

MICRO HYDRO GENERATOR TURBINE

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Abstract— This study developed a micro-hydro generator turbine utilizing water flowing into a single inflow pipe which makes the turbine rotate continuously within a specific water pressure. The device is intended to be connected to the household's main water pipeline to generate energy and convert it into electricity that can operate small devices during emergency power outages. It comprises a turbine, generator, step-down voltage, charger module, rechargeable battery, and dc-dc boost module. From the tests conducted, the device generated an average voltage, current, and power of 4.99 V, 0.48 A, 2.40 W at 35 psi, and 4.36 V, 0.35 A, 1.54 W at 20 psi. The power efficiencies of the device at 35 psi and 20 psi were 23.97% and 15.44%, respectively. The percent charge of the built-in battery increases by 1% after an average of 9 minutes and 14.6 minutes for high and low pressure, respectively. The results showed that the device generated enough energy to supply small devices rated 5 volts like smartphones, power banks, portable lamps, and portable fans.

Keywords— *hydroelectric generator, portable turbine, sustainable energy*

I. INTRODUCTION

Electricity is one of the energy sources commonly used by households. However, Electric Cooperatives in the Philippines are generally undercapitalized, and their operational performance is poor. As a result, the electrical supply in rural areas is unstable, with frequent power outages and fluctuating voltages [1]. Currently, there are limited alternatives for power supply during power outages [2]. Because of this, the utilization of alternative energy technologies is in great demand in rural and urban areas [3]. Renewable energies are evolving to fulfill the rising global electricity demand, but it is not enough; it needs to be sustainable [4].

Hydropower has been an excellent power generation system for rural electricity and a leading sustainable energy source [5]. Since there is an increasing electricity demand in the domestic and industrial sectors, the water turbine was developed and was widely used for industrial power before electrical grids. Water turbines are primarily used for hydroelectric power generation [6]. Studies were done on water technology in which the force of moving water propels a turbine that drives a generator to generate electricity [7]. Regardless of its small capacity, small-scale hydropower generates clean, affordable, and reliable electricity [8].

Researchers and engineers developed alternative solutions to sudden power outages. A study has developed an axial microturbine with a generator and successfully generated a maximum power of 28 watts with an efficiency of 18%; however, when coupled to a small generator, the device generates 16 W of electrical power, corresponding to a total efficiency of 10.5% [9]. In connection with this, research proved that hydroelectric power could be applied on a small scale to generate energy to suffice the temporarily lost power. To generate energy scale hydroelectric power, water pitches on the blades of the turbine, making the wheel rotate (due to the force of the flowing water), producing torque and power through the runner to turn the alternator/generation at a particular speed. The turbine's blades transform water's kinetic and potential energy into rotational motion, creating an electric voltage at the output [10]. The most notable small hydro generator turbines currently developed are portable hydroelectric generators [11]. In this device, the voltage regulator is not included; hence there is a possibility that it may not guarantee a continuous power source because it is unfit to install on the water pipelines. Another

device is a micro-hydro water pipeline generator. Unfortunately, the maximum operating water pressure is ten psi which is very low compared to other hydro generators [12] and snail hydroelectric generators. This device is an aluminum alloy with an internal coil. However, it is expensive and not advisable for rural areas [13].

This study developed a micro-hydro generator turbine connected to the household's main water pipeline to generate and convert it into electricity that can operate small devices during power outages. The device stores energy in a lithium-ion battery to supply rated 5 volts of devices like smartphones, power banks, small lamps, and portable fans. When water flows into a single inflow pipe, it will cause the turbine to rotate at a certain speed depending on the water pressure. It will flow into two outflow pipes. The device will generate electricity accumulated and stored in a Li-ion battery. Li-ion batteries' high energy efficiency may allow them to be used in a variety of electric grid applications, such as improving the quality of energy harvested from hydro, solar, and other renewable sources, allowing them to be used more widely and contributing to the development of an energy-sustainable economy [14]. Thus, this mini hydroelectric power device can produce a higher voltage and current by connecting the turbine to the main water pipeline of the household.

II. RELATED WORKS

Today, much work, money, and time have improved renewable energies. Many aspects of renewable energies have been subject to change or upgrade over time, and with that, challenges in renewables are inevitable. The demand for electricity increases as the population grows, and because of that, researchers paved the way to provide alternative solutions to the global energy demand. However, renewable energy resources are undervalued and not accepted socially because of limitations. In connection with this, studies refute such ideas — proving that renewable energies can meet energy demands globally.

One of the many ways of generating electricity is by using hydroelectric power. A micro-hydropower generator [15] was developed, which uses the flow of water inside the domestic pipeline that can be utilized to produce electricity. The kinetic energy of the water flow can turn the turbine, and the turbine shaft rotates in lockstep with magnets inside the generator. Large magnets spin around copper coils, which generate power. A rechargeable battery stores this energy. The water flow rate determines the amount of energy generated by the pipeline, the amount of water consumed, the pressure head, and the turbine and generator employed in this project. The potential for generating electricity and mechanical power from small-scale hydro devices is qualitatively considered enormous in many places based on present technology.

A new cost-effective energy generation uses portable water turbines [10]. It is a mini-hydro turbine power plant for emerging society capable of producing electricity and essential during power shortages. This hydropower turbine was constructed to generate electricity at different flow rates, and the most effective generation was at the complete opening of the

valve. The flexible rotation of the blade as the water flows on it allows electricity generation at various flow rates, thus increasing the machine's efficiency. This design has numerous advantages over other methods of hydroelectric power production. Aside from its eco-friendly design, it makes less noise when operating than a conventional waterwheel. Overall, it is built of cost-effective and long-lasting materials, and it does not significantly interrupt the water flow.

Rural communities suffer from an acute shortage of electricity. Because of this, a reduced pressure differential hydroelectric turbine system [16] was designed to be small enough to be carried out without too much effort. The new design also created a structurally sound turbine that withstands much pressure. It involves a hydroelectric turbine system capable of producing electricity while sustaining most of the fluid flow or hydraulic pressure within the pipeline or pipe network driving the system. The system's objective is to reduce the amount of pressure in an enclosed pipe system that requires force to run and function effectively. The device is a hydroelectric turbine generator system with a unique impeller and fluted turbine housing that allows a generator device to produce a specific amount of electric current and voltage while decreasing flow restriction and pressure loss to the fluid pressure driving the system.

To minimize the need for alterations to the water supply, a small-scale power wheel system (SSPHS) [17] was developed in 2016. It worked efficiently, producing electricity from the water supply. It is based on a small Pelton turbine that takes energy from flowing water and converts it into mechanical energy and then electricity by a suitable generator. Despite the control's mechanism's simplicity and low cost, tests revealed that it operates effectively. The output electric power is sufficient for lighting LED lines, and small lamps, and charging small electronic devices such as cellular phones, tablets, and other devices. The discharge water from the power wheel can be collected and used for showering, hand washing, and kitchen sink.

III. METHODS

A. Project Design and Specification

The block diagram shown in Fig. 1 is the interconnection of the turbine, generator, voltage regulator, DC to DC step-down voltage, lithium battery charger module, rechargeable battery, and a boost converter. Water coming from a single inlet pipe powers the turbine. Then the generator will generate a voltage of up to 32V dc.

The voltage regulator will stabilize the output voltage to 12V, and the DC-to-DC step-down voltage will convert the 12V to 5V compatible with small devices rated 5V. The charger module will charge the rechargeable battery and serve as the generator's power storage. The boost converter increases the battery output voltage from 3.7V to 5V.

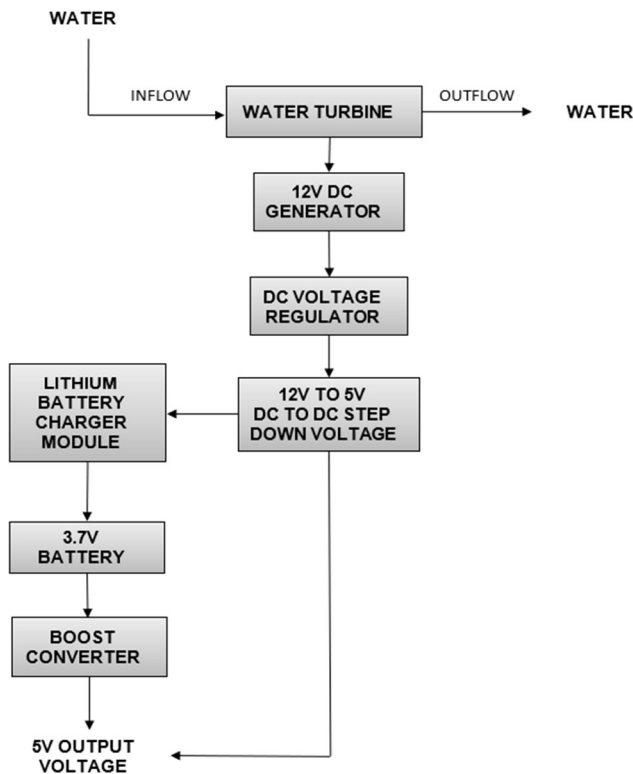


Fig. 1. Block Diagram of the Device.

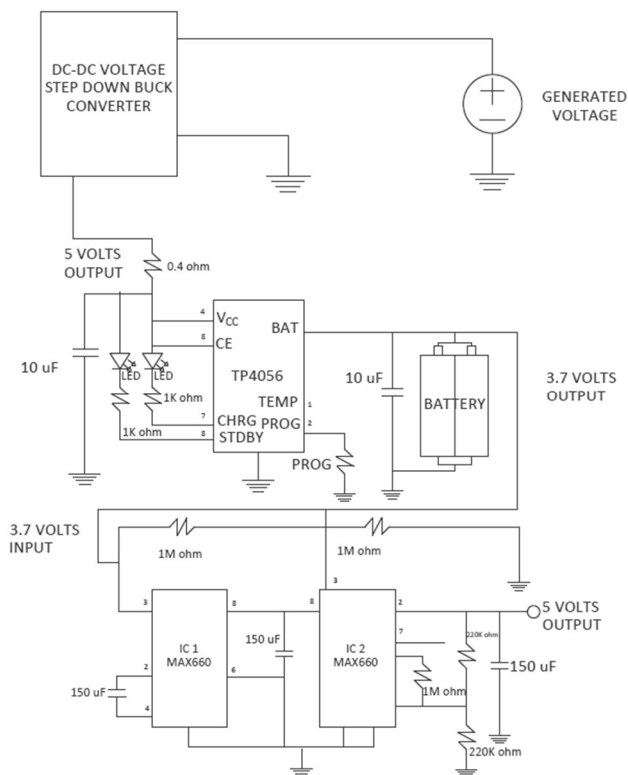


Fig. 2. Circuit Diagram of the Device.

The circuit diagram of the water flow pump micro-hydro generator turbine is shown in Fig. 2. The generated voltage from the turbine, which is up to 32 volts DC, is connected through a wire to the DC-to-DC Voltage Step Down Buck Converter module, making the generated voltage up to 5V. Using a USB Micro connector cable, the TP4056 charger module can be connected to the DC-to-DC Voltage Step Down module to store the collected power in the battery or directly into a small device rated 5V. The battery's output is connected to the input of the DC-DC Booster Converter Module to boost the voltage or improve the voltage for charging small devices rated 5V.

B. Testing and Evaluation

The current and voltage generated was measured at a high and low water pressure, 35 psi and 20 psi respectively. These specific pressures were used because it is the common water pressure in households. It is used to compare the estimated value of current and voltage at different flow rates.

The power efficiency of the device was measured in this study. Power efficiency (η) is defined as the ratio of the output power P_{out} divided by the input power P_{in} , as shown in (1). η is the percent efficiency (%). P_{out} is the output power or actual work in watts (W) of the device. P_{in} is the input power consumption in watts (W). In this study, the generator's power rating was rated at 10 watts, and this served as our input power, while its output was measured through a multimeter.

$$\% \eta = \frac{P_{out}}{P_{in}} \times 100\% \quad (1)$$

The change in the time of charge of the device was measured by getting an increase in charge over time (minutes). As presented in formula (2), the previous time is subtracted from the current time.

$$\Delta Time = Current\ time - Previous\ time \quad (2)$$

IV. RESULTS AND DISCUSSION

The voltage and the current produced by the micro-hydro generator turbine shown in Fig. 3 were measured in twenty trials. The power output is computed by multiplying the recorded current and voltage. The change in percent charge of the battery was also recorded to test the charging potential of the device.

At 35 psi, the device produced an average voltage, current, and power of 4.9885 V, 0.4805A, and 2.397155 W. At 20 psi, it produced an average of 4.3625V, 3.5375A, and 1.543561 W. The result of the study also shows that the water pressure is directly proportional to the current, voltage, and power output. The water pressure speeds up the rotation of the turbine. The higher the pressure, the faster the turbine rotates; thus, the output voltage increases as the water pressure increases. The data explain that the resulting current, voltage, and power produced at 35 psi with an efficiency of 23.97155% are higher than the 20 psi with 15.43561% efficiency.

As a result, the battery charges slower at lower water pressure while it charges faster at higher water pressure. It takes about 9 minutes to increase the battery's charge by 1% at high-point water pressure, and it takes 14.6 minutes at low-point pressure. With a continuous water flow, the battery will take approximately 15 hours to fully charge from zero percent by using 35 psi, and it will take 24.33 hours by using 20 psi. The gathered data show that the device has achieved a higher efficiency than other existing devices. A related study has tested a micro-hydro generator using rainwater for domestic energy harvesting. The device could produce a maximum output current and voltage of 250mA and 9 volts, respectively. The efficiency of the device is 22.5% [18]. The researchers successfully produced a relatively higher energy efficiency than other devices. This indicates fewer losses from this device than from the previous device. Therefore, the power generated is maximized.



Fig. 3. The Micro-Hydro Generator Turbine.

Table I show the result of the device's power efficiency with a regulator. With an input voltage not higher than 5V, the efficiency is low compared to without a regulator. This is because there will be much current flow in the circuit, which causes more energy production. The efficiency increased when the pressure applied was higher. Therefore, the device's efficiency increases when the pressure increases.

Table 2 shows how the charge of the power bank changes over time. The initial charge of the battery is 20%. The time was recorded in minutes every time the power bank was recharged. The charge percentage increases by 1%, with an average of 9 minutes at 35 psi and an average of 14.6 minutes at 20 psi. Based on the average time, the total time the device will fully charge is 900 minutes and 1,460 minutes, respectively. This indicates that the device is capable of charging the power bank continuously.

TABLE I. POWER EFFICIENCY OF THE DEVICE WITH VOLTAGE REGULATOR

Trial	WATER PRESSURE							
	35 psi				20 psi			
	(V)	(A)	(W)	(%)	(V)	(A)	(W)	(%)
1	4.97	0.46	2.29	22.86	4.10	0.33	1.37	13.65
2	4.98	0.47	2.34	23.41	4.41	0.36	1.57	15.74
3	4.98	0.48	2.39	23.90	4.35	0.35	1.54	15.36
4	5.00	0.49	2.45	24.50	4.37	0.36	1.57	15.69
5	4.96	0.48	2.38	23.81	4.37	0.35	1.54	15.43
6	4.95	0.48	2.38	23.76	4.37	0.36	1.55	15.51
7	4.99	0.49	2.45	24.45	4.35	0.35	1.53	15.31
8	4.99	0.49	2.45	24.45	4.36	0.35	1.54	15.39
9	5.09	0.49	2.49	24.94	4.41	0.36	1.57	15.74
10	4.97	0.47	2.34	23.36	4.37	0.36	1.55	15.51
11	4.96	0.48	2.38	23.81	4.35	0.35	1.54	15.36
12	4.98	0.47	2.34	23.41	4.41	0.36	1.57	15.74
13	4.97	0.46	2.29	22.86	4.37	0.36	1.55	15.51
14	5.00	0.49	2.45	24.50	4.41	0.36	1.57	15.74
15	5.09	0.49	2.49	24.94	4.41	0.36	1.57	15.74
16	4.95	0.48	2.38	23.76	4.36	0.35	1.54	15.39
17	4.99	0.49	2.45	24.45	4.35	0.35	1.53	15.31
18	4.97	0.47	2.34	23.36	4.35	0.35	1.53	15.31
19	4.99	0.49	2.45	24.45	4.41	0.36	1.57	15.74
20	4.99	0.49	2.45	24.45	4.37	0.36	1.55	15.51
AVERAGE	4.99	0.48	2.40	23.97	4.36	0.35	1.54	15.44

TABLE II. CHANGE OF CHARGE WITH RESPECT TO TIME

Trial	20% INITIAL CHARGE		Change in Time	30% INITIAL CHARGE		Change in Time
	35 psi			20 psi		
	% Charge	Time (m)		% Charge	Time (m)	
1	21%	9	9	31	13	15
2	22%	18	9	32	28	14
3	23%	27	9	33	42	14
4	24%	36	9	34	56	14
5	25%	45	9	35	70	14
6	26%	54	9	36	84	14
7	27%	63	9	37	98	15
8	28%	72	8	38	113	15
9	29%	80	10	39	128	16
10	30%	90	9	40	144	15
AVERAGE	9 minutes			14.6 minutes		

V. CONCLUSION

The device developed from this study could generate a certain amount of current that can be used to charge specific small-scale devices such as phones, tablets, and batteries. The

device produces a higher current at higher pressure; hence, the charging time of the battery is faster at higher water pressure. Therefore, the researchers conclude that a higher output of the device depends on the pressure of the water. The device is best used for emergency power interruption as an alternative. Energy storage can be utilized to charge our small devices at home.

The researchers found out in the study that when a bigger turbine is used, it will produce a larger current output regardless of the water pressure. That being the case, the researchers recommend using a bigger type of turbine that will give a higher output efficiency. It is also recommended to connect the mini-hydro generator to the main pipeline of the household because it gives more water flow and will result in a faster time of charging. In addition, the researchers also recommend that future researchers test the charging capability of the device with different types of batteries.

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