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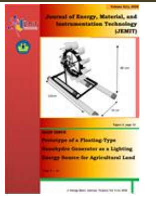

Prototype of a Floating-Type Nanohydro Generator as a Lighting Energy Source for Agricultural Land

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Abstract

A floating-type nano-hydro generator prototype has been developed as a source of electrical energy for lighting in agricultural areas. This generator is designed to produce electrical energy without modifying the flow medium, making it easy to apply in various water channels such as irrigation systems, small rivers, and large rivers, as the generator can automatically adjust to the ebb and flow of water. The electricity generated benefits agricultural lands far from PLN (Indonesia's state electricity company) power sources. The average voltage produced in this study was 19.19 volts, with an average generator speed of 30.1 rpm and a turbine speed of 104.4 rpm. Meanwhile, testing results showed voltages ranging from the lowest rotation of 8 volts to the highest rotation of 56 volts. The voltage output from this device can be used to power lights or other small electrical needs.

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Abstrak

Telah dilakukan pembuatan prototype generator nanohidro tipe apungan sebagai sumber energi listrik untuk penerangan pada lahan pertanian. Generator ini dirancang untuk dapat menghasilkan energi listrik tanpa harus memodifikasi media alir sehingga mudah diaplikasian pada berbagai lintasan perairan seperti irigasi, sungai kecil dan besar, karena generator dapat menyesuaikan diri secara otomatis terhadap pasang surut aliran air. Listrik yang dihasilkan sangat bermanfaat bagi lahan pertanian yang jauh dari sumbar listrik PLN. Tegangan yang dihasilkan dari penelitian ini rata-rata 19,19 volt, kecepatan rata-rata rpm generator sebesar 30,1 rpm dan turbin 104,4 rpm. Sedangkan hasil pengujian didapatkan tegangan dari rotasi terendah 8 volt hingga rotasi tertinggi 56 volt. Hasil tegangan dari alat tersebut dapat digunakan untuk menghidupkan lampu atau keperluan listrik kecil lainnya.

1. Introduction

Using electricity has become crucial for developing, modifying, maintaining, and processing agricultural and fishery lands. According to State Power Plant (PLN) (2022), electrification of agricultural and fishery lands can increase agricultural production (Samuda, 2023) by up to 200%. The availability of electricity networks is beneficial (Alfiani & Hamidah, 2023) like electrical machines (Wikarta et al., 2023), irrigating rice fields using water pumps with solar panels and fuel (Wakidah et al., 2022), controlling pests with trap lights, or providing lighting for livestock and areas requiring intensive monitoring (PLN, 2022).

The central issue farmers face is the difficulty in accessing electricity due to the distance from PLN's power grid. Farmers' challenges in obtaining electricity include the high costs of installation, such as geography area and cable networks (Institute for Essential Services Reform, 2019), electricity bills, and the safety of the installations. These problems are even more pronounced in remote agricultural areas where implementing PLN's electricity grid is not feasible (Sinaga et al., 2017).

The presence of rivers and streams with low flow, caused by gentle elevation, some of which are quite wide, makes it impractical to construct unique irrigation systems or dams to install micro-hydro generators (Winarso et al., 2021). This research represents an innovative solution more applicable to such conditions, particularly for rivers, streams, irrigation channels, or swamps with low flow, without modifying existing water flow paths by creating a floating-type electricity generator. The floating generator could be used in solar cells (Espos, 2024; Meti, 2024). Power plants with less than 100 kW capacity and those used for very small-scale applications, such as for households or

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small communities, are called nano-hydro power plants. This device has the advantage of being able to remain on the surface during fluctuations in water levels and can be easily moved (portable).

Regarding agricultural needs, research on low-power generators is adequate for lighting, light traps, or pest control. Research related to portable nano-hydro systems (Aw & Biggs, 2013) and low-flow, easily transportable nano-hydro generators for lighting in mountainous areas (Pauzi et al., 2022) has been conducted. Research on pico-hydro systems and the addition of a joule thief circuit) demonstrated an increase in the power output of the electricity generator.

2. Research Methods

2.1 Mathematical Formulation

The amount of power generated by the generator is determined by the river's flow rate, which produces a torque that rotates the turbine and generator. Below is the schematic of the turbine with forces originating from the water flow (F_{water}), friction force ($F_{friction}$), and load force on the generator ($F_{generator}$). The schematic force on the turbine can be seen in **Figure 1**.

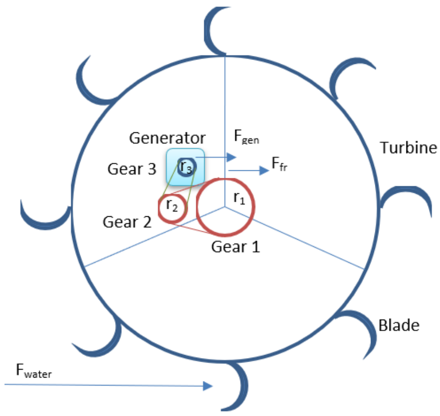

Figure 1. Turbine Generator Schematic

The torque on the turbine applies

$$\tau = F.L \quad (1)$$

Power generated by force at translational velocity

$$P = F.v \quad (2)$$

Where vv is the velocity of water flow. where

$$v = \omega.L \quad (3)$$

Thus, the rotational power is

$$P = F.(\omega.L) \quad (4)$$

thus

$$P = \tau.\omega \quad (5)$$

The total torque on the turbine is the torque from the water minus the friction torque and the load torque on the generator

$$\tau_{total} = \tau_{water} - \tau_{friction} - \tau_{generator} \quad (6)$$

The torque on the turbine can be expressed as

$$\tau_{turbine} = \frac{P_{turbin}}{\omega_1} \quad 7$$

In the turbine, there is a frictional force caused by the movement of the gears, gear connections, and rotor, and overall can be expressed as

$$\tau_{friction} = (K_1 . \omega_1 + K_2 . \omega_2 + K_3 . \omega_3) \quad 8$$

There are two types of power in a generator: active induction power and loss power. Active induction power refers to the power generated when electricity is connected to a load, while loss power is the internal power dissipation within the generator.

$$P_{generator} = P_{active} + P_{loss} \quad 9$$

$$\tau_{generator} = \frac{P_{active} + P_{loss}}{\omega_3} \quad 10$$

orque can be calculated by involving the rotational speed of the gear in the generator

$$\tau_{generator} = \frac{P_{generator}}{\omega_3} \quad 11$$

if the translation velocity is

$$v_1 = \omega_1 . r_1 \quad 12$$

$$v_2 = \omega_2 . r_2 \quad 13$$

$$v_3 = \omega_3 . r_3 \quad 14$$

or interconnected gears, rotation velocity can be expressed as

$$v_1 = v_2 \quad 15$$

$$\omega_1 . r_1 = \omega_2 . r_2 \quad 16$$

$$\frac{\omega_1}{\omega_2} = \frac{r_2}{r_1} \quad 17$$

$$\omega_2 = \frac{\omega_1 . r_1}{r_2} \quad 18$$

with

$$v_2 = v_3 \quad 19$$

$$\omega_3 = \frac{\omega_1 . r_1}{r_3} \quad 20$$

The total torque is

$$\tau_{total} = \frac{P_{turbin}}{\omega_1} - \left(K_1 \omega_1 + K_2 . \omega_2 + K_3 . \omega_3\right) - \frac{P_{active} + P_{loss}}{\omega_3} \quad 21$$

With the assumption that K has an approximately equal value, then the total torque is

$$\tau_{total} = \frac{P_{turbin}}{\omega_1} - K . \omega_1 \left(1 + \frac{r_1}{r_2} + \frac{r_1}{r_3}\right) - \frac{(P_{active} + P_{loss}) r_3}{\omega_1 . r_1} \quad 22$$

2.2 Tools and Materials

The tools and materials used in this research are a DC Generator as an electrical energy generator and a water turbine as the generator's driving mechanism. PVC pipes are floaters with a length of 4 meters, a diameter of 3.5 inches, and a thickness of 3 mm. 12 V LED lamp as a testing device. Multimeter to measure current and voltage.

Tachometer to measure the water wheel's rpm on the generator. Stopwatch to measure time. Wire mesh as a trash filter. Acrylic, angle iron, and adhesive for casing and bonding.

2.3 Generator Design and Analysis

The design process includes fabricating the casing and water wheel and testing. The prototype design is created using 3D design software (**Figure 2**).

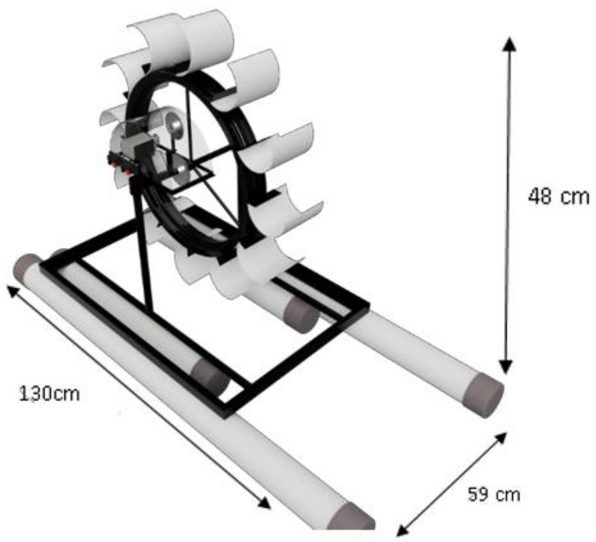

Figure 2. 3D Design of a Floating-Type Power Generator

2.4 Data Collection

The collected data includes the voltage generated by the generator, the turbine's rotational speed, and the generator's rotational speed. The voltage is measured using a digital multimeter, while the turbine's rotational speed (rpm) and the generator's rotational speed (rpm) are measured using a tachometer. For generator voltage data collection using a digital multimeter, measurements are taken every 2 seconds for 40 seconds. The field data collection was conducted in SB 7 Village, Seputih Banyak District, Central Lampung.

3. Results and Discussions

3.1 Prototype Implementation

Figure 3 below shows the realization of the prototype device designed in **Figure 2**. Additionally, data collection is performed by measuring the turbine's rotational speed using a tachometer.

a. b.

Gambar 3. Realization of the device: a. Floating-type electric generator b. Measurement using a tachometer

The system's total mass is 8.35 kg, including the turbine, pipes, support structures, blades, accumulator, and other components. The turbine wheel has a diameter of 44 cm, while the blades have a diameter of 9 cm. As illustrated in Figure 4, the system is supported by three converter gears that modify the rotational speed in two stages.

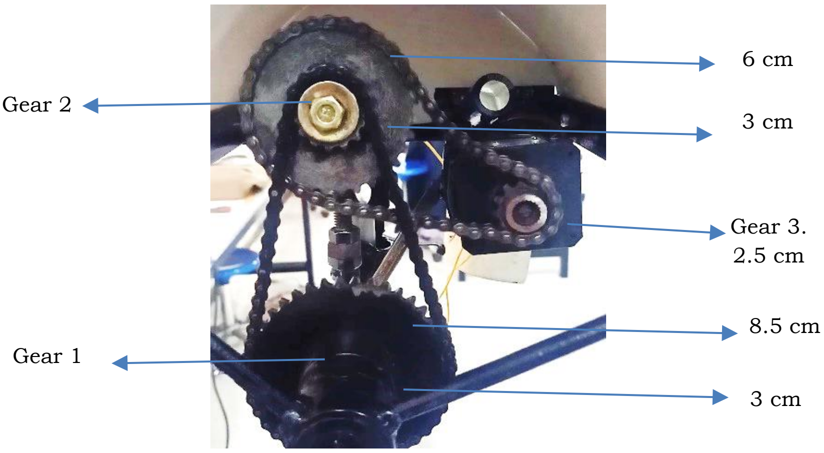

Figure 4. Turbine Rotational Speed Converter with Gears

3.2 Laboratory Testing of Turbine Rotational Speed

Data collection is conducted by rotating the turbine using a manual turning device (impact drill), which provides a stable rotational speed (rpm) that is adjustable from low to high. Water flow, turbine rotational speed, and generator rotational speed are measured using a digital multimeter and tachometer. The graph of the turbine rotational speed relationship is shown in **Figure 5**.

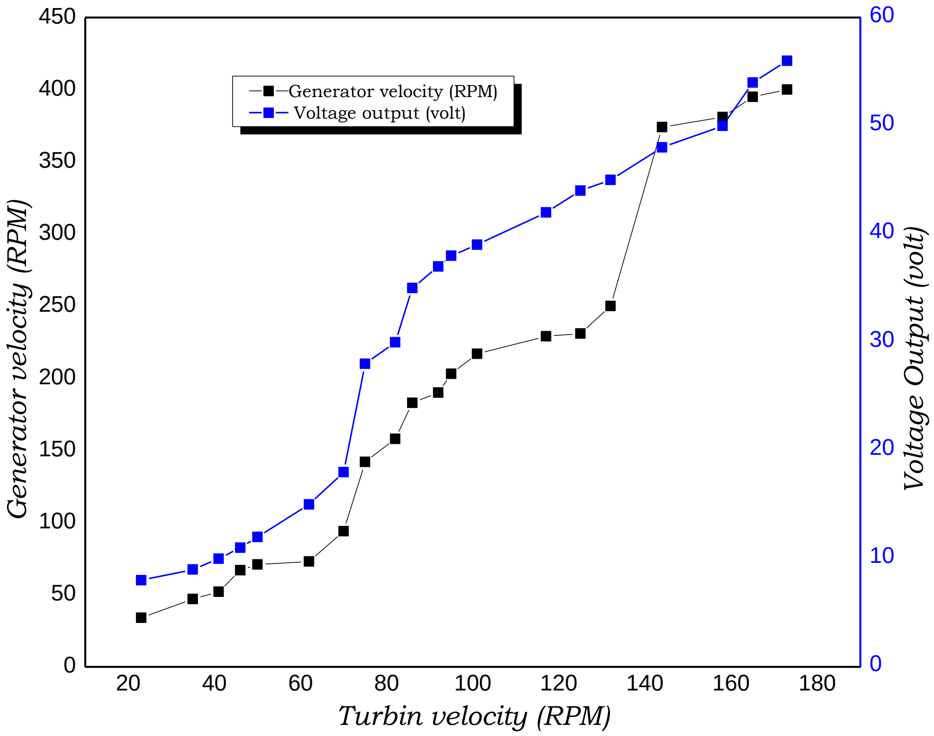

Figure 5. Graph of Turbine Speed, Generator Speed, and Output Voltage

3.3 Realization of Floating Turbine Testing

Data was collected over one day during the daytime, with measurements taken every 60 s. Twenty times a minute, data was recorded. Data were obtained from the measurements conducted, as shown in **Table 1**.

Table 1. Field Testing of the Floating Turbine

Minute	Turbin velocity (rpm)	Generator velocity (rpm)	Output voltage (v)
1	104.8	30.9	19.08
2	104.1	29.3	19.03
3	103.9	28.2	19.27
4	104.1	29.5	19.10
5	105.4	31.4	19.38
6	104.2	29.9	19.06
7	106.3	37.3	19.33
8	105.4	31.0	19.24
9	104.2	29.9	19.02
10	104.1	28.4	19.14
11	104.2	29.8	19.14
12	104.1	29.1	19.17
13	104.6	30.6	19.01
14	104.2	29.8	19.36
15	104.1	29.8	19.13
16	104.1	29.2	19.44
17	104.1	29.2	19.46
18	104.1	29.3	19.05
19	104.6	30.6	19.31
20	104.1	29.6	19.11
average	104.4	30.1	19.19

The data collection above results from several recorded measurements over 20 minutes, with additional images in the appendix. The average voltage generated is 19.19 V, with the average turbine speed reaching 104.4 rpm and the generator speed at 30.19 rpm. The difference in average speeds between the generator and the turbine is quite significant, with a ratio of 1:3. This occurs due to a gearbox that affects the turbine rotation, transmitting it to the generator using gear ratios. As a result, the generator's rotation speed increases, but the turbine rotation becomes heavier, a phenomenon known as transmission torque.

This difference is implemented to maximize the utilization of water flow in rice fields, where the available thrust is sufficient to drive the turbine. Consequently, a conversion process is applied, increasing the resistance of the thrust while tripling the rotation speed. This study utilizes a three-gear transmission system composed of a motor timing gear and a motor starter gear.

4. Conclusions

Based on the testing and discussion conducted, the following conclusions can be drawn:

1. The designed nano hydro generator functions well and consistently as long as the waterwheel rotates. Data collected over 20 minutes at 60-second intervals proves this, producing a voltage ranging from 19.02 to 19.46 volts.
2. The turbine rotation speed in this experiment remains constant over 20 minutes, with an average of 30.1 rpm.
3. Due to the gearbox, the generator's rotation speed is three times higher than the turbine's, achieving an average of 104.4 rpm.

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