

OVERSHOT WATERWHEEL GENERATOR AT BARANGAY BONFAL WEST, BAYOMBONG, NUEVA VIZCAYA

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ABSTRACT

This study aimed to design and construct an overshoot waterwheel generator at Colocol Irrigation in Barangay Bonfal West, Bayombong, Nueva Vizcaya, capable of supplying streetlights on a minor road in the area. The researchers observed that Colocol Irrigation has the potential to become a community energy source; hence, a prototype overshoot waterwheel generator was developed. The testing site was a channel beside the sluice gate of the Colocol Irrigation. The testing was conducted three times a day for four consecutive days, and valuable data were collected. The result showed that a maximum of 30 volts dc can be generated and a current of 8.31 amperes for a stable supply load of 250 watts. Because the generated voltage exceeded 30 volts DC, the inverter shut down due to overvoltage. The lowest generated voltage was 22.2 volts DC, and the current was 2.25 amperes, supplying a load of 50 watts. Still, no data was collected when the water level was too low to reach the turbine. The output load was represented by 25-watt lightbulbs connected in parallel, and the voltage was measured using the voltmeter reading on the inverter. At the same time, the current was determined using the power formula. The overshoot waterwheel showed potential for further development to harness the Colocol Irrigation as a renewable energy source in the area.

Keywords: Overshoot waterwheel, generator, renewable energy, colocol irrigation

INTRODUCTION

The demand for energy worldwide has been increasing due to population growth and the rapid development of civilization, which has also led to greater use of fossil fuels for energy production. Despite posing serious environmental and health risks, fossil fuels remain the primary source of energy (Olabi, A. G., & Abdelkareem, M. A., 2022).

Brahim, S. P. (2014) also stated that, in terms of global final energy consumption, fossil fuels remain the main source of energy despite the constant contribution of renewable energy. However, many countries are driven to seek and develop alternative energy sources for several reasons, such as the depletion of fossil fuels, environmental impacts, climate change, volatility in oil prices, and pollution from their use. Renewable resources such as solar, hydro, wind, and geothermal have great potential in this regard, and as a result, renewable energy has become a major part of many countries' energy agenda to maintain energy sustainability and security.

In the Philippines, the government implemented policies and set short- and long-term renewable energy goals to support the development of renewable energy. Aside from its goal of achieving energy security and self-sufficiency, the country aims to become a leading figure in geothermal energy, the largest wind power user, and a solar manufacturing hub, which drives these efforts. The country's share of renewable energy is expected to increase in the following years with these established goals and policies (Brahim, S. P., 2014).

By the year 2030, the Philippines energy plan has set a goal in its power energy mix consisting of 70% generating capacity using coal, biomass, hydro power, and nuclear, a 20% capacity generated from natural gas and a capacity of 10% using oil-based plant as well as variable renewable energy like wind and solar (Gulagi et al., 2021).

In the northern part of the Philippines, the province of Nueva Vizcaya, situated in Luzon, is said to be 79% mountainous, distinguished by steep to very steep landforms; 8% rolling to

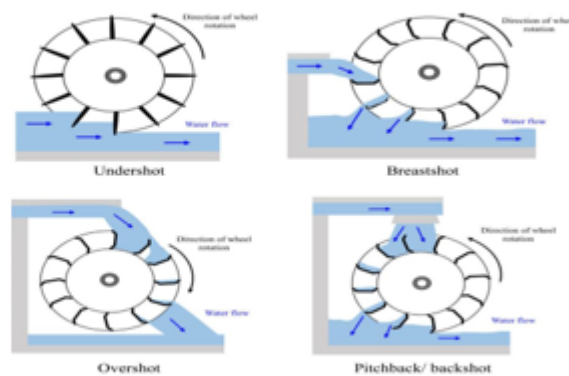
moderately steep; and 13% undulating to rolling, gently sloping to undulating, and flat to near flat. Given its rocky terrain, the province developed intricate waterways like rivers, creeks, streams, and springs, according to the province's official website. Along with small irrigations, the province provides suitable locations for small hydro power generation.

Hydroelectric power plants are commonly situated near water sources, where water is guided through a pipe or penstock to a turbine, which spins to produce electricity. The energy that can be harnessed from moving water depends on the volume of flowing water and the head of water, according to the U.S. Energy Information Administration (2023).

In modern times, waterwheels are essentially slow-running hydroelectric machines, most suitable for locations with low-head water that do not rely on technical irrigation systems. Historically, there have been four known types of waterwheels: undershot, breastshot, overshot, and pitchback/backshot (Basar et al., 2024).

This study aimed to design an overshot waterwheel for irrigation at the proposed location and to generate power to supply streetlights.

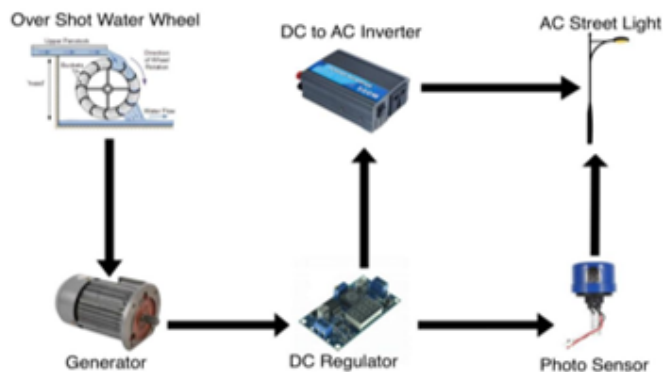
Figure 1.1
Waterwheel Types



Source: <https://doi.org/10.1515/ehs-2023-0138>

A. Conceptual Framework

Figure 1.2
Prototype Architecture



This system harnesses the natural energy of flowing water to spin a wheel, which powers a generator. The generator produces electricity that flows through a DC regulator, ensuring a stable voltage supply even during grid fluctuations or changes in load temperature. To expand its functionality, the researchers incorporated an inverter that seamlessly converts the steady DC into versatile AC power suitable for various applications. Additionally, the system included a smart photosensor that optimizes energy efficiency by automatically switching the lights off during daylight hours and turning them on when darkness falls, ensuring reliable, eco-friendly operation.

B. Statement of the Problem

In some parts of Nueva Vizcaya, rural areas lack sufficient street lighting to illuminate streets for passing vehicles. One example of this is the road beside Colocol Irrigation at Barangay Bonfal West, Bayombong, Nueva Vizcaya. To address this problem, the researchers designed and built an Overshoot waterwheel that uses the flow of water from the irrigation to generate renewable energy for energy harvesting and to power streetlights in the area.

METHODOLOGY

A. Research Design

The method used in this study involved gathering, illustrating, and interpreting data for the design. Necessary data, such as water head and channel width, were collected to design a prototype overshoot waterwheel in SketchUp. The prototype was then tested and evaluated. Tables, figures, and layout plans were developed to present the data results and design.

B. Research Environment

Figure 2.1
Site Location



Source: *Google Maps*

The study was conducted at the Colocol Irrigation Canal in Bayombong, Nueva Vizcaya. A part of that irrigation stretches through Brgy. Don Mariano Marcos, Brgy. Sta. Rosa and Brgy. Bonfal West with a single-lane minor road alongside it. The irrigation has two gates, one located at Sta. Rosa and one at Bonfal West.

The researchers chose the gate in Barangay Bonfal West, Bayombong, Nueva Vizcaya, for this study because of its higher flow rate, as observed during ocular inspection. This particular gate is just behind Muir Woods Academy and the GT Oil Gasoline Station, as shown in **Figure 2.1**. The area also faces challenges in providing reliable and eco-friendly street lighting. By

harnessing the natural flow of water in the irrigation, the system can provide continuous, clean energy, benefiting the community and serving as a model for other rural areas.

C. Research Instruments

To design and create a prototype of an Overshot waterwheel, the researchers used the following instruments:

Sketch up was used to design a 3D model for the Overshot waterwheel. It was also used to design a 3D representation of the site development plan for streetlights in the area.

AutoCAD was used to create 2D designs for streetlights and layout plans for the study.

Microsoft Word was used to create and edit related paperwork.

Tape measure was used to measure the dimensions of the channel.

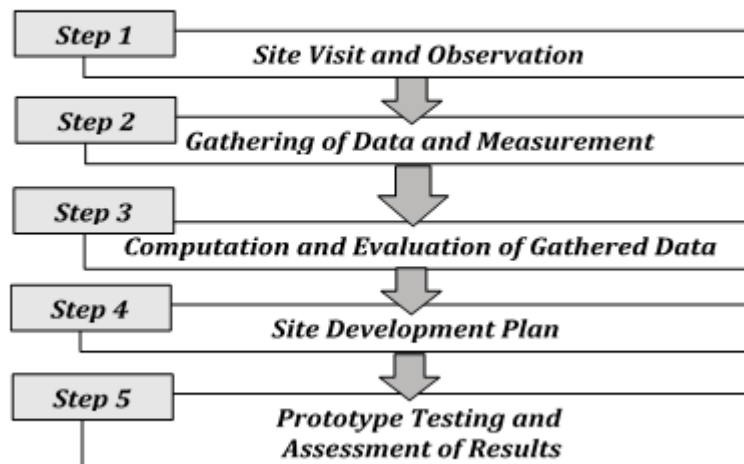
Multimeter was used to measure the electrical values produced by the prototype

D. Data Gathering Procedure

The researchers designed and built a 3D model of an Overshot waterwheel to create an efficient energy-harvesting system that generates electricity to power the streetlights. Also, the researchers developed a plan for the streetlights at the location. The researchers exerted effort to gather reliable sources to ensure the reliability of their study.

To achieve the creation of an Overshot waterwheel generator, the following steps were noted:

Figure 2.2
Data Gathering Procedure



RESULTS

A. Site Visitation and Data Gathering

Figure 3.1

Gate 2 at Bonfal West, Bayombong, Nueva Vizcaya



Surveying the site allowed the researchers to select an appropriate testing location and to properly design a prototype that fits it.

The testing site is part of the long Colocol Irrigation Canal, which stretches from Brgy. Don Mariano Marcos to Brgy. Bonfal West, Bayombong, Nueva Vizcaya. The irrigation canal has a minor road beside it and two sluice gates, sluice gate 1 and sluice gate 2, which control water flow. Sluice gate 1 is located in Brgy. Sta Rosa, while the sluice gate 2 is located at Brgy. Bonfal West.

Upon observation, the researchers found that sluice gate 2, as shown in Figure 3.1, located at Brgy. Bonfal West is the most suitable site for the study because the water flow is visibly stronger and easier to access.

After the observation, the researchers gathered data on the channel's width and height, which are important for the design of the prototype. The day of the data gathering happened to be rice harvesting season, and the planting season followed, so no water was flowing in the channel. The researchers took this chance to measure the width and height of the channel. The channel width was measured at the top, middle, and bottom, and the results were approximately 186 cm, 187 cm, and 190 cm, respectively. The channel depth is approximately 117 cm. These data are important to determine the dimensions of the prototype so that it fits the channel. The minor road spans 1km.

Figure 3.2
Data Gathering



B. Computation and Evaluation of Gathered Data

Power Consumption of Streetlights

LOAD	POWER	QUANTITY	TOTAL POWER
Streetlights	30 watts	50	1500 watts

The power that could be generated theoretically in the flow of water that feeds the turbine was calculated using the following formula:

$$P_{th} = \rho \cdot q \cdot g \cdot H$$

Where;

- P_{th} = Theoretical Power (W)
- ρ = density of water (1000 kg/m³)
- q = flow rate of water (m³/s)
- g = gravitational constant (9.81m/s²)
- H = head (m)

The theoretical power that the generator must extract to supply the streetlights with a net power capacity of 1500 watts was calculated as:

$$P_{th} = P_{load} / 80\%$$

$$P_{th} = 1500 / 80\%$$

$$P_{th} = \mathbf{1,875\ W}$$

To account for the losses, since the generator can only produce 80% of its capacity, the load was divided by 0.8 to calculate the theoretical power capacity.

Streetlight Development Plan

The researchers aimed to illuminate a 1 km stretch of a minor road; 50 streetlights will be installed in a one-sided arrangement. Each streetlight will be placed at 10 m-40 m apart in accordance with the *DOE Roadway Lighting Guideline*, but as the road to be illuminated has a width of less than 4m, the researchers rescaled the height of the streetlight, mass arm length, and its wattage.

Figure 3.3a
DOE Roadway Lighting Guidelines

Road	Road Width, meters	Arrangement	Lamp Wattage, Watts	Luminaire Spacing, Meters	Mounting Height, meters	Mast Arm Length, meters
Expressway	10	Twin Central	250	25-35	12	1.5
	15		250	20-35	12	3.0
	20	Opposite	250	20-45	12	1.5
	25		250	20-40	12	1.5
	30		250	20-30	12	1.5
	36		250	20-25	12	1.5
40	250	20-22	12	1.5		
Major	10	One-side	250	10-40	10	1.5
	15		250	10-45	12	3.0
	10	Twin Central	150	20-37	10	1.5
	15		250	20-43	12	3.0
	20	Opposite	150	20-40	10	3.0
	25		250	20-45	10	1.5
	30		250	20-45	10	1.5
	36		250	20-45	12	3.0
40	250	20-45	12	3.0		
Collector	10	One-side	150	10-40	10	1.5
	15		250	10-50	12	3.0
	10	Twin Central	150	20-40	10	1.5
	15		150	20-37	12	3.0

Source: *legacy.doe.gov.ph*

Figure 3.3b
DOE Roadway Lighting Guidelines

Road	Road Width, meters	Arrangement	Lamp Wattage, Watts	Luminaire Spacing, meters	Mounting Height, meters	Mast Arm Length, Meters
Collector	20	Opposite	150	20-47	10	1.5
	25		250	20-48	10	1.5
Rural Highway	8	One-side	150	10-38	8	1.5
	10		150	10-37	8	3.0
	15		150	15-38	10	3.0
	10	Twin Central	150	20-45	10	3.0
	15		150	20-39	12	3.0
	20	Opposite	150	20-45	8	1.5
Minor	4	One-side	70	10-40	8	1.5
	6		70	10-40	8	1.5
	8		70	10-40	8	1.5
	10		70	10-39	8	1.5
	10	Twin Central	70	20-35	8	1.5
	15	Staggered	70	10-20	8	1.5
	15	Opposite	70	20-40	8	1.5

Source: *legacy.doe.gov.ph*

Streetlight Specification

Figure 3.4
Streetlight Specification

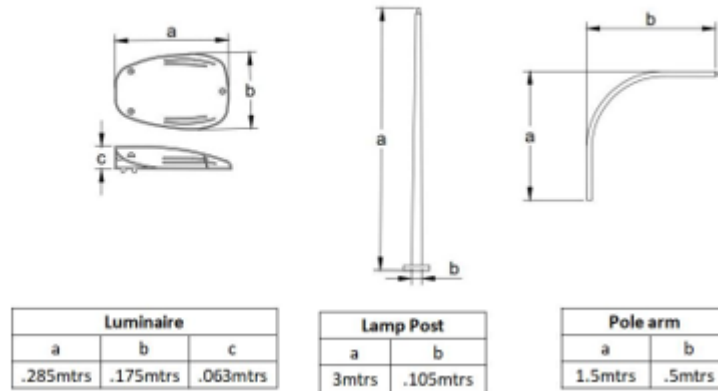


Figure 3.5a
Streetlight Model



Figure 3.5b
Streetlight Model



Based on the *DOE Roadway Lighting Guideline* for minor roads, as shown in **Figure 3.3b**, the mounting height should be 8 meters. Still, as the road to be illuminated has a width of less

than 4m, the researchers rescaled the height of the streetlight and mast arm length. Therefore, the streetlights were designed to have a height of 4.5m and a mast arm length of .5m. Based on available materials, a mini streetlight with a wattage of 30 watts and 3300 lumen output was used.

Illumination Requirements

To calculate the illumination required by the streetlights, the following formula was used:

$$E = (Al \times cu \times mf) / w \times d$$

Where;

- E = Horizontal Illumination level
- Al = Average illumination
- cu= coefficient of utilization
- mf= maintenance factor
- w = road width
- d = distance between fixtures

The road to be illuminated has a classification of light pedestrian traffic and very light vehicular traffic, so the following parameters were used to calculate the illumination:

$$E = 2.15; cu = .29; mf = .8; w = 4; d = 25mtrs.$$

So, the average illumination was calculated as:

$$Al = (E \times w \times d) / cu \times mf$$

$$Al = (2.15 \times 4 \times 25) / .29 \times .8$$

$$Al = 927 \text{ lumens}$$

Based on the calculations, an LED mini streetlight with a wattage of 30 watts and a 3300 lumen output was used.

Calculation of the actual illumination level for the chosen luminaire is shown as:

$$E = (3300 \times .29 \times .8) / 4 \times 25$$

$$E = 7.656 \text{ lumens}$$

The actual illumination level was more than that of the required value, so the chosen streetlight was more than enough to illuminate the roadway.

Figure 3.6
Recommended Average Horizontal Illumination Level

Pedestrian Traffic	Vehicular Traffic Classification			
	Very Light	Light	Medium	Heavy to heaviest
	Under 150	150-500	500 to 1200	1200 up
Heavy	9.68	12.91	16.14	21.52
Medium	6.48	8.61	10.26	12.91
Light	2.15	4.30	6.46	9.68

Source: dpwh.gov.ph/DPWH/sites/default/files/webform/civil_works/advertiseme

C. Prototype Design and Construction

The whole prototype design was composed of four parts, which consisted of the raceway, the frame, the turbine, the gears, and the generator. It has a height of 117 cm and a width of 141cm. The prototype was designed to specifically fit the water channel in order to achieve maximum results during the process of testing. The whole prototype was made of steel angle

bars, galvanized steel sheets, A 24 Volt Dc Generator, and mechanical components such as gears and bearings.

Figure 3.8
Raceway



Figure 3.9
Frame



Figure 3.10
Turbine



Figure 3.12
Gears



Figure 3.13
24V, 350-Watt DC Generator



Figure 3.14
24V, 1000-Watt Inverter



Figure 3.15
Gear Protection



Figure 3.16
Bearing covers



D. Prototype Testing

To gather data, the researchers conducted an open-circuit test to measure the voltage. They took the current by connecting a load. The test load consisted of 12 25-watt bulbs connected in parallel, mounted on a piece of plywood. The researchers tested the prototype for four days with three trials each at three different timeframes.

E. Summary of Tests

After a series of tests, the data gathered was compiled. The output power was based on the generator's capacity to maintain a stable supply to the connected loads without causing the bulbs to turn on/off. The researchers mainly relied on the voltage reading on the inverter to determine the generator's output voltage while using the power formula to determine current during the trials. The output power was recorded during the mornings on those testing days. There were instances when the prototype was unable to produce power due to factors such as the water level dropping too low, the water not reaching the top of the channel, and component limitations. Some factors increased the water level and flow rate, thereby increasing the prototype's power output, such as sudden rainfall in the area.

DISCUSSION

Table 3.5
Summary of Tests

No. of Trials	Voltage	Current	Output Load
<i>Day 1 of testing</i>			
Trial 1	30 volts	8.31 amps	250 watts
Trial 2	29.6 volts	7.6 amps	225 watts
Trial 3	22.2 volts	2.25 amps	50 watts
<i>Day 2 of testing</i>			
Trial 1	33.1 volts	null	null
Trial 2	25.9 volts	6.76 amps	175 watts
Trial 3	27.2 volts	7.35 amps	200 watts
<i>Day 3 of testing</i>			
Trial 1	29.5 volts	4.24 amps	250 watts
Trial 2	null	null	null
Trial 3	null	null	null
<i>Day 4 of testing</i>			
Trial 1	23.6 volts	4.24 amps	100 watts
Trial 2	null	null	null
Trial 3	null	null	null

A. Conclusions

Using the gathered data throughout the study and carefully testing trials, the results have successfully met the objectives of the study:

1. The researchers were able to design a site development plan for streetlights in the area by following the standard procedures and guidelines for roadway lighting.
2. The researchers were able to calculate the power consumption of the streetlights in the area in accordance with the design and the energy production of the prototype.
3. Design and construct a prototype of an overshot waterwheel generator capable of generating power to use for the streetlights.
4. Successfully test the prototype in the chosen location, providing valuable data that was analyzed to prove that the Colocol irrigation is a good potential source of energy.

B. Recommendations

Based on the findings and conclusions of this study, the following recommendations are forwarded to address issues observed in the study:

1. Redesign the system by adding a battery and a charge controller for a consistent power supply to store energy during peak periods to be used when the water level is low.
2. Replace the inverter with a higher voltage rating to avoid overvoltage.
3. Expand the raceway so that it can completely cover the channel and direct more water into the turbine.
4. Redesign the raceway so that it can properly regulate the water that flows into the turbine.
5. Create a tightly sealed gear protector to prevent water from getting on the gears.
6. Study the design of the turbine further for maximum energy conversion.
7. Use other materials to substitute for steel. Researchers may replace other components with lighter materials as long as it does not affect its performance by a large margin to reduce the weight because the waterwheel is large and heavy.
8. Regular maintenance is needed to keep the prototype at maximum working condition.

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