an outside diameter of 4 inches, a width of $1^{1}/_{4}$ inches with a total of 24 blades. Testing was carried out at the Thermal, Energy and Fluid Laboratory of the Department of Mechanical Engineering, Faculty of Engineering, Universitas Negeri Padang. For data collection using a digital multimeter. Data collection schemes with variations of input valve openings 100%, 75% and 50%. In each scheme, 2 input modes are given, namely the input mode of a single pump system and input with a dual pump system. Each system is carried out in real time for 90 minutes with a retrieval time interval of one time in 10 minutes. So that the total data obtained is 54.

The results of data collection from this study will compare the results of the input system with a double pump and input system with a single pump. So that the performance of each system can be seen. Including turbine performance efficiency, output power, output voltage and output current obtained. After the data is obtained, a graph will be made. Making graphs using computer software.

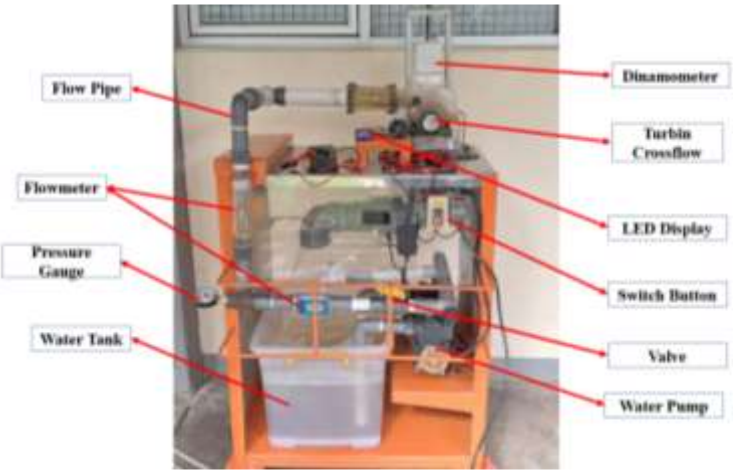

Fig. 1. Crossflow Turbine Simulation Tool

2.1 Research Instrument

In this study, the turbine will drive the generator. Electricity generated by the generator will be read using a multimeter. The use of a multimeter by connecting the output cable from the generator with the input cable dat to the multimeter. The working cycle of the turbine simulation tool is in Figure 2. Water in the water tank will be channeled using. After that it will pass through the pressure gauge, and flowmeter. The flowmeter will read the flowing water discharge. After that the water will enter the turbine, so the turbine will move. The rotating turbine will move the generator that has been connected to the pulley. The electricity generated by the generator will be read by a multimeter that has been connected to the output cable of the generator.

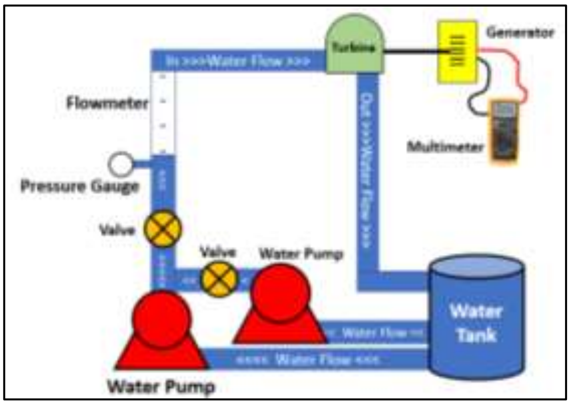

Fig. 2. Work Cycle of Crossflow Turbine Simulation Tool

RESULTS AND DISCUSSION

The test results show varied values for each system. In the double pump and single pump systems, the water discharge from the pump is relatively constant with a value of 0.0008 m³/s in the double pump and 0.0005 m³/s in the single pump. But from each opening the value of output current, output voltage, output power and efficiency obtained is different.

3.1 Current Output

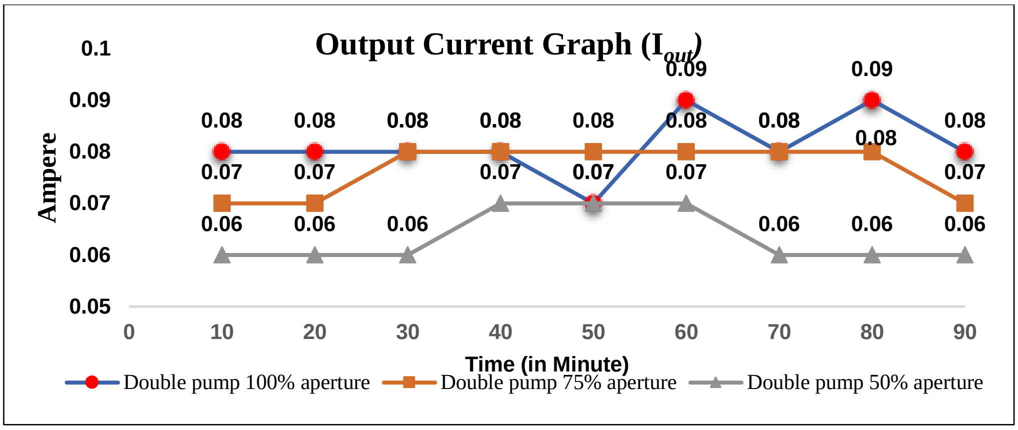

Fig. 3. Output Current On Dual Pump System

From Figure 3, it can be seen that the maximum current generated is 0.09 amperes with a 100% opening marked with a red dot blue line. The maximum current is 0.06 amperes at 50% opening. However, the resulting current tends to be unstable. This factor occurs because the flow that occurs in the pipe is unstable. At 100% opening, the flow model tends to be fast and less stable (turbulent), so the power generated is relatively unstable.

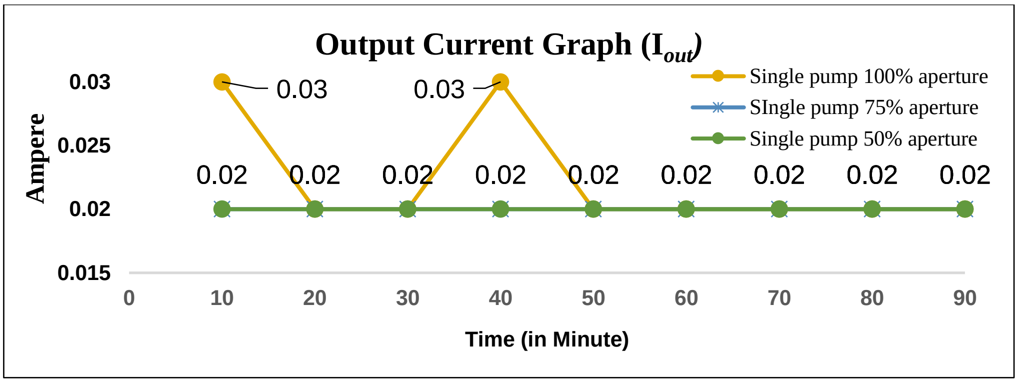

Fig. 4. Output Current On Single Pump System

Figure 4 is the current generated from a single pump system. It can be seen that the maximum current generated is 0.03 amperes with a 100% opening. The minimum current that can be generated in this trial is 0.02 amperes. From the test results, the single pump system produces a relatively stable current at 75% and 50% openings. This factor occurs because the flow that occurs in the pipe is more stable (laminar) so that the resulting output power is more stable. At 100% opening, the flow model tends to be fast and less stable (turbulent), so the power generated is relatively unstable. When viewed from the pump use system, the use of a double pump produces a greater current than the current generated by using a single pump. In Figure 3 the single pump system is only able to produce 0.03 amperes with 100% opening. In the double pump system, the minimum current generated is 0.06 amperes with a 50% opening. The results of using a double pump produce a greater current than the current generated by using a single pump. So that a large discharge will affect the value of the resulting current.

3.2 Output Voltage

The maximum voltage obtained is 21.4 Volts with a minimum output voltage obtained of 15.8 Volts. In this test, the voltage results are influenced by the amount of current and resistance that occurs. Because the voltage is directly proportional to the incoming current. So if the current given is stable, the resulting voltage is relatively stable.

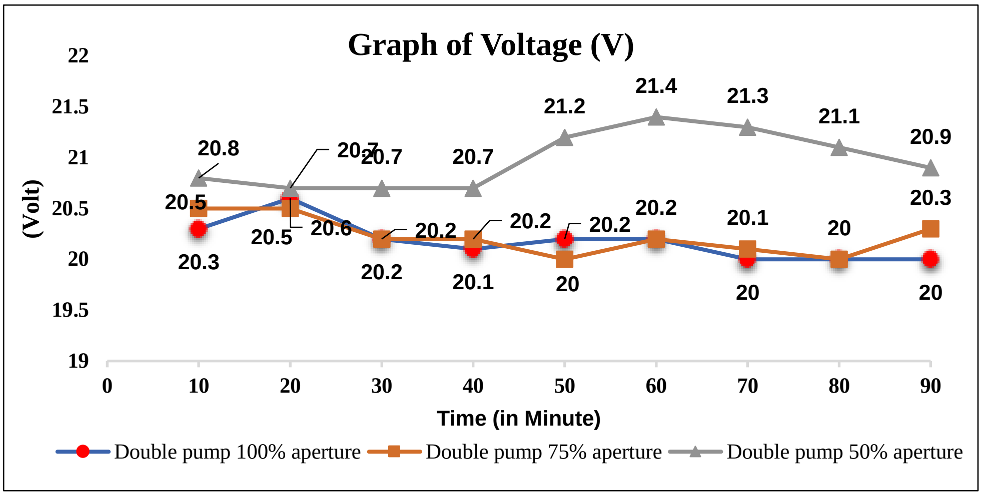

Fig. 5. Output Voltage On Dual Pump System

The maximum voltage obtained in the dual pump system is 21.4 Volts at 50% opening and the minimum voltage is 20 Volts at 100% opening. In Figure 4 the minimum voltage value at 50% opening is 20.7 Volts and the minimum voltage value at 100% opening is 20 Volts. In this test, the voltage results are influenced by the amount of current and resistance that occurs. Because the voltage is directly proportional to the incoming current. So if the current given is stable, the resulting voltage is relatively stable.

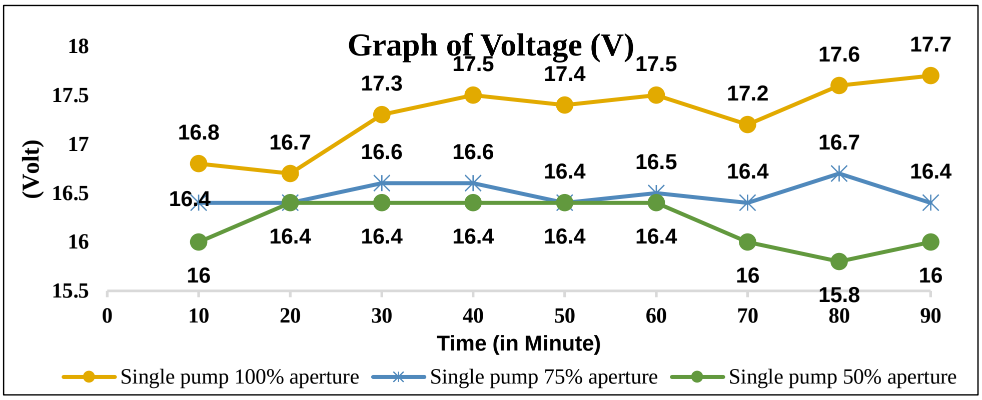

Fig. 6. Output Voltage On Single Pump System

In Figure 6 the system with a single pump opening of 50% is only able to reach 16.4 volts and a minimum value of 15.8 volts. While at 100% opening, the maximum value is 17.7 volts and the minimum value is 16.7 volts. When compared to the 50% opening with a single pump system, the voltage value is lower than other openings and systems. So that the double pump system will provide an impetus to produce a stronger voltage. But this is exactly the opposite of the opening given. The double pump system with a 50% aperture produces a greater voltage than the 75% and 100% aperture systems. The voltage generated from the 75% opening is relatively greater than the 100% opening.

3.3 Output Power

The output power obtained is dominant at 1.4 Watt in the double pump system. The maximum power obtained is 1.818 and a minimum of 0.316.

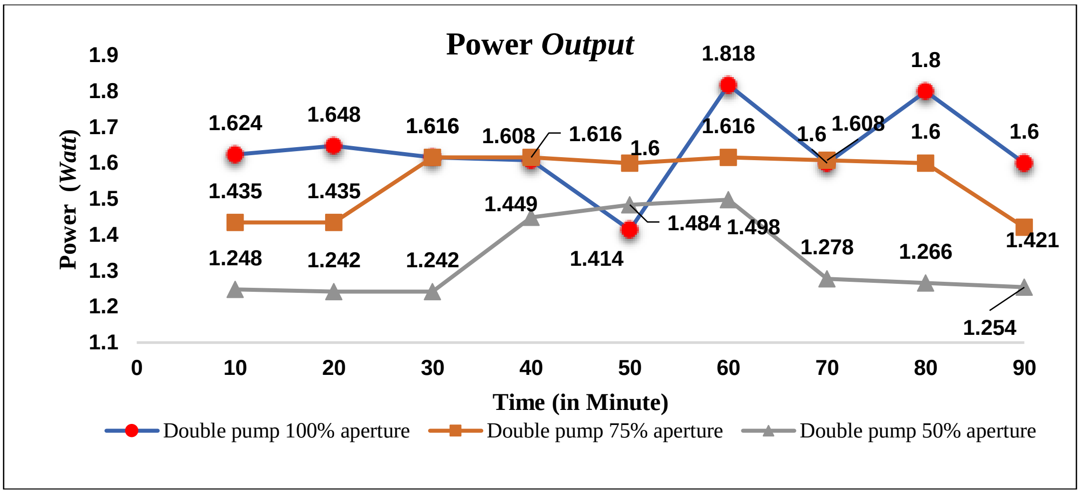

Fig. 7. Output Power On Dual Pump System

The maximum power obtained with a double pump system at 100% opening at 60 minutes is 1,818 Watt. From Figure 3 graph of output current (ampere) at minute 60 obtained 0.9 ampere is the largest value obtained. Voltage at 100% opening at 60 minutes based on Figure 5 graph of output voltage (Volt) of 20.2 Volts. While the minimum power obtained is 1.254 Watt at 50% opening.

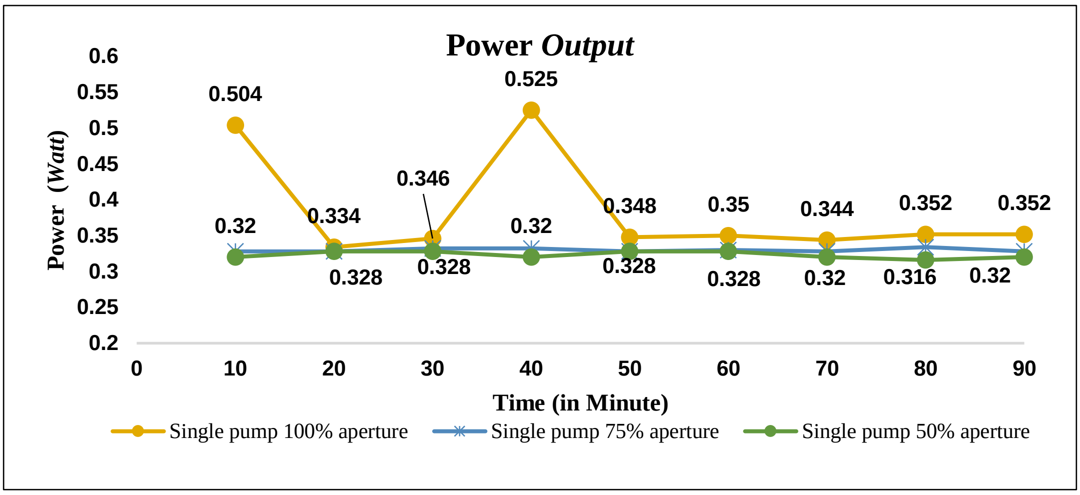

Fig. 8. Output Power On Single Pump System

So that the amount of output power obtained is influenced by the value of the voltage generated with the strong current generated. The greater the current and voltage generated, the greater the output power generated. In the double pump system, the power produced tends to be more labih and unstable, in contrast to the single pump system at 75% and 50% openings, the power produced tends to be more stable than the 100% opening in the single pump system and also the double pump system with 100%, 75% and 50% openings.

3.4 Efficiency

Efficiency is the maximum capability obtained from the system. The resulting efficiency depends on the amount of output power produced.

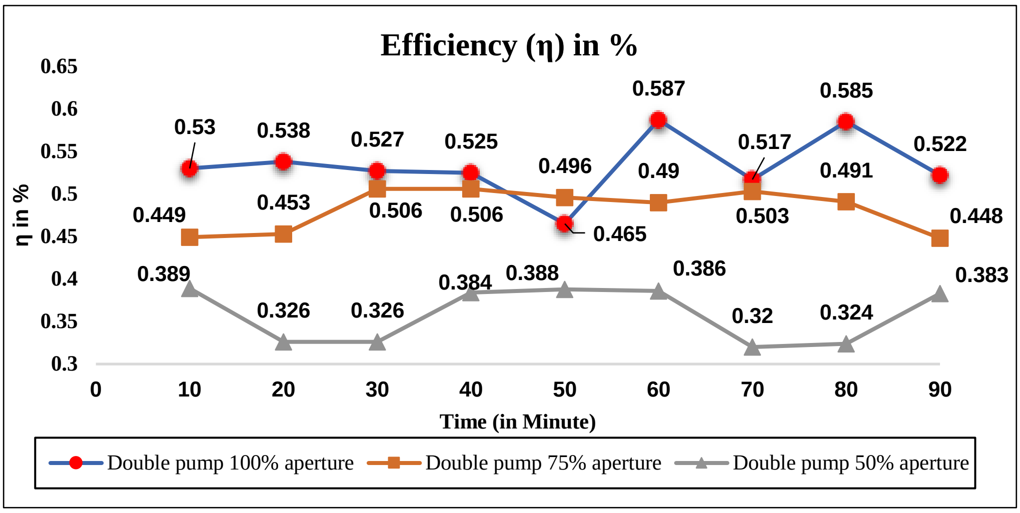

Fig. 9. Efficiency Graph On Dual Pump System

Turbine performance efficiency graph from Figure 9 Turbine with double pump system at 100% opening shows greater efficiency results than turbines with other systems. Because at 100% opening all pressure, discharge and flow optimally so as to provide a large rotation on the turbine. When compared to openings of 75% and 50%. Of course the pressure will change and it is less efficient if you want to get maximum results.

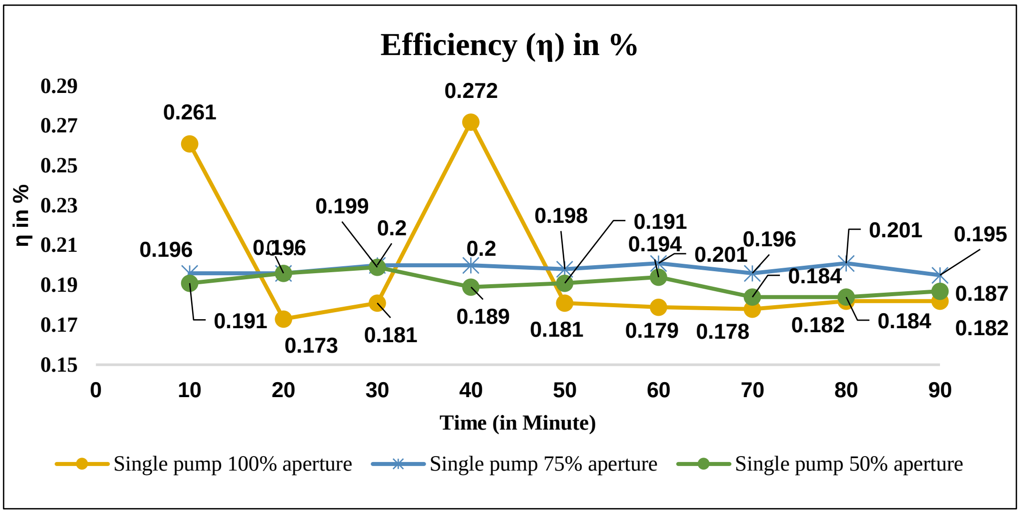

Fig. 10. Efficiency Graph On Single Pump System

Seen in Figure 10 in the single pump system, the largest efficiency value is 0.272 but relatively unstable. At openings of 75% and 50% the efficiency value is also unstable but the changes that occur are not too large. This is due to the influence of the pressure of the flowing water discharge. So that to get a large efficiency requires a large discharge. The large opening given will provide a large discharge and pressure. When compared to a single pump system, of course the use of a double pump is able to provide a greater boost compared to the capacity of a single pump.

CONCLUSIONS

The potential for micro hydro energy sources in Indonesia is very large. From this potential, it is necessary to use tools that can provide schemes, components and processes of microhydro utilization. This research was conducted using a crossflow turbine simulation tool. The purpose of this research is as a simulation for planning hydropower plants with crossflow turbines. So that later it will be easy to develop and plant infrastructure and the process of understanding to the public. In this study, two input systems were used, namely a double pump system and a single pump system with openings of 100%, 75% and 50% in each system. The results of the study found that the pressure and discharge given were constant in each system. The current, voltage, and output power obtained in the double pump system with 100% opening are relatively larger than the 75% and 50% opening in the same system and in the single pump system. The maximum output current obtained in this study was 0.09 amperes with the 100% opening dual pump system and the minimum output value was 0.02 amperes in the 50% opening single pump system. The maximum output power obtained in this study was 1.81 watts with the 100% opening dual pump system and the minimum output value was 0.32 watts in the 50% opening single pump system. The maximum output voltage obtained was 21.5 volts at 50% opening on the dual pump system, and the minimum output voltage was 15.8 volts at 50% opening on the single pump system. A large discharge will provide a large current, voltage and power output because it is able to crush the turbine with a relatively large speed. Discharge will affect the pressure and flow that occurs in the pipe, because the amount of discharge will be linear with the amount of pressure. The use of double pumps will get high efficiency with a large discharge. The greatest efficiency occurs when the double pump system.

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