Preliminary Studies of Hydro Power Plant using Laboratory-Scale Pelton Turbine: Speed-Variable Controlled and Their Effect on Electrical Power

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Abstract. Indonesia is one of the richest countries, with 70% of its areas abundant in water. These advantages can be utilized for the necessities of life, for example, building the hydroelectric power plant considering that some areas in Indonesia have yet to be reached by electricity. Hence, this work was conducted by the preliminary study of Pelton turbines on the laboratory scale to verify their performance in the real condition to flow electricity. This work started by analyzing the effect of speed-variable control on electrical power. The speed variable is controlled by managing the guide valve at various angles, i.e., 60°, 70°, 80°, and 90°. The larger the guide valve angle produces, the more flowing water with a high velocity. That condition caused the blade turbine to rotate at a high velocity and take effect on the electrical power generated by the Pelton turbine. Furthermore, it can be concluded that the faster-flowing water will affect the rotation of the blade turbine, which generates a large amount of electrical power.

Keywords: Hydro Power Plant, Laboratory-Scale Pelton Turbine, Electrical Power

1 Introduction

As reported by Prasetyo in 2022, the rising population in Indonesia has reached around 200 million people. This condition shows that the need for electrical energy is also getting bigger [1]. To meet this need, Indonesia still uses non-renewable energy, which is reduced each year and causes the price of electricity to continue to increase [2]. Therefore, the innovation of renewable energy is an interesting discussion to overcome this problem. One potential renewable energy considered to be developed in Indonesia is hydropower plants [3]. This condition has boosted the interest of researchers or engineers in the energy sector to explore the potential hydro energy in Indonesia. Several

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studies have explored the potential of water turbines, especially in Indonesia. Some of them are done by Setiawan in 2018 [4], Prabowoputra in 2020 [5], Wulandari in 2021 [6], Zakariz in 2022 [7], and Lillahulhaq in 2022 [2]. These studies used various types of hydraulic turbines. However, Decaix in 2022 reported that the best performance of turbines was reached by the Pelton turbine, which could keep the efficiency value higher than 80% [8]. A Pelton turbine has been chosen as one of the recovery energy to fulfill the electricity demand, as reported by Rossi in 2021 [9]. Hence, this type of turbine is the best choice to apply in Indonesia with further study.

Furthermore, from 2003 – 2020, Indonesia observed the National Energy Policy. It focused on energy efficiency according to the target planned by the Ministry of Energy and Mineral Resources to renewable energy of about 23% of the total supply in 2025 [10]. As explained before, that planning was reflected by the electricity demand in Indonesia, which has increased about 6% per year since 2000 [11]. Based on a statement from Maulidia in 2019, it is hard to fulfill the electricity demand due to the lack of investment in the electricity sector[12]. On the other hand, it is also caused by the lack of utilization of energy reserves. For instance, according to the explanation above, hydro energy in Indonesia has potential due to reserves that reach 75.000 MW, and it is not fully utilized. The report showed that the utilization is less than 10.1%. PLN reported this number with Nippon Koei in 1983[13]. It is evidenced by gaps in several areas that still do not have electricity supply; based on data it reached 1.1% of total villages in Indonesia [14]. Furthermore, hydro energy has brought several advantages; besides fulfilling the shortages of energy demand, it also reduces the harmful gases that pollute the environment [15].

Based on the explanation above, this work was conducted as a preliminary study of developing a hydropower plant to generate the electrical power transmitted to some areas not reached by the electricity. The authors proposed Pelton turbines on a laboratory scale to monitor their performance in generating electrical power. This work was focused on analyzing the speed variable on the rotation of blade turbines due to the falling water velocity and their effect on the electrical power. This case became an interesting topic on water turbines because the speed variable was related to the electrical power generated by the turbine. Moreover, the findings of this study can be implemented in the real condition of a hydropower plant, and it can control the speed to generate the electrical power needed to meet the electrical demand in Indonesia.

2 Methodology

Pelton turbines are employed in this research. The SPHC material used to make the turbine blades has a thickness of about 2.0 mm. SPHC material specifications according to JIS G-313[16]. The turbine shaft joins the turbine and generator. The stainless steel ST60 used for the shaft complies with a study that Suprayitno did in 2022 [17]. The turbine is housed in a polypropylene box to optimize the process and meet safety standards. Polypropylene is a plastic that is widely used in a wide range of industrial applications [18]. Fig. 1 depicts testing with a Pelton turbine. This testing used several apparatuses: a tachometer, amperemeter, voltmeter, and lamp.

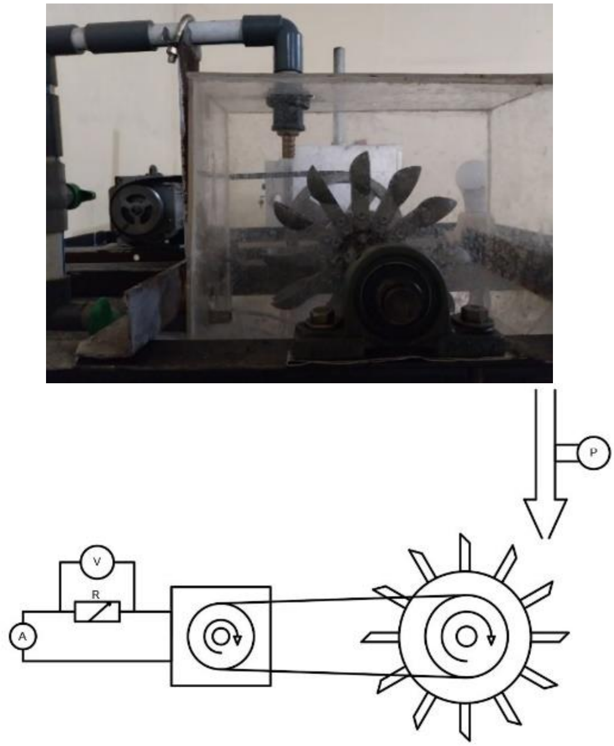

Fig. 1. An illustration of laboratory-scale Pelton turbine (Rewrite from Agar in 2008 with some modification) [19].

Then, these apparatuses respectively have a function in each procedure. Tachometer was used to measure the generator's speed caused by the nozzle turbine rotation generated by the falling water. This step is also a part of the process to prove that the water turbine that was made can produce electricity, as shown by the electrical power raised by the turbine. Furthermore, the electrical power was known from the current and potential of the electricity generated by the turbine and respectively measured using an amperemeter and voltmeter.

The experiment was detailed by the flowchart shown in Fig. 2. Firstly, make sure all the apparatus are prepared and in good condition. Then, manage the guide valve to ensure the water pump can flow to the turbine. In this work, the guide valve has to be managed in four variation angles, i.e., 60°, 70°, 80°, and 90° as illustrated in Fig. 3. This variation obtained the difference in the falling water velocity. Then, the falling water moves the turbine blades, and that moving depends on the falling water's velocity. Furthermore, the turbine blade is connected to the DC generator. Then, the DC generator is assembled as the circuit illustrated in Fig. 1; it consists of an amperemeter, voltmeter, and lamp to verify that the current flow can generate electricity.

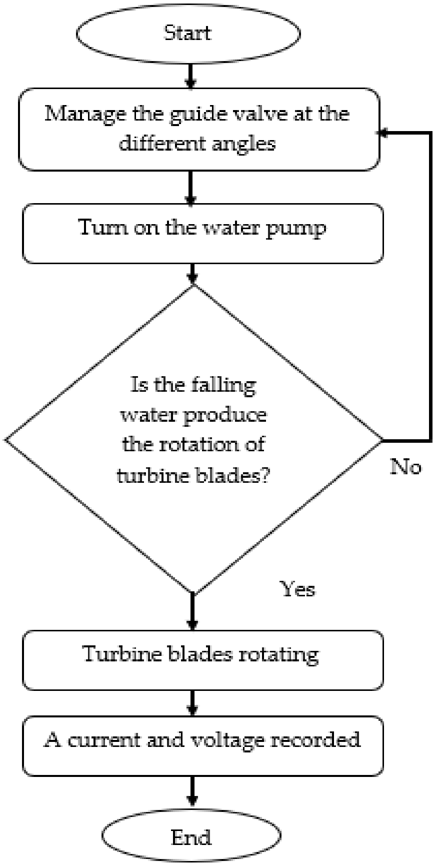

Fig. 2. Flowchart

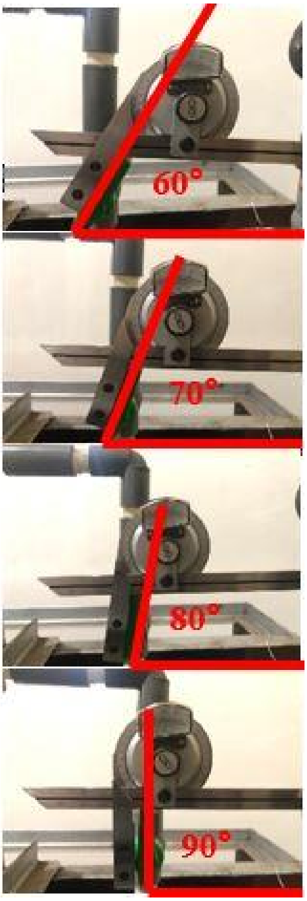

Fig. 3. Managing the guide valve in different angles.

The last important procedure in this experiment is to record the current and voltage that is legible in the measurement process. The presence of currents and voltages that are recorded indicates that the assembled water turbine is capable of producing electrical power. Then, the data recorded was calculated using Equation 1 to obtain the electrical power generated by the turbine [20].

$$P = I \times V \tag{1}$$

Where P is an electrical power that is generated by the turbine, I is a current flow that is recorded by an amperemeter, and V is the voltage that is recorded by the voltmeter.

3 Results and Discussion

The specific data that resulted from this experiment is shown in Table 1. The speed variable was controlled by managing the guide valve at different angles. This condition caused the falling water to flow at a different velocity. A larger angle of the guide valve caused the falling water to flow with high velocity and hit the turbine blades in a difficult condition. It also causes the turbine blades to rotate quickly and produce high electrical power.

Table 1. The electrical power that generated in different speed of blade turbine.

Guide valve angles	Speed of turbine blade (rpm)	Current (A)	Voltage (V)
60°	284	0.20	0.75
	298	0.25	0.95
	306	0.30	1.00
70°	286	0.28	1.45
	391	0.32	1.60
	393	0.36	1.75
80°	482	0.39	2.10
	487	0.40	2.15
	504	0.44	2.35
90°	508	0.50	2.40
	513	0.55	2.53
	515	0.60	2.57

These results were calculated using Equation 1, mentioned in *section 2.2*, to obtain the number of electrical powers generated by the turbines. Then, Fig. 4 illustrates the electrical power calculation finding from each guide valve angle. The results claimed that the electrical power increased with the increasing speed rotation of the turbine blades.

Based on Fig. 4 informs that electrical power is generated in the large number when the falling water has a high velocity. A large number of guide valve angles represent this work. The 90° of guide valve angle produces an average of 1.38 W. This condition proved that the Pelton turbine successfully generated the electrical power. The principle of energy conversion generates electrical power; potential energy is converted to kinetic energy. The falling water brings the potential energy and hits the turbine blades until it moves with a rotation. This rotation indicates that potential energy is successfully converted to kinetic energy [21]. The turbine blades were connected to the DC generator. Then, the rotation of the turbine blade also stirred the DC generator to produce electricity, as seen from the electrical current and the voltage that can be recorded in the experiment.

A laboratory-scale Pelton turbine provides an overview of the potential for utilizing renewable energy to supply electricity needs in unreachable or isolated areas. However, keep in mind that the areas that can be used as potential places to build hydroelectric power plants are areas that are close to water potential.

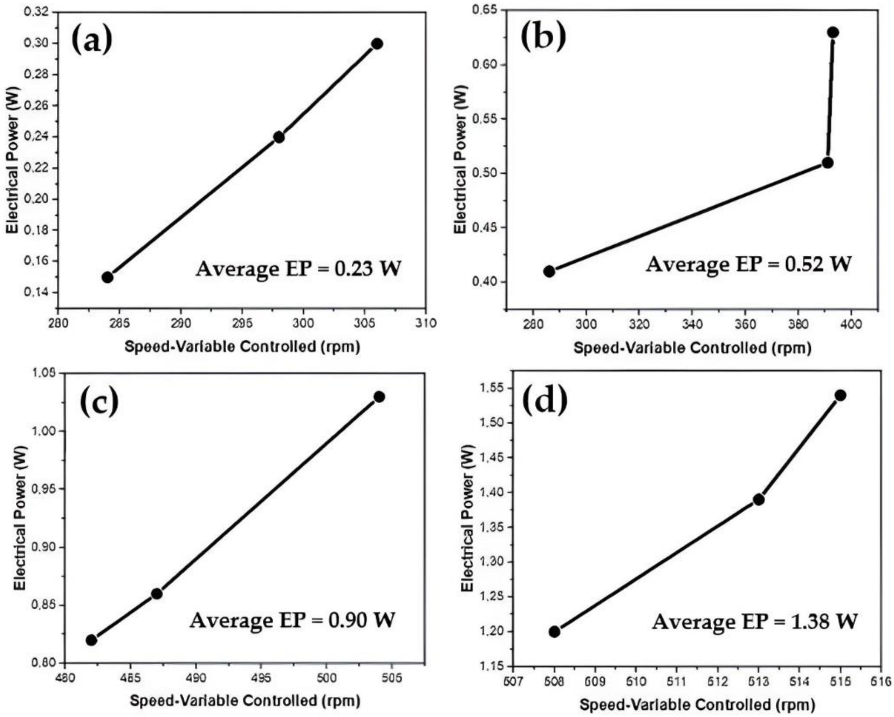

Fig. 4. The relation between speed-variable controlled and electrical power for each guide valve angles (a) 60° (b) 70° (c) 80° and (d) 90°.

4 Conclusion

A preliminary study of a hydropower plant has been successfully demonstrated using laboratory-scale Pelton turbines. The turbine was constructed in 12 vanes evenly spaced. This experiment found that the turbine could produce an electrical current, proving by turning on the light. It means that the turbine can generate electrical power as well as expected. The electrical power was increased with the increase of water flow velocity. This finding also proved that the Pelton turbine on the laboratory scale was suitable for the hydropower plant principles. Hoping this finding can be applied as renewable energy to build a hydropower plant that can flow the electrical current, especially to the areas that have not yet been reached by electricity.

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