Effect of Flywheel Weight on Generator Efficiency in Micro Hydro Power Plants

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Abstract: Micro Hydro Power Plant is a power plant that utilizes low-head hydropower to produce electrical energy. The problem is the unstable rotation of the generator caused by changes in water flow, resulting in changes in generator efficiency that affect the quality of electricity distribution. Therefore, in this study, a flywheel is used to determine its effect on generator efficiency. This study uses a water turbine as a generator drive. The flow of water falls into the turbine through pipes equipped with valves. The head and water flow are kept constant by adjusting the valve opening. The generator is a 3-phase generator, 220 V (Y)/ 380 V (Δ), 4 Pole. The flywheel weight is 0.5 kg, 2 kg, 2.2 kg, and 3 kg. The measuring instrument is a wattmeter to measure the electrical power output, a torque meter to measure torque and a tachometer to measure the generator's rotational speed. The torque and shaft rotation is used to calculate the mechanical power supplied to the generator. The largest generator efficiency is at a flywheel weight of 0.5 kg. The smallest efficiency is at a flywheel weight of 2.2 kg.

1 INTRODUCTION

Micro Hydro Power Plant (MHPP) has advantages, namely being economical because it does not require fuel, the technology is simple, easy to apply in remote areas, and is environmentally friendly because the energy source is water. Among several hydroelectric power plants, MHPP is recommended to be used for areas with lower heads and lower water flows to generate electricity (Satarkar, 2020), (Utama, 2018).

One of these is the negative environmental impact of using fossil fuels, particularly climate change, and the other is the depletion of the reserves of fossil fuels. The most significant source of greenhouse gas emissions is the combustion of fossil fuels like CO2, which thus causes global warming (Rahman, 2017). MHPP utilizes a small head of water, so it is suitable for use in areas where the height of the waterfall is relatively small (Dwiyanto, 2020). The results of the MHPP planning, with a water discharge of 0.834 m3/second, produced an electric power of 39.36 kVA (Likadja, 2019). In another study, with a water discharge of 14 litres/minute, a 12 Volt generator produced a voltage of 13.18 Volts and an average current of 102.2 mA. (Akhwan, 2021). Micro-hydro, hydro energy on a "small" scale, provides electricity to small communities by converting hydro energy into electrical energy. The resulting power is 5 – 100 kW (Anaza, 2017).

Hydropower causes the water discharge to be not constant, which causes the turbine speed to be not constant; hence the turbine connected to the generator to generate electricity will cause the generator rotation to become unstable, thus affecting the quality of the electricity produced. In addition, sudden load changes cause unstable generator rotation. Therefore, an energy storage device is needed at the plant that will provide additional energy if needed to maintain the turbine rotation. Flywheel is one of the energy storage media that can store excess energy and reuse it when needed. The flywheel is a component of a rotating machine, a disc that can withstand speed changes so that the engine's rotational motion becomes stable. The weight of the flywheel can resist speed changes. The flywheel has a moment of inertia that can withstand changes in engine rotational speed. Flywheel energy is a generator's mechanical energy converted into electrical energy (Tangko, 2019). A mains motor of two horsepower capacity is used to drive a series of belt and pulley drive, which form a gear train and produces over twice rpm at the shaft of an alternator. The gravity wheel or flywheel is coupled with the gear train to produce more excess or

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free energy. Detail study is done to obtain the maximum free energy out of the system using a flywheel of 10 kg (Kattimani, 2019) and a flywheel of 50 kg (Thakre, 2018). As a result, they have obtained more electrical output, which is their free energy. The AC generator has produced extra electricity from a 1 HP motor using the flywheel. The main advantage of the flywheel-free energy generator is that it can generate energy without any extra equipment. This free energy generation is non-hazardous and environmentally friendly. The flywheel with a weight of 7.74 kg is used in various applications such as electric fuel cars, household and industrial and increases the efficiency of traditional electrical (Shinde, 2017). A flywheel in a four-wheeled vehicle with a weight of 96.05 kg produces an engine speed of 64.87 km /h, while a flywheel with a weight of 86.24 kg produces an engine speed of 68.05 km/h (Ratnawati, 2019).

Micro-hydro power plants are the solution to reach remote areas that the limited accessibility for transport, technology, and cost (Elbatran, 2015), (Marliansyah, 2018), (Timur, 2020).

Previous studies used flywheels in a weight range of 7.74 kg to 96 kg. Therefore, this study analyzes the effect of flywheel weight on MHPP using a flywheel in the weight range of 0.5 kg to 3 kg.

2 METHOD

This study uses a water turbine as a generator drive. Water flow falls into the turbine through pipes equipped with valves that can be opened and closed. The head and water flow are kept constant by adjusting the valve opening. The generator is a 3-phase generator, 220 V (Y)/ 380 V (Δ), 4 Pole. The flywheel weight 0.5 kg, 2 kg, 2,2 kg, 3 kg. Flywheels are used interchangeably to determine the effect of flywheel weight on the MHPP turbine. Measurement of the electric power output of the generator using a wattmeter. Measurement of torque on the shaft using a torque meter. Measurement of shaft rotation using a tachometer. The results of the measurement of torque and shaft torque are used to calculate the mechanical power supplied to the generator.

The angular velocity:

$$\omega = 2.\pi.\frac{n}{60} \quad (1)$$

ω = angular velocity [rad/s]
n = shaft speed [rpm]

The mechanical power:

$$Pm = T.\omega \quad (2)$$

Pm = mechanical power [Watt]
T = torque [Nm]

The efficiency:

$$\eta = \frac{P_e}{P_m} \quad (3)$$

η = efficiency [%]
P_e = electrical power [Watt]

Figure 1: MHPP System Diagram.

Figure 1 shows the flywheel mounting position between the turbine and generator. Water flowing into the turbine causes the turbine to rotate and generate mechanical power, turning a generator to produce electrical power. The flywheel is used to maintain the stability of the generator rotation.

3 RESULTS AND DISCUSSION

The results of measurements and calculations are summarized in Table 1, Table 2, and Table 3. The angular velocity in Equation (1) is used to calculate the mechanical power. The mechanical power is calculated using Equation (2) and entered into table 1.

The weight of the flywheel ranges from 0.5 kg to 3 kg. Changes in flywheel weight cause changes in mechanical power and electrical power, as shown in Table 1.

Table 1: Measurement Result of Mechanical Power and Electrical Power.

Flywheel Weight (kg)	Mechanical Power (Watt)	Electrical Power (Watt)
0.5	83.279	64.125
2	88.393	68.0625
2.2	86.786	66.825
3	86.182	66.36

The results of the turbine shaft rotational speed (shaft speed) measurement are shown in Table 2. Variations in flywheel weight cause changes in the rotational speed of the turbine shaft.

Table 2: Measurement Result of Shaft Speed.

Flywheel Weight (kg)	Shaft Speed (rpm)
0.5	702
2	725
2.2	756
3	731

Table 3: Result of Efficiency.

Flywheel Weight (kg)	Efficiency (%)
0.5	77.0002
2	76.99988
2.2	76.99975
3	76.99984

Efficiency in Table 3 is calculated based on Equation (3).

Based on Table 1, Table 2, and Table 3, the mechanical power, the shaft speed, and the efficiency versus flywheel weight graph are obtained as shown in the Figure 2, Figure 3, and Figure 4.

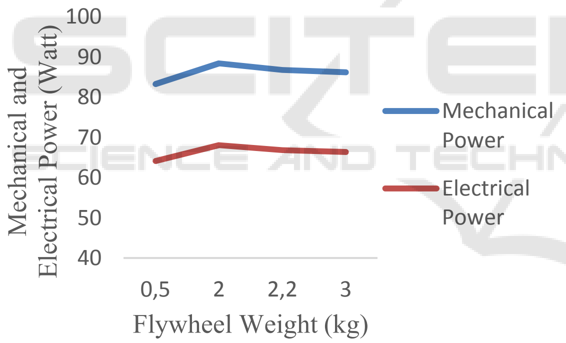

Figure 2: Mechanical Power (Shaft Power) and Electrical Power versus Flywheel Weight.

In Figure 2, the lowest mechanical power and electrical power is at a flywheel weight of 0.5 kg, while the highest mechanical power and electrical power is at a flywheel weight of 2 kg.

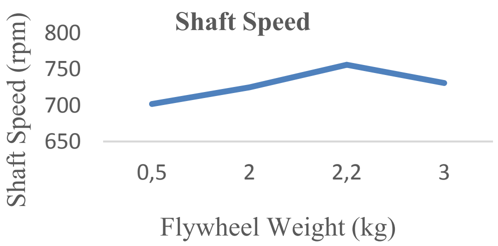

Figure 3: Shaft Speed versus Flywheel Weight.

In Figure 3, the lowest shaft speed is at a flywheel weight of 0.5 kg, and then the shaft speed increases when a flywheel weight of 2 kg. The highest shaft speed is at a flywheel weight of 2.2 kg and then decreases as the flywheel weight increases to 3 kg.

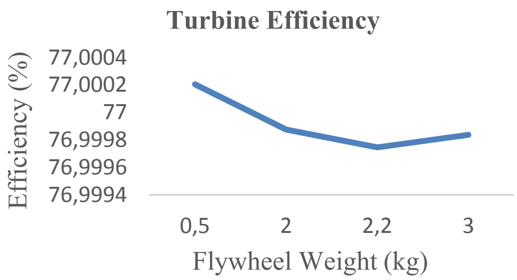

Figure 4: Efficiency Versus Flywheel Weight.

Figure 4 shows the efficiency of the MHPP generator. The highest efficiency at a flywheel weight of 0.5 kg. Efficiency decreases with increasing flywheel weight, but at 3 kg, the efficiency rises to 76.99984 %. Efficiency changes for the flywheel weight of 2 kg, 2.2 kg and 3 kg are relatively small.

4 CONCLUSION

Changes in flywheel weight cause changes in shaft rotation speed, mechanical power, electrical power, and generator efficiency. The lowest mechanical power and electrical power is at a flywheel weight of 0.5 kg, while the highest mechanical power and electrical power is at a flywheel weight of 2 kg. The lowest shaft speed is at a flywheel weight of 0.5 kg, and then the shaft speed increases when a flywheel weight of 2 kg. The highest shaft speed is at a flywheel weight of 2.2 kg and then decreases as the flywheel weight increases to 3 kg. The highest efficiency is at a flywheel weight of 0.5 kg. The changes are due to the relatively small difference in flywheel weight. It is hoped that further research will use a significant difference in flywheel weight to determine its effect on the efficiency of the MHPP system.

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